SAE Formula Electric

ECE Team #3/ME Team #21

Milestone: 5

TEAM MEMBERS:

ALDREYA ACOSTA
TOMAS BACCI
DANNY COVYEAU
SCOTT HILL
STEPHEN KEMPINSKI
RYAN LUBACK
GEORGE NIMICK
SAM RISBERG
COREY SOUDERS

Objectives

- Design and fabricate a prototype of an electric vehicle that would appeal to the non-professional weekend autocross competitor.
- Comfortable
- Easy to maintain
- Reliable

Chassis

PRESENTED BY:

GEORGE NIMICK

Chassis Design – Approach

- Purpose
  - Structural Barrier
    - Debris and accidents
    - Enclosure
    - Incorporation of a body
  - Platform for mounting systems
    - Steering, Braking, Suspension, Propulsion, Driver Equipment

Chassis – Material Selection

- Major types:
  - Monocoque
  - Tubular
    - Metal
      - Steel
      - 1018 vs. 4130

	Cost	Strength	Weight	Fabrication	Total
Monocoque w/4130	8	14	8	2	32
Monocoque w/1018	10	10	8	2	30
Mild Steel	20	8	4	6	38
4130 Steel	8	12	4	6	30
Aluminum	5	5	10	3	23

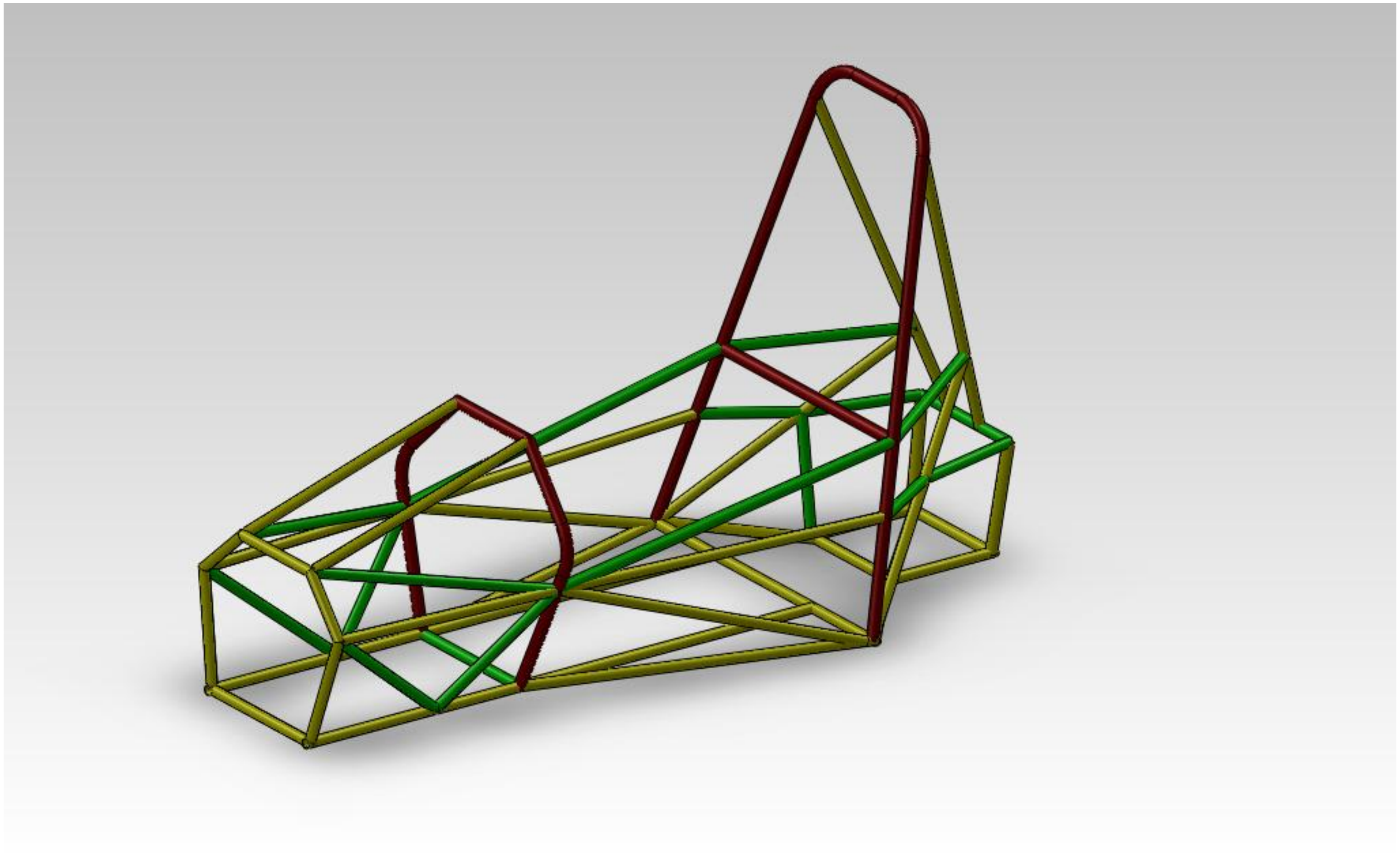
Chassis - Calculations

- Bending Stiffness
  - Proportional to *E*I*
  - Primarily based on I

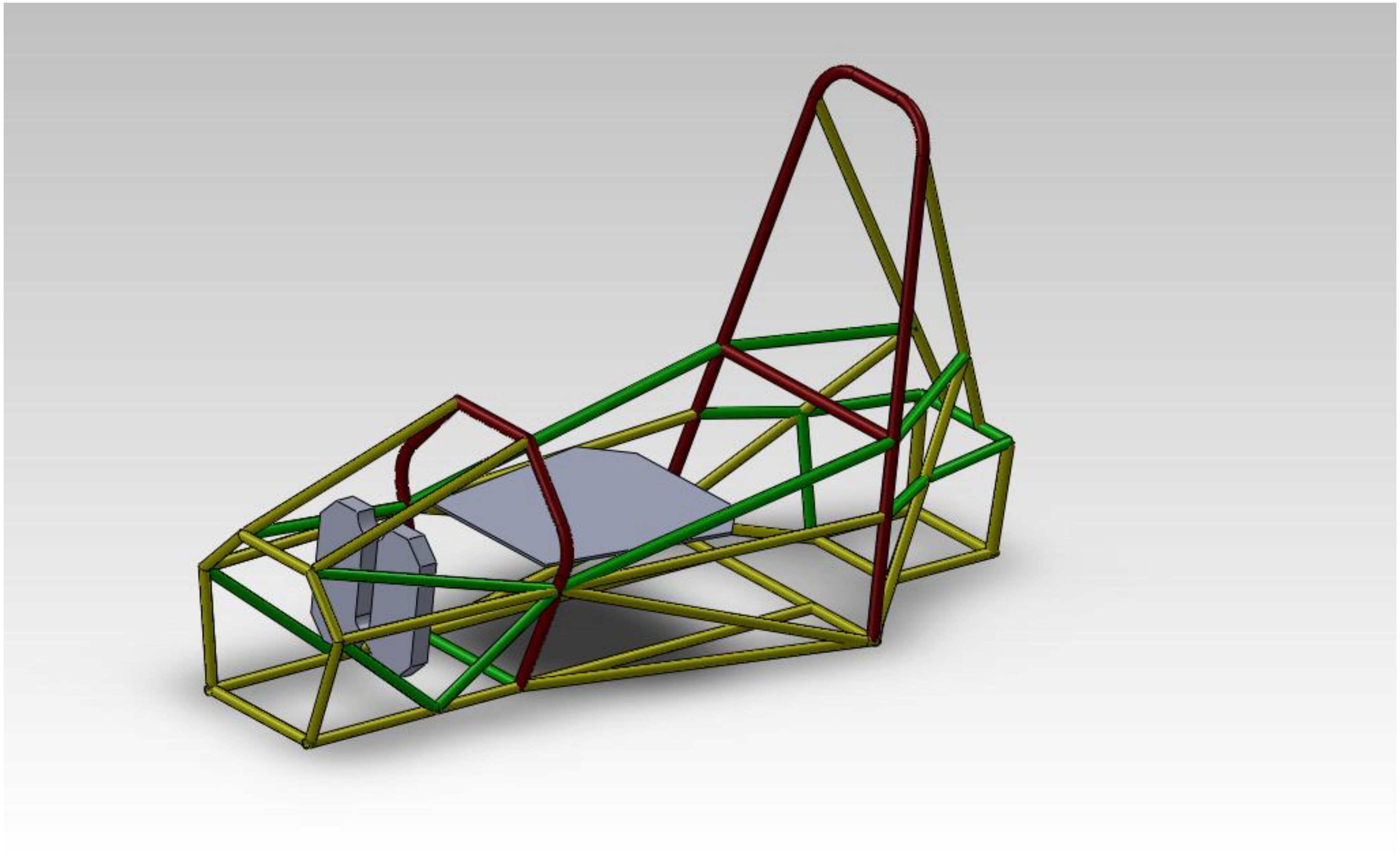
$$I = \frac{\pi}{4}[(r_o^4 - r_i^4)]$$

- Bending Strength
  - Given by $\frac{S_y I}{c}$
- Compare to requirements in rules

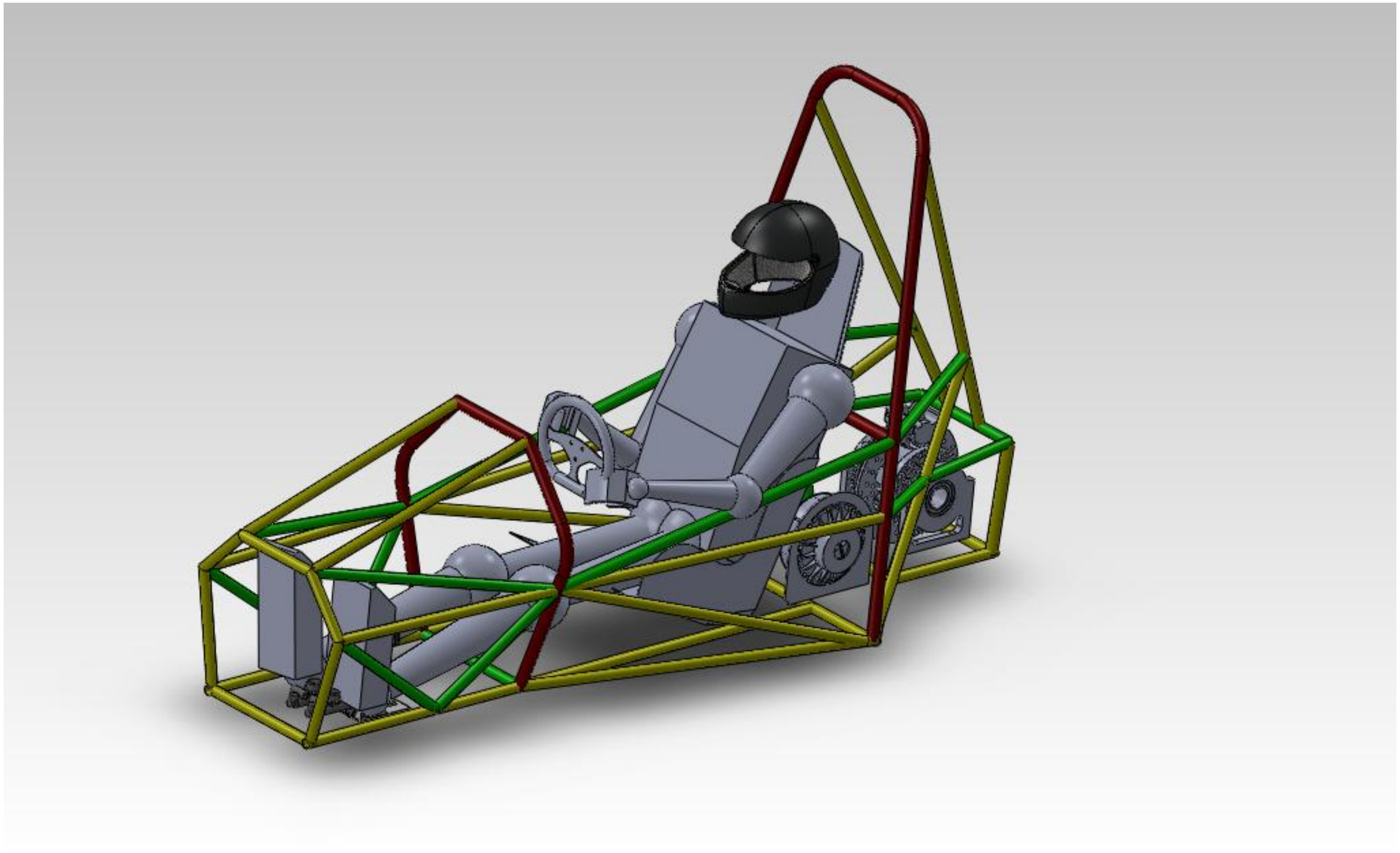
Chassis



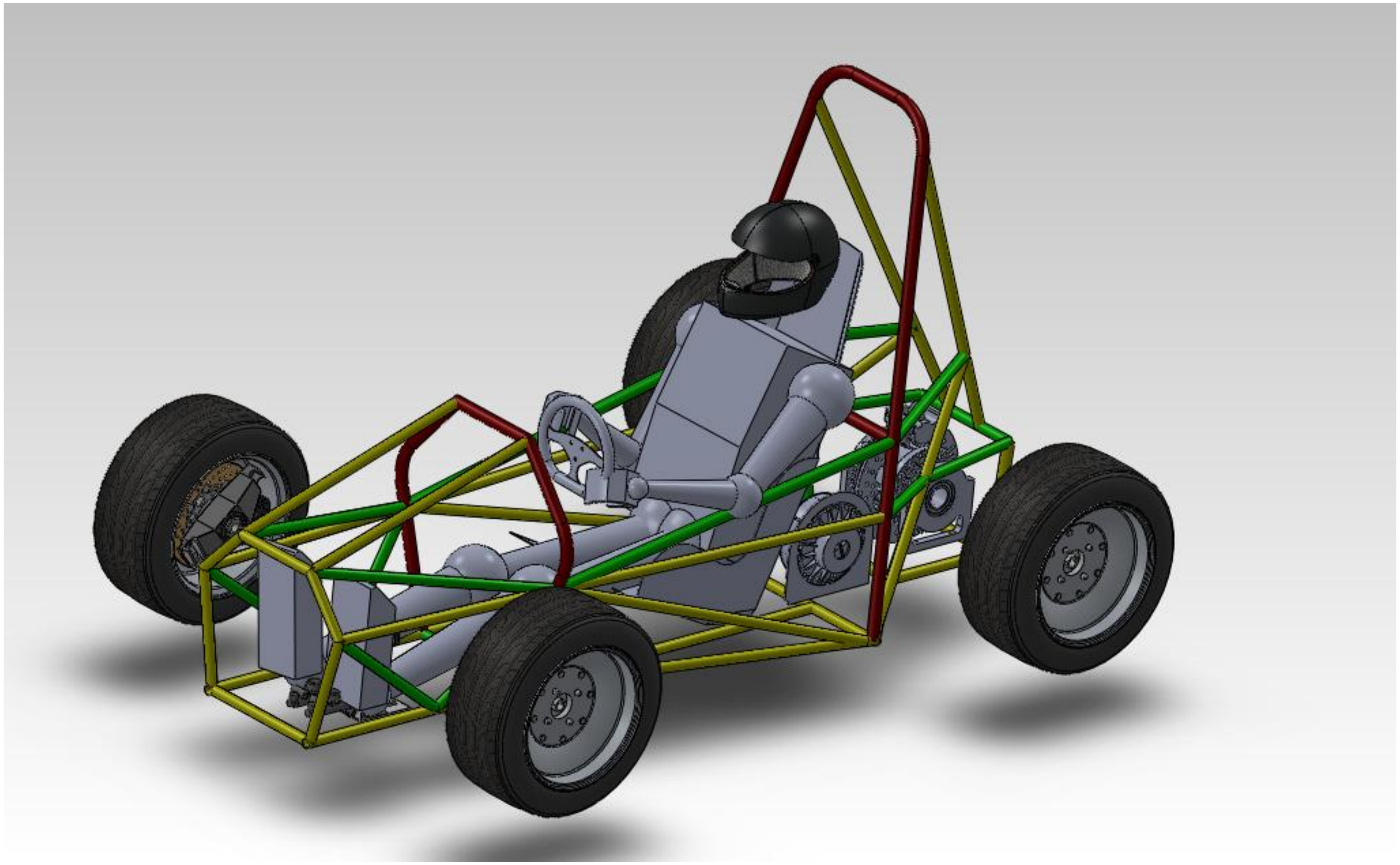
Chassis – Test Plan 1



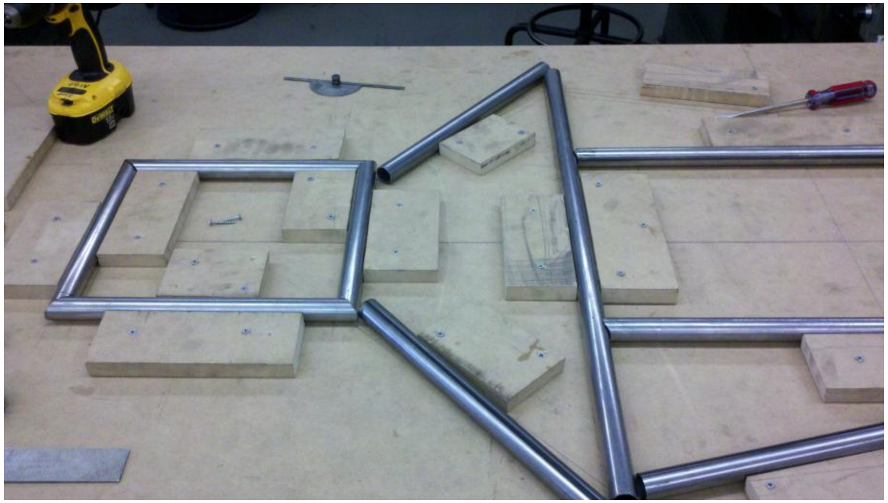
Chassis – Test Plan 2



Chassis



Chassis

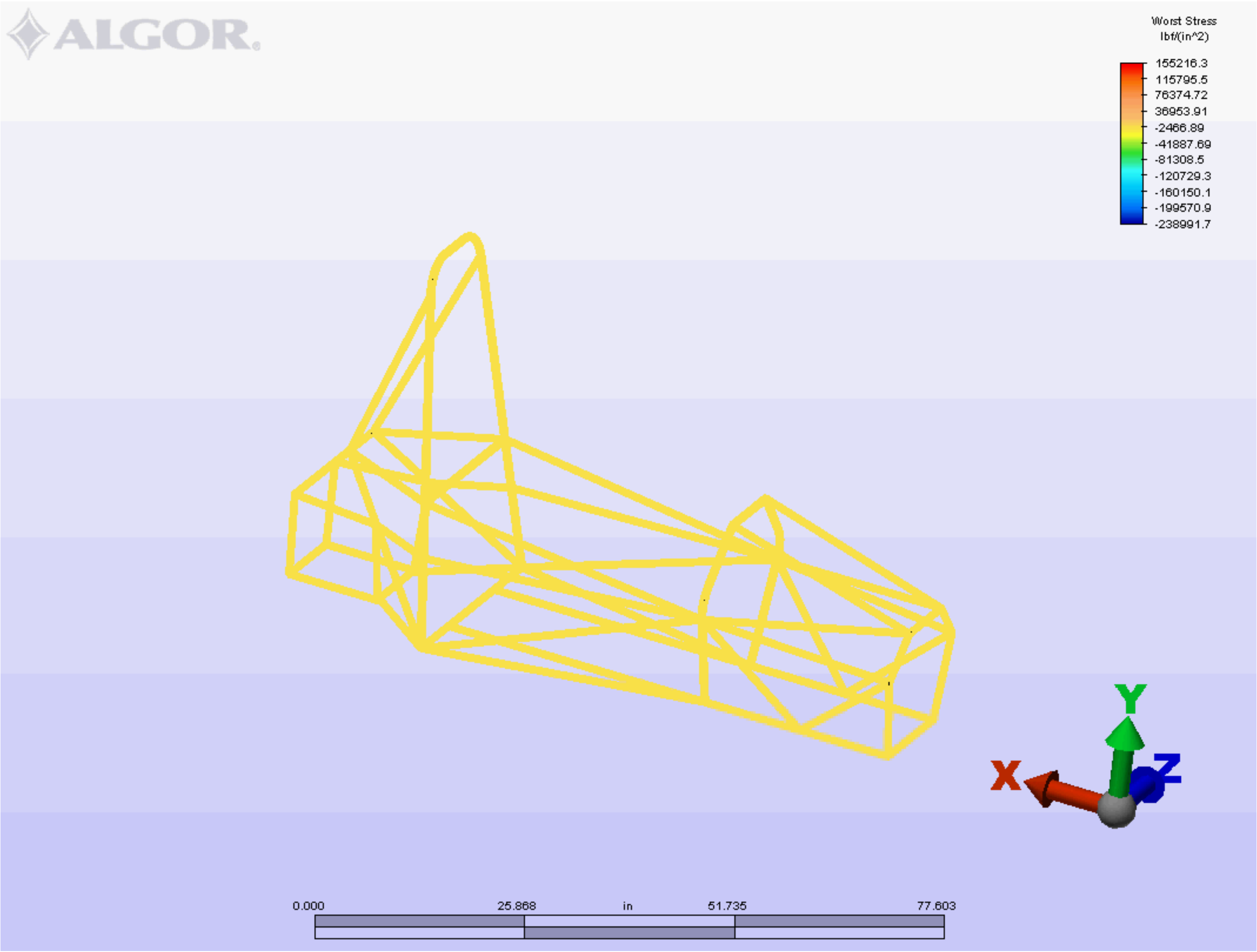


Jig fabrication
•Placement sketched
•Blocks screwed into position
•Members cut and placed

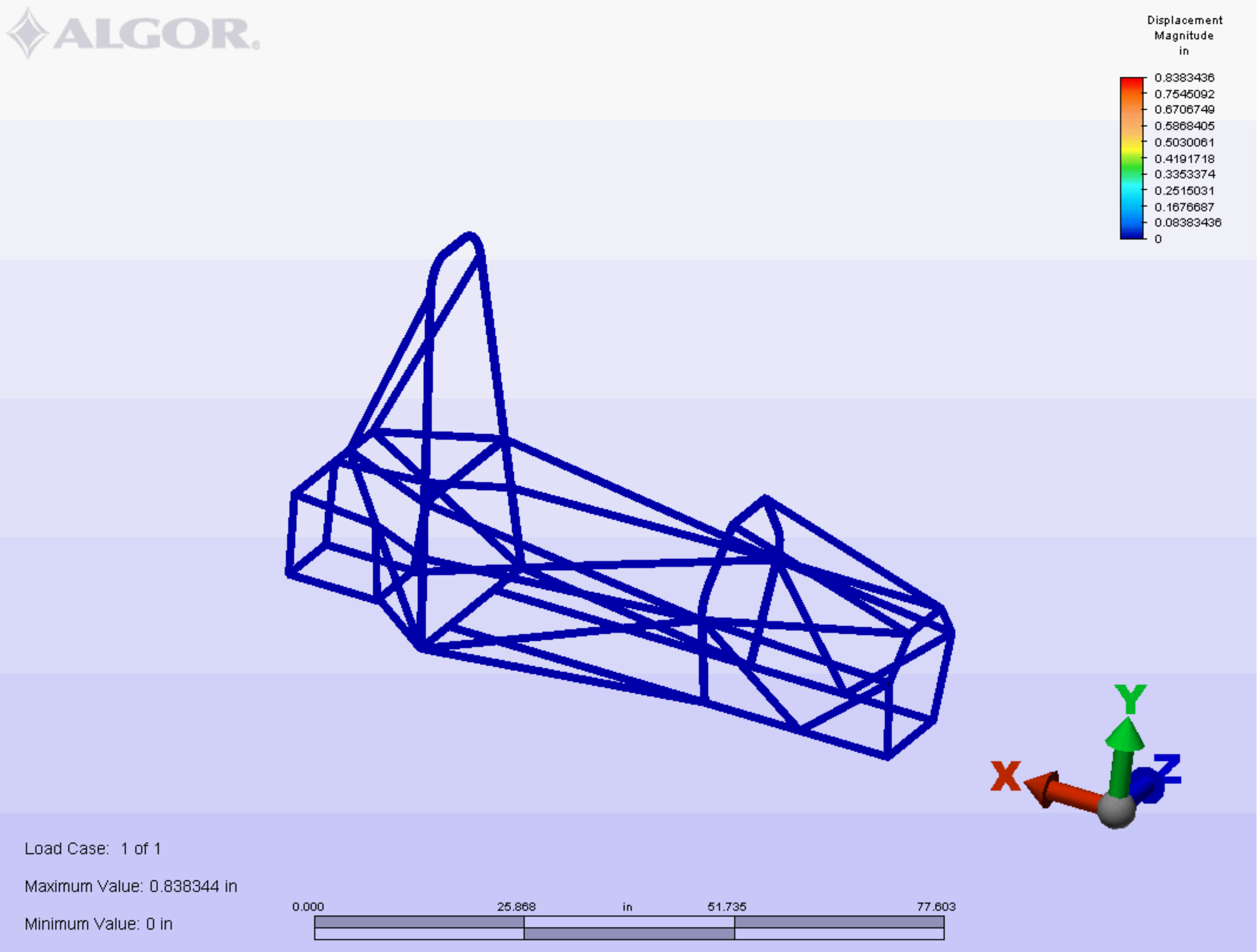
FEA Tests Performed

- Finite Element Analysis
- Difficult to perform and properly assess
- Tests performed
  - Front Impact
  - Rear Impact
  - Side Impact
  - Full Suspension Loading
  - Single Side Loading for suspension

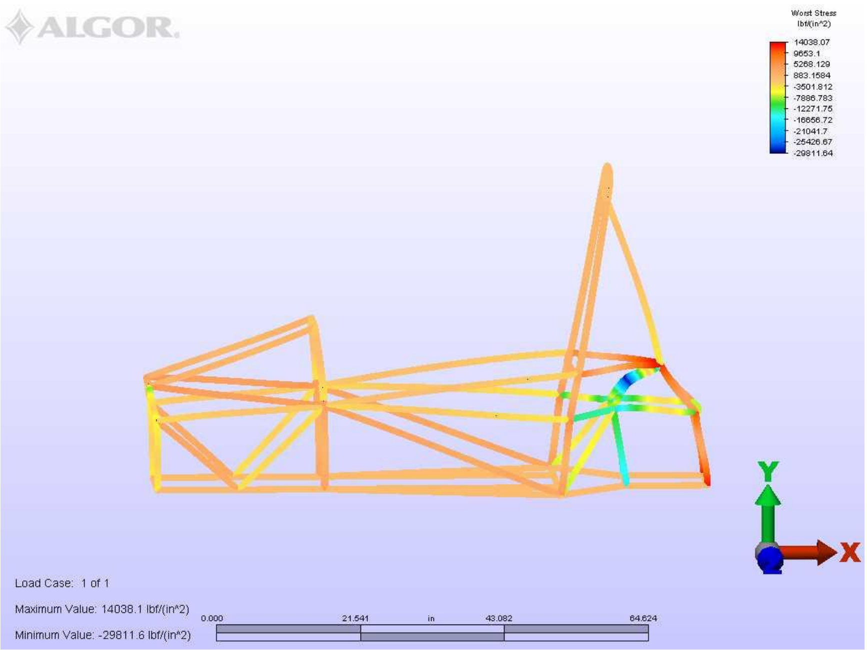
Front Impact - Worst Stress



Front Impact - Displacement

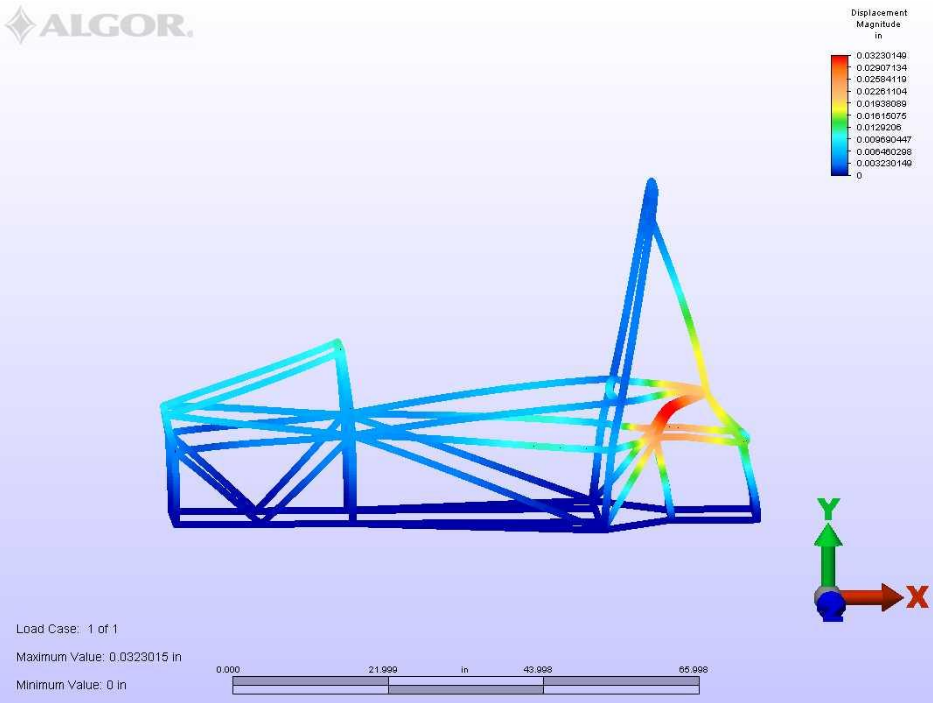


Full Suspension Test



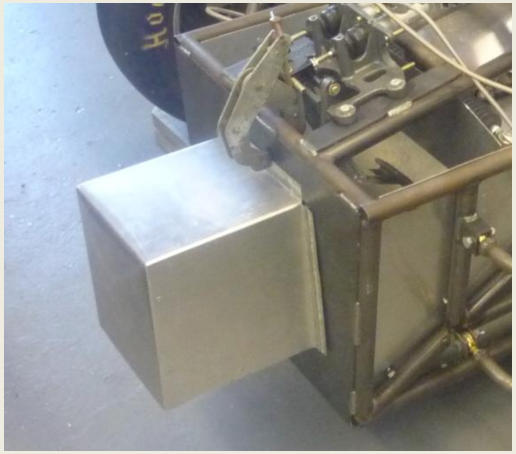
Displays Worst Stresses

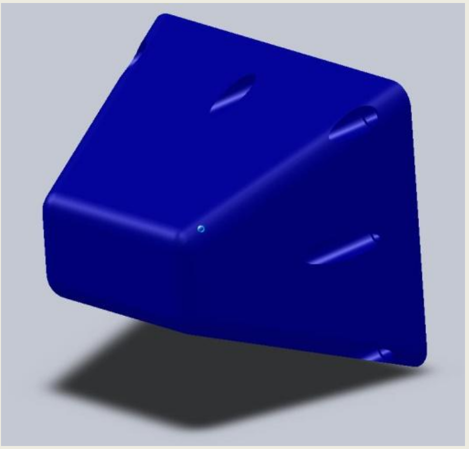
Displays Displacement Magnitude



Impact Attenuator

- Material Selection
  - Hexcel Aluminum Honeycomb
    - ½" thick and ½"cells
    - 190psi
  - Dow Impaxx 700 Energy Absorbing Foam
    - 121psi
- Using Impaxx Foam
  - Average of 20G
  - Dimensions: 10" x 10" x 6"



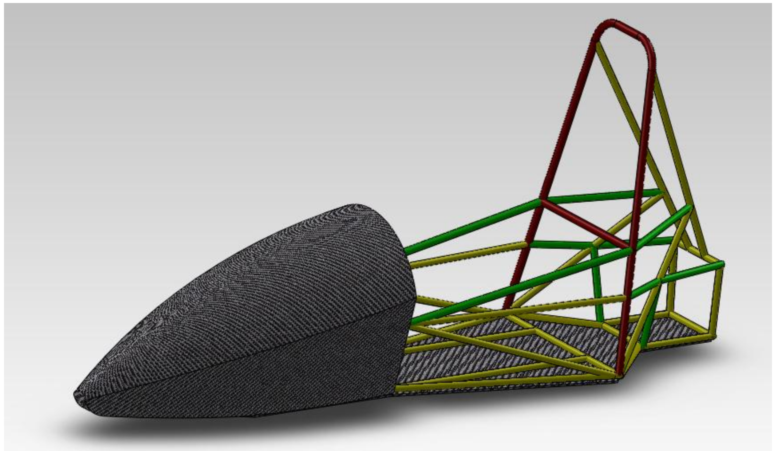


Mold

PRESENTED BY:
COREY SOUDERS

Nose Cone

- MDF
- Insulation Foam
- Plaster
- Fiberglass
- Carbon Fiber



Suspension

PRESENTED BY:

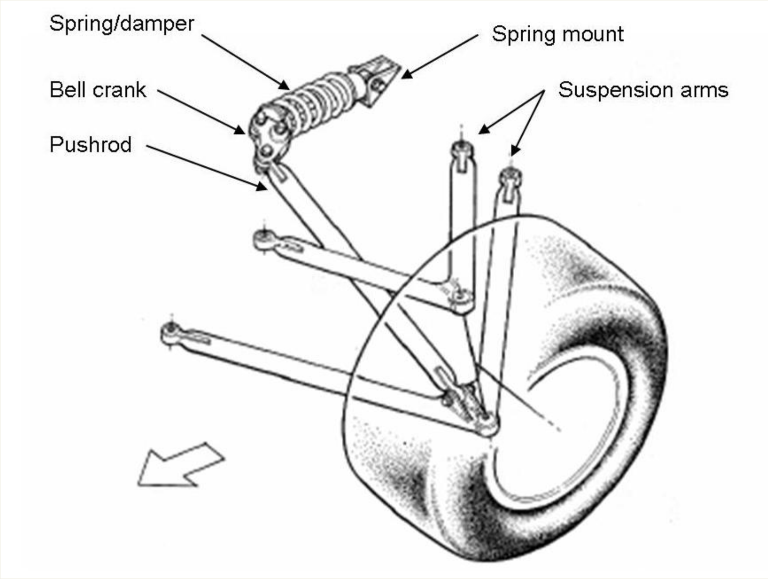
STEPHEN KEMPINSKI

What’s to come

- Brief overview
- Current progress
- Deadline
- Test plan

Suspension Design Overview

- Independent
- Short-Long Arm
- Push-rod



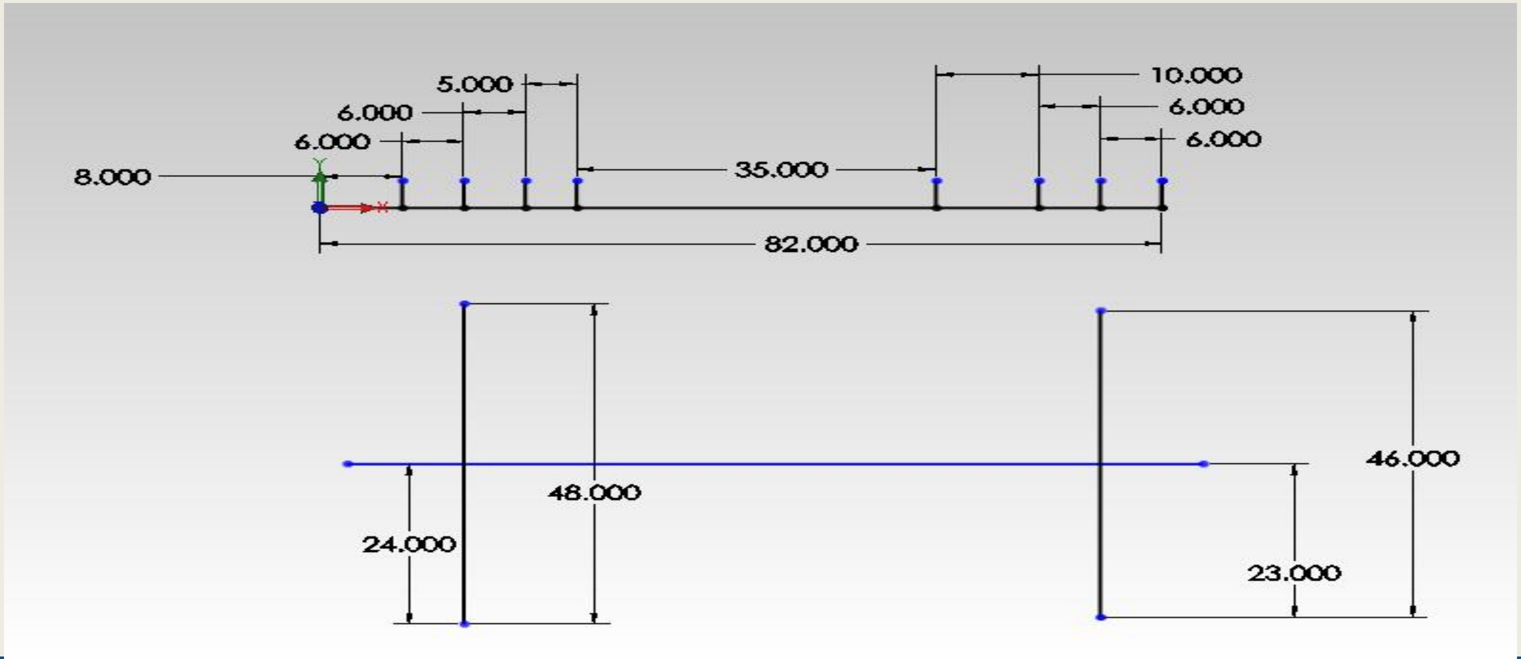
- Better ride quality
- Improved handling
- fully adjustable
- Short Long Arm Suspension
- Lower A-Arm is longer than the Upper A-Arm
- Reduced changes in camber angles
- Reduces tire wear
- Increases contact patch for improved traction

Design Method

- Determine Wheel-Base, Track-Width
- Design for Front View Swing Arm
- Design for Side View Swing Arm

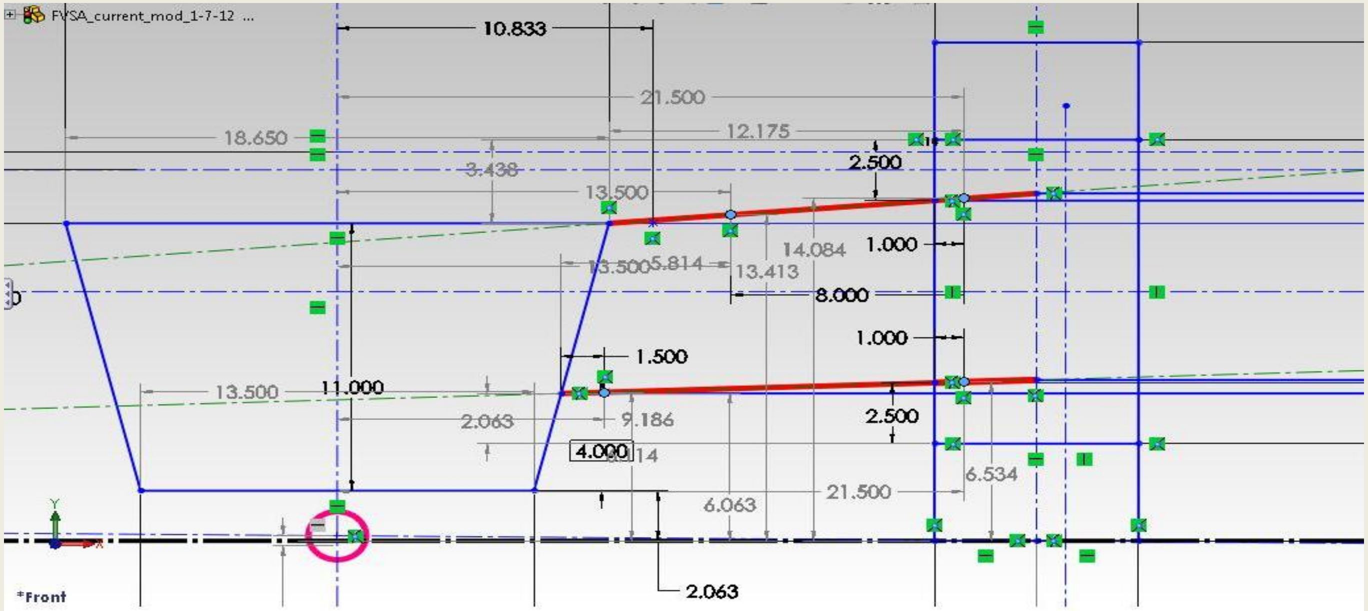
Suspension Layout

- Compromise between chassis and suspension design
- Averaged from well scoring FSAE teams
- Basis of suspension design



Front View Swing Arm(FVSA)

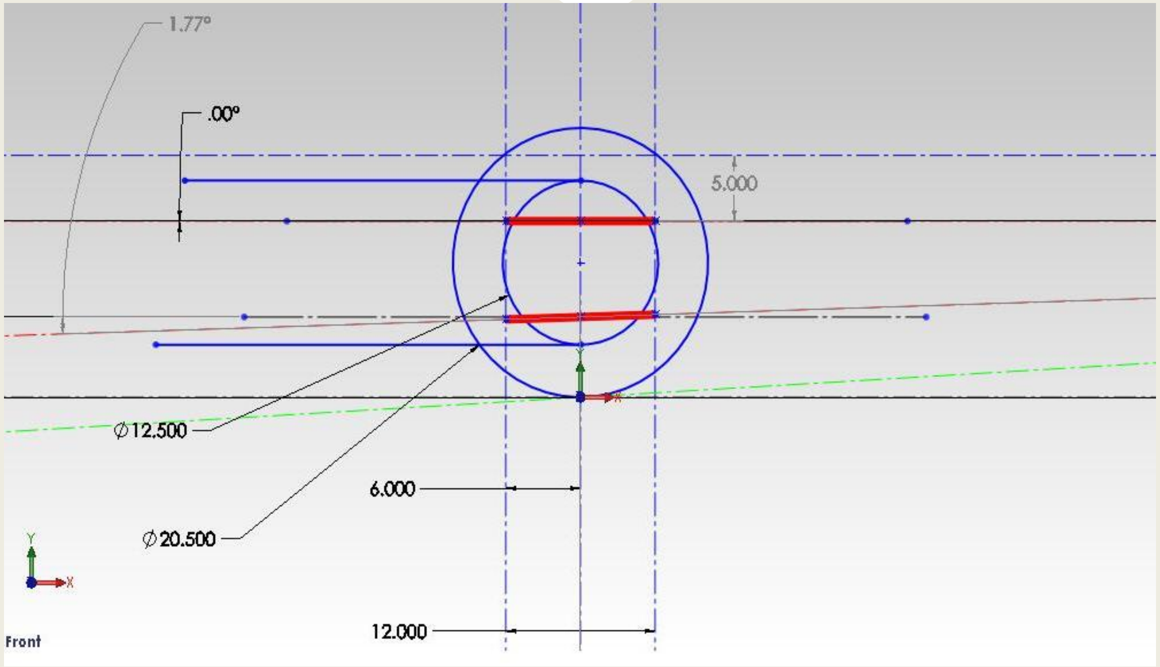
Determining the Geometry from a front 2D plane



- Static case
- Instant center location
- Roll instant center location
- FVSA length

Side View Swing Arm (SVSA)

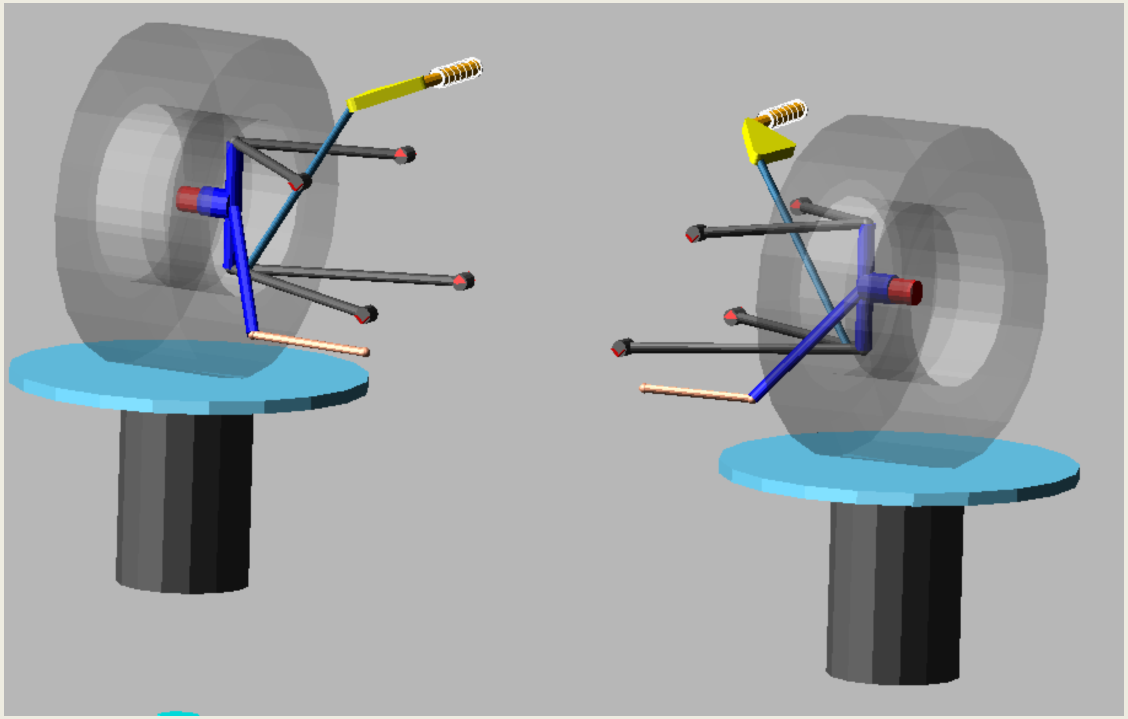
Determining the Geometry from a side 2D plane



- Static case
- Anti features
- Instant center location
- SVSA length

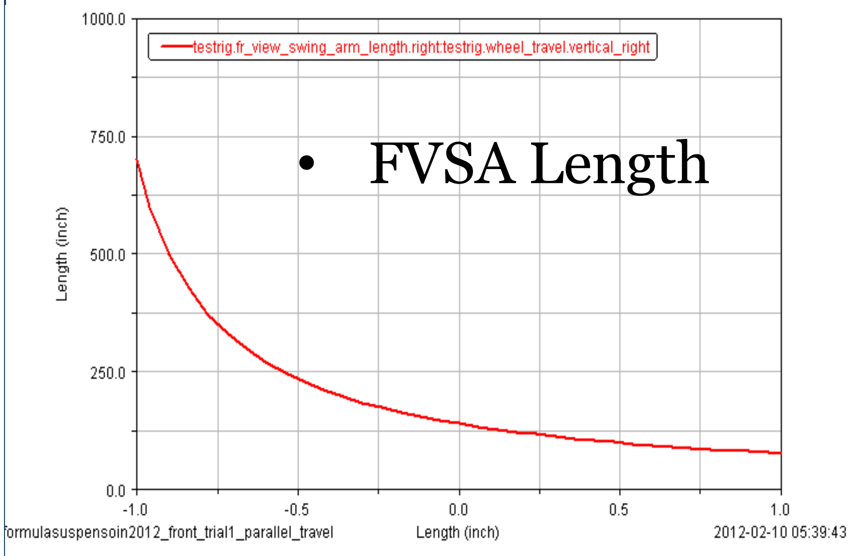
Adams-Car

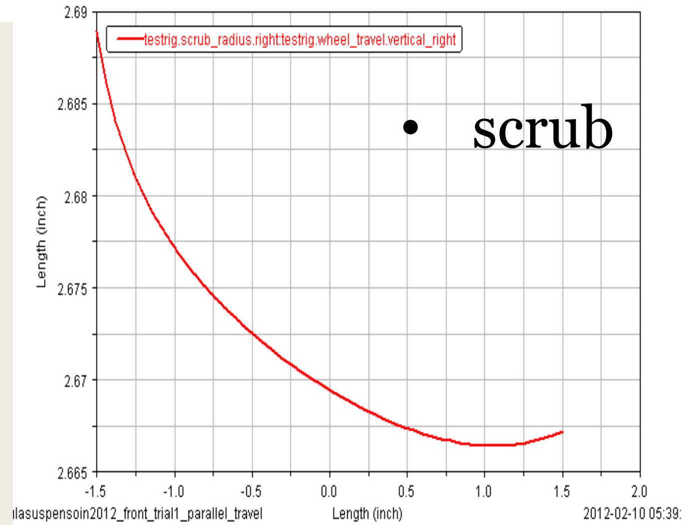
- Virtual product development software
- Simulation of suspension control characteristics



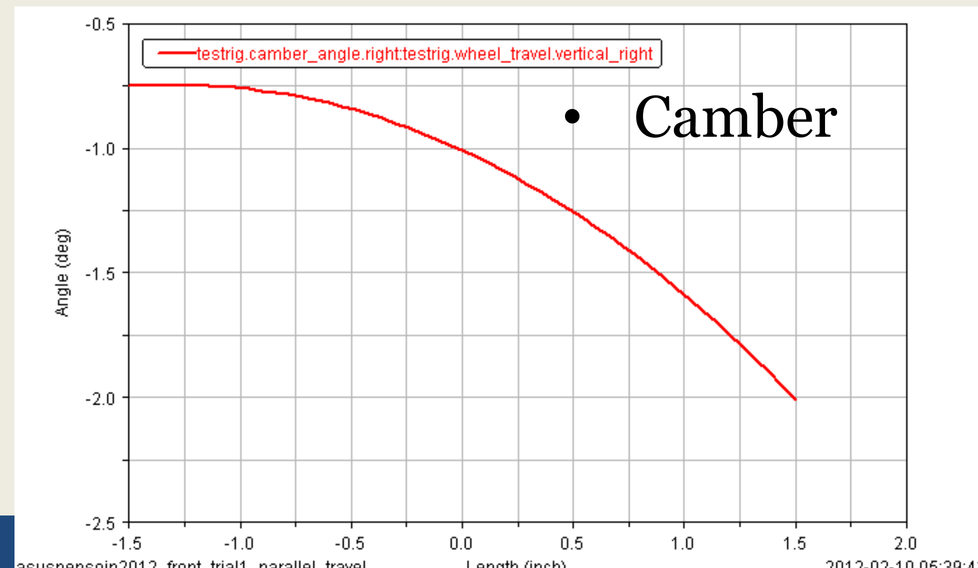
Stephen Kempinski

FVSA results

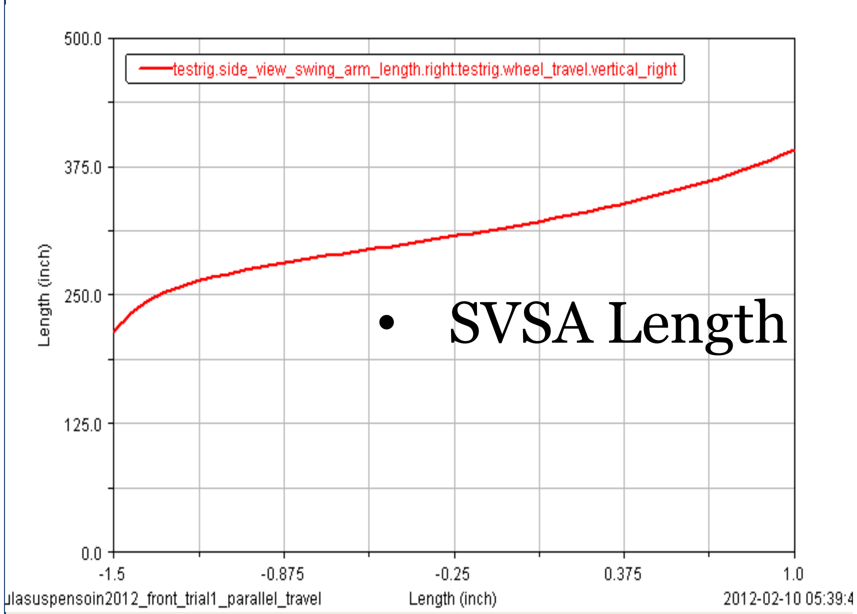




- Minimize camber change
  - negative gain
- Reduce jacking effect
- Reduce scrub

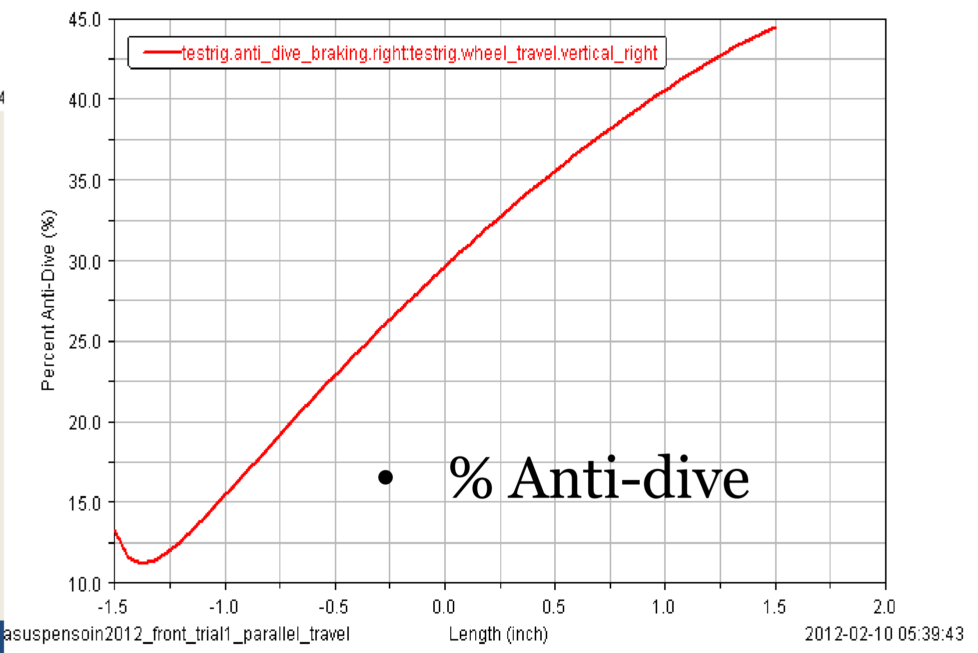


SVSA results



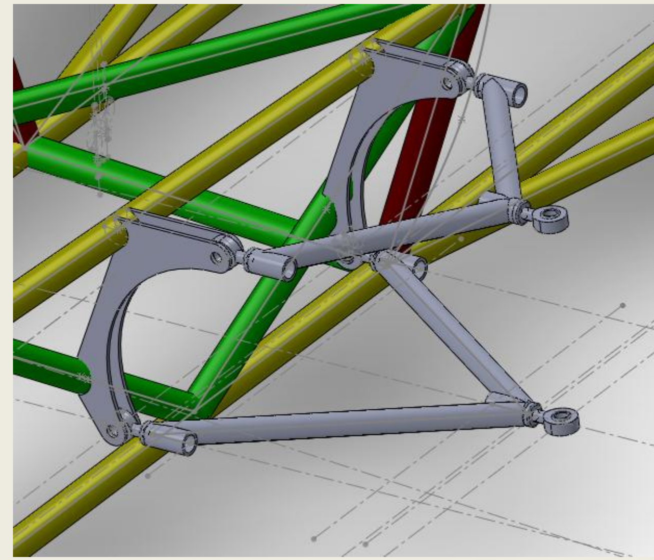
- % anti is relative to the amount of force carried in the members

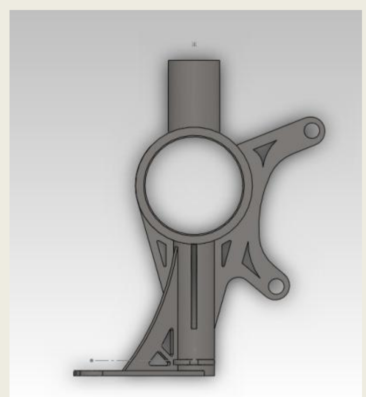
- Static conditions
- 30% front anti-dive
- 15% rear anti-lift

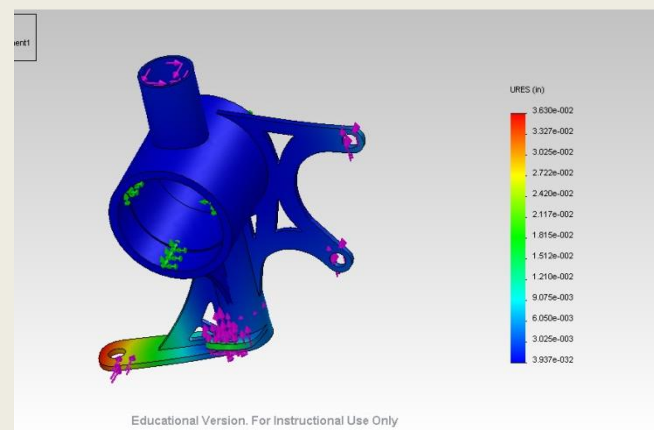


A-arm and Upright design

- Connect sprung and un-sprung mass.
- Adjustable with Heim joint
- Individual Bracket attachment
- Light weight upright
  - Under 2 lbs







Current Status

- All suspension design and simulation is completed
- Construction phase is underway.

Test plan

- Two stage plan
  - Fitment
  - Adjustment

Test 1

- Objective:
  - Fitment to rules and design
- Procedure:
  - Measure accurate mounting locations for suspension brackets.
    - Ensure points are squared along longitudinal center
  - Final placement and attachment

Test 2

- Objective:
  - Set up
    - Determine optimal characteristics
- Procedure:
  - Test and tune suspension while other tests are being run
    - Ensure toe, caster, camber, spring rate, and tire pressure are adjusted for optimal handling

Steering

PRESENTED BY:

TOMAS BACCI

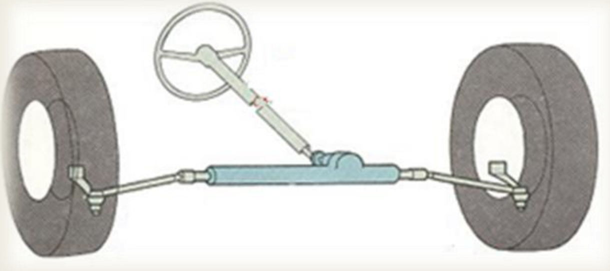
Steering Design Overview

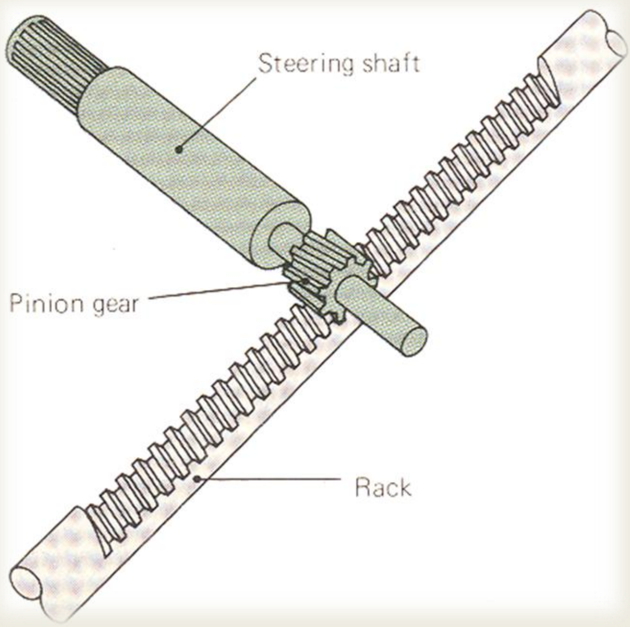
- Hardware, Steering Geometry
- Simulation Results
- Progress on Assembly Build
- Test Plan

Steering - Hardware

Rack and Pinion steering

- Rotation on wheel displaces a rack horizontally
- Tie rods connect rack to uprights (hubs)
- Rack is low mounted, tilted
- U-joint transfer motion at the wheel to the rack

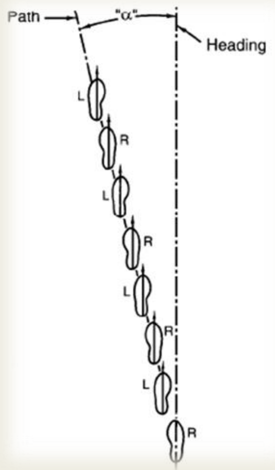


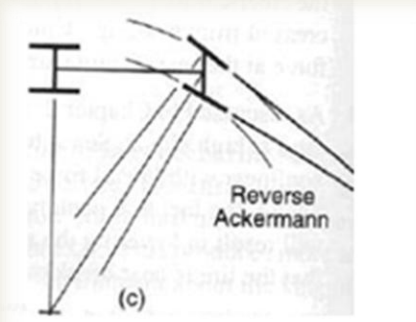


www.motorera.com

Steering Geometry

- Reverse Ackermann / Parallel steering Geometry
  - Desirable for racing applications
  - In a turn, outside tire is more loaded
    - Corresponds to a higher slip angle
  - Effect not drastic: 1° Reverse Ackerman Design Goal

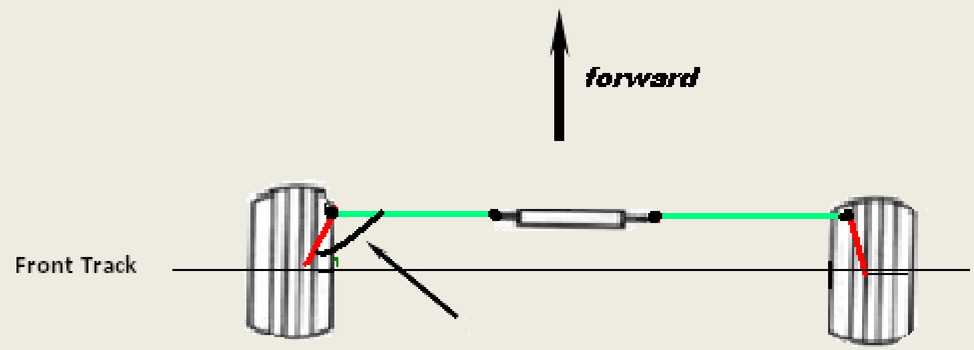




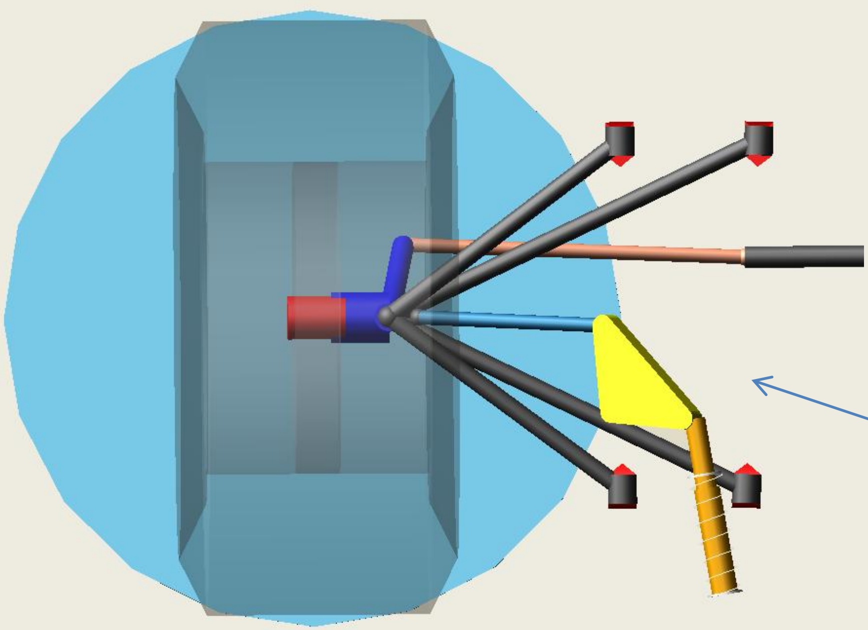
19.2 Ackermann steering geometry.

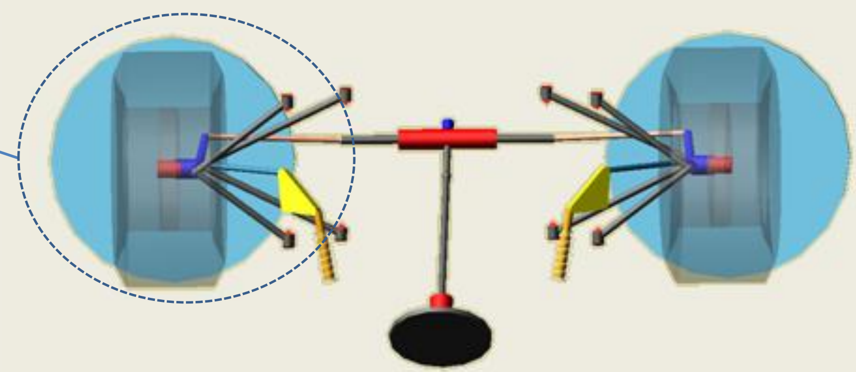
From Vehicle Design Slides (Hollis)

How to Obtain Reverse Ackermann



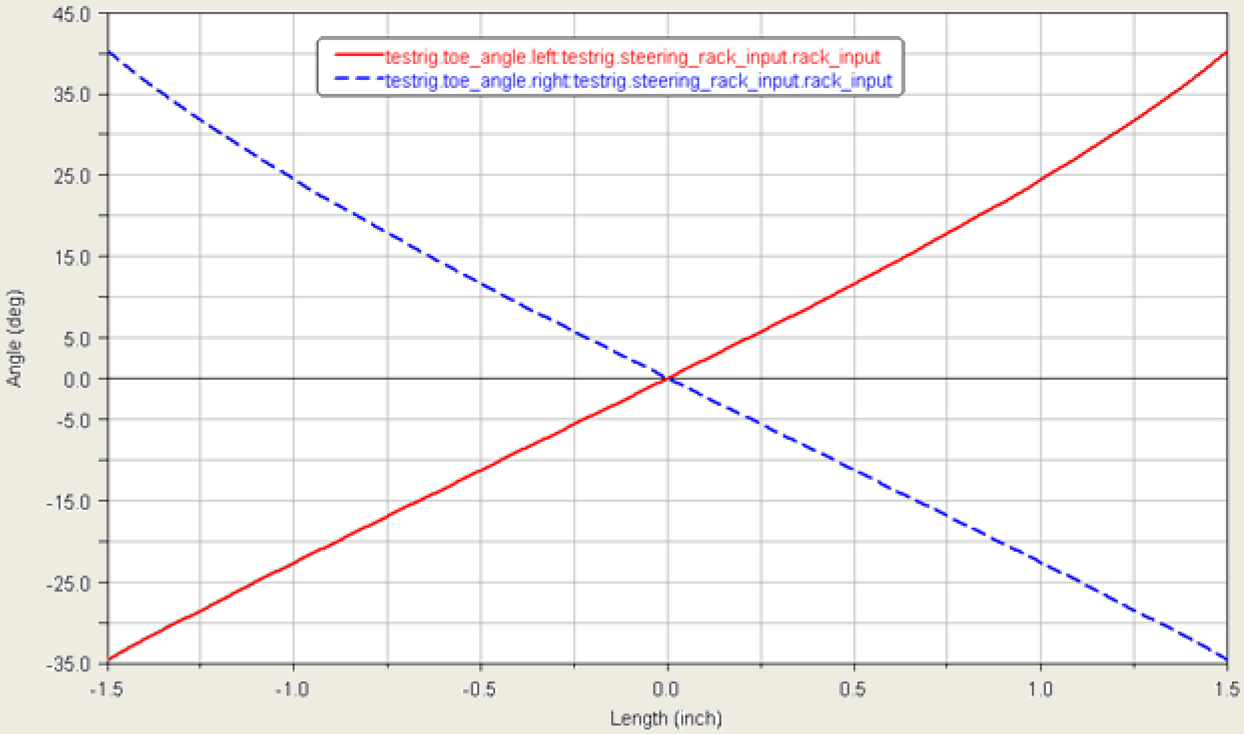
Angle	Geometry
90°	Parallel
<90°	Ackermann
>90°	Reverse Ackermann



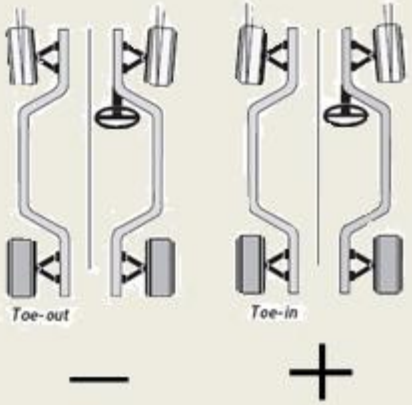


Simulation Results

Toe angle vs. Rack Travel input

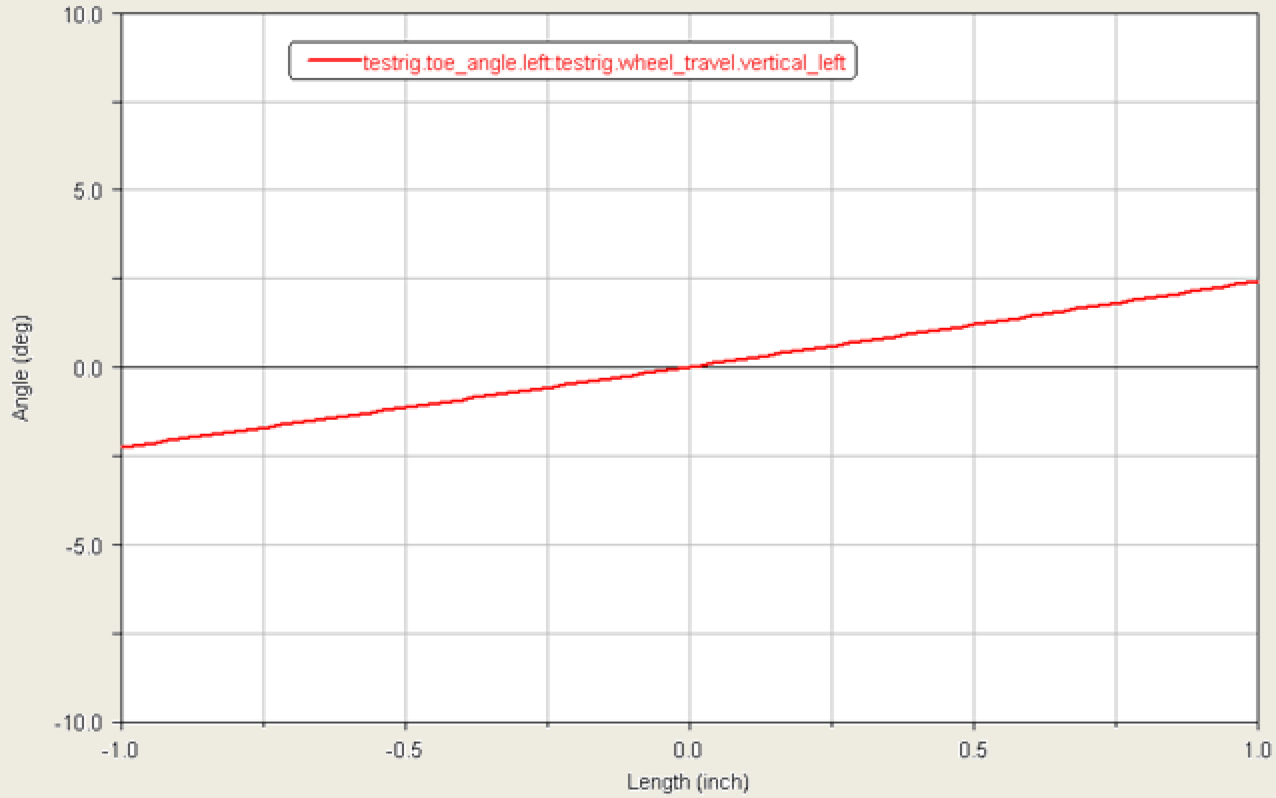


Wheel:
Right ,Left



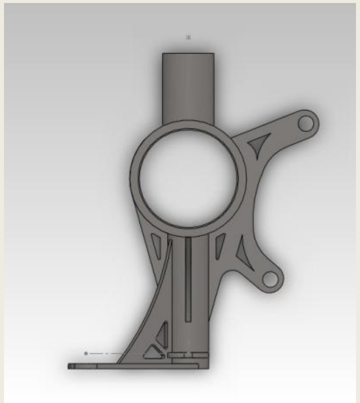
Simulation Results

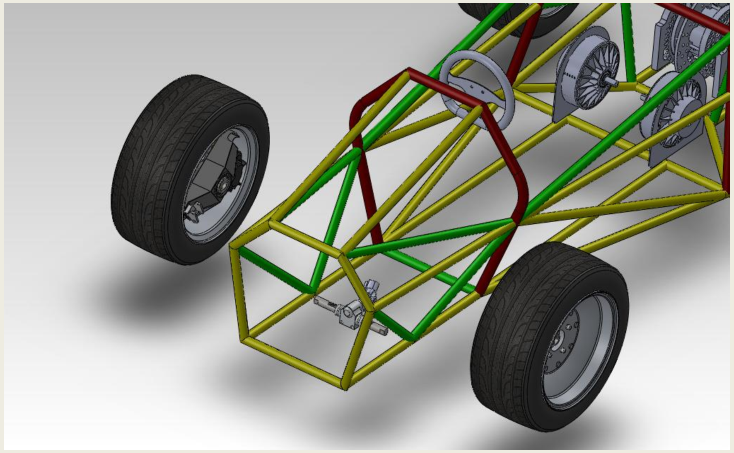
Toe Angle (Bump Steer) vs. Vertical Wheel Travel



Assembly Progress

- Components purchased and received
  - Build in progress
  - Hub has been Modeled
    - Set to be fabricated





Steering Test Plan

Steering Test # 1:

Objective: Create Reverse Ackermann Geometry,

Procedure: Using Adams Car software, tie rod locations must be input to the model and display the desired geometry, minimal bump steer, and be non-binding.

Results: Model completed. Rack placement determined. Tie rod pickups on hub and on rack finalized.

Steering Test Plan

- ***Steering Test # 2:***

  Objective: Verify functionality of final steering build

  Procedure: Each wheel's steer angle must be assessed from the same input rack travel. The free play in the steering will be measured from the wheel must be < 7 °. Test functionality of steering wheel quick disconnect.

  Results: Pending Completion of Assembly.

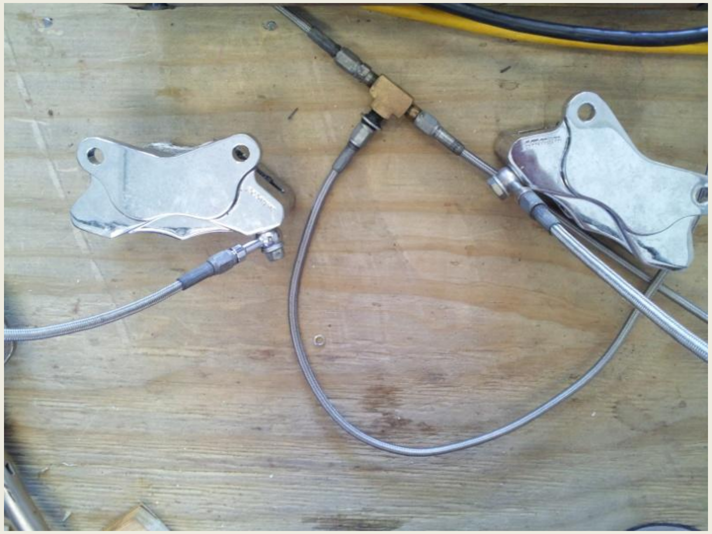
  - ~ 1 Week

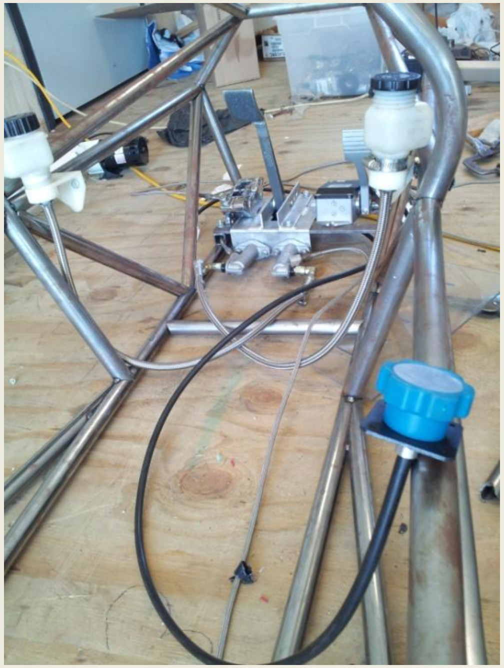
Brakes and Components

PRESENTED BY:
SAM RISBERG

Our Formula Hybrid Braking System

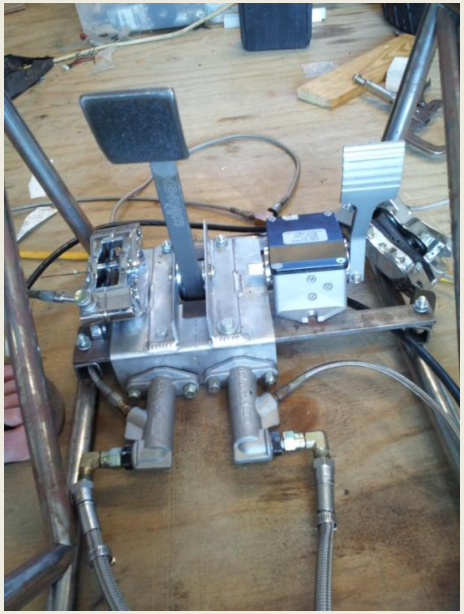
- Overall system includes two front brake calipers, one rear caliper, brake pedal assembly and brake bias adjuster.





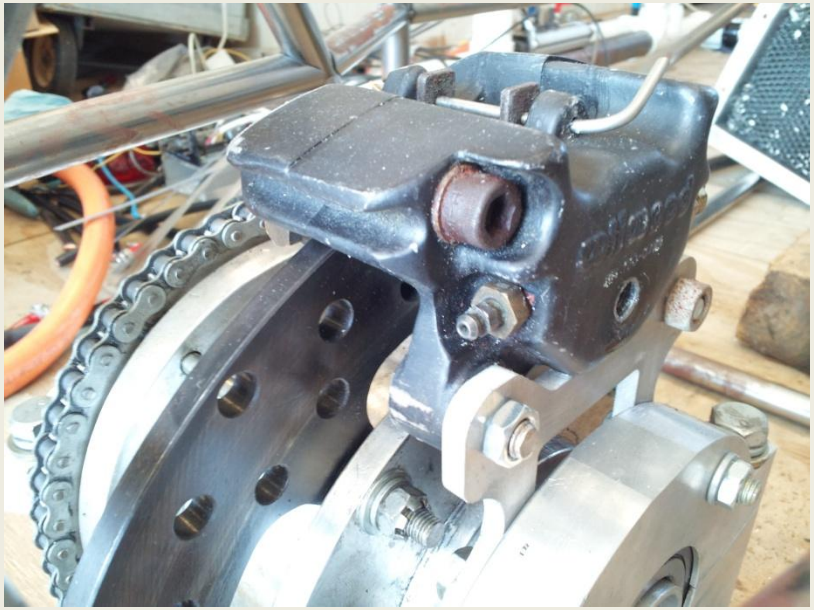
Our Formula Hybrid Braking System

- The brake bracket has various adjusting points and can accommodate many drivers.



Inboard Braking

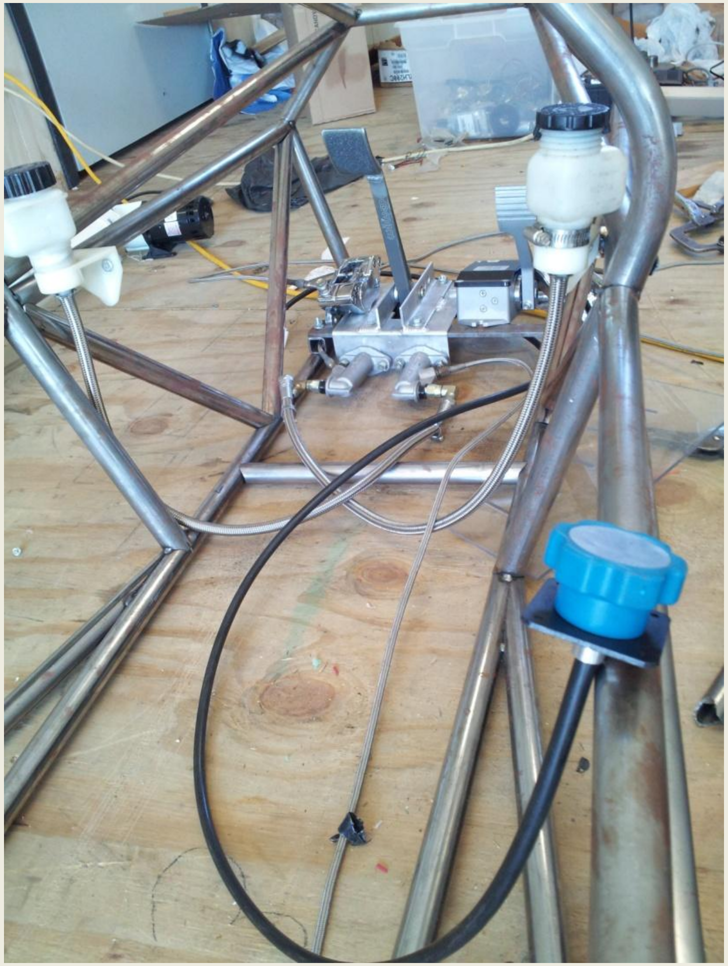
Inboard mounted brake rotor and caliper reduces the un-sprung weight and simplified the rear braking system



Brake bias bar

- The bias bar will allow us to put more brake force bias in the front or rear.

