Shell Eco-Marathon

Urban Concept: Team #44

Team: Mallory Bartow(ME), Chris Breath(ME), Coury Courtney(EE), Dylan DeGruy(ME), Dante' Hebert(ME), Garrett McCarrol(EE), Huyen Pham(ME), Sam Sciortino(ME)

- **Advisor:** Professor Gabriel De Souza
- **Alumni Advisor:** Greg Talmage
- **Sponsors:** Shell, Dr. Dimitris Nikitopoulos

Objective Statement

Shell Eco-marathon AMERICAS

Team #44's objective is to design, manufacture, and test LSU's first **Urban Concept Vehicle** to successfully compete and place in all relevant categories of the Shell Eco-marathon Americas 2020 competition. Emphasis will be placed on maximizing fuel efficiency in an urban driving environment.

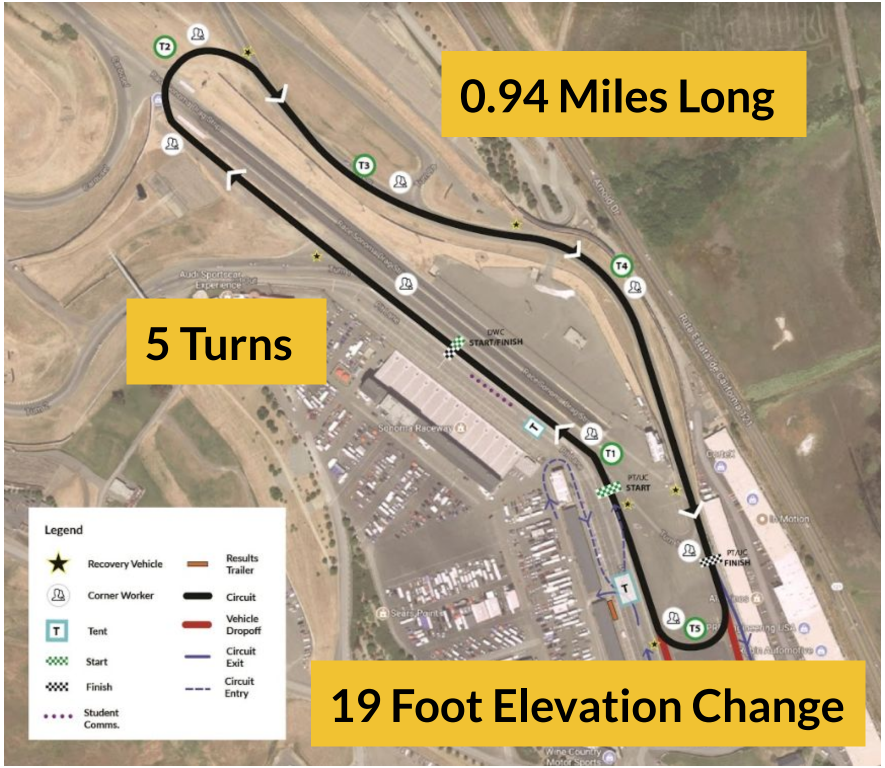
Customers

Shell
Eco-marathon
AMERICAS

- Primary
  - 2020 Shell Eco-marathon Judges
  - Shell
  - Driver
- Secondary
  - Automotive Industries
  - LSU

[1]

Competition Info



[2]

- Shell Eco-marathon Americas 2020
  - Sonoma, CA
  - April 1 - 4
- Track
  - 0.94 Miles per lap
  - 6 laps
  - 1 complete stop per lap
- Competition
  - 6 attempts
  - Best attempt recorded

Competition Scoring

Shell Eco-marathon AMERICAS

- Efficiency determined by both fuel consumption and electrical energy consumption
- Gasoline equivalents are calculated and totaled

$$Fuel\ Economy\ (mpg) = \frac{Miles\ Traveled\ (miles)}{Fuel\ Consumption\ (gal)}$$

$$Fuel\ Consumption\ = Gasoline\ (gal) + Equivalent\ Electricity\ (gal)$$

$$Equivalent\ Electricity\ (mpg) = \frac{Electrical\ Consumption\ (kWh)}{0.1875 * 34.99}$$

Off-Track Awards

Shell Eco-marathon AMERICAS

- Communications Award
- Vehicle Design Award
- Technical Innovation Award
- Safety Award
- Perseverance & Spirit of the Event Award
- Circular Economy Award

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Competing Technologies

Shell
Eco-marathon
AMERICAS

1st Place in Previous Years

- 2019
  - Wawasee High School
  - Diesel - 680.7 mpg
- 2018
  - Mater Dei High School
  - Gasoline - 841.3 mpg
- 2017
  - Mater Dei High School
  - Gasoline - 602.3 mpg

2019 Winner Wawasee High School [4]

Key Functions

Function	Description
Protect the Driver	Vehicle must keep the driver safe from outside impact, weather effects, and potentially dangerous elements.
Move	Vehicle must be able to easily move across the ground surface.
Steer	Driver can turn the vehicle left/right.
Stop the Car	Driver can stop the vehicle while remaining seated inside.
Convert Power	Vehicle must be able to convert the stored energy into mechanical energy.
Transfer Power	Vehicle must be able to use mechanical energy to propel itself.

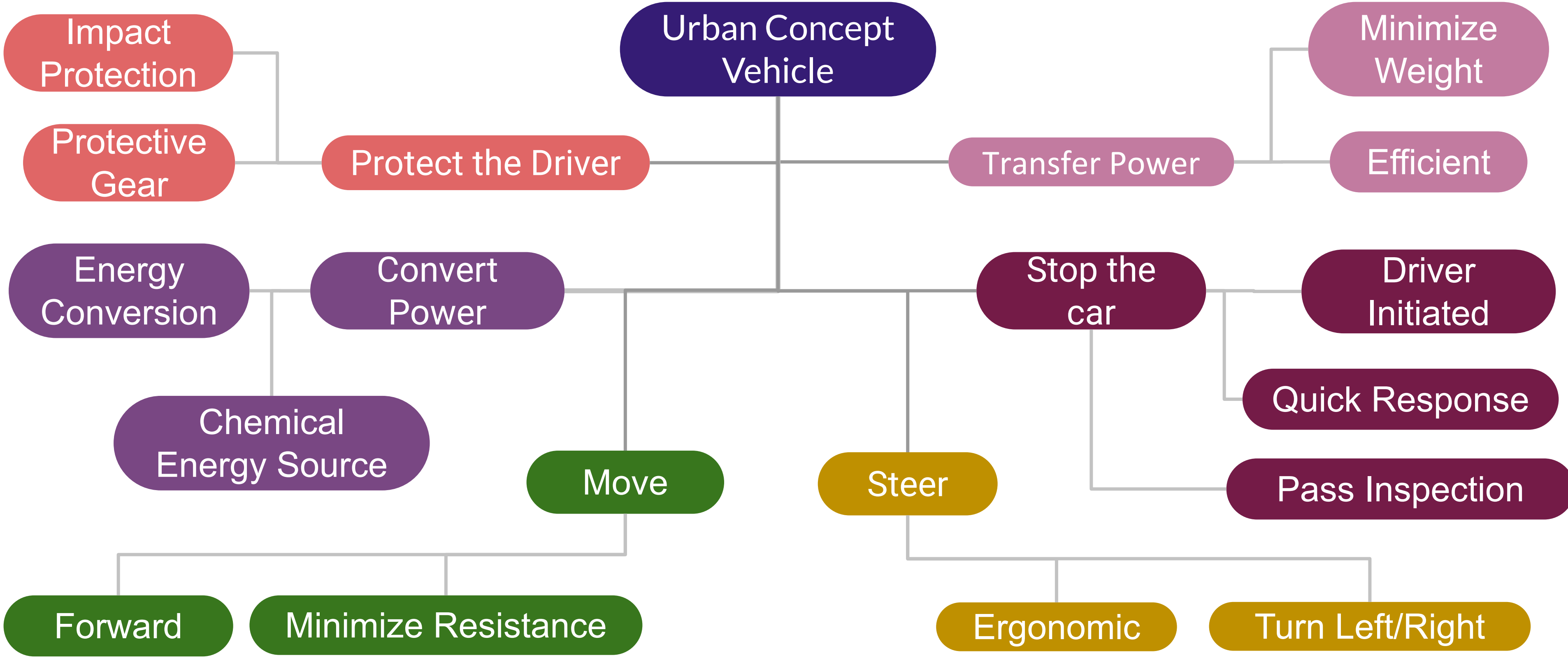
Qualitative Constraints

Constraint	Description
Maximize Efficiency	Vehicle will have the highest possible energy efficiency.
Reliability	Vehicle is able to perform repeated tests without failure.
Weather Resistant	The body and external parts are durable and water-resistant.
Ease of Manufacturing	Parts and components are easy to manufacture and assemble.
Accessible Fuel and Power Source Compartment	Fuel source and battery compartment are easy to access for refueling/recharging.

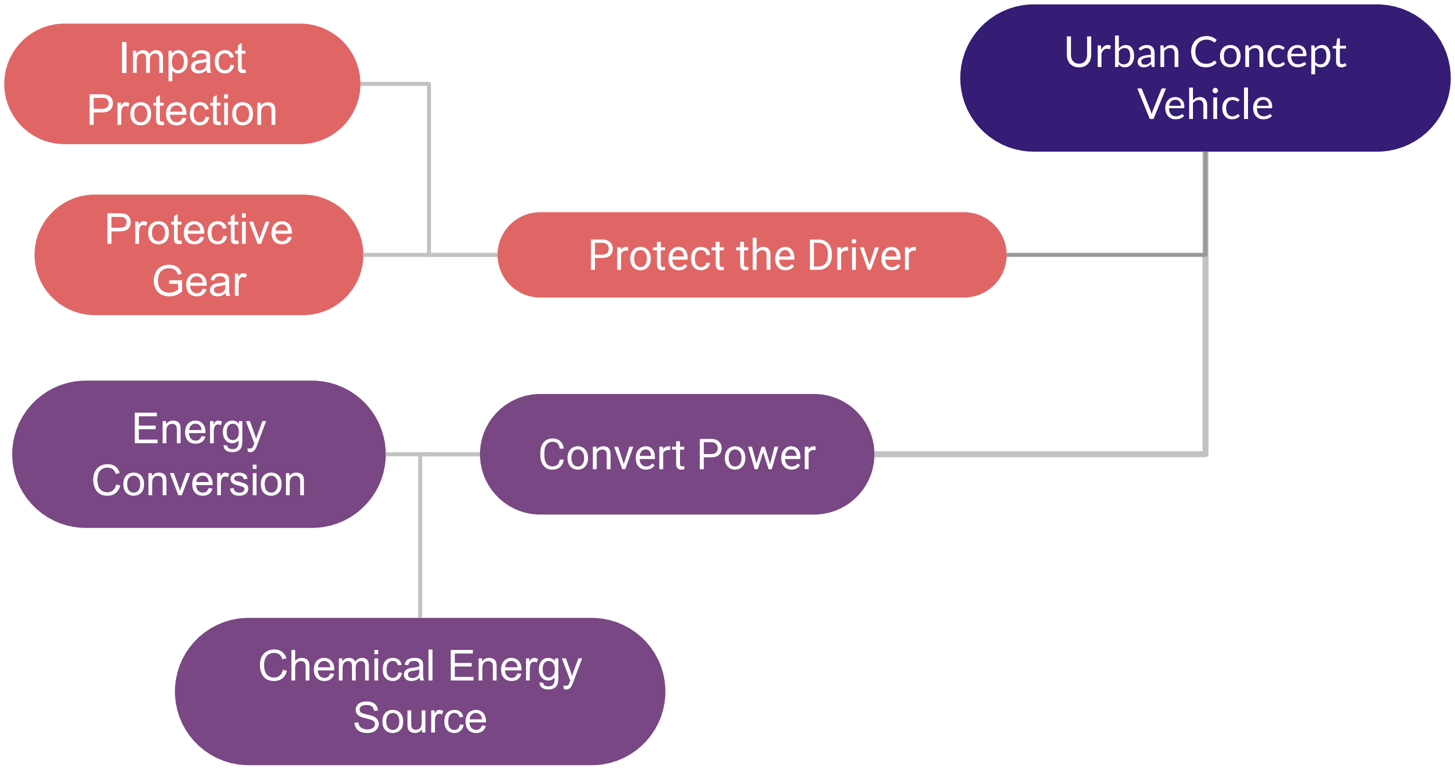
Quantitative Constraints

Constraint	Description
Budget	$10,000 Proposed Budget from LSU
Vehicle Dimensions	Internal and External Dimensions set by Shell Eco-marathon
Vehicle Weight	225 kg max Vehicle Weight
Driver Weight	75 kg min Driver Weight
Velocity	Average Velocity of at least 15 mph

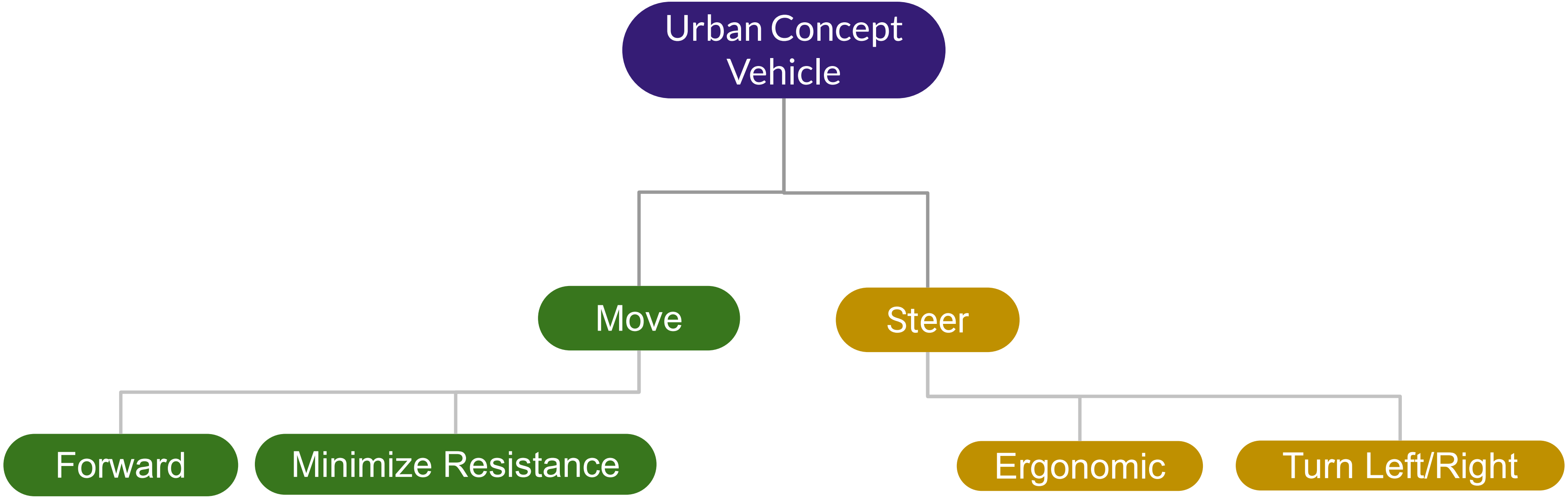
Function Objective Tree



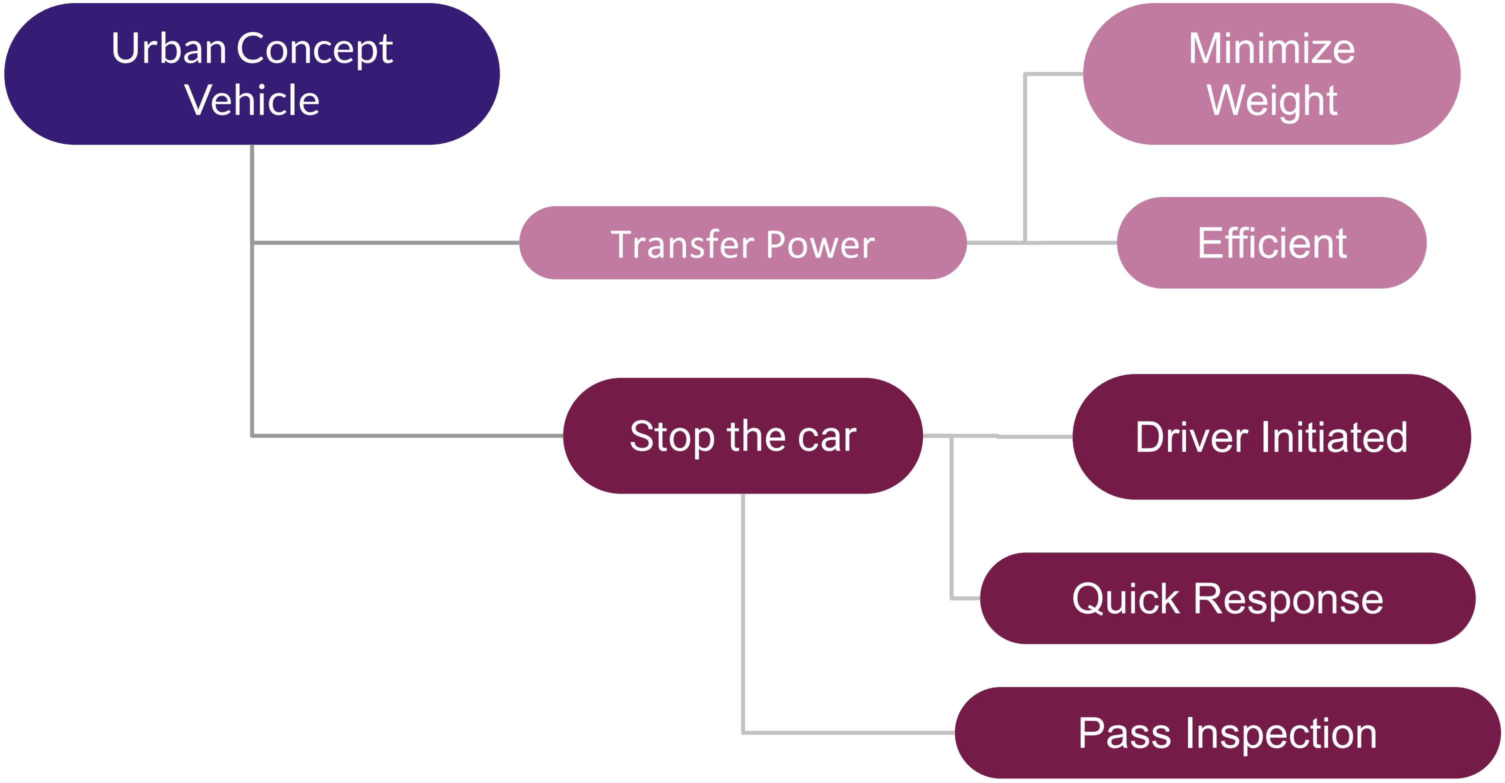
Function Objective Tree



Function Objective Tree

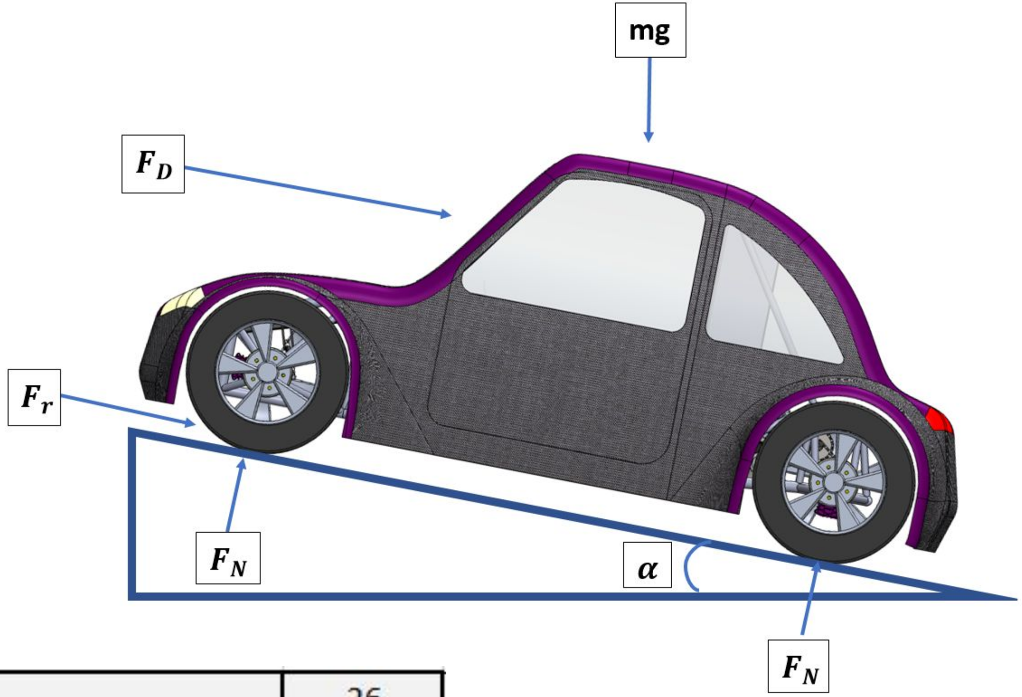


Function Objective Tree



Efficiency Factors

List of Parameters		
Frontal Area of Car (m^2)	A	1.1
Percent Grade	P_G	0.02
Vehicle Mass (kg)	m	200
Drivetrain Efficiency	ε	0.78
Tire Rolling Resistance Coefficient	C_{RR}	0.01
Brake and Steering Resistance	C_{BSR}	0.003
Drag Coefficient	C_D	0.3
Air Density (kg/m^3)	ρ	1.225
Wheel Radius (in)	r	11.5
Time to Accelerate (s)	t	10

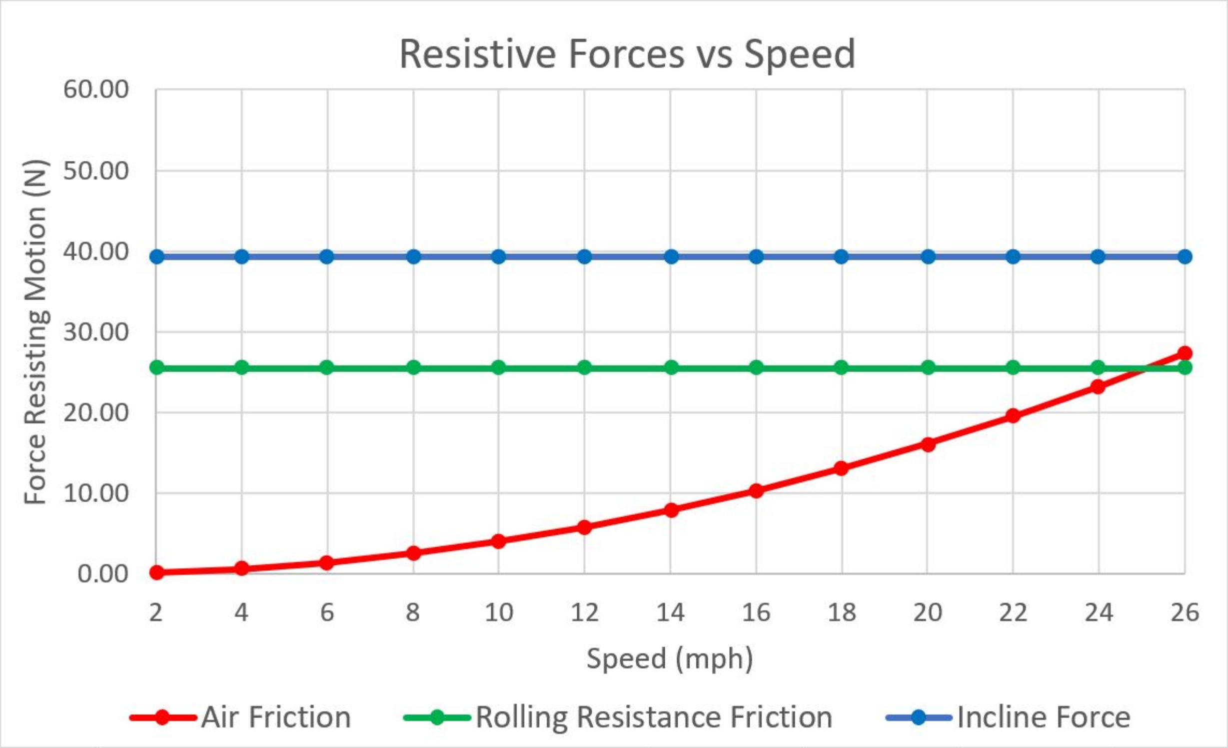


Velocity (mph)		26
F-Air (N)	$F_{air} = 0.5 C_D A \rho v^2$	27.31
F-RR (N)	$F_{RR} = mg(C_{RR} + C_{BSR})$	25.51
F-Incline (N)	$F_{incline} = mgP_G$	39.24
F-Resistance (N)	$F_{Resistance} = F_{air} + F_{RR} + F_{incline}$	92.05

Efficiency Factors

Prioritize:

1. Minimize Weight
2. Reduce Rolling Resistance
3. Minimize Drag



Driver

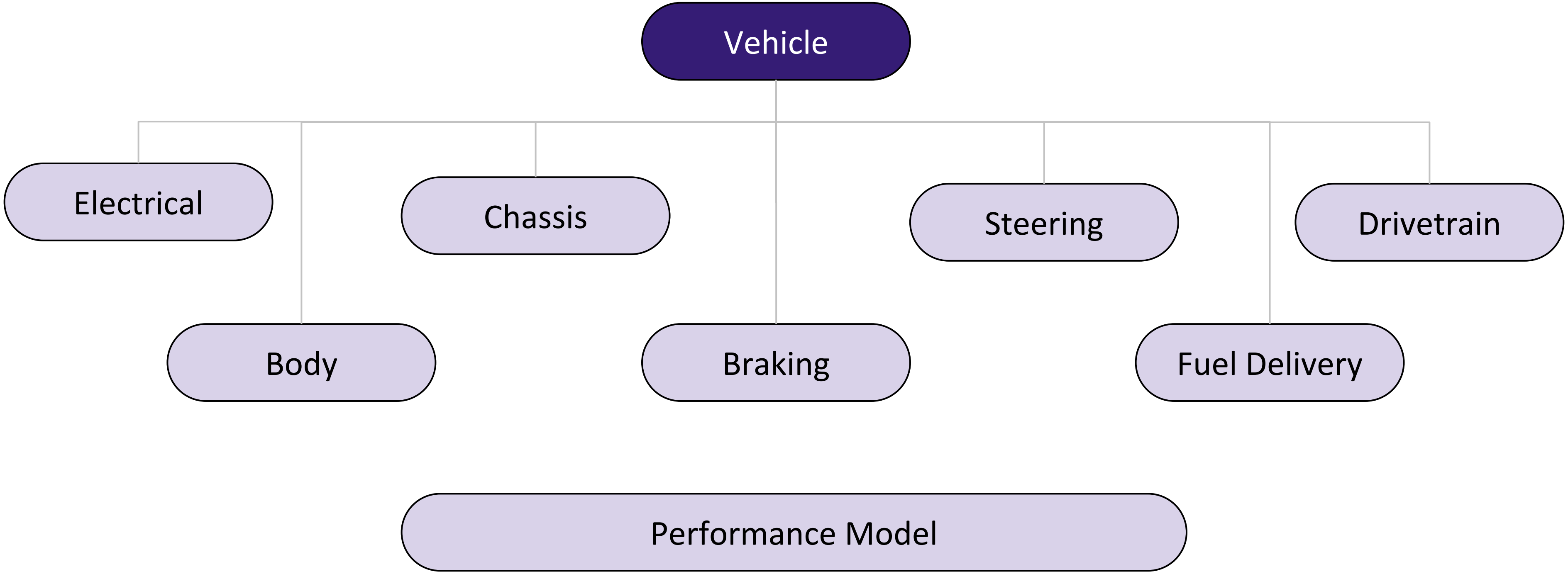
Metric	Weight	Coury	Mallory	Huyen	Dante’
Weight (lbs)	3	155.4	126.2	96	155.0
Height (in)	1	35	33.75	32.25	35
Width (in)	1	17.5	15.25	14.5	18

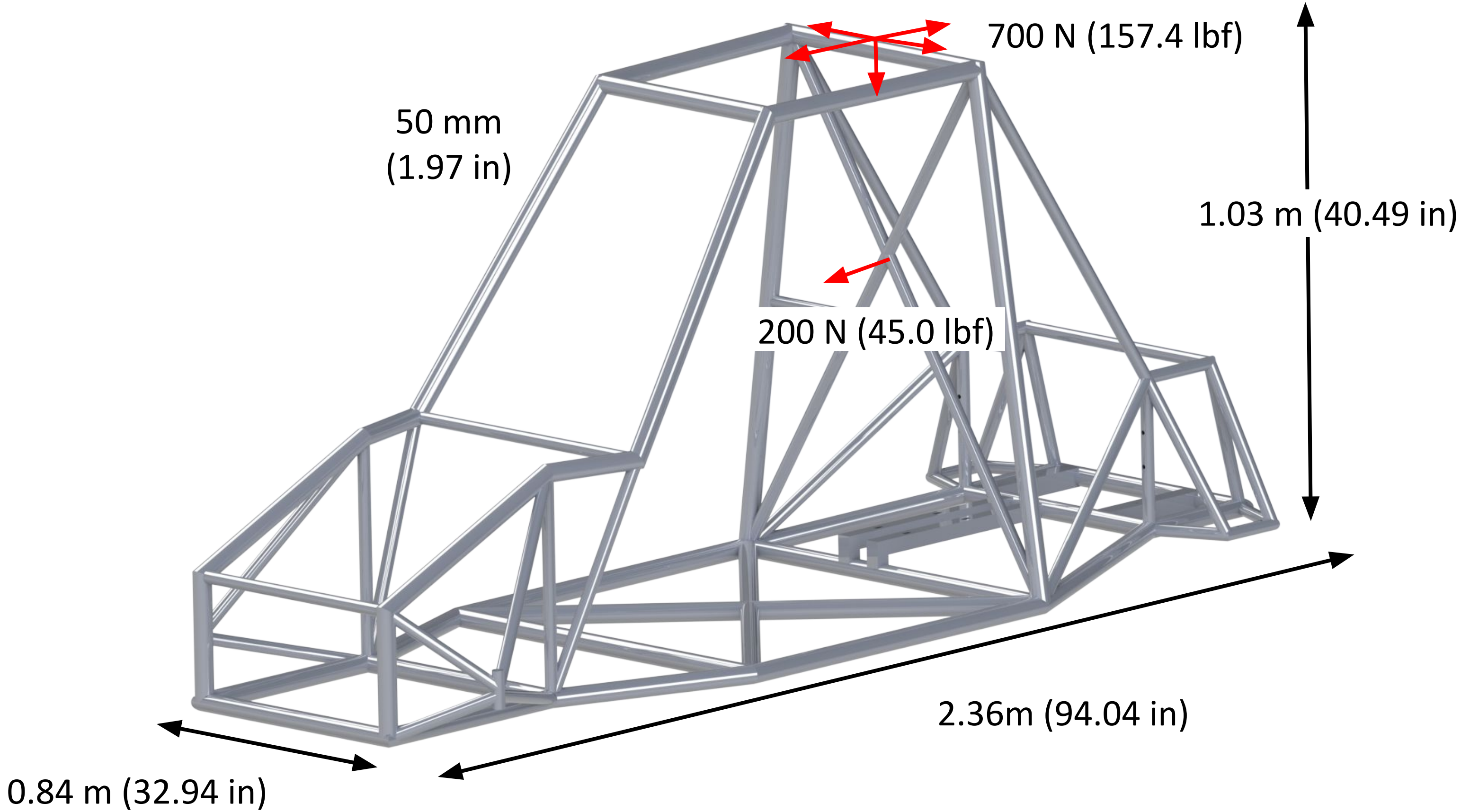
$$\% \, Diff = \left| \frac{x_1 - x_2}{x_{min}} \right| * 100 * Weight$$

Driver

Metric	Coury & Dante’
Weight (lbs)	0.38
Height (in)	0.00
Width (in)	3.45
Total	4.60

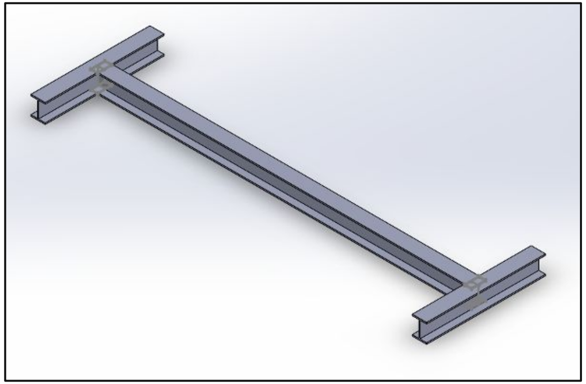
Subsystem Breakdown

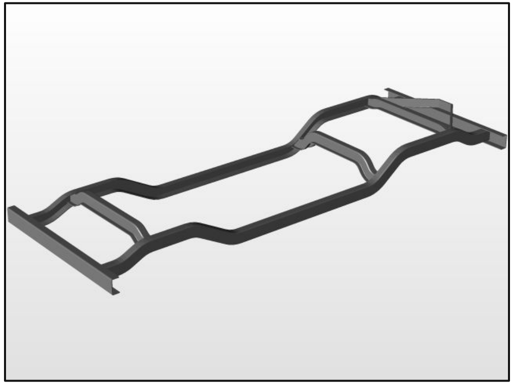




Speaker: MB Slide Author: MB

Concepts





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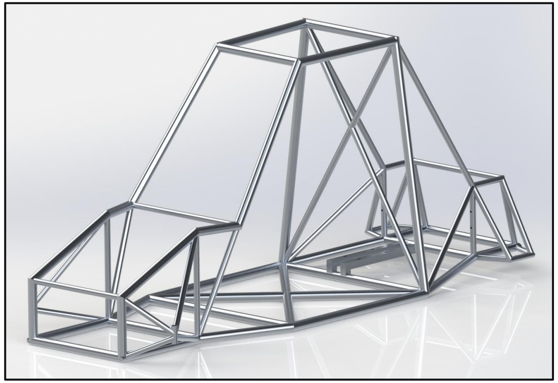

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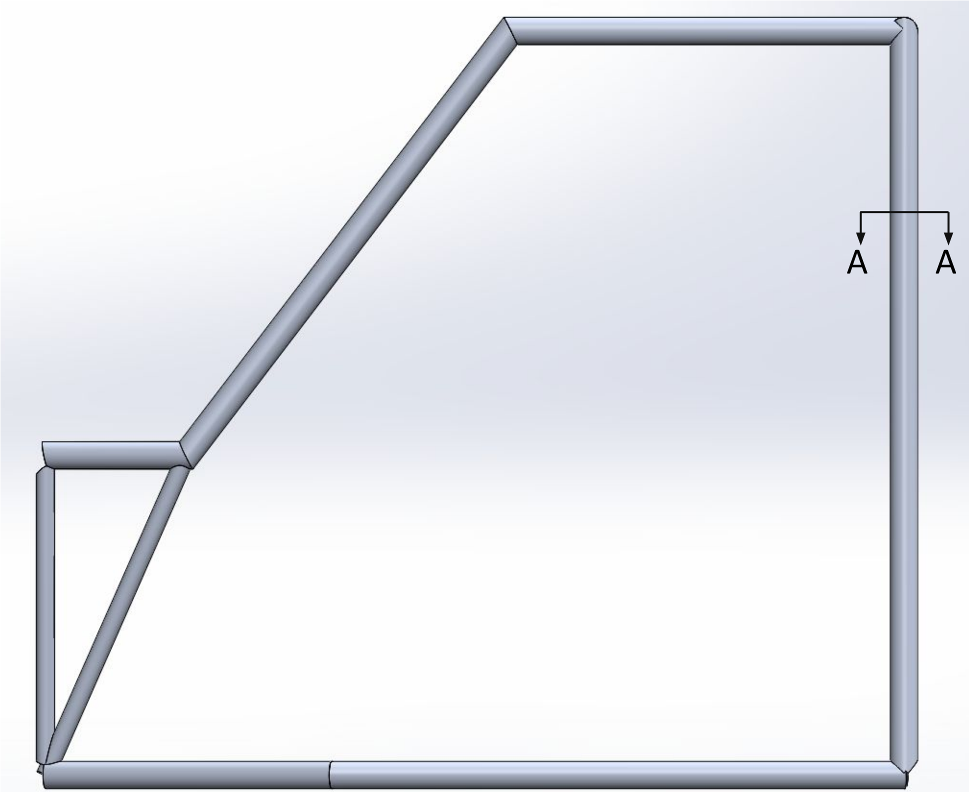
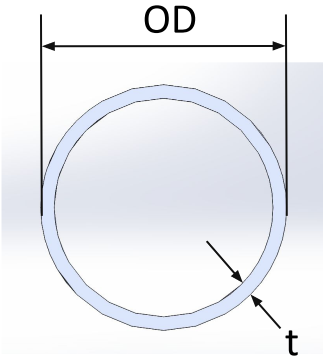
Parametric Design

- Total Length = 4.7 m (185.08 in)
- Arbitrary Load = 700 N (78.7 lbf)

$$\sigma = \frac{4P}{\pi(D^2 - d^2)}$$

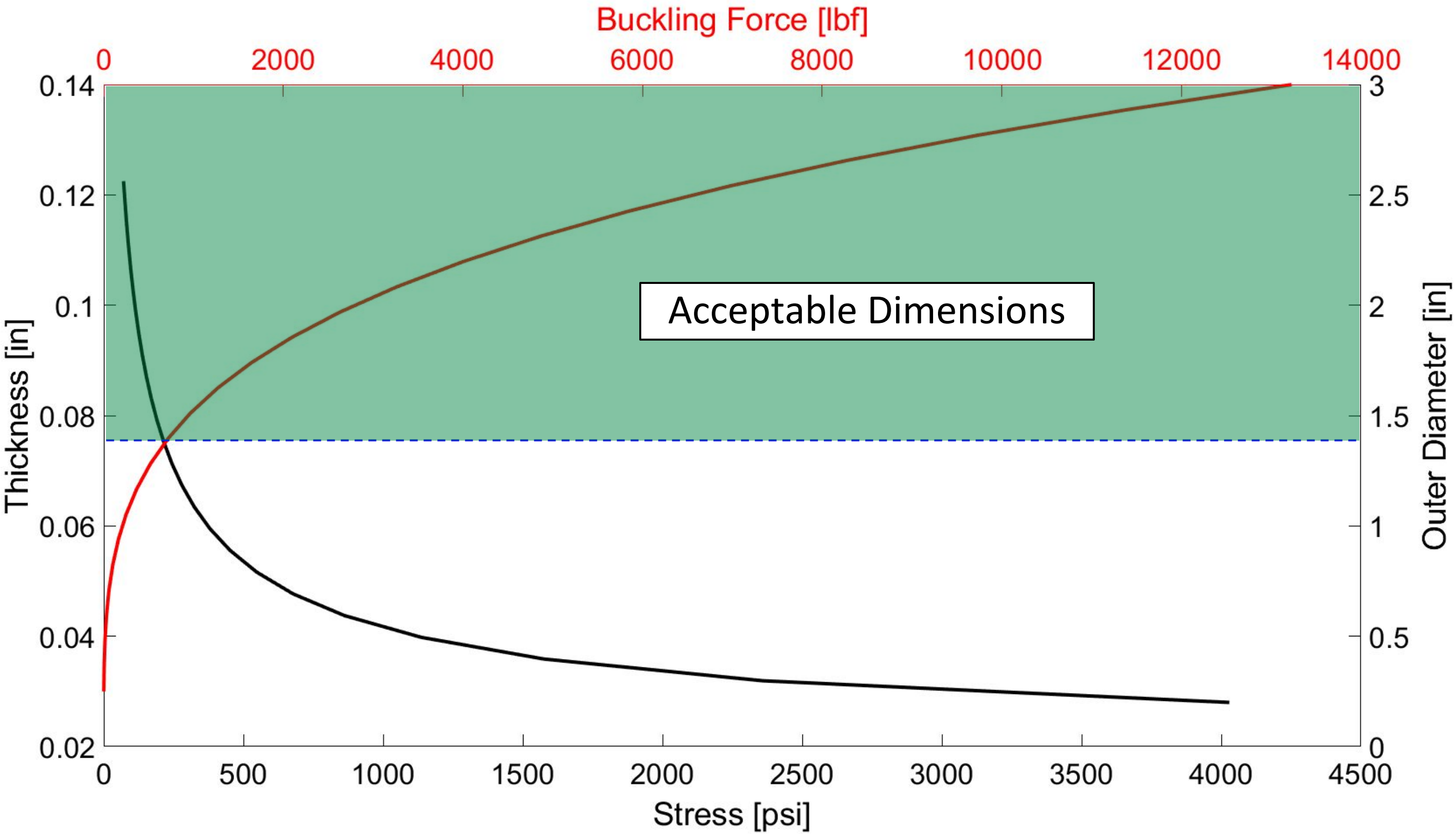
$$F_{cr} = \frac{\pi^3 E}{16L^2}(D^4 - d^4)$$





Section A-A

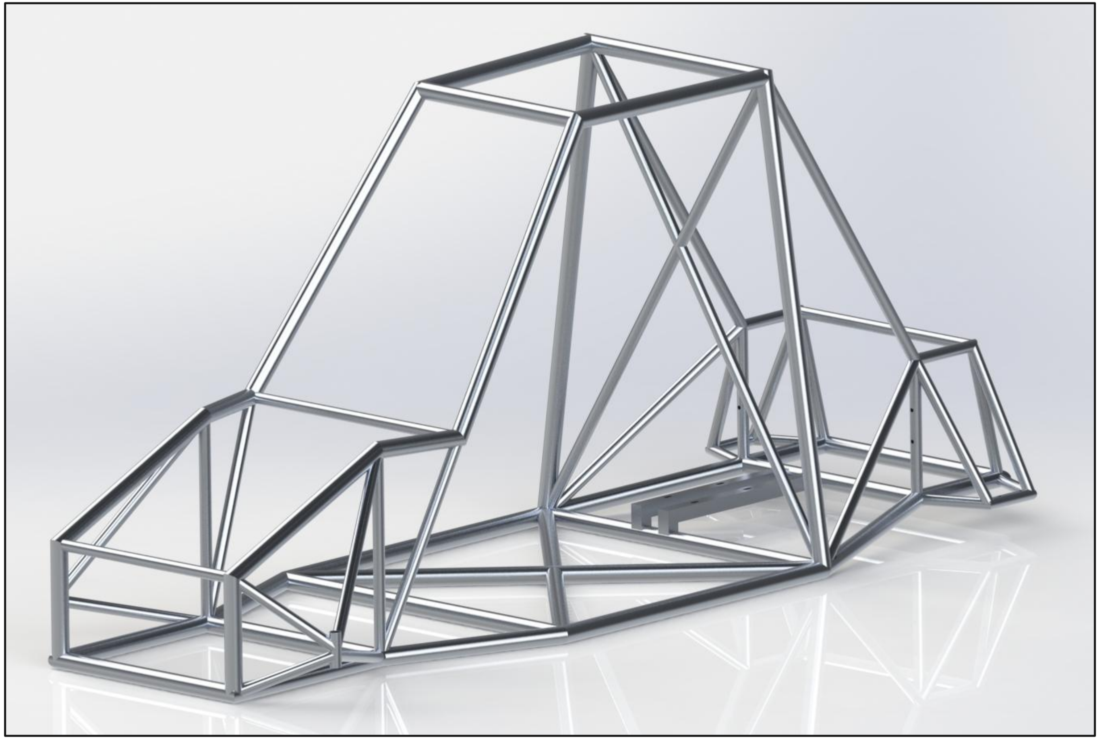
Stress & Buckling Force vs. Tube Size



Weight Reduction

- Original Tubing Size:
  - Outer Diameter **1.50 in**
  - Thickness **0.083 in**
- Original Weight **46.7 lbf**

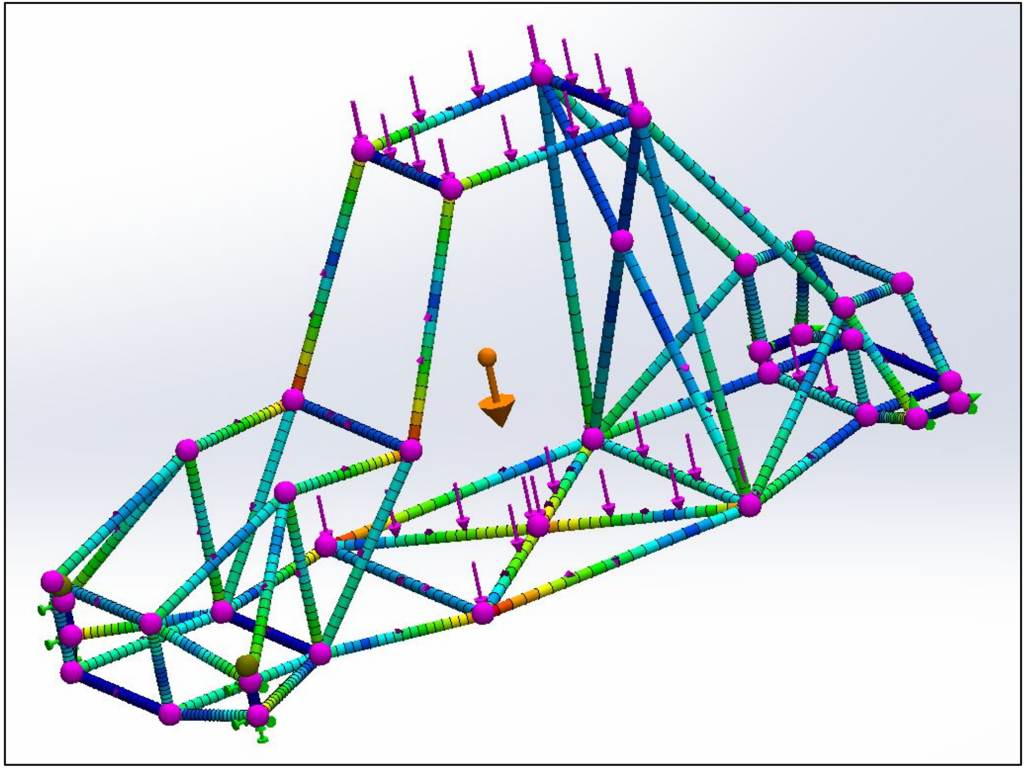
- **21%** Weight Reduction
  - Outer Diameter **1.00 in**
  - Thickness **0.065 in**
- Final Weight **36.9 lbf**



Static Load Analysis

- Load Cases:
  - 700 N in all directions
  - Driver, Body, and Engine
  - 200 N Safety Harness
  - Torsional Load
  - Buckling

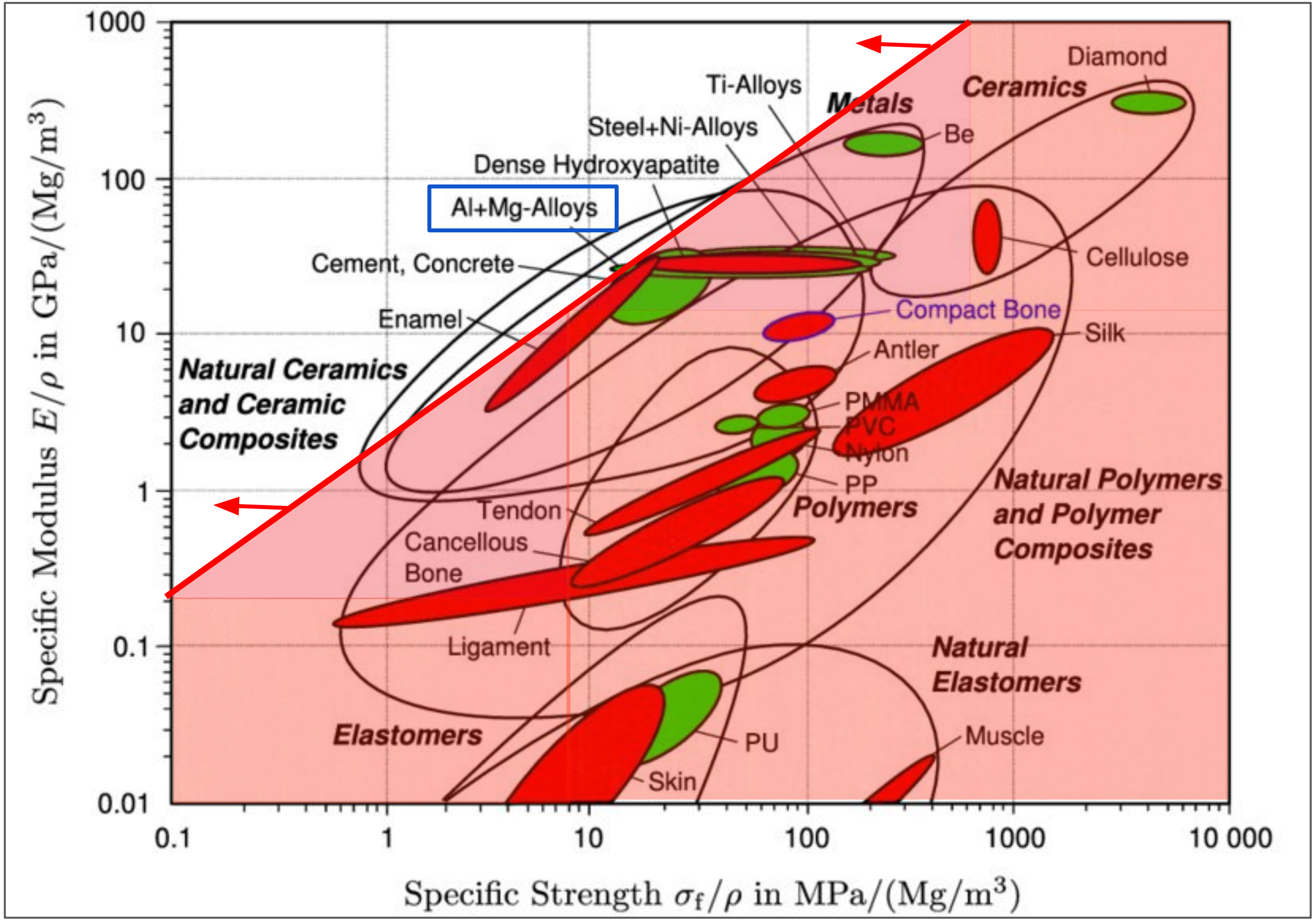
- Minimum Factor of Safety:
  - Driver, Body, and Engine: 48.2 MPa
  - Max Deflection: 6.0 mm (0.24 in)
  - F.S. = 4.05



- Material Index:

$$M = \frac{E}{\sigma_f}$$

- Al 5052-H32
- Ultimate Strength: 228 MPa (33 ksi)
- Yield Strength: 193 MPa (28 ksi)



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Manufacturing

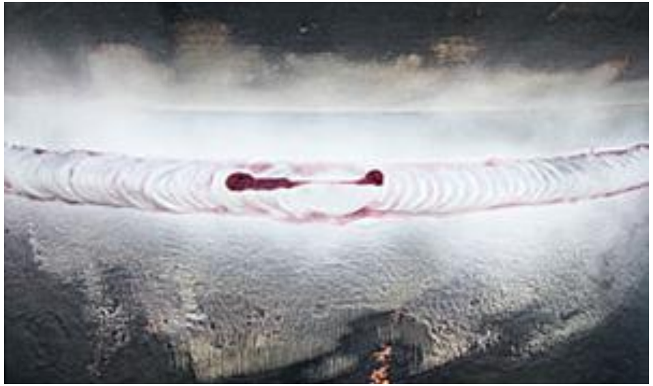
- Material
  - VR3 Engineering
  - CNC Notched and Formed Tubing
  - Cost $2,830
- Welding
  - 4043 Aluminum Tig Rod

- December
  - Week 1: Order Materials
  - Week 2: Processing and tube shipping
  - Week 3: Manufacturing by VR3
  - Week 4: Manufacturing by VR3
- January
  - Week 1: Chassis Materials Ship
  - Week 2: Begin welding
  - Week 3: Welding Cont.
  - Week 4: Welding Cont.
- February
  - Week 1: Complete Chassis

Testing

- Testing
  - Liquid Dye Penetrant of Welds
  - Ultrasonic Testing of Welds
  - Destructive Testing of Welds

- January
  - Week 1: Destructive Testing
- February
  - Week 2: Liquid Penetrant and Ultrasonic Testing



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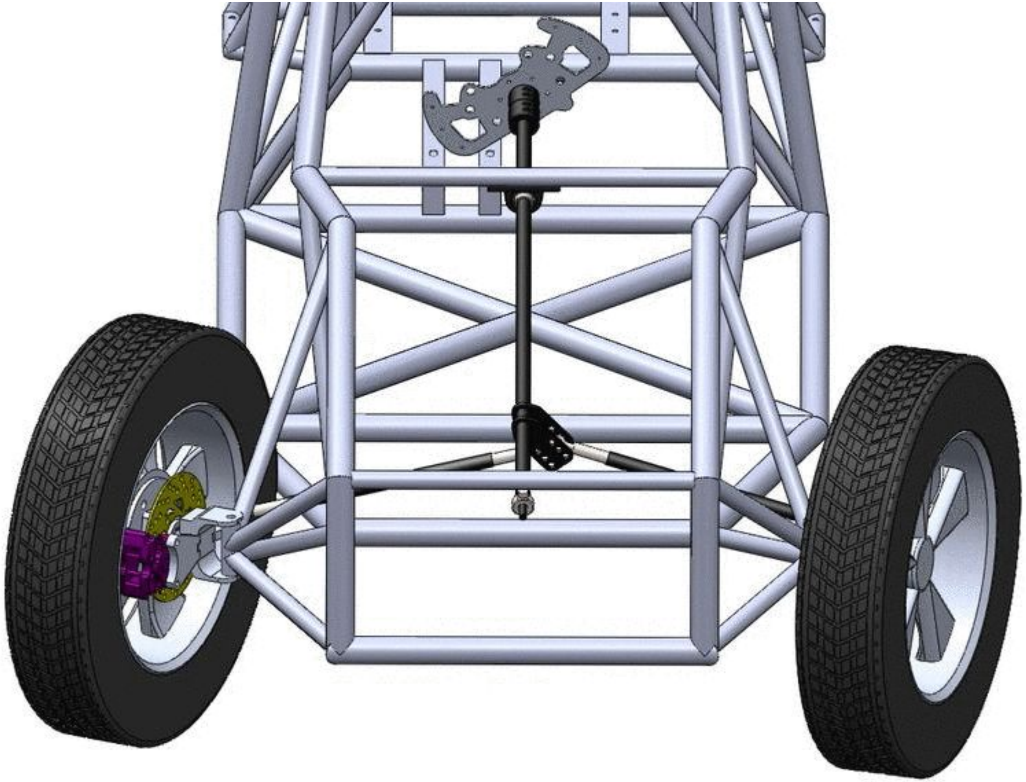
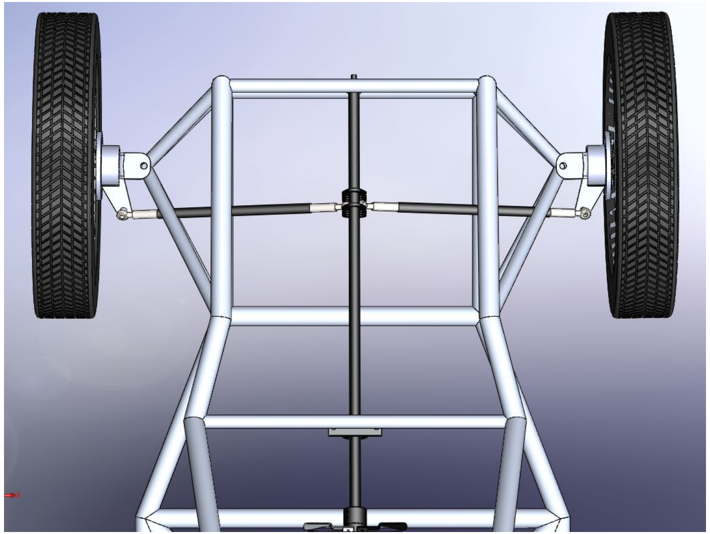
Speaker: MB Slide Author: MB

Steering

- Bell crank design
- Ackermann geometry
- Materials: 6061 Aluminum and Chromoly Steel



Concepts



Bell Crank

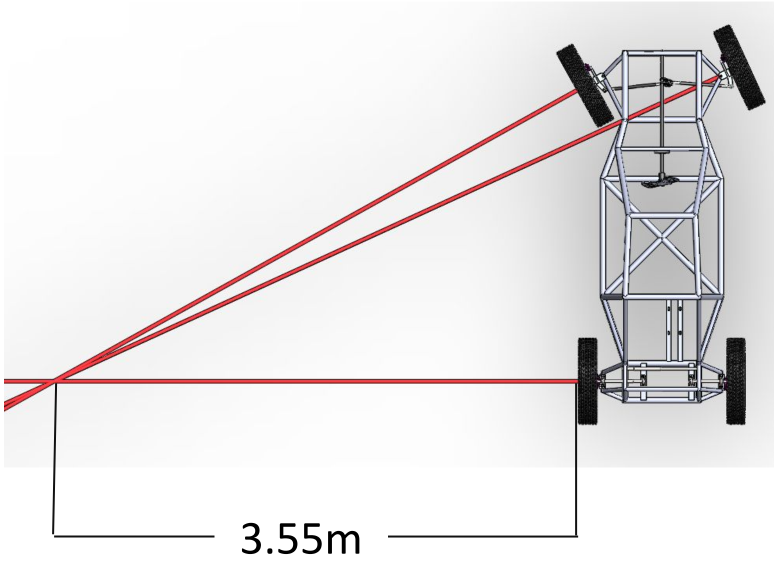
Rack and Pinion

Ackermann Steering Geometry

- Minimum turn radius: 6 m
- Turn radius as function of car geometry and steering angle:

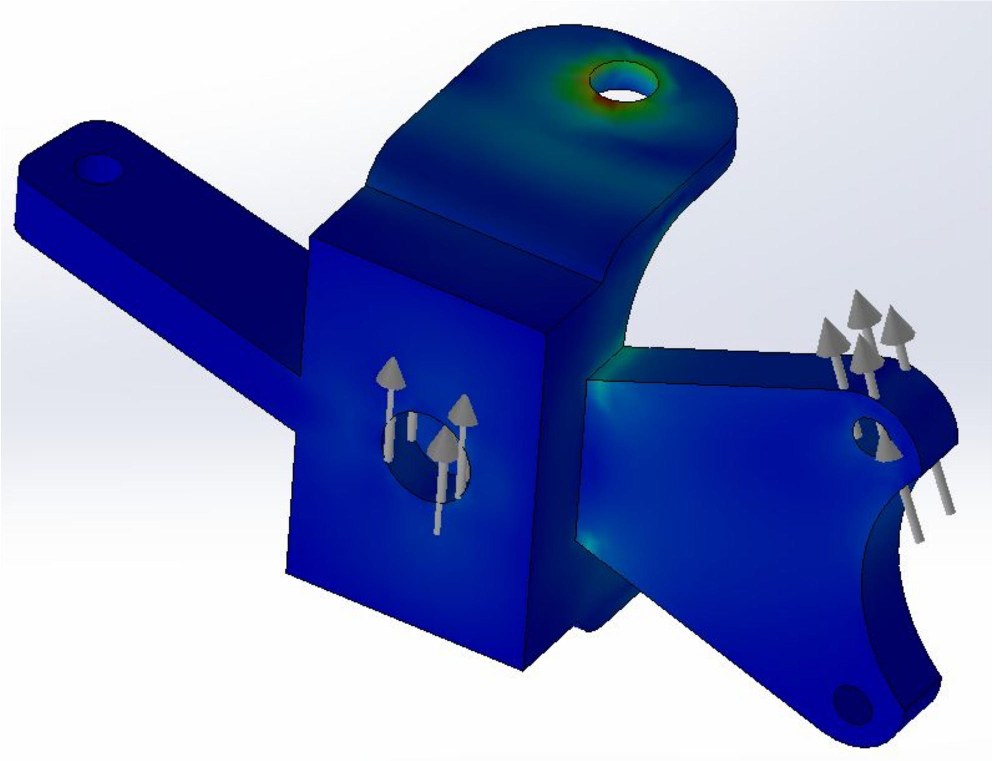
$$r_{turn} = \frac{x_{wheelbase}}{\sin\theta} - \frac{x_{ftrack} - x_{rtrack}}{2}$$

- Steering Angle: 11. 3°



Load Analysis

- Loads Applied:
  - 500 N Car Weight
  - 55 N-m Brake Torque
- Max Stress: 72.34 MPa
- Yield Strength: 276 MPa
- Factor of Safety: 3.8



Material Selection

	Chromoly Steel Yield: 435 MPa (63.1 ksi)	**Aluminum** Yield: 276 MPa (40 ksi)
Steering Shaft	Weight: 1.84 lbs FoS: 3 Angular Deflection: 0.0008°	Weight: 0.44 lbs FoS: 3.55 Angular Deflection:0.0021°
Linkages	Weight: 2.16 lbs FoS: 32.7	Weight: 0.746 lbs FoS:11
Steering Knuckles	Weight: 3.87 lbs FoS: 6.1	Weight: 1.32 lbs FoS: 3.8

Manufacturing

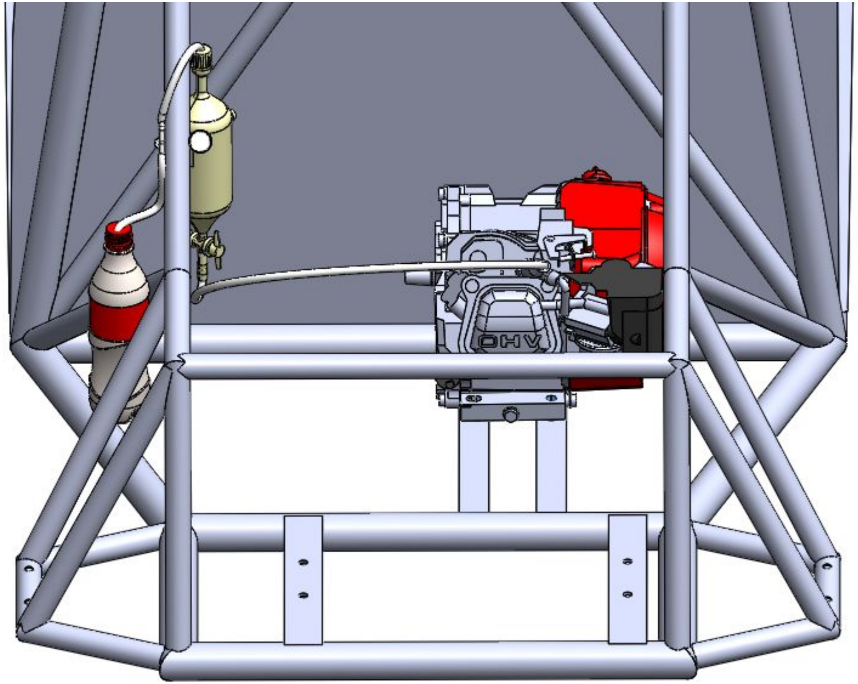
- Cost:
  - Shaft w/Pitman arm (Purchase and weld) $21.30
  - Linkage Parts (Purchase) $92.29
  - Steering Knuckles (CNC) $300

- December
  - Week 1: Order Materials
  - Week 2: Processing and Shipping
  - Week 3: Create Assembly Jig
- January
  - Week 1: CNC Steering Knuckles
  - Week 2: Linkage Assembly
- February
  - Week 2: Addition to Chassis

Testing

- Testing
  - Liquid Dye Penetrant of Pitman arm Weld

- January
  - Week 2: Geometry testing
- February
  - Week 3: Live motion turn radius test



Pressurized Soda Bottle → Pressure Relief Valve → Pressure Gauge → Pressure Regulator → Bleeder Valve → Fuel Tank → Fuel Injector → Combustion Chamber

Concepts: Energy Source

Internal Combustion Engine

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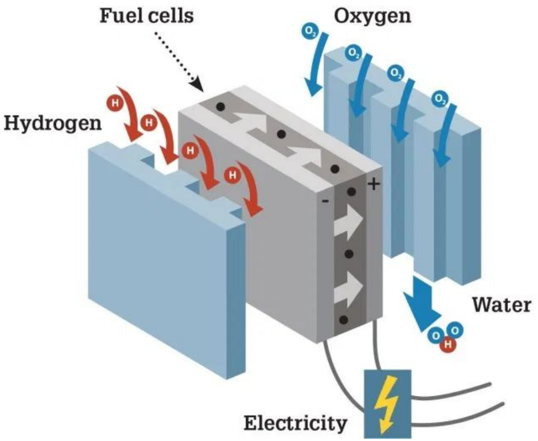
Battery Electric

[10]



Hydrogen Fuel Cell

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Concepts

Pressurized Bottle

[12]

Mechanical Fuel Pump

[13]

Ecotrons Fuel Injection Kit

Capabilities

- Dual Performance Maps
- On the Fly Calibration
- External Calibration

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Engine Power Required

$$Total\ Resistive\ Force = F_T = F_a + F_r + F_i$$

$$Force\ of\ Air\ Drag = F_a = 0.5 C_D A \rho V^2 = 17.4\ N$$

$$Force\ of\ Rolling\ Resistance = F_r = mgC_r = 25.5\ N$$

$$Force\ from\ Incline = F_i = mgP_g = 39.2\ N$$

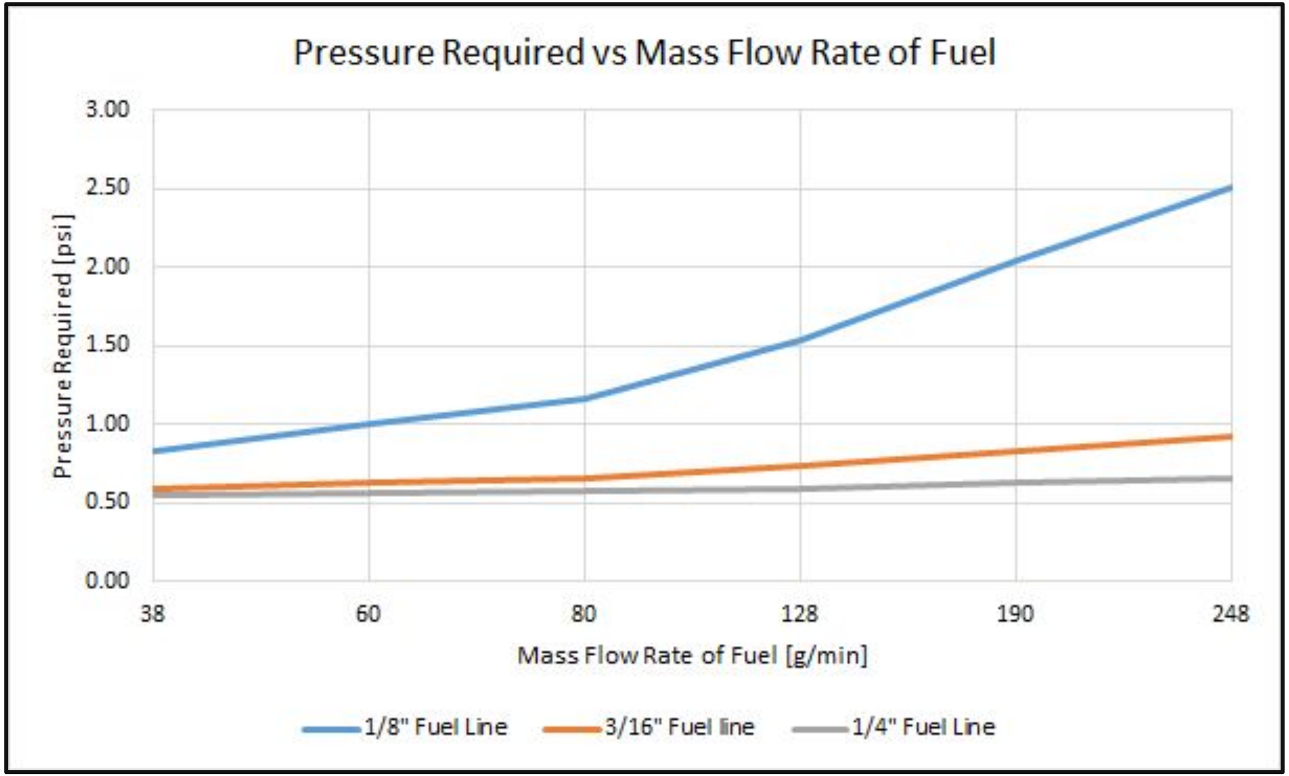
$$Power = \frac{F_T * V}{\varepsilon}$$

$$Power\ Required = 4\ horsepower$$

Engine Power Required

Power required to maintain 26 mph is 4 hp

Fuel Line Sizing



Pressure needed to move the correct amount of fuel

$$P_1 = \rho g\left(\frac{h_1}{g} + \frac{\alpha_1 {V_2}^2}{2g} + z_2\right)$$

Selected 3/16" Diameter Fuel Line

Manufacturing

- Manufacturing
  - Install Ecotron Fuel Injection System
  - Build Pressurized Fuel System
  - Install Engine into Vehicle
- Cost
  - $1160

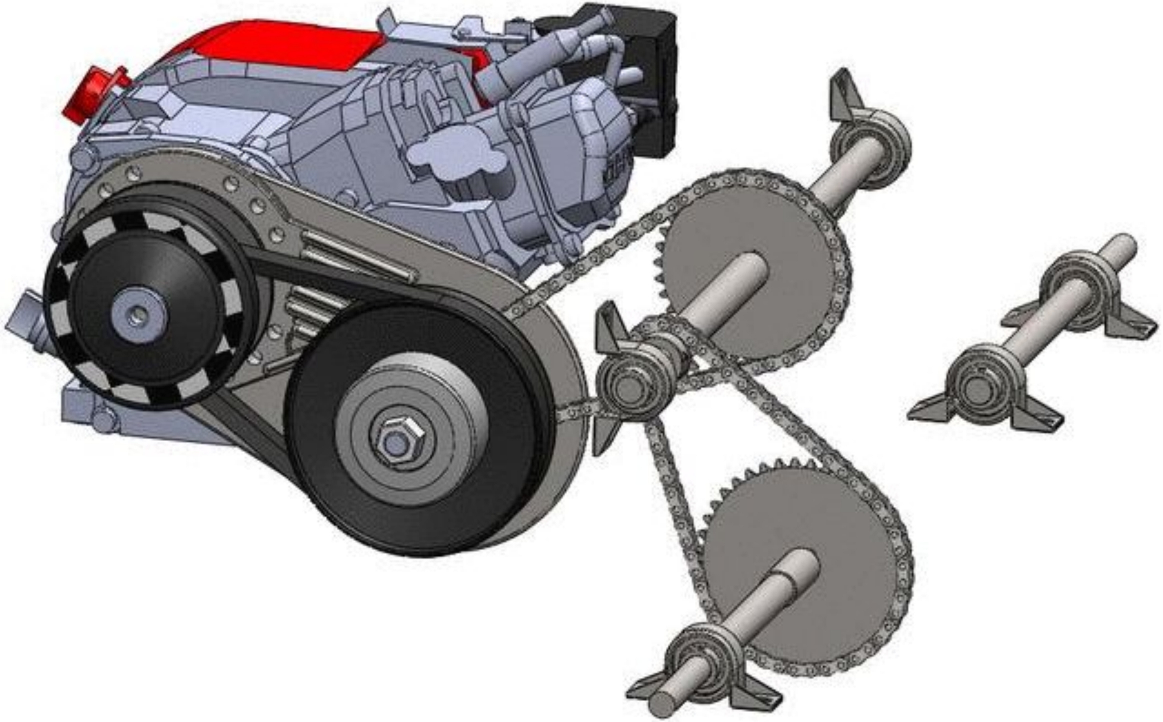
- January
  - Week 4: Install Fuel Injection
- February
  - Week 2: Build Fuel System
  - Week 2: Install Engine

Testing

- Testing Plan
  - Pressurized Bottle
    - Destructive testing for maximum pressure
  - Tune the ECU
    - Correct Air/Fuel Ratio
    - Build Performance Map
    - Determine Fuel Consumption

- February
  - Week 1: Destructive Bottle Testing
  - Week 3: ECU Tuning
  - Week 4: ECU Tuning
- March
  - Week 1: ECU Tuning
  - Week 2: ECU Tuning

Drivetrain



Concepts

Comet TAV 30-75 Torque Converter

- Engagement RPM = 2200
- Designed for 18”+ tall tires
- Variable gear ratio 2.7:1 - 0.9:1

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[16]

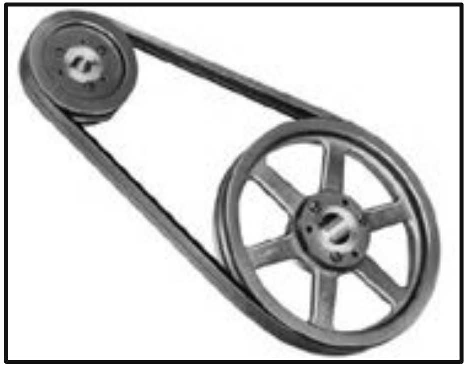
Centrifugal Clutch

- Engagement RPM = 1800
- Designed for < 16” tall tires
- Single gear ratio 1:1

Concepts

Chain and Sprocket

[17]



Belt and Pulley

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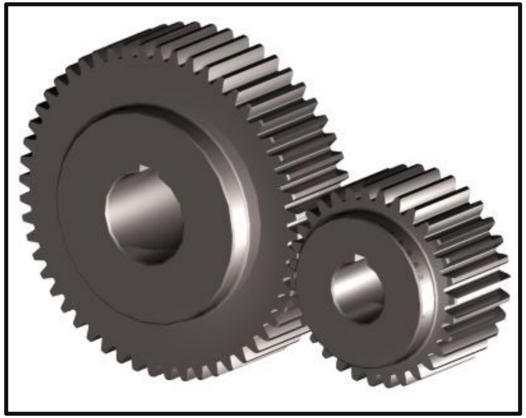

Gearbox

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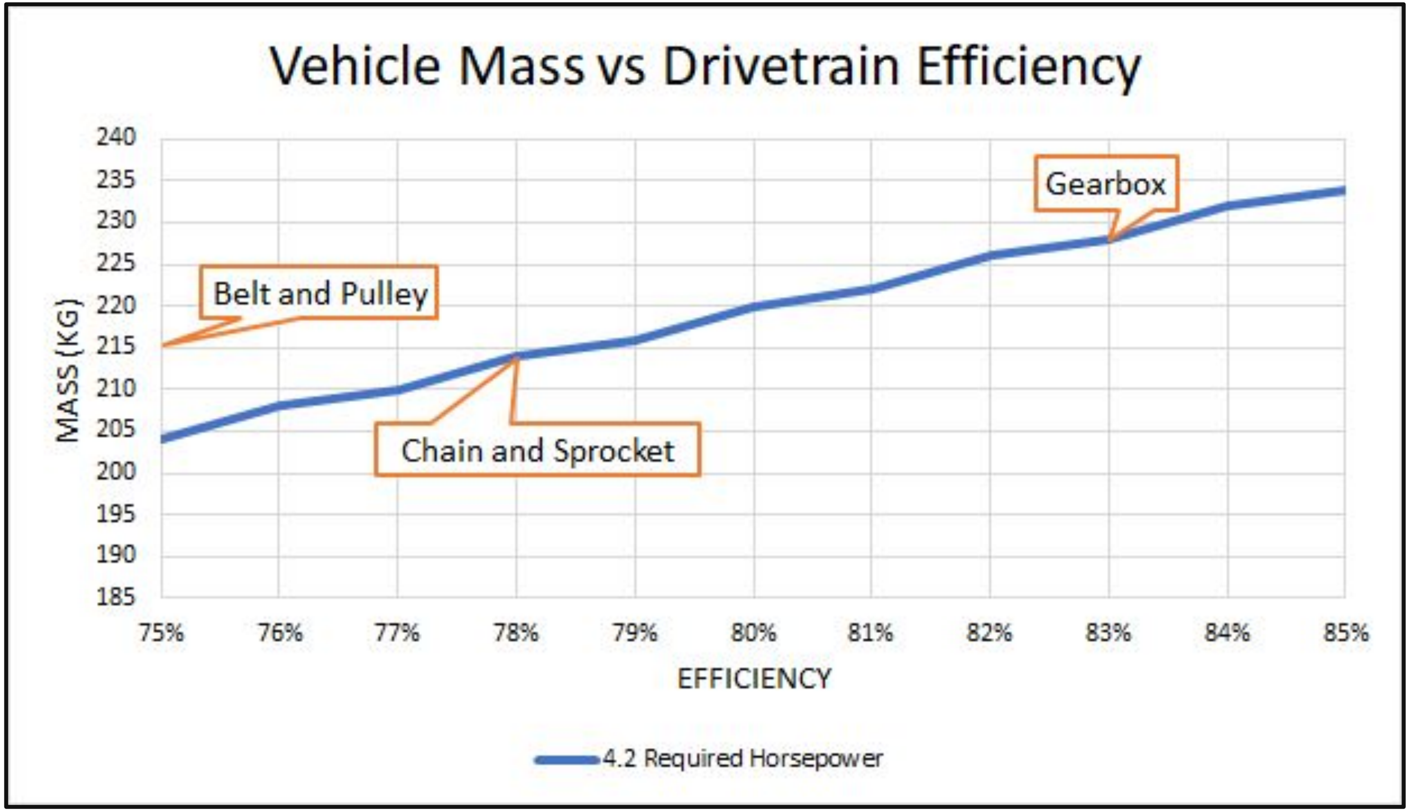
Efficiency



$$Total\ Efficiency = n_T$$

$$n_T = n_{brg}{}^{N_{brg}} * n_{cs}{}^{N_{cs}}$$

Chain Drive Efficiency = 78%

Chain Drive Weight = 5 kg

Gearbox Efficiency = 83%

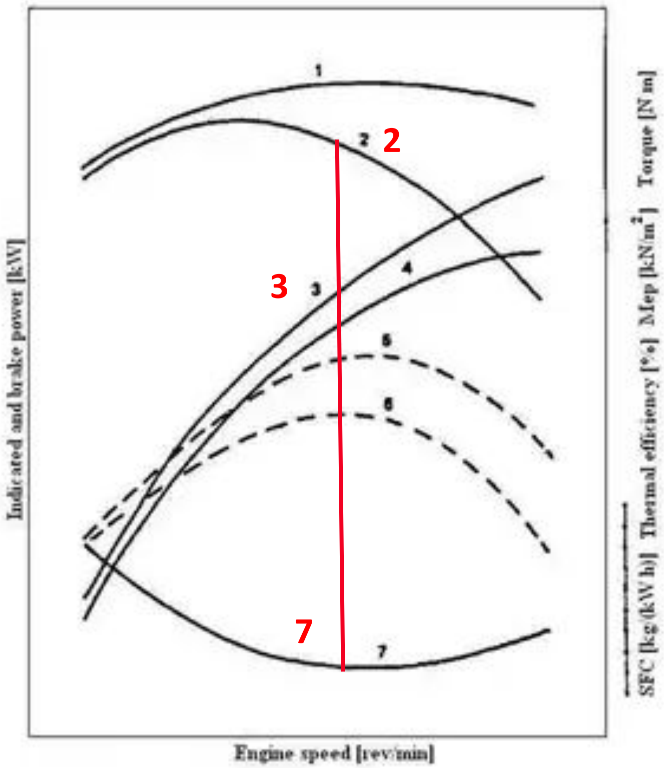
Gearbox Weight = 15 kg

Pulley Drive Efficiency = 75%

Pulley Drive Weight = 5 kg

Engine Performance Curve

- Torque Curve - 2
- Horsepower Curve - 3
- Specific Fuel Consumption Curve - 7



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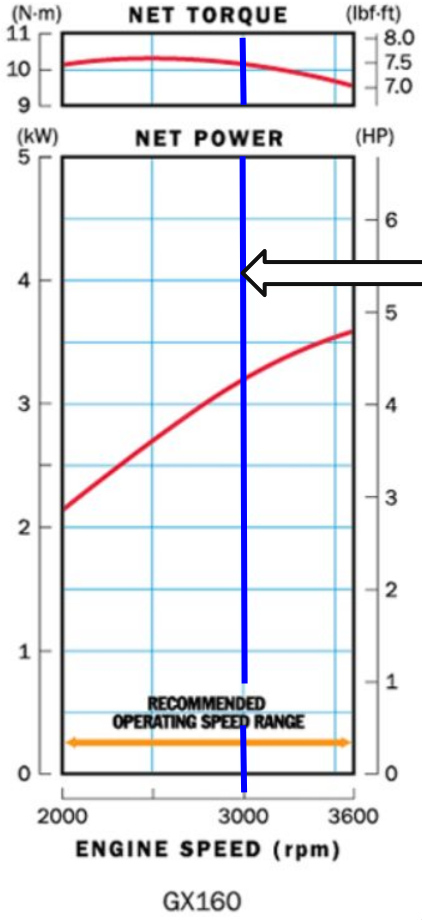
RPM Selection

Performance Curve for Honda GX160 Engine

- 3000 RPM Selected
  - 4.2 HP at 3000 RPM
  - 7.5ft-lbf at 3000 RPM

- Desired Top Speed = 26 mph
  - Gear Ratio 8.1:1



Line shows assumed lowest fuel consumption (BSFC)

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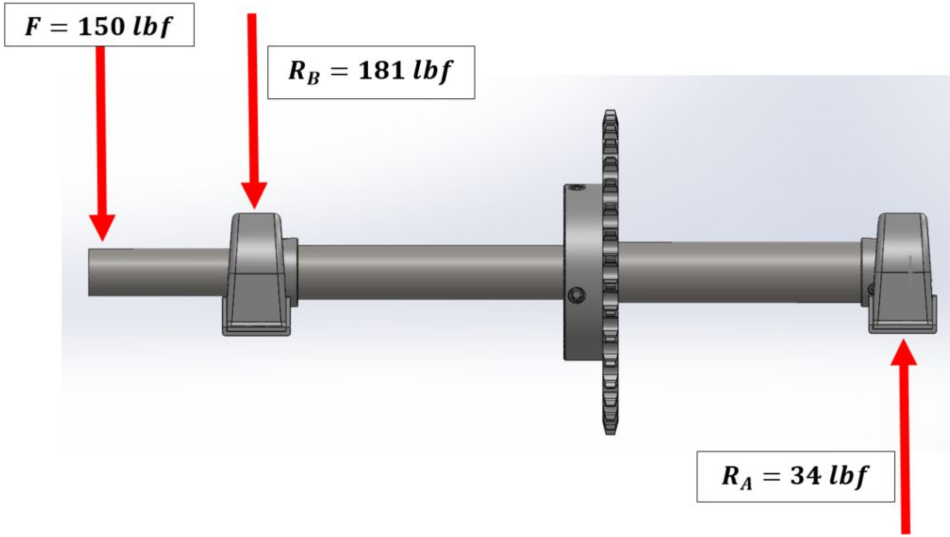
Rear Axle Design



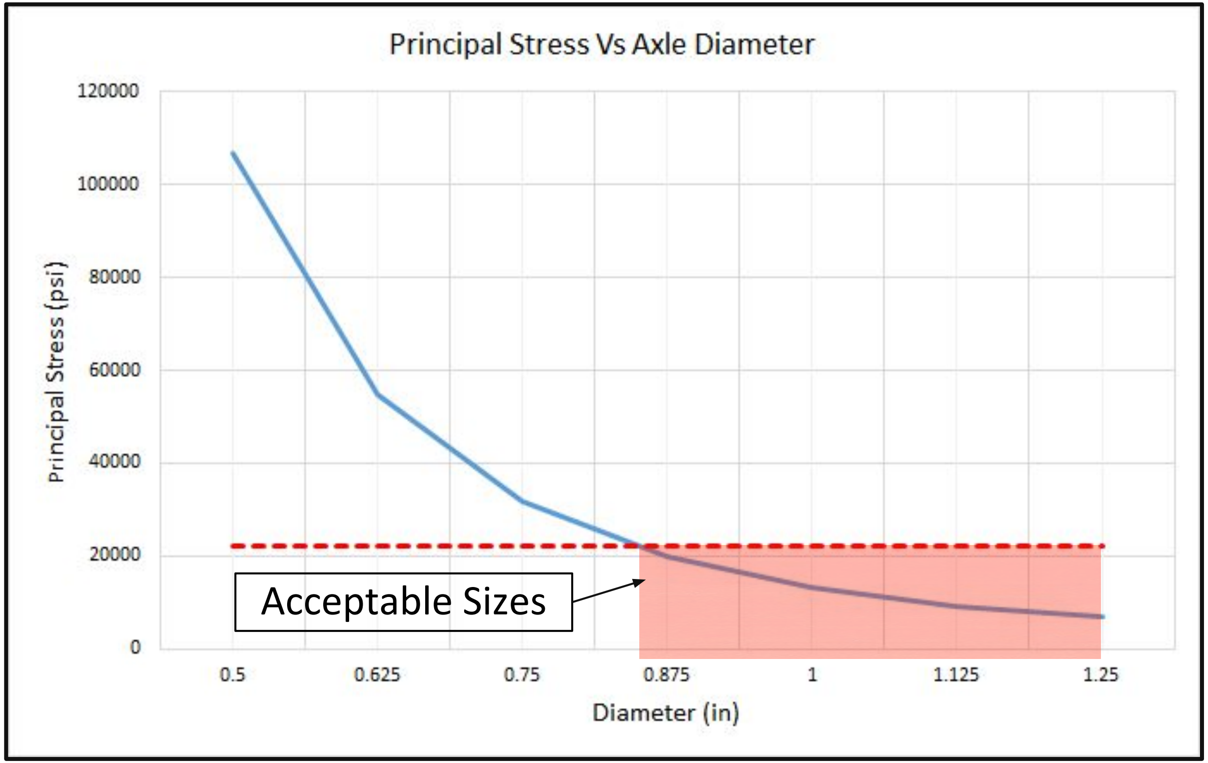
Rear Axle Design

$$\sigma_{1,2} = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$$\tau_{xy} = \frac{16T}{\pi d^3}$$

$$\sigma_x = \frac{32M}{\pi d^3}$$

Axle Diameter of 0.875 in Selected



Chain Selection

$$Force\ on\ the\ Chain = F_c = \frac{HP * 33000}{S}$$

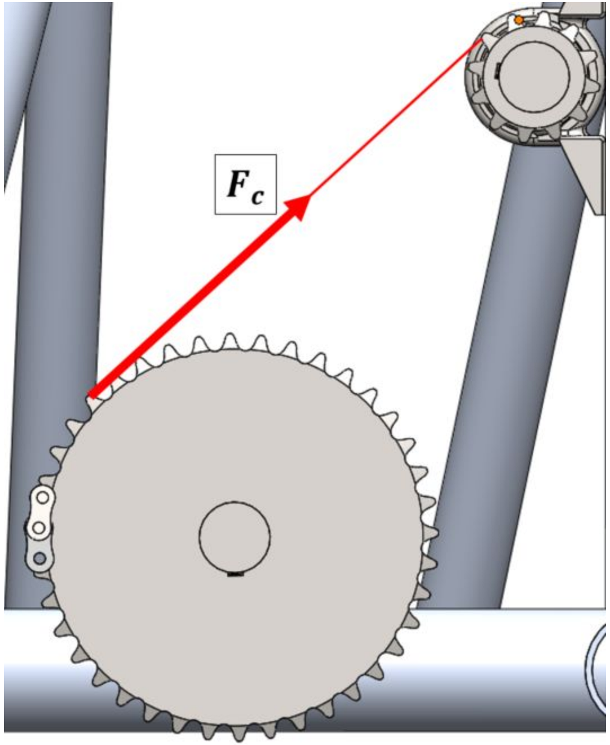
$$Speed\ of\ the\ Chain = S = \frac{T * P * N}{12}$$

$$Number\ of\ Teeth\ on\ Sprocket = T$$

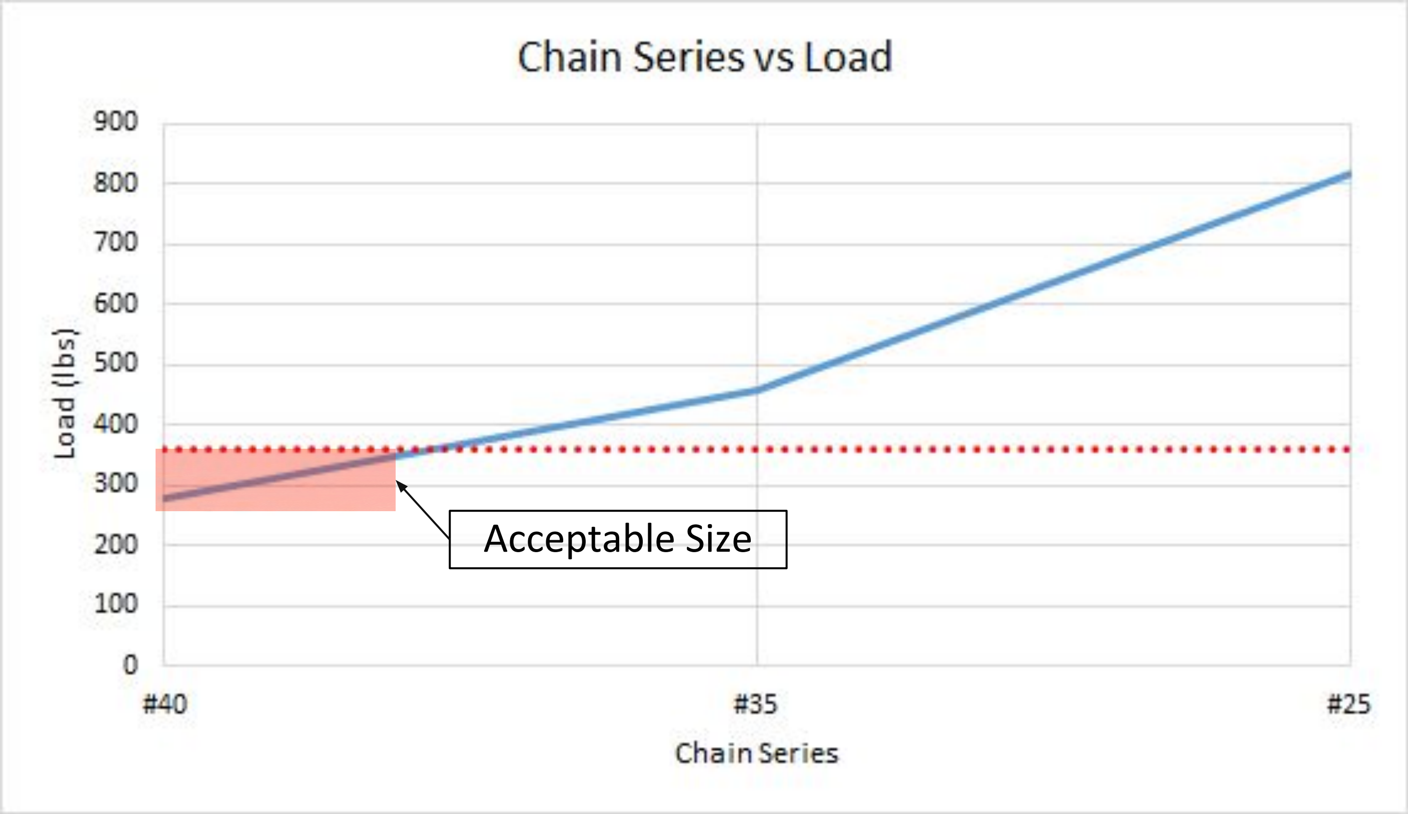
$$Pitch\ of\ the\ Chain = P$$

$$Speed\ of\ Sprocket = N$$

$$\boldsymbol{Maximum\ Force\ on\ Chain = F_c = 277\ lbf}$$



Chain Selection



Chain Working load Capacity = 360 lbf

Selected #40 Chain

Axle Material Selection

4130 Annealed Chromoly Steel

- Yield Strength = 66.5 ksi
- Machinability = 72%
- E = 29.7 ksi

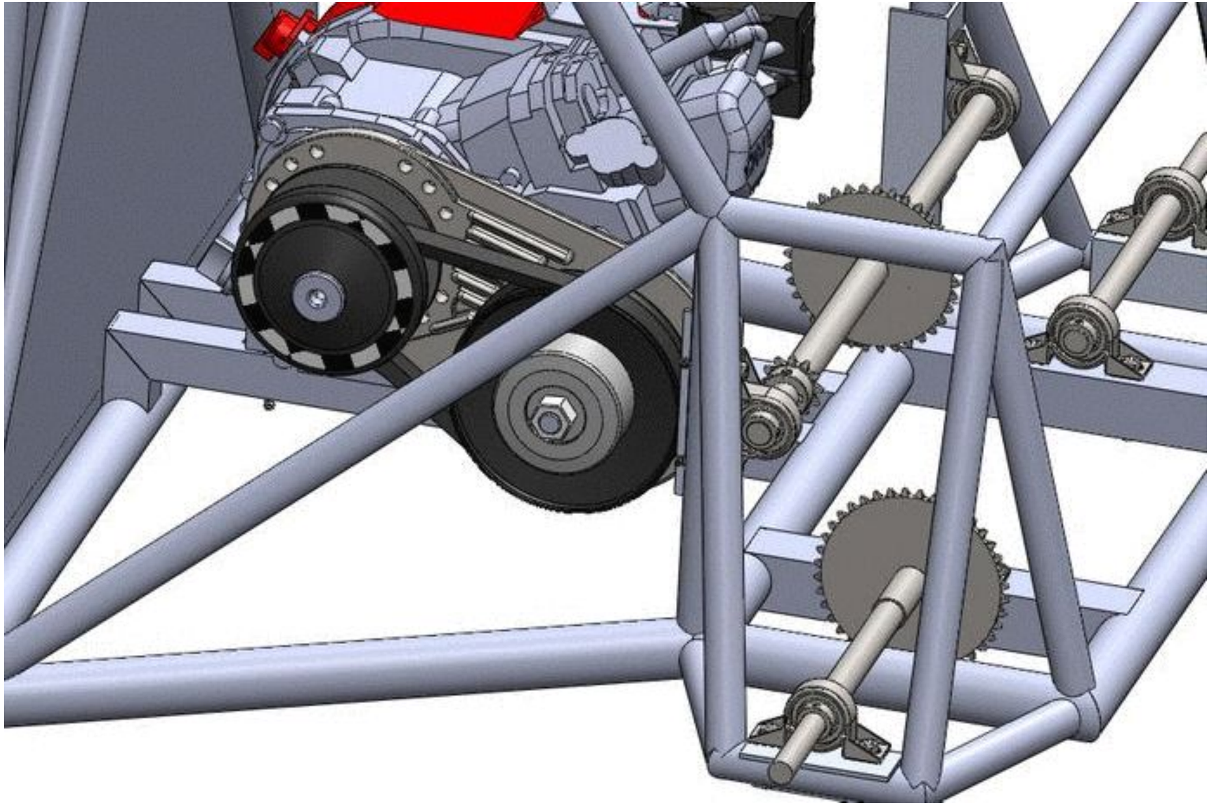
1020 Carbon Steel

- Yield Strength = 42.7 ksi
- Machinability = 72%
- E = 29 ksi

2024 Aluminum

- Yield Strength = 47 ksi
- Machinability = 76%
- E = 10.6 ksi

Tensioning



Manufacturing

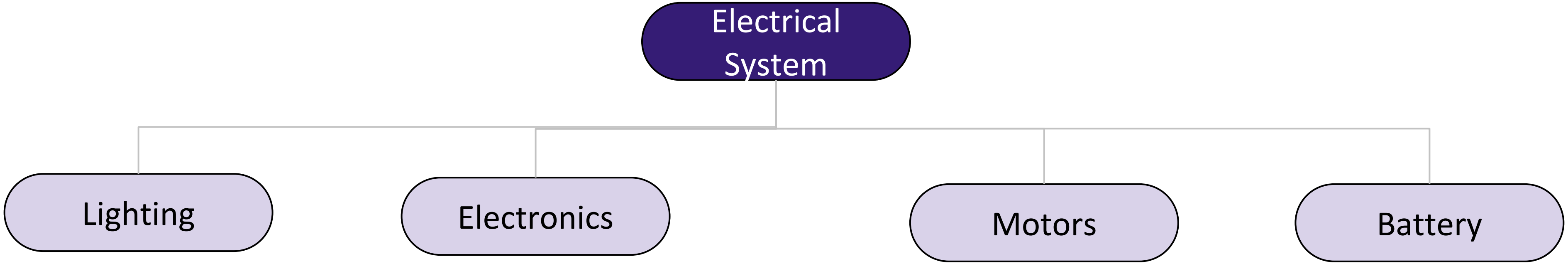
- Manufacturing
  - Manufacture Rear Axle
  - Manufacture Intermediate Axle
  - Instal Torque Converter to Engine
  - Install Axles to Chassis
- Cost $75 total

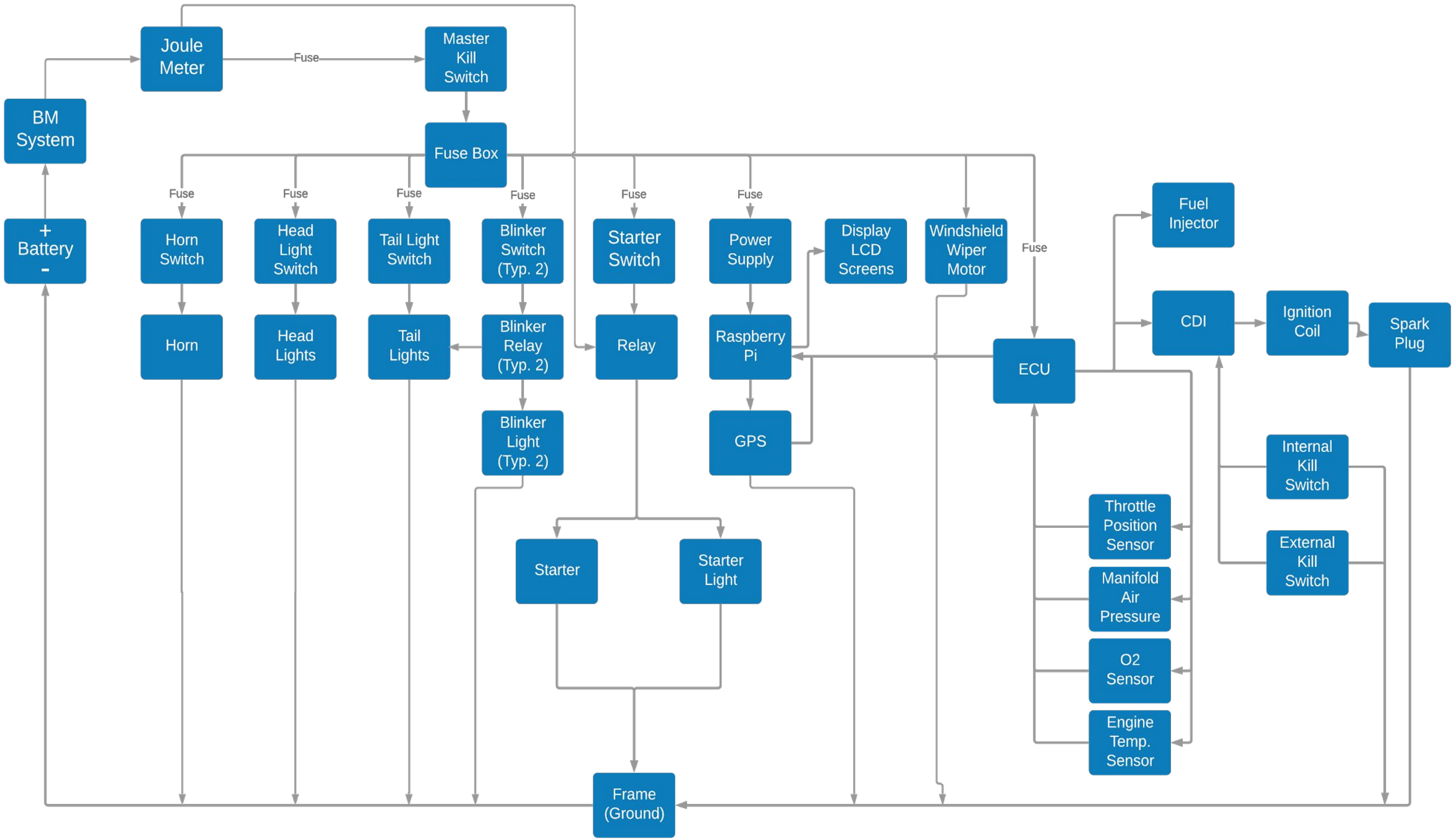
- February
  - Week 1: Rear and Intermediate Axle
  - Week 2: Torque Converter and Axle Instal

Testing

- Testing
  - Top speed tests to confirm the correct gear ratio
  - Acceleration and Coastdown testing to determine performance model coefficients
- March
  - Week 1: Top Speed Tests
  - Week 2: Acceleration and Coastdown Testing

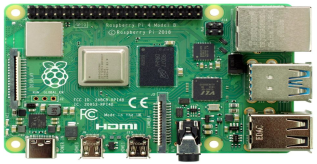
Electrical System



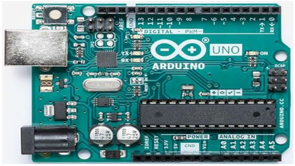

Joule Meter
Fuse
Master Kill Switch
BM System
Fuse Box
+ Battery -
Fuse
Fuse
Fuse
Fuse
Fuse
Fuse
Horn Switch
Head Light Switch
Tail Light Switch
Blinker Switch (Typ. 2)
Starter Switch
Power Supply
Display LCD Screens
Windshield Wiper Motor
Fuse
Fuel Injector
Horn
Head Lights
Tail Lights
Blinker Relay (Typ. 2)
Relay
Raspberry Pi
ECU
CDI
Ignition Coil
Spark Plug
Blinker Light (Typ. 2)
GPS
Internal Kill Switch
External Kill Switch
Throttle Position Sensor
Manifold Air Pressure
O2 Sensor
Engine Temp. Sensor
Starter
Starter Light
Frame (Ground)

Electronics

Control Unit

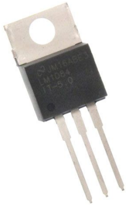


Raspberry Pi [22]



Arduino Uno [23]

Power Supply



Linear Voltage Regulator [24]

Switching Voltage Regulator [25]

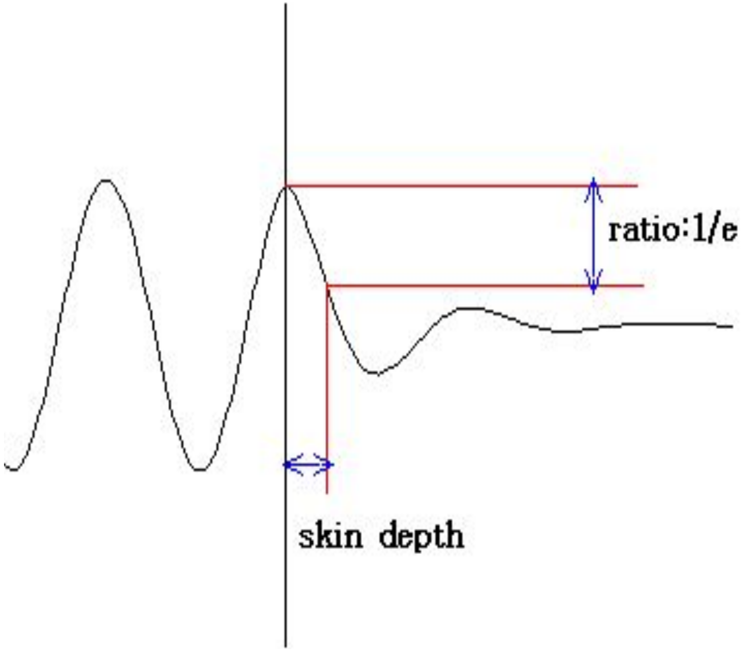
ECU

ECU-4T2C [26]

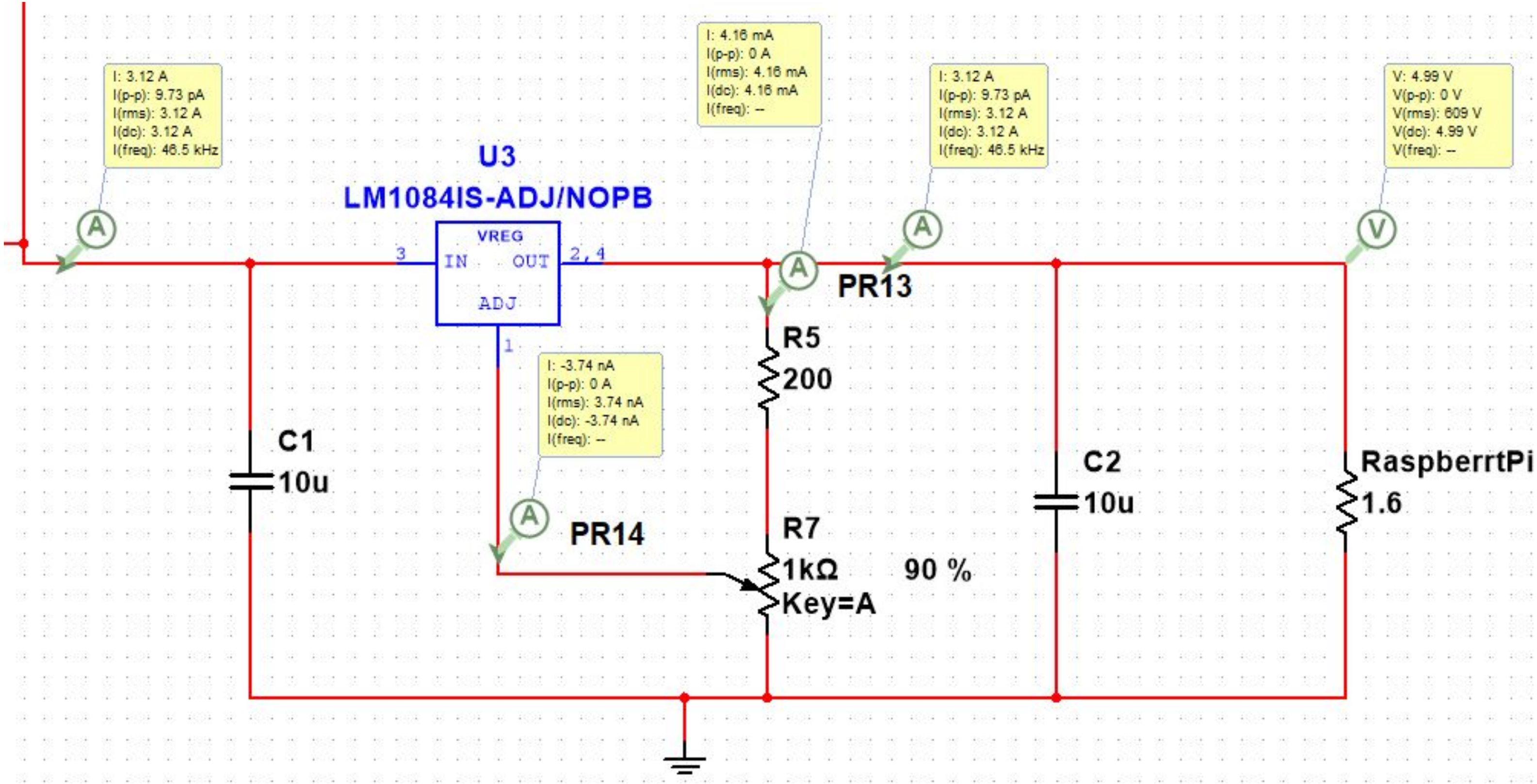
ECU-2T1C [27]

RF Shielding

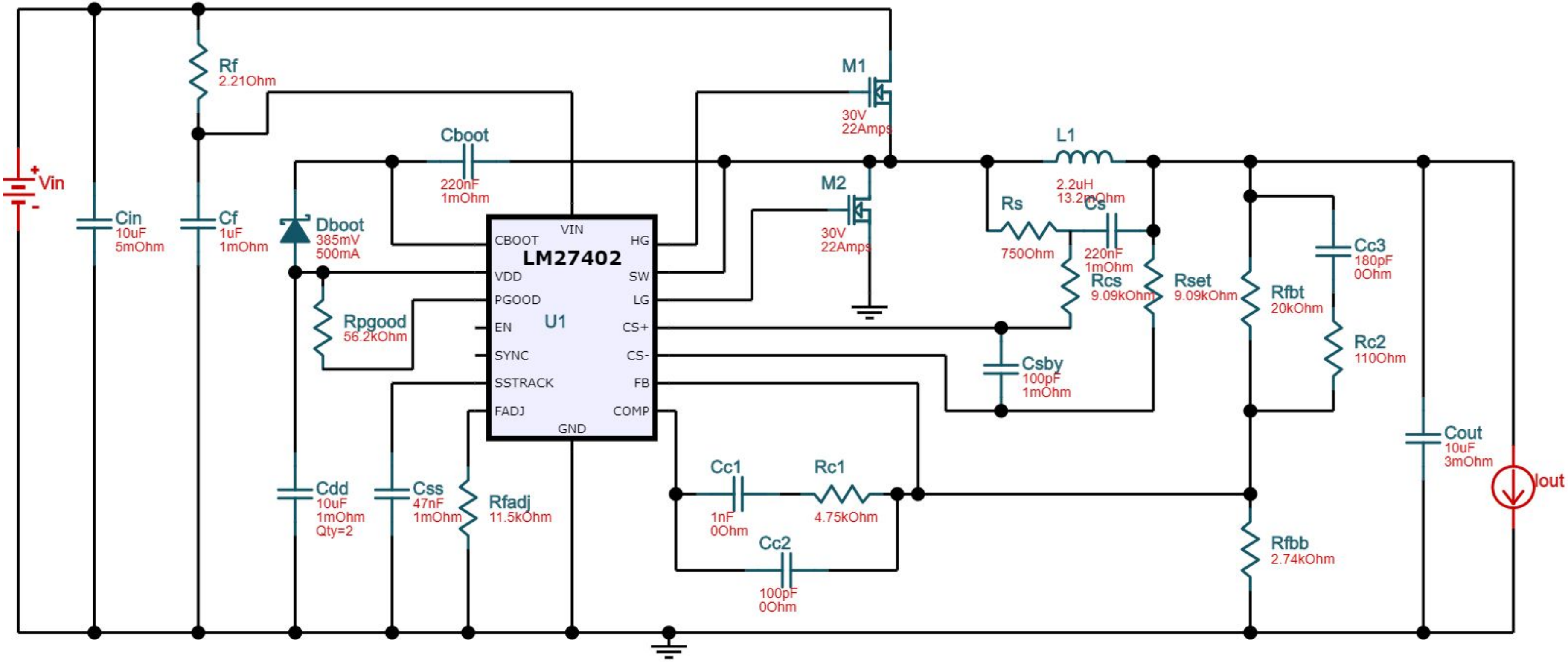
Aluminum Foil Shielding
$Resistivity, \rho = 2.65 * 10^{-8}$
$Permeability\ of\ Aluminum, \mu = 1$
$Permeability\ of\ Free\ Space, \mu_0 = 4\pi * 10^{-7}$
$Lowest\ Freq = 1.176\ GHz$
$Skin\ Depth = \sqrt{\frac{\rho}{(\pi * f * \mu * \mu_0)}} = 2.39\mu m$
$Average\ Aluminum\ Foil\ Thickness \rightarrow 0.16mm$
$Number\ of\ Sheets = \frac{2.39\mu m * 5}{0.16mm} \rightarrow 2$



Electronics



Electronics



Electronics

- Manufacturing
  - PCB
  - 3D Print Housings
  - ECU Wiring
- Cost $40 total

- December
  - Week 3: PCB
  - Week 3: Testing
  - Week 3:3D Printing
- January
  - Week 4: ECU Wiring
- February
  - Week 1: ECU Tuning

Electronics

- Measure Voltage/Current Outputs
- Continuity of Switches and Fuses
- Thermal Testing with thermal gun
- Confirm Fitness Tests
- ECU Tuning
  - Adjusting ignition timing
  - Adjusting fuel injection rate

- January
  - Week 1: Measure voltage and current outputs
  - Week 1: Measure continuity
  - Week 1: Thermal testing
  - Week 1: Physical sizing test
  - Week 2: ECU tuning

Concepts

Lithium Ion

[28]

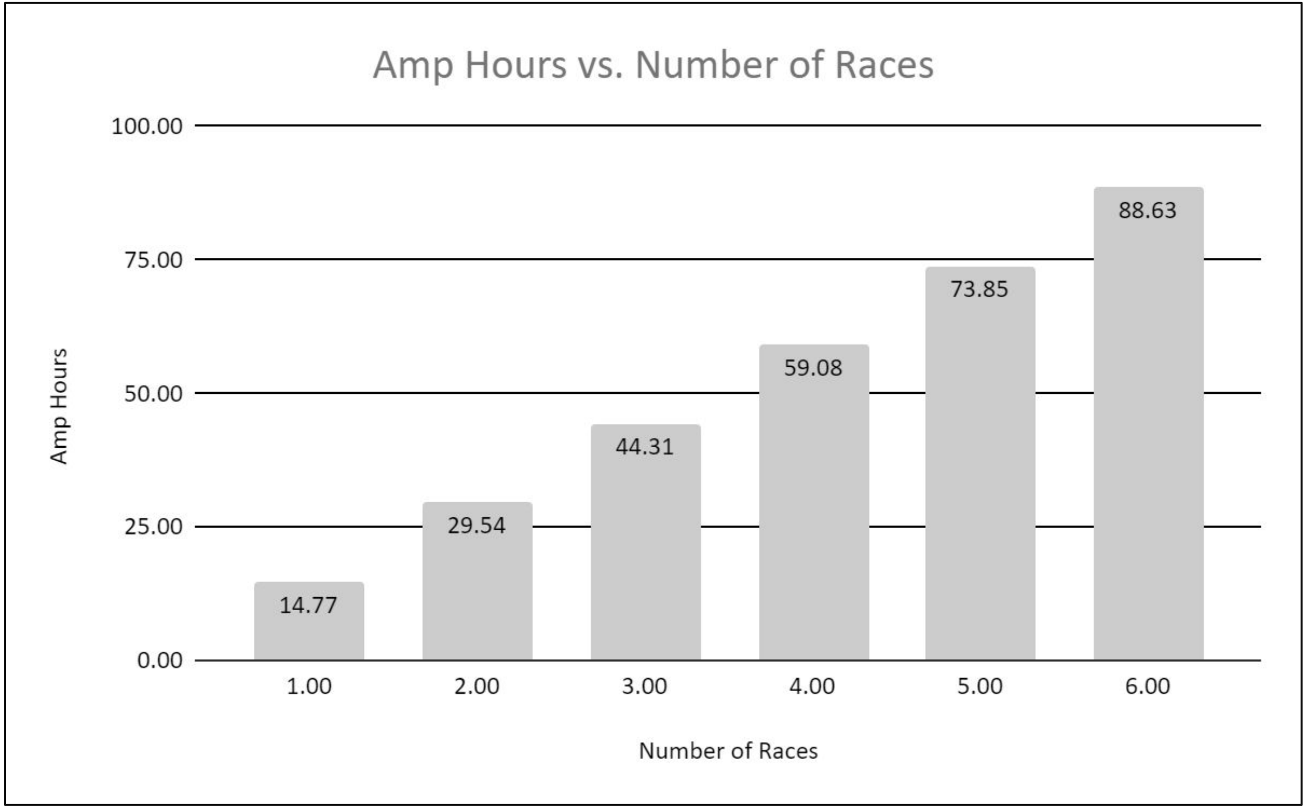
Lead Acid

[29]

Battery

Battery Sizing: Max Load					
	Starter	**Rpi**	**Lighting**	**WindShield**	**Losses**
Watts	1500.00	15.00	72.00	24.00	12.00
Watt Hours	81.25	7.50	60.00	12.00	6.00
Amp Hours	6.77	0.63	5.00	1.00	0.50
Amp Hour Per Race	**13.90**				
Battery Amp Hour	**55.00**				

