SAE Mini Baja

Frame Team

Project Proposal

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12-3-14

Overview

- Introduction
- Customer’s Needs and Project Goals
- Constraints, Objectives, QFD, and Timeline
- Concept Generation and Decision Matrix
- Testing and Analysis
- Final Design
- Bill of Materials

Introduction

- SAE sponsored 2015 Mini Baja Competition
- Designing a Mini Baja
  - Frame
  - Driver Safety

Customer’s Needs

Customer: Dr. John Tester

- Weight reduction
- Weight distributions cannot exceed a 40x60 front to rear weight ratio
- Must be safe and ergonomic for driver.
- Obstacle clearance

Goals

- Design and build a light weight frame that will meet strength, safety, and dimension requirements for SAE Baja Competition(s) and customer needs.
- Integrate all additional equipment into frame with mounting tabs
- Incorporate packaged extras. Examples: Glove box, Speakers, Winch, Lights, and Body Paneling
- Driver ergonomics
- Outperform previous NAU Baja team in events

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Constraints

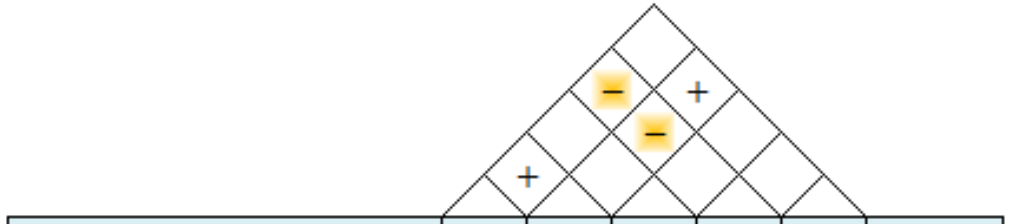
- All major constraints are within SAE Baja Rules
  (such as dimensions, materials, support members)
- Width of vehicle must not exceed 59 inches.
- Total weight cannot exceed 150 lbs

Objectives

- Design and build a light weight frame (under 150lbs)
- Build within a short amount of time
- Strong, via compression testing for strength
- Dimensions of frame allow vehicle to be transported to competition(s) with ease

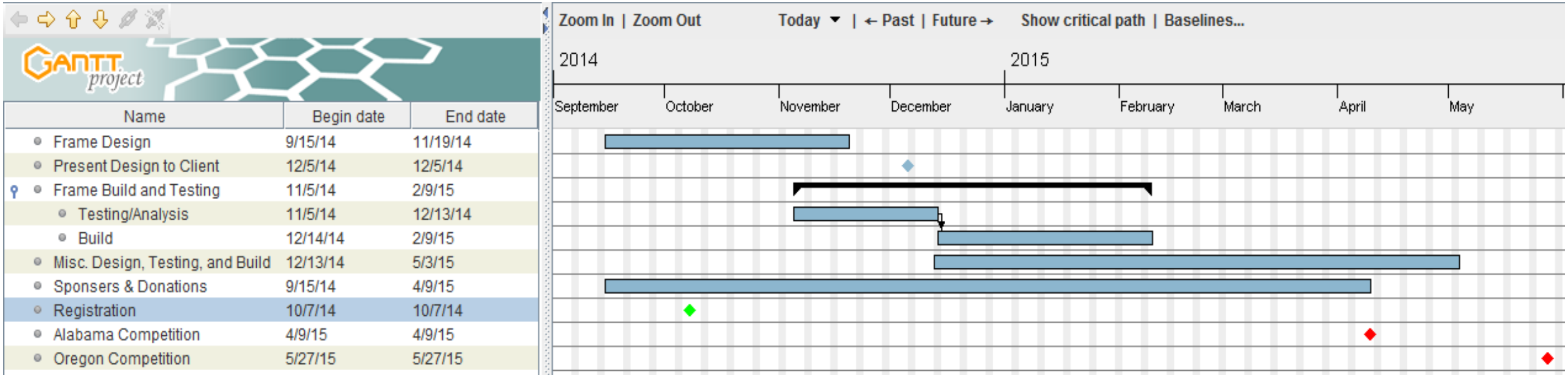
QFD and House of Quality

Relationships	
Strong	●
Moderate	○
Weak	▽



Column #	1	2	3	4	5	Bench Marks	
Customer Requirements (Explicit and Implicit) / Engineering Requirements	Weight	Strength	Build Time	Cost	Dimensions	NAU Baja 2013-2014	ASU Baja 2013-2014
Overall Weight	●	○		▽		−	+
Dimensions	○			○	●	−	+
Weight Distribution	●	○		▽		+	+
Safety & Ergonomic		●		○	○	+	−
Units	lbs	lbf/N	Days	$	in.		
	450	5,000	30	10,000	59		

Timeline



Name	Begin date	End date
Frame Design	9/15/14	11/19/14
Present Design to Client	12/5/14	12/5/14
Frame Build and Testing	11/5/14	2/9/15
Testing/Analysis	11/5/14	12/13/14
Build	12/14/14	2/9/15
Misc. Design, Testing, and Build	12/13/14	5/3/15
Sponsers & Donations	9/15/14	4/9/15
Registration	10/7/14	10/7/14
Alabama Competition	4/9/15	4/9/15
Oregon Competition	5/27/15	5/27/15

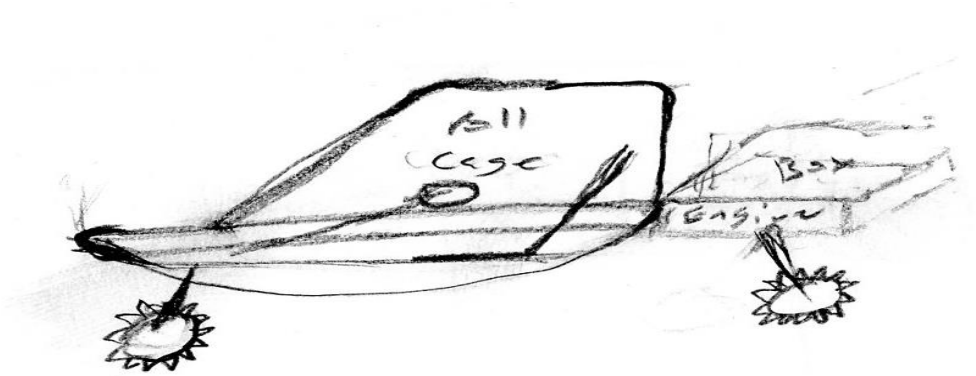
Concept Generation

- Six Frame Designs
  - Truck Frame
  - Old Volkswagen
  - Rear Bracing
  - Front Bracing
  - Front Supported
  - Compact Frame

Truck Frame Design

Description:

A truck frame design that is built with toe and chamber off road racing suspension.



Reasons for Selection:

- Light Weight
- Unique Design of Baja Vehicle
- Reliable on off road

[1]

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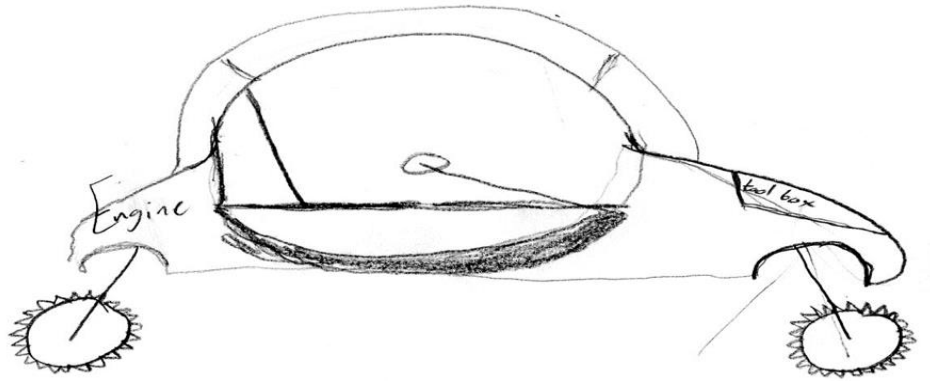
Old Volkswagen Design

Description:

A baja vehicle frame that has the same concept of an old Volkswagen Buggy frame, but with toe and chamber off road racing suspension.



Reasons for Selection:

- Attractive frame design for an off-roading Baja vehicle
- Small size vehicle → Less weight
- Simple frame design → Less cost
- Designed for obstacle clearance
- Frame can be equipped with a tool box

[2]

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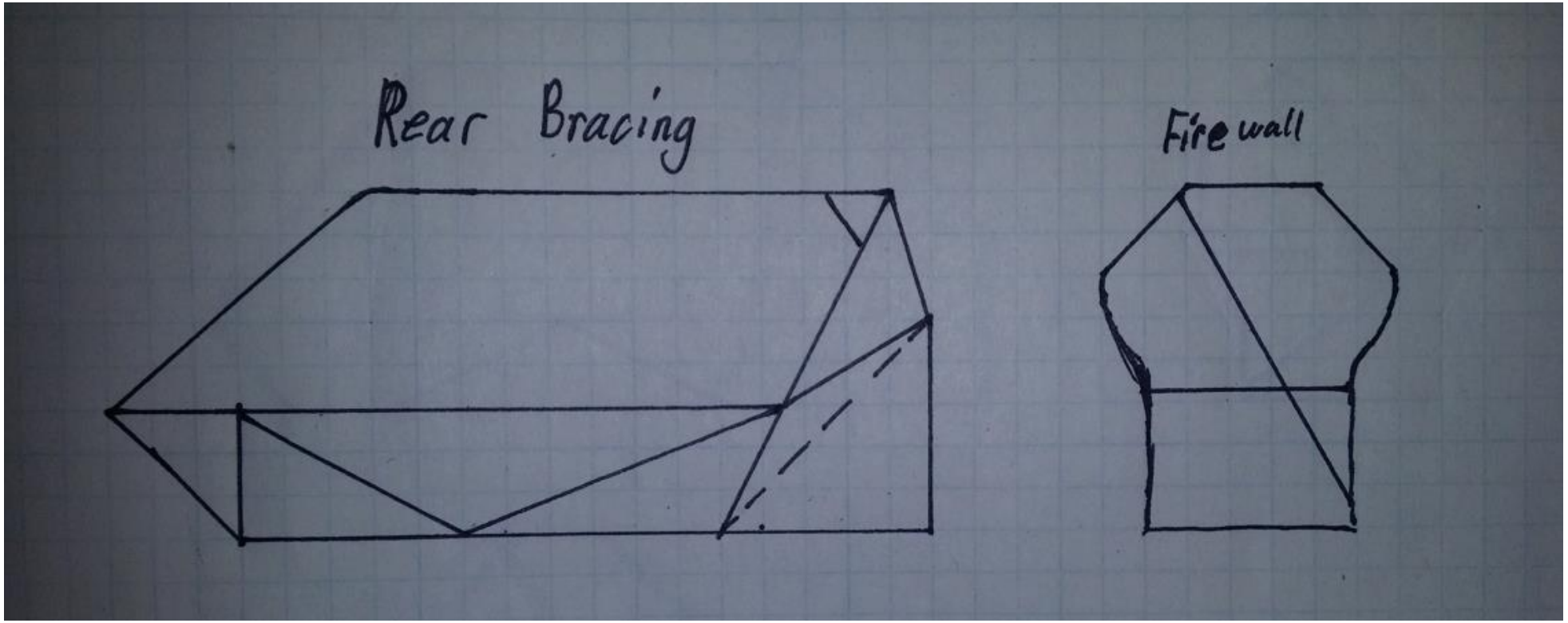
Rear Bracing Concept



Description:

- A rear brace design with a structural triangle made of main member tubing.

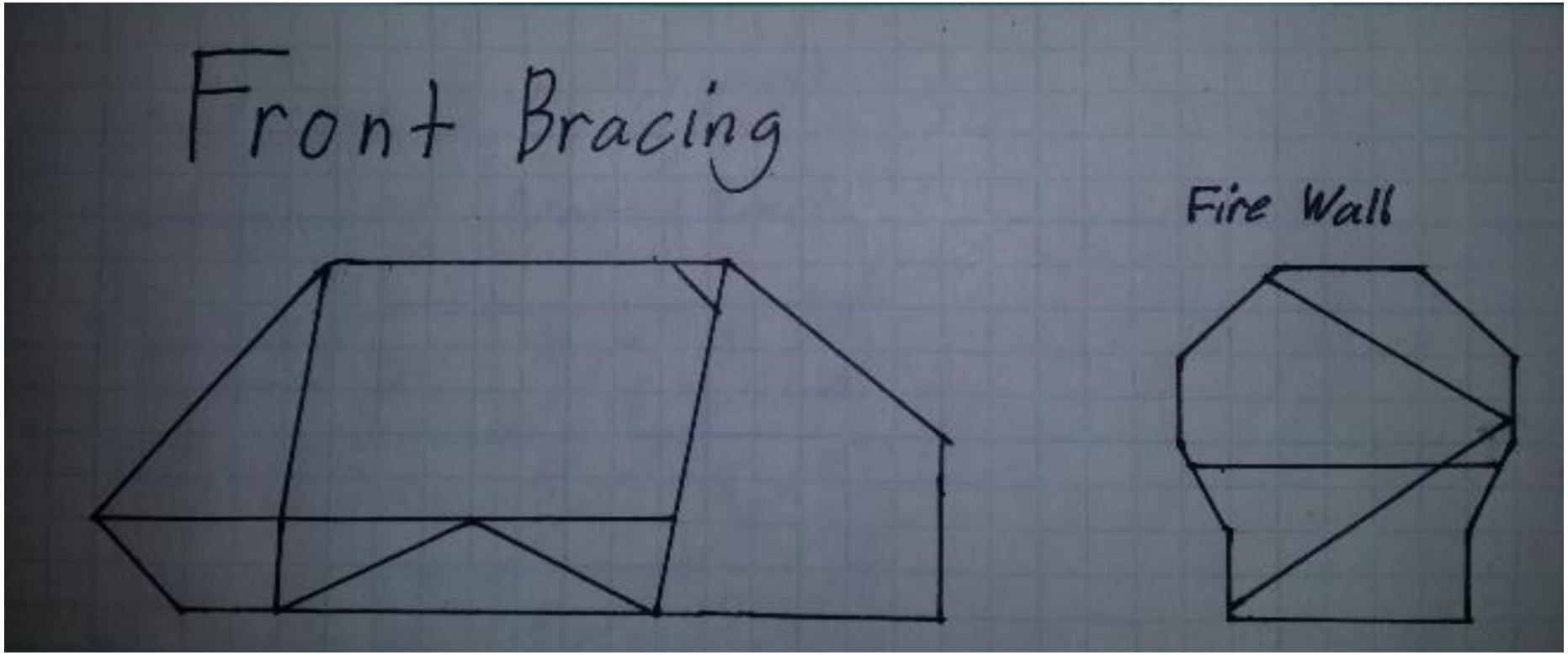
Advantage:

- This allows for a more simple firewall bracing design for the roll cage loop.
- Optional position of bottom member leaves room for alteration to incorporate the subgroup's material

Disadvantage:

- Negative impact on weight ratio

Front Bracing Design



Description:

- A front bracing design with a structural support in the front made with main member tubing.

Advantage:

- This allows for pure customization of the rear of the vehicle for sub group installations.
- Positive impact on weight ratio

Disadvantage:

- Visibility loss for driver

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Front Supported Design

Description:

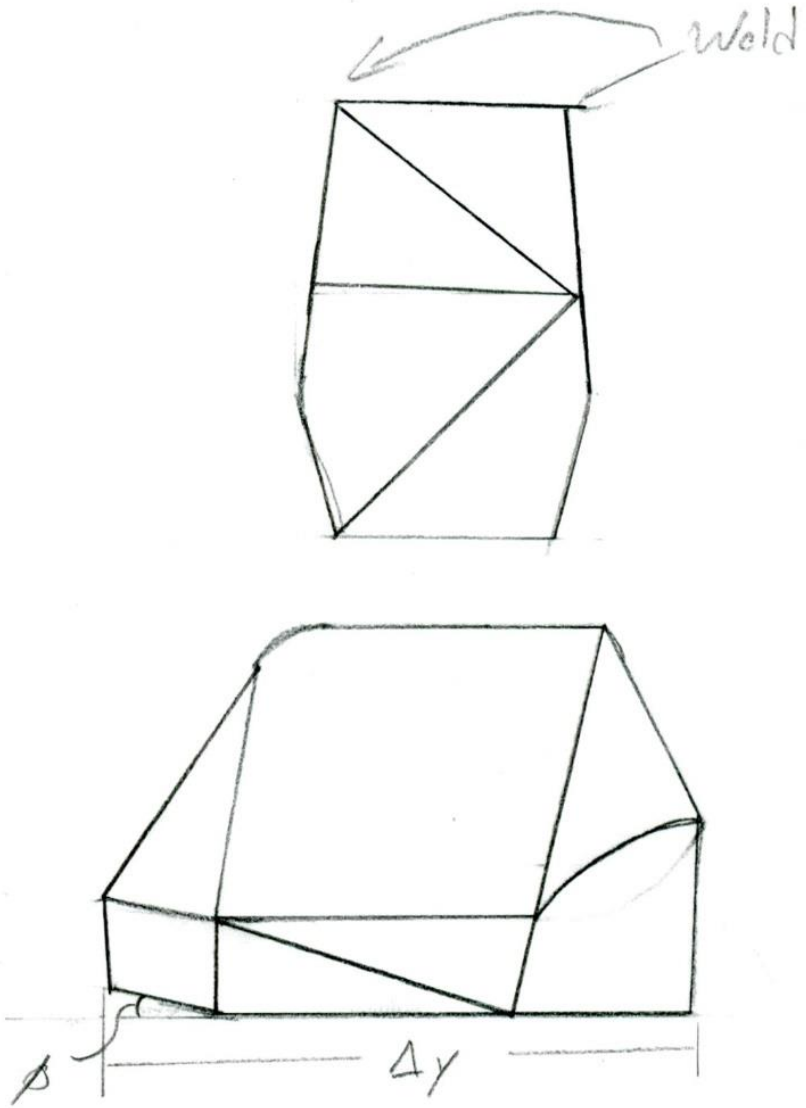
This design is a rear supported frame with the smallest dimension Δy while keeping it within the rule's constraints.

Advantages:

- Simple design
- Light weight
- Cheap

Disadvantages:

- Strength



Compact Frame Design

Description:

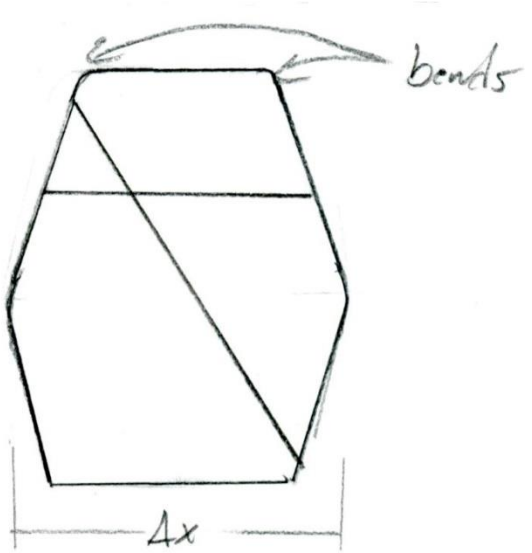
This design is a front supported frame with the smallest dimensions for Δx and Δz while keeping it within the rule's constraints.

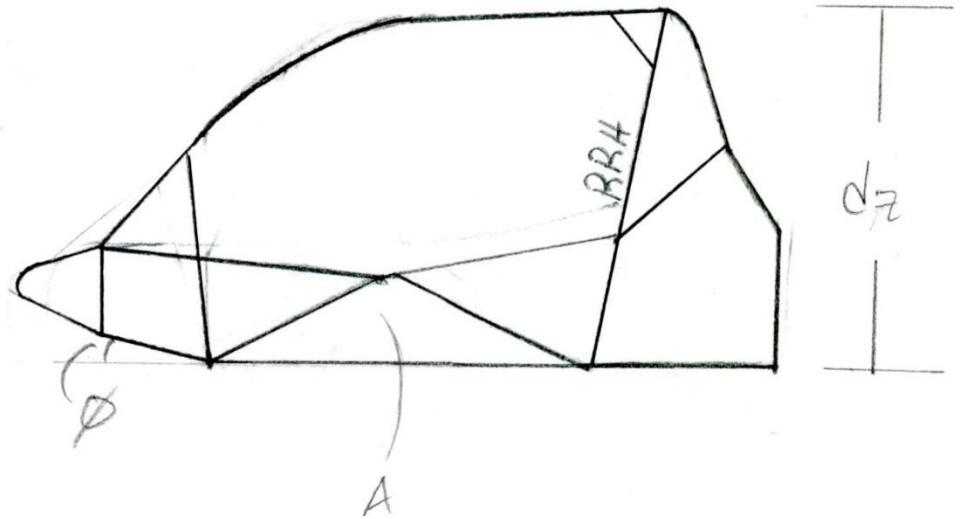
Advantages:

- Weight distribution
- Lower center of gravity

Disadvantages:

- More complex design



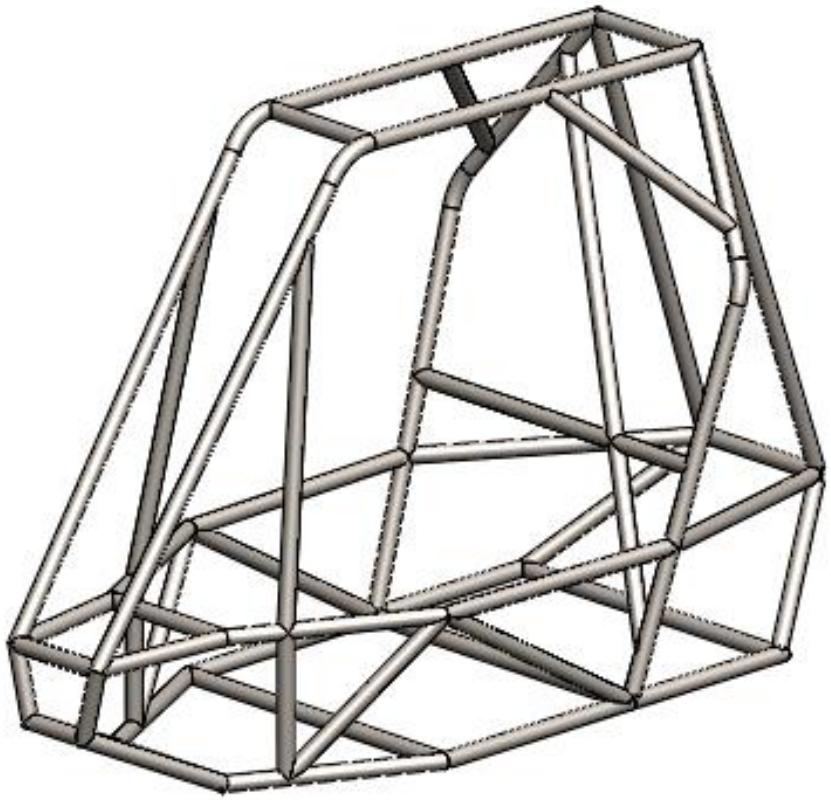


Decision Matrix

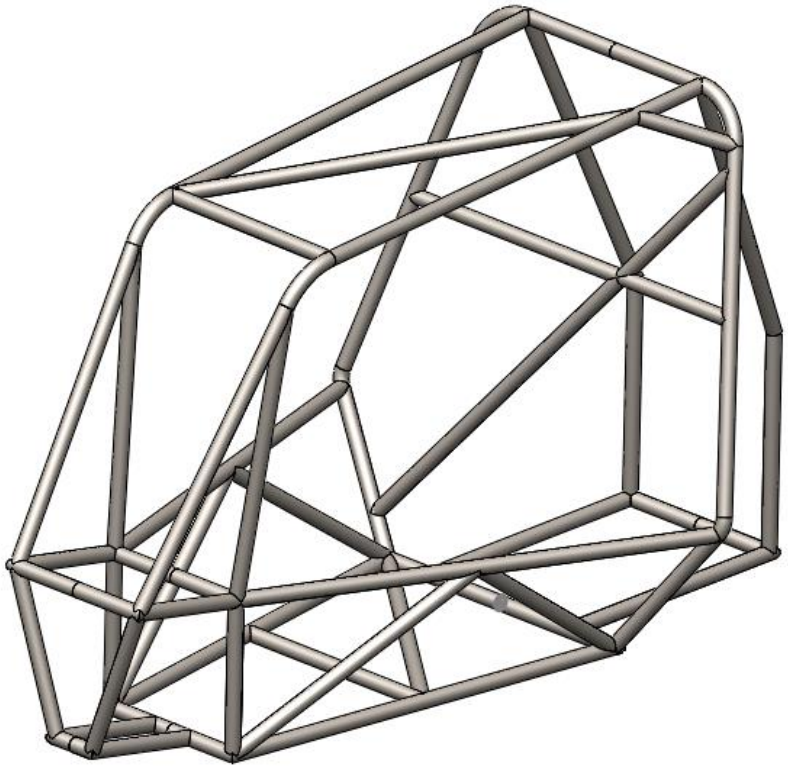
Criteria Rating System: 1-5								
Designs	Overall Weight	Driver Accessibility	Strength	Simplicity	Room for Modifications	Cost	Ability to Accessories	Total Score
Truck Frame	2.67	3.67	3.33	3.33	3.00	3.00	3.33	3.12
Volkswagen Buggy Frame	3.00	3.67	4.33	2.67	2.33	3.33	3.67	3.30
Rear Brace	4.67	4.33	4.00	3.67	4.00	4.33	3.67	4.17
Front Brace	4.67	4.33	4.33	3.67	4.33	4.00	3.67	4.21
Front Supported	4.67	4.33	4.00	4.33	4.00	4.33	3.67	4.23
Compact Frame	4.33	4.33	4.67	3.00	4.00	4.33	3.67	4.15
Scale	20%	9%	18%	10%	14%	20%	9%	

Chosen Designs

Front Bracing Design



Front Supported Design



SolidWorks Analysis

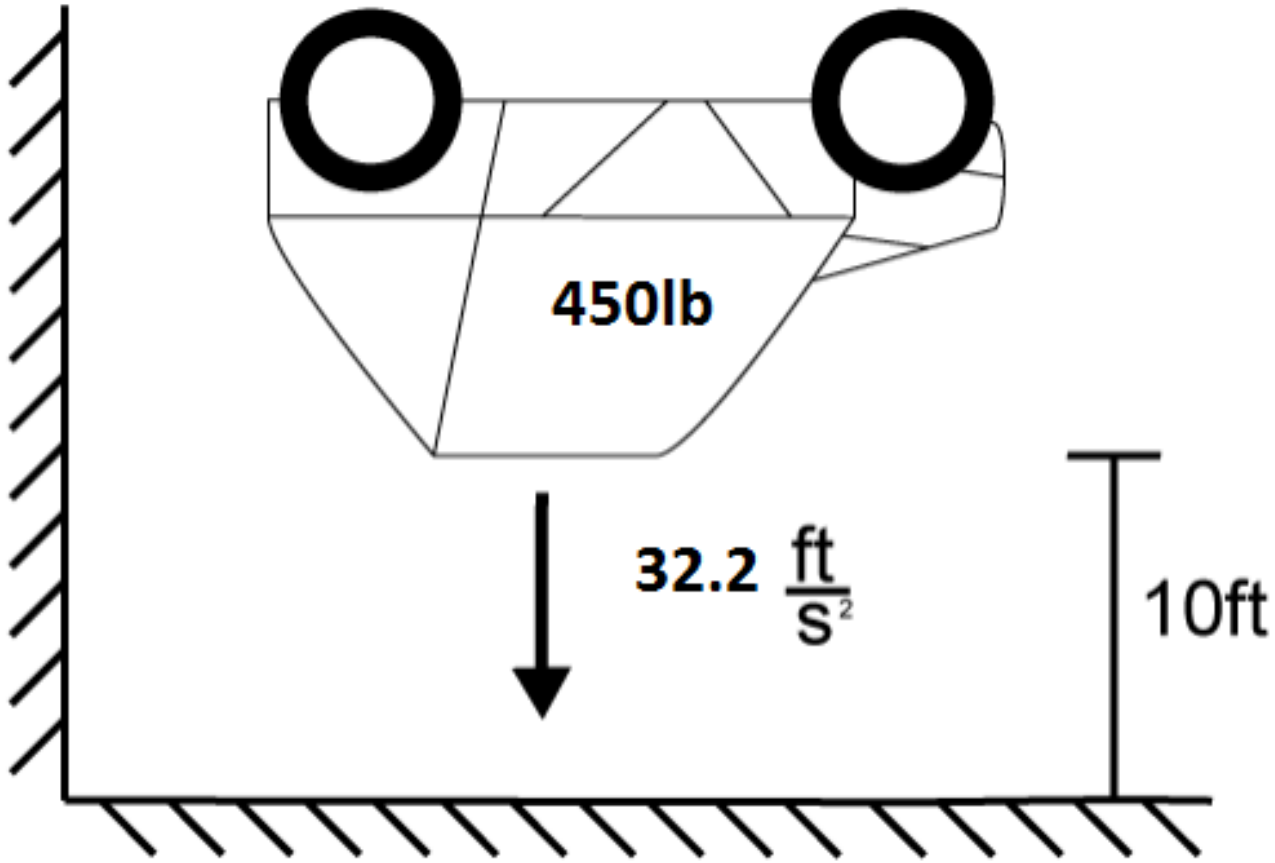
- Four Simulation Studies:

1. Rollover Test
2. Front Impact
3. Rear Impact
4. Side Impact

- Test Assumptions:

1. Drop height of 10 ft
2. Impact velocity of 25 mph
3. 0.1 and 0.2 second drop and impact impulse times

Drop Test



Drop Test Calculations

- Applied Equation:

$$F = m \cdot \frac{\sqrt{2gh}}{t} = 2507.752\ lbf \qquad F_a = \frac{F}{l}$$

where,

$F = total\ force,$

$F_a =$ applied force,

$m = mass,$

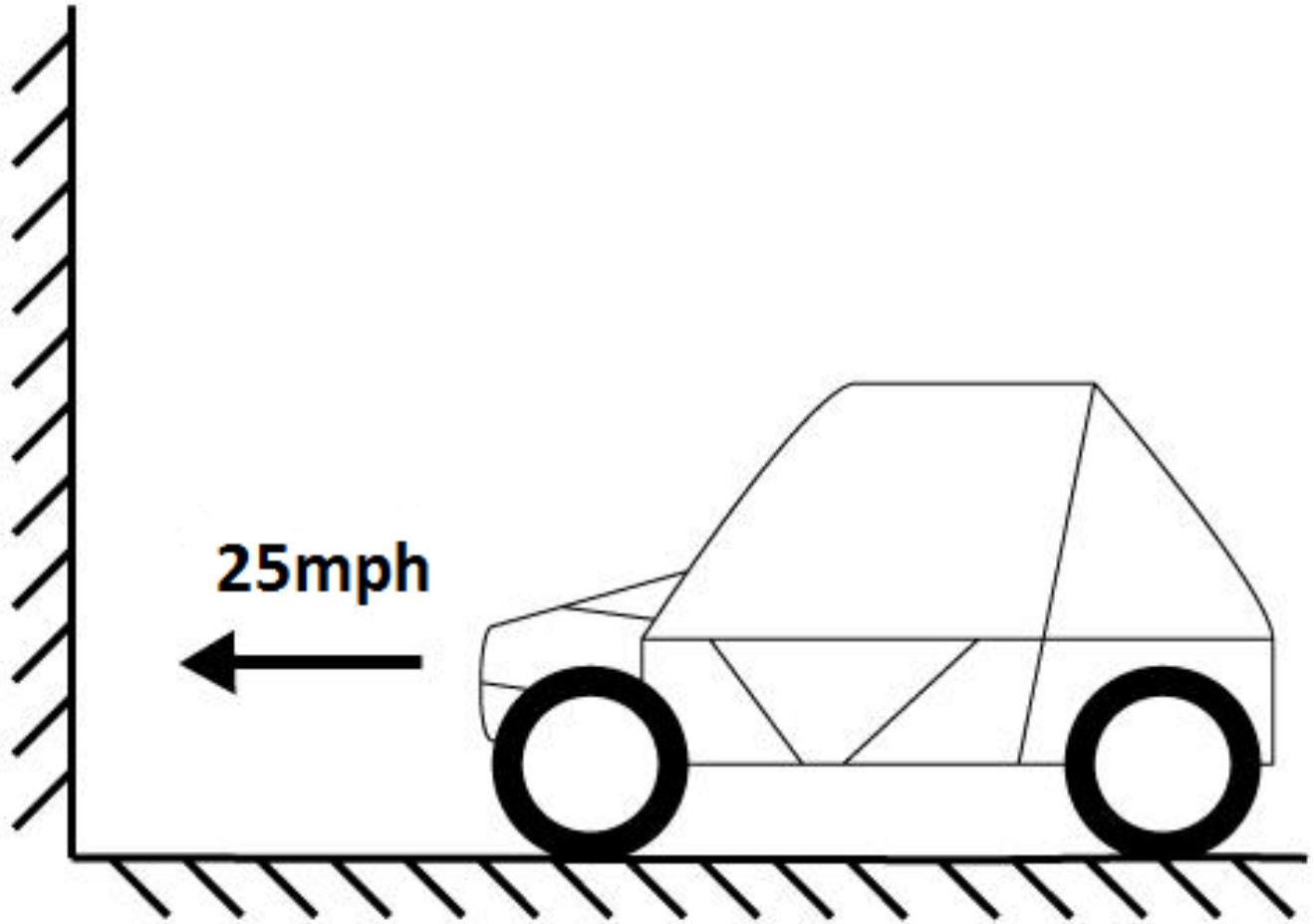
$g = acceleration\ of\ gravity,$

$h = drop\ height,$

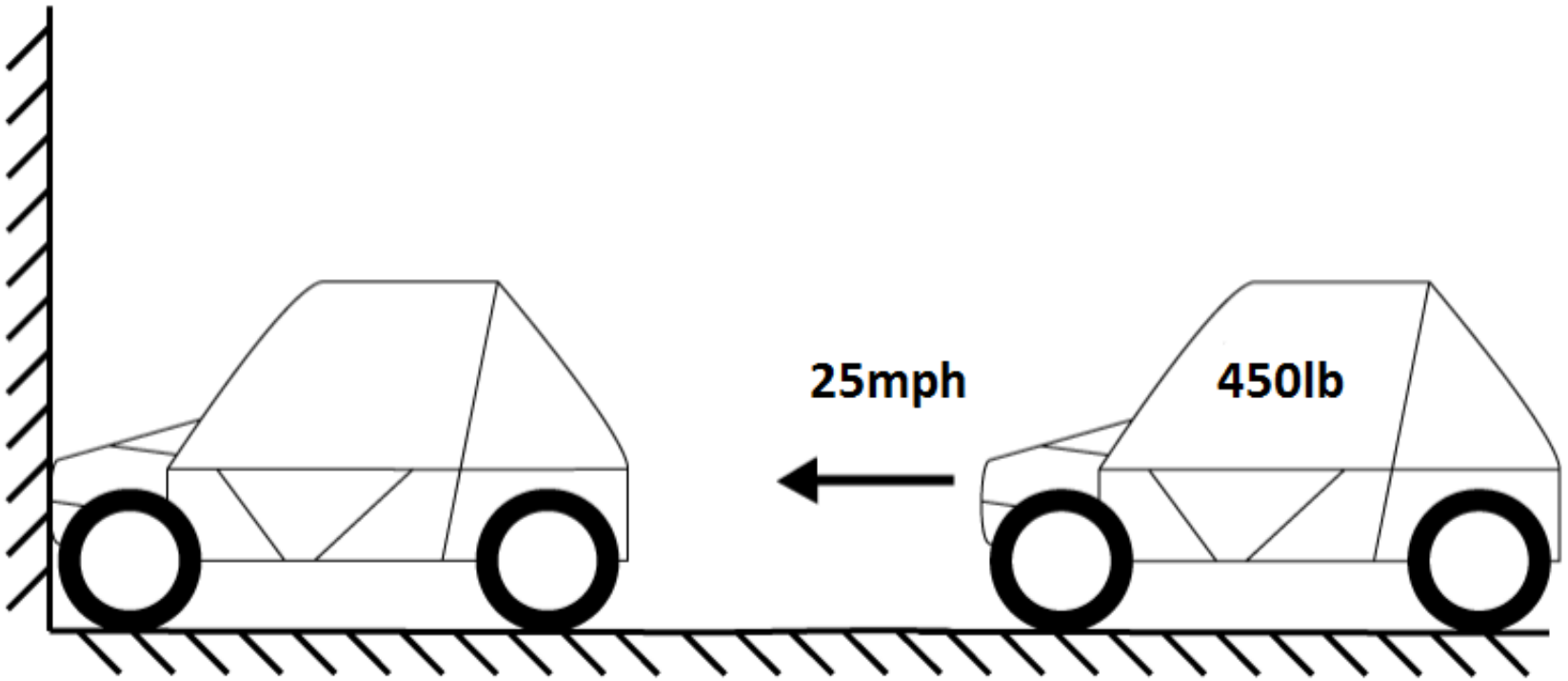
$t = impulse\ drop\ test\ time,$

$l = total\ length\ of\ members\ force\ is\ applied\ to.$

Front Impact Scenario



Rear Impact Scenario



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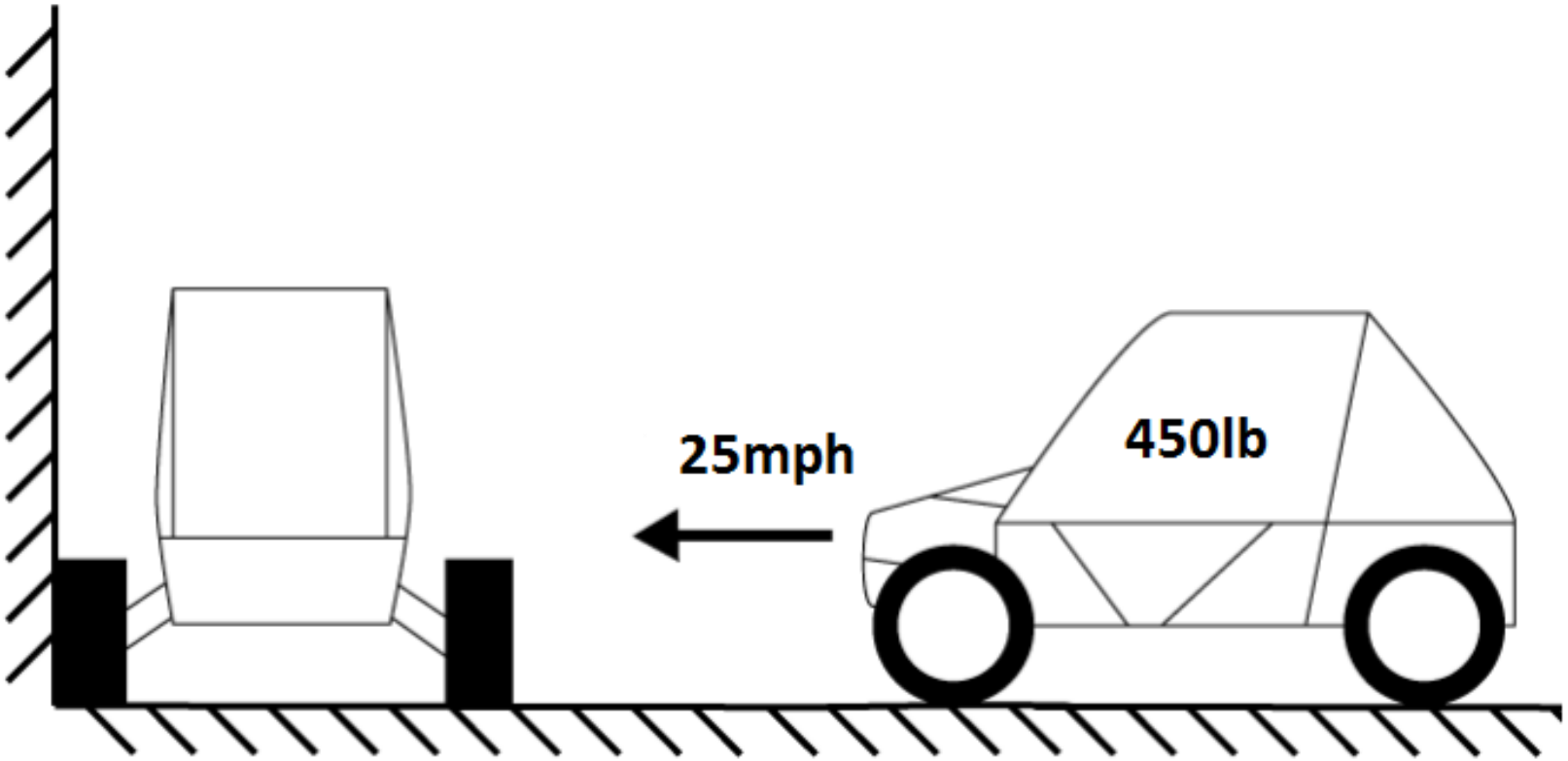
Side Impact Scenario



Impact Test's Calculations

- Applied Equations:

$$F = \frac{V_o}{t} m = 1192.175\ lbf \qquad F_a = \frac{F}{l}$$

where,

$F = total\ force,$

$F_a = \text{applied force},$

$m = mass,$

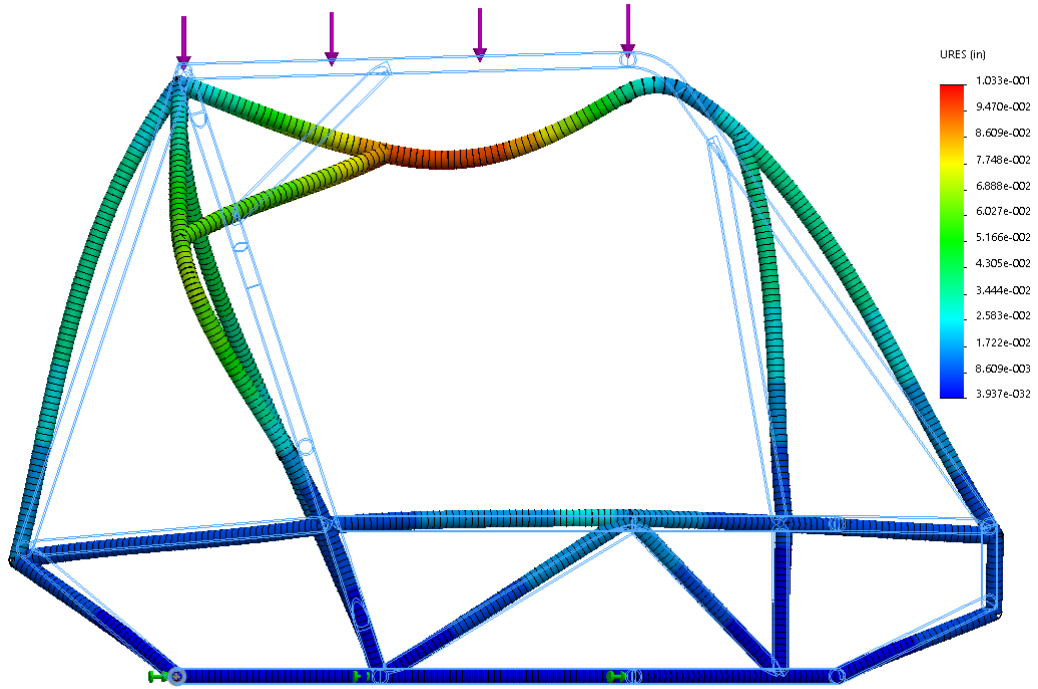
$V_0 = \text{impact velocity},$

$t = impulse\ impact\ test\ time,$

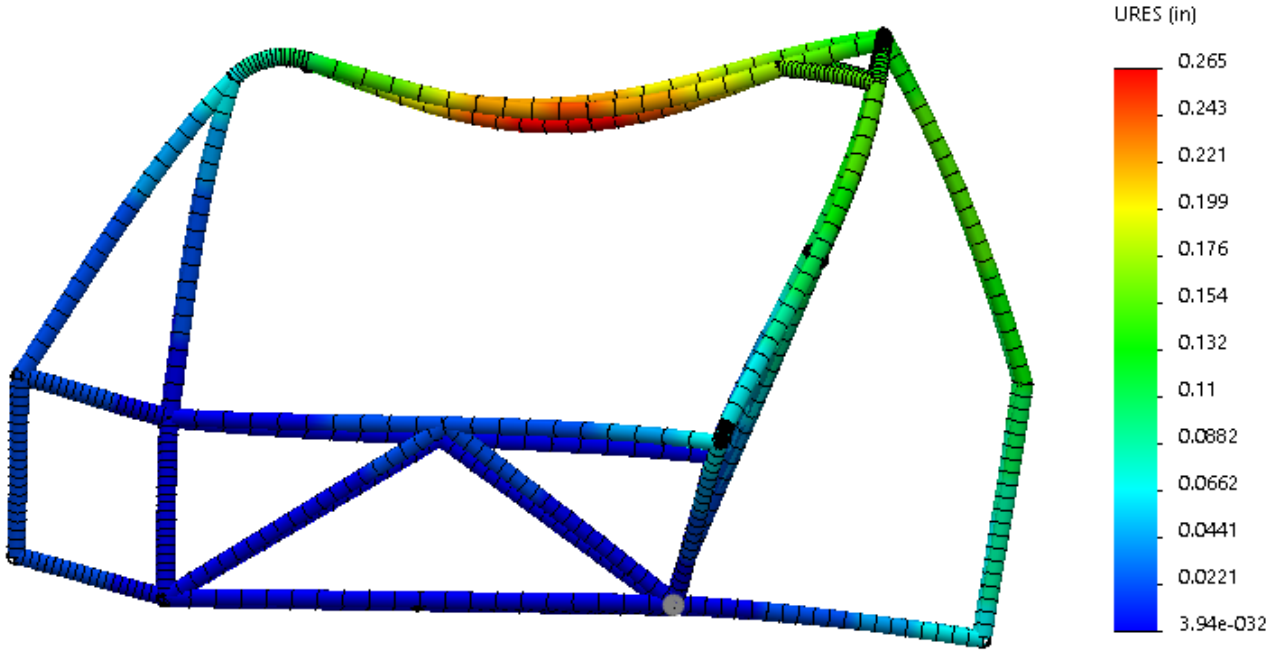
$l = total\ length\ of\ members\ force\ is\ applied\ to.$

Drop Test Displacement

Front Bracing Design



Front Supported Design



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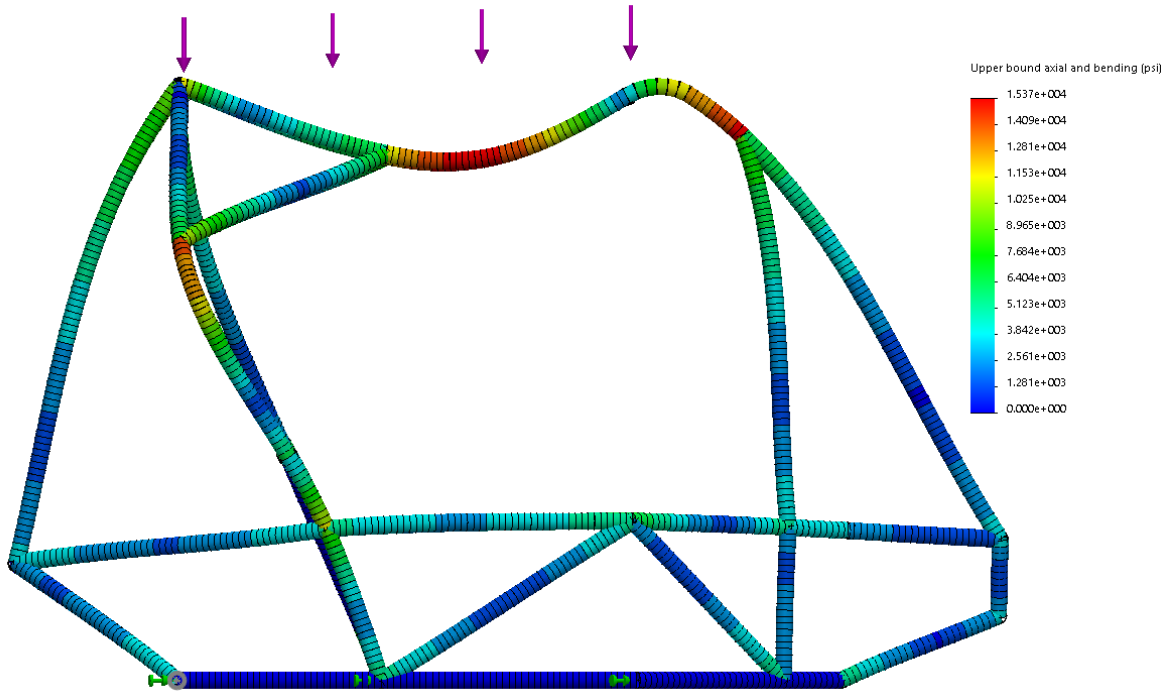
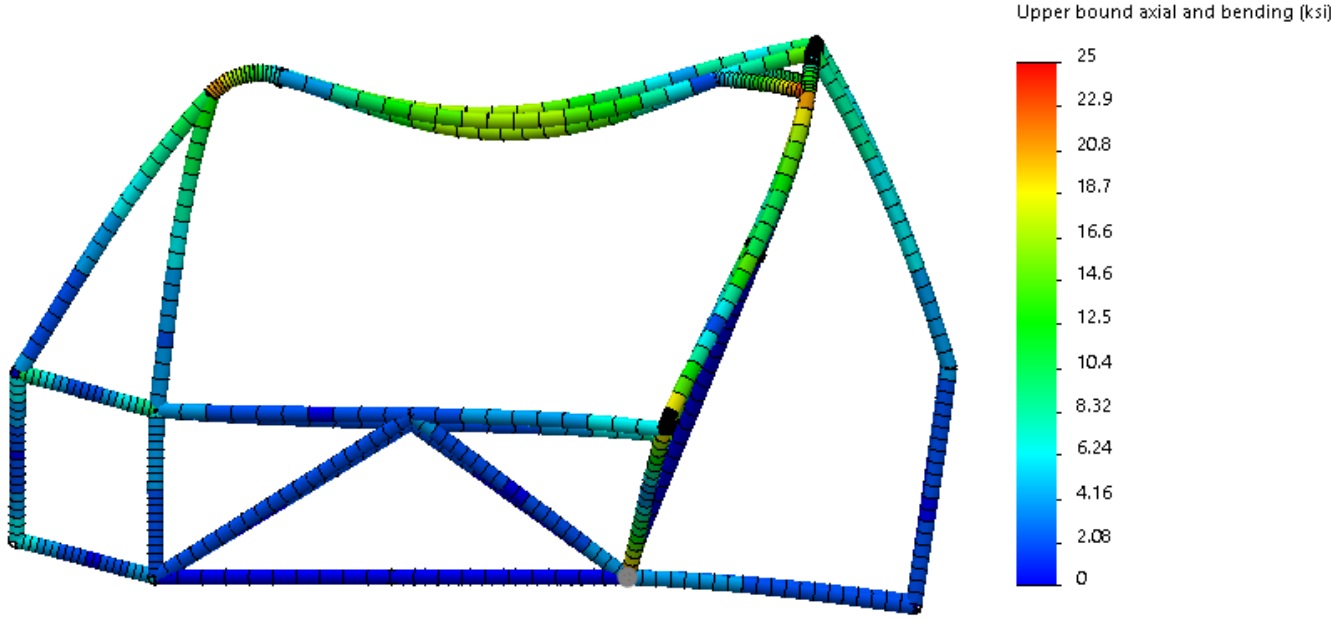
Drop Test Stress

Front Bracing Design



Front Supported Design



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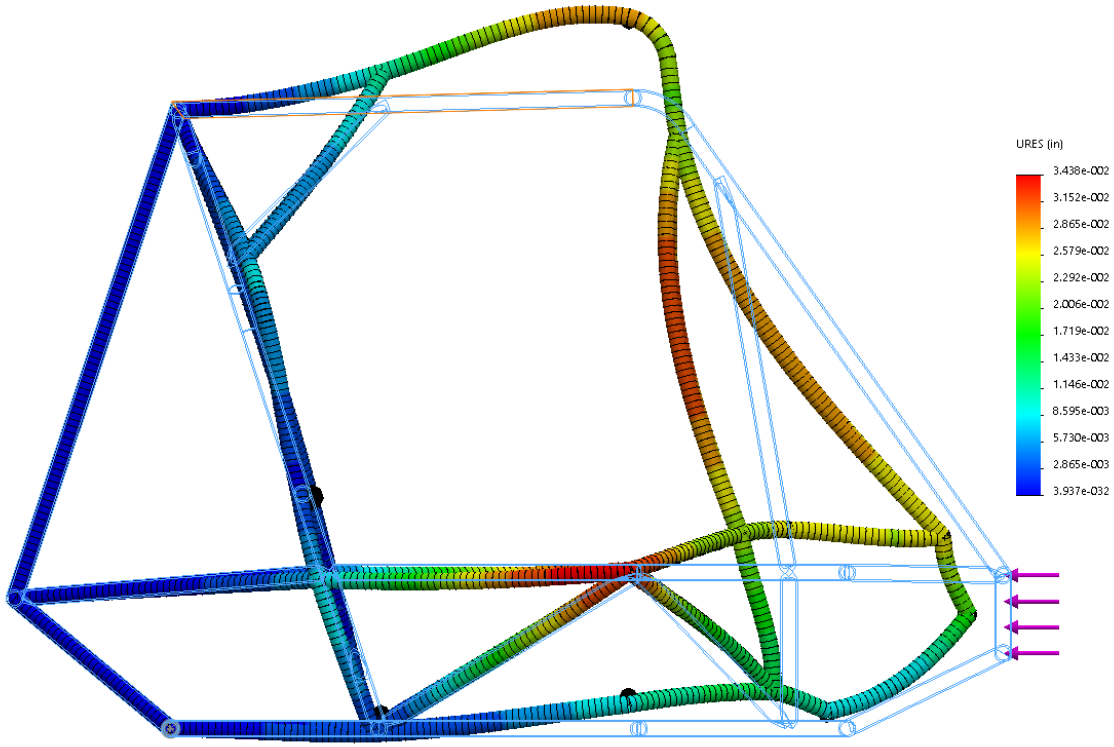
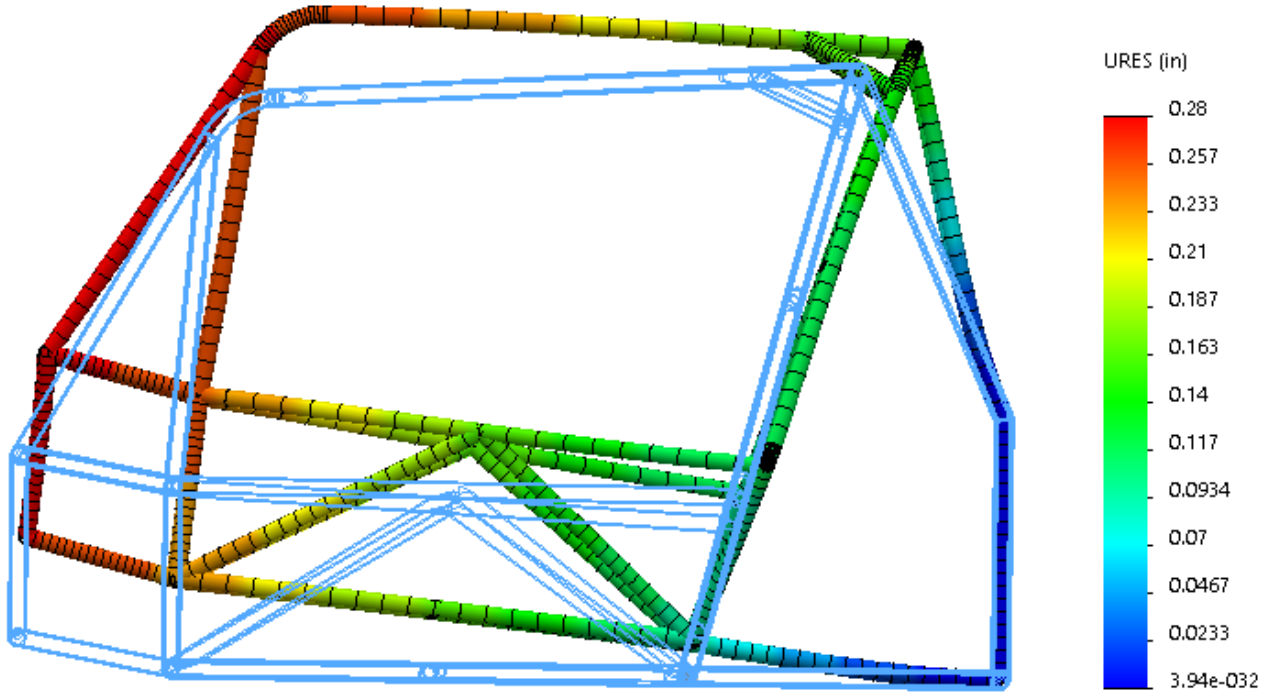
Front Impact Test Displacement

Front Bracing Design



Front Supported Design



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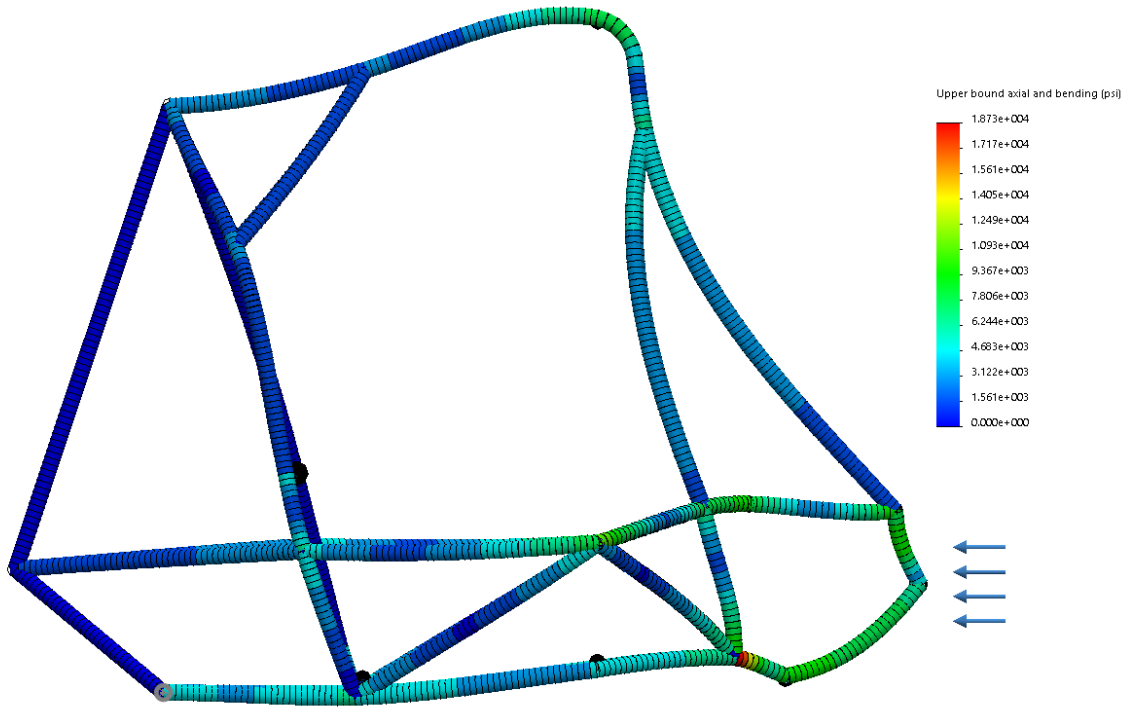
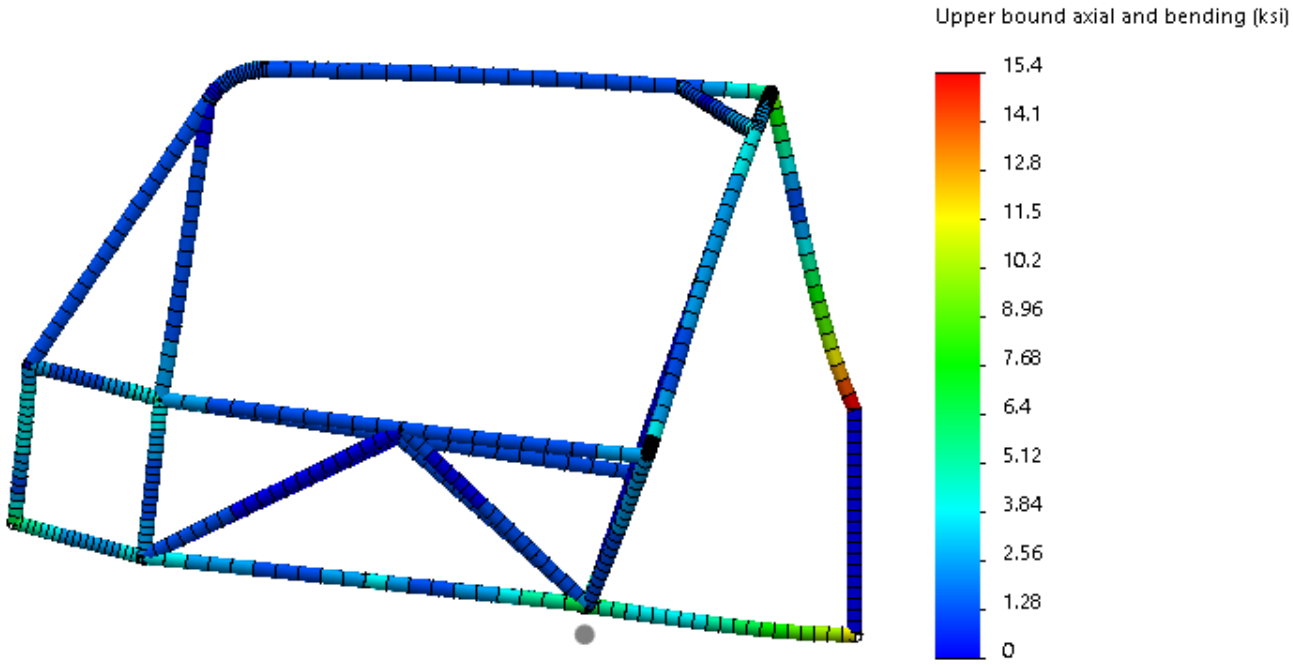
Front Impact Stress

Front Bracing Design



Front Supported Design



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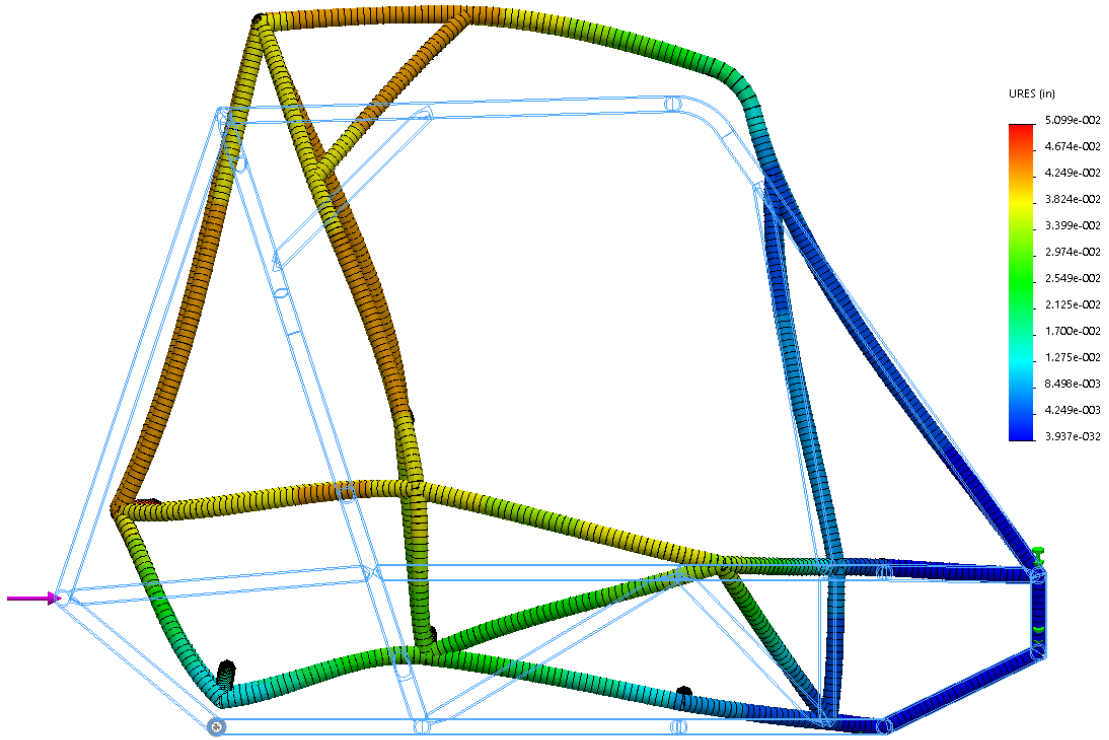
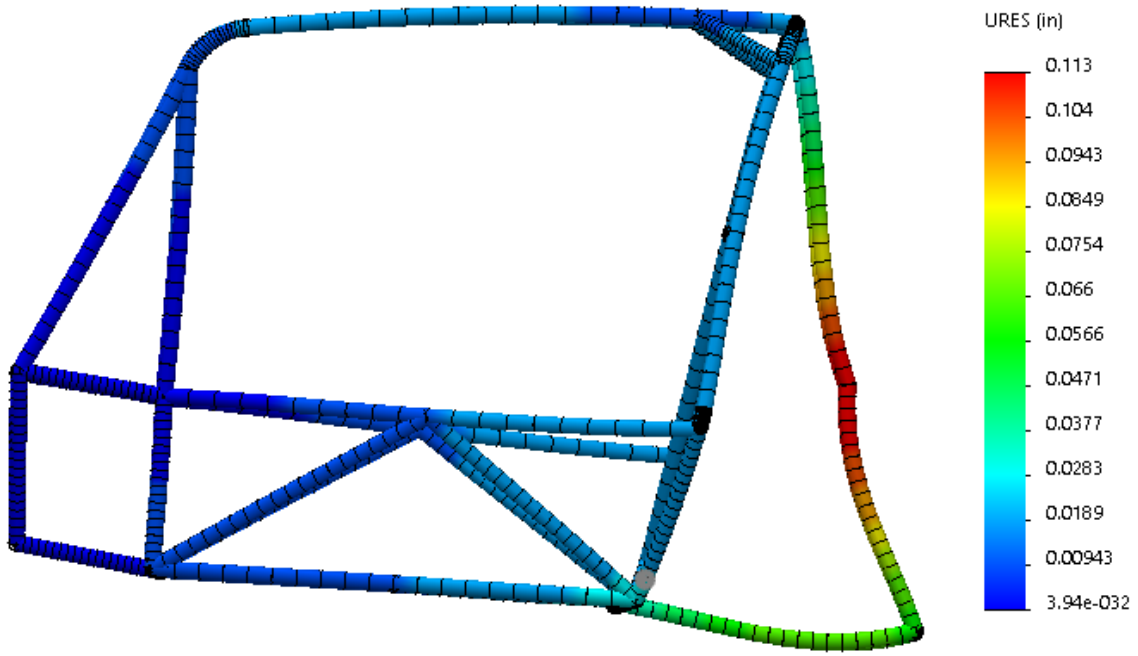
Rear Impact Test Displacement

Front Bracing Design



Front Supported Design



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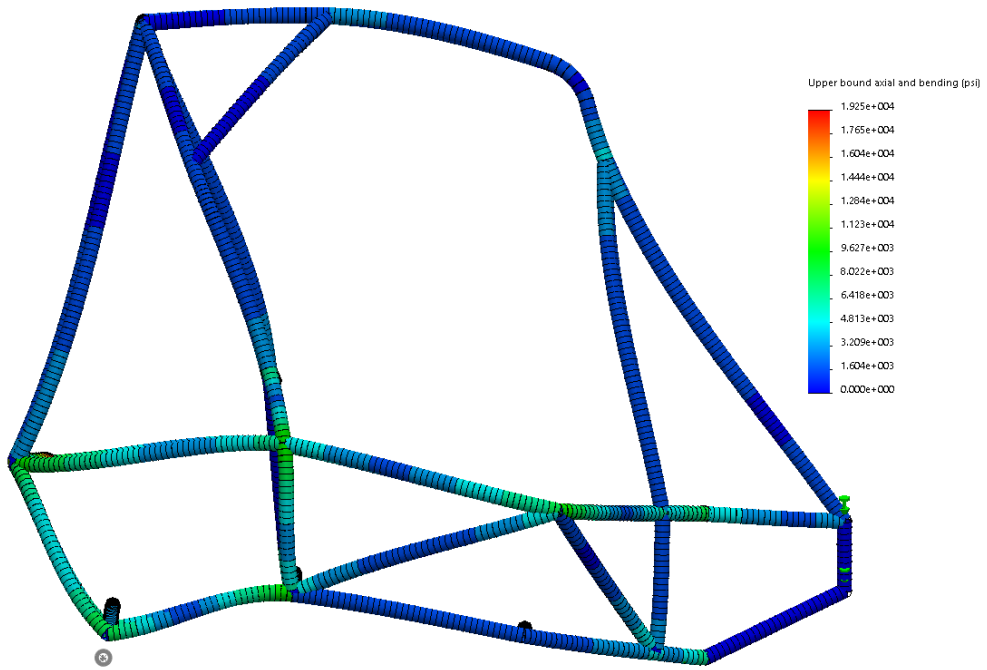
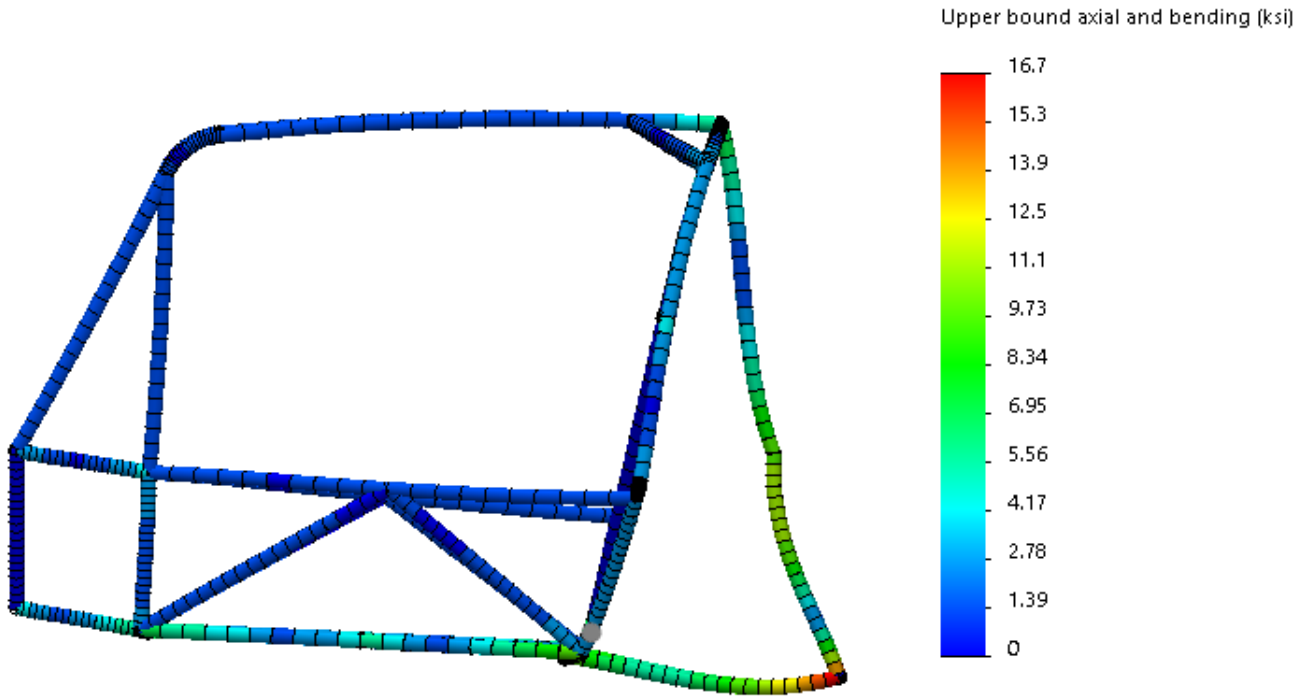
Rear Impact Test Stress

Front Bracing Design



Front Supported Design



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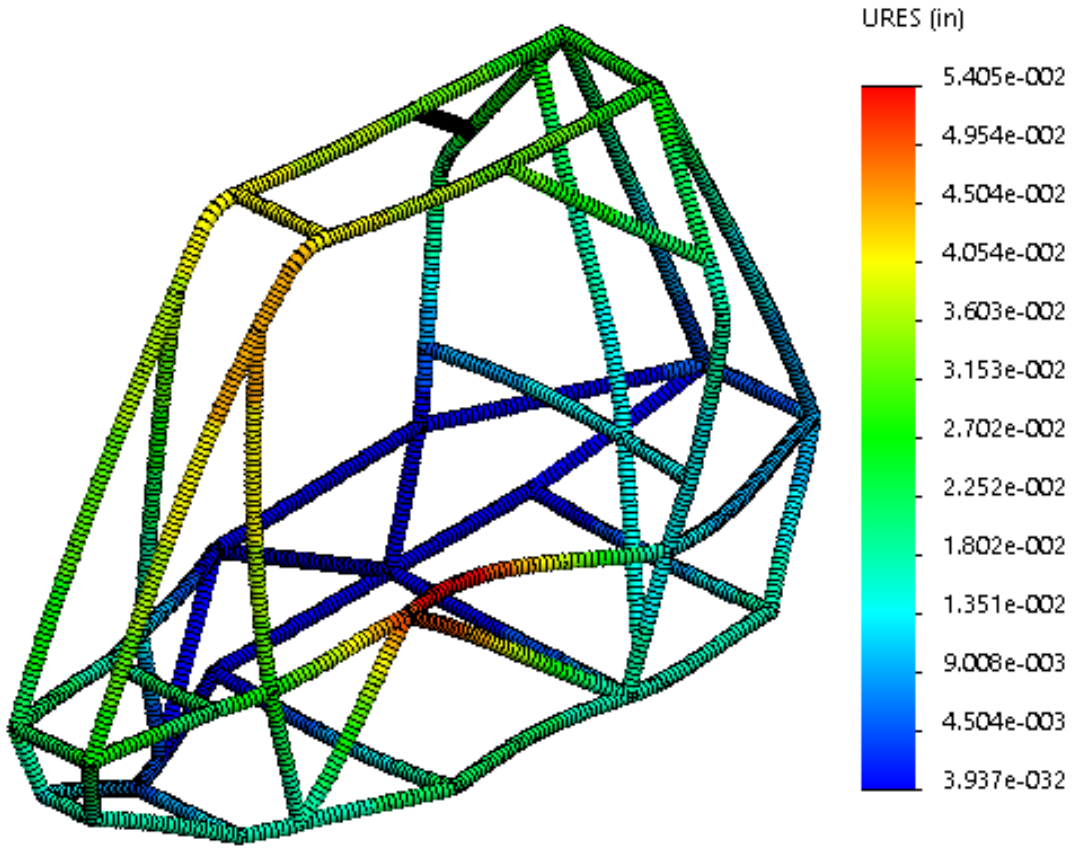
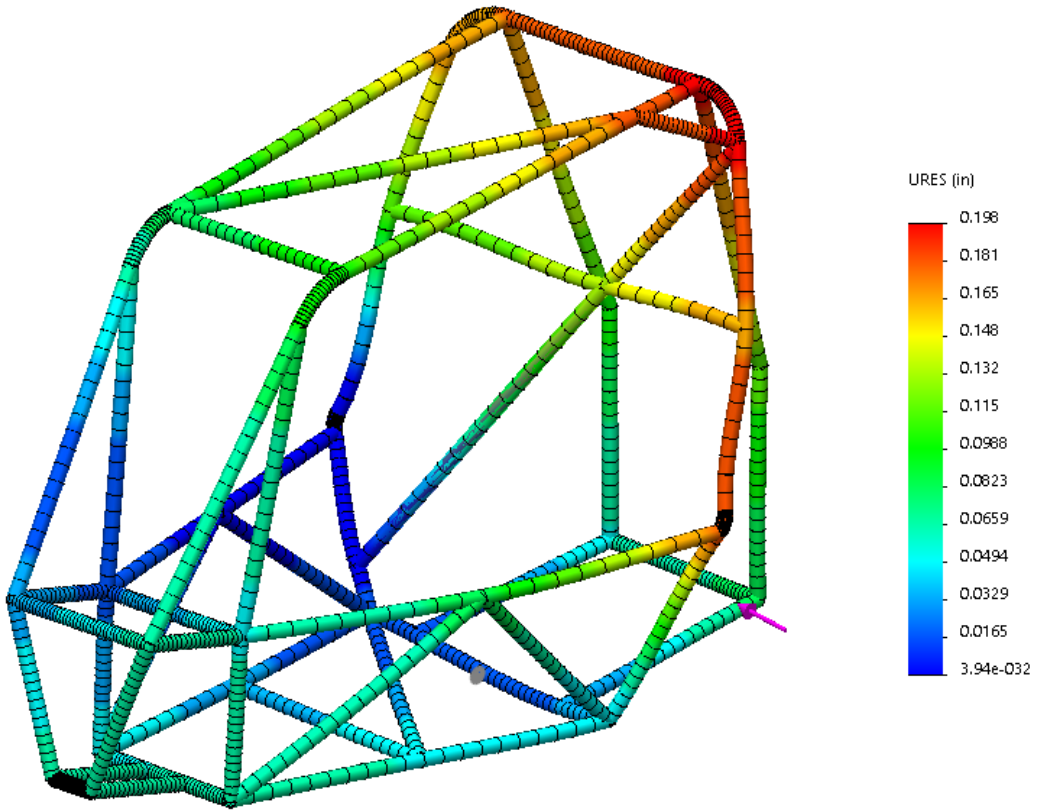
Side Impact Test Displacement

Front Bracing Design



Front Supported Design



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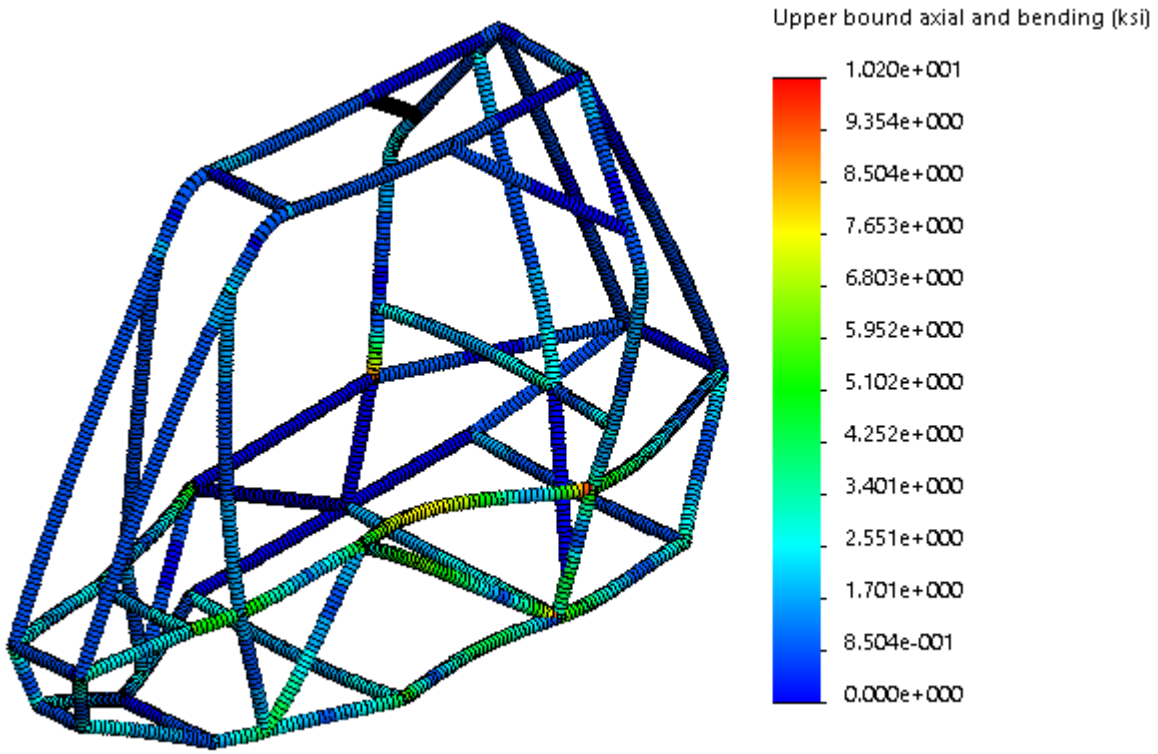
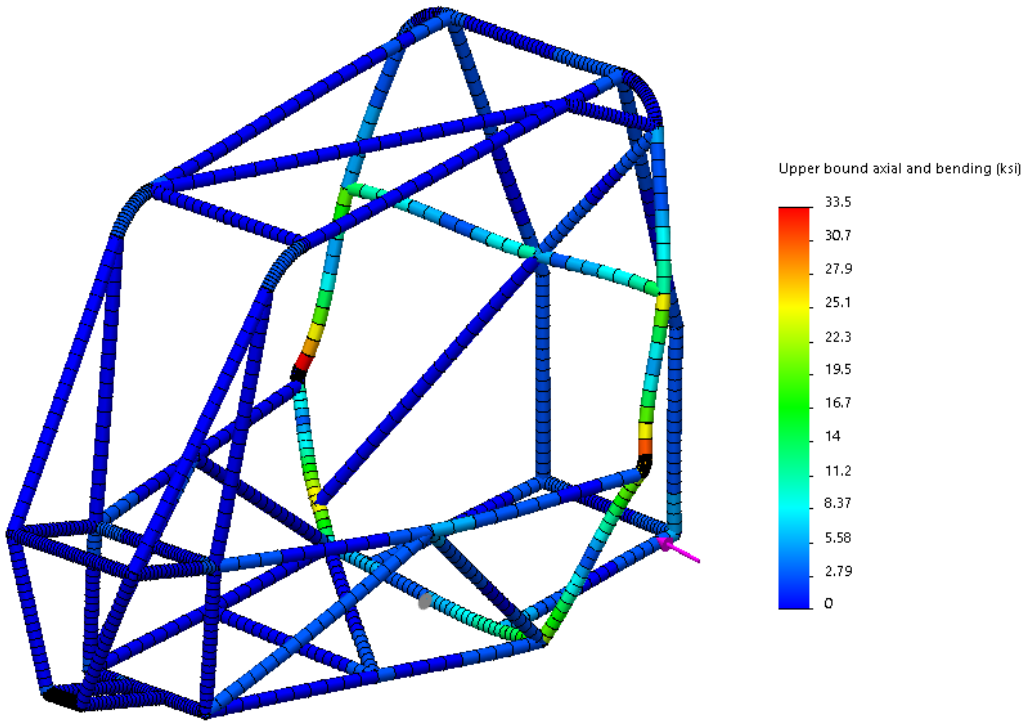
Side Impact Test Stress

Front Bracing Design



Front Supported Design



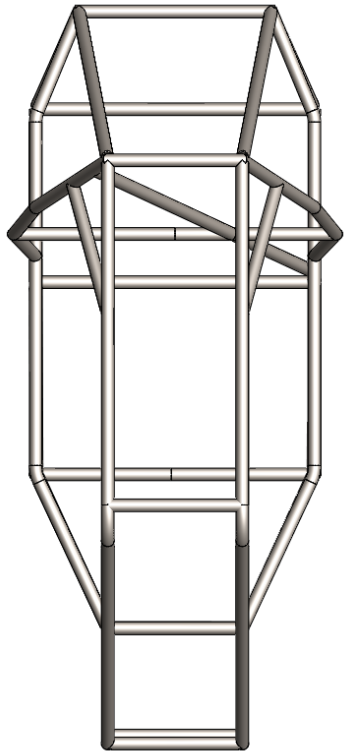
Legg

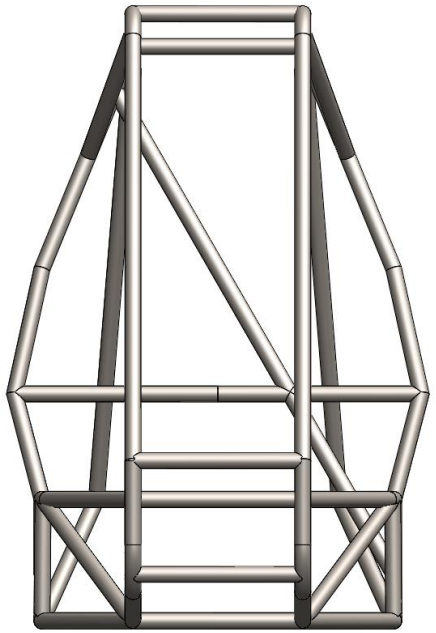
Factor of Safety Comparison

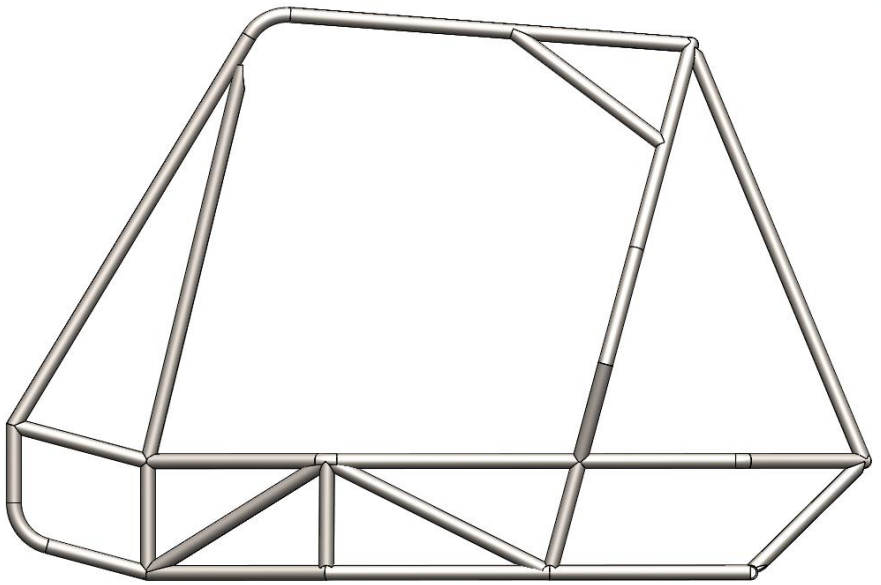
Tests	Front Supported	Front Bracing
Drop Test	2.7	4.3
Front Impact	4.7	3.6
Rear Impact	4	3.5
Side Impact	2	6.5

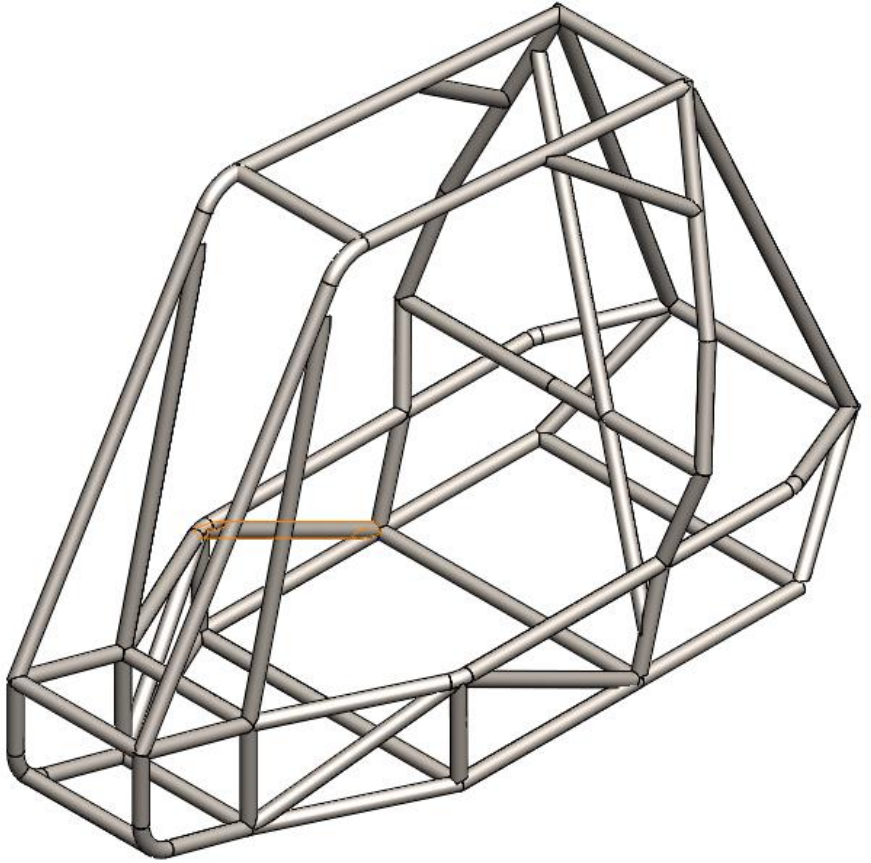
Legg

Final Design









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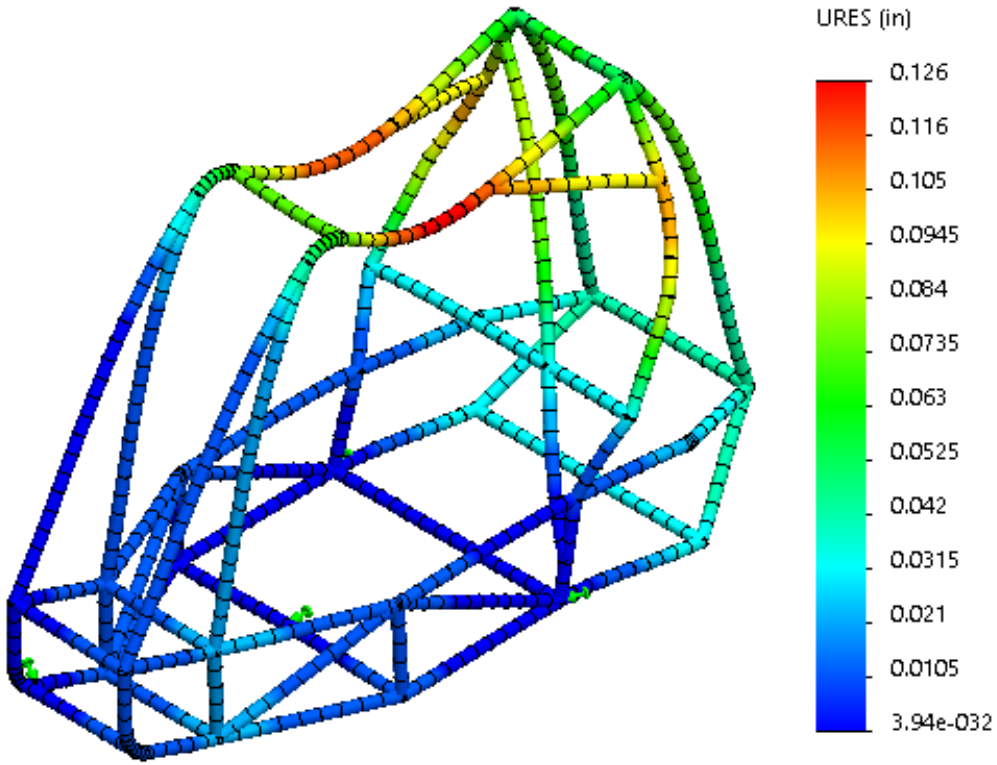
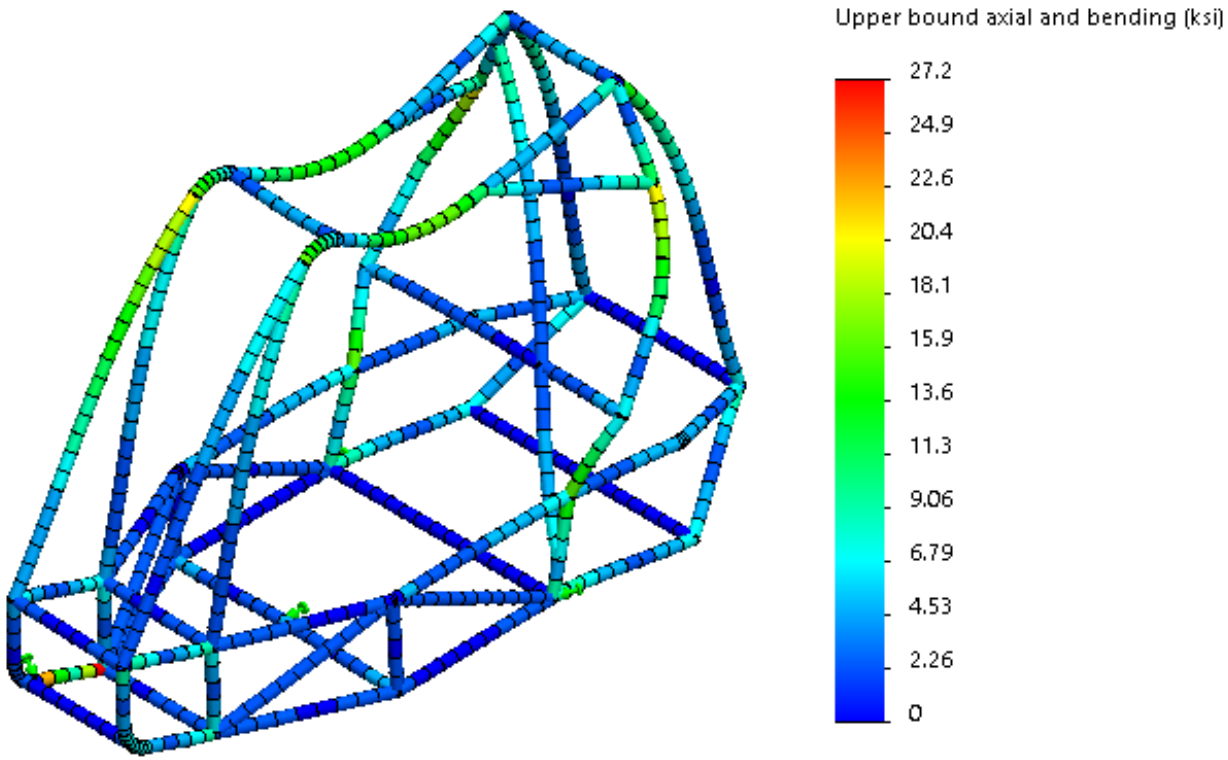
Drop Test

F.O.S. = 2.9





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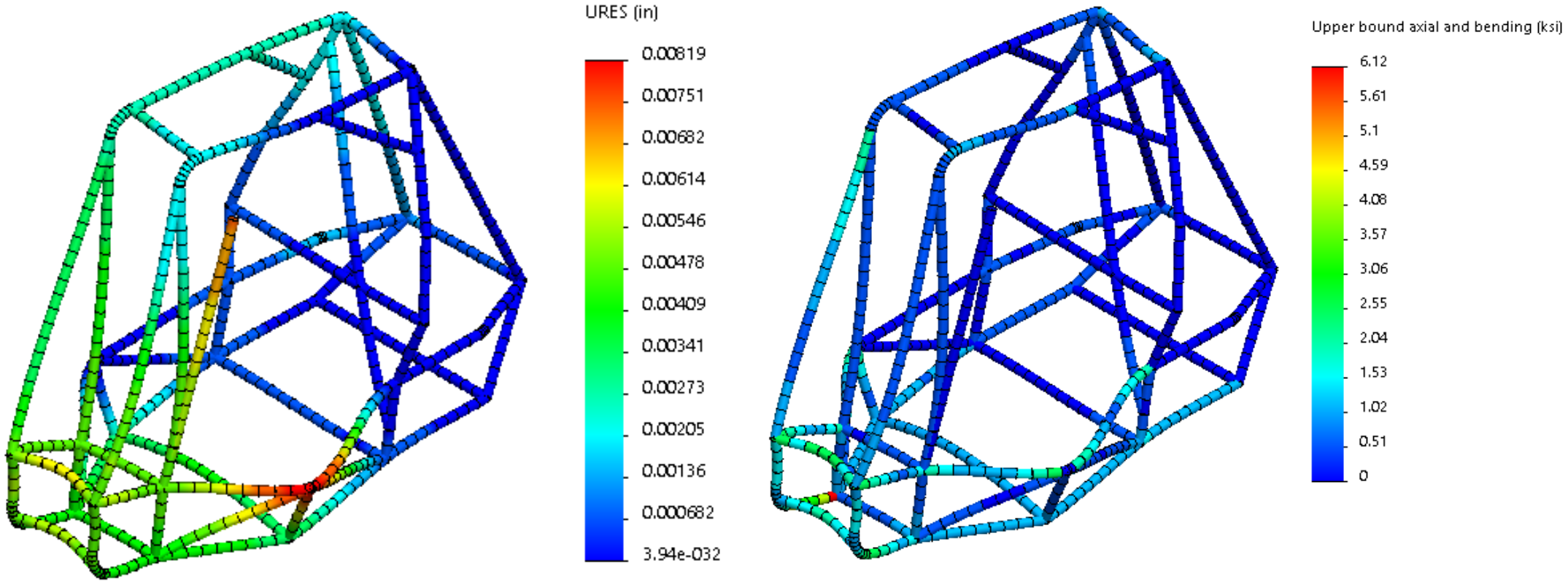
Front Impact

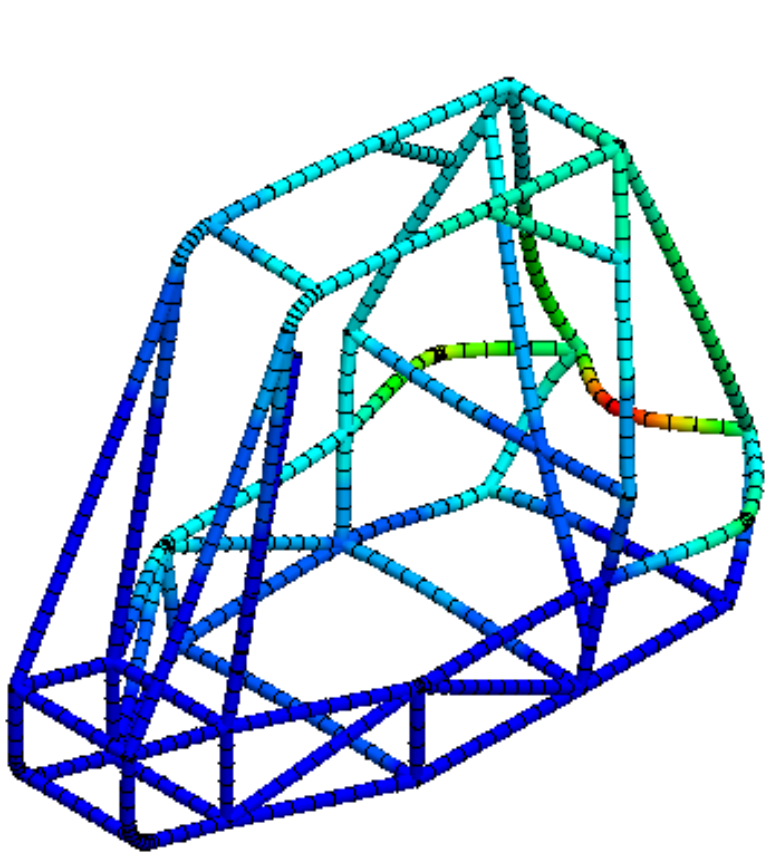
F.O.S. = 11.0

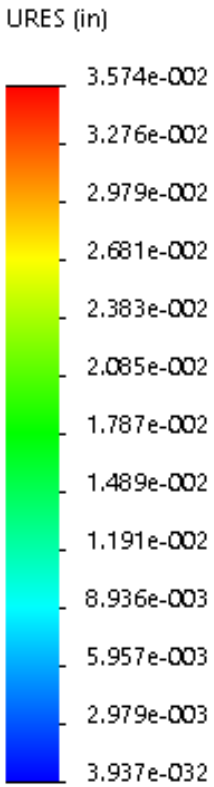


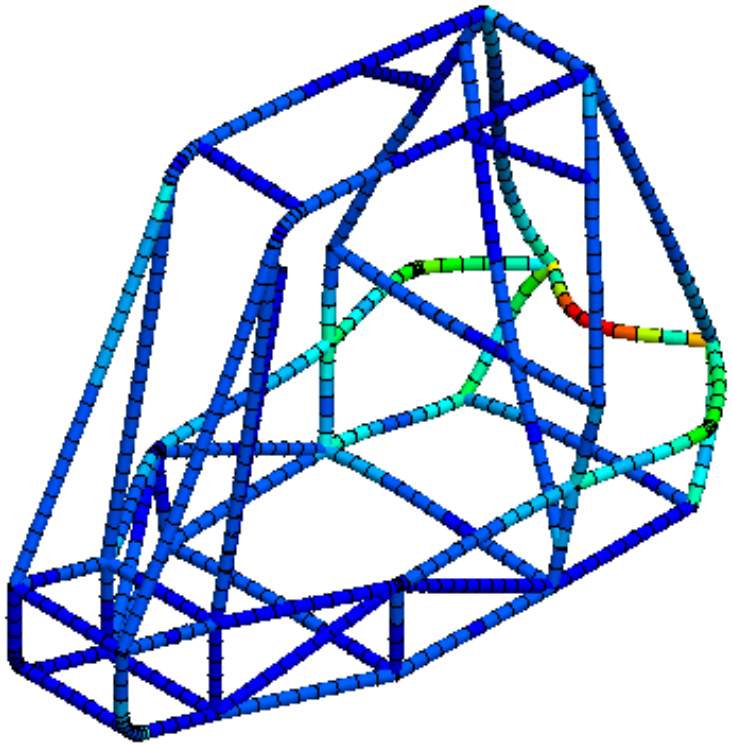
Legg

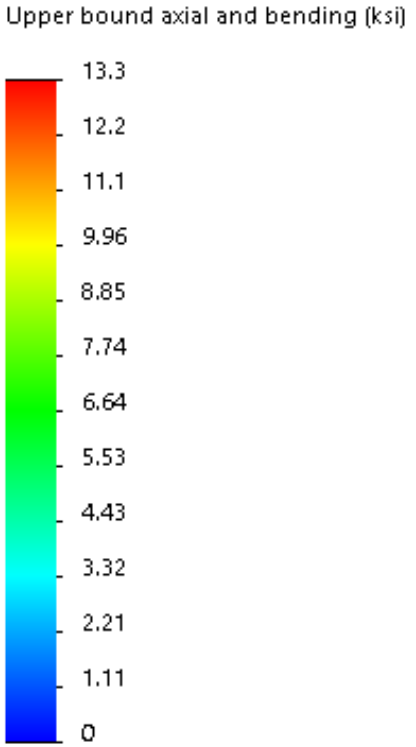
Rear Impact

F.O.S. = 5.0





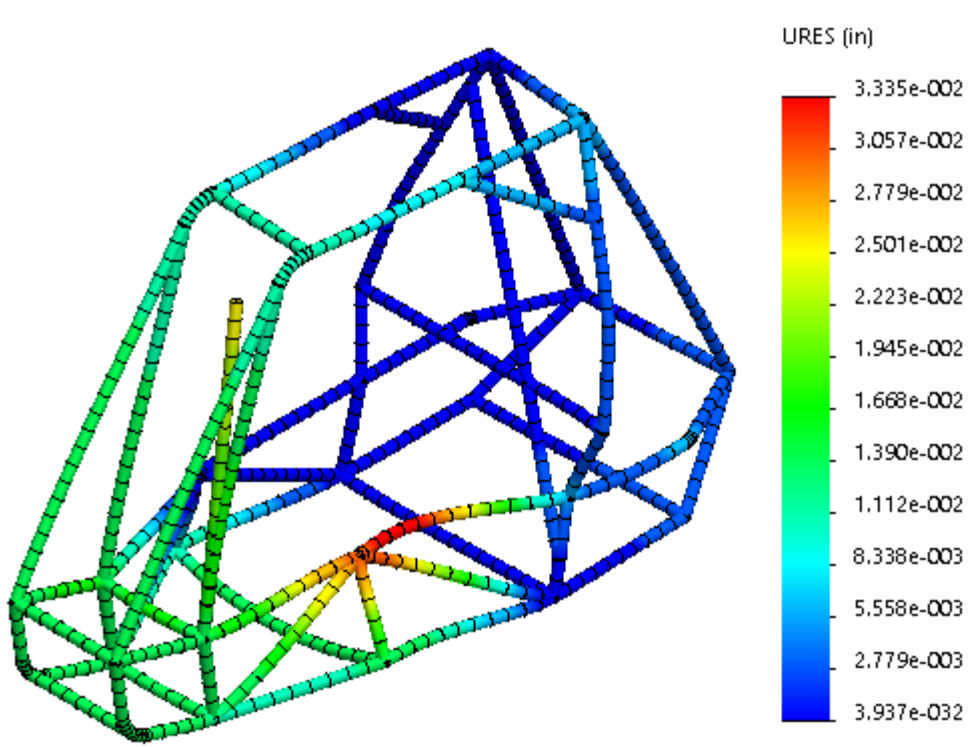


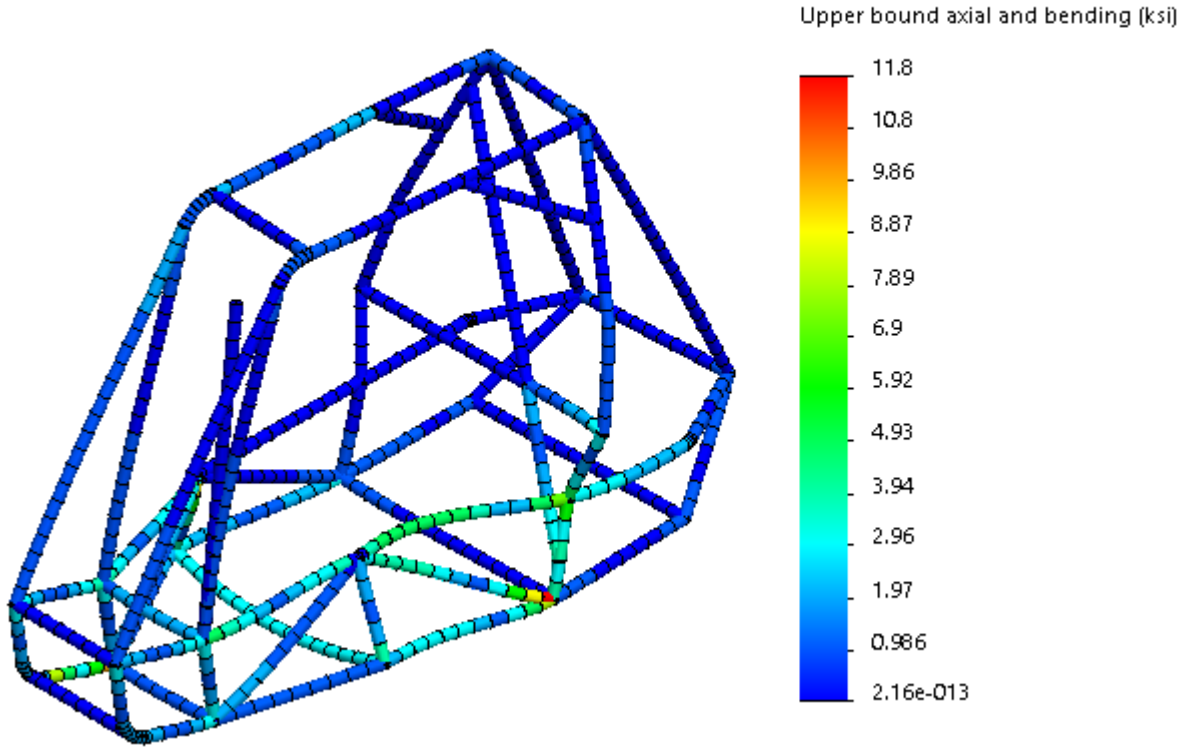


Legg

Side Impact

F.O.S. = 5.6





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Bill of Materials

Raw Materials		
Material	Quantity	Cost
AISI 4130 Steel Tubing $(d = 1.25'', t = 0.065'')$	90 ft.	$580
AISI 4130 Steel Tubing $(d = 1'', t = 0.056'')$	30 ft.	$210
$0.375'' \times 6''$AISI 1018 Steel Plate	2 ft.	$50
Sheet Metal	3 x 3 ft.	$25
Plastic Sheeting	2 x 3 ft.	$20
PVC	120 ft.	$30
	Total	$915

Legg

Bill of Materials

Commercial Parts		
Part	Quantity	Cost
Safety Harness	1	$75
Kill Switch	2	$40
Fire Extinguisher and Mount	2	$120
Brake Light	1	$20
Neck Brace	1	$25
Helmet	1	$80
Goggles with Tear-Away	1	$25
	Total	$385

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Bill of Materials

Item	Cost
Raw Materials	$915
Commercial Parts	$385
Total Cost	$1300

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References

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- Introduction to Finite Element Analysis and Design
- 2015 Collegiate Design Series Baja SAE® Rules
- Structural Considerations of a Baja SAE Frame
- NAU SAE Baja 2013-2014

Inquiries?

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