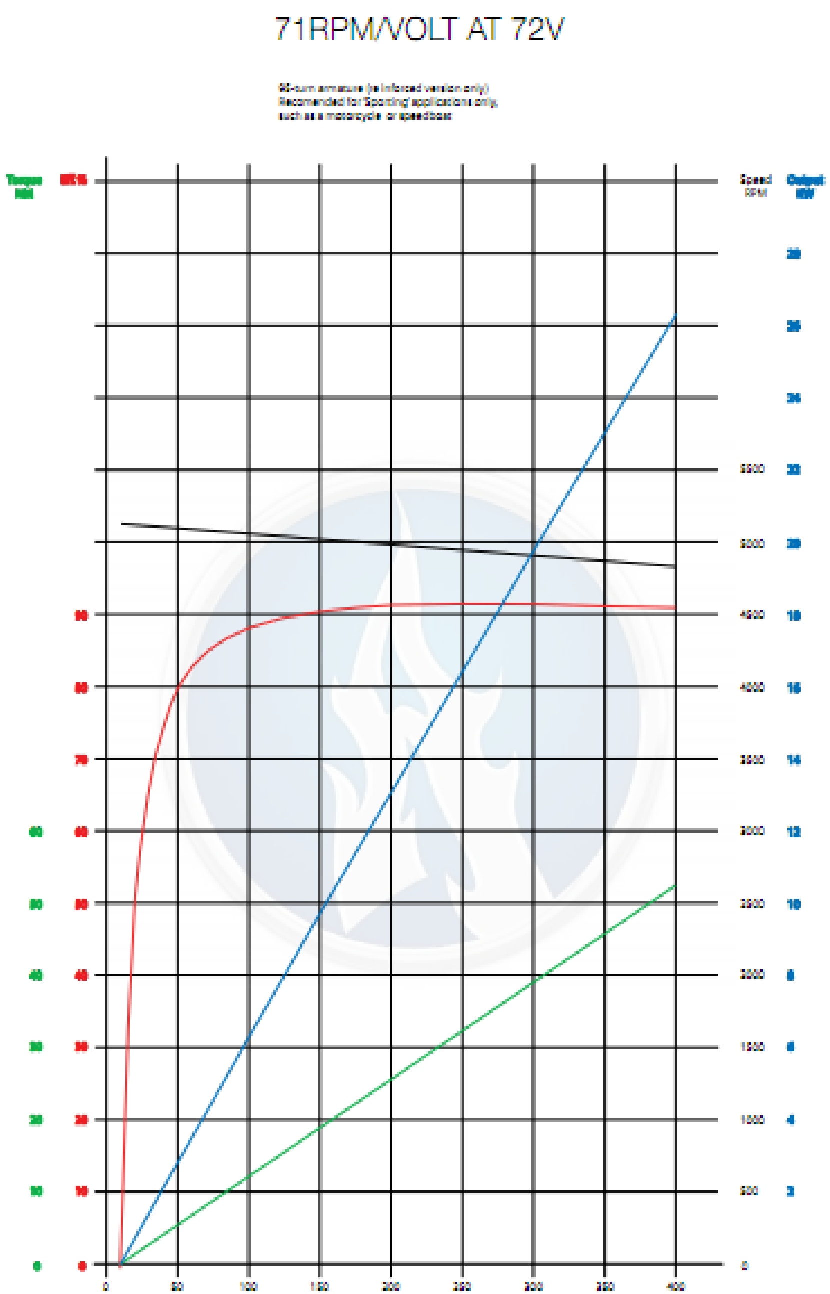
Brake Bias Adjusting Knob



Battery System, BMS, Other electrical components

PRESENTED BY:

GEORGE NIMICK (FOR DANNY COVYEAU)

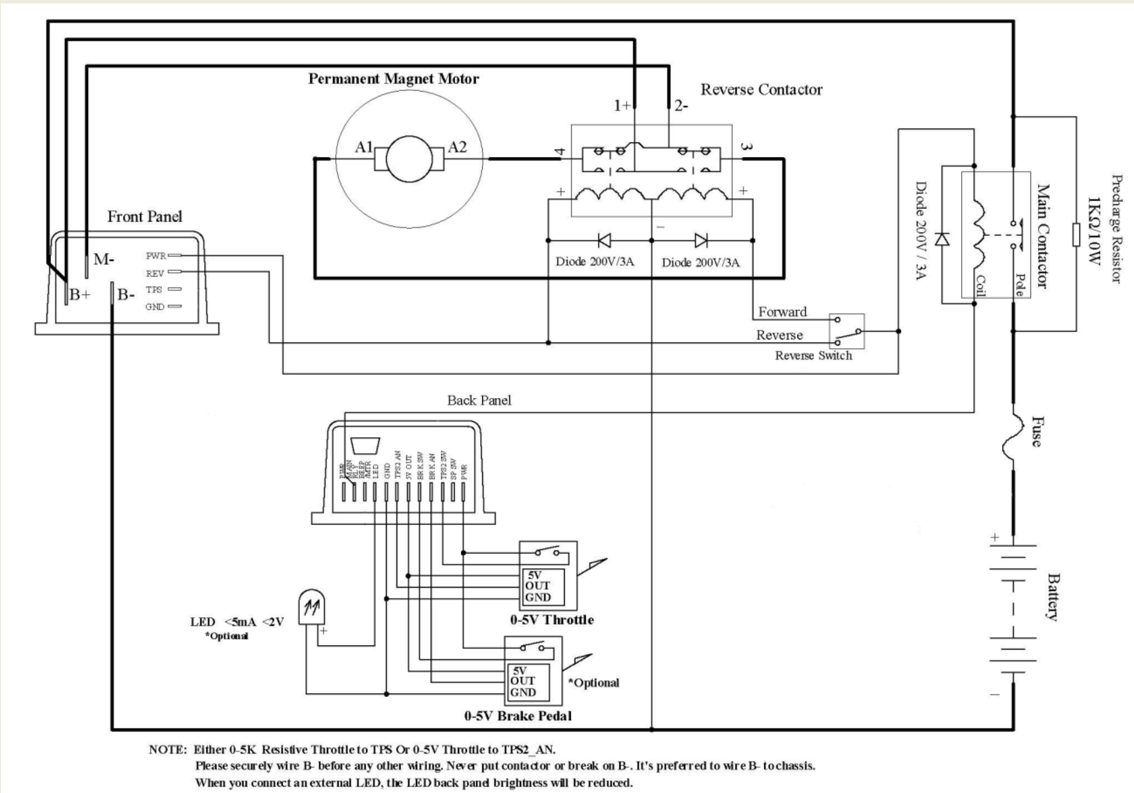


Danny Covyeau

Agni 95-R Motor

- Peak Efficiency: 93%
- Constant Torque: 42 Nm
- Continuous Output Power: 22 kW
- Weight: 24 lbs
- Popular, dependable choice among Formula Hybrid teams

Kelly KD72501 Motor Controller

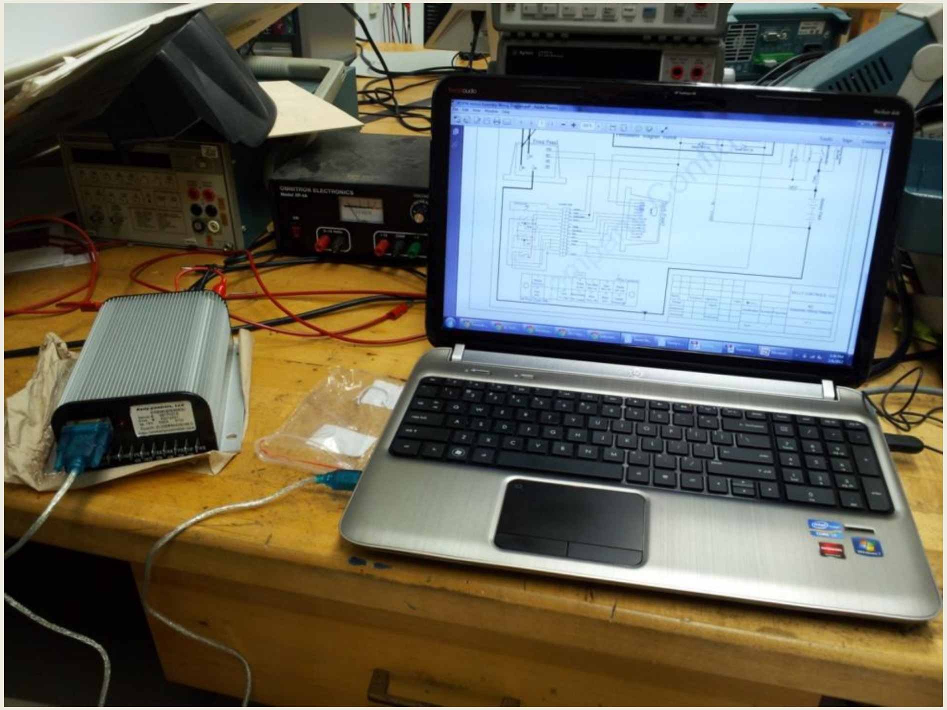


** Courtesy Kelly KD User Manual*

- Optical Isolated:
  - throttle potentiometer
  - brake potentiometer
  - switches
- Uses high power MOSFETs to achieve ~99% efficiency
- 200 Amps continuous
- 500 Amp peak for 1 minute
- Built in regenerative braking that can recapture up to 100 amps
  - Still requires mechanical brakes
- Programmable controller with a user-friendly GUI

Motor & Controller Testing

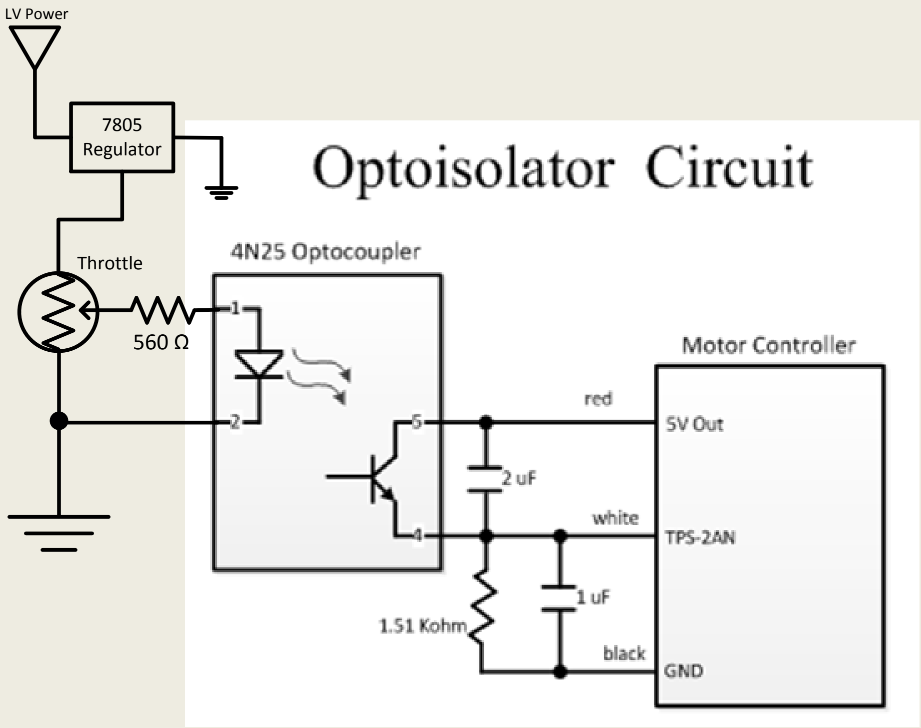
Objective:
Verify that the electric motor controller works properly by testing that the forward and reverse functions of the motor operate



Desired Result:
The controller will be able to accelerate in both the forward and reverse directions

Status:
Communication with the controller was successful and has been able to be programmed. High DC voltage power supply was used

Optoisolator Circuit Testing



- **Objectives:**
  - The LV and HV grounds have a minimum resistance of 40,000 ohms between them
  - The output voltage of the circuit corresponds linearly with the input voltage of the circuit
- **Test Plan:**
  - Use a low voltage variable DC power supply and a voltmeter to test the optoisolator circuit will be built.
- **Desired Result**:
  - The input and output voltage of the throttle should vary from zero to five volts linearly.

Speedometer Testing

- Calibrated Using Sine Wave Generator
- Requires at least 500 pulses per mile from a Hall Effect Sensor

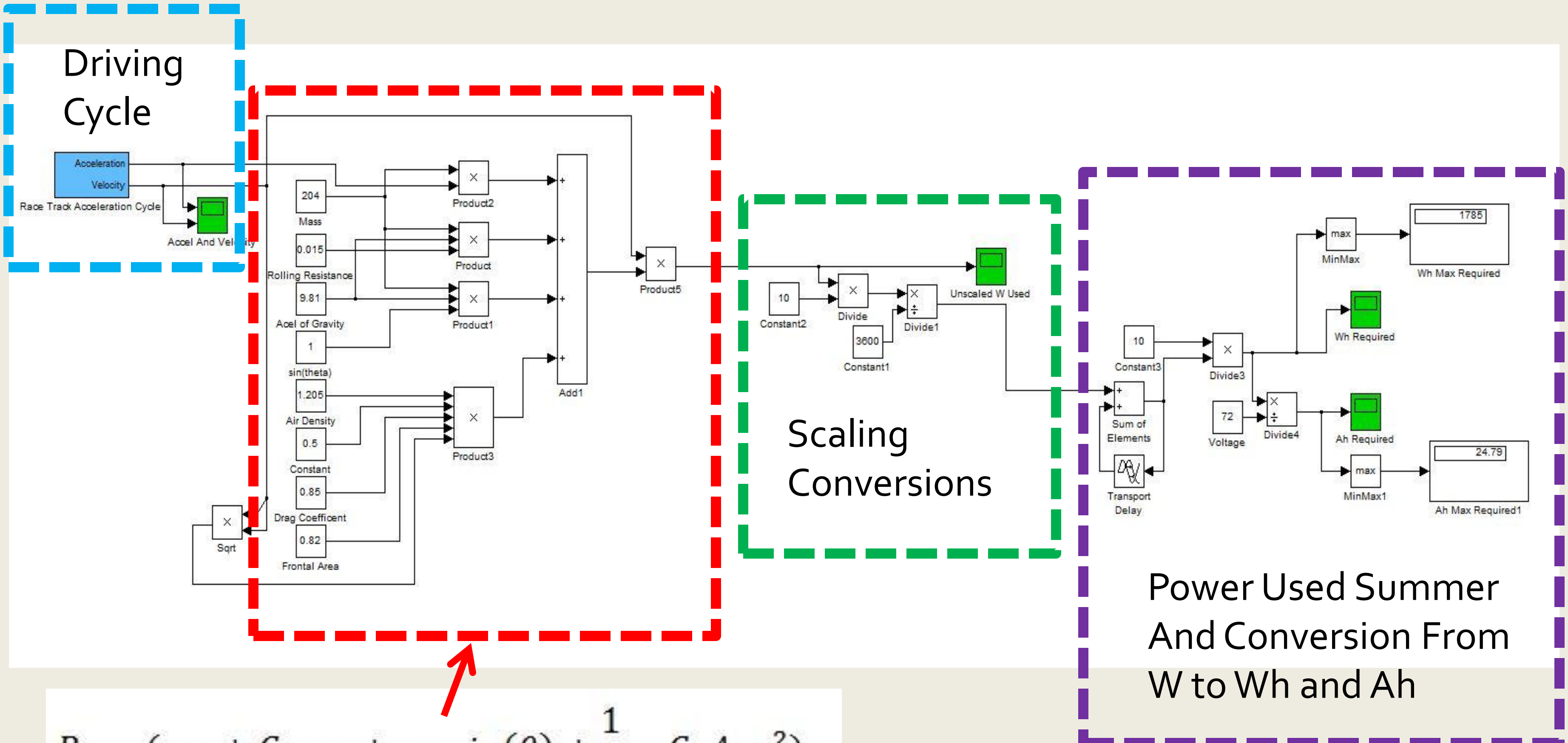
- **Status:**
  - Tested Successfully

Battery System, BMS, Other electrical components

PRESENTED BY:

GEORGE NIMICK (FOR SCOTT HILL)