Battery

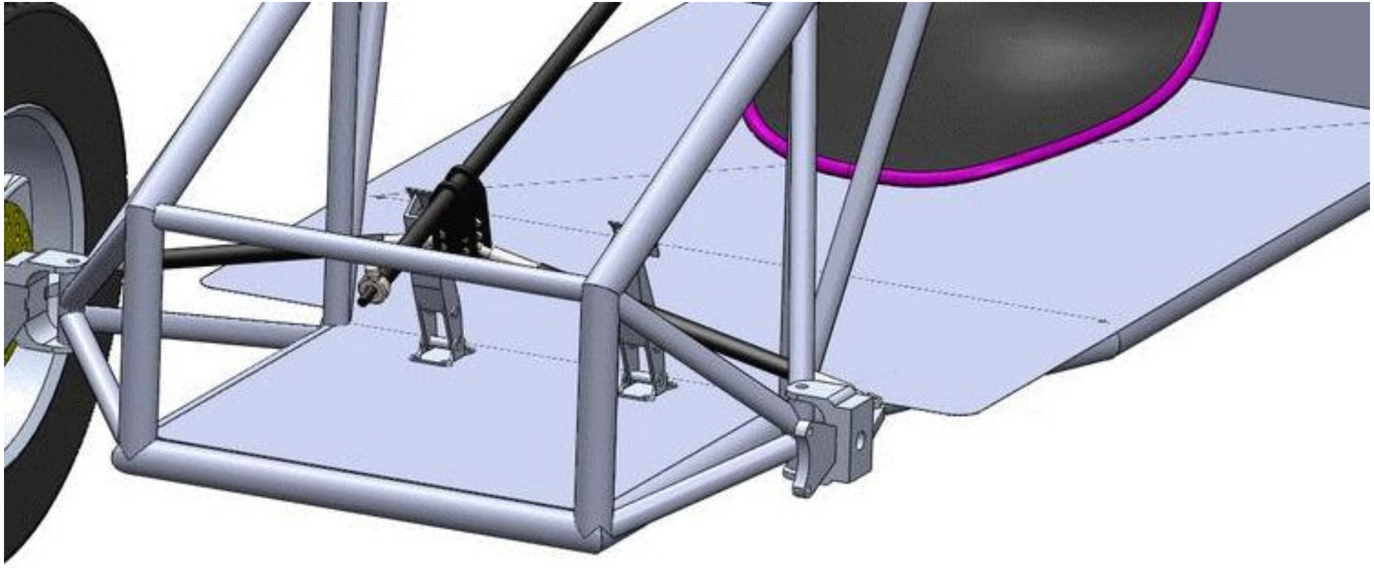

Amp Hours vs. Number of Races
Amp Hours
100.00
75.00
50.00
25.00
0.00
14.77
29.54
44.31
59.08
73.85
88.63
1.00
2.00
3.00
4.00
5.00
6.00
Number of Races

Battery

- Manufacturing
  - Installation
- Testing
  - Verify Proper Voltage and Current Outputs
  - Verify Battery Management Functionality
- Cost $650 total

- March
  - Week 1: Install
  - Week 1: Testing

Braking



Concepts

Wilwood GP200

[30]

Wilwood PS1

[31]

Concepts

Wilwood Master Cylinder

[32]

Duralast New Master Cylinder

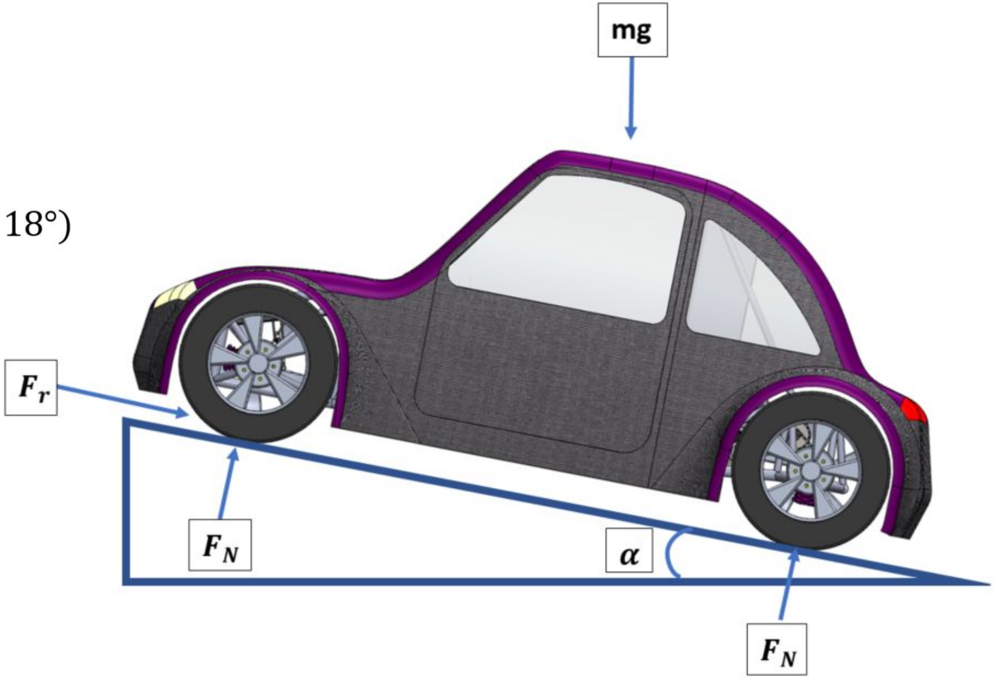
[33]

20% Incline Test

$$F_{Brake} = -mg\cos\theta\,\mu_{tire} + mg\sin\theta$$

$$F_{Brake} = (-225 * 9.81\cos 18° * 0.06) + (225 * 9.81\sin 18°)$$

$$\boldsymbol{Required\ Brake\ Force = F_{Brake} = 556\ N}$$



$$Pressure\ Needed = P = \frac{F}{A} = \frac{F_{Brake}}{Area\ of\ Brake\ Pad} = 216\ kpa$$

$$Pressure\ Generated = P = \frac{F}{A} = \frac{Leg\ Force}{Area\ of\ Master\ Cylinder\ Piston} = 879\ kpa$$

Maximum Force Required

$$Mass\ of\ the\ Vehicle = m = 225\ kg$$

$$Maximum\ Velocity = V = 11.6\frac{m}{s} = 26\ mph$$

$$Stopping\ Distance = X = 11\ m$$

$$F_B = \frac{\frac{1}{2}mV^2}{X}$$

[34]

$$Total\ Braking\ Force = F_B = 1376\ N$$

$$Per\ Brake = F_B = 344\ N$$

$$Pressure\ Needed\ to\ Stop\ Car = P = \frac{F}{A} = \frac{F_{Brake}}{4 * Area\ of\ Brake\ Pad} = 292\ kpa$$

Weight Reduction

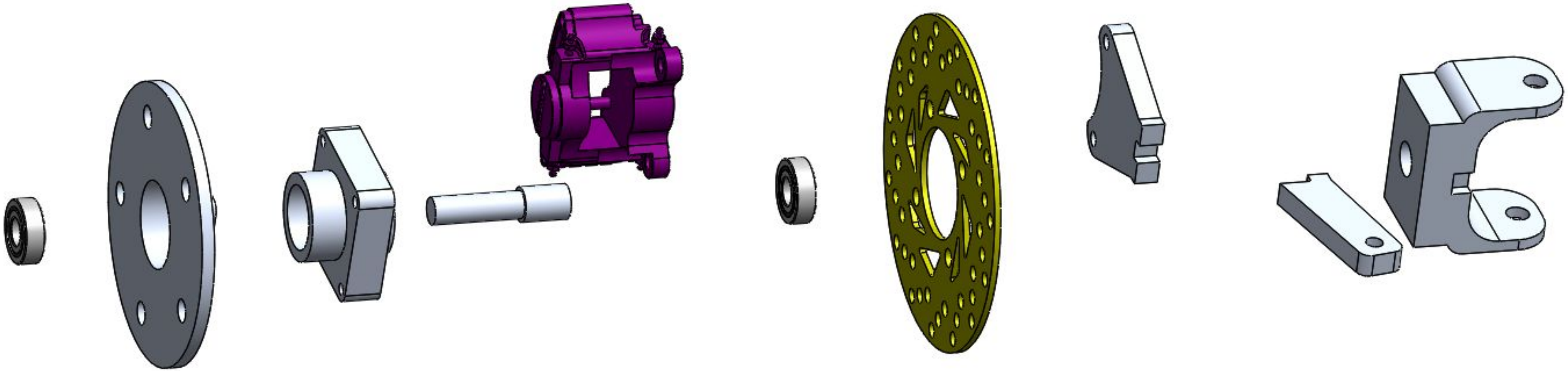
- Original Selection:
  - Mustang II Disc Brake Rotor
  - 5 on 4-¾ Inch
  - $131.96 ($32.99 per hub)
- **44 lbf** (11 lbf per hub)

- Team #44 Design:
  - **89%** Weight Reduction
- Final Weight **4.8 lbf** (1.2 lbf per hub)

[35]

Mustang II Disc Brake Rotor

Front Hub



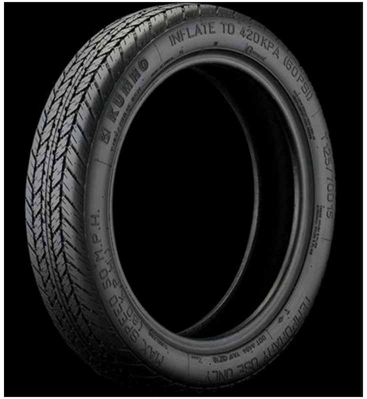
Weight Reduction

Wheel and Tire Selection

- 15”-17” wheel diameter
- 3.15” minimum tire width
- 1.6mm tire tread
- Tire profile must be flat

15” 5kg

[36]



T125/80 D15 4kg each

[37]

- February
  - Week 2: Reduce weight with End-mill by 1 kg per wheel
  - Week 3: Attach rim and tire to assembly

Testing

- Testing
  - 20% Incline Simulation
  - Stopping Distance Confirmation

- February
  - Week 4: 20% Incline Simulation
- March
  - Week 1: Stopping Distance Confirmation

Body

Body

Coupé style

[38]

SUV/Bus

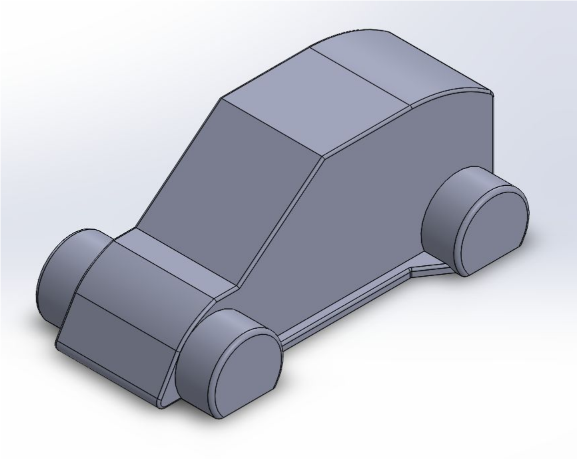
[40]

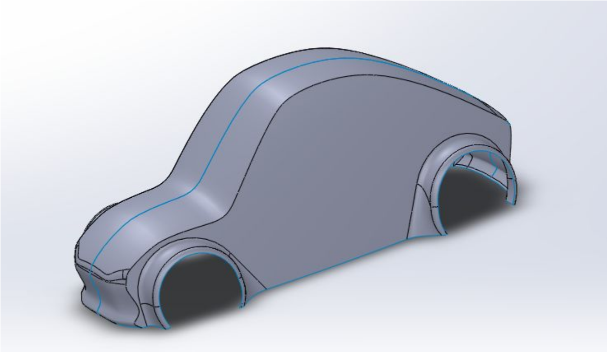
Tear drop

[39]

Hatchback

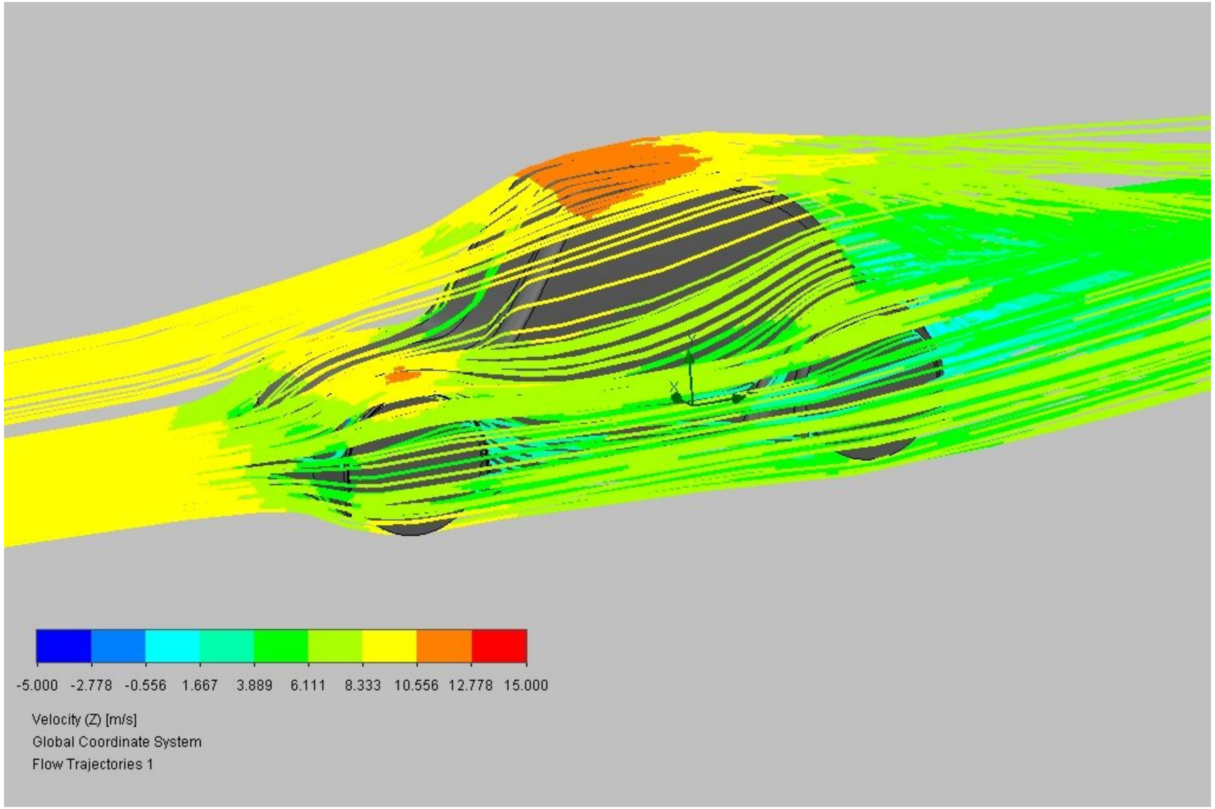
[41]





Final body design

Aerodynamics



$$F_D = C_D A \frac{\rho V^2}{2}$$

$$A = frontal\ area = 1.175\ m^2$$

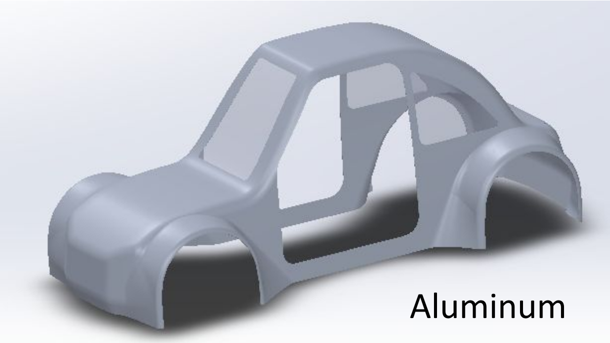
$$\rho = fluid\ density = 1.199\ \frac{kg}{m^3}$$

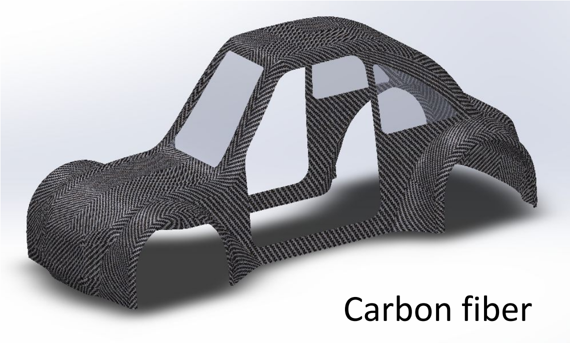
$$V_{avg} = average\ velocity = 10.730\ \frac{m}{s}$$

$$F_D = drag\ force = 41.02\ N$$

$$C_D = drag\ coefficient = 0.5$$

Materials Selection

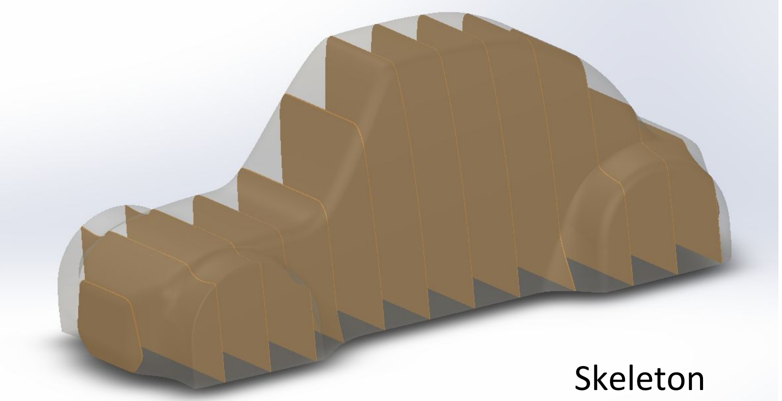




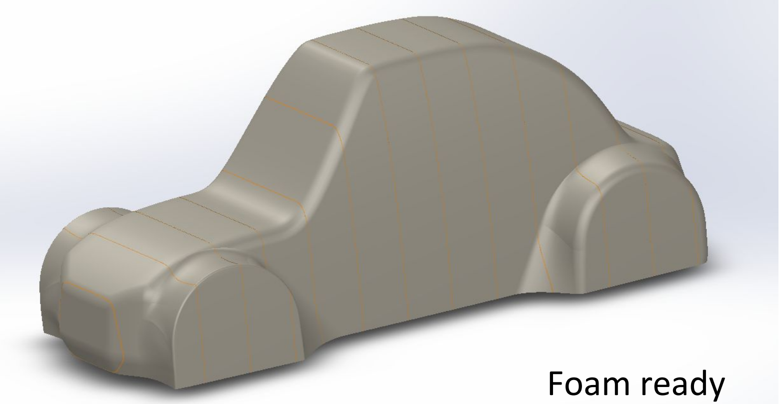
Materials	Thickness (mm)	Weight (kg)	Cost
Carbon fiber F-586 (x2)	0.5	2.6	$205
105 Epoxy + Hardener	N/A	2.6	$150
Total	~1	5.2	$355

Manufacturing Plan

1. Order Materials - December
2. Foam shaping - 2nd week of January (1-3 days)
   a. Plywood template
   b. Foam fills
3. Fiberglass female mould -3rd week of January
   a. Fiberglass fabric
   b. chopped strand mat
   c. Epoxy and hardener
4. Carbon fiber body - 4th week of January (7-10 days)
   a. Carbon fiber
   b. Epoxy and hardener
   c. Vacuum Bagging



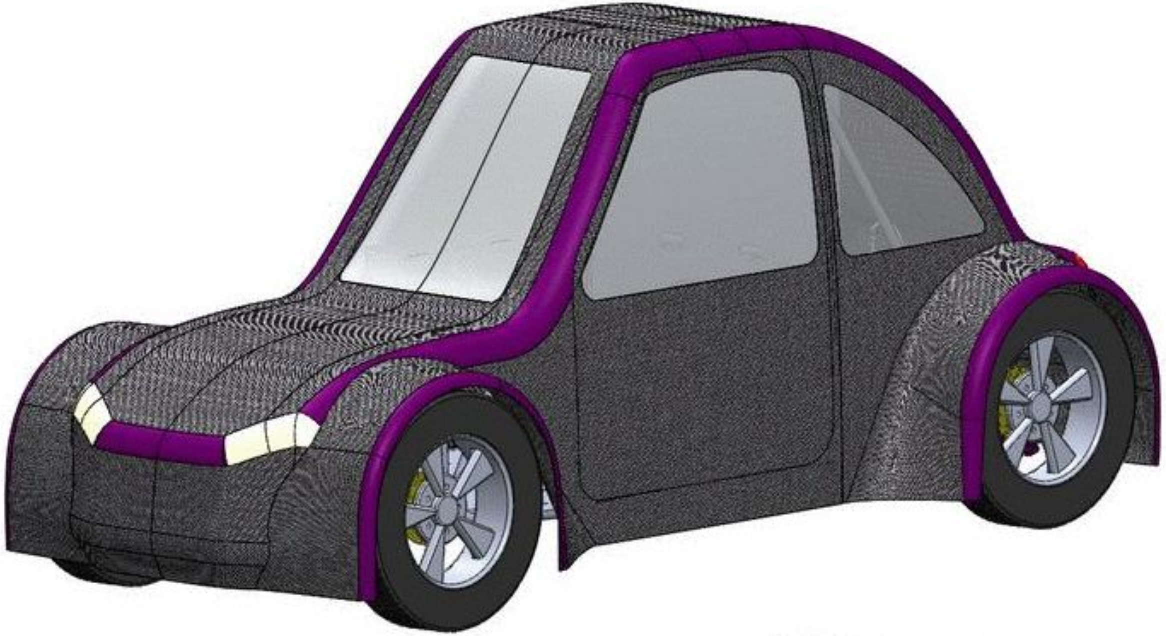
Skeleton

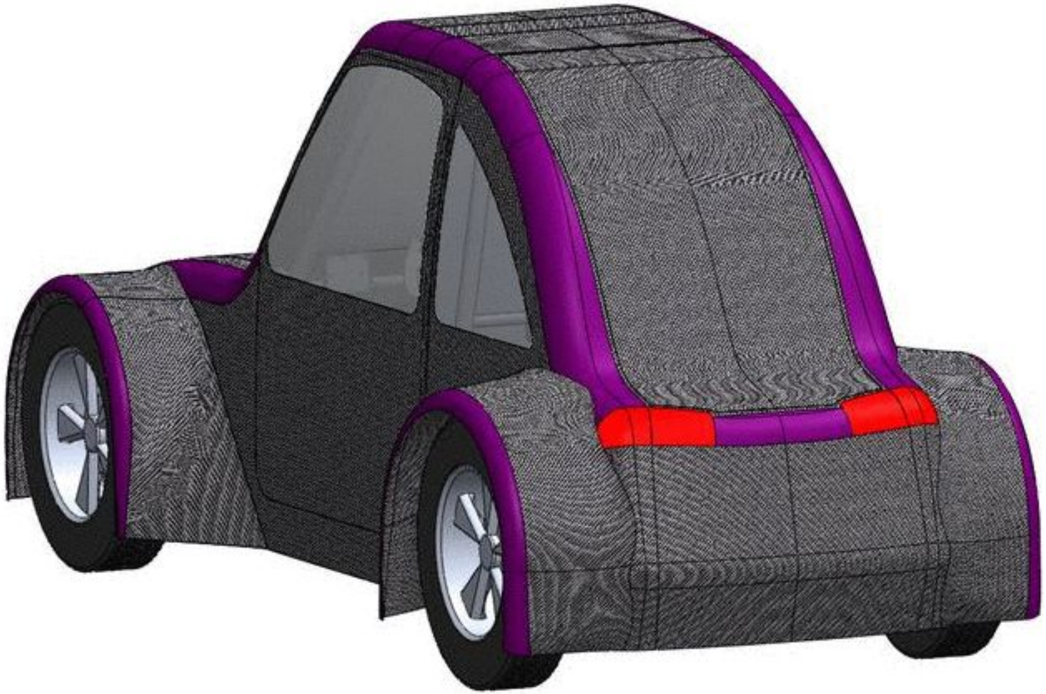


Foam ready

Suicide Doors

- Allow driver to exit vehicle quickly





Removable Rear Hatch

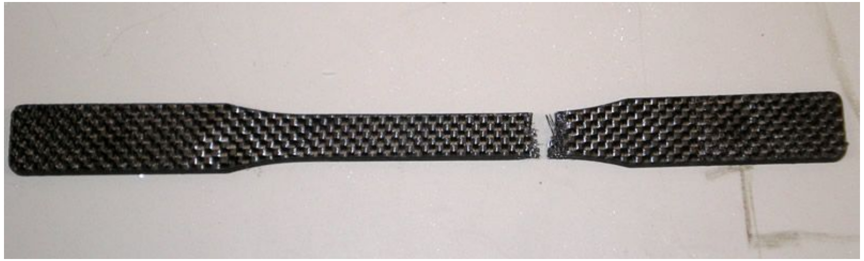
Access to energy compartment for maintenance

Trunk Door

Quick access for refueling

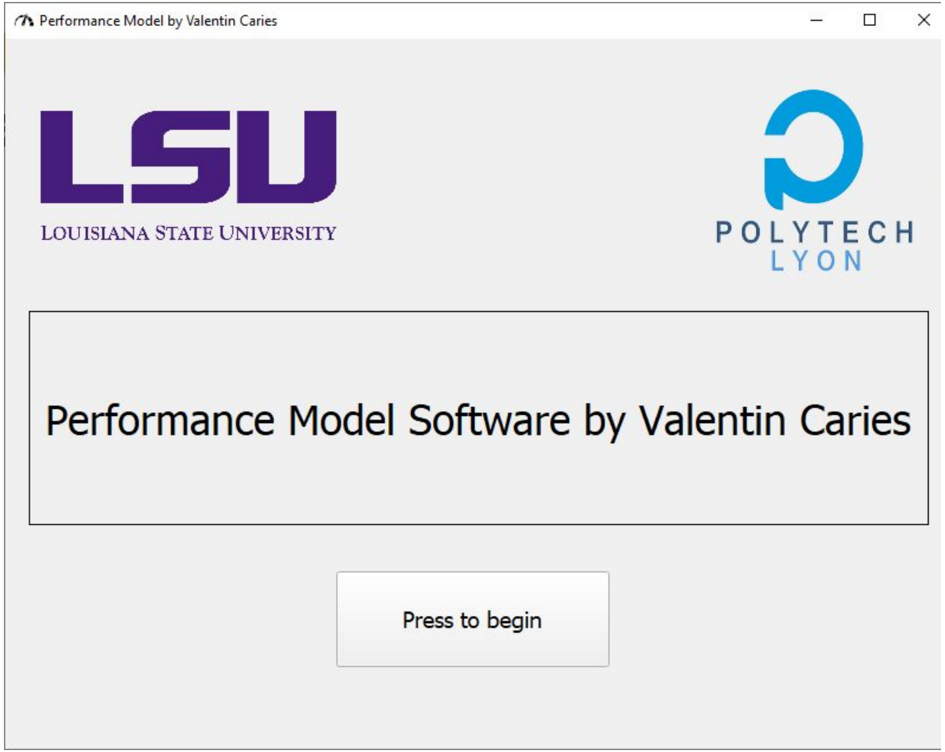
Testing Plan

- Bending test to figure out the deflection under driving condition
- Tensile test to get the mechanical properties of the final body material
- January - Week 1

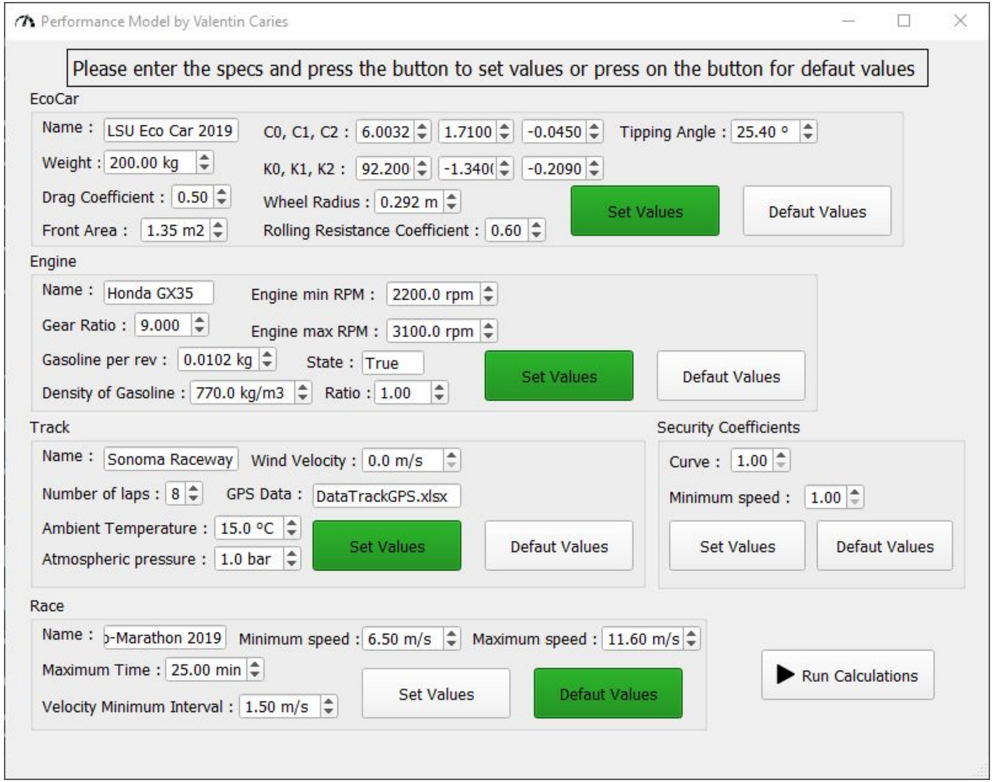


[42]

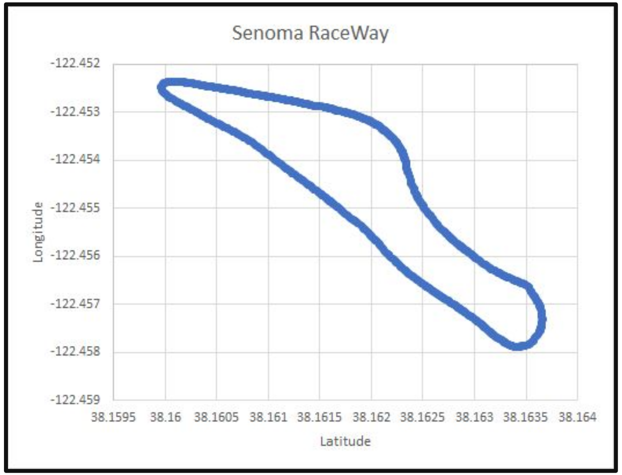
Performance Model

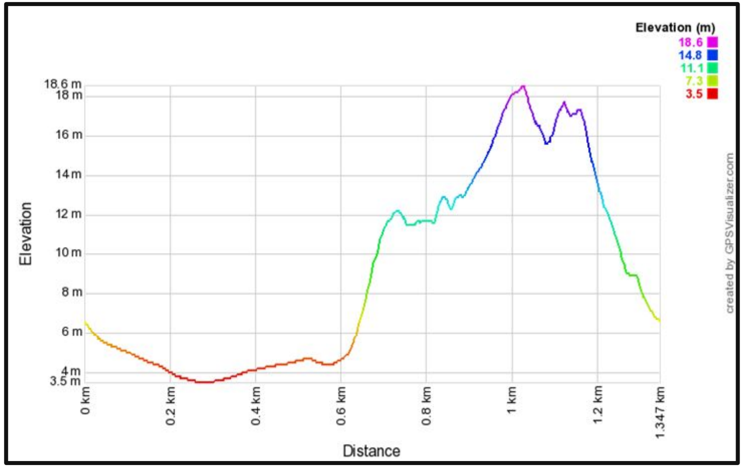


Input Parameters



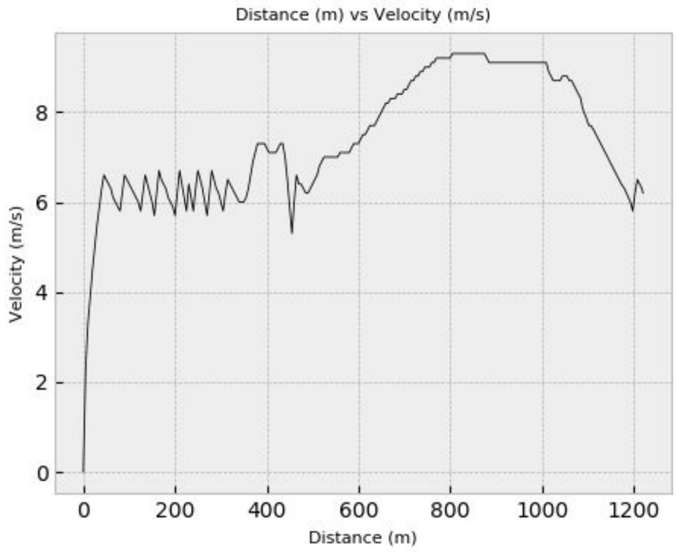
Track Information

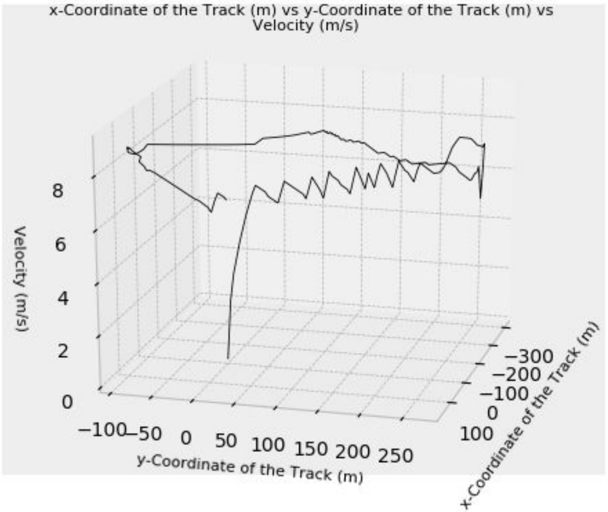




- Model uses GPS data that can be gathered from any track, allowing us to test on any track.

