



LAFAYETTE  
MOTORSPORTS

**FSAE Hybrid Team  
Prototype Specification Report**

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## DOCUMENT OVERVIEW

The Prototype Specification Report is a document that will convey how the car as a whole will be tested before competition date and focus on the engineering specifications of the Formula Hybrid Vehicle. Furthermore, this report will demonstrate that the Lafayette College Motorsports Team car is fully compliant with all Formula Hybrid competition rules relevant to the mechanical design, as well as the successful integration of the electrical subsystems into the car.

Per the sub-system, the particular specifications that each must meet will be listed. These engineering solutions and design choices will be further explained and supported by analysis and experimental results. These results will clarify the validity and completeness of the engineering design specifications.

The deliverables for the Dynamic Test Plan include inspection, testing, and analysis for each of the following subsystems: the Chassis, Suspension, Drivetrain, Interconnect, Tractive System Voltage (TSV battery), Steering, and Pedals.

The Prototype Specification Report will specify the measurements, analysis, or inspections that will be conducted in order to demonstrate that a requirement has been met.

The measurements will be provided as an explicit test, experiment, or demonstration that can be used to prove compliance with a specific requirement by acquiring new measurements.

# CHASSIS

## INTRODUCTION

The chassis is the heart of the Car. The chassis is the central part of the formula car that everything is bolted and attached to. Our biggest goal is to maintain a lightweight car that can withstand the downward forces that are produced as the vehicle moves.

The primary goals of the for the Chassis are: widening the cockpit and to be rules compliant by cutting out the top two side-impact frame members and weld on bent ones. This will give one-inch of extra space on each side, and mounting the seat to give driver comfort and ease of access to controls. Also included is designing and installing side and rear firewalls, design and weld mountings onto Chassis for other systems, shortening the battery box frame to make more room for suspension, and confirm impact attenuator testing.

### ERGONOMICS: TEST ONE

Put the tallest, widest, shortest and skinniest people of our team in the cockpit to rate comfortability with seating angle, leg and arm room, pedal distance, and ease of operating steering.

Our tallest person is Zach Miller at 6' 4". Our shortest person is Tim LaGreca at 5' 3". The skinniest person is Monserrat Mendes, and our biggest person is Carl Doucette. These people meet the 95th percentile and fifth percentile range specified in the rules. Each of these people will have to be able to easily use the steering wheel and reach any necessary buttons, as well as the pedals, with only the seat being adjusted.

### ERGONOMICS: TEST TWO

The Egress test entails getting out of the car in 5 seconds while starting fully harnessed in the cockpit. Being out of the car means at least one foot on the ground entirely outside of the car enclosure. One driver will begin seated in the car and be timed while getting out of the car.

### ERGONOMICS: TEST THREE

To ensure the roll hoops will sufficiently protect a driver in the event of the car flipping, with the tallest driver, Zach Miller, seated in the car, a line will connect the top of the two roll hoops, and a ruler will measure the space between the top of Zach's head with a helmet on and the line, which must be at least 50mm to be rules compliant.

Along with this spacing test, the Percy test will be conducted. With the seat as far back as it goes, a straight distance from a 200mm circle at the seat bottom and the rear face of the pedals will be measured, and has to be at least 915mm to be rules compliant.

### IMPACT ATTENUATOR

We will evaluate the impact attenuator test done by last year's team and verify for data accuracy and completeness, and evaluate our calculations for peak and average deceleration to prove it is within the specified limit set by the rules.

The graphs in Figure One and Figure Two provide maximum force, energy, and displacement information, which are reported in Table One and used to find average and peak

deceleration. The average and peak deceleration must be under certain limits set by the rules in order for the impact attenuator to be accepted.

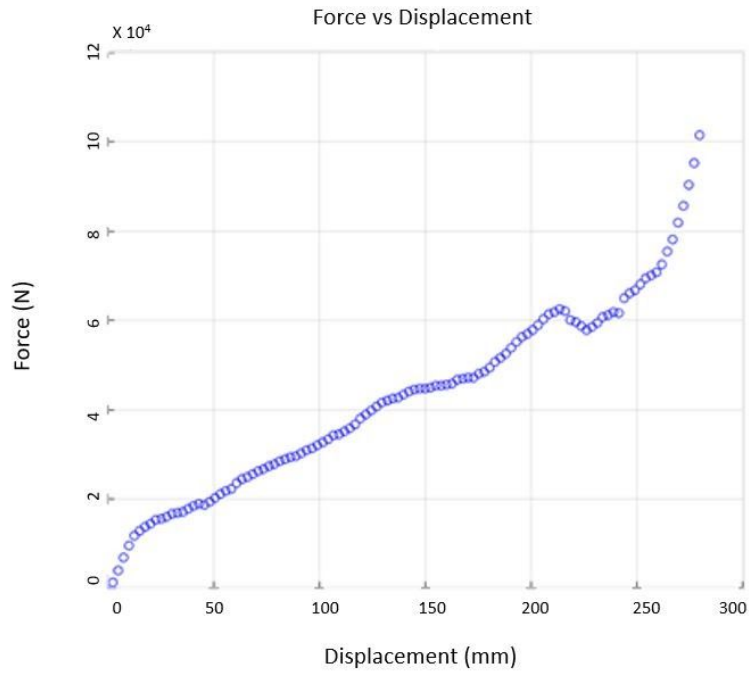


Figure One: Graph of Force vs. Displacement

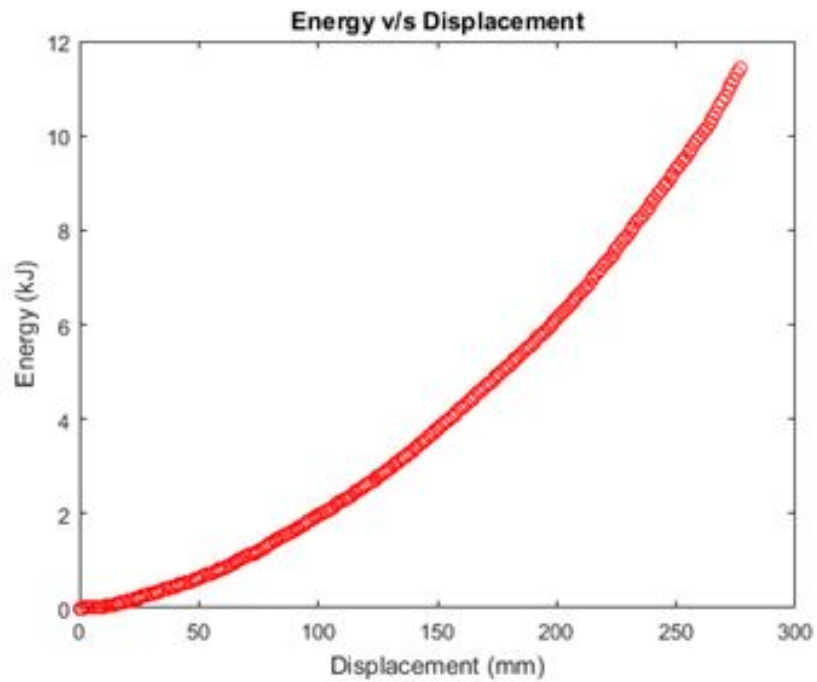


Figure Two: Graph of Energy vs Displacement

Energy Absorbed (J):	11,825 J	Vehicle includes front wing in front of front bulkhead?	No
IA Max. Crushed Displacement (mm):	279.4 mm	Wing structure included in the test?	No
IA Post Crush Displacement - demonstrating any return (mm):	277.3 mm	Test Type: (e.g. barrier test, drop test, quasi-static crush)	Quasi-Static Crush
Anti-Intrusion Plate Deformation (mm)	20.5 mm	Test Site: (must be from approved test site list on website for dynamic tests)	Lafayette College

*Table One: Impact Attenuator Data*

Table One consolidates necessary checks on the type of testing done on the impact attenuator, as well as the primary geometrical outcomes of the testing, which are used in the calculations for deceleration.