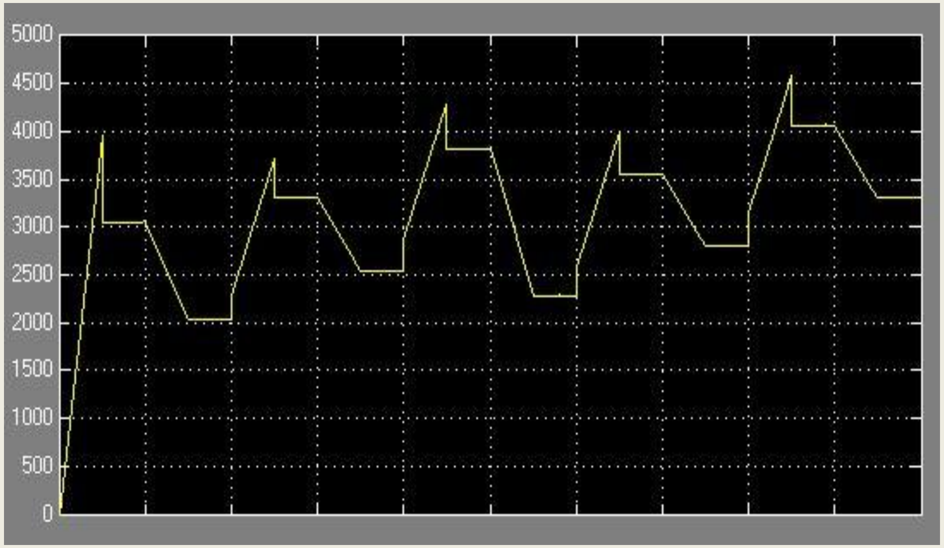
Power Calculations



$$P_d = (ma + C_R mg + mgsin(\theta) + \frac{1}{2}\rho_a C_D A_f v^2)v$$

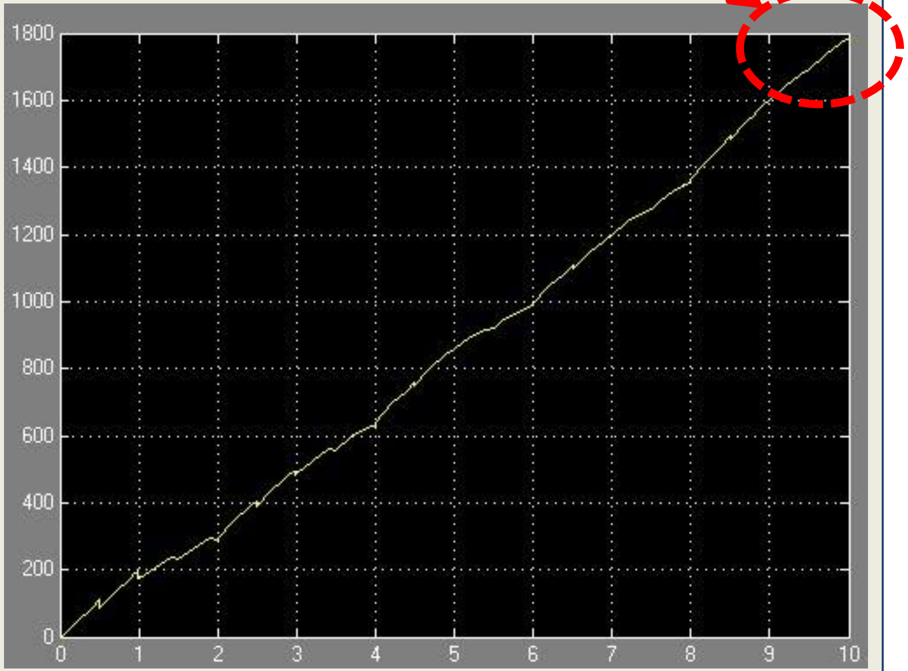
Results From Power Calculation Model

Power used during driving cycle (W)

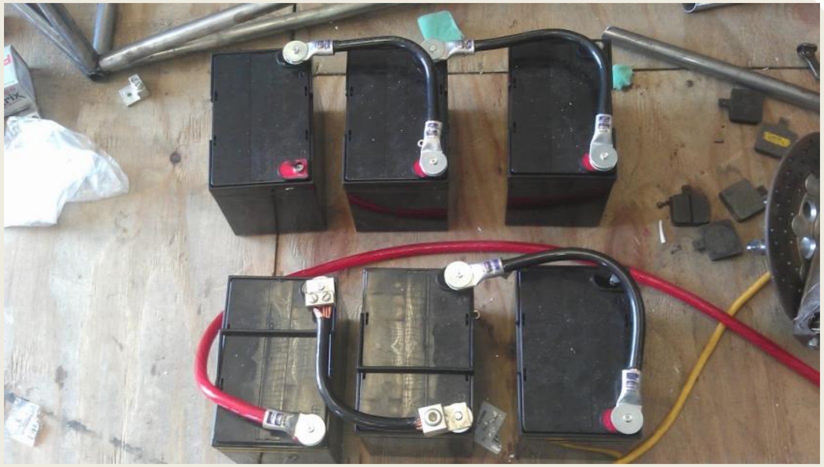


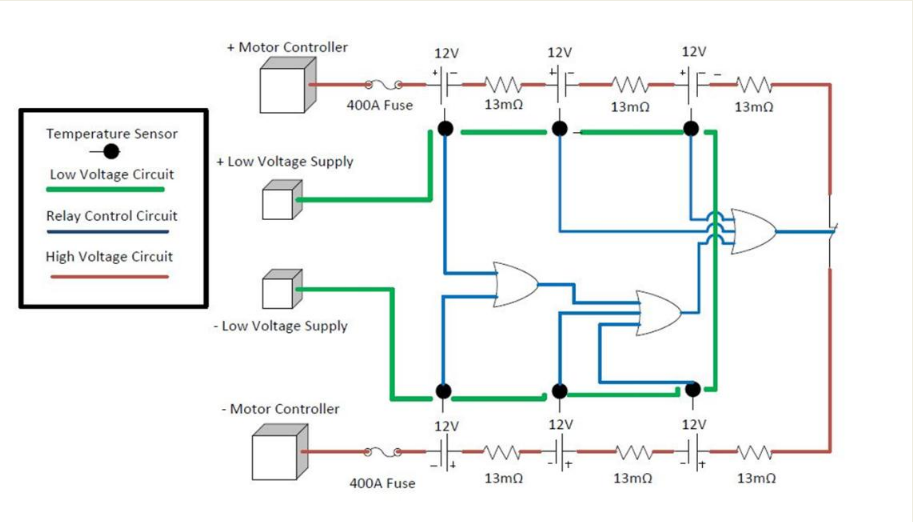
Wh required to complete
10 laps of track at 100s per lap

Wh Requirement



Battery Specifics





Battery Characteristics	
Voltage	12V
Capacity	36Ah
Weight	26.6lbs
Max Discharge Current (5s)	300A
Internal Resistance	13mΩ
Max Charging Current	9.9A

Schedule and Budget

PRESENTED BY:

GEORGE NIMICK (FOR ALDREYA ACOSTA, RYAN LUBACK AND COREY SOUDERS)

Schedule

Task	Task assignment	Time lapse	September	October	November	December	January	February	March	April
EE Tasks										
Fundraising	Everyone	120 Days								
Motors	Danny	28 Days								
Motor Design										
Motor implementation										
Accumulator	Scott									
Accumulator Design		42 Days								
Accumulator Implementation		21 Days								
BMS*	Scott									
BMS Design		28 Days								
* BMS was not used or needed										
LV System	Scott	14 Days								
Battery Charging System	Scott	7 Days								
EE System Testing	Scott and Danny	20 Days								
EE System Integration	Scott and Danny	20 Days								

Schedule

ME Tasks		
Chassis	Alex	
Chassis Design		90 Days
Chassis Assembly		42 Days
Suspension	Stephen	
Suspension Design		
Suspension Assembly		
Steering	Thomas	21 Days
Braking	Sam	35 Days
IE Tasks		
Floor Pan	Ryan, Corey, Aldreya	14 Days
Nose Cone	Ryan, Corey, Aldreya	28 Days
Total System Integration	Everyone	28 Days
Total System Debugging	Everyone	28 Days

Budget

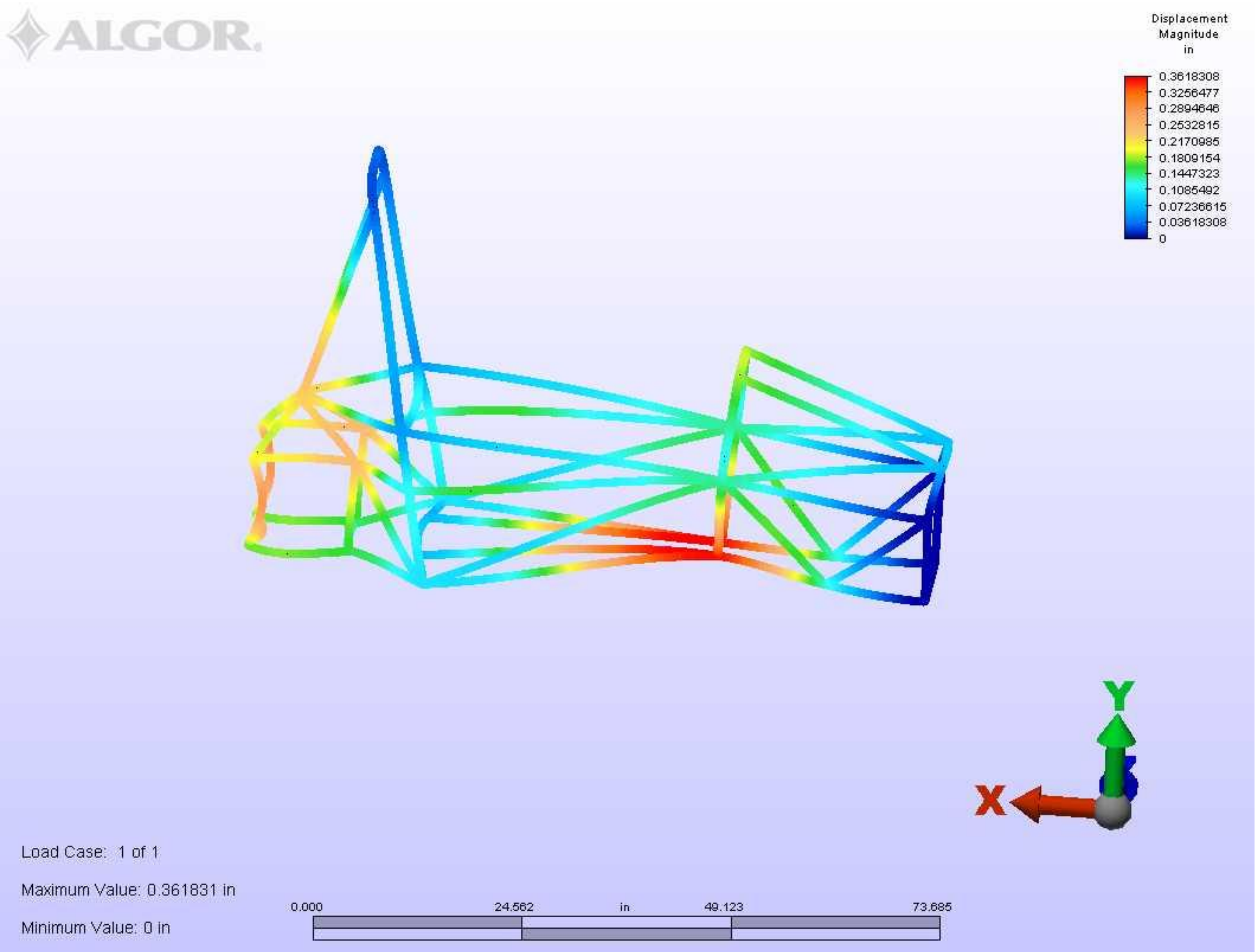
Cost Analysis		
Total Budget:		$9,000.00
Expenses		
	Registration	($1,500.00)
Mechanical		
	Chassis	($560.00)
	Brakes	($55.00)
Electrical		
	Batteries	($850.00)
	BMS System	($316.00)
	Conduit	($45.00)
	Accelerator	($109.00)
	Miscellaneous	($100.00)
Industrial		
	Foam	($80.00)
	Epoxy Resin	($150.00)
	MDF	($40.00)
Remaining		$5,195.00

- Future Expenses
  - Safety Equipment
  - Trip

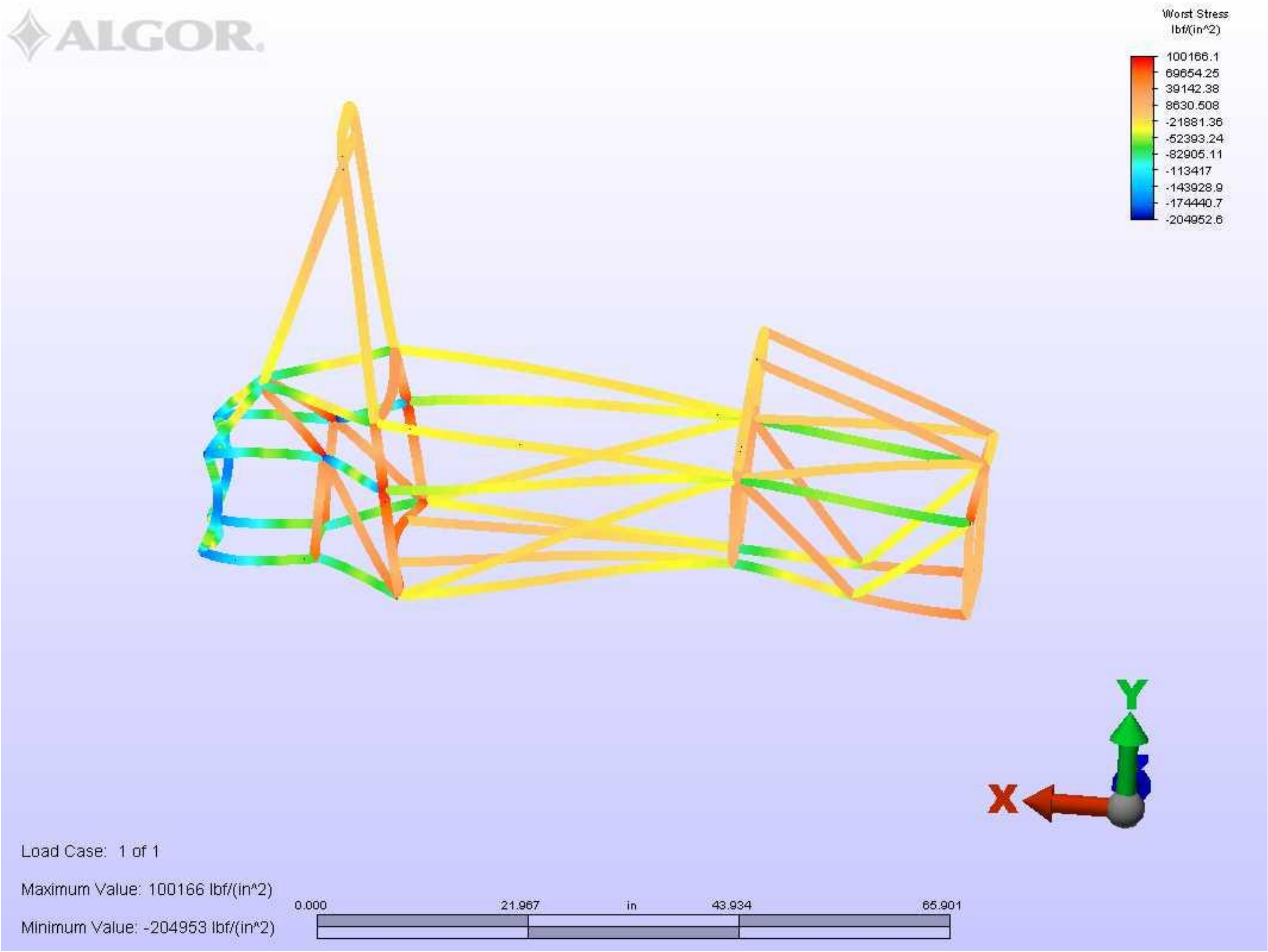
Questions?

“Questions?… Comments?”

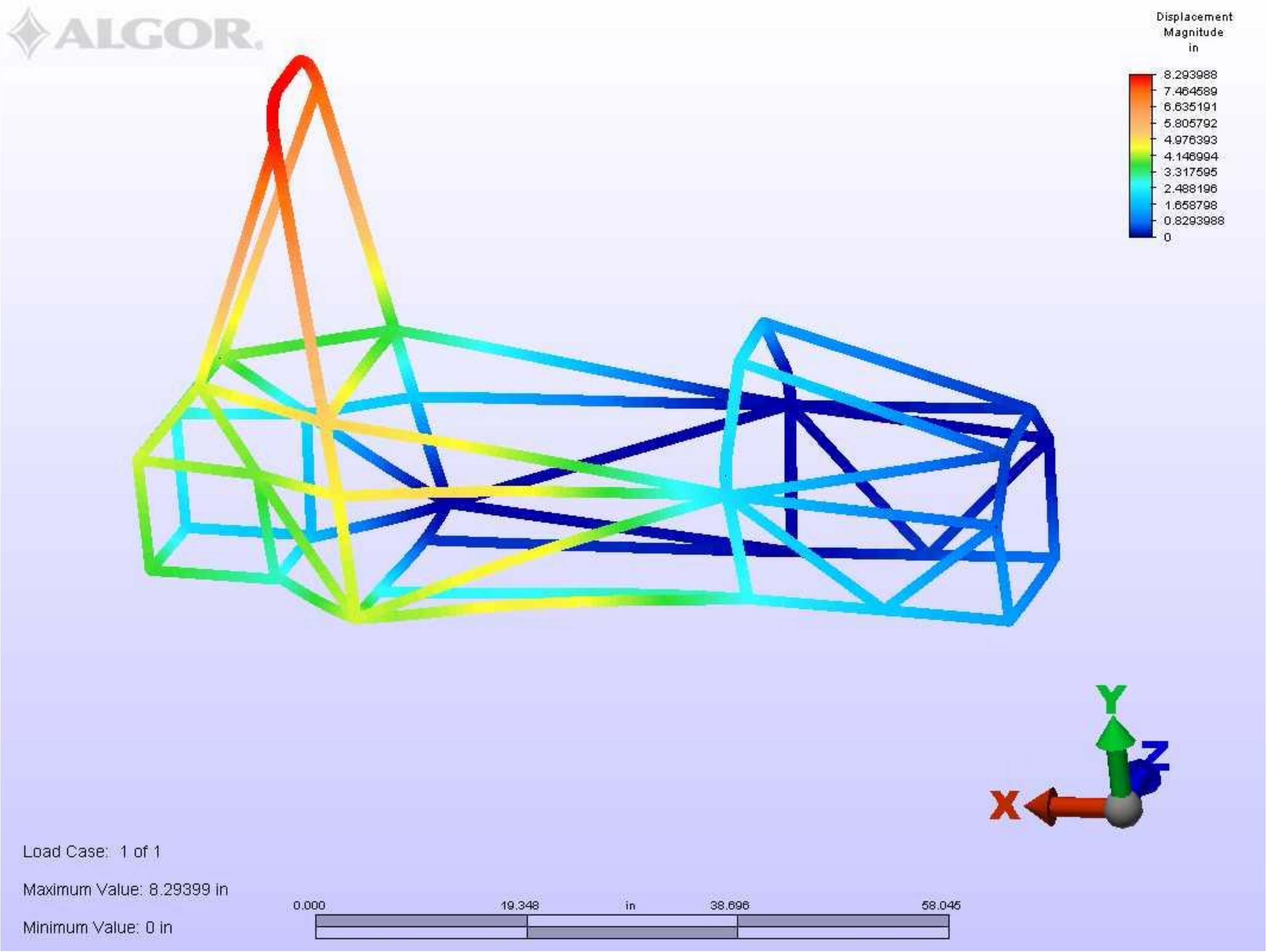
Appendix - Chassis



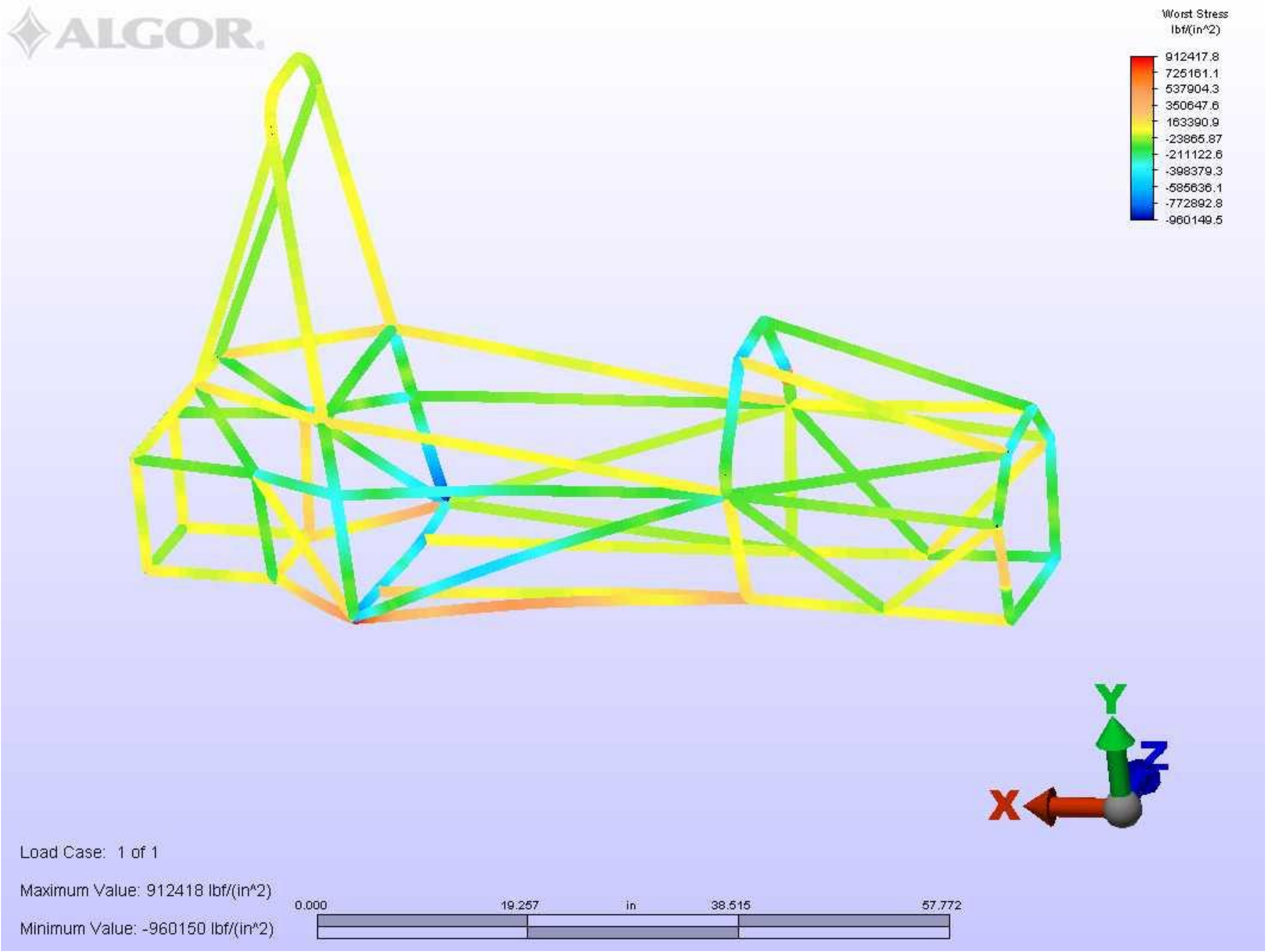
Appendix - Chassis



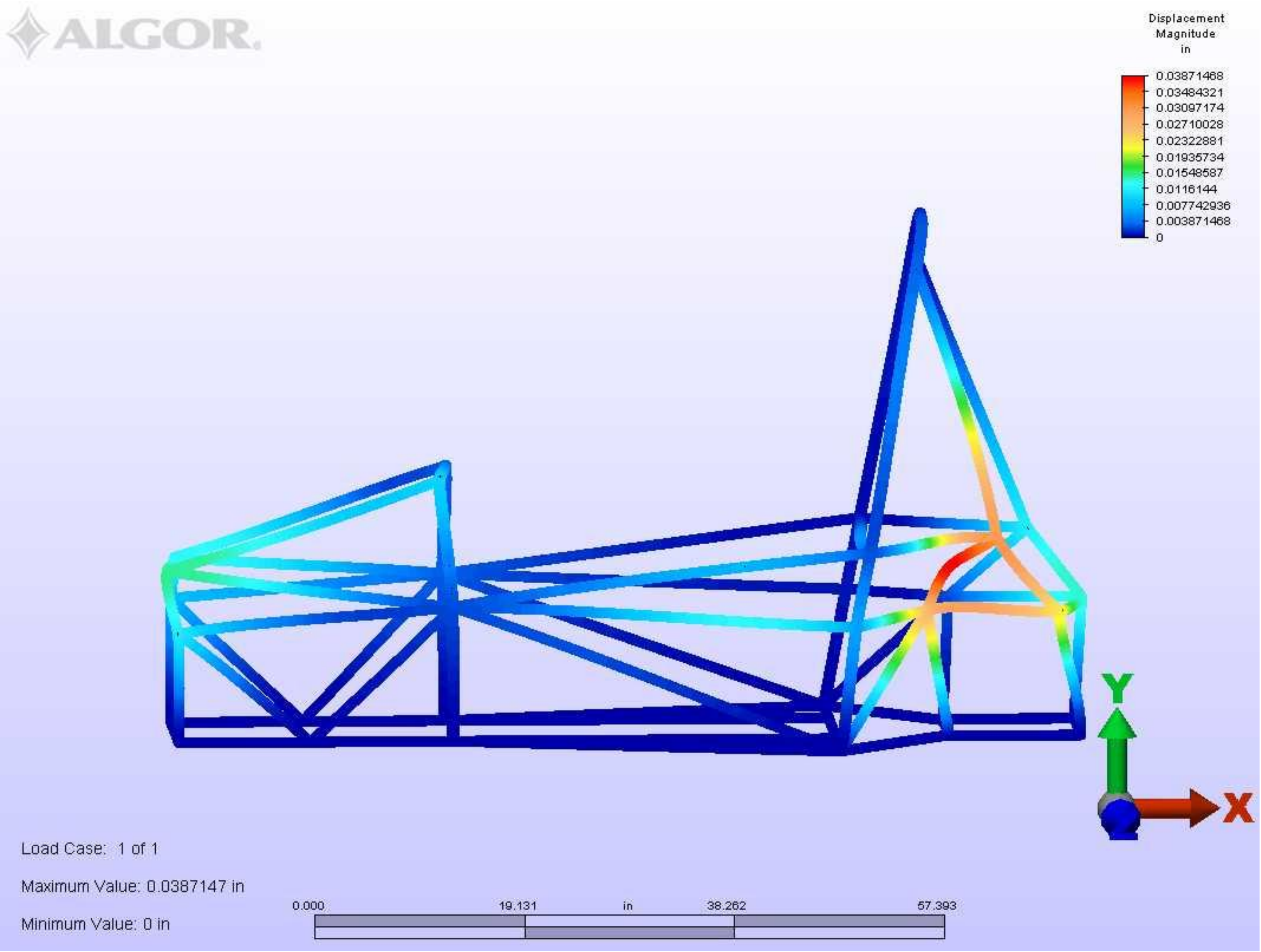
Appendix – Chassis



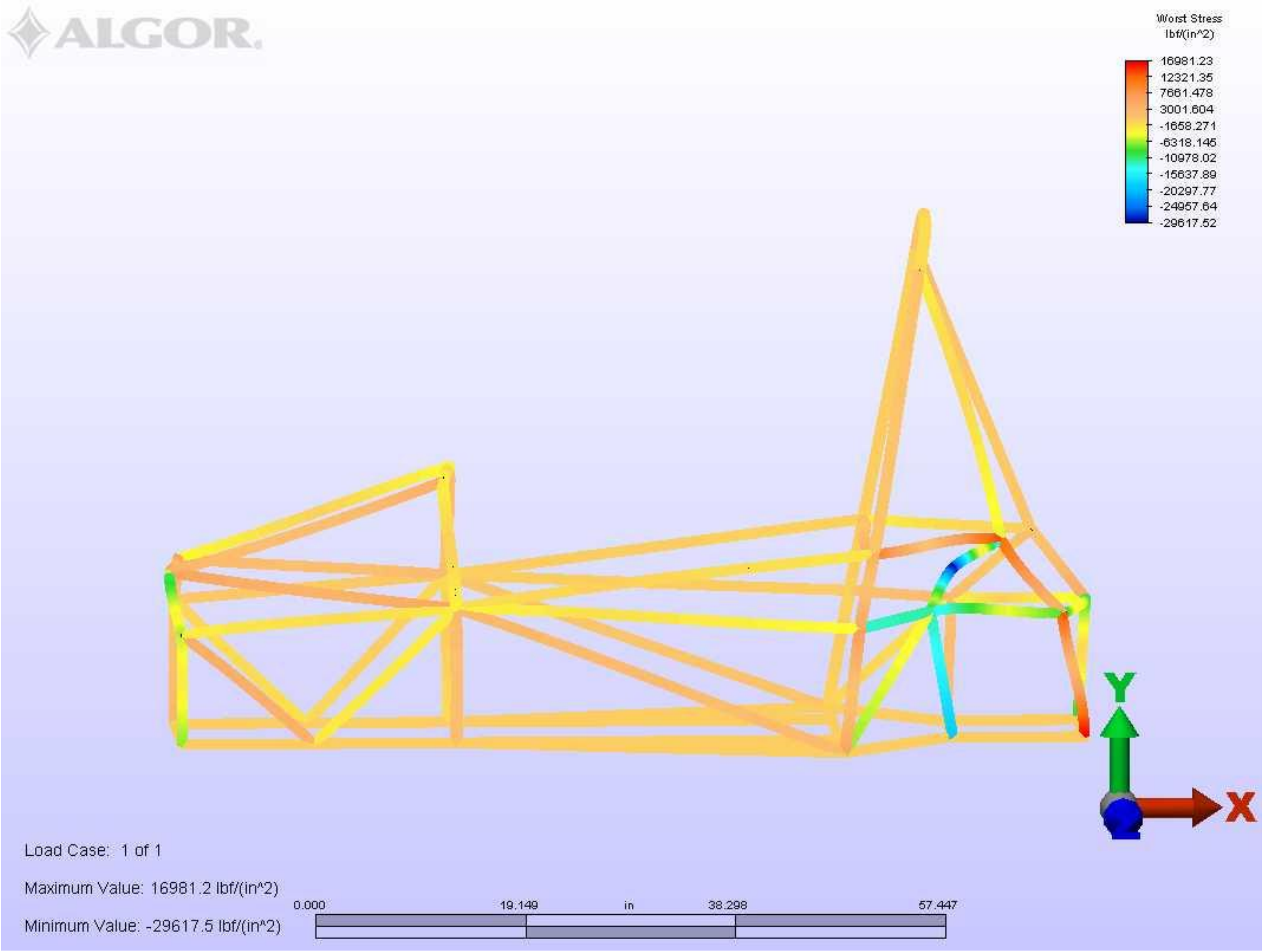
Appendix - Chassis



Appendix - Chassis



Appendix - Chassis



Appendix - Impact Attenuator

Impact Attenuator Calculations:

Velovity at Impact $Vi := 7\frac{m}{s}$ $Vi = 22.966 \cdot \frac{ft}{s}$

Vehicle Weight with driver $W := 600lb$

Gravity $g = 32.174 \cdot \frac{ft}{s^2}$

Max average force $G := 20$

Acceleration $Ac := G \cdot g$

$Ac = 643.481 \cdot \frac{ft}{s^2}$

time for impact $t := \frac{Vi}{Ac}$ $t = 0.036 \cdot s$

Solving for height h

$$h := \frac{1}{2}\left[\frac{(Vi)^2}{g}\right] \qquad h = 8.197 \cdot ft$$

solving for crush distance

$$s := \frac{h}{G-1} \qquad s = 0.431 \cdot ft$$

Thickness of Material needed

$Tc := s + (0.5 \cdot s)$

$Tc = 0.647 \cdot ft$

solving for dynamic force

$$FcrAcr := \frac{W \cdot (h + s)}{s}$$

$Fdyn := FcrAcr$

$Fdyn = 1.2 \times 10^4 \cdot lb$

Solving for needed crossectional area

$Fcr\_dyn := 121 \frac{lb}{in^2}$ Value from supplied data table

$$A := \frac{Fdyn}{Fcr\_dyn} \qquad A = 99.174 \cdot in^2$$

for equal length and height L=H of foam block

$$L := A^{\left(\frac{1}{2}\right)} \qquad L = 9.959 \cdot in$$

Appendix - Reverse Ackermann Calculation

$W_{car} := 650\,lbf$ $\quad v_{turn} := 40\,mph$ $\quad r_{turn} := 75\,ft$

$h_{cg} := 12\,in$ $\quad r_w := 10.25\,in$ $\quad a_x := \frac{v_{turn}^2}{r_{turn}} = 1.426 \cdot g$

$$F_{lat} := \frac{W_{car}}{g} \cdot a_x = 927.106 \cdot lbf \qquad t_{rack} := 48\,in$$

Given

$$F_{iz} = \frac{W_{car} \cdot \frac{t_{rack}}{2} - F_{lat} \cdot (h_{cg} - r_w)}{t_{rack}}$$

$$F_{iz} = W_{car} - F_{oz}$$

$$F_{ix} = F_{lat} - F_{ox}$$

$$F_{ix} = \frac{F_{oz} \cdot \frac{t_{rack}}{2} - F_{iz} \cdot \frac{t_{rack}}{2} - F_{ox} \cdot (h_{cg} - r_w)}{(h_{cg} - r_w)}$$

$$F_{oz} = 180\ lbf$$

$$F_{iz} = 145\ lbf$$