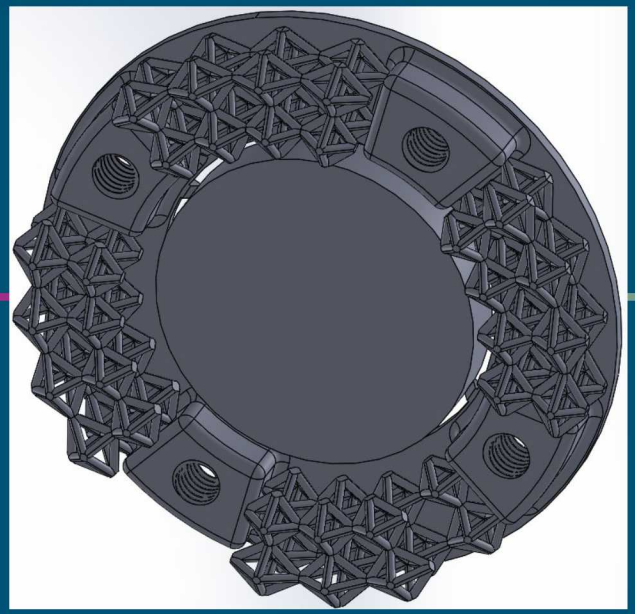
Sandia National Laboratories

SAND2019-7991PE

Selective Lattice Destruction



PRESENTED BY

1/c Patrick Irwin, USCGA

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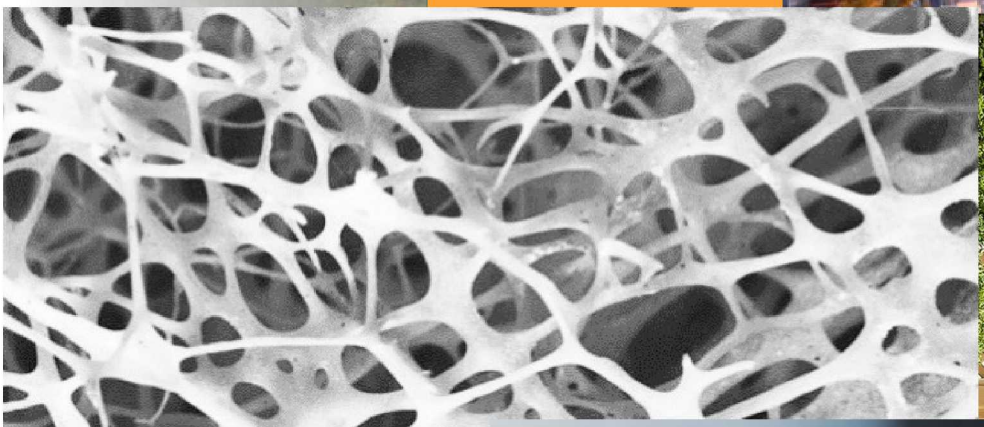
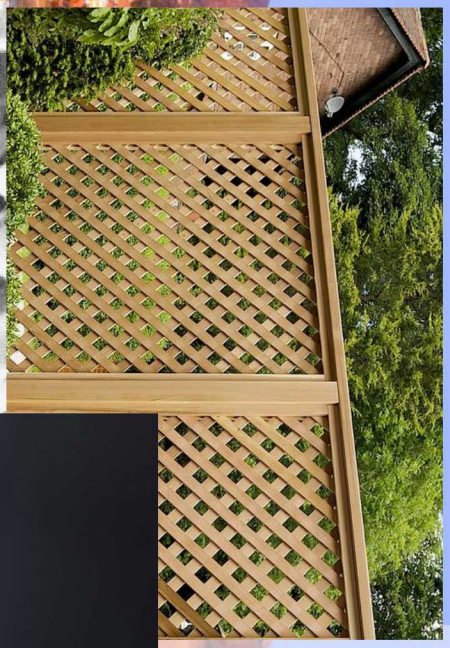
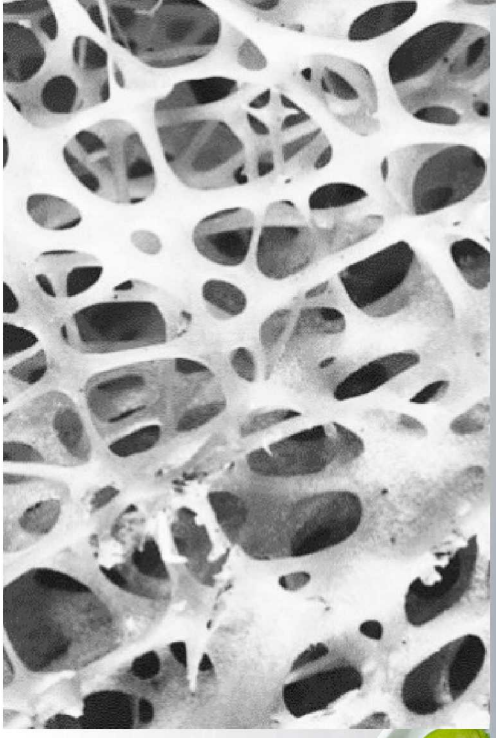
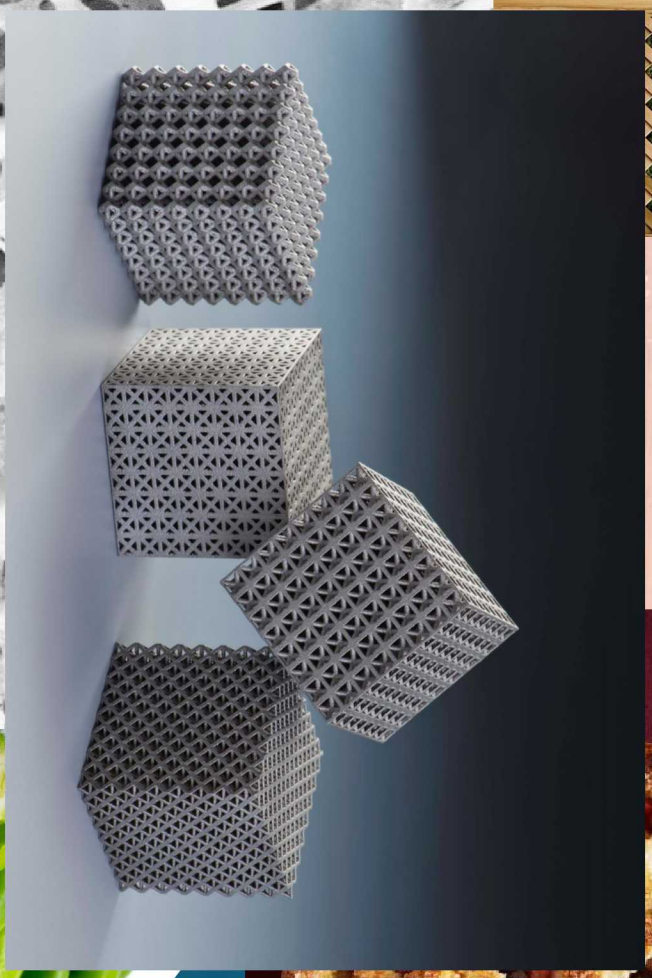


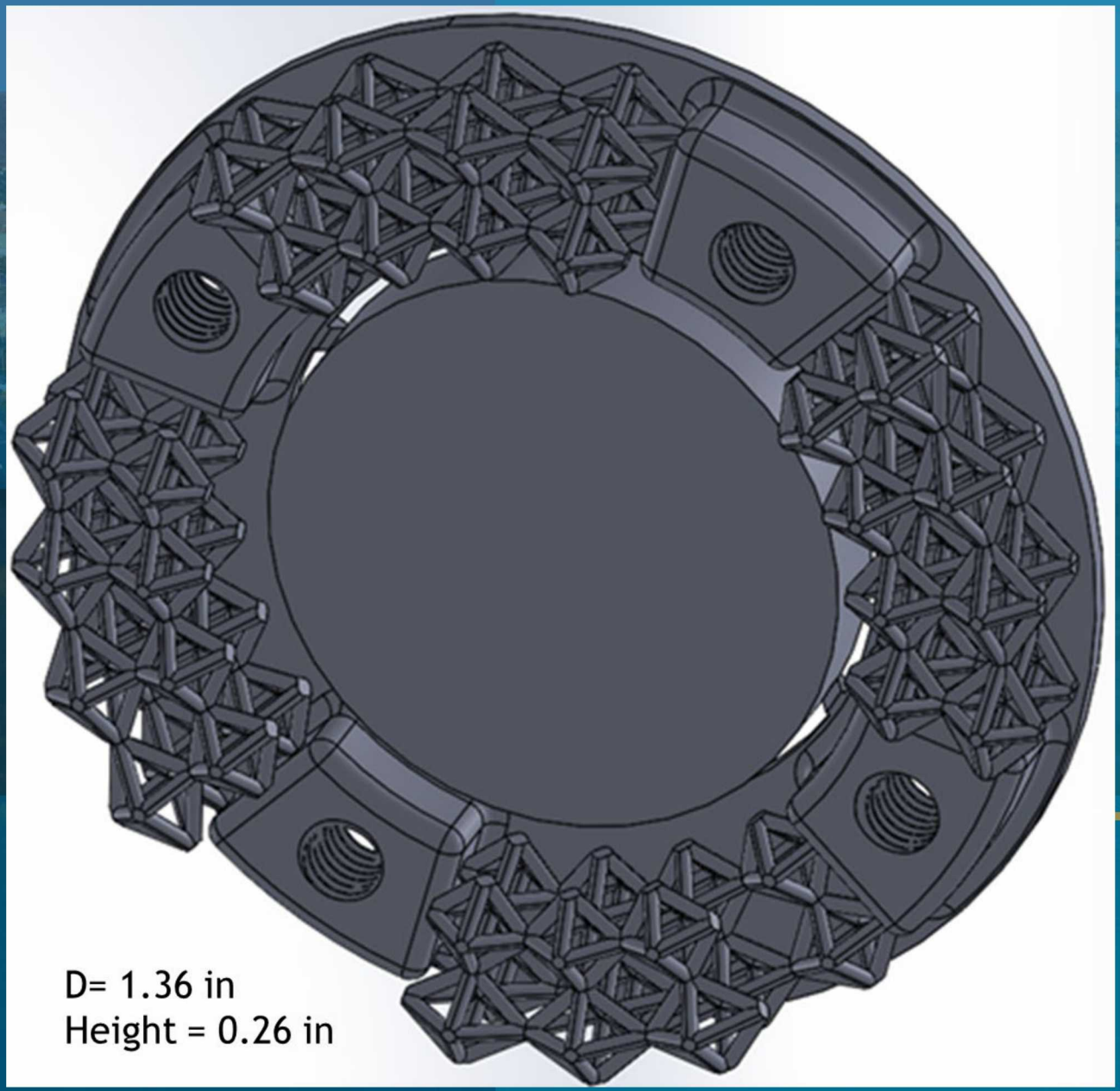




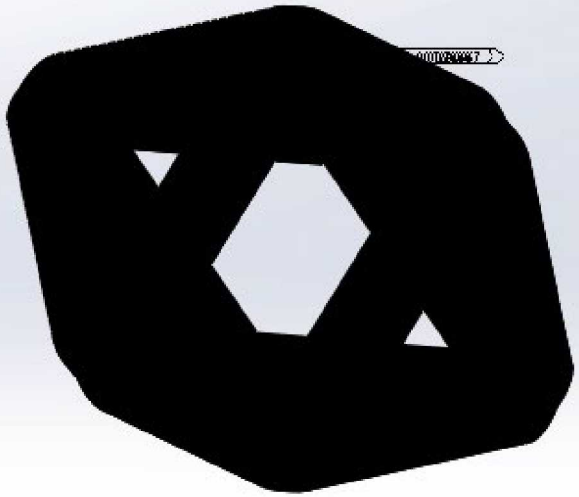


Manufacturing Lattices

ProX 200, materials science lab



Motivation & Agenda



Stiffness Equation:

(1) $\boldsymbol{k = \frac{F}{\delta}}$

Where k is stiffness (lb/in)
F is force applied (lb)
δ is displacement (in)

(2) $\boldsymbol{\sigma = \frac{F}{A}}$

Where σ is stress (psi)
F is force applied (lb)
A is cross sectional area (in^2)

(3) $\boldsymbol{\frac{\sigma}{\varepsilon} = E}$

Where σ is stress (psi)
ε is strain
E is Young's Modulus (psi)

(4) $\boldsymbol{\varepsilon = \frac{\Delta L}{L}}$

Where ε is strain
ΔL is change in length
L is the length

$$E = \frac{F/A}{\varepsilon}$$

$$\frac{F/A}{E} = \frac{\Delta L}{L}$$

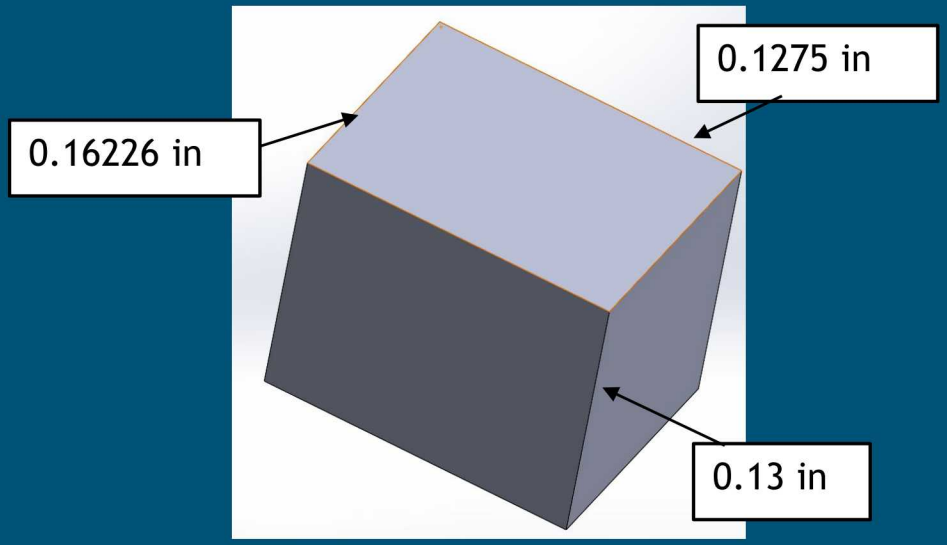
$$\Delta L = \frac{LF}{EA}$$

$$k = \frac{F}{\frac{LF}{EA}}$$

$$k = \frac{EA}{L}$$

Stiffness is found by dividing force and displacement

Model Validation:



$A = (0.1275)(0.16226)$

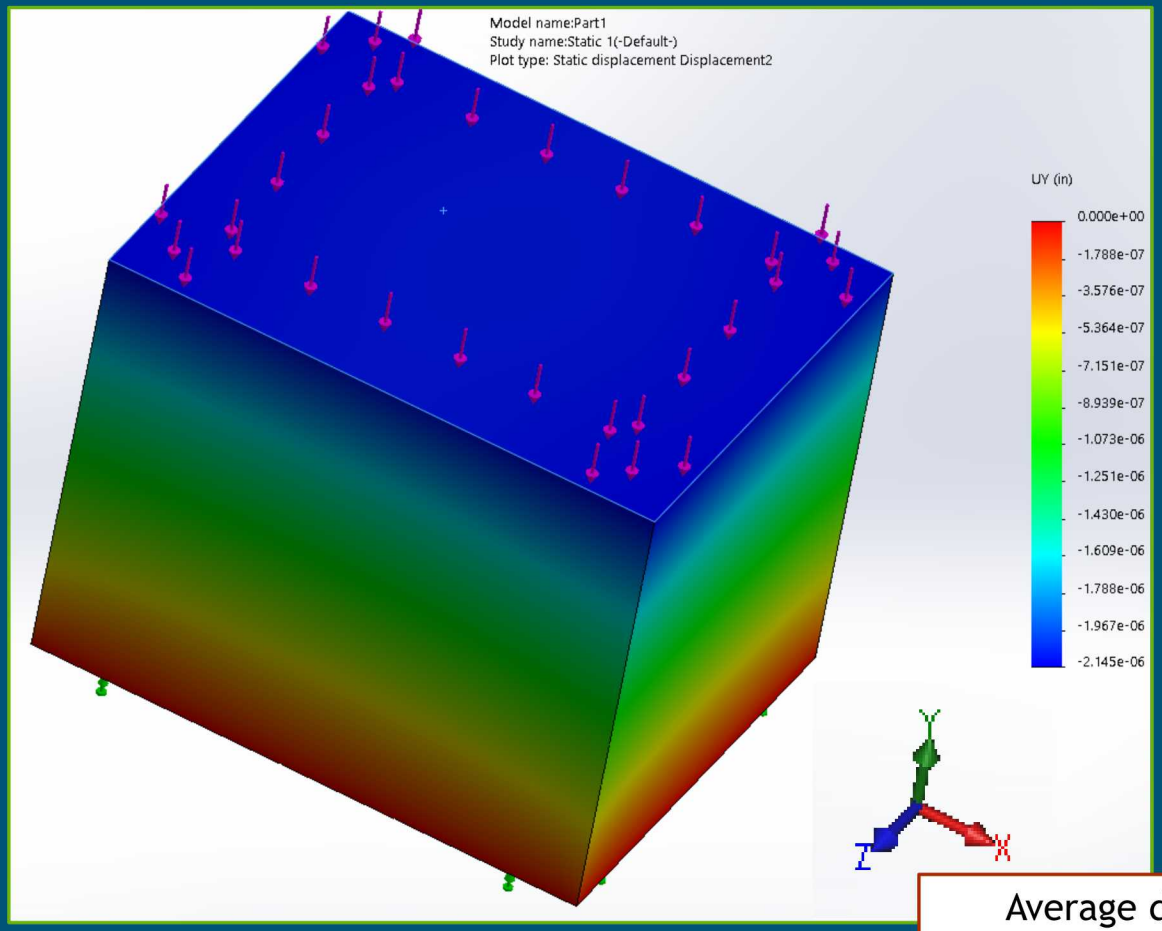
$= \mathbf{0.02069}$ **square inches**

$\mathbf{E = 29{,}000{,}000\ psi}$

$$k = \frac{(29x10^6\ psi)(0.02069\ in^2)}{0.13\ in}$$

$$\underline{\boldsymbol{k = 4.456x10^6\ lb/in}}$$

Model Validation:



Summary

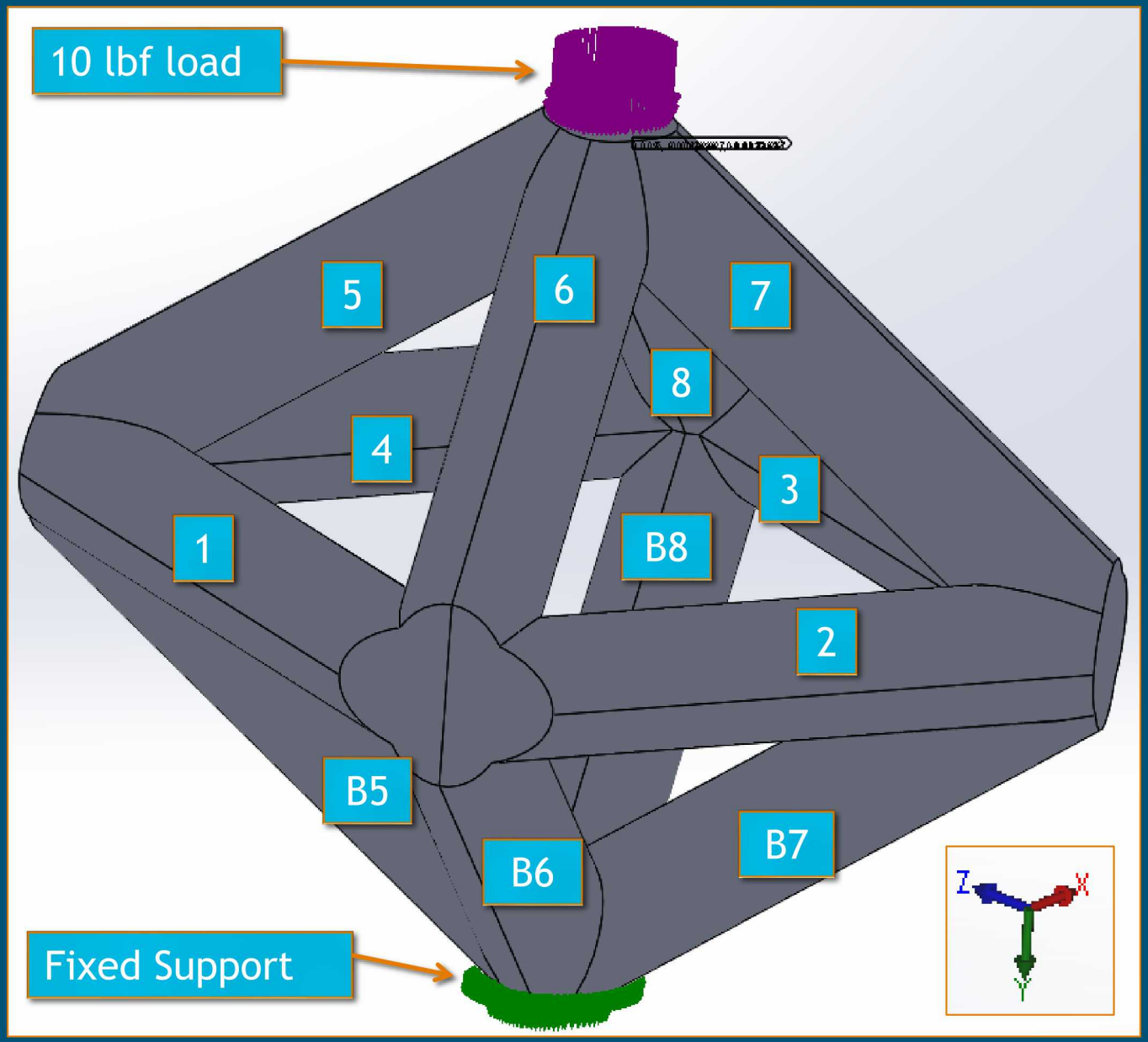
	Value	
Sum	-3.842e-03	in
Avg	-2.112e-06	in
Max	-2.089e-06	in
Min	-2.145e-06	in
RMS	2.112e-06	in

