Team 19F14
Electric Baja Capstone Team

To: Dr. Oman

From: Drew Stringer, Shamlan Albahar, LeAlan Kinlecheenie, Fahad Alhowaidi, and Andres Parra

Date: 28 February 2020

Subject: Implementation 1 Memo

We are the 2019-2020 senior E-Baja Team from Northern Arizona University. The team is composed of five Mechanical Engineers and four Electrical Engineers. We have been tasked with converting the 2015 NAU SAE Baja car to being fully electric. To convert the car, this requires disassembling the original car, then redesigning the car using only the original frame. The mechanical components being redesigned are the brakes, the front suspension, rear suspension, steering and the gearbox. The brakes have arrived and are ready to be attached to the vehicle February 28th as well as the front suspension and steering. The rear suspension parts have been quoted and should be completed by March 25th along with the gear box and implementing the electrical components.

1 Implementation

The design is ready to begin implementation. Many parts have been ordered and manufacturing of other parts has begun. The front of the vehicle is underway to completion. This section will overview which parts are being manufactured and which others are undergoing design changes. Then it will report on how all these affect the implementation of the project and will go into detail on how future parts will be designed and created.

1.1 Manufacturing

For the car, there are a few parts that needed to be manufactured to finalize our design. There are multiple methods that will be used to manufacture the parts. We will outsource some of the parts that are going to be manufactured. Any parts that we can manufacture ourselves will be done at the shop to minimize costs of labor.

1.1.1 Trailing Arm

The trailing arm is one of the main pieces that must be manufactured. It consists of the actual trailing arm and three attachment points. The attachment points are the heim joint that connects to the frame, the metal plate that connects the trailing arm to the shock, and the attachment point to the rear knuckle. Number of safety calculations have been made using FEA. This ensures that none of the pieces will yield under max contact in different directions.

First, the trailing arm will be cut from a metal plate in one complete piece. A CNC machine will be used for precision in the chamfers and holes. The plate is 6061 T6 Aluminum and will be an inch thick. The trailing arm has been designed with a thicker end where the heim joint will be placed as seen in figure 3. A hole will be tapped into that end and a HMX10G Series heim joint will be screwed into it. A bolt will then attach tw plates from the frame to the joint.

Two steel plates will then be connected to the other end of the trailing arm. One on each side to bolt onto the arm itself. Steel was chosen so that the aluminum trailing arm can have some support when taking the impact from the wheel. The plate has two holes to fasten the plates together onto the trailing arm and then two more holes to attach the shock on top and the other to the rear knuckle. The same will be done with two steel plates on the bottom of the trailing arm. The plates will be manufactured on the CNC for accuracy and the holes can be made on the mill for dimension accuracy.

1.1.2 Rear Suspension Link

The rear link will be used to attach the trailing arm to the rear knuckle. It will be manufactured using the same steel as the steering links. The team will attach to the rear knuckles with four bolts and attach to the trailing arm with two bolts. The link will need to be cut precisely because it let the driveshaft attach to the rear knuckle as well. The cute will be done with the CNC mill for precision and the holes will also be made with the mill to ensure dimension accuracy. The bend will be made by using the hydraulic press in the machine shop. Slowly applying pressure until the right angle has been made.

1.1.3 Steering Link

The steering link was made of ¼" scrap sheet metal donated by K&M machine shop located in Flagstaff, this sheet metal will be used for the steering links, rear suspension links, and brackets for mounting purposes. The sheet metal was cut with a cut off wheel to close dimensions and grinded down to accurate dimensions and the holes were drilled for the bolts and tie rod connection point. To get the proper angle for the link to fit on the front knuckle, it was bent with the hydraulic press in the machine shop. It was completed and fits perfect on the knuckle and is ready to be placed on the car.

1.1.4 Front suspension

The front suspension has two arms in each side and made from steel. The manufacture process for the front suspension has been made. First the team disassembled the suspension from the car in building 47a so we can start working on it. After that, the team drilled bigger holes for the heim joints and bolts to avoid the bending on the car. The team did some grinding and welding in the machine shop to make the new heim joints and bolts fits on the new suspension. All calculations have been made for the front suspension and is shown in figