Center for Technology and Innovation Sculpture

Binghamton University Mechanical Engineering Department

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Agenda

- Introduction
- Scope
- Fall Progress
- Internal Lighting Design
- External Lighting Design
- Environmental Analysis
- Structural Analysis
- Manufacturability
- Cost Analysis
- Next Steps

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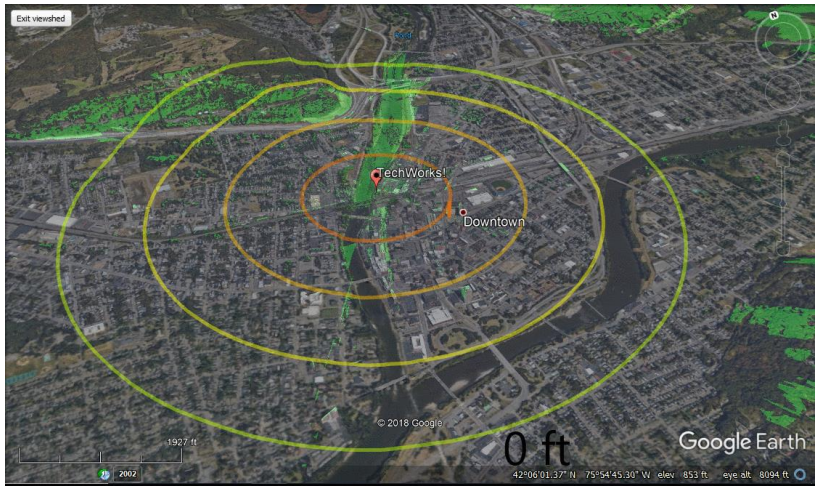
Scope

- Create a feasibility analysis for a sculpture on the roof top that:
  - Symbolizes the mission of TechWorks!
  - Piques the public to ask “What’s That?”
  - Act as a visual guide to where we are
  - “Questions lead to good ideas”
- Fall semester focus on visibility
- Spring focused on structural analysis

Fall Progress

- Initial conceptual design
  - 4 individual designs compared
  - 1 final conceptual design created
- Visibility Analysis
  - Line of Sight
  - Resolvability
- Final sculpture height and dimensions

Distance From Sculpture (miles)	Sculpture Height (feet)	Base Thickness (feet)	Question Mark Thickness (feet)	Sculpture Width (feet)
¼ mile	23.1	3.78	.94	13.96
½ mile	47.1	7.71	1.92	28.46
¾ mile	70.4	11.49	2.87	42.43
1 mile	94.4	15.42	3.85	56.93

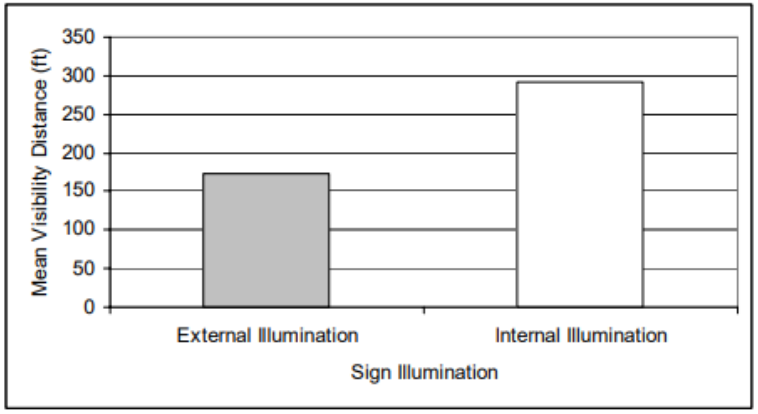


Internal vs. External Lighting Design

- Goal of the semester is to analyze these two systems of lighting and determine if they are structurally viable and able to project enough illumination to be seen at critical points and far distances

Internal vs External Lighting Continued

- External design has no change to the initial model besides hollowing to reduce weight
  - Analysis boils down to can it support itself
- Early research showed that internal lighting provides better visibility than external for signs



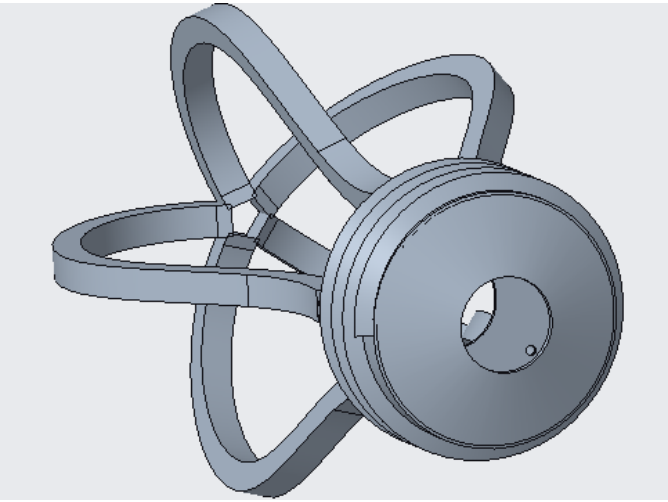
http://www.mautc.psu.edu/docs/PSU-2008-02.pdf

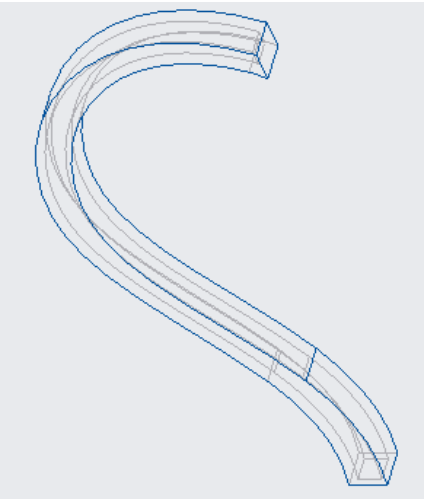
Research done at Penn State University by Philip M. Garvey

- Focus of change in design is in the internal lighting design

Internal Lighting Design - Overview

- Entire Sculpture needs to be made hollow and have holes to allow wiring to pass through and electronics to be installed



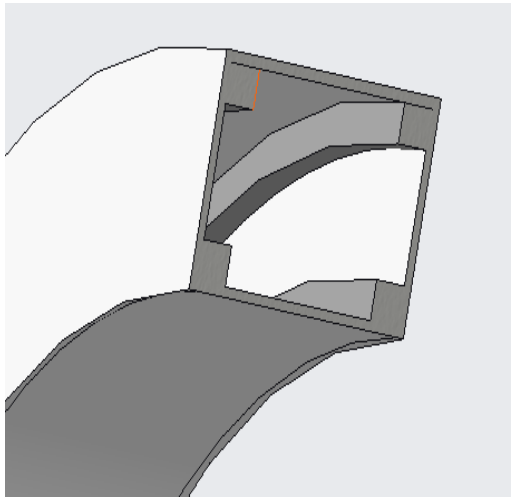


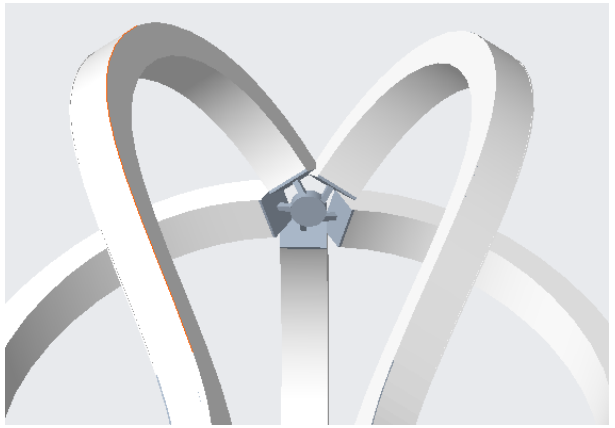
Internal Lighting Design - Overview

- Chamber is created made out of acrylic plates to house lighting equipment and allow for light transmittance.
- Bolted onto aluminum bars at each corner for structural stability

Internal Lighting Design - Overview

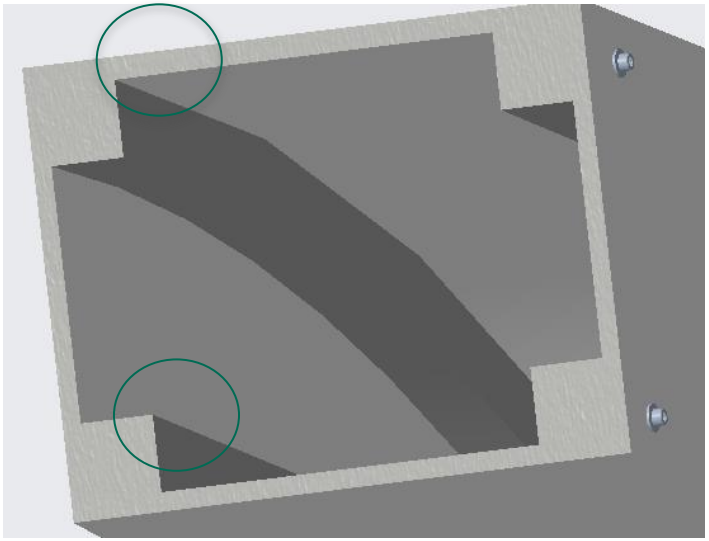
- Overlap the acrylic plates onto the aluminum bar and bolt them for ease of installation
- Created a top support to lessen the effect of deformation due to wind





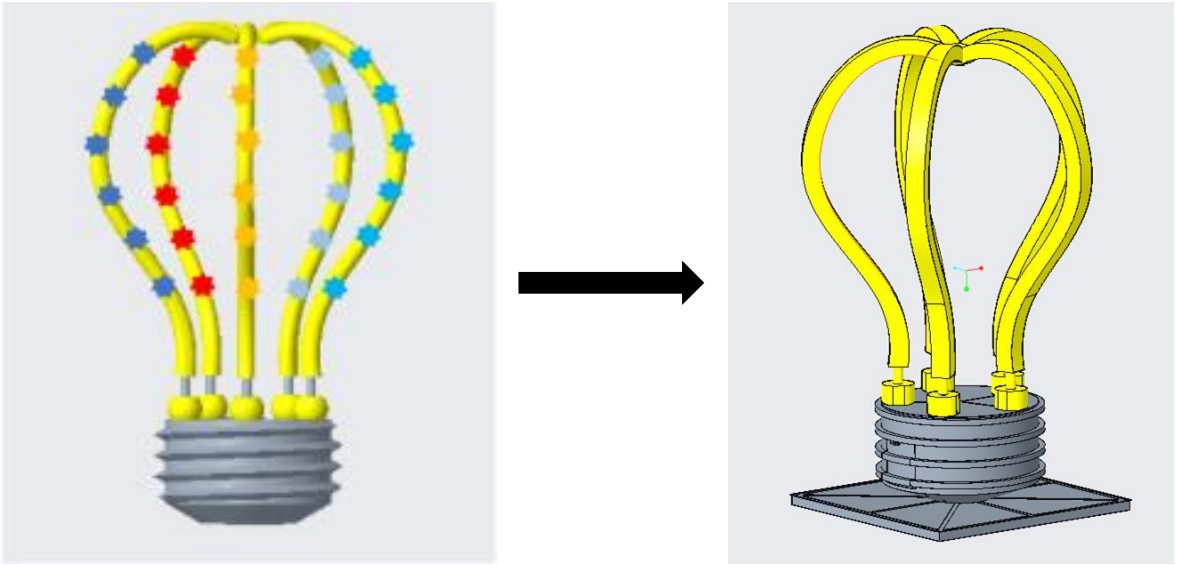
Internal Lighting Design - Overview

- Stainless steel screws that are resistant to corrosion to secure acrylic plates to the aluminum bar
- Washers used to increase bolting area to prevent stress cracking



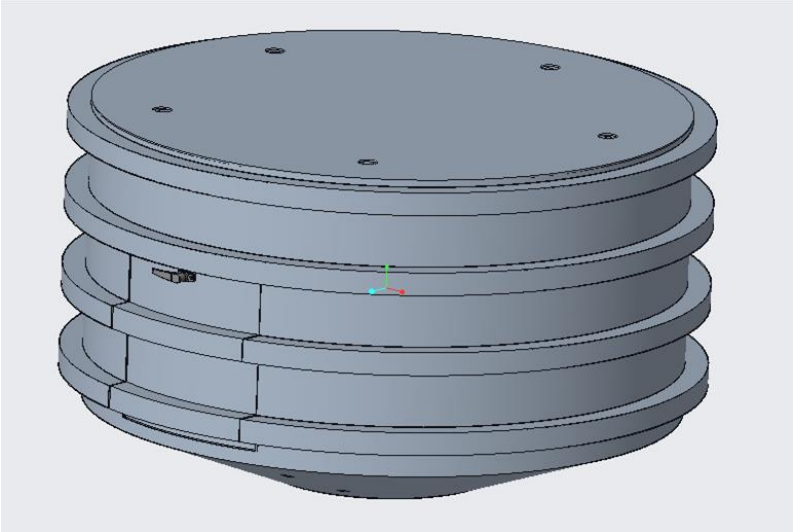
External Lighting Design - Overview

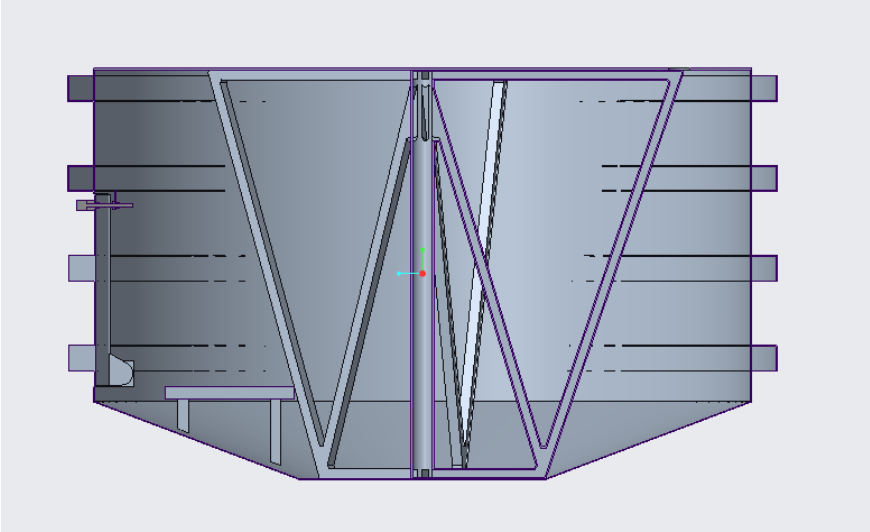
- 5 hollow square question marks
  - Curved aluminum section
  - Stainless steel support pole and base
  - Top support structure
- Flat surfaces for mounting lights
- Hollow cross-section for electronic components



External Lighting Design - Screw Base

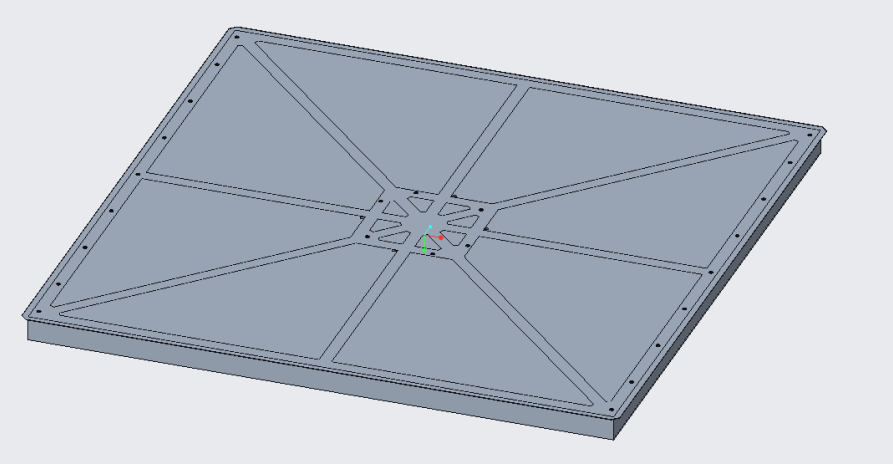
- Aluminum shell and rings
- Stainless steel inner support
- Internal platform for electronics
- Access door with locking handle

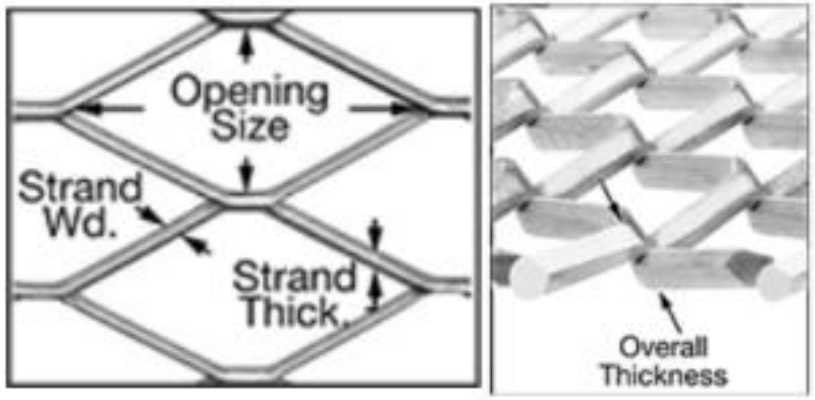




External Lighting Design - Platform Base

- Stainless steel mesh panels
- Stainless steel beam supports
- Rests between I-Beams





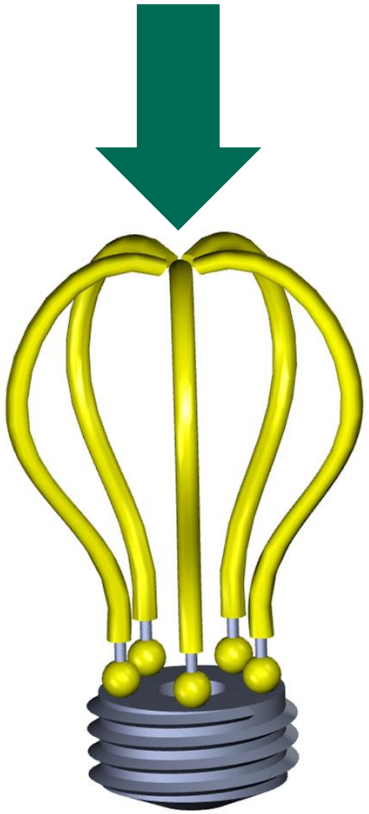
Environmental Analysis - Conditionals

- Calculations for external lighting design
- Seismic loading is N/A

State	County	Min. Basic Wind Speed V (mph)	Max. Basic Wind Speed V (mph)	Min. Basic Wind Speed with Ice V_i (mph)	Max. Basic Wind Speed with Ice V_i (mph)	Min. Design Ice Thickness t_i (in.)	Max. Design Ice Thickness t_i (in.)	Design Frost Depth (in.)	Min. S_S	Max. S_S	Notes
NY	ALBANY	90	90	40	40	0.75	0.75	60	0.25	0.28	2
NY	ALLEGANY	90	90	40	40	0.75	0.75	60	0.18	0.27	2
NY	BRONX	95	105	50	50	0.75	0.75	50	0.42	0.43	1
NY	BROOME	90	90	40	40	0.75	0.75	50	0.18	0.20	2
NY	CATTARAUGUS	90	90	40	40	0.75	0.75	60	0.17	0.27	2
NY	CAYUGA	90	90	40	40	0.75	1.00	60	0.18	0.19	2

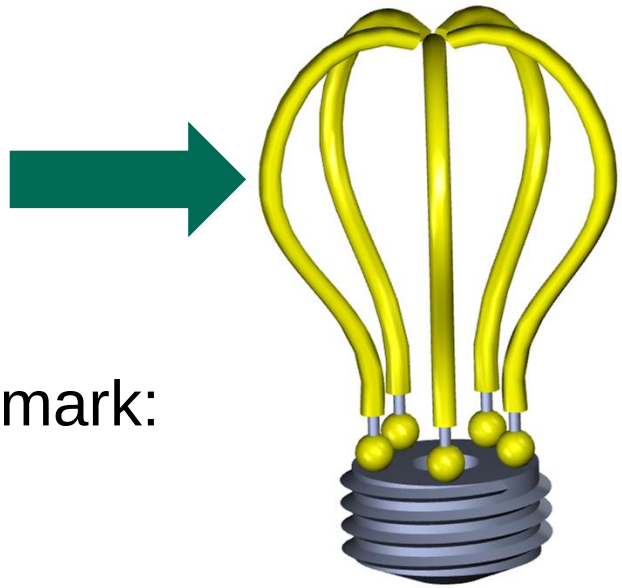
Environmental Analysis - Axial Loading

- Axial Loads:
  - Weight of Structure: 1510 lbs
  - Weight of Ice: 261 lbs
  - Total Loading: 1761 lbs
- Axial Strength for each question mark:
  - 6061 Aluminum Alloy
  - YS = 35 ksi
  - Design Strength = 4387 lbs
- Factor of Safety: 2.48
- Minimum required Factor of Safety: 1.5



Environmental Analysis - Shear Loading

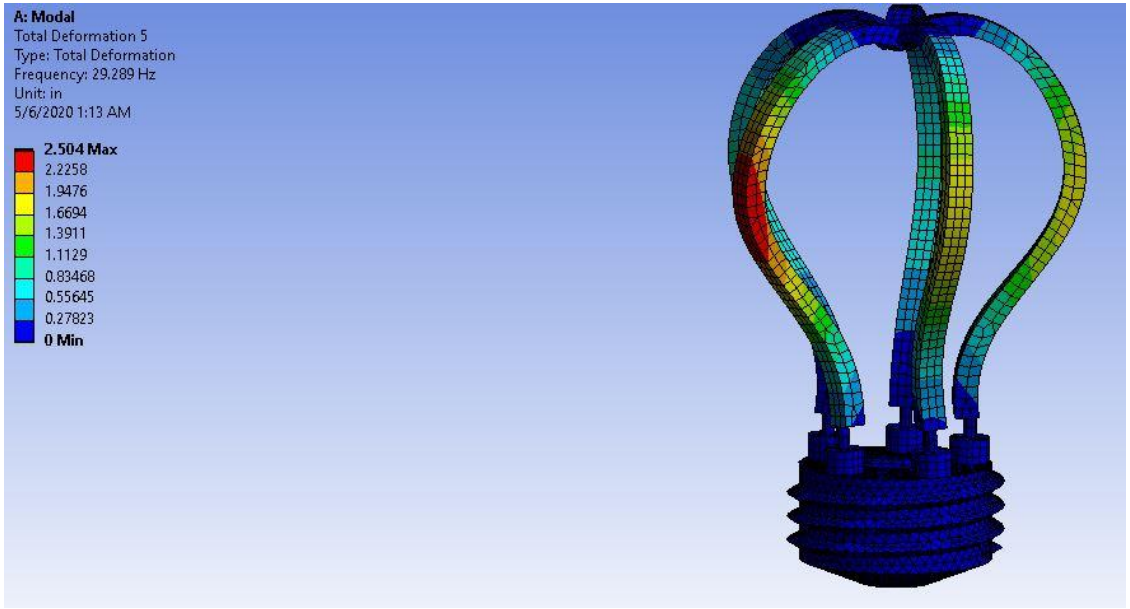
- Shear Loads:
  - Wind Loading (No Ice): 3375 lbs
  - Wind Loading (With Ice): 3414 lbs
  - Resonance: 178 lbs
  - Total Loading: 3591 lbs
- Shear Strength for each question mark:
  - 6061 Aluminum Alloy
  - YS = 35 ksi
  - Strength = 8427 lbs
- Factor of Safety: 2.35
- Minimum required Factor of Safety: 1.5



Environmental Analysis - Natural Frequency

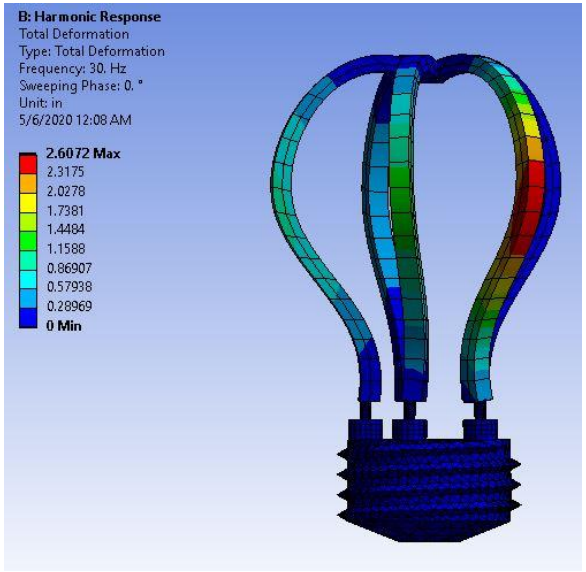
- Modal Frequency with no external forces:
- 5 iterations - values converge
- 30 Hz = 30 gusts of wind per second

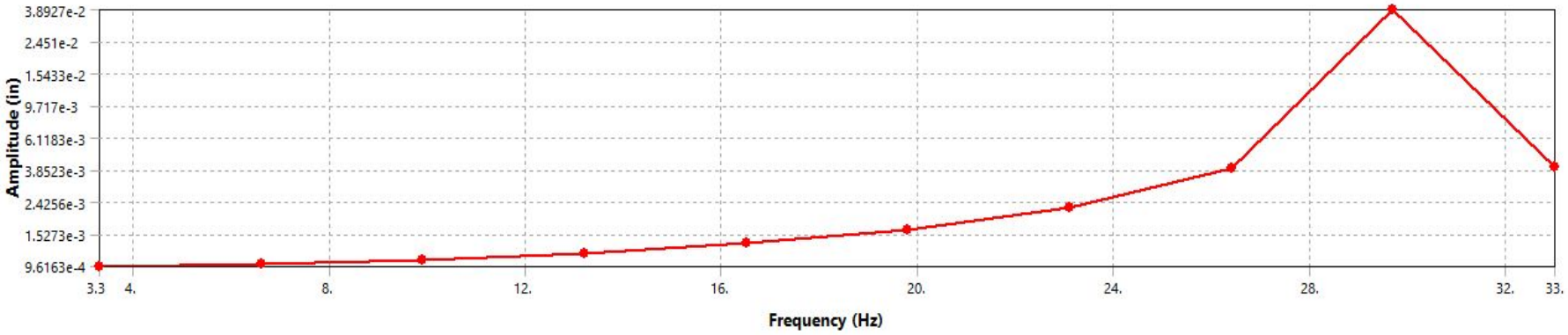
	Mode	Frequency [Hz]
1	1.	29.082
2	2.	29.123
3	3.	29.203
4	4.	29.232
5	5.	29.289



Environmental Analysis - Natural Frequency

- Natural Frequency: 30 Hz
  - Amplitude spikes at 30 Hz
- Deformation: 2.6” max
- Tolerance is 5% of total height
  - 9 inches
- F = Asin(wt)
  - Max Amplitude is .031”

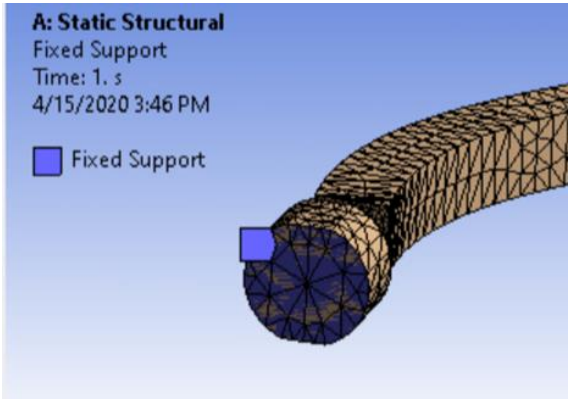




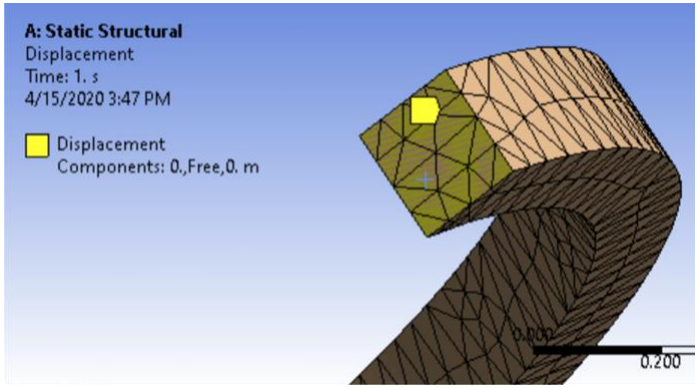
External Lighting - Structural Analysis

No External Environmental Forces (gravity only)

- Constraints:
  - Fixed

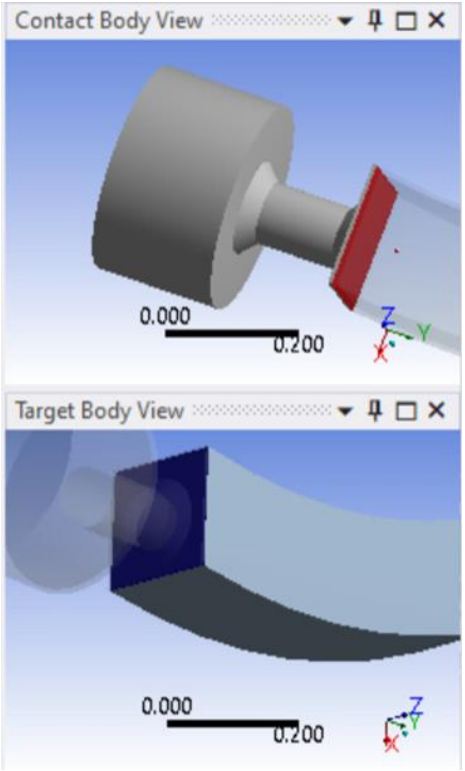


  - Movement restricted



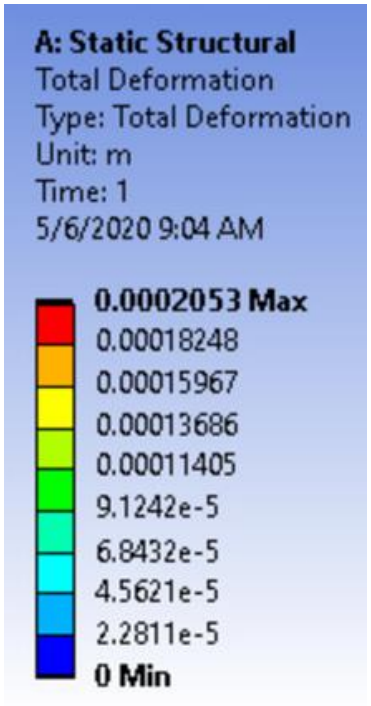
External Lighting - Structural Analysis

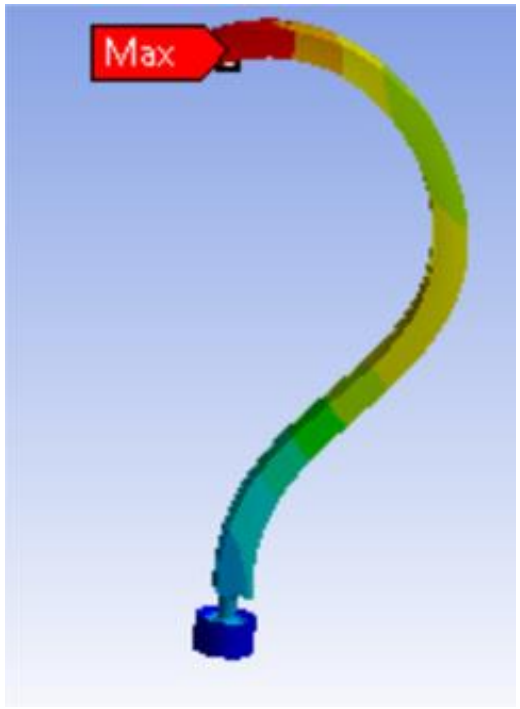
- Additional Constraints
  - Bonded connections



External Lighting - Structural Analysis

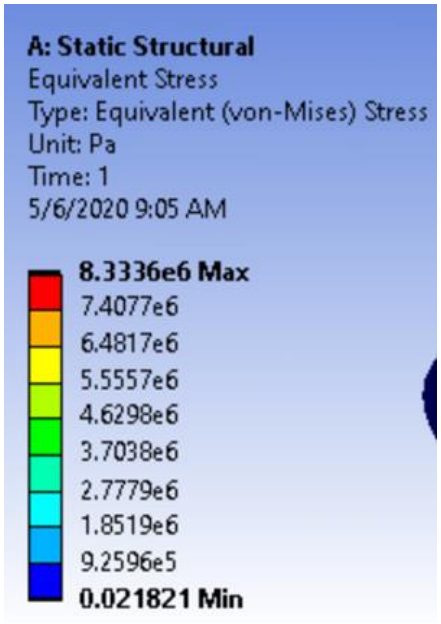
- Deformation Analysis
  - Total Deformation: 0.008 in (0.205mm)
  - Deformation is 0.0044% of the sculpture height

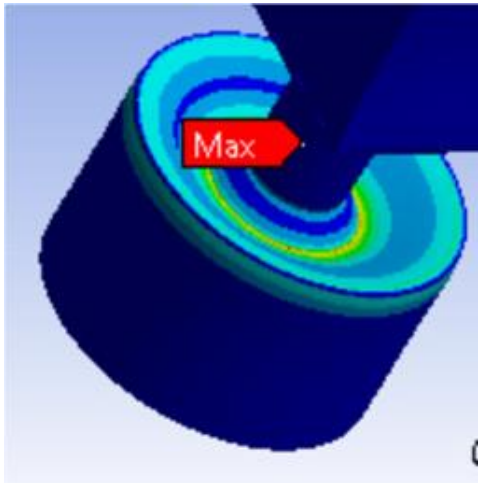


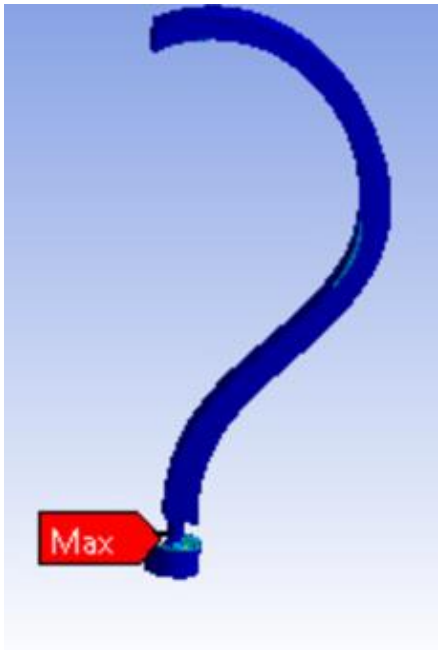


External Lighting - Structural Analysis

- Stress Analysis
  - Max Stress: 1208.16 psi (8.33 MPa)
  - Factor of Safety (FOS): 28.97



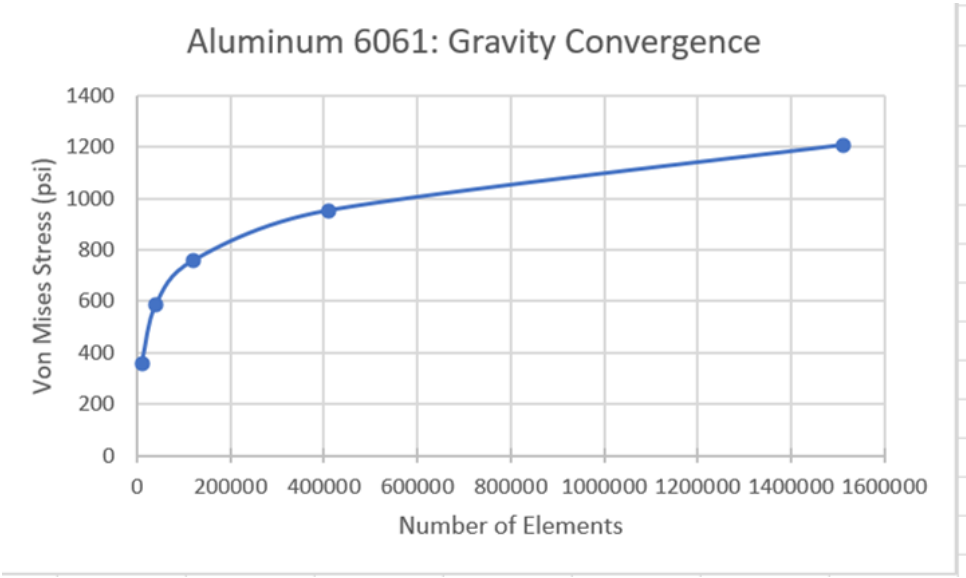




External Lighting - Structural Analysis

- Stress Convergence Analysis

Aluminum 6061	
Elements	Max Stress (psi)
9877	358.24
39826	584.5
121111	758.55
410122	952.89
1513610	1208.16



Aluminum 6061	
Yield Strength (psi)	35000
FOS	28.97

External Lighting - Structural Analysis

- Results Summary

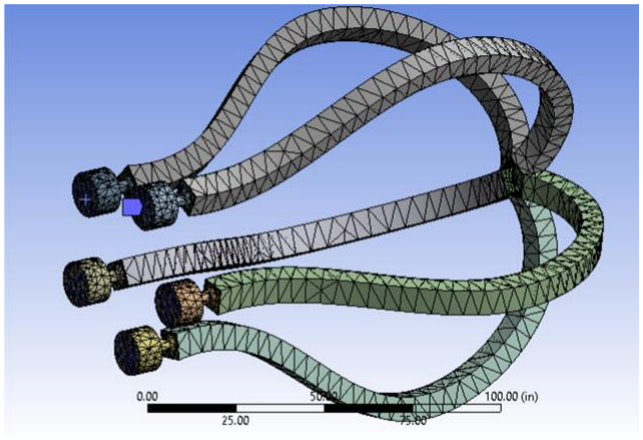
Deformation Analysis			
Height of Sculpture (ft)	Max. Allowable Deformation (in)	Tested Sculpture Deformation (in)	Pass/Fail
15	9	0.008	PASS

Stress Analysis				
Yield Strength (psi)	Tested Max. Stress (psi)	Required Minimum FOS	Calculated FOS	Pass/Fail
35000	1208.16	1.5	28.97	PASS

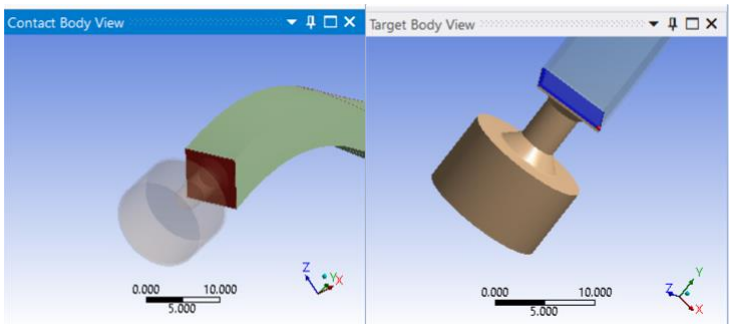
External Lighting - Structural Analysis

Including Environmental Loads

- Constraints:
  - Fixed Support

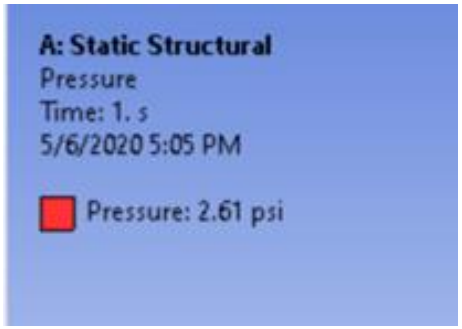


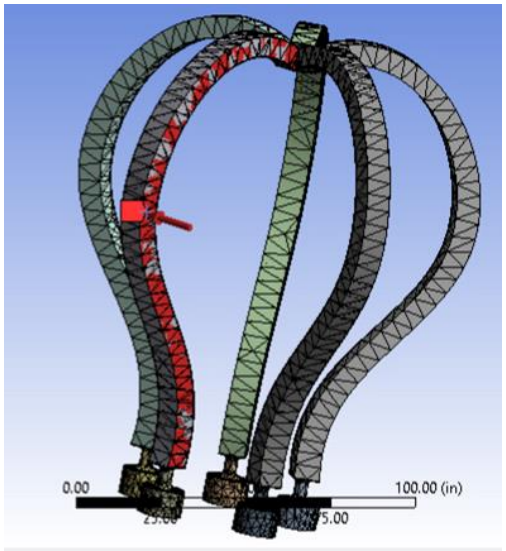
  - Bonded Connections



External Lighting - Structural Analysis

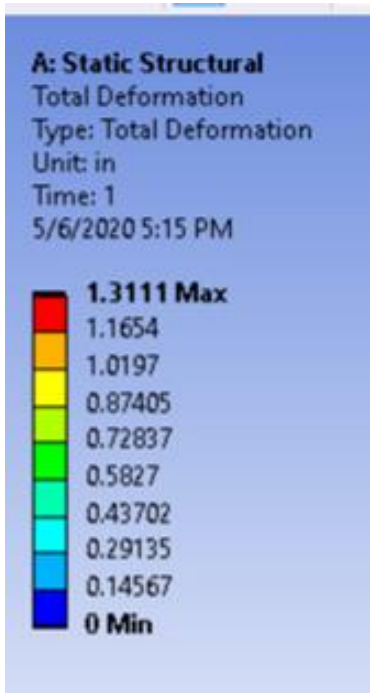
- Calculating Shear Pressure (wind and ice load)
  - All loads need to be applied as pressures acting on the question mark
  - Pressure = Force/Area
    - Force = 3414 lbs
    - Area = Cross Sectional Area of one Question mark
      - Area = 1,307.81 sq. in.
    - Pressure = 2.61 psi

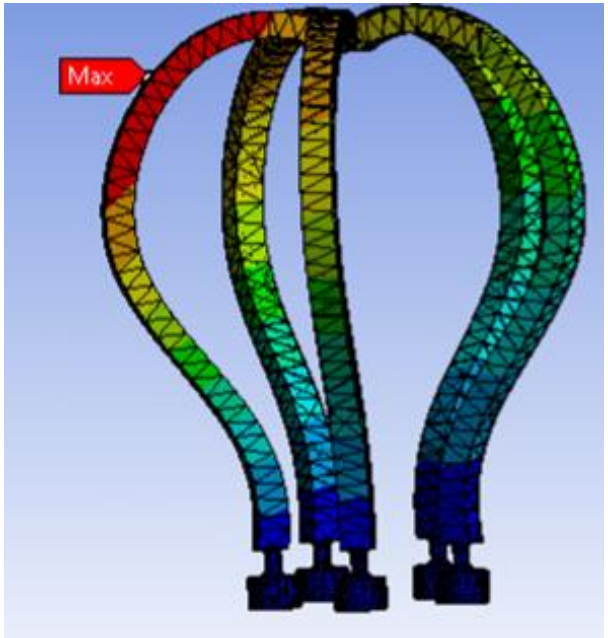




External Lighting - Structural Analysis

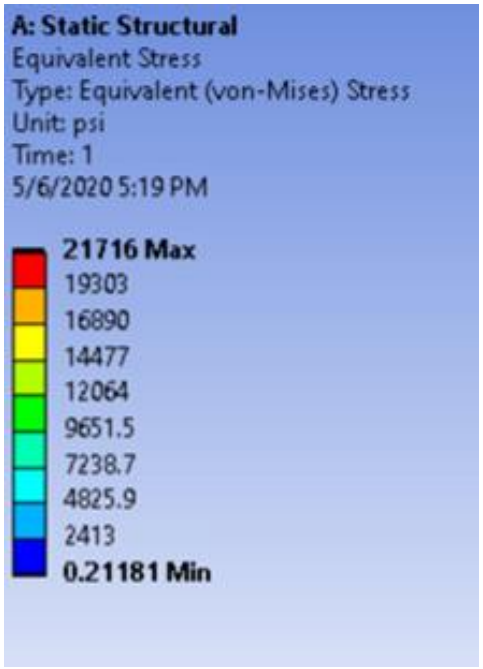
- Deformation Analysis
  - Total Deformation: 1.31 in
  - Deformation is 0.73% of the sculpture height

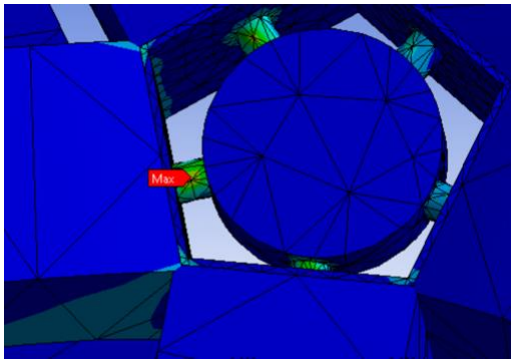




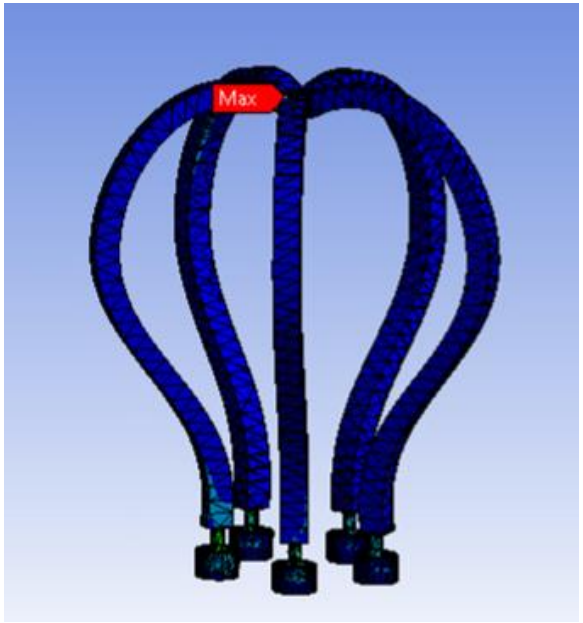
External Lighting - Structural Analysis

- Stress Analysis
  - Max Stress: 21716 psi



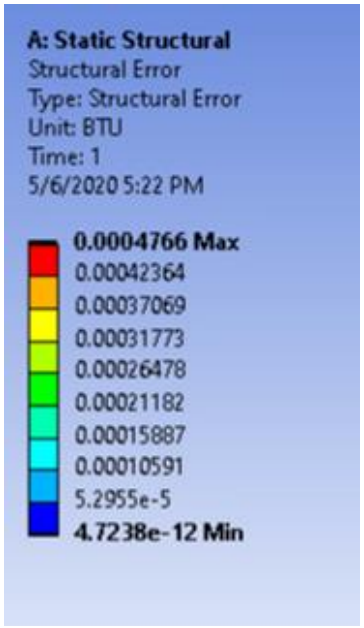


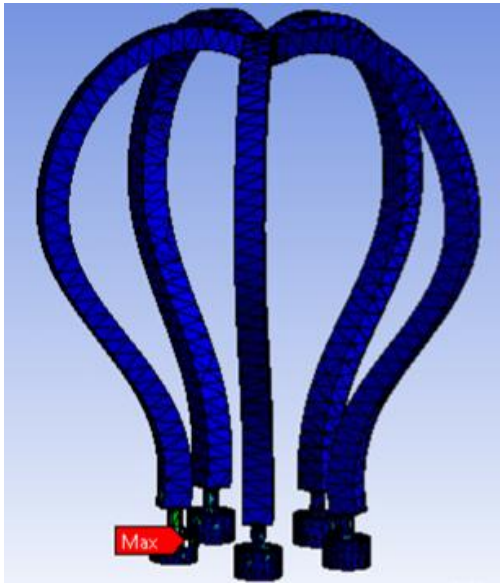
Aluminum 6061	
Yield Strength (psi)	35000
Max Stress (psi)	21716
FOS	1.61



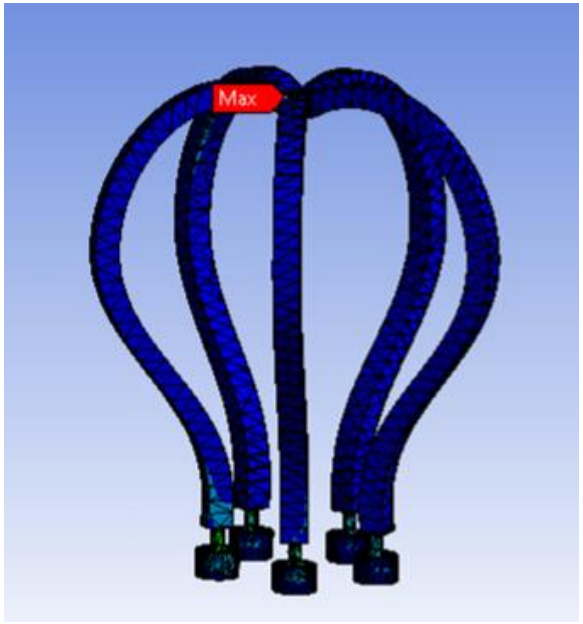
External Lighting - Structural Analysis

- Error Plot





Recall: Max Stress location



External Lighting - Structural Analysis

- Results Summary

Deformation Analysis			
Height of Sculpture (ft)	Max. Allowable Deformation (in)	Tested Sculpture Deformation (in)	Pass/Fail
15	9	1.31	PASS

Stress Analysis				
Yield Strength (psi)	Tested Max. Stress (psi)	Required Minimum FOS	Calculated FOS	Pass/Fail
35000	21716	1.5	1.61	PASS

Cost Analysis

Features	Price
ELD Question Marks	$5,900.83
ILD Question Marks	$3,119.19
Bases	$6,677.57
Total	$12,578.40/$9,796.76

Cost Analysis - Additional Items

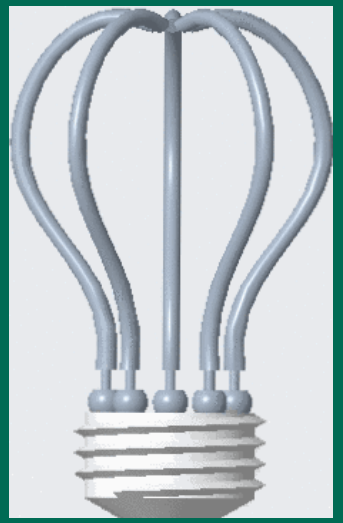
- Labor Costs
  - Welding, water jet, assembly
  - Seneca Steel
  - Empire Plastics
  - Crowley Fabrication & Machining
- Specific Lighting Units
- Electrical/Computer Components

Summary

- 2 Potential Designs
  - Internal
  - External
- Secured to roof via platform attached to screw base
- Environmental Analysis - MATLAB
  - Wind Loading
  - Ice Loading
  - Seismic Load
  - Resonance
- Structural Analysis - ANSYS
  - Major stress points are within tolerance
  - Verifies Environmental Analysis
- Both designs pass the industry standards

Special Thanks To:

- Art Law, Ryan Donovan, and the TechWorks! team
- Professor Razavi and Professor Murray



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