Average displacement in y direction is -2.112x10^{-06} , thus the stiffness is:

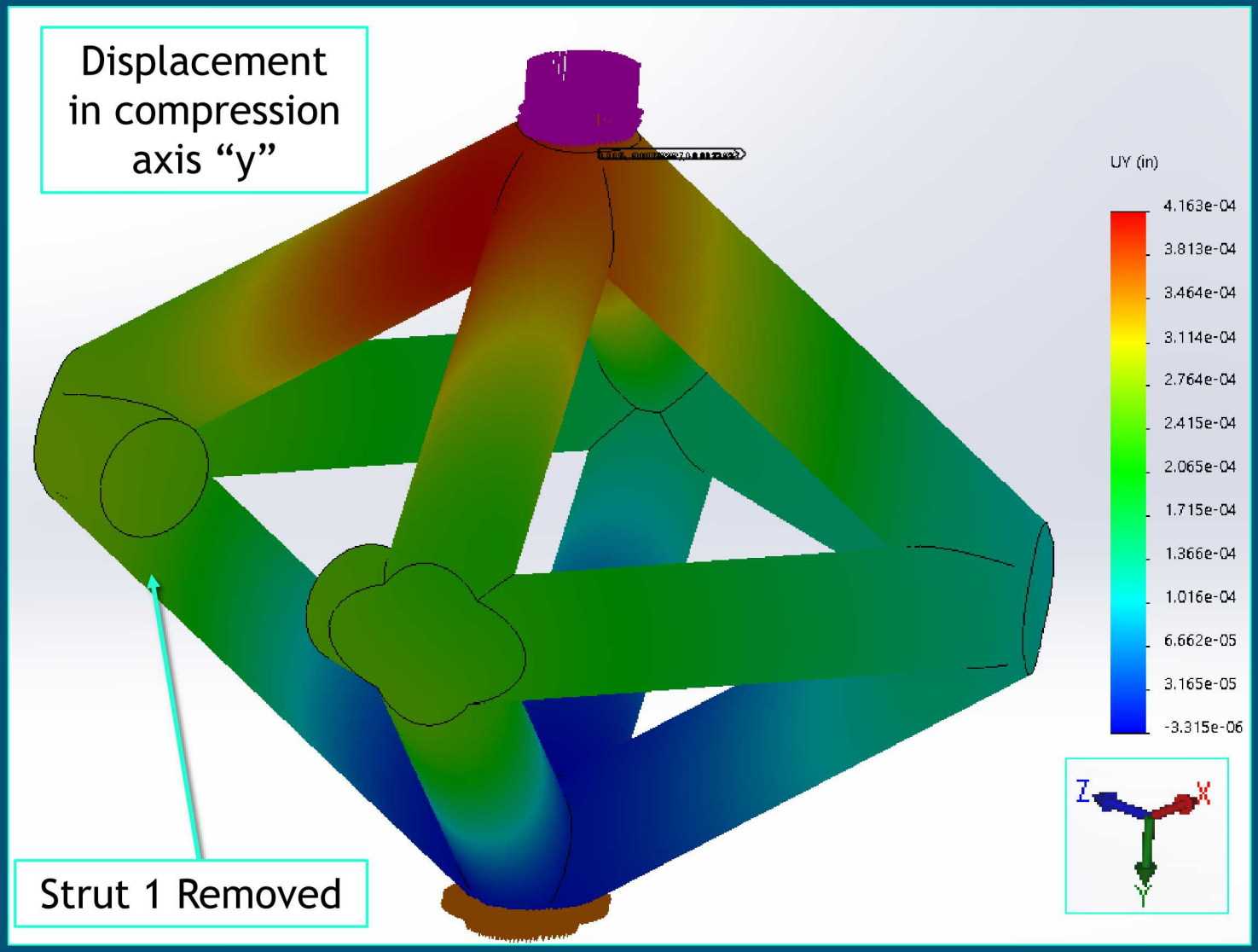
$$k = \frac{10\ pounds}{2.112x10^{-06} inches}$$