Predicted Performance





- Model predicts 806.23 MPG using this strategy.

Safety

- Max Tipping Speed for 6 m turn:
  - 6.86 m/s (15.3 mph)
  - Low Center of Gravity
- Safety Harness: 6 Points Connected to Frame
  - 200N
- Zero deformation roll bar
- Personal Protective Gear
- Kill switch

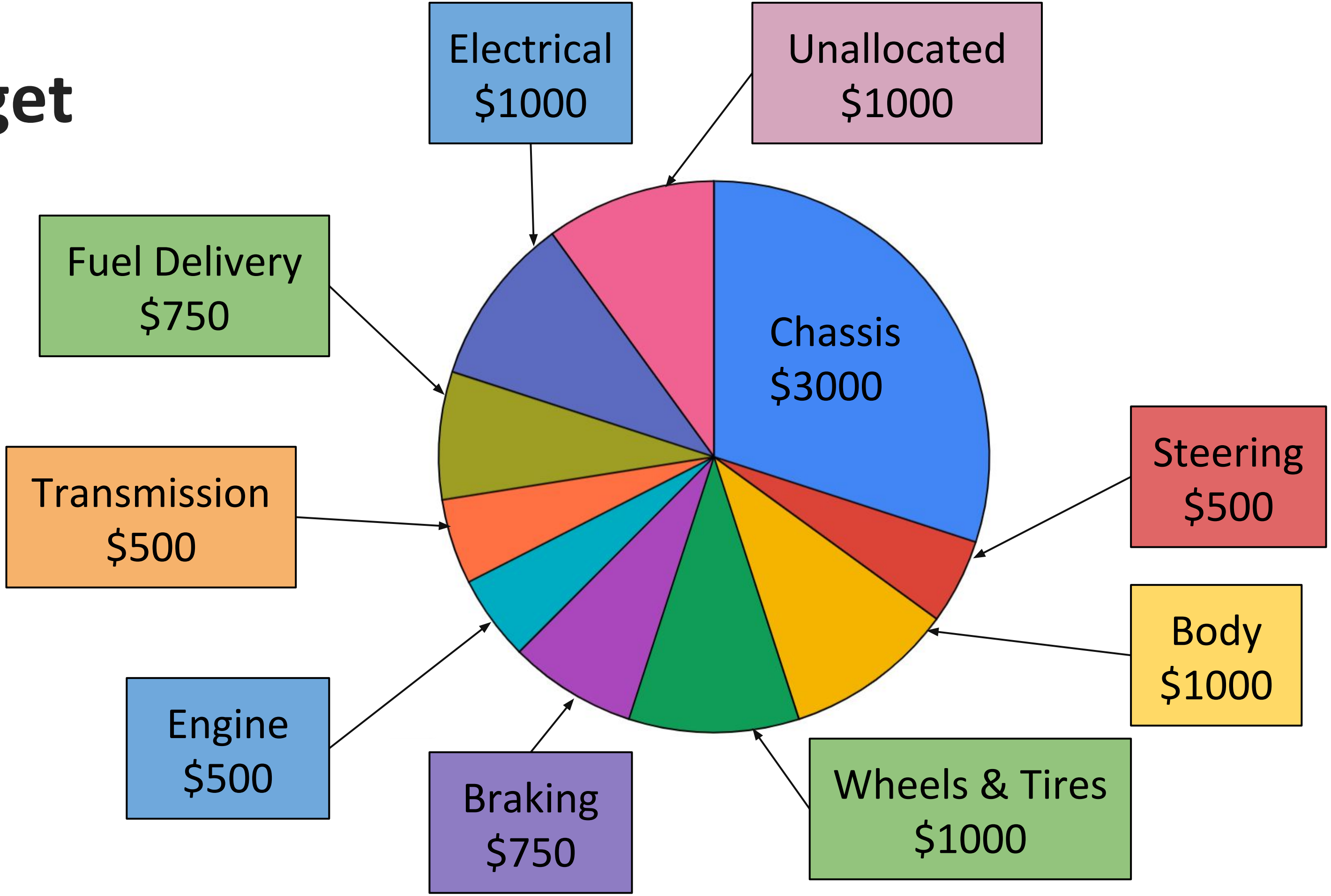
Driver Gear:

- Flame retardant suit, gloves, and shoes
- Helmet

[43]

- SFI 16.1 Profi 2x2
- Cost $260 donated by Schroth Racing

Budget



Electrical $1000
Unallocated $1000
Fuel Delivery $750
Chassis $3000
Steering $500
Transmission $500
Body $1000
Engine $500
Braking $750
Wheels & Tires $1000

Timeline - Fall

Research & Ideation

- Existing Technologies
- Popular Strategies
- Efficiency Factors
- Generate Concepts

September

Design

- Determine Subsystems
- Begin Vehicle Design
- Optimize for Efficiency

October

Design $ Assembly Synthesis

- Finalize Design
- Verify Subsystem Synthesis
- Draft Manufacturing Plan

November

Order Parts

- Chassis
- Body Mold
- Engine
- Electronics

December

Timeline - Spring

Order Parts
- Chassis
- Body Mold
- Engine
- Electronics

December

Manufacturing
- Chassis Welding
- Body Shaping
- Engine Conversion
- CNC Custom Parts
- Order Miscellaneous Parts

January

Manufacturing & Testing
- NDT Testing Chassis
- Drivetrain Installation
- Steering Installation

February

Testing & Tuning
- Verify Tech Inspection
- Tune Engine
- Reduce Weight

March

Competition Analysis
- Analyze Flaws
- Determine Potential Improvements
- Create Packet for Next Year’s Team

April

Timeline - Shell Registration

Sep 12

Phase 1: Opens
- Vehicle Specifications
- Team sign-up
- Vehicle Photo

Oct 30

Phase 1: Deadline

Nov 7

Phase 2: Opens
- Technical Information
- Power Flow Diagram
- Fuel Flow Diagram

Dec 17

Phase 2: Deadline
Phase 3a: Opens
- Logistics
- Team Member Information

Feb 28

Phase 3a: Deadline
Phase 3b: Opens
- Optional
- Off-Track Award Registration

Apr 1

Phase 3b: Deadline

Competition
- April 1-4
- Sonoma Raceway

Final Weight: ~ 143 kg (315 lbs)

References

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[28]https://www.amazon.com/Powersonic-PS-12550-Battery-Nut-Bolt-Terminal/dp/B004HN5BGE/ref=sr_1_24?keywords=lead+acid+battery+12v+55ah&qid=1575213759&sr=8-24
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[41] https://innovate.dreamcatcher.asia/shell.html
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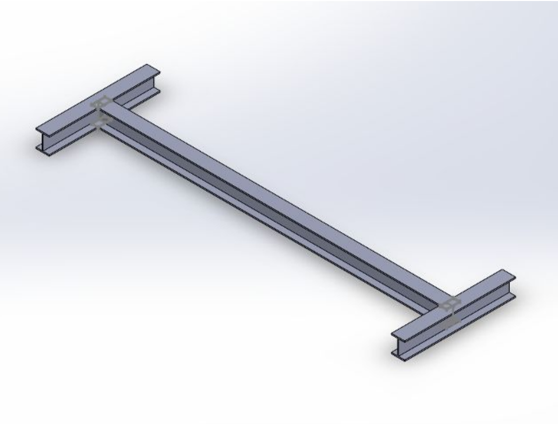
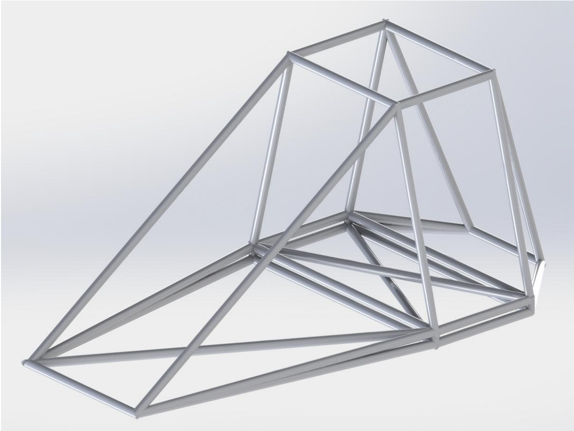
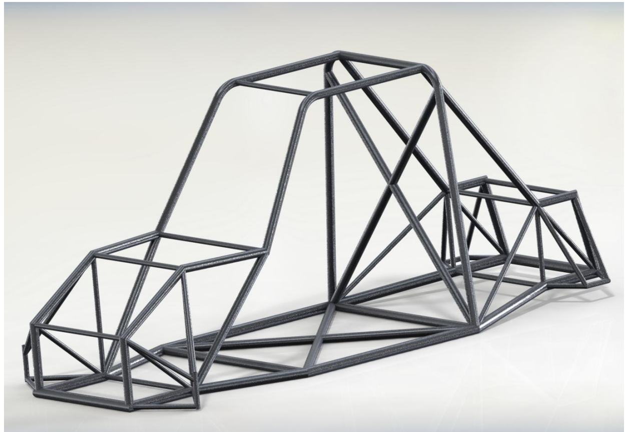
Other Designs Generated







Concept Selection

Metric	Weight	Ladder	Monocoque	Space Frame	I Beam
Cost	**0.20**	0.27	0.08	0.27	0.38
Weight	**0.33**	0.18	0.39	0.23	0.19
Manufacturable	**0.25**	0.38	0.11	0.23	0.28
Safety	**0.22**	0.18	0.33	0.31	0.18
Score		**0.25**	**0.21**	**0.26**	**0.25**

Slide Author: MB

Parametric Design

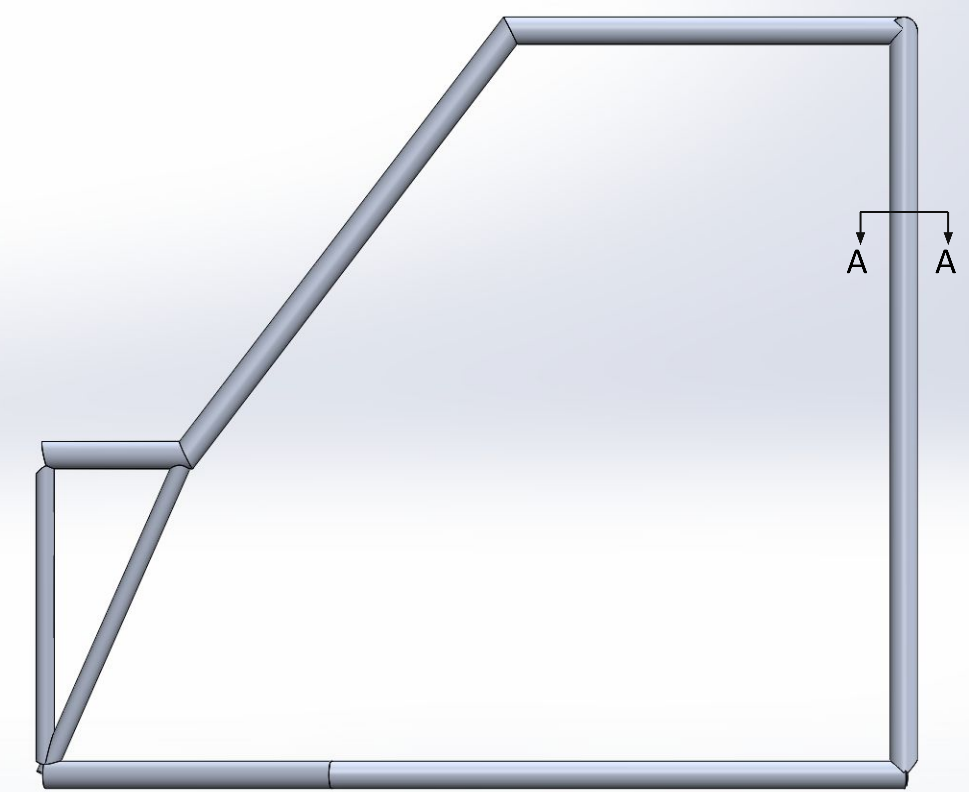
- Total Length = 4.7 m (185.08 in)
- Arbitrary Load = 700 N (78.7 lbf)
- Material Properties:

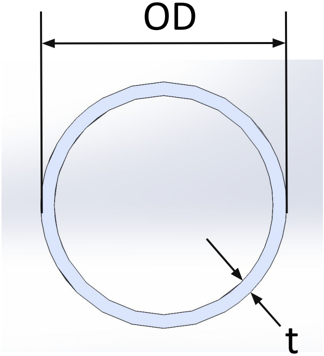
$$E = 70.3\ GPa$$

$$\rho = 2688\frac{kg}{m^3}$$

$$\sigma = \frac{4P}{\pi(D^2 - d^2)}$$

$$F_{cr} = \frac{\pi^3 E}{16L^2}(D^4 - d^4)$$





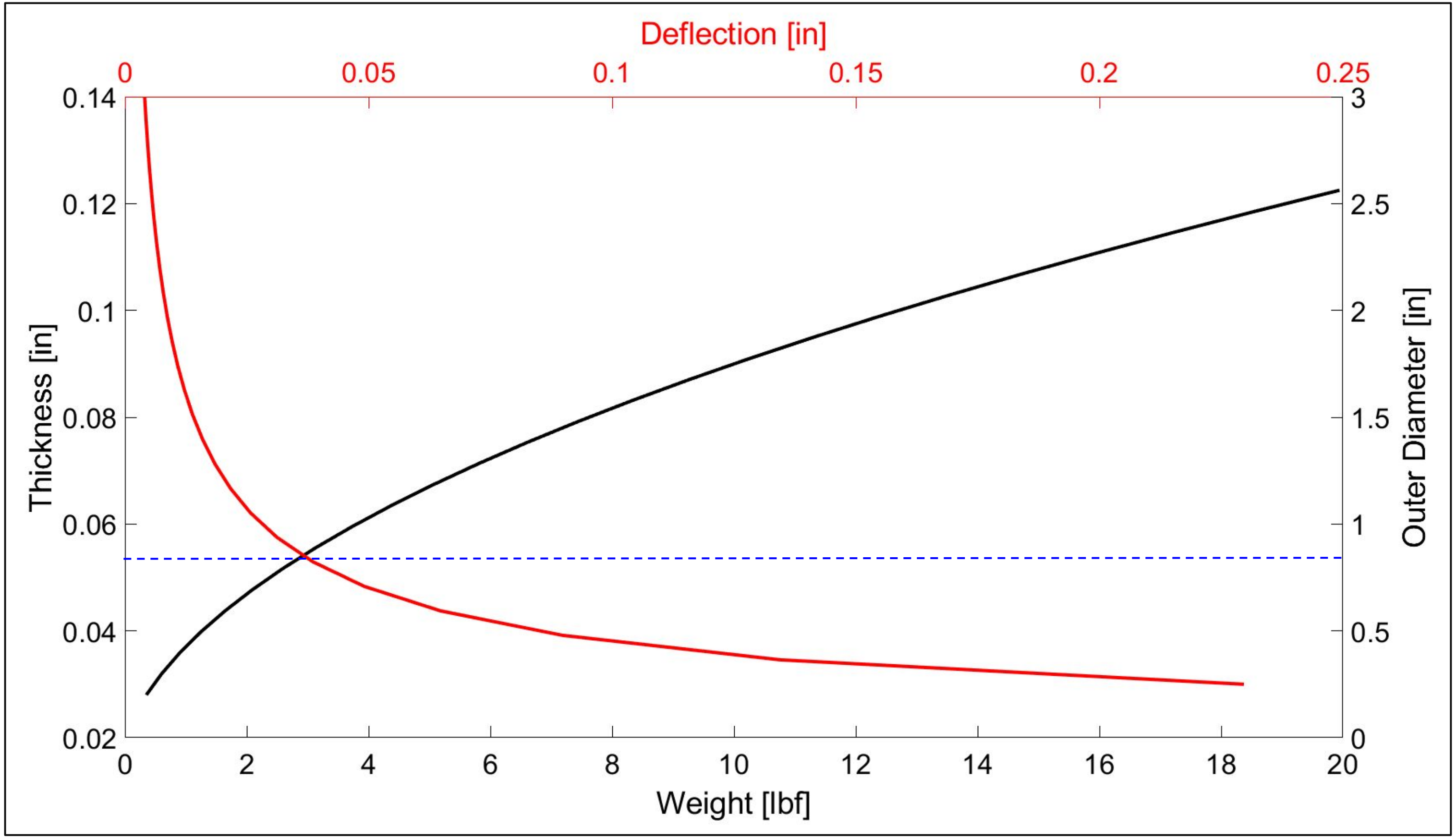
Section A-A

$$\delta = \frac{4PL}{E(D^2 - d^2)}$$

$$W = \frac{g\rho\pi}{4}(D^2 - d^2)$$

Slide Author: MB

Weight & Deflection vs. Tube Size



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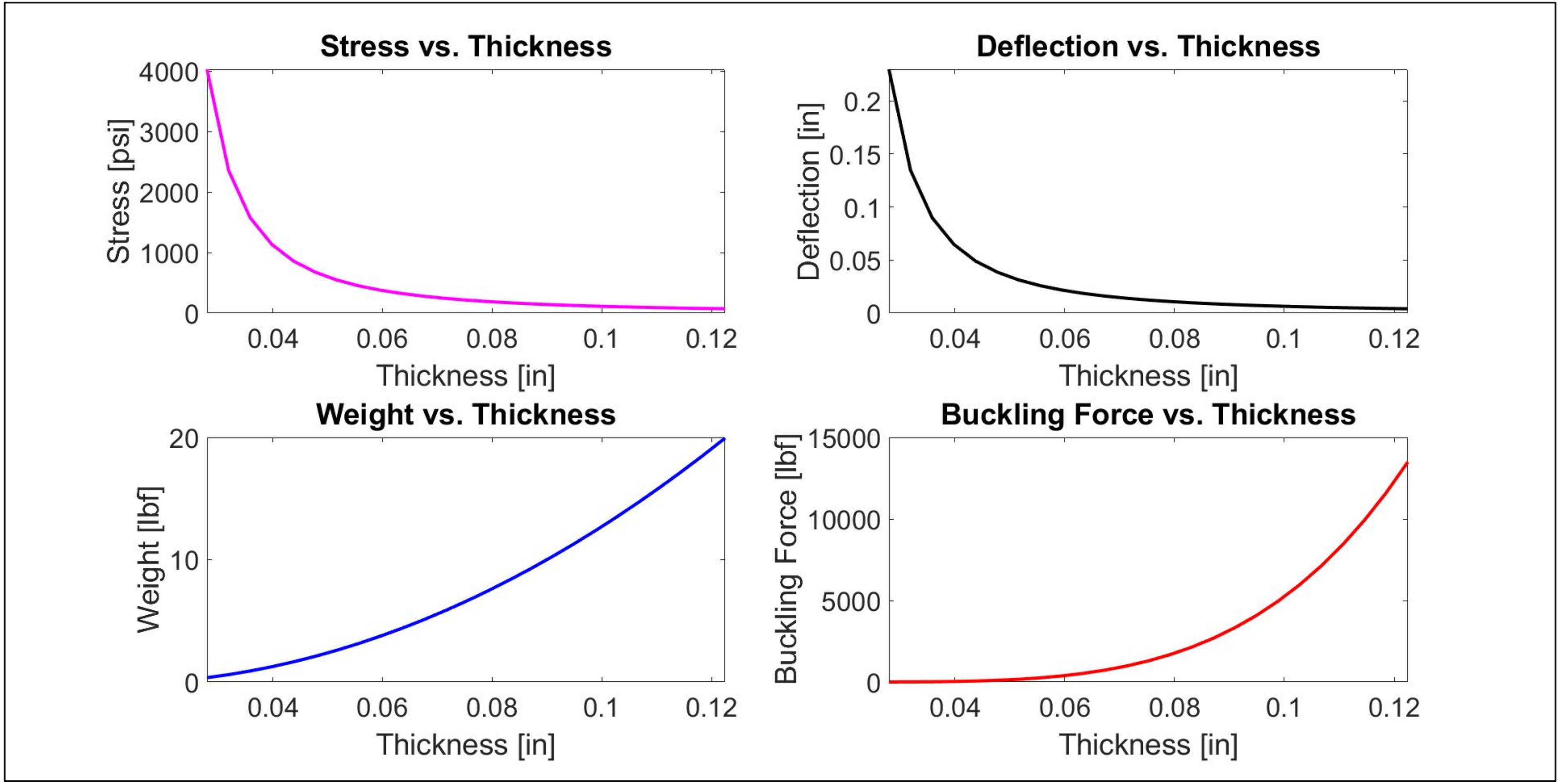
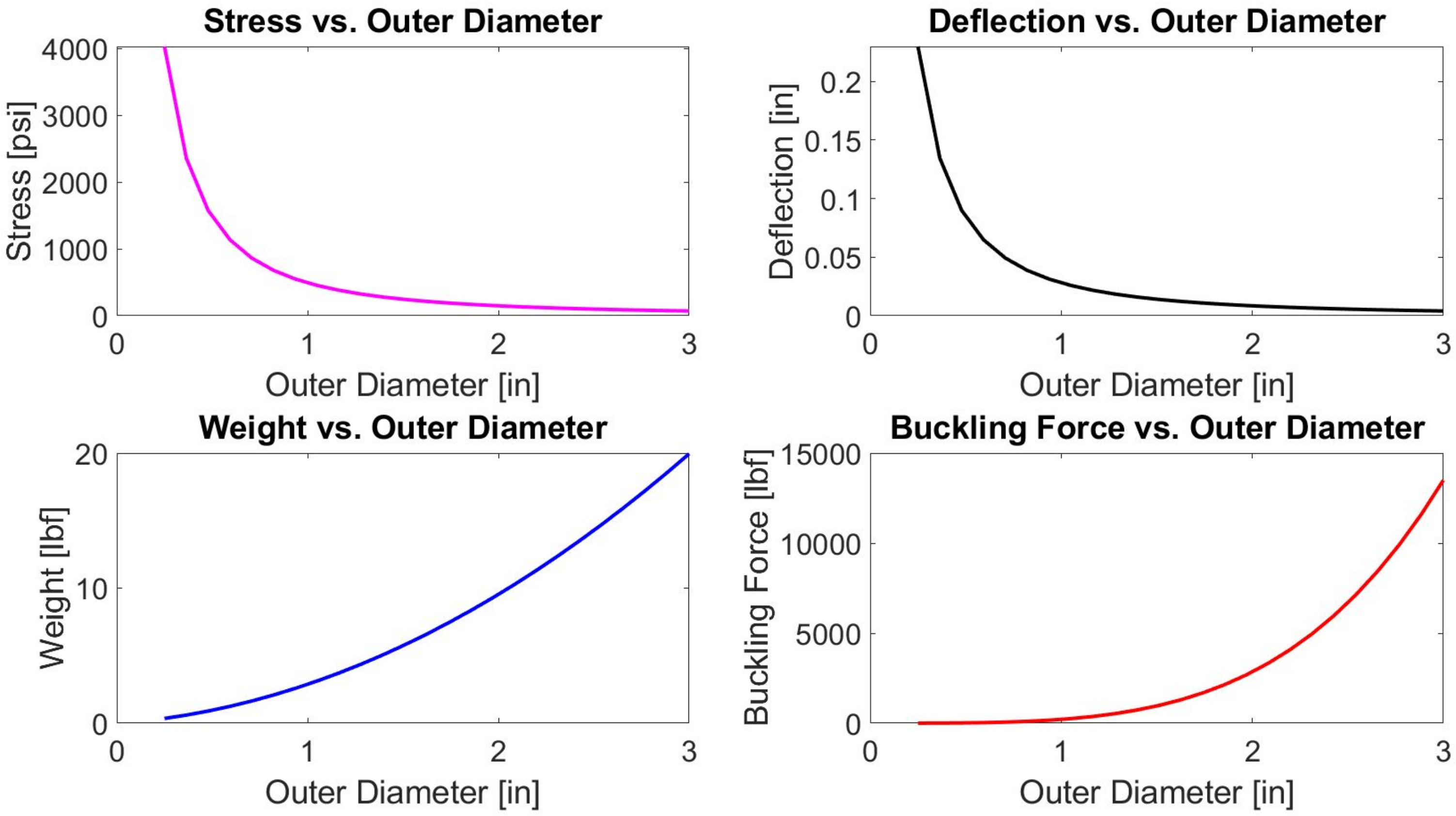
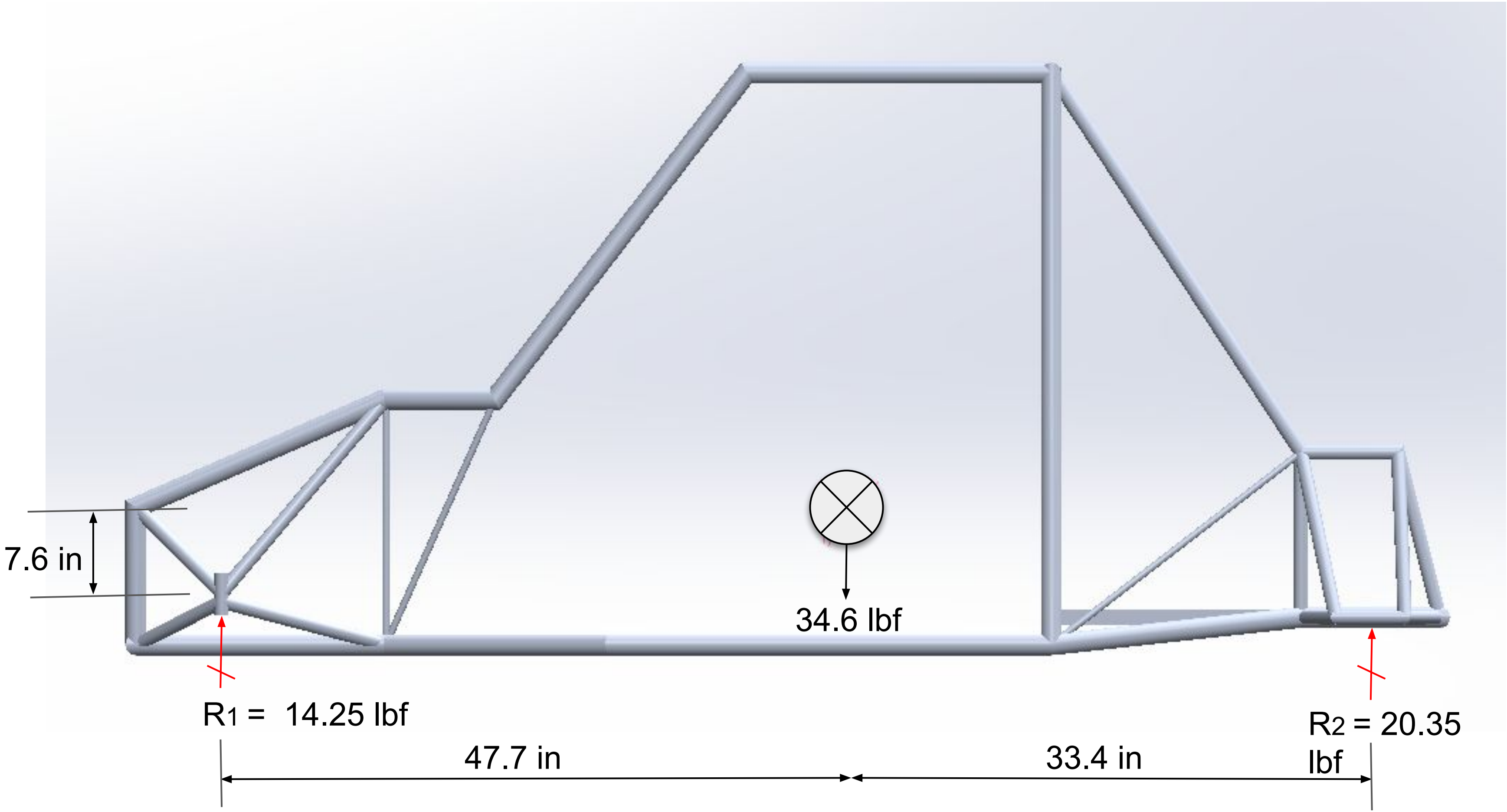
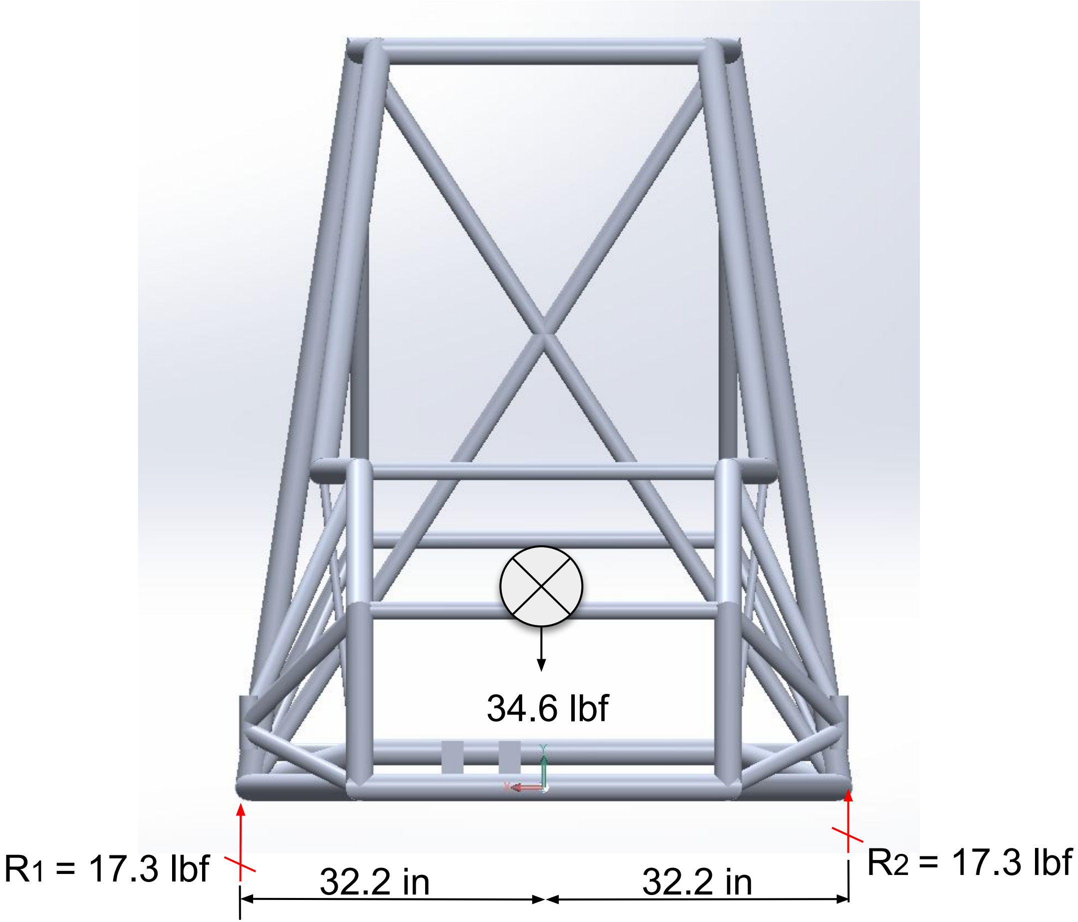

