FORMULA SAE®

Frame/Body/Aero

Primary structure/tub/tubing, body, and aerodynamic/ductwork systems. Rigidity and stress-relief methods. Load analyses. Fasteners. Selection and use of materials.

Chassis Design Goals

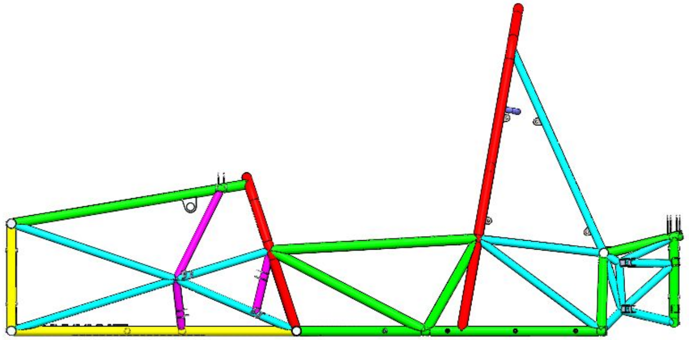
Goals:

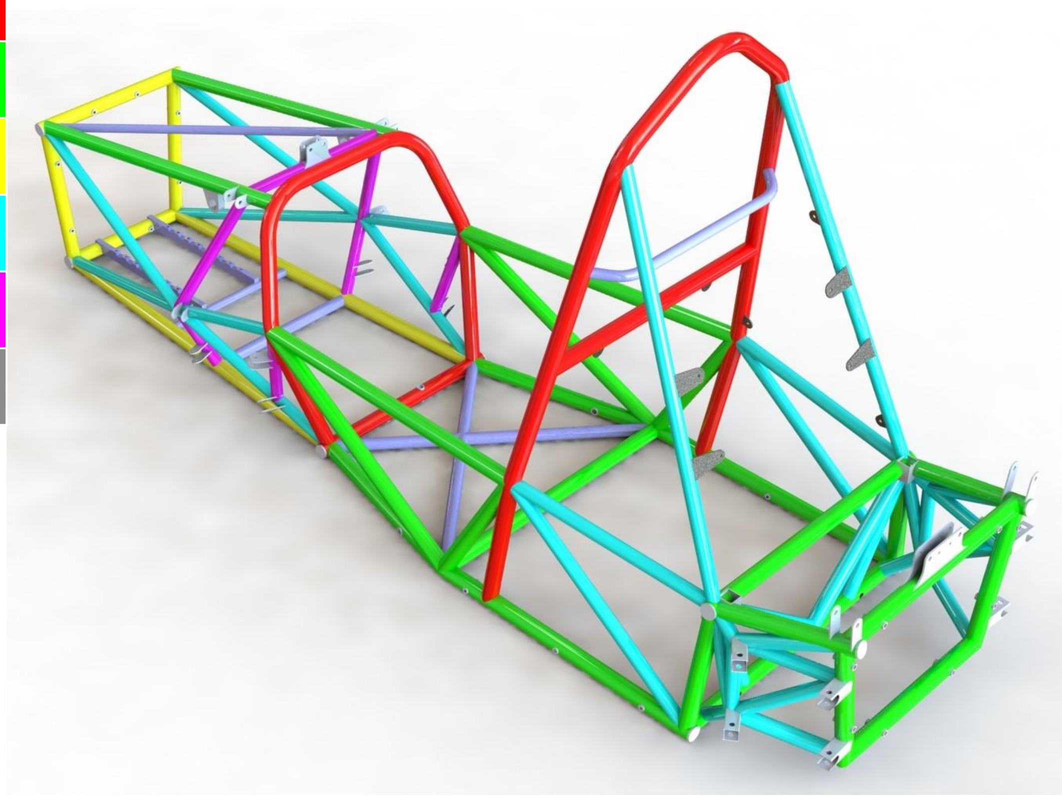
- Lower CG
- Optimize chassis torsional stiffness
- Optimize the geometry for EV systems

Important Requirements:

- Passes structural equivalence for a hanging differential
- Accommodate drivetrain packaging with the Emrax 208 Motor and the High Voltage Enclosure
- Accommodate suspension pick up points

1.25 x 0.083 in
1.25 x 0.065 in
1.25 x 0.049 in
1 x 0.065 in
1 x 0.049 in
Non Structural





- In order to get triangulation and the points to sit at nodes, we created the geometry and tabs shown above.
- In addition, having a hanging differential necessitated larger tubes in the rear, and the inclusion of welded inserts.

Weight Analysis (for CG)

CG Height: 9.831 in

Front/Rear weight distribution:

- 48.94/51.06 (static)
- 73.42/26.58 (dynamic)
  under a breaking acceleration of 1.5g's

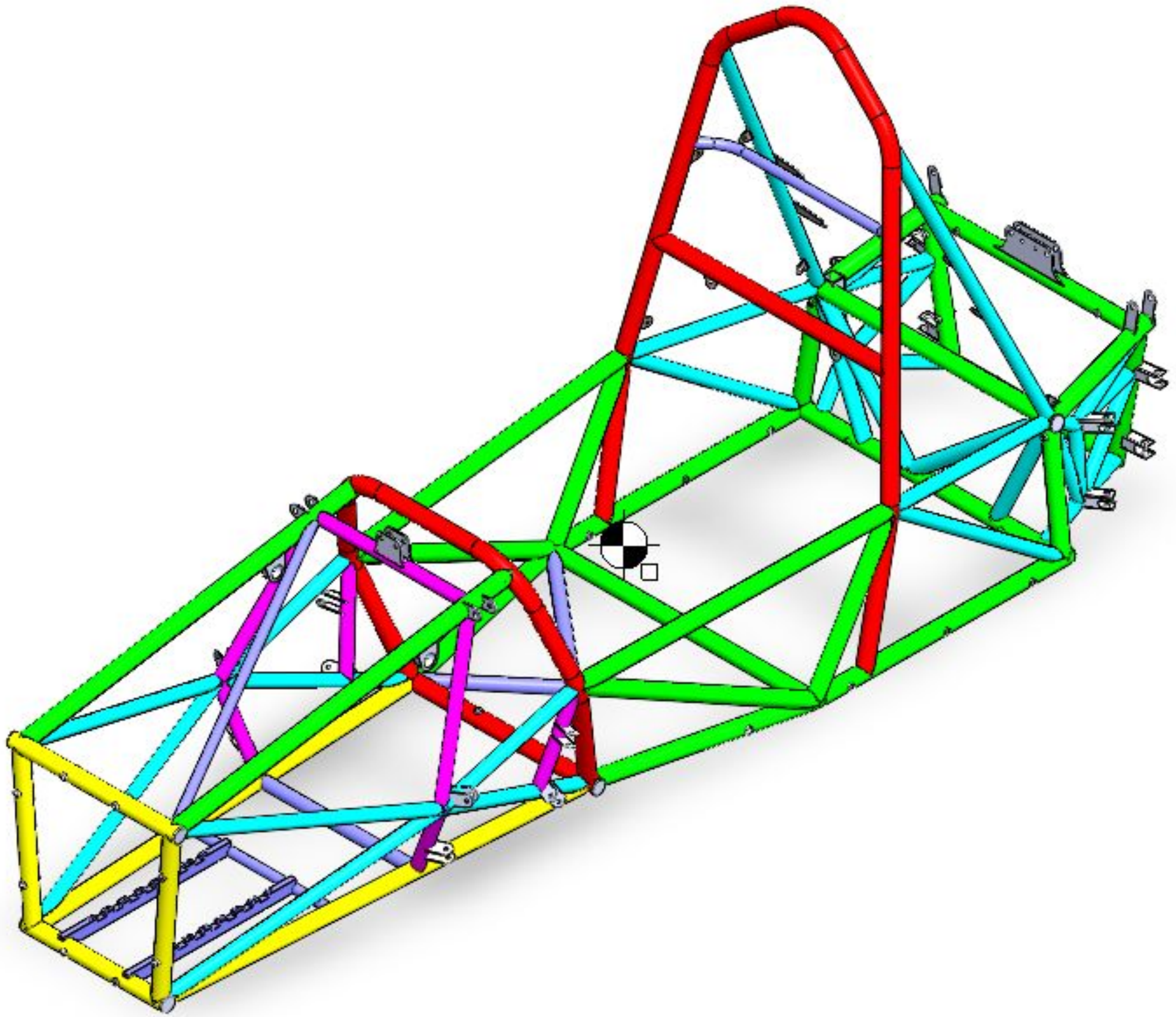
Chassis weight: 93.41 pounds

Ride height: 1.25 inches

Unique Features: Welded Inserts, Rear Clip, Geometry

Material: 4130 Steel
(2x the amount of yield strength, ultimate strength as 1020 steel due to increased Cr content in 4130)

Alternative materials considered (Aluminum) but not used based on price.



Torsional Stiffness

Simulation setup:

- Got a working mesh by combining bodies
- Constrained the rear pick up points
- Added a force component to the front suspension points in equal and opposite directions
- Ran Mesh and took notes of the Z-Deflection. Solved a triangle for degrees and for N*M, and N*M/degs

Stress concentrations:

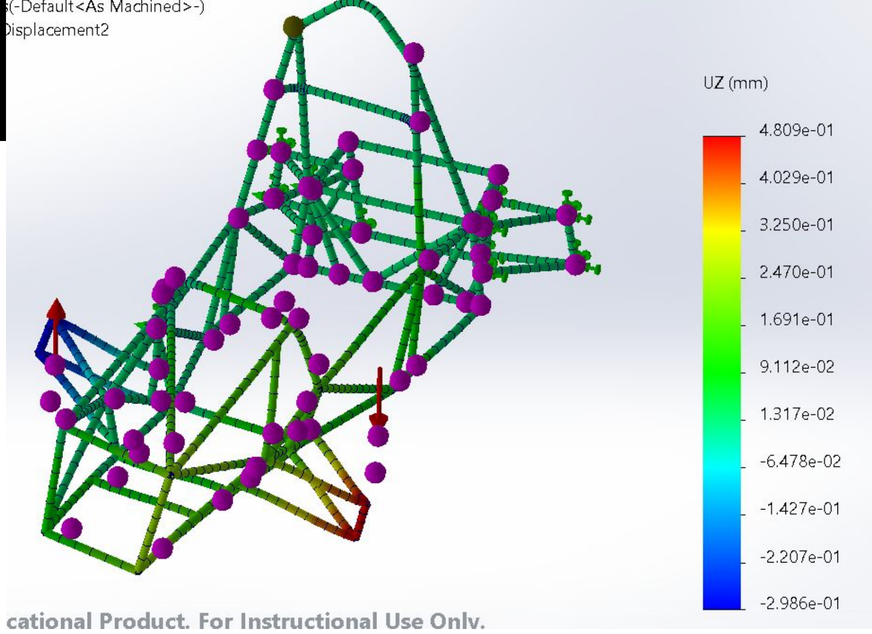
- 50 N at each of the front suspension pick up points. Going down in the Z on positive x side and the opposite on the negative x side
- Only a force component to simulate load

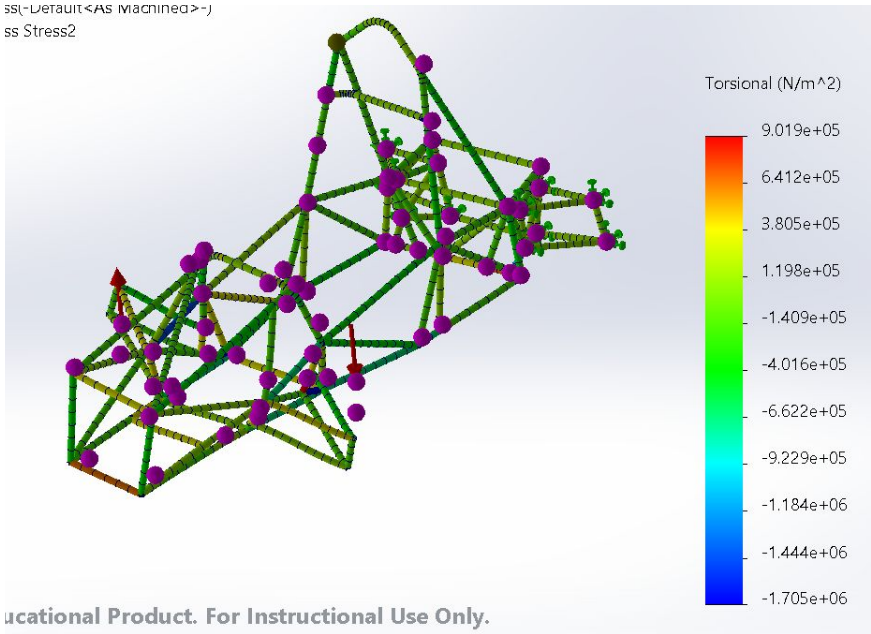
Sampling:

- From the point of deflection to the midplane
- You could also sample along an originally horizontal bar as a reference point

Results/conclusions:

- 1506.79 Ft*Lbs/ Deg
- More samples need to be taken and compared with suspension stiffness in series

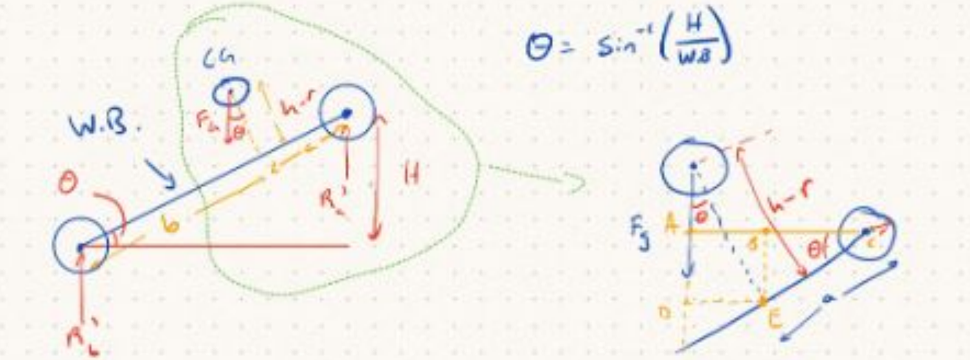




Weight Distribution

- Measure & Calculate Static Weight Distribution
  - Static F/R: 48.94/51.06
  - CG Height: 0.2497m (9.831 in)

- Calculate Dynamic Weight Distribution
  - Braking acceleration: -1.5g
  - **Dynamic F/R:** 73.42/26.58



$$\Sigma M_A: \ R_r'(0) + R_L' \cos\theta\,(W.B) - F_G|\overline{AC}| = 0$$

$$|AB| = |DE| = (h-r)\sin\theta$$

$$|AD| = |BE| = a\sin\theta$$

$$\text{So } |AC| = |AB| + |BC| = (h-r)\sin\theta + a\cos\theta$$

Inserting back into the original sum of moments:

$$R_L'\cos\theta\,(W.B) - F_G\left((h-r)\sin\theta + a\cos\theta\right) = 0$$

$$\text{rearrange } (h-r)\sin\theta + a\cos\theta = \frac{R_L'}{F_G}\cos\theta\,(W.B)$$

$$(h-r) = \cot\theta\left(\frac{R_L'}{F_G}(W.B) - a\right)$$

also $= WB\left(\frac{R_L}{F_G}\right)$

So: $\boxed{(h-r) = \cot\theta\left(\frac{R_L' - R_L}{F_G}\right)(W.B)}$ where $\theta = \sin^{-1}\left(\frac{H}{WB}\right)$

raised height

C.G. height from ground

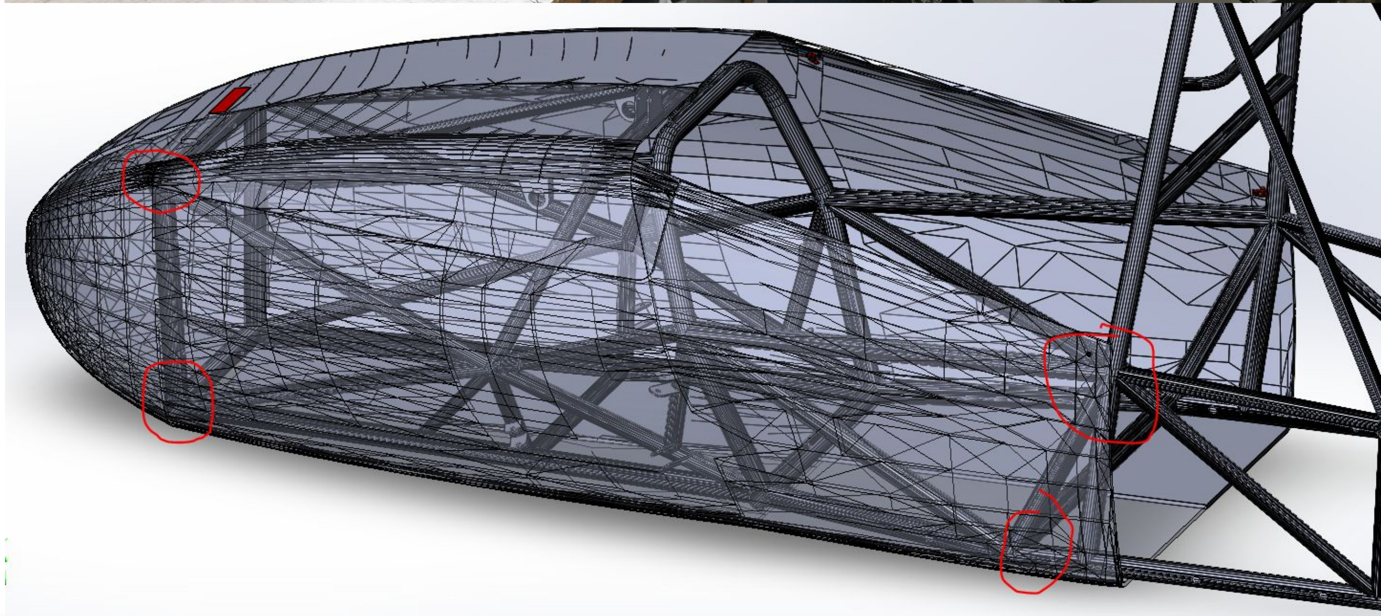
tire radius

wheel base

Body Design Goals

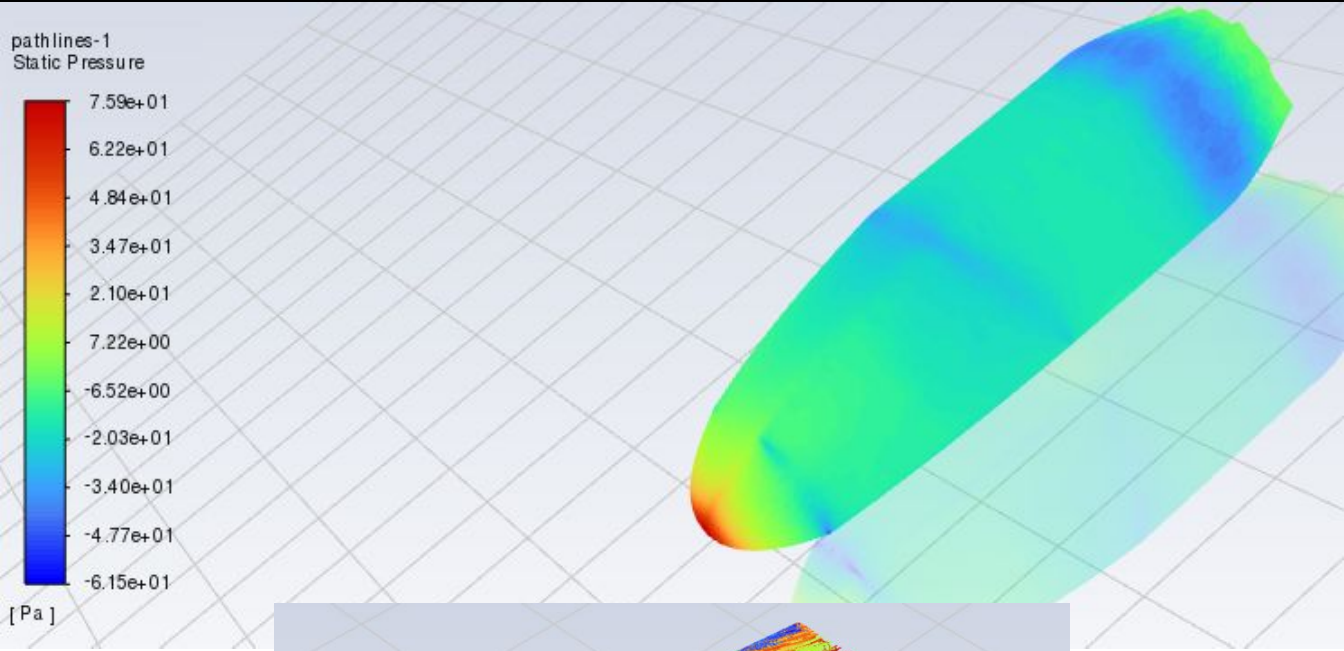
Click to add title

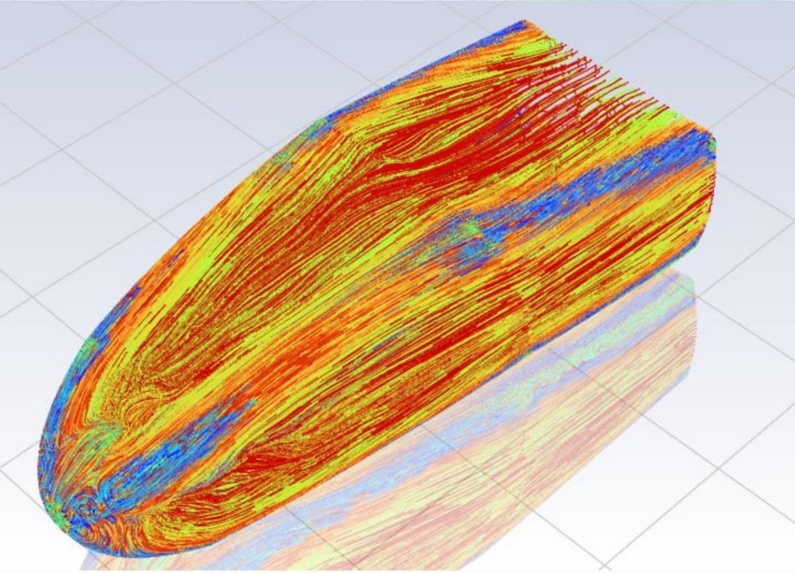
- Body directs air over the chassis to reduce drag coefficient and air resistance
- Lower drag reduces force required to move car forward and produces less strain on powertrain components
- Body cuts to allow accessibility
- Secure mounting to chassis
- Aerodynamic simulations for drag coefficient verification
- T.7.2.3. [No Opening to the Cockpit]
- T.7.2.4. [Forward Facing Edge Radii]
- Prevent debris from entering the cockpit



Body Analysis

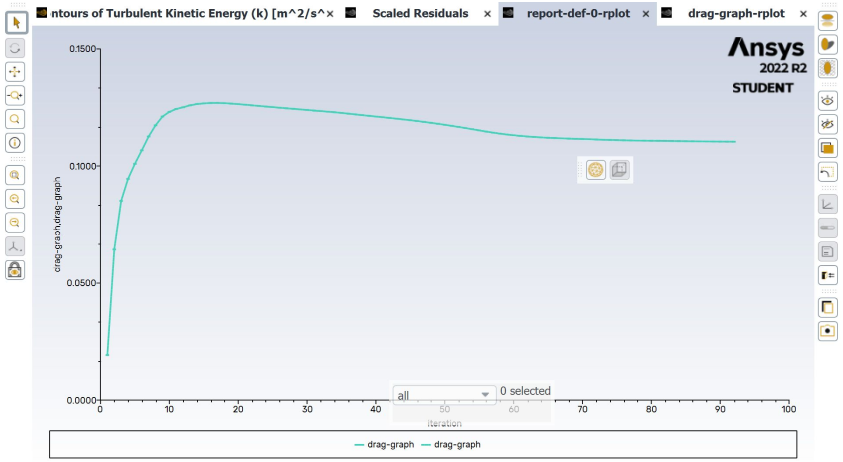
- Designed to be as aerodynamic as possible with regards to contours of chassis
- Frontal Area Minimization
- Nose is detachable to access pedals
- Multiple forms of attachment (e.g. quarter turns, velcro)
- A smooth curve on the body prevents flow separation and reduces pressure which lowers air resistance
- ANSYS pressure and drag simulation
- Currently, we have a physically impossible drag coefficient





Body Analysis

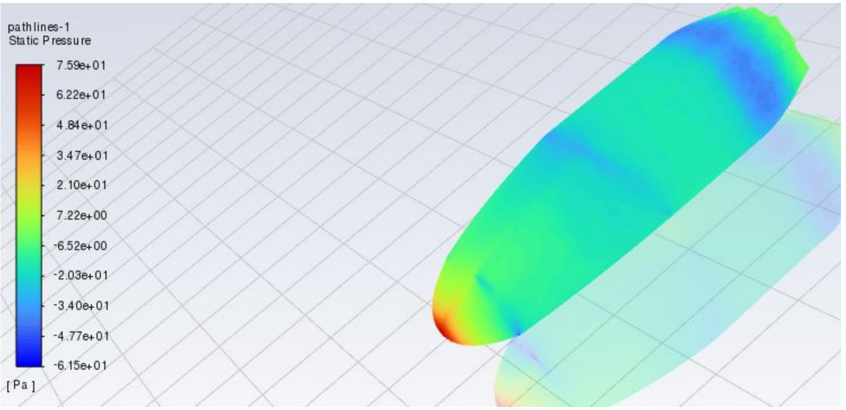
Drag Analysis of 2D Body



Frontal Area Calculation

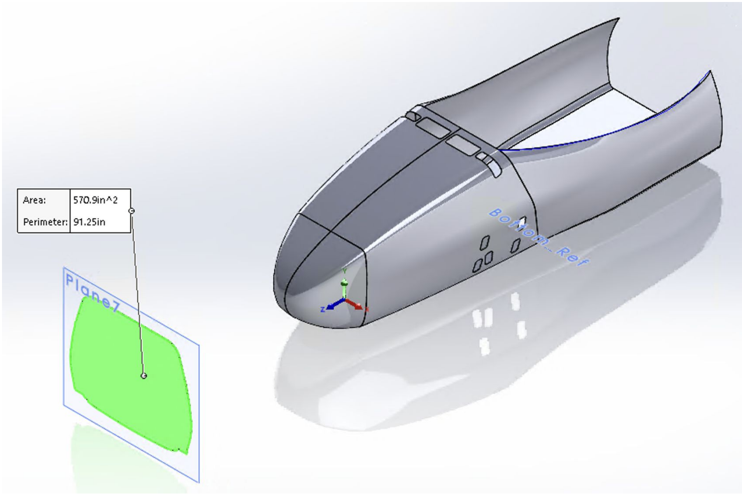
Approximately constant pressure throughout the body

- No unnecessary lift created



Frontal Area Calculation

Frontal Area: 3.96 ft^2

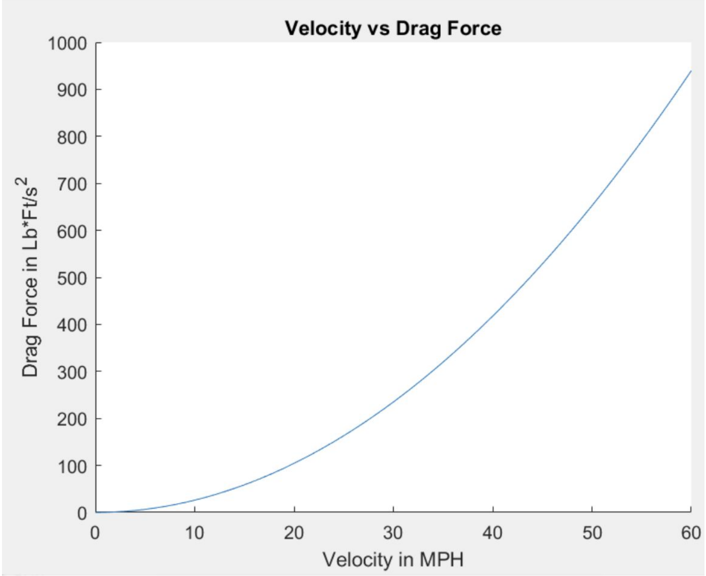


Velocity vs Drag Force

$$Area = 3.96527\ ft^2$$

$$C_d = 0.8$$

$$\rho = 0.0765\ \frac{lb}{ft^3}$$



Aerodynamics

Why we chose not to run an Aero kit:

- Heavy
- Slow
- Shaky
- Complex
- Expensive
- Bad
- Manufacturing, time, mounting are main difficulties

- An aero kit would most likely increase the lateral load transfer because the CG would go up and so would the weight.

- The downforce produced would only marginally decrease the time on a skidpad event if it produced enough load to keep the tire contact patch in contact with the road taking into account increased CG and Weight.

- In the future, the goal is to validate a full aero kit that would help with endurance, skidpad, and autocross.