$$\underline{\boldsymbol{k = 4.734x10^{6} lb/in}}$$

Single Unit Cell Support/Load Scheme

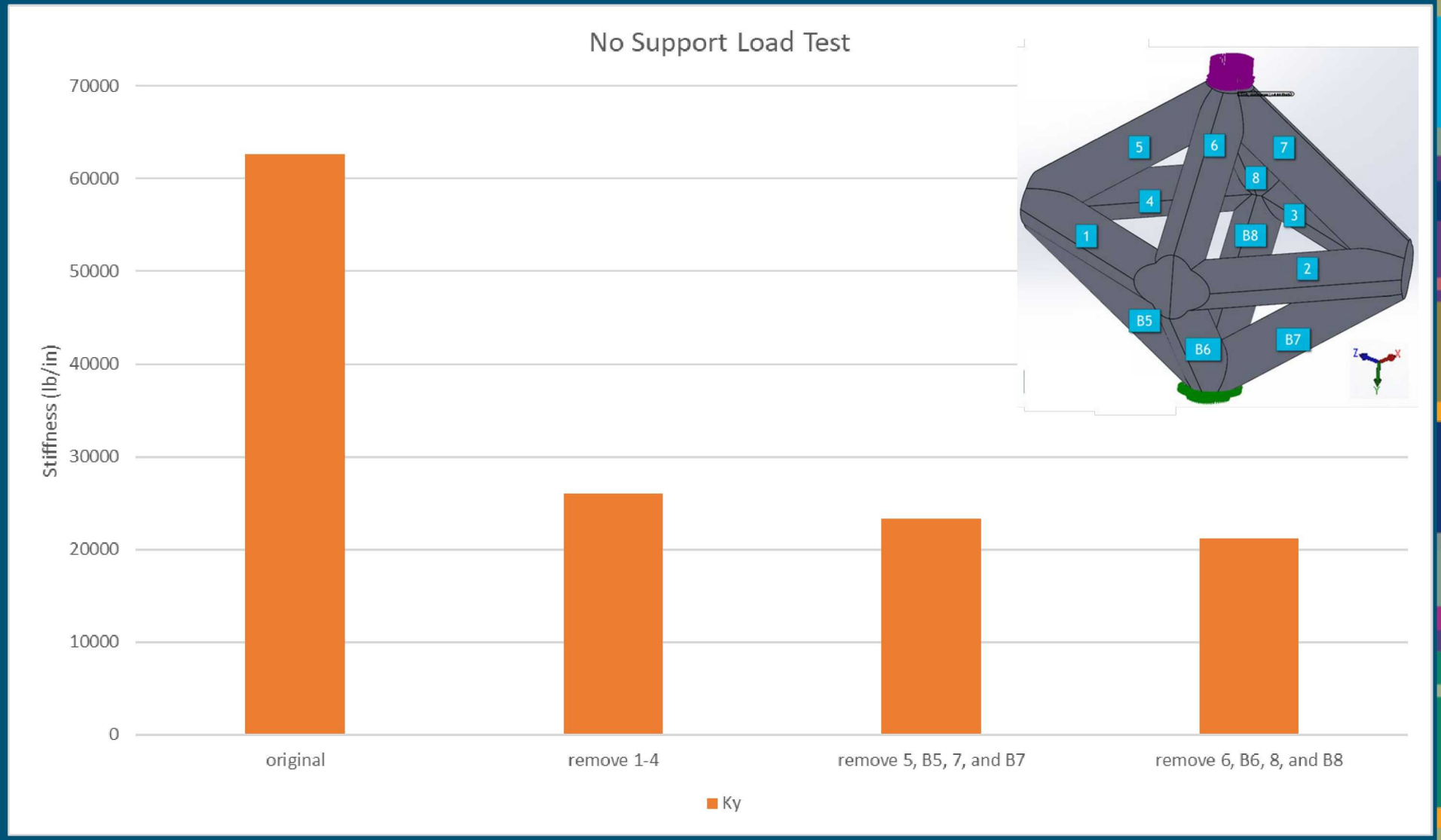


Preliminary Results: Single Unit Cell FEA

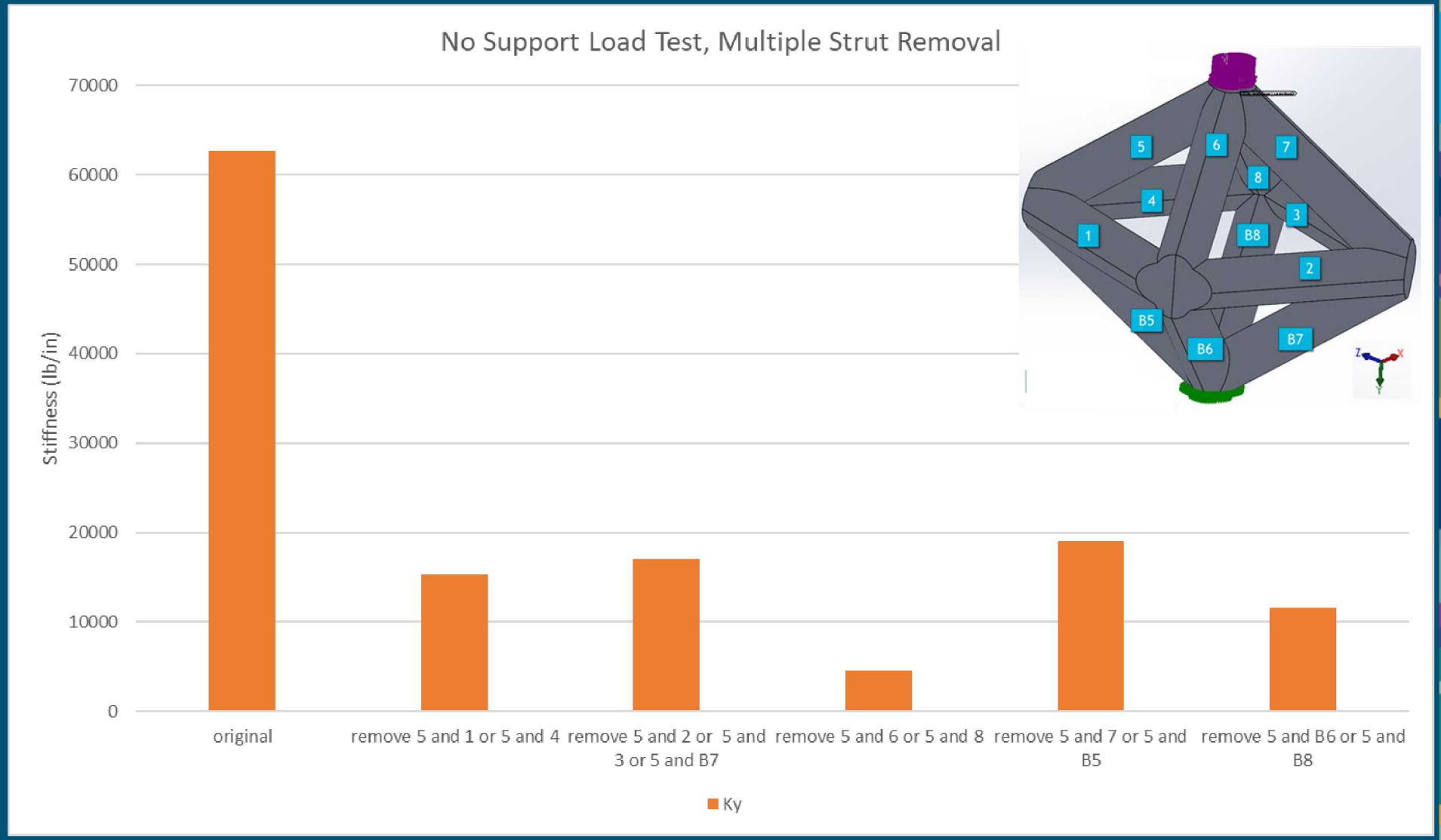


Stiffness was calculated by dividing the applied force by the displacement at the loaded face: $k = {}^{F}/_{\delta}$

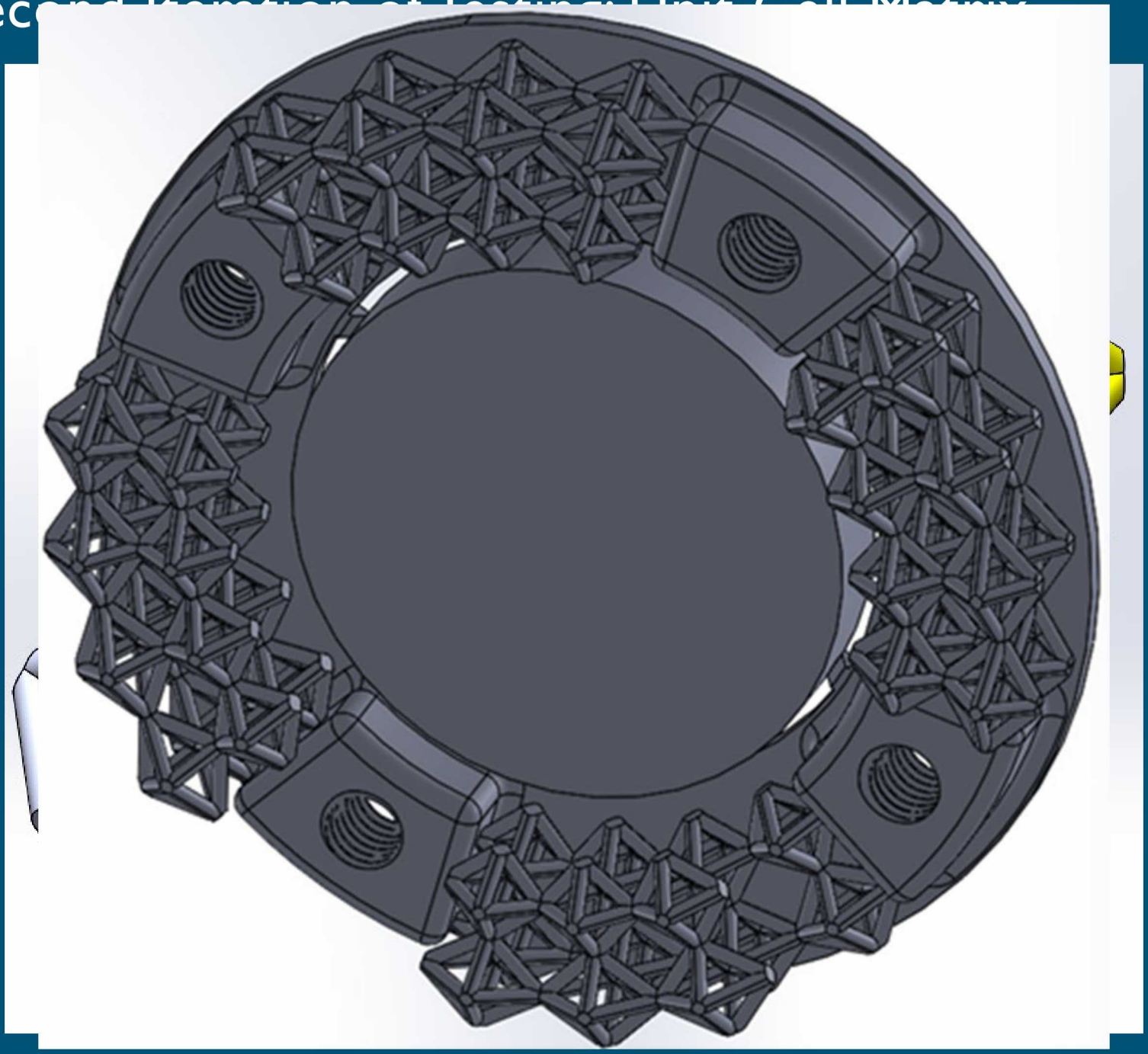
Preliminary Results: Single Unit Cell, One Strut Removed



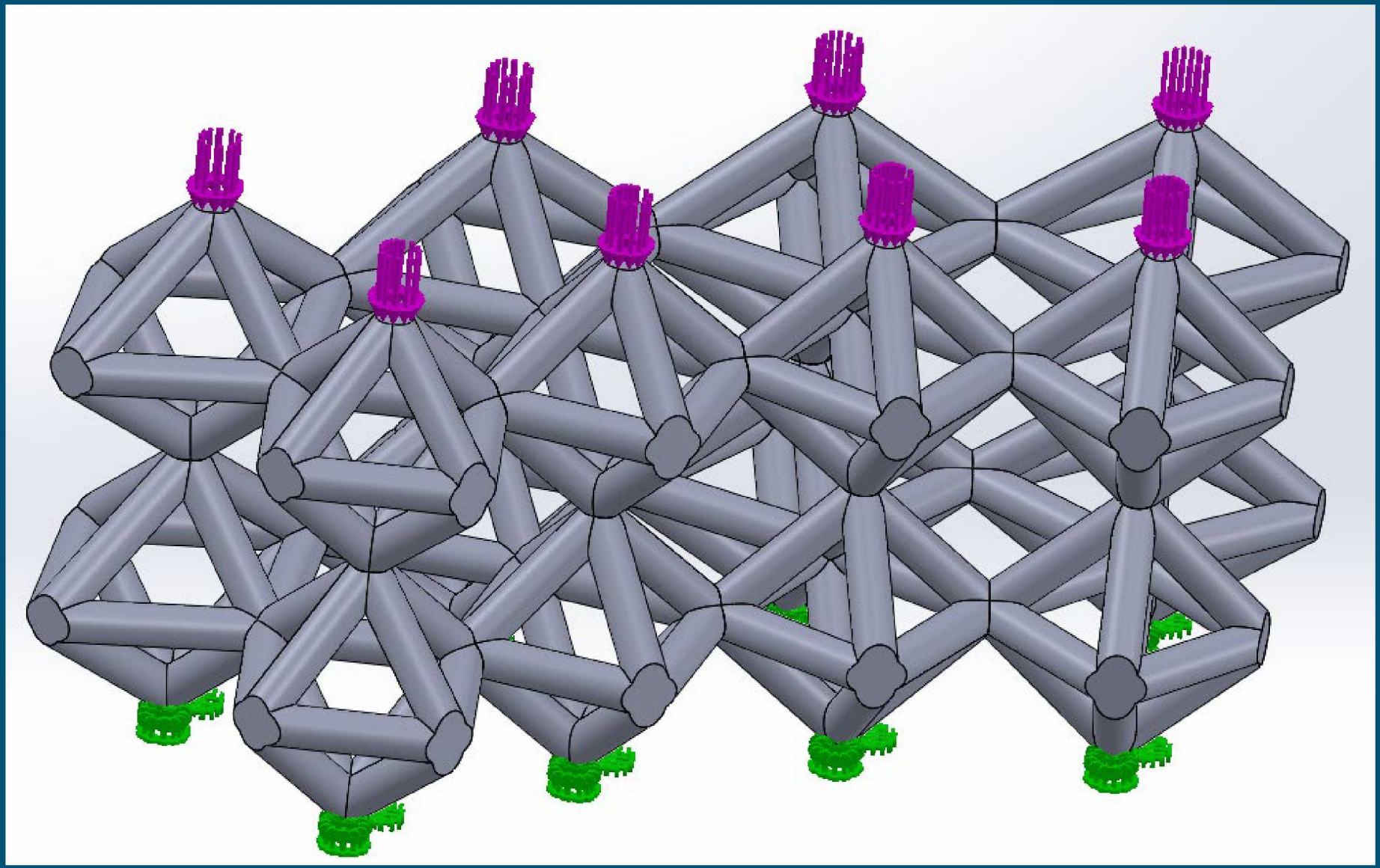
Preliminary Results: Single Unit Cell, Multiple Struts Removed