Material(s) Used	IMPAXX 700 Series Foam	
Description of form/shape	Standard Impact Attenuator With Extended Base	
IA to Anti-Intrusion Plate mounting method	(4) 8mm Metric Grade 8.8 (5/16" SAE Grade 5)	
Anti-Intrusion Plate to Front Bulkhead mounting method	AI Plate is fully welded to around perimeter to Front Bulkhead	
Peak deceleration ( $\leq 40$ g's)	25.48 g	
Average deceleration ( $\leq 20$ g's)	10.26 g	
Vehicle Mass	Amount = 408kg	Please Circle: Measured or <u>Estimate</u>

*Table Two: Material and Mounting Specifications*

Table Two provides specifications about the material and mounting of our impact attenuator, as well as the two most important outcomes of the testing: peak and average deceleration. These values must be less than 40g and 20g, respectively.

### FRAME SPACING

To determine that the frame spacing rules compliant, we will place templates in necessary spaces in the cockpit and front bulkhead. The template sizes are specified in the rules, and shown in Figure Three and Figure Four below. The team has templates of the same geometry as these, and they will be passed through the binding regions of the cockpit and front bulkhead. Template A below will be passed vertically down in the cockpit, starting above the top frame member

forming the cockpit, to a point just below the top member of the side impact. Template B below will be passed horizontally through the front bulkhead, starting at the front roll hoop, to a point 10cm behind the frontmost pedal.

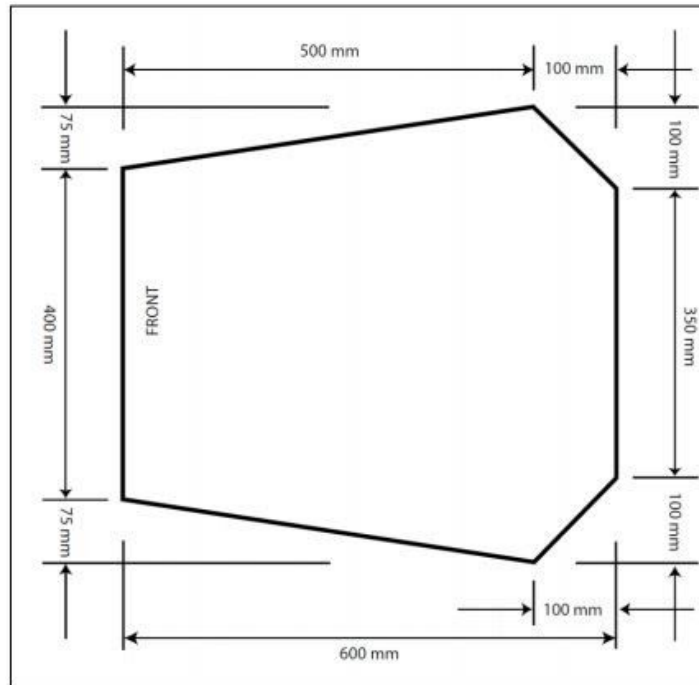


Figure Three: Template A

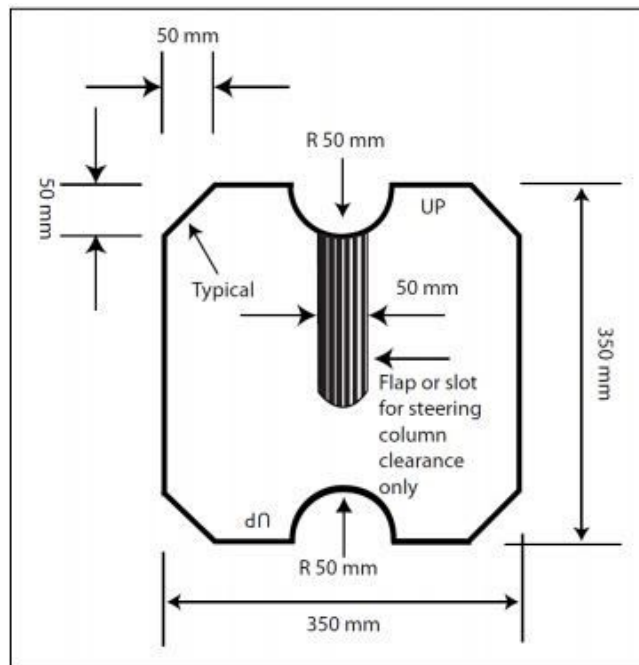


Figure Four: Template B

# SUSPENSION

## INTRODUCTION

The primary goal for a suspension system on any race car is to act as a filter between the chassis and the rough surface it drives over while also ensuring the tires remain in contact with the surface to achieve the maximum performance possible. In order to design a suspension system that allows the maximum possible performance given the limits of the chassis, many criteria must be considered. The main criteria focused on the design of the new suspension system were camber and toe changes during heave, roll, and steering. The previous year's team used Optimum Kinematics to simulate expected performance, which played a crucial role in deciding the alignment specifications and placements for this year. Aside from the analysis, however, metrics needed to be made to determine acceptable performance given the restraints during testing.

## ENSURE IDEAL FUNCTIONALITY

In order to ensure the car will perform as desired, all aspects that influence handling must be considered not only when designing the suspension, but also when assembling the car. An ideal handling car would remain as stiff as possible while still allowing enough weight transfer, through roll and pitch, to meet not only technical requirements but also maintain maximum possible grip while cornering, braking, and accelerating. However, the added effects when including suspension travel must be considered in order to be sure the car will still handle as desired.

The easiest way to account for the effects that the suspension will experience overall possibilities is to use simulation software, such as Optimum Kinematics. Using the expected suspension geometries and given parts, such as dampers and springs, the following results were obtained from Optimum Kinematics:



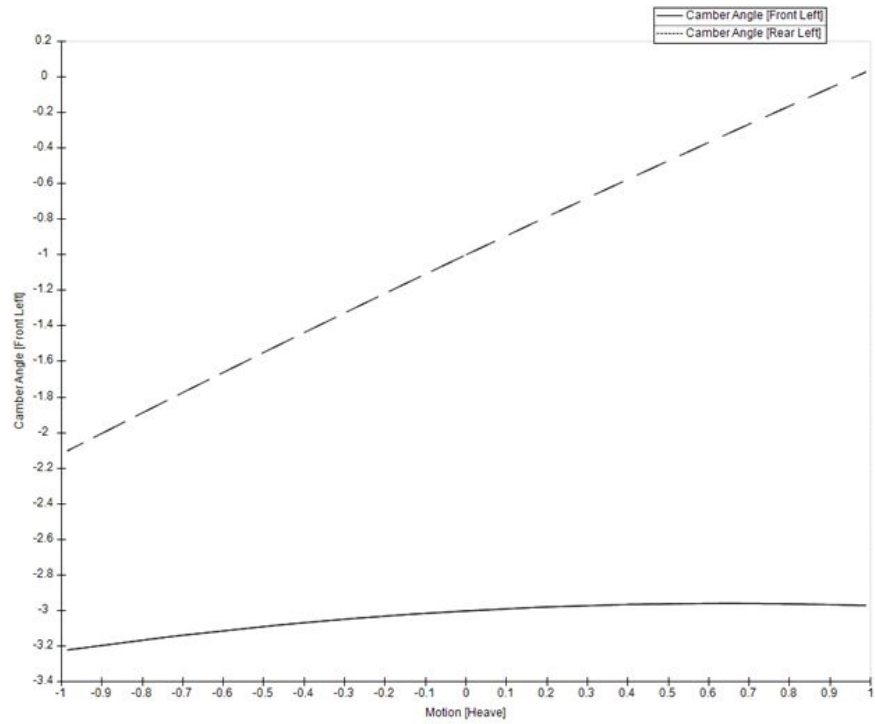


Figure Five: Camber Angle vs Heave

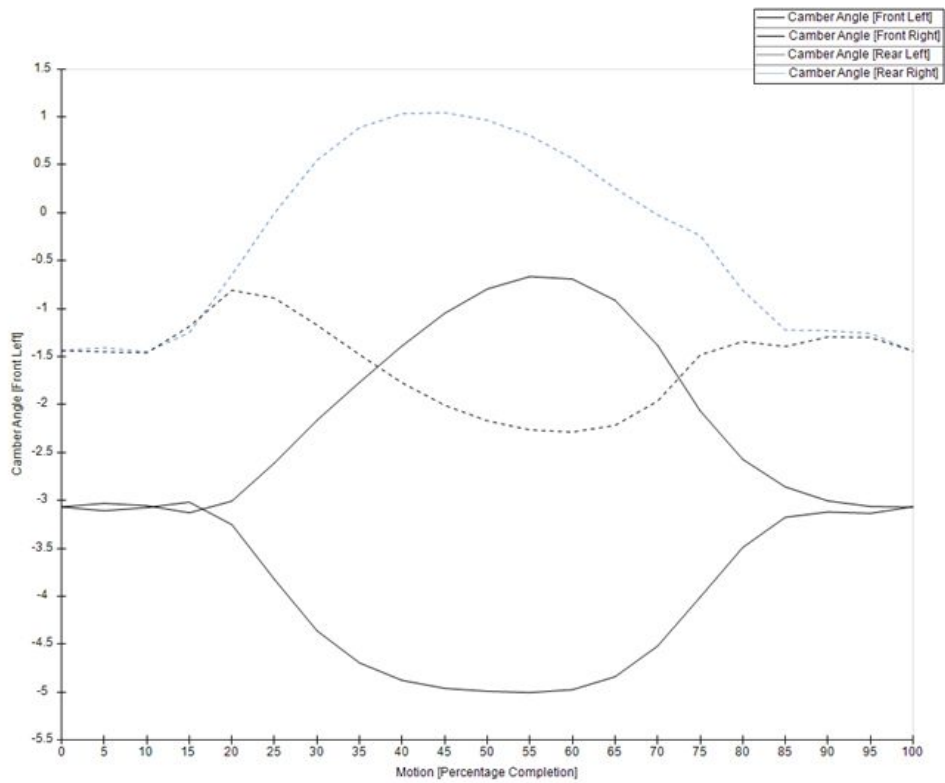


Figure Six: Camber vs Turing Motion

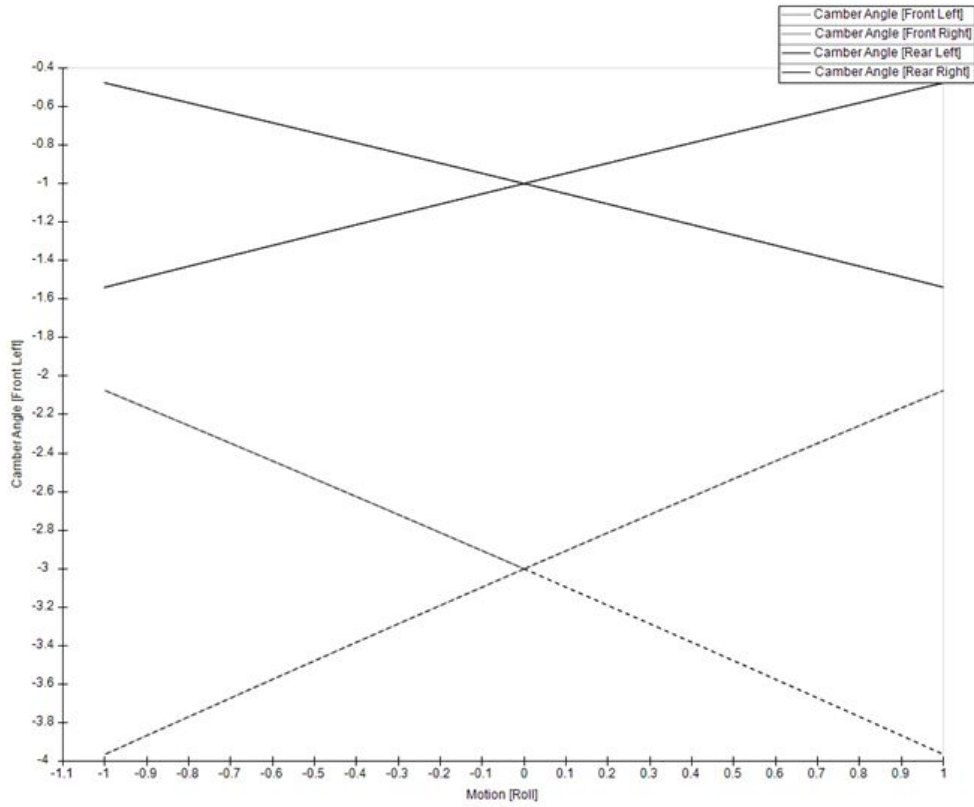


Figure Seven: Camber vs Roll

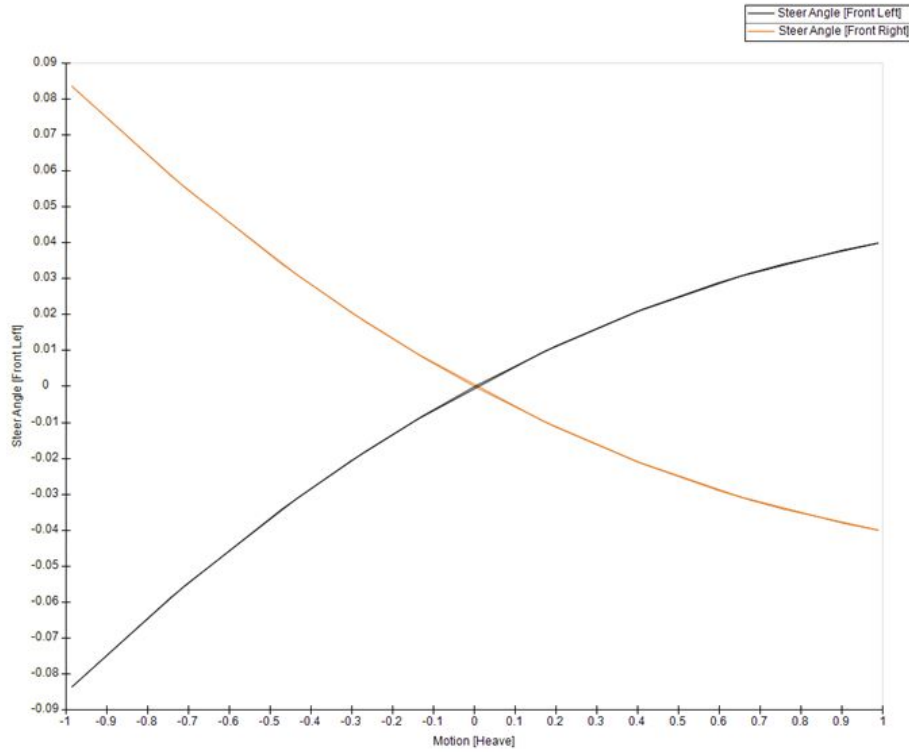


Figure Eight: Bump Steer vs Heave

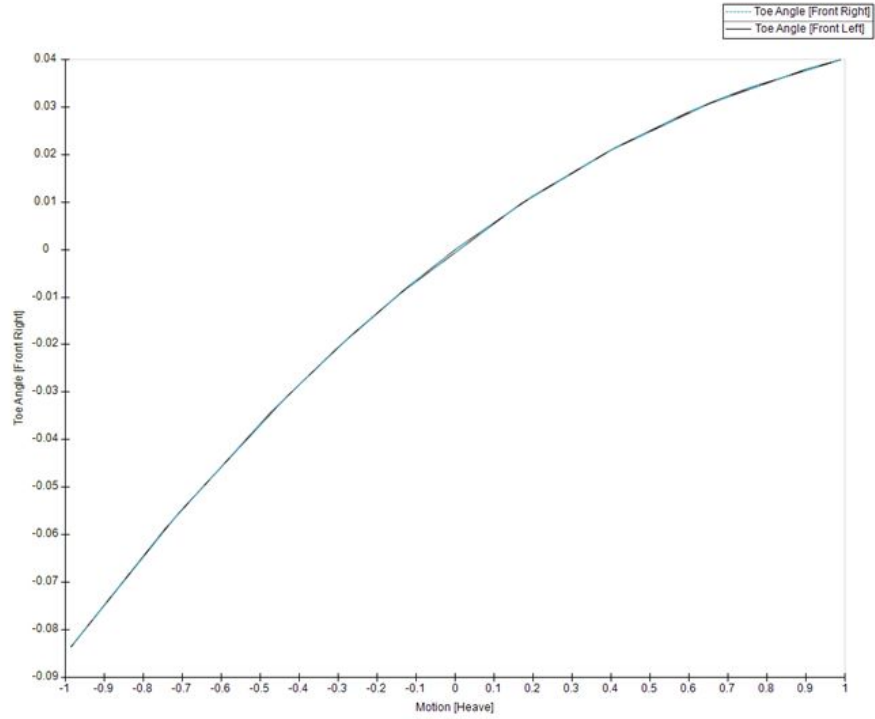


Figure Nine: Bump Toe vs Heave

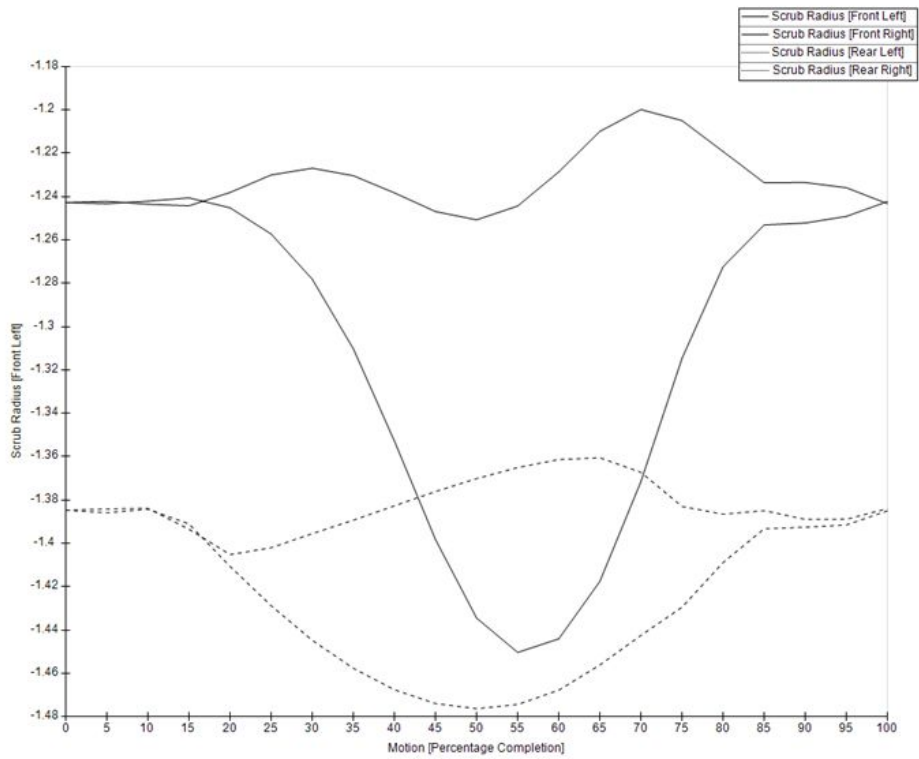


Figure Ten: Scrub Radius vs. Motion

Each graph represents an effect that will be experienced during various driving events, such as roll, heave, or turning. In order to be deemed acceptable given the car's restraints and the performance desired, the following criteria were set:

1. Camber to remain equal to or below 0 during all motions to account for roll and allow the contact patch to remain as flat as possible.
2. A maximum camber change during the roll of roughly 3 degrees to ensure the contact patch stays as flat as possible on outside tires during turns to achieve maximum grip.
3. As little bump steer and bump toe as possible to avoid instability when accelerating or braking.
4. Small and negative scrub radius throughout all motions, which ensures straight-line stability during braking.

As can be seen through the graphs above, all characteristics are met within reason. There are some small instances where the camber becomes positive while turning, so that will need to be monitored and addressed if needed during testing. Further optimization was not done due to time restraints during the first semester, as it was essential to begin manufacturing as soon as possible, so testing will be done to ensure the validity of these results.

#### TEST TRAVEL: JOUNCE AND REBOUND

In order to meet the technical requirement of 50.8mm of equal parts jounce and rebound, the dampers will be mounted midway between their allowable travel, which will ensure equal amounts of travel. The dampers that will be used on the car have an overall allowable trip of roughly 4 inches, meaning maximum possible jounce and rebound will be nearly 2 inches. With springs installed and the car on the ground, jounce and rebound can be measured to ensure the rule is met. If it is not, springs can be changed to a softer setting to allow more travel if needed, but more analysis will need to be done on its effects to the rest of the suspension.

#### GROUND CLEARANCE WITH DRIVER

Based on models and initial designs, the ground clearance of the car is expected to be within 2 to 2.5 inches without a driver, which is needed in order to pass the rule requiring the side impact bars to be a certain height above the ground. Initial models show that the pushrods and bellcranks will have adequate room for movement on both front and rear, but care will be taken when assembling the car and during initial tests to ensure that this is still the case. Height will be limited by the damper and spring, but can be adjusted using the push rods in or out.

Ride height will be tested statically with the most substantial driver in the car, but given the current spring rates on the dampers, initial estimates assume the car will not go below 1.5 inches of ground clearance.

#### DATA FROM SCADA

To make sure the models are valid, accelerometers from SCADA will be placed on various parts of the car in order to measure G-forces, roll, and pitch. All of these will be measured during various driving maneuvers. The data that will be most important to us will be degrees of roll per G, degrees of pitch per G, and overall G-forces experienced during cornering, acceleration, and braking. Comparing the results to the model will point towards what areas of the suspension may need to be changed or adjusted as well as what the driver can expect during various handling events in order to better prepare for competition.

# DRIVETRAIN

## INTRODUCTION

The drivetrain is the part of the formula car that supplies the torque from the motor to the wheels. In our car, that consists of the motor, motor mount, chain, sprockets, differential, and half shafts.

Now that the drivetrain is close to completion, we have conducted tests to determine if our designs match our expectations for performance. Structural analysis of supports and housings were completed in order to confidently mount the motor to the car. Tests were also completed to determine the amount of torque that would be applied to supports holding the motor. Temperature data was taken from the cooling system as load was applied to the motor to ensure safe operation and make sure that overheating was not a possibility during the endurance test. Calculations were also performed to ensure that the radiator would fill the specific requirements demanded during the endurance test, which is the most demanding test in terms of cooling. A gear ratio test was performed to ensure that the Matlab model correctly mirrored actual performance.