Stress vs. Thickness
Stress [psi]
4000
3000
2000
1000
0
0.04
0.06
0.08
0.1
0.12
Thickness [in]
Deflection vs. Thickness
Deflection [in]
0.2
0.15
0.1
0.05
0
0.04
0.06
0.08
0.1
0.12
Thickness [in]
Weight vs. Thickness
Weight [lbf]
20
10
0
0.04
0.06
0.08
0.1
0.12
Thickness [in]
Buckling Force vs. Thickness
Buckling Force [lbf]
15000
10000
5000
0
0.04
0.06
0.08
0.1
0.12
Thickness [in]



Stress vs. Outer Diameter
Stress [psi]
4000
3000
2000
1000
0
0
1
2
3
Outer Diameter [in]
Deflection vs. Outer Diameter
Deflection [in]
0.2
0.15
0.1
0.05
0
0
1
2
3
Outer Diameter [in]
Weight vs. Outer Diameter
Weight [lbf]
20
10
0
0
1
2
3
Outer Diameter [in]
Buckling Force vs. Outer Diameter
Buckling Force [lbf]
15000
10000
5000
0
0
1
2
3
Outer Diameter [in]



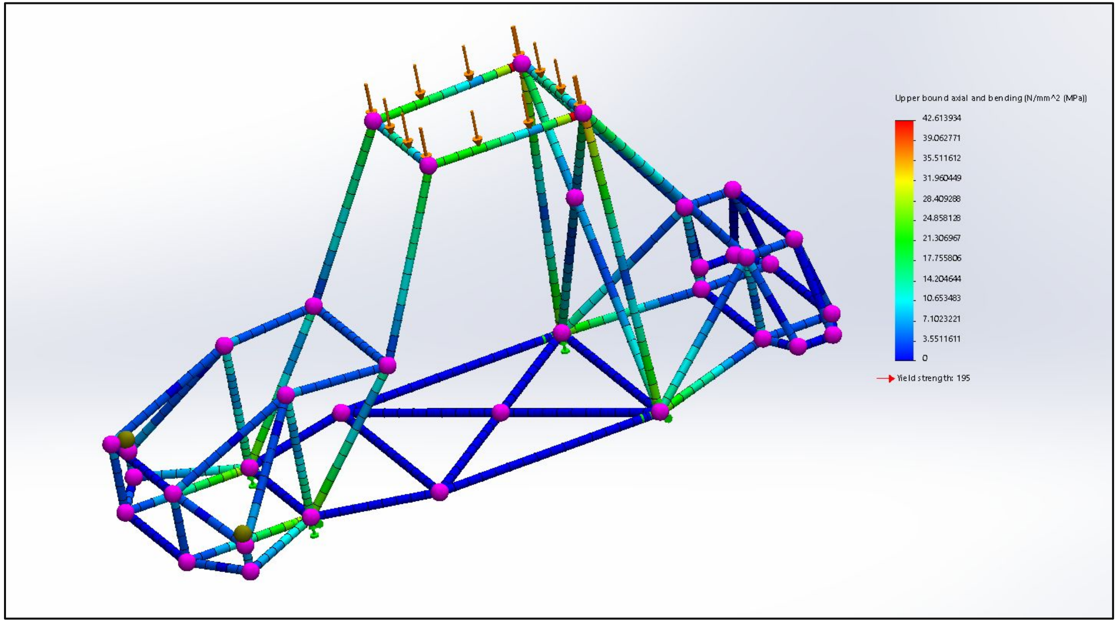
Slide Author: MB



Slide Author: MB

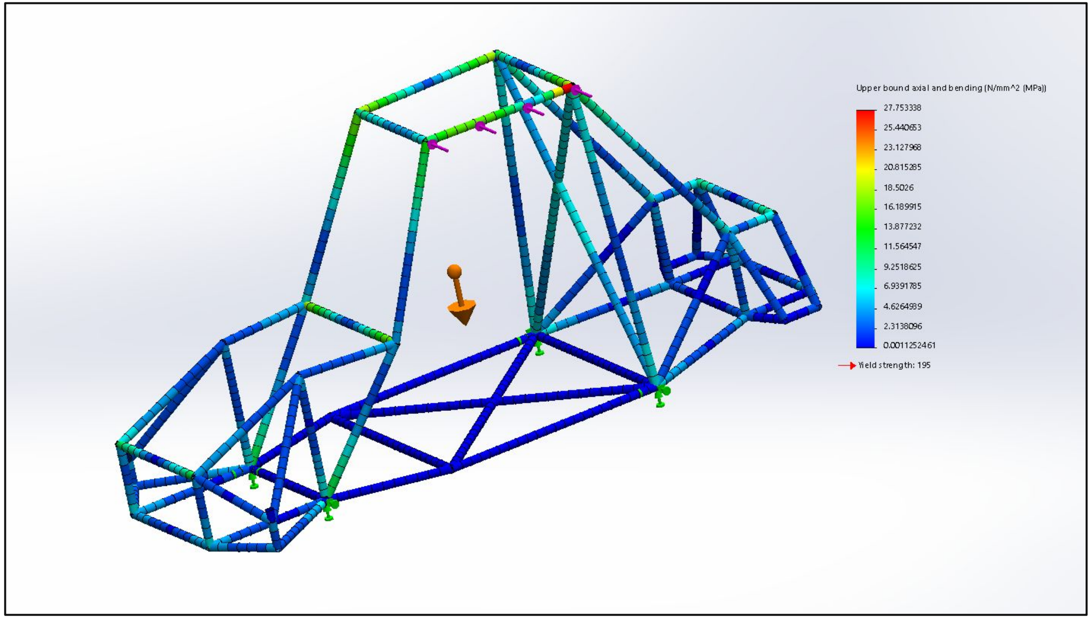
Chassis: 700 N Downward

- Von Mises Stress: 42.6 MPa
- F.S. = 4.58
- Max displacement: 3.62 mm (0.14 in)



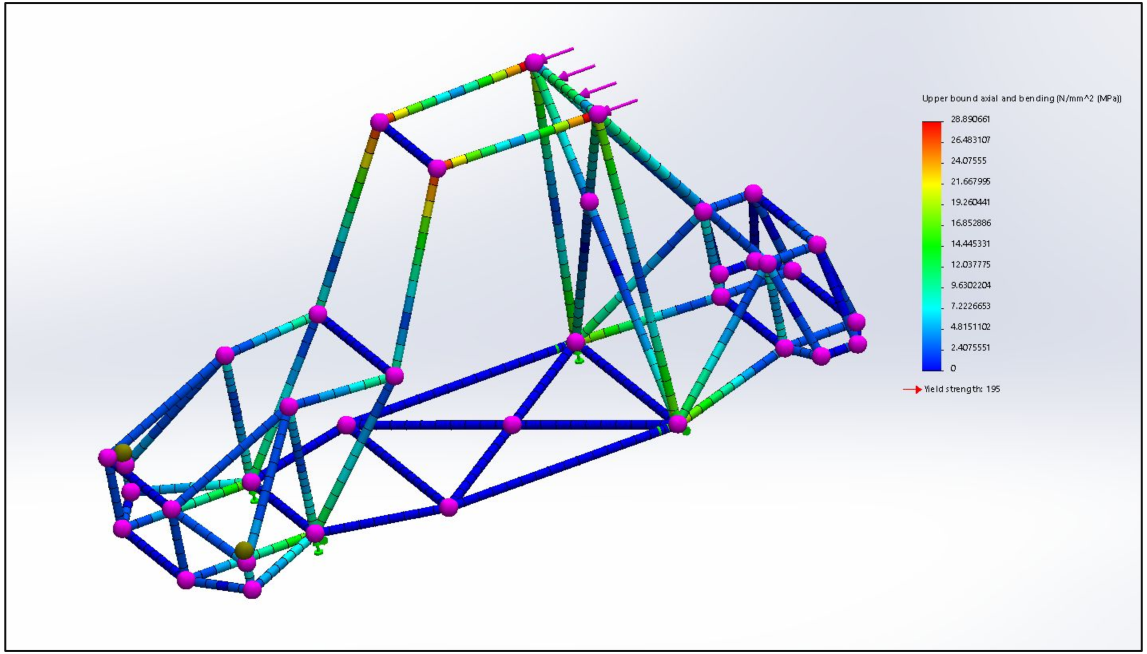
Chassis: 700 N Side

- Von Mises Stress: 27.8 MPa
- F.S. = 7.03
- Max displacement: 2.54 mm (0.10 in)



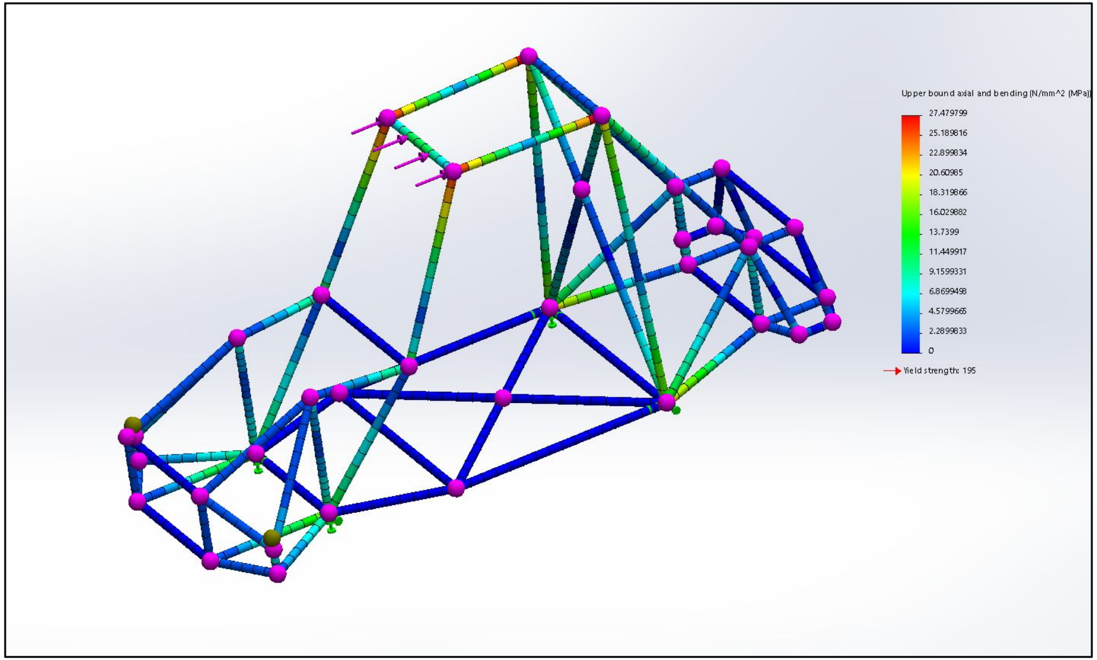
Chassis: 700 N Back

- Von Mises Stress: 28.9 MPa
- F.S. = 6.75
- Max displacement: 2.82 mm (0.11 in)



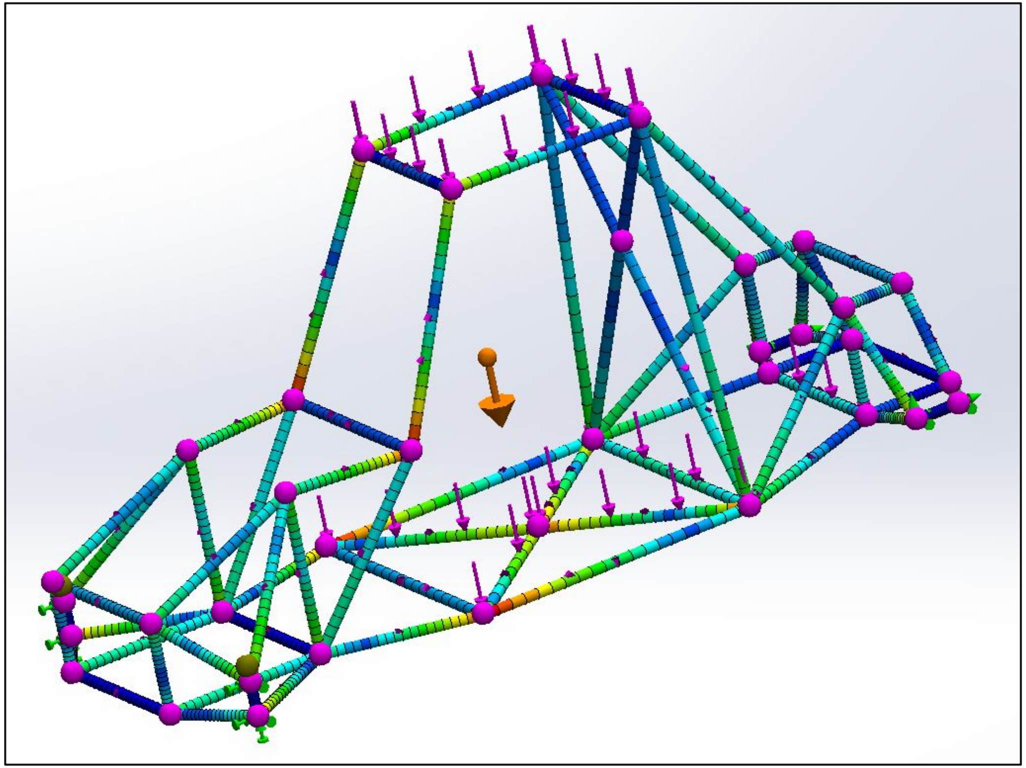
Chassis: 700 N Front

- Von Mises Stress: 27.5 MPa
- F.S. = 7.10
- Max displacement: 2.96 mm (0.12 in)



Chassis: Driver, Body, Engine

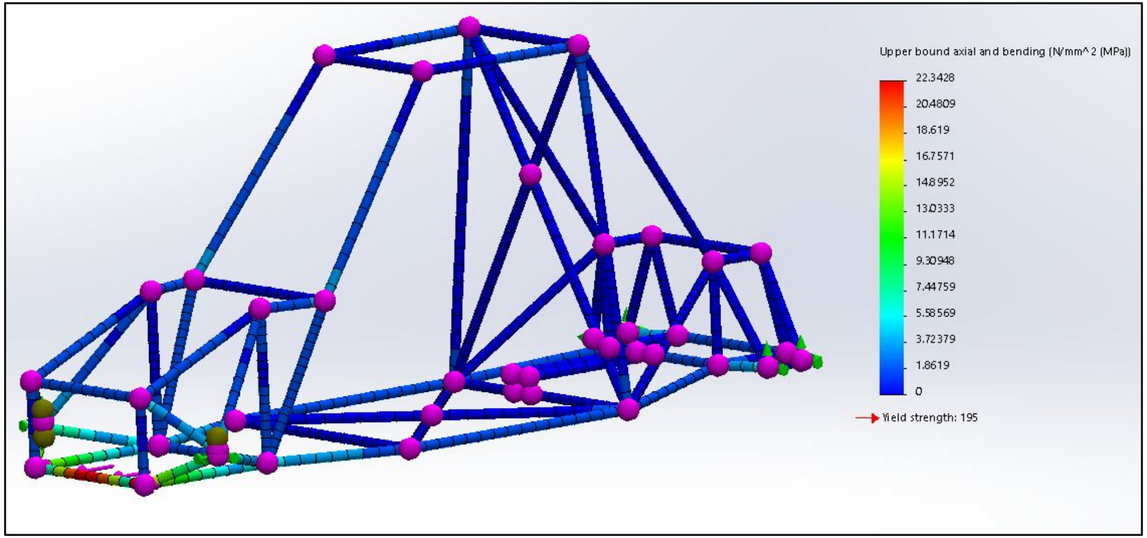
- Driver, Body, and Engine: 48.2 MPa
- Max Deflection: 6.0 mm (0.24 in)
- F.S. = 4.05



Slide Author: MB

Chassis: Tow Hook

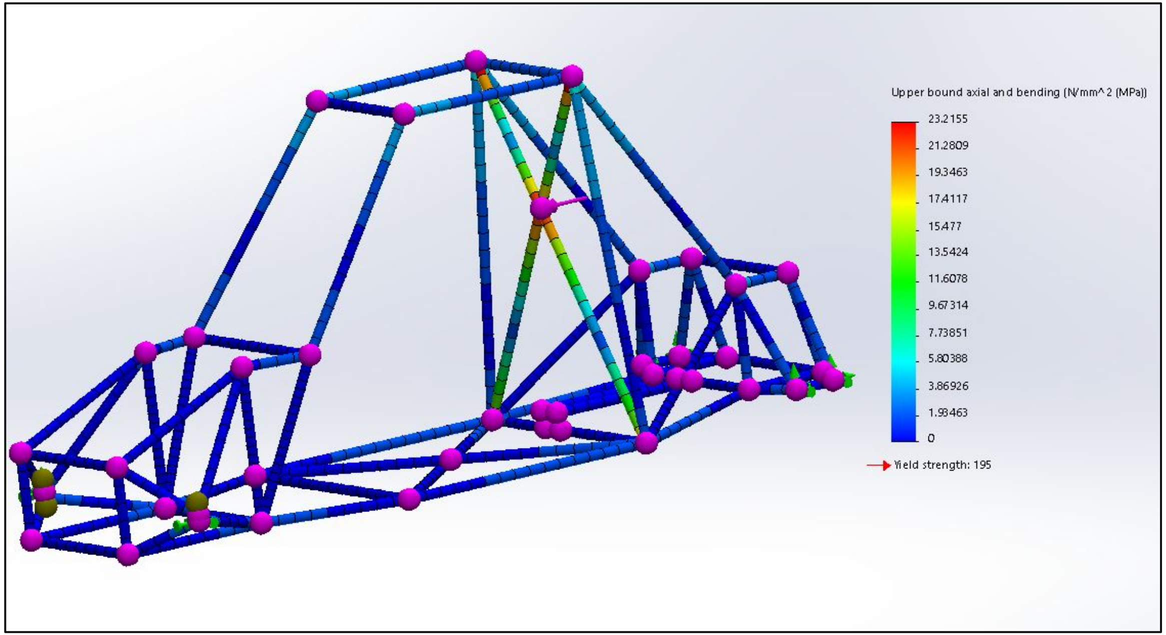
- Von Mises Stress: 22.3 MPa
- F.S. = 8.74
- Max displacement: 0.42 mm (0.02 in)



Slide Author: MB

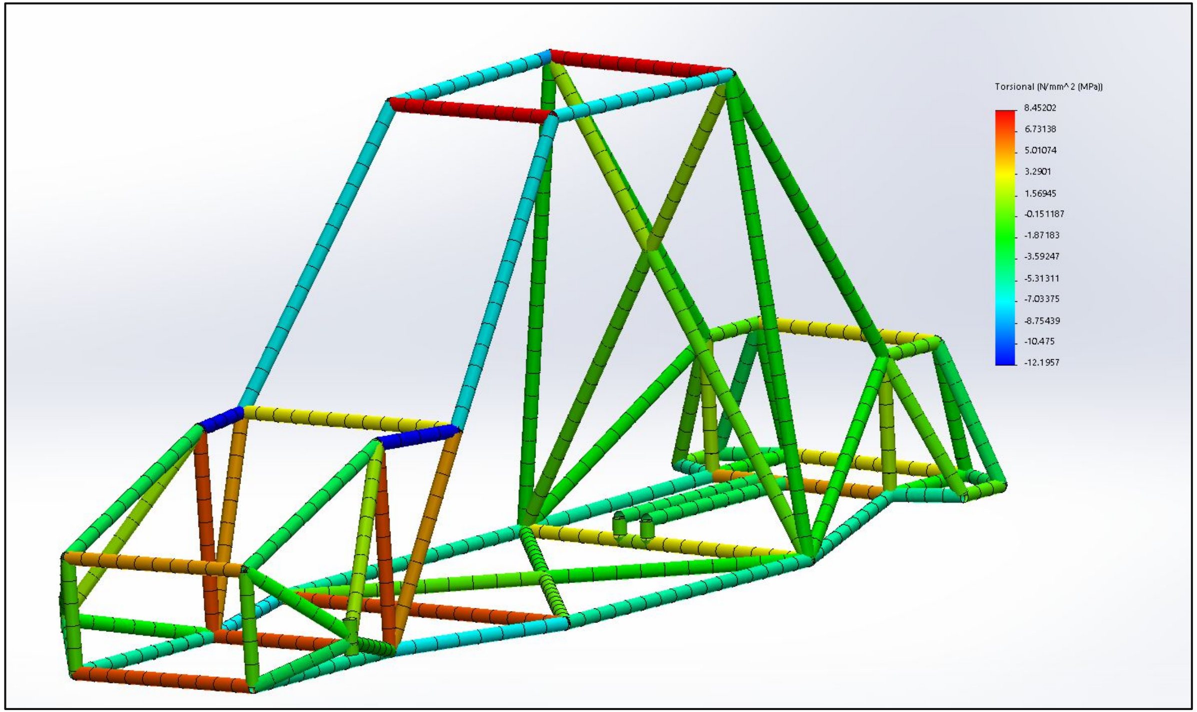
Chassis: Safety Harness

- Von Mises Stress: 23.2 MPa
- F.S. = 8.40
- Max displacement: 1.77 mm (0.07 in)



Chassis: Torsional Load

- 1.96 G’s
- Max Torsion 8.45 MPa
- F.S. = 8.09
- 0.4 degrees rotation



Critical Force for Buckling

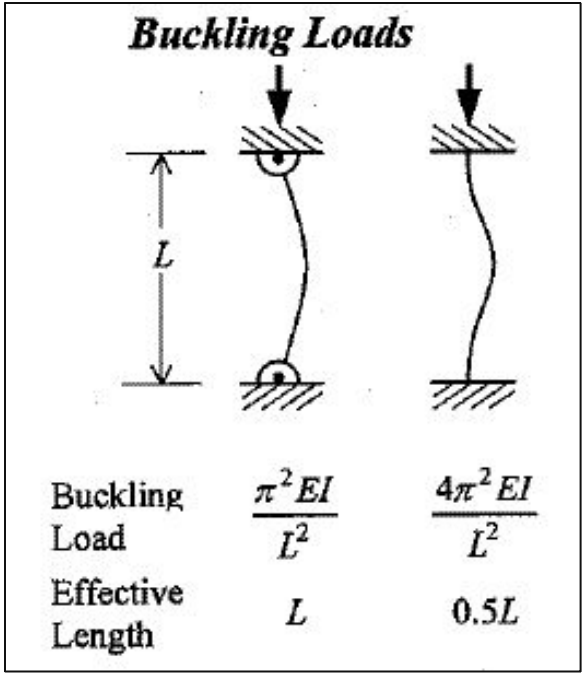
- Assuming fixed ends on both sides:

$$L_e = \frac{L}{2}$$

$$F_{cr} = \frac{4\pi^2 EI}{L^2}$$

$$I = \frac{\pi(D^4 - d^4)}{64}$$

$$F_{cr} = 4,864\ N$$



https://blogs.solidworks.com/tech/2016/09/nonlinear-buckling-no-penetration-contact-support-2017.html

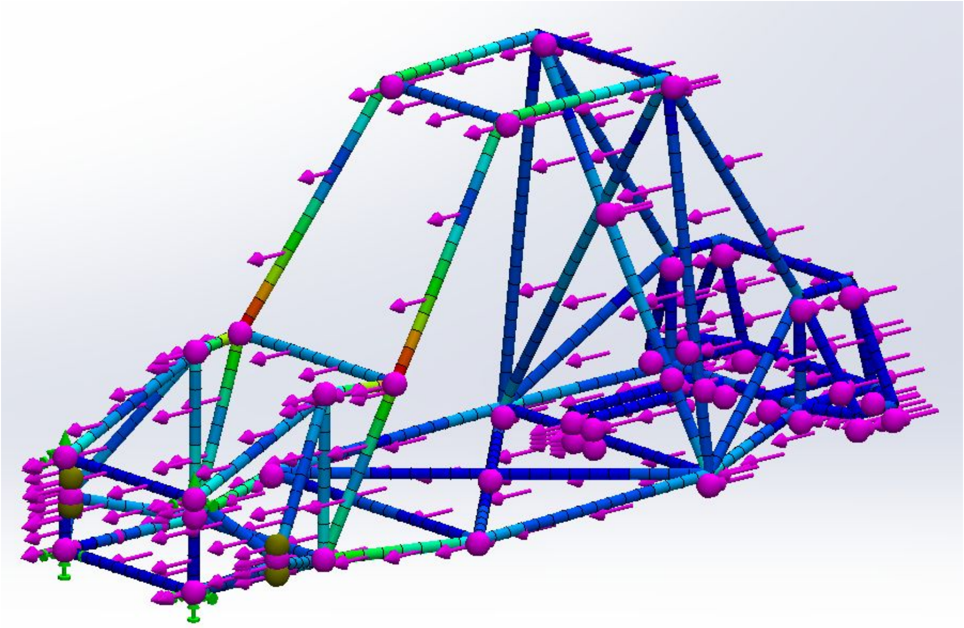
- A force of 4,864 N (1,093 lbf) is required to buckle the 1.5” OD and 0.083” thick tube.

Slide Author: MB

Chassis: Dynamic Load

- Impact Analysis Performed:
  - Vertical Drop Test by 1 Foot
  - Side Drop Test from 1 Foot
  - Horizontal Drop Test from 1 Foot
  - Frontal Crash
  - Side Impact from moving car
- Minimum Factor of Safety:
  - Frontal Crash: 185.2 MPa
  - Max Deflection: 0.047 mm (1.85 in)
  - F.S. = 1.05
  - Impact Factor: 8.11

$$n = \sqrt{\frac{\eta v^2}{g\,\delta_{static}}}$$

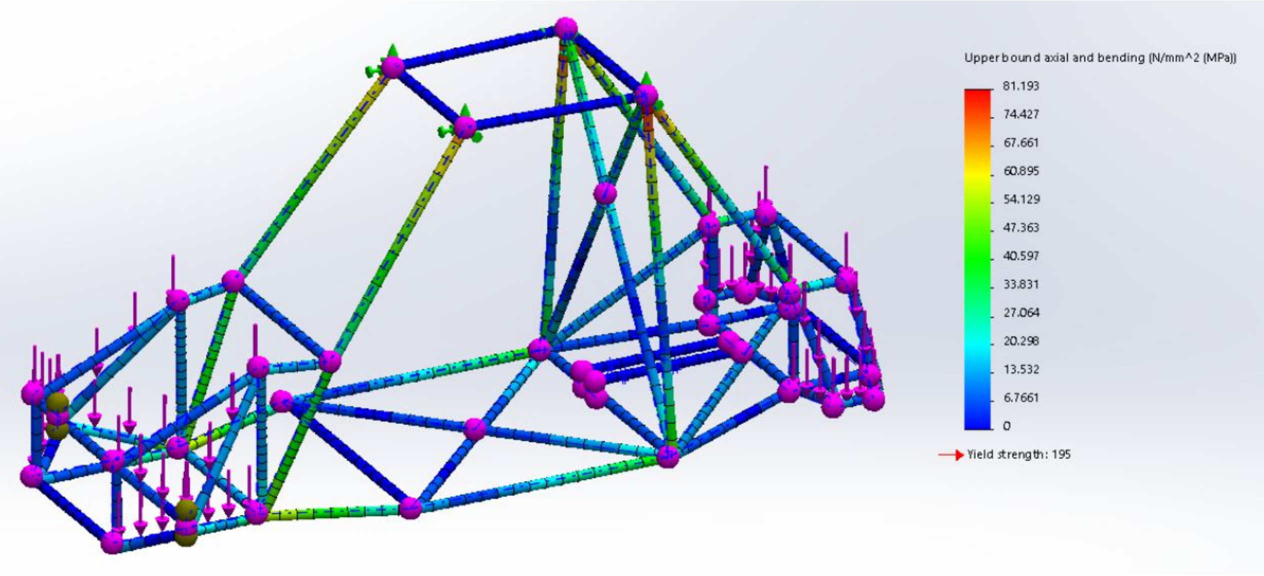


Vertical Drop Test from 1 Foot

- Max Stress: 81.19 MPa
- F.S. = 2.40
- Impact Factor: 26.2

$$n = 1 + \sqrt{1 + \frac{2h\eta}{\delta_{static}}}$$

- Max Deflection: 0.0227 m (0.9 in)

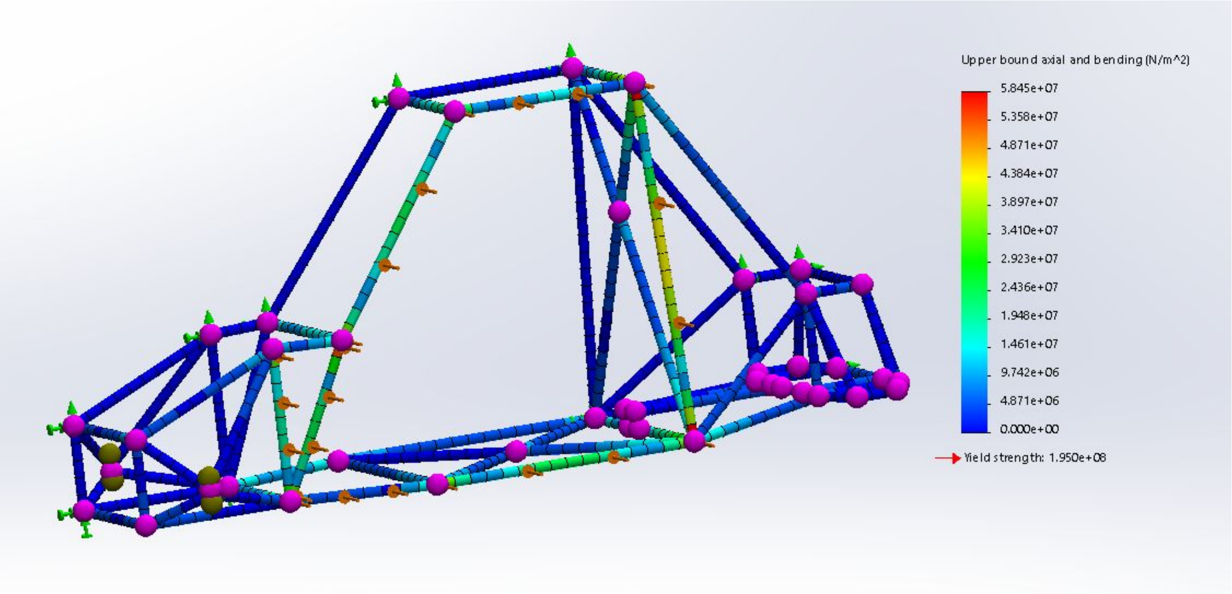


Side Drop Test from 1 Foot

- FEA Static Analysis Performed:
  - 1 Foot Drop Test
  - Max Stress: 58.4 MPa
  - F.S. = 3.34

$$n = 1 + \sqrt{1 + \frac{2h\eta}{\delta_{static}}}$$

  - Impact Factor: 47.8
  - Max Deflection: 0.00281 m (0.11 in)

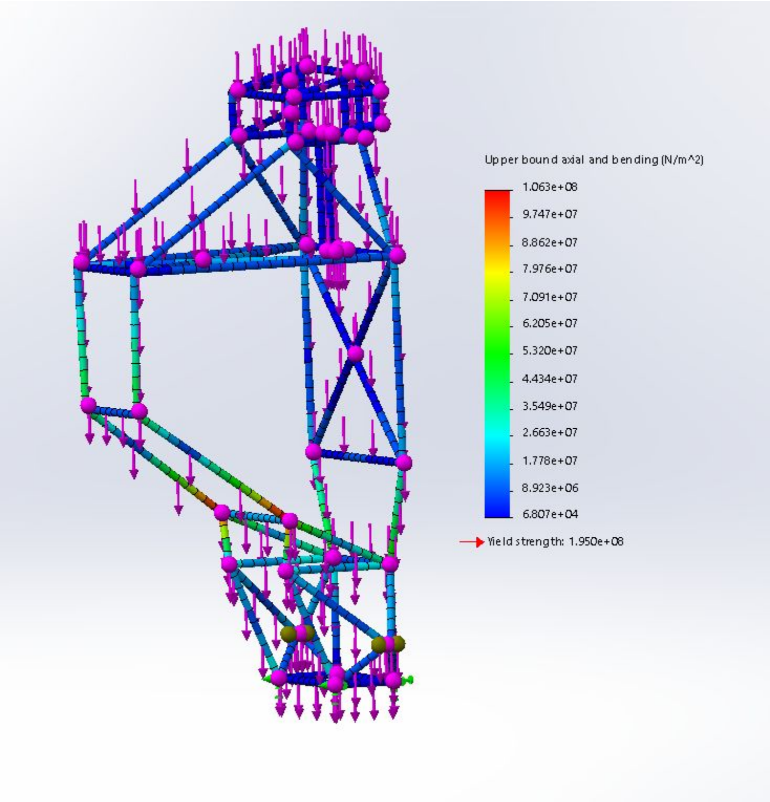


Horizontal Drop Test from 1 Foot

- FEA Static Analysis Performed:
  - Max Stress: 106.3 MPa
  - F.S. = 1.83

$$n = 1 + \sqrt{1 + \frac{2h\eta}{\delta_{static}}}$$

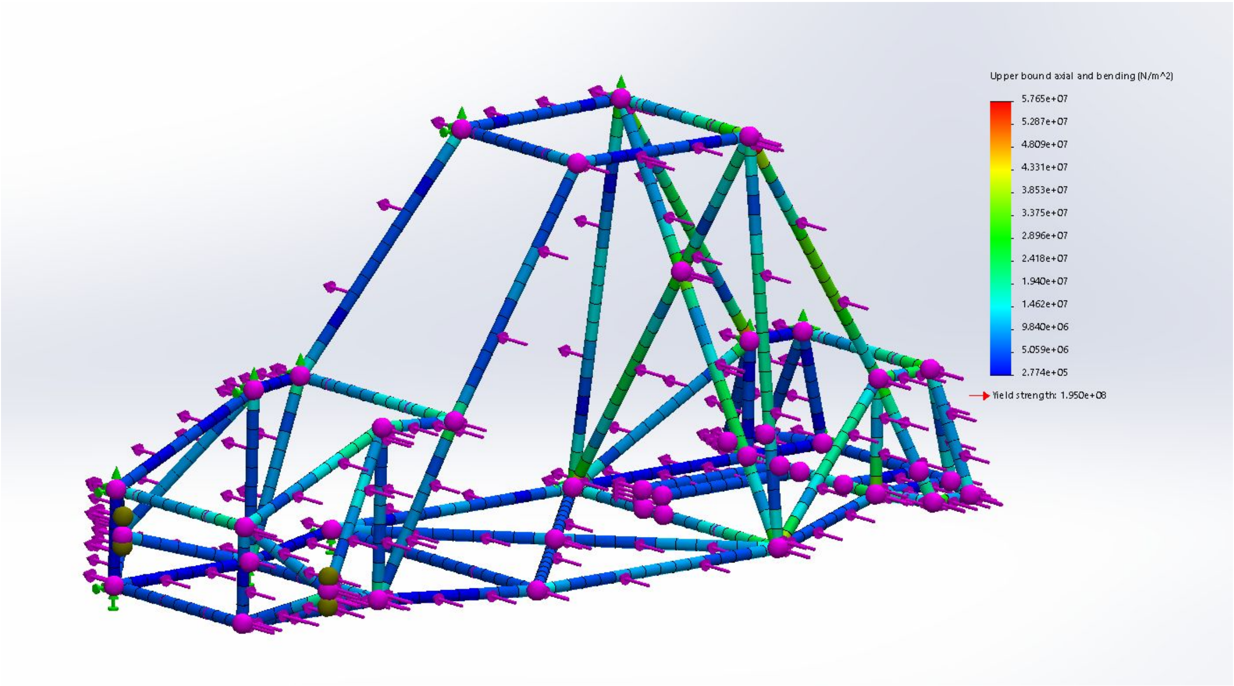
  - Impact Factor: 4.65
  - Max Deflection: 0.0271 m (1.1 in)



Slide Author: MB

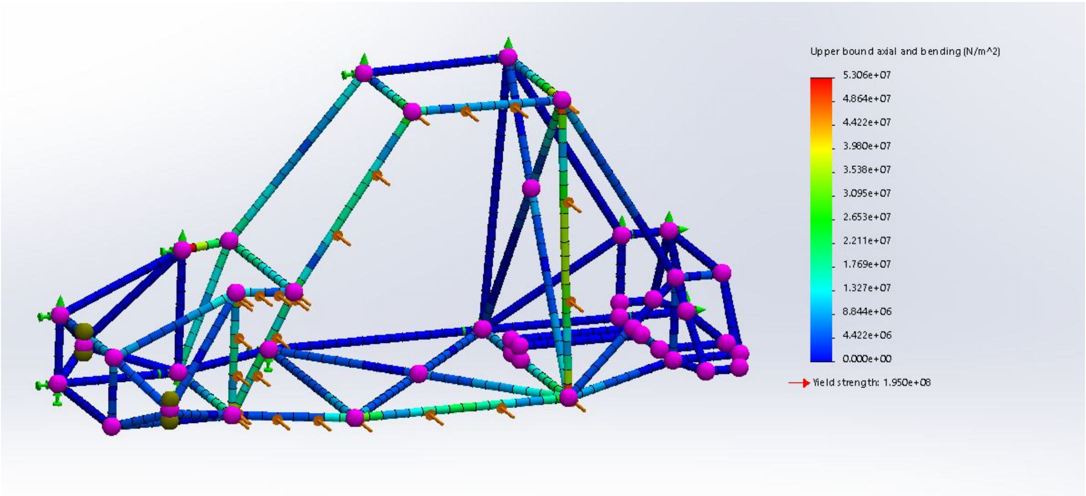
2G Force from Side

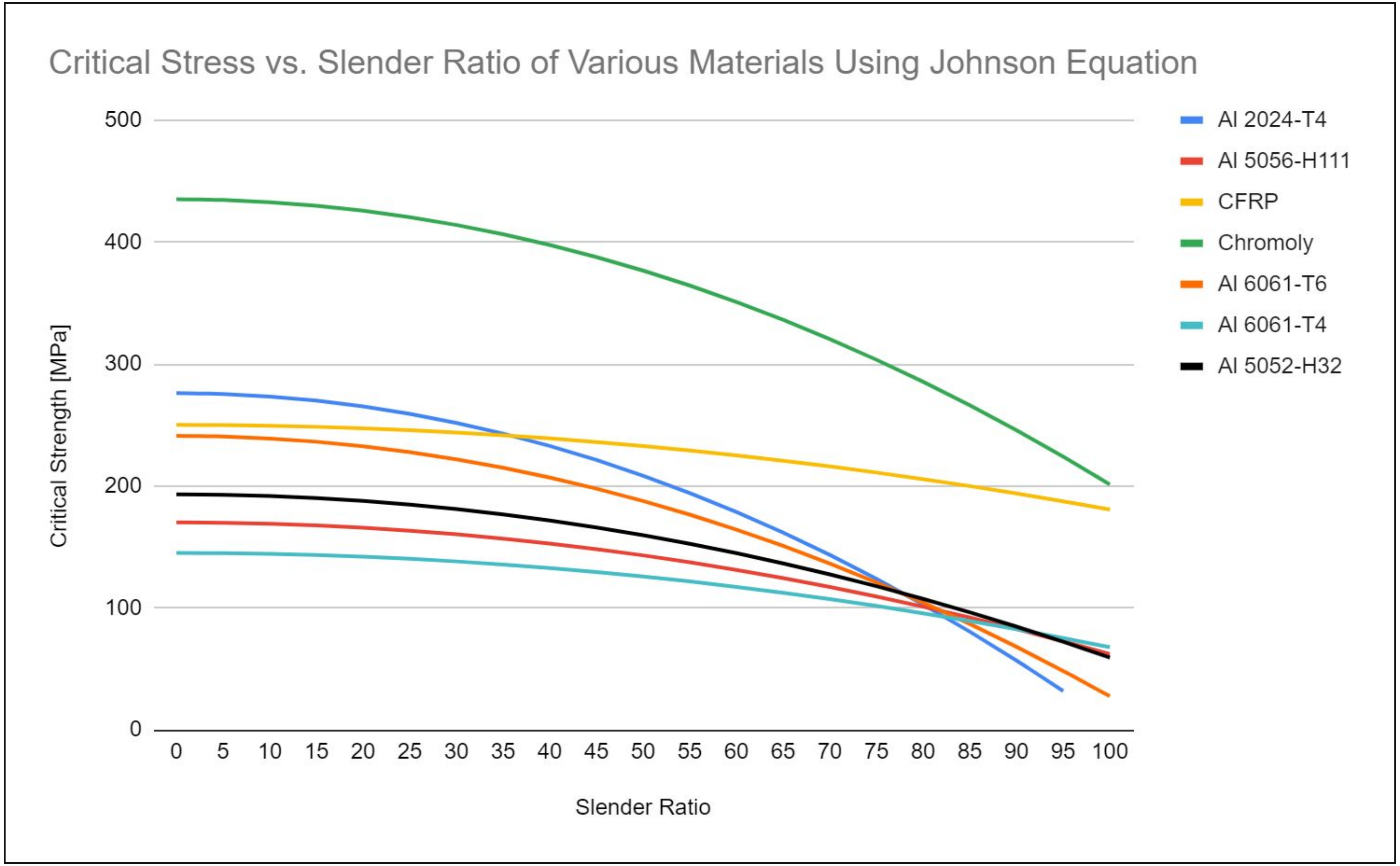
- FEA Static Analysis Performed:
    - Max Stress: 58.4 MPa
    - F.S. = 3.34
- Max Deflection: 0.00262 m (0.10 in)



Side Impact from Car

- Assume a 225 kg vehicle traveling 26 mph
- Distributed Force: 1245 N/m
- Max Stress: 53.1 MPa
- F.S. = 3.67
- Max Deflection: 0.00235 m (0.1 in)





Slide Author: MB

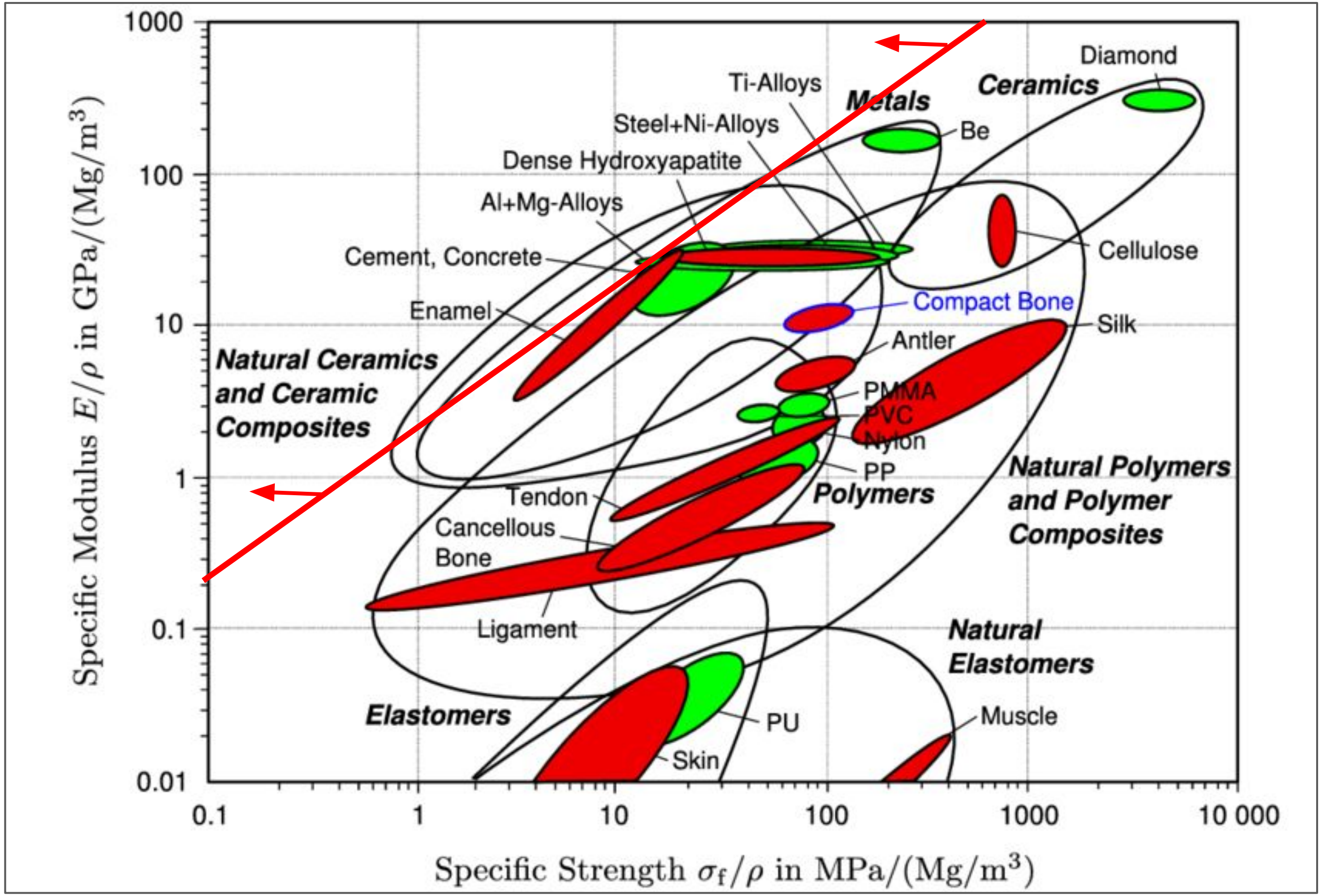
- Chassis Material Index: Light, Stiff, and Strong Tie Rod

$$M_1 = \frac{E}{\rho}$$

$$M_2 = \frac{\sigma_f}{\rho}$$

$$M = \frac{E}{\rho} * \frac{\rho}{\sigma_f}$$

$$M = \frac{E}{\sigma_f}$$



Slide Author: MB

Metric	Weight	CFRP	Al 6061-T6	Al 5052-H32	4130N Steel
Cost	**0.18**	0.12	0.26	0.26	0.36
Weight	**0.36**	0.41	0.23	0.22	0.14
Manufacturable	**0.27**	0.14	0.23	0.28	0.35
Safety	**0.18**	0.18	0.25	0.25	0.32
Score		**0.24**	**0.23**	**0.25**	**0.21**

Al 5052 Properties	Metric	English
Ultimate Tensile Strength	228 MPa	33 ksi
Yield Tensile Strength	193 MPa	28 ksi
Modulus of Elasticity	70.3 GPa	10200 ksi

Slide Author: MB

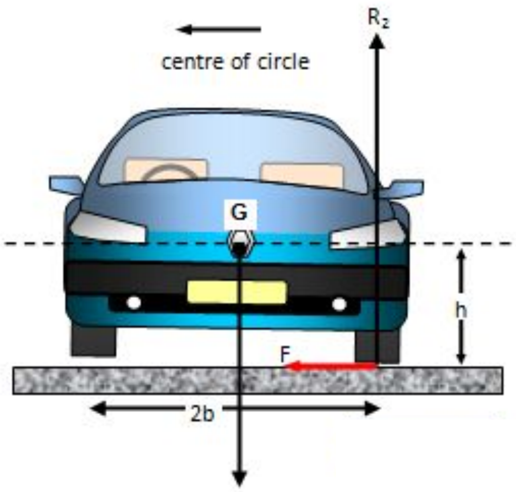
Slip vs. Tip Analysis

- Sharpest Turn: 6 m
- Coefficient of Friction of Tires: 0.8

$$v = \sqrt{\mu_s g r}$$

- Max velocity: 6.86 m/s (15.3 mph)
-
- Tipping Angle: 49.2°

$$\theta_{tip} = \tan^{-1}\frac{b}{h}$$



http://www.schoolphysics.co.uk/age16-19/Mechanics/Circular%20motion/text/Cars_cornering/index.html

Chassis: Weld Analysis

Material		Electrode	
Tensile Strength (Mpa)	195	Tensile Strength (Mpa)	62
Yield Strength (Mpa)	89.6	Yield Strength (Mpa)	50
Allowable Stress (Mpa)	35.84	Allowable Stress (Mpa)	18.6
Total Allowable Stress (Mpa)		18.6	

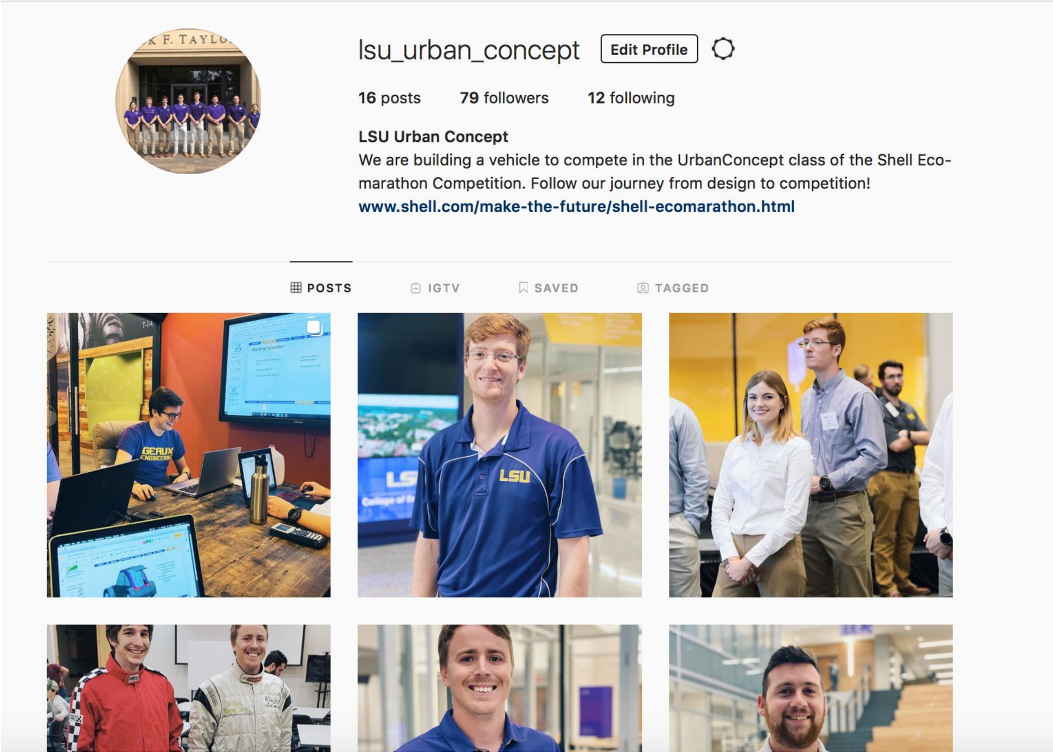
Force (lbs)	700
Length of Weld (in)	3.141593
h (in)	0.3125
Throat Area (in^2)	0.694096
Moment Arm (in)	7

Mpa	6.95
Safety Factor	2.67

Slide Author: CB

Off-Track Award: Communications Award

- Create multiple outlets for promotion of the competition and the team through social media.
- Apply online with a Communication Plan, Impact Analysis, and Campaign portfolio.



Off-Track Award: Vehicle Design Award

- Design an original and coherent vehicle in terms of aesthetics, ergonomics, technical feasibility, choice of materials, and eco-friendliness.
- Submit an application with various views of the design with details about each aspect.

https://www.flickr.com/photos/shell_eco-marathon/47486506532/in/album-72157707742297034/

Slide Author: MB

Off-Track Award: Technical Innovation Award

- Demonstrate outstanding technical ingenuity with new materials, components and inventions in the drive train, chassis, body, instrumentation, and tires.
- Must submit an application with photographs, drawings, or animations demonstrating technical innovation.

https://www.flickr.com/photos/shell_eco-marathon/48198625877/in/album-72157709143080816/

Slide Author: MB

Off-Track Award: Safety Award

https://www.flickr.com/photos/shell_eco-marathon/47480052072/in/album-72157706137660511/

- Demonstrate excellent understanding of safe design concepts, road safety, and safe manufacturing process.
- Must pass technical inspection.
- Submit an application with supporting videos, photographs, documents, and drawings.

Off-Track Award: Perseverance & Spirit of the Competition Award

- Does not require application
- Award: $3,000
- Chosen by the organizers
- Examples include:
    - Overcoming great obstacles to attend Shell Eco-marathon
    - Mastering exceptional challenges during competition
    - Supporting other participants
    - Keeping high spirits, showing outstanding resilience, resolve, and resourcefulness

https://www.flickr.com/photos/shell_eco-marathon/33676222738/in/album-72157690531148133/

Slide Author: MB

Off-Track Award: Circular Economy Award

- Develop an innovative concept with focus on re-manufacturable materials, minimizing natural resources, maximizing material reuse, and biodegradable products.
- Apply with a report describing the circular design, images of the design, and the solution scaled to tackle real life problems.

https://www.flickr.com/photos/shell_eco-marathon/48198626777/in/album-72157709143080816/

Slide Author: MB