Second Iteration of Testing Unit Cell Matrix



Second Iteration of Testing: Unit Cell Matrix Support/Load Scheme

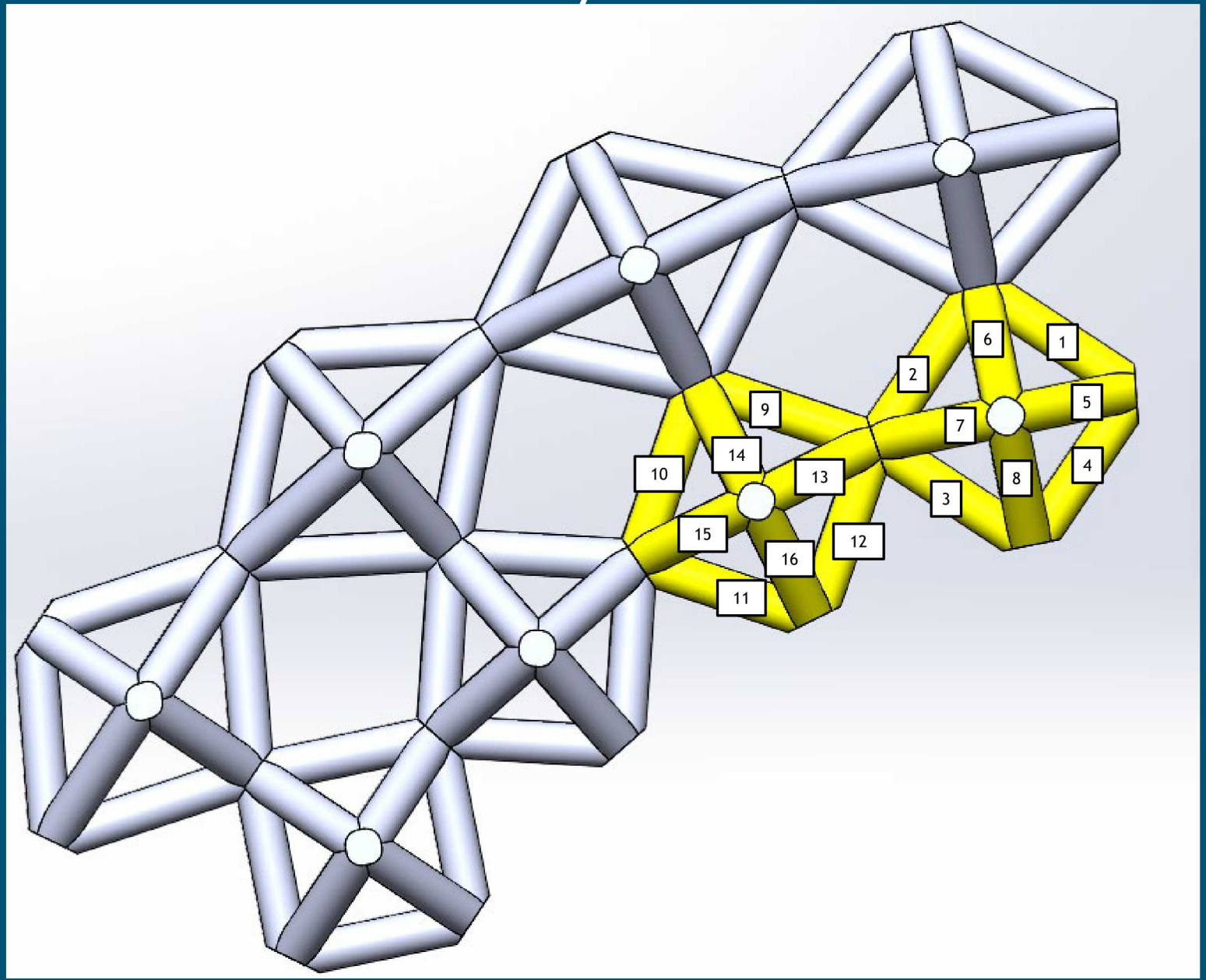


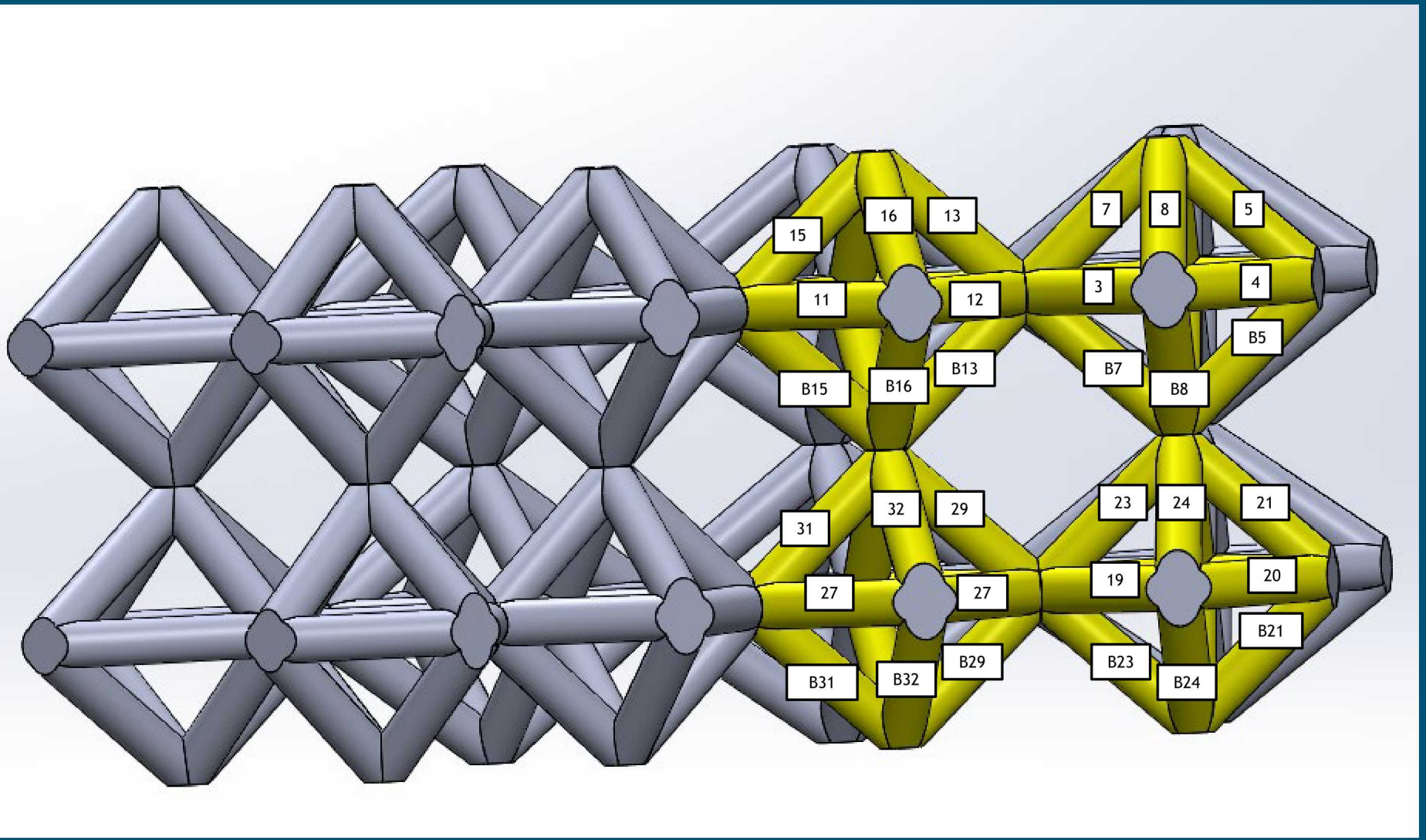
No Struts Removed

Second Iteration of Testing: Unit Cell Matrix Testing Plan

- Selectively remove struts from different locations
- Measure Displacement from the 8 top faces
- Compare for different removal locations

Data Collection and Analysis




15
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B29
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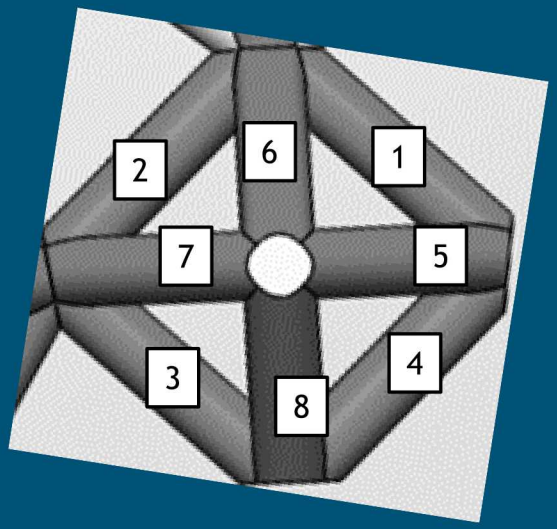
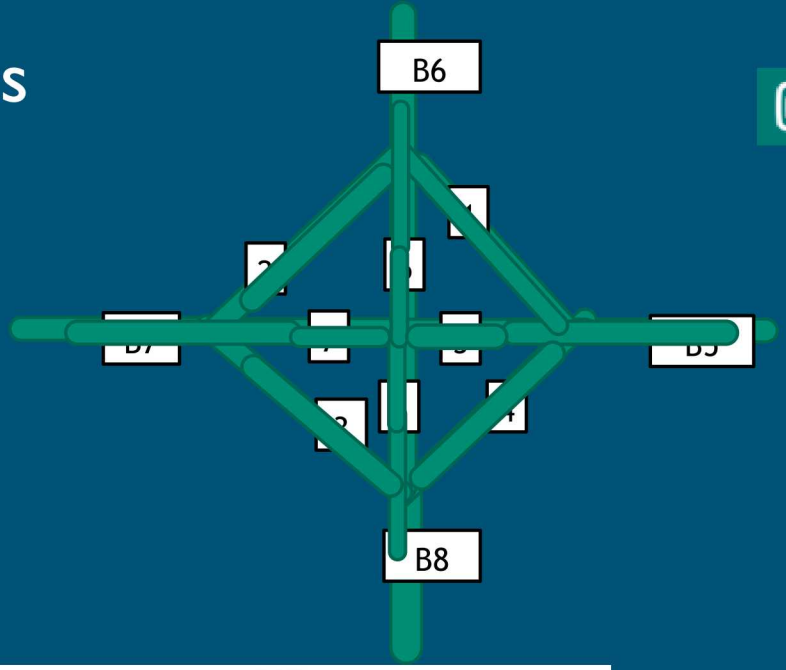
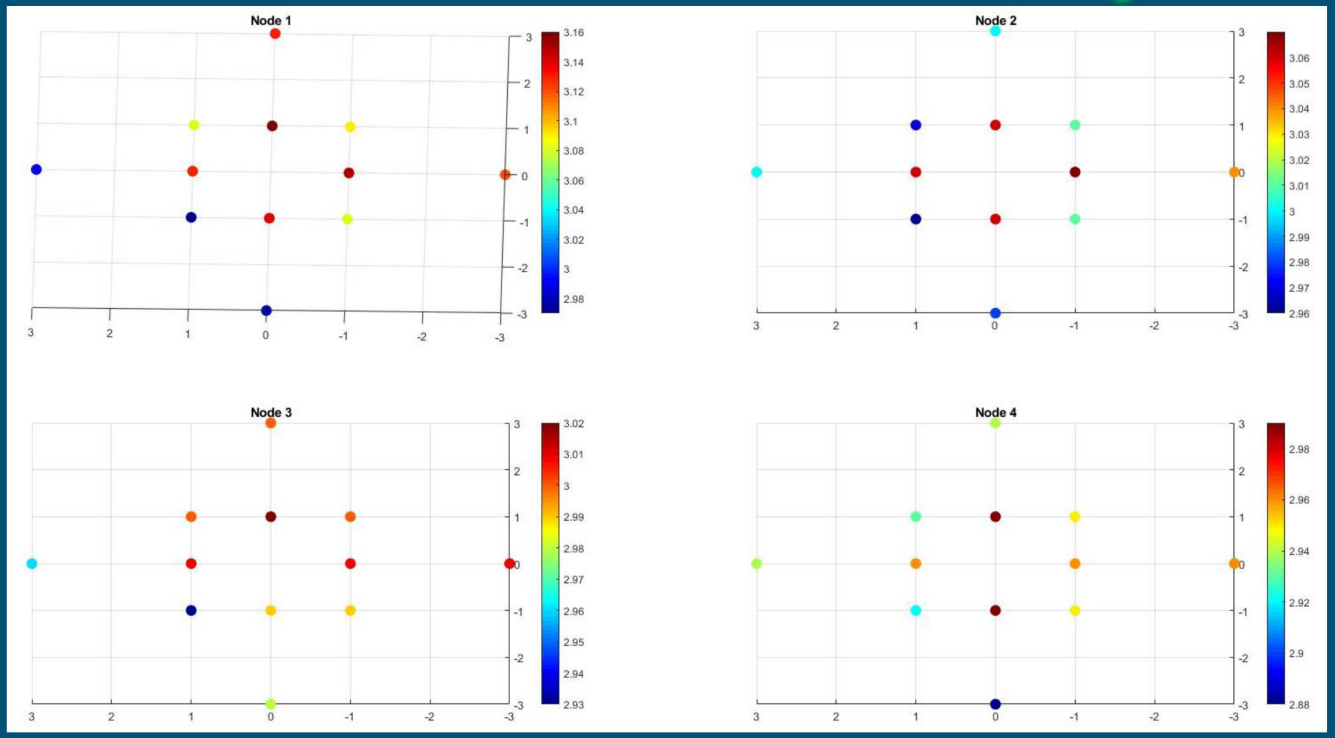
B24

Data Collection and Analysis

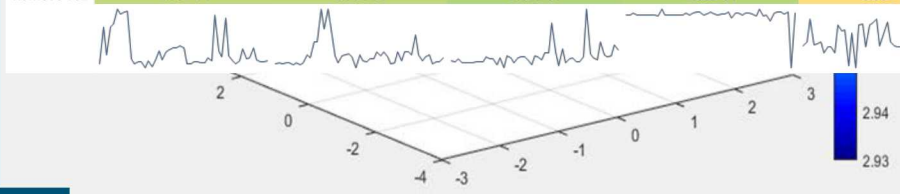


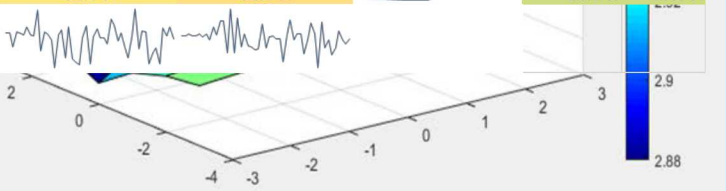




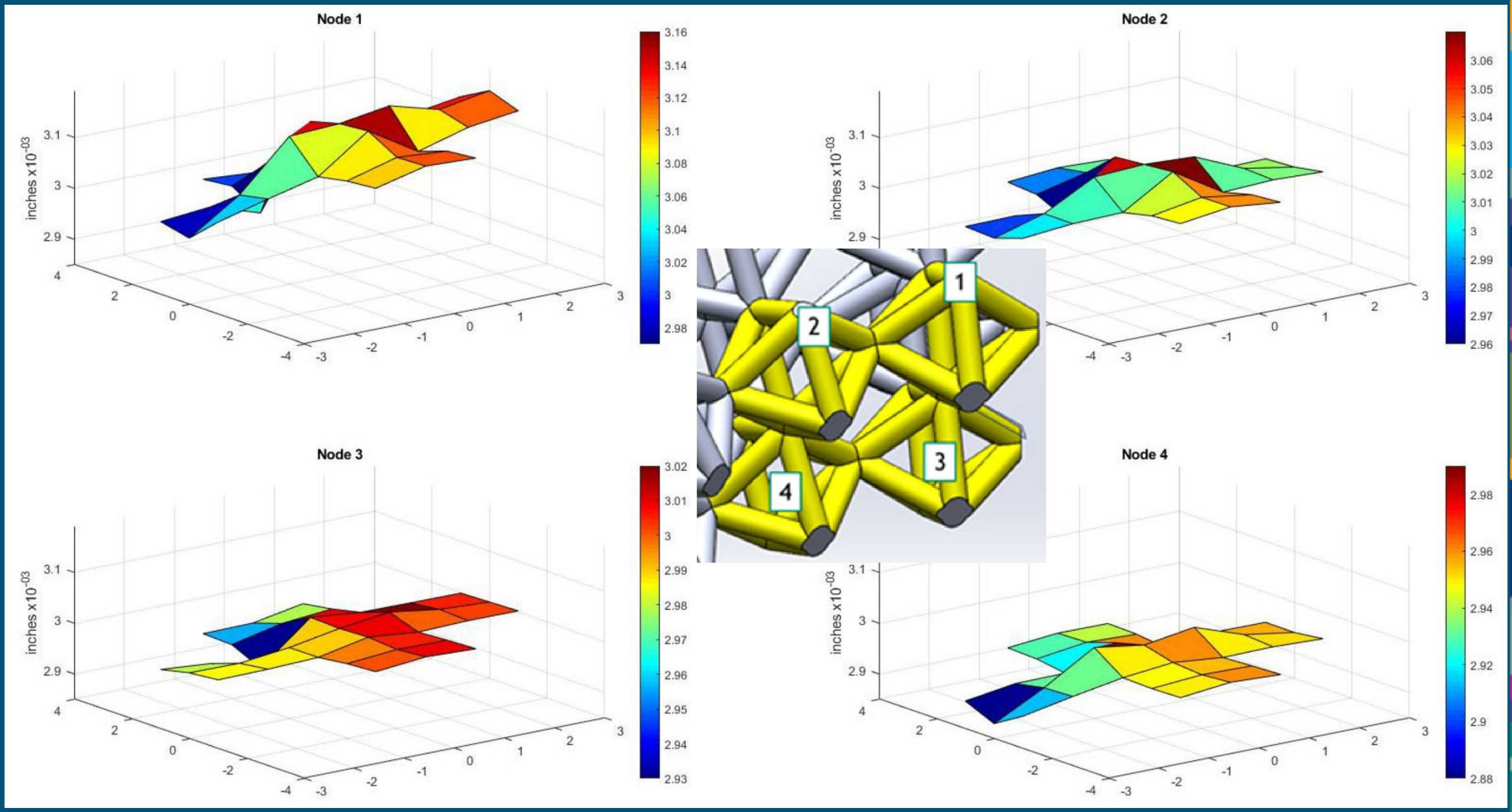
Initial Results

	1	2	3	4	5	6	7	8	SUM	AVERAGE
Original	2.63E-04	2.53E-04	2.53E-04	2.63E-04	3.31E-04	3.18E-04	3.18E-04	3.31E-04	2.33E-03	2.91E-04
Remove 1	3.96E-04	2.55E-04	2.53E-04	2.63E-04	3.33E-04	3.18E-04	3.18E-04	3.31E-04	2.47E-03	3.08E-04
Remove 2	2.94E-04	2.55E-04	2.55E-04	2.64E-04	3.47E-04	3.12E-04	3.14E-04	3.32E-04	2.37E-03	2.97E-04
Remove 3	3.95E-04	2.57E-04	2.52E-04	2.62E-04	3.32E-04	3.18E-04	3.19E-04	3.31E-04	2.47E-03	3.08E-04
Remove 4	4.06E-04	2.56E-04	2.52E-04	2.63E-04	3.32E-04	3.17E-04	3.18E-04	3.31E-04	2.48E-03	3.09E-04
Remove 5	4.60E-04	2.52E-04	2.52E-04	2.63E-04	3.33E-04	3.18E-04	3.18E-04	3.32E-04	2.53E-03	3.16E-04
Remove 6	4.40E-04	2.56E-04	2.52E-04	2.62E-04	3.27E-04	3.19E-04	3.20E-04	3.30E-04	2.51E-03	3.13E-04
Remove 7	4.46E-04	2.50E-04	2.53E-04	2.62E-04	3.30E-04	3.21E-04	3.18E-04	3.32E-04	2.51E-03	3.14E-04
Remove 8	4.53E-04	2.58E-04	2.53E-04	2.63E-04	3.30E-04	3.19E-04	3.17E-04	3.29E-04	2.52E-03	3.15E-04
Remove 9	2.81E-04	2.78E-04	2.53E-04	2.61E-04	3.27E-04	3.19E-04	3.25E-04	3.35E-04	2.38E-03	2.97E-04
Remove 10	2.62E-04	2.71E-04	2.57E-04	2.69E-04	3.43E-04	3.20E-04	3.13E-04	3.31E-04	2.37E-03	2.96E-04
Remove 11	2.71E-04	3.12E-04	2.55E-04	2.62E-04	3.40E-04	3.13E-04	3.19E-04	3.38E-04	2.41E-03	3.01E-04
Remove 12	2.71E-04	3.12E-04	2.55E-04	2.63E-04	3.41E-04	3.13E-04	3.18E-04	3.38E-04	2.41E-03	3.01E-04
Remove 13	2.49E-04	4.03E-04	2.50E-04	2.62E-04	3.19E-04	3.27E-04	3.16E-04	3.23E-04	2.45E-03	3.06E-04
Remove 14	2.72E-04	3.48E-04	2.56E-04	2.62E-04	3.39E-04	3.20E-04	3.08E-04	3.44E-04	2.45E-03	3.06E-04
Remove 15	2.51E-04	4.03E-04	2.49E-04	2.62E-04	3.18E-04	3.27E-04	3.18E-04	3.23E-04	2.45E-03	3.06E-04
Remove 16	2.74E-04	3.49E-04	2.57E-04	2.62E-04	3.44E-04	3.10E-04	3.19E-04	3.39E-04	2.45E-03	3.07E-04
Remove 17	3.08E-04	2.75E-04	2.56E-04	2.65E-04	3.45E-04	3.12E-04	3.11E-04	3.26E-04	2.40E-03	3.00E-04
Remove 18	2.77E-04	2.57E-04	2.52E-04	2.63E-04	3.30E-04	3.16E-04	3.20E-04	3.32E-04	2.35E-03	2.93E-04
Remove 19	3.07E-04	2.75E-04	2.56E-04	2.65E-04	3.44E-04	3.12E-04	3.11E-04	3.27E-04	2.40E-03	2.99E-04
Remove 20	3.13E-04	2.77E-04	2.56E-04	2.65E-04	3.45E-04	3.11E-04	3.10E-04	3.26E-04	2.40E-03	3.00E-04
Remove 21	3.19E-04	2.81E-04	2.56E-04	2.65E-04	3.48E-04	3.11E-04	3.09E-04	3.25E-04	2.41E-03	3.02E-04
Remove 22	3.19E-04	2.72E-04	2.54E-04	2.62E-04	3.31E-04	3.25E-04	3.17E-04	3.25E-04	2.40E-03	3.01E-04
Remove 23	3.27E-04	2.43E-04	2.51E-04	2.63E-04	3.38E-04	3.13E-04	3.20E-04	3.37E-04	2.39E-03	2.99E-04
Remove 24	3.20E-04	2.79E-04	2.57E-04	2.66E-04	3.45E-04	3.10E-04	3.09E-04	3.26E-04	2.41E-03	3.01E-04
Remove 25	2.63E-04	2.62E-04	2.56E-04	2.63E-04	3.33E-04	3.18E-04	3.17E-04	3.30E-04	2.34E-03	2.93E-04
Remove 26	2.65E-04	2.59E-04	2.54E-04	2.62E-04	3.31E-04	3.18E-04	3.19E-04	3.31E-04	2.34E-03	2.92E-04
Remove 27	2.70E-04	2.66E-04	2.59E-04	2.64E-04	3.30E-04	3.23E-04	3.17E-04	3.30E-04	2.36E-03	2.95E-04
Remove 28	2.70E-04	2.66E-04	2.59E-04	2.64E-04	3.30E-04	3.23E-04	3.17E-04	3.30E-04	2.36E-03	2.95E-04
Remove 29	2.66E-04	2.85E-04	2.80E-04	2.66E-04	3.39E-04	3.24E-04	3.15E-04	3.19E-04	2.39E-03	2.99E-04
Remove 30	2.66E-04	2.75E-04	2.60E-04	2.59E-04	3.35E-04	3.18E-04	3.22E-04	3.32E-04	2.37E-03	2.96E-04
Remove 31	2.85E-04	2.85E-04	2.50E-04	2.64E-04	3.24E-04	3.23E-04	3.21E-04	3.38E-04	2.39E-03	2.99E-04
Remove 32	2.73E-04	2.72E-04	2.62E-04	2.65E-04	3.30E-04	3.23E-04	3.16E-04	3.29E-04	2.37E-03	2.96E-04
Remove B5	4.36E-04	2.53E-04	2.52E-04	2.63E-04	3.36E-04	3.16E-04	3.18E-04	3.32E-04	2.51E-03	3.13E-04
Remove B6	3.09E-04	2.57E-04	2.55E-04	2.65E-04	3.54E-04	3.08E-04	3.14E-04	3.32E-04	2.39E-03	2.99E-04
Remove B7	2.88E-04	2.87E-04	2.56E-04	2.64E-04	3.36E-04	3.20E-04	3.11E-04	3.23E-04	2.38E-03	2.98E-04
Remove B8	4.26E-04	2.62E-04	2.53E-04	2.63E-04	3.31E-04	3.16E-04	3.18E-04	3.30E-04	2.50E-03	3.12E-04
Remove B13	2.93E-04	2.85E-04	2.53E-04	2.61E-04	3.21E-04	3.23E-04	3.25E-04	3.37E-04	2.40E-03	3.00E-04
Remove B14	2.75E-04	2.87E-04	2.56E-04	2.69E-04	3.33E-04	3.31E-04	3.14E-04	3.32E-04	2.40E-03	3.00E-04
Remove B15	2.63E-04	2.77E-04	2.90E-04	2.61E-04	3.38E-04	3.22E-04	3.19E-04	3.16E-04	2.39E-03	2.98E-04
Remove B16	2.74E-04	3.31E-04	2.58E-04	2.62E-04	3.41E-04	3.12E-04	3.19E-04	3.38E-04	2.43E-03	3.04E-04
Remove B21	3.16E-04	2.78E-04	2.56E-04	2.56E-04	3.47E-04	3.12E-04	3.09E-04	3.25E-04	2.40E-03	3.00E-04
Remove B22	2.82E-04	2.62E-04	2.54E-04	2.64E-04	3.47E-04	3.16E-04	3.13E-04	3.29E-04	2.37E-03	2.96E-04
Remove B23	2.85E-04	2.71E-04	2.67E-04	2.65E-04	3.39E-04	3.20E-04	3.14E-04	3.22E-04	2.38E-03	2.98E-04
Remove B24	3.18E-04	2.79E-04	2.58E-04	2.66E-04	3.45E-04	3.11E-04	3.09E-04	3.25E-04	2.41E-03	3.01E-04
Remove B29	2.76E-04	2.54E-04	2.56E-04	2.63E-04	3.32E-04	3.18E-04	3.20E-04	3.33E-04	2.35E-03	2.94E-04
Remove B30	2.69E-04	2.60E-04	2.57E-04	2.65E-04	3.32E-04	3.24E-04	3.17E-04	3.29E-04	2.35E-03	2.94E-04
Remove B31	2.69E-04	2.60E-04	2.65E-04	2.08E-04	3.35E-04	3.21E-04	3.20E-04	3.27E-04	2.30E-03	2.88E-04
Remove B32	2.73E-04	2.70E-04	2.61E-04	2.65E-04	3.30E-04	3.23E-04	3.17E-04	3.29E-04	2.37E-03	2.96E-04

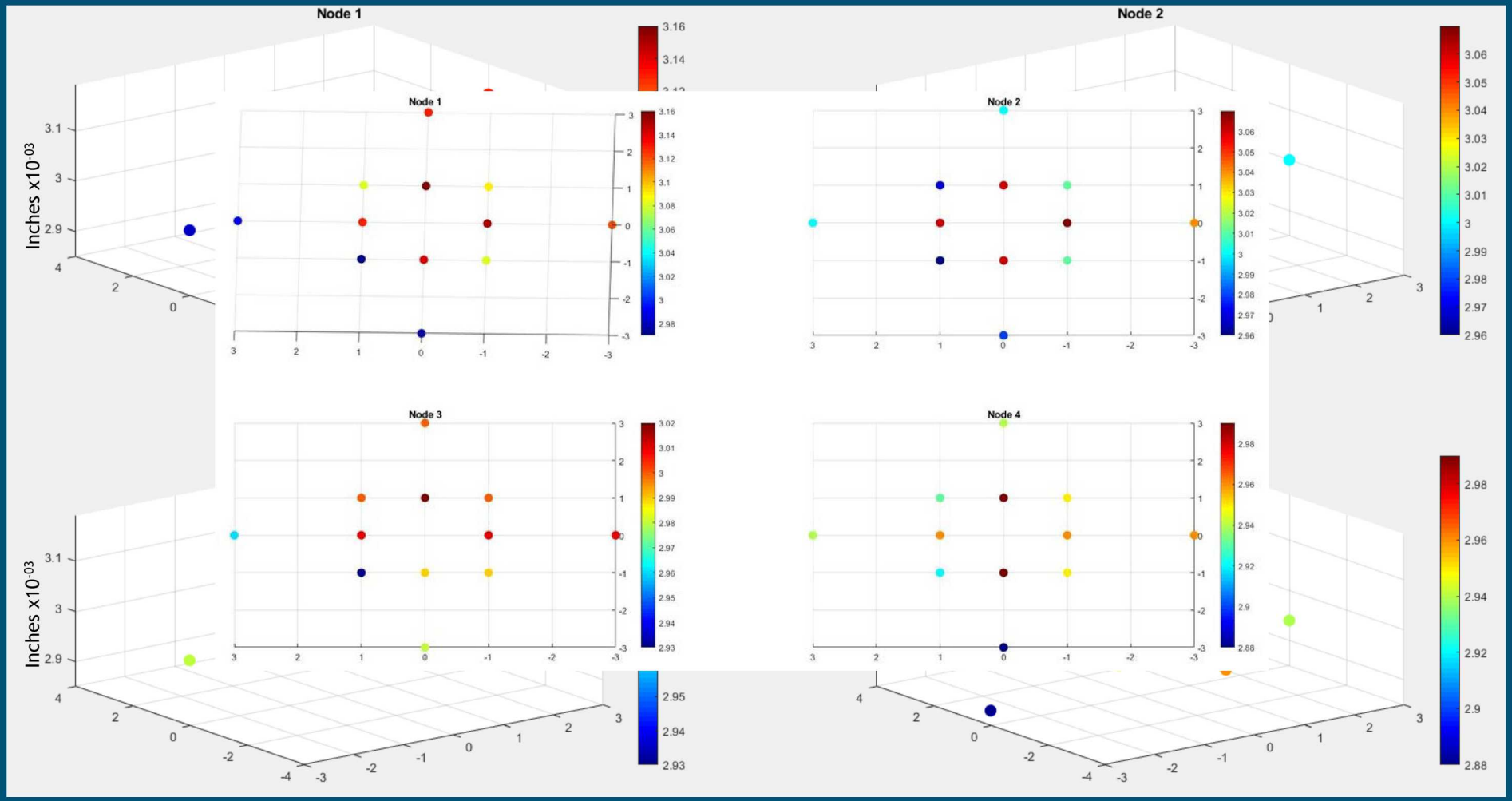




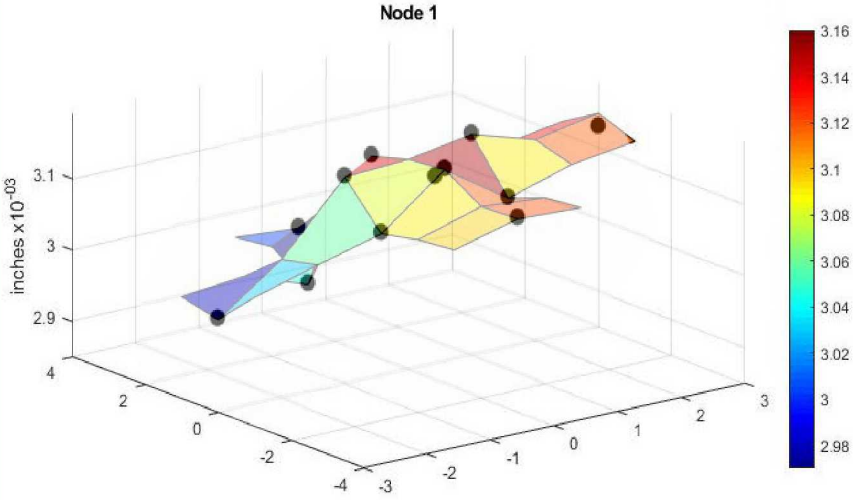
MatLab surf function

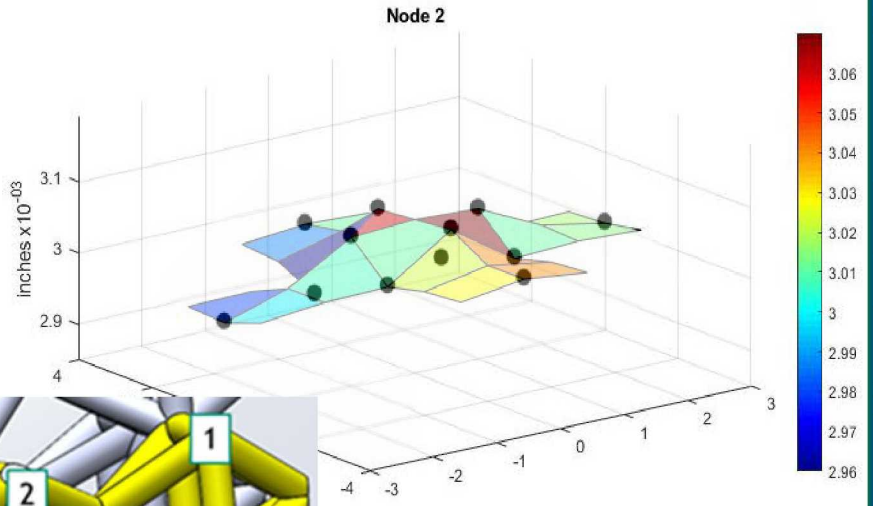


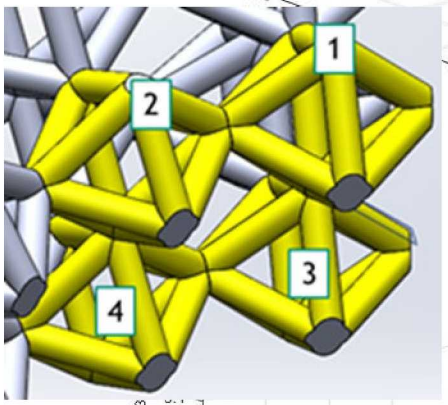
MatLab scatter3 function

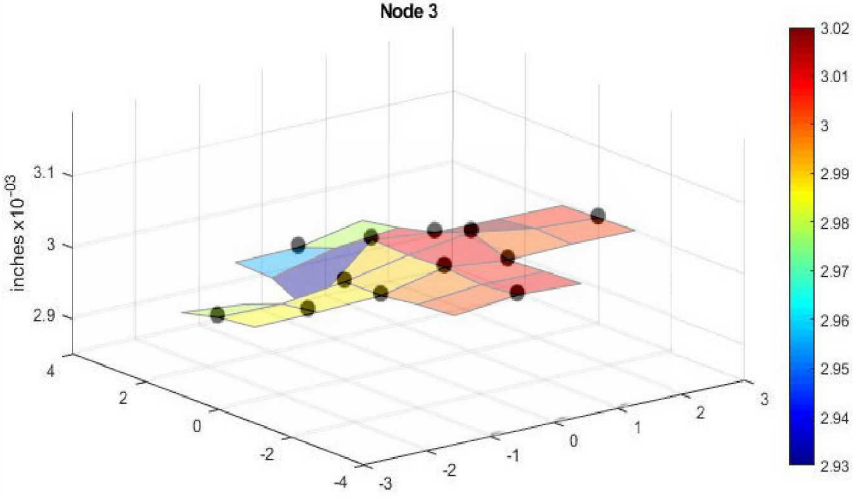


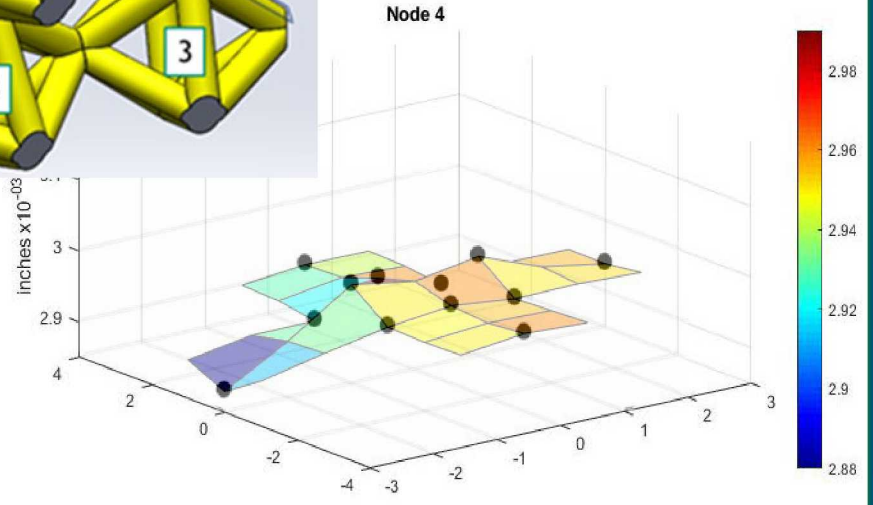
Surf and Scatter3 Transposed



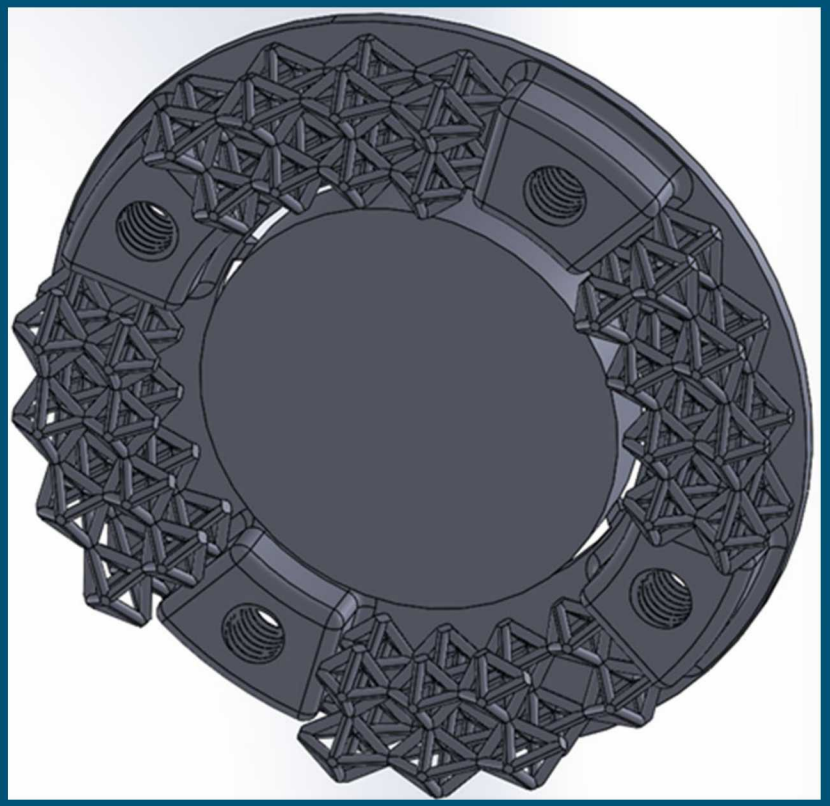


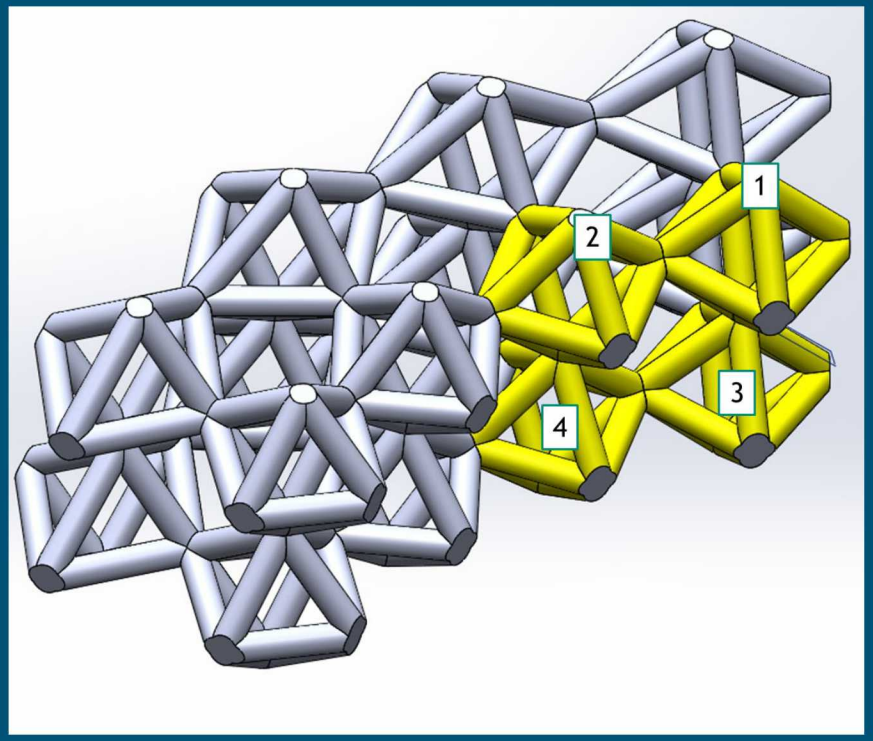






Conclusions





Future Work

Verify the computer simulation

- Destructive model testing
- Rerun with mirror unit cells
- Hand Calculations

Changing the strut size

768 total struts

- How does one affect other sections

Is this the best lattice arrangement for the loading parameters

Engineering Does not Happen in a Vacuum

Technology ≠ People

CLIMBING GYM

SPROUTS FARMERS MARKET

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