### MOTOR: TEST ONE

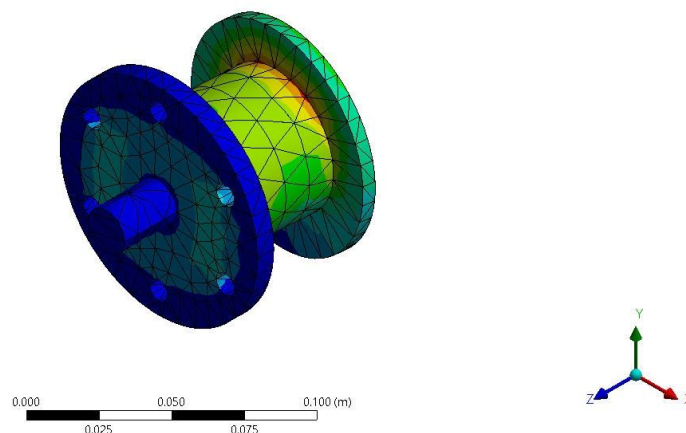
Make sure the motor spins appropriately and does not overheat under load. The motor has a temperature sensor already built-in, so taking data will be straightforward. The motor has a specified running temperature, which we will use as the max. Running the motor to failure is not beneficial to the car. Emrax states the min, and max temps are  $-40\text{ }^{\circ}\text{C}$  and  $120\text{ }^{\circ}\text{C}$ , respectively. We will compare the temperature to these values with an added factor of safety.

### MOTOR: TEST TWO

Make sure sprockets are attached correctly, and there is no oscillation while under power. This will be inspected during the install phase, and it will be made sure there is no play in the shaft when it is installed, and all bolts are fastened correctly. In order to determine there is no

**A: Static Structural**  
Equivalent Stress  
Type: Equivalent (von-Mises) Stress  
Unit: Pa  
Time: 1  
2/24/2020 1:05 PM

1.6431e7	Max
1.4605e7	
1.2779e7	
1.0954e7	
9.1284e6	
7.3028e6	
5.4772e6	
3.6517e6	
1.8261e6	
561.42	Min



*Figure Eleven: Equivalent Stress*

oscillation of the sprockets and chain ANSYS models were created on the small sprocket. The motor shaft connecting the motor to the sprocket was modeled with the sprocket as one piece, since we assumed a perfect connection. A max torque of 120 N-m was applied to the top of the sprocket and the equivalent strain and total deformation were recorded. A max deformation of  $2.70 \times 10^{-5}$  (Figure 12) was recorded on the top of the sprocket and a maximum stress of  $1.64 \times 10^7$  Pa (Figure 11) was applied.

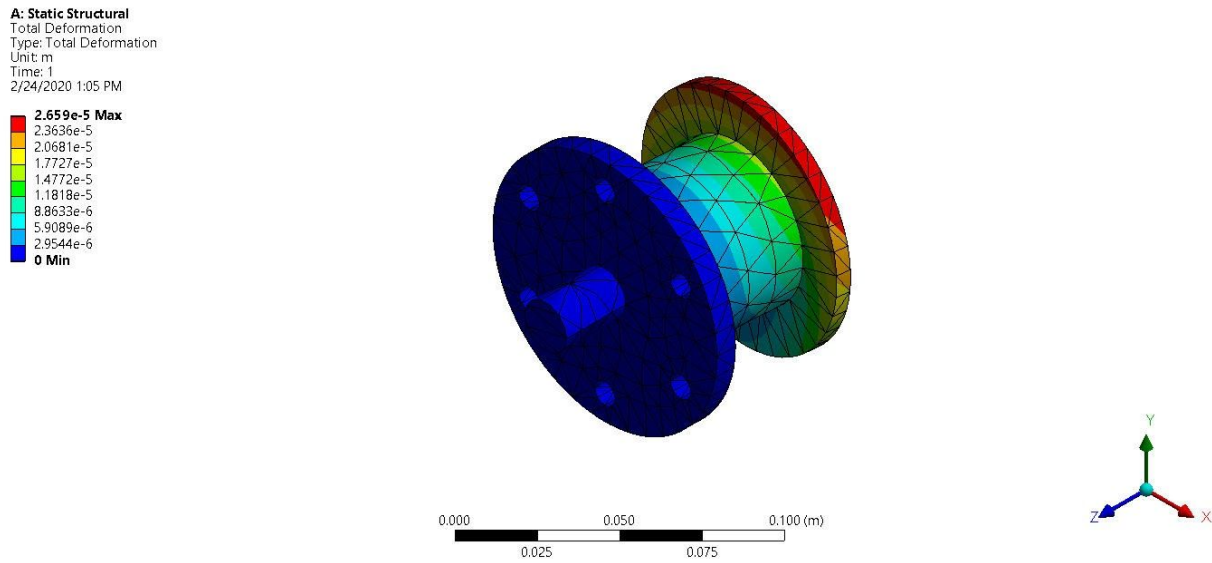


Figure Twelve: Total Deformation

## WATER COOLING SYSTEM

Take temperature data at the inlet and outlet ports of the motor under load and measure the amount of heat added on its course through the motor and motor controller. The motor has a min and max temp of  $-40$  °C and  $120$  °C respectively. The motor controller has a min and max temp of  $-20$  °C and  $65$  °C respectively. We must make sure that the temp through the plumbing never exceeds the max temperature for each electronic component.

## GEAR RATIO

Take power-torque curves, and acceleration data with the current gear ratio, approximately three, with the car running. Make sure that the data is correct and lines up with previous Matlab code and, if not, reevaluate the code. Calculate expected speeds and accelerations with Matlab and see if those are met under real conditions. Below are three graphs that depict various gear ratio's effect on acceleration in the form of distance vs. time over 250 ft, which is approximately 75 meters. The gear ratio selected for the car is 3:1, given the size constraints this will give us the fastest 75 meter time.

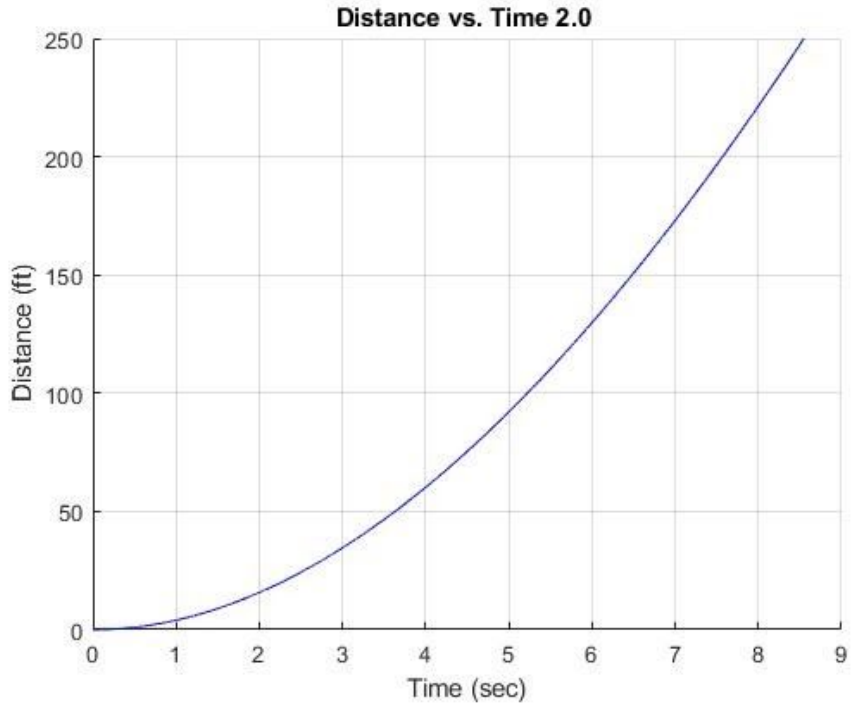


Figure Thirteen: \_\_\_\_\_

Figure thirteen shows the distance vs. time plot for a 1000 lb car with a gear ratio of 2:1. Compared to figure fourteen and fifteen a gear ratio of 2:1 takes the longest amount of time to get to 75 m.

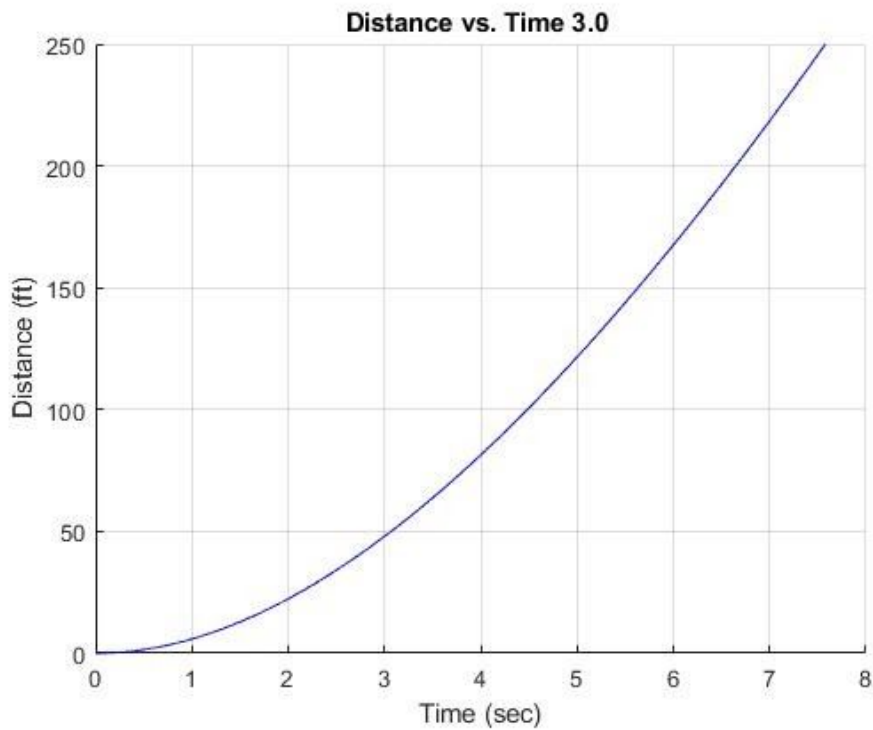
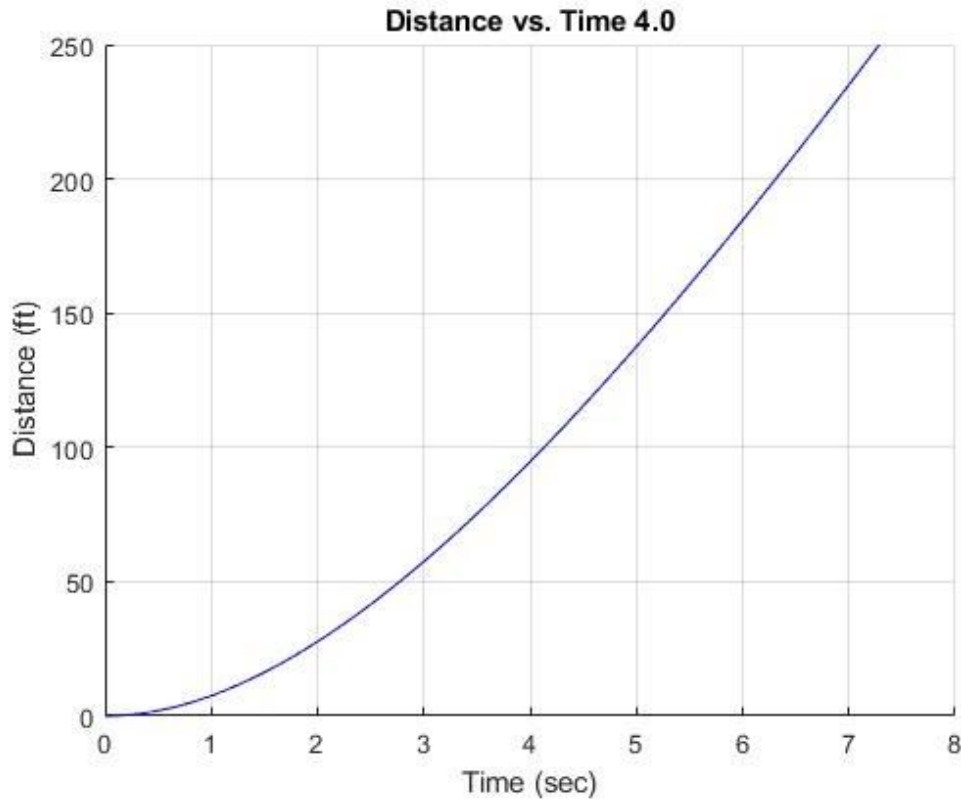


Figure Fourteen: \_\_\_\_\_

Figure fourteen shows the distance vs. time plot for a 1000 lb car with a gear ratio of 3:1. This is the gear ratio that we selected for our application, this ratio combines decent acceleration without compromising speed on the top end.



*Figure Fifteen:*

Figure fifteen shows the distance vs. time plot for a 1000 lb car with a gear ratio of 4:1. This gear ratio favors acceleration over top speed and still remains only a little faster than the 3.1 ratio. A gear ratio of 4:1 also requires a much larger rear sprocket to accommodate the increased amount of teeth which introduces design issues.

### TOP SPEED/ACCELERATION

Arrange a straight-line test and see what the acceleration time is to 75 meters, mimicking the acceleration test we will experience at competition. If we can hit top speed, also get data for the top speed. To do this, we can use a speedometer and accelerometer app to collect data. In order to determine if the car is performing up to our expectations, we will calculate what the expected time to complete the 75-meter acceleration test would be. In addition to checking if our calculations are correct, we will have an idea of how we will perform in the actual 75-meter acceleration test at the competition. If we do not have 75 meters of road to test on, we can see how our performance matches up with a shorter distance.



# INTERCONNECT

## INTRODUCTION

The focus of the Interconnect team's test plan will be to prove the efficacy and durability of the electrical enclosure and, most importantly, that it is ruled compliant. The team will test the strain relief capability of connectors and cables, waterproofing, high voltage, and low voltage separation and the electrical grounding of all-metal enclosure components. Most of the success criteria are based on FSAE 2020 rules. The primary design objectives of the ME Interconnect team are to design, manufacture, and install an electrical enclosure for the Tractive System Interface (TSI), Grounded Low Voltage (GLV), and Motor Controller systems.

### HIGH VOLTAGE AND LOW VOLTAGE SEPARATION

In order to make sure that all the high and low voltage components are adequately separated, separation distances will be measured using an appropriately sized wooden dowel. Each cable within the enclosure will be wiggled to make sure it cannot reach any low voltage component. These tests will mimic the tests performed by FSAE judges when determining rules compliance. The metrics for spacing distances as specified by the rules. In general, it is 10mm through air and 6mm of a UL certified surface. These Rules are listed below:

**EV.7.1.5** Where both Tractive System and GLV are present within an enclosure, they must meet one of:

- a. Be separated by insulating barriers made of moisture resistant, UL recognized or equivalent insulating materials rated for 150° C or higher (such as Nomex based electrical insulation)
- b. Maintain the following spacing through air, or over a surface (similar to those defined in UL1741):

U < 100 V DC	10 mm
100 V DC < U < 200 V DC	20 mm
U > 200 V DC	30 mm

**EV.7.1.7** If Tractive System and GLV are on the same circuit board:

- a. They must be on separate, clearly defined areas of the board
- b. The Tractive System and GLV areas must be clearly marked on the PCB.
- c. Required spacing related to the spacing between traces / board areas are as follows:

Voltage	Over Surface	Thru Air (cut in board)	Under Conformal Coating
0-50 V DC	1.6 mm	1.6 mm	1 mm
50-150 V DC	6.4 mm	3.2 mm	2 mm
150-300 V DC	9.5 mm	6.4 mm	3 mm
300-600 V DC	12.7 mm	9.5 mm	4 mm
- d. If integrated circuits are used such as opto-couplers which are rated for the respective maximum Tractive System voltage, but do not fulfill the required spacing, then they may still be used and the given spacing do not apply.

## ELECTRICALLY GROUNDED

A multimeter will be used in order to properly check every fastener and metal component throughout the electronic enclosure to ensure each part is properly grounded and will be modified if need be. Success criteria are determined by whether or not the measured voltage across components is less than the threshold value as specified by the FSAE 2020 rules. These rules are listed below.

### **EV.7.3 Grounding**

- EV.7.3.1 All electrically conductive parts of the vehicle (parts made of steel, (anodized) aluminum, any other metal parts, etc.) which are within 100 mm of any Tractive System component must have a resistance below 300 mOhms (measured with a current of 1 A) to GLV system ground.
- EV.7.3.2 All parts of the vehicle which may become electrically conductive (completely coated metal parts, carbon fiber parts, etc.) which are within 100 mm of any tractive system, must have a resistance below 5 Ohm to GLV system ground.
- EV.7.3.3 Electrical conductivity of any part may be tested by checking any point which is likely to be conductive, for example the Driver Harness attachment bolt, but where no convenient conductive point is available then an area of coating may be removed.

*Carbon fiber parts may need special measures such as using copper mesh or similar to keep the ground resistance below 5 Ohms.*

## STRAIN RELIEF

In order to test connector and cabling strain relief, a force gauge will be used to pull the high voltage cables at a maximum force of 200N without any damage. The same force gauge can be used to test the low voltage cables and should withstand 25N without damage. FSAE 2020 rules specify the measurements. After each test is performed, the test connectors will be inspected for any visual damage.

### **EV.7.5.7 All Tractive System wiring that runs outside of electrical enclosures**

- a. Must either be enclosed in separate orange nonconductive conduit or use an orange shielded cable.
- b. Except in the case where the Tractive System wiring runs in a fully enclosed container, the conduit or shielded cable must be securely anchored at least at each end so that it can withstand a force of 200 N without straining the cable end crimp, and must be located out of the way of possible snagging or damage. Body work is not sufficient to meet this enclosure requirement.
- c. Any shielded cable must have the shield grounded.

# TSV (BATTERY)

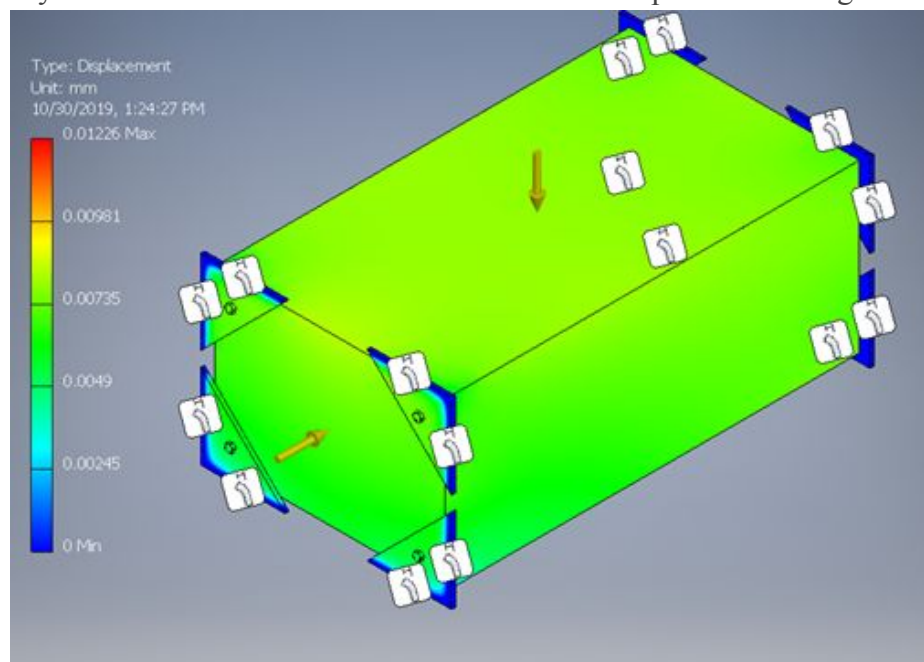
## INTRODUCTION

The TSV team is responsible for developing the high voltage accumulators that will deliver electrical energy to the motor. This includes ensuring the enclosure that houses the electrical equipment is structurally robust and thermally and electrically insulated. The team's top priority is guaranteeing safe and efficient delivery of electrical current to the motor controller.

There are seven goals for the TSV system. (1) Simplify GLV/TSV isolation by minimizing areas of possible electrical contact inside the pack. (2) standardize fasteners and parts. (3) create packs that allow rapid cell replacement. (4) develop a Sophisticated State of Charge (SoC) algorithm through the acquisition of vital cell parameters. (5) create an accurate Cell Model. (6) implement algorithms on the microcontroller, and finally (7) design a system for robust charging.

## CHASSIS MOUNTING SURVIVES 40G-20G TEST

Finite Element Analysis will be used to ensure that (1) the accumulator mounting to the chassis will withstand these forces and (2) the accumulators and their contents will withstand these forces, as specified by the rules. This will be completed by placing 40g and 20g forces in the horizontal and vertical planes, respectively on the battery assembly/mounting in ANSYS, and recording measurements of computer-generated stress-strain estimations. The accumulators and accumulator mounting will pass this test by demonstrating deformities below 2 mm of deflection in any direction and actual stresses below the ultimate tensile strengths of all bolts and gussets. FEA is an appropriate way of modeling and evaluating the way material deforms under loads. Inspection records will be provided in the form of photographs that verify the built accumulators match the assembly modeled in ANSYS. The ANSYS model is depicted in the figure below.



*Figure Sixteen: ANSYS Model*

### HIGH VOLTAGE DISCONNECT IN 10 SECONDS

This test ensures the high voltage disconnect can be disconnected in 10 seconds as specified by the rules. The test will be performed by (1) recording the time duration of a team member disconnecting the TSV cables from an accumulator while mounted to the chassis, and (2) recording the time duration of a team member completely disconnecting the SMD switch from an accumulator while mounted to the chassis. The test will be passed if either can be disconnected in less than 10 seconds as both the TSV cables and SMD are considered high voltage disconnects by the rules. Time records and images of team members performing high voltage disconnect, if necessary, will be provided for inspection records.

### BATTERY ASSEMBLY PHYSICALLY SURVIVES A BRAKING TEST

This test acts as a corollary to the braking test under the Suspension Section to ensure the accumulators can withstand this extreme form of braking. After the braking test, accumulator parts will be manually measured within the assembly to ensure they do not move more than 1 mm in any dimension. Measurements of moving parts will be recorded, using the bottom, back, left corner of the accumulator as the origin. These measurements will be taken in addition to a complete visual inspection of the inside of the accumulator by removing aluminum plates of the enclosure. Pictures will be captured and included for inspection records.

# STEERING

## Introduction

The steering team is responsible for designing, manufacturing, and implementing a steering control system that contains three major subsections. The first and most important is the steering rack control itself. This contains the apparatus from the steering wheel and the transmission elements culminating in the steering rack itself. Additionally, there are the front control arms that are used to connect the steering rack to the uprights and align the front wheels with a prescribed steering angle. Finally, there are the rear control arms. The primary difference between the front and rear control arms is that the rears are designed to keep the rear wheels pointing straight at all times as the team elected not to have an active rear-wheel steering system.

The main design criteria revolve around turning radius, Ackermann, and toe angle. The turning radius was calculated using a combination of industry standards for the competition and information presented about the autocross course. Ackermann's analysis was carried out in-depth by last year's team, and this was used to inform the designs created for this year's vehicle. The general requirements were for a parallel design or a small amount of reverse Ackermann. Toe angle was calculated in optimum kinematics and was described in the suspension section of this report.

## WHEEL CLEARING

Tires must not come into contact with any other aspect of the car at full lock. This will involve having the required three-inch requirement of clearance between the outside of the tire and the battery enclosure. Additionally, it will involve checking for visible space between the tire and chassis at full lock. There may be no parts of the car within a 75mm box of the tires.

## TEST TURNING RADIUS

As part of the steering system geometry, the vehicle must be able to negotiate a 9 meter hairpin turn during both the endurance and autocross events. The 9 meter is defined as the diameter of the outside of the turn. This will be tested by using a series of traffic cones at Metzger fields to recreate an 8m diameter hairpin. Analytically, this was calculated by using the steering ratio of the Stiletto box and the steering axis length to estimate what the final turning radius will be. We expect to have a steering radius of 4 meters.

## TEST STEERING PLAY

The competition guidelines limit steering play, defined as steering wheel input with no output at the tire, to 7 degrees. Our system is designed to have no steering play. The play will be tested by using the apparatus for our ratio steer-steer test. This consists of a protractor being mounted to the steering column and having the steering wheel be rotated slowly and having the input angle be measured against the motion of the wheels measured by taping a dowel to the top of the tire and hanging a weighted string on top of a larger protractor showing the steering angle.

## TEST BUMP STEER

Put weight on the nose of the car and make sure the wheels do not begin to toe in/out. This will be done by video-recording the test and reviewing the footage in slow motion. In order

to pass, the wheels should not bump by more than 0.05 inches. This will be measured using a bump steer gauge and confirming in the video.

# PEDALS

## INTRODUCTION

While the pedal system is a small part of the car, it is a crucial system of the car as it gives the driver control over nearly all systems. While the throttle pedal design is almost entirely borrowed from the previous year's team, small design changes were made to improve functionality that will need to be tested. The critical component of the pedal system, however, is the brakes, as the braking test is a test that all teams need to pass without exception. The design of the brake system took this into account and focused heavily on ensuring the car would pass.

### THROTTLE PEDAL

The throttle pedal and mechanism for this year's car was almost entirely taken from the previous car. The significant improvements made were the implementation of a new potentiometer mount and a new pedal mount. Aside from that, all aspects of the pedal are the same, including the return spring mechanism. However, to remain rules compliant, positive stops need to be added at both the front and back of the pedal to prevent breaking the potentiometers. The initial design of the pedal system shows the mounts will limit that forward motion, but when the throttle is pressed, there is no stop behind it. A stop is thus being designed to prevent this. It consists of an L-shaped bracket that will contact the backside of the pedal to stop its motion and will be adjustable to allow for small corrections if needed.

### BRAKE OVER-TRAVEL SWITCH FUNCTIONS

The over-travel switch is again taken from the previous car as it still functions properly, so no new design or modifications are being made. It will be mounted to the brake pedal mount and tested by pressing it while the car is running to ensure it cuts all power.

### BRAKE PEDAL TO WITHSTAND 2000N OF FORCE

A new brake pedal was being designed for this year's car as the previous design was too large to fit in the foot box of the new chassis. Initial designs focused on simplicity while still allowing enough mechanical advantage to operate and lock the brakes efficiently. After many iterations, a design featuring an I-beam arm with a fulcrum point on the bottom of the pedal was chosen. After looking through old designs and parts, a pedal made by Wilwood very similar to this design was found that worked perfectly for the new car. It features a lightweight aluminum frame, with high strength, reinforced I-Beam style forged 6:1 ratio pedal arm that will easily withstand the 2000N requirement, as well as provide a slightly improved mechanical advantage to make operating the brakes easier for the driver.

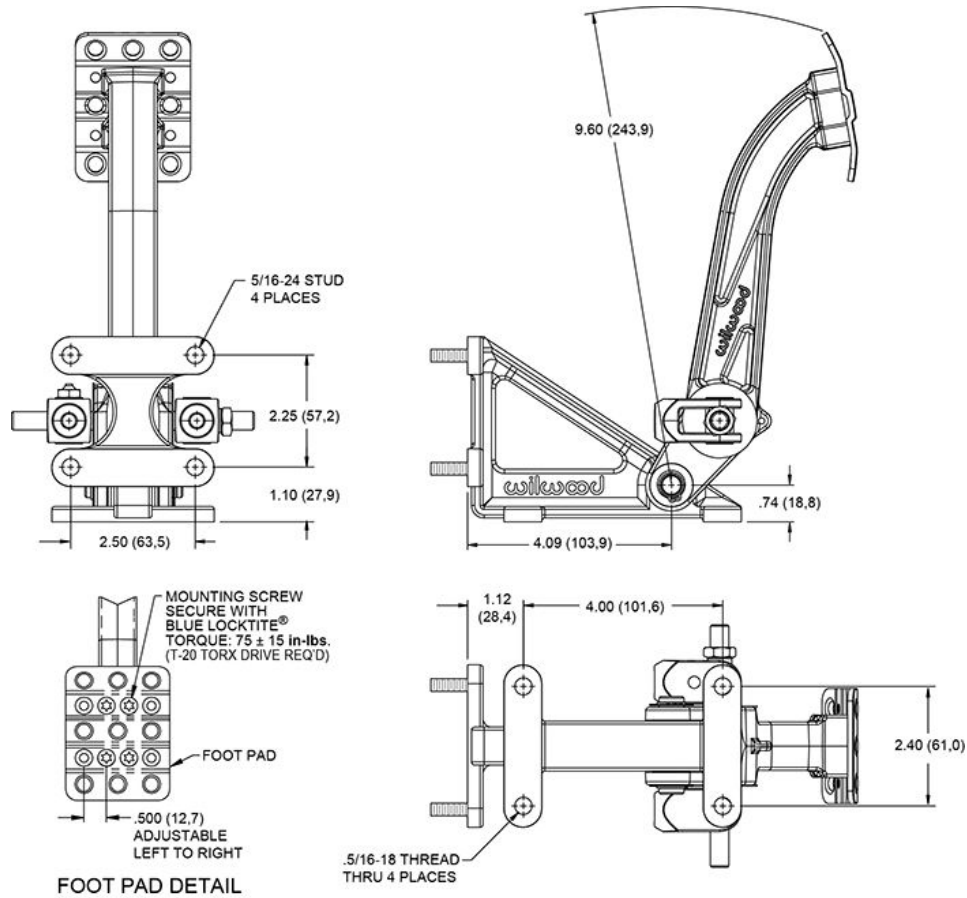


Figure Seventeen: Brake Pedal

### BRAKES LOCK

In order to ensure any driver can lock all brakes, an analysis was done using an estimated weight and center of gravity of the car. It used the known bore size of the master cylinders and brake calipers, brake disc and wheel diameters, coefficients of friction for the tires and brake pads, wheelbase, and other parameters of the car. The analysis was executed in MATLAB. The force required on the pedal for the driver to lock the brakes, and the reasonable force on the front and rear wheels at that point. Assuming a loaded car with a driver is about 1000 lbs, the force required to lock the wheels were found to be 37.7 lbs, which, along with other info, can be seen in the table below.

Force to Lock All Four Wheels	37.7 lbs
Normal Force on Front Wheels	793.3 lbs
Normal Force on Rear Wheels	207.2 lbs
Deceleration Rate	-57.9 ft/s <sup>2</sup>

Table Three: Brakes Lock



## CONCLUSION

The Prototype Specification Report ensures the Lafayette Motorsports Team is focused on designing a well-established set of engineering specifications that drive the design of the car. The Team's engineering solutions and design choices have been exemplified through this report and the specifications are thoroughly explained including supporting analysis and experimental results which clarify the validity and completeness of the engineering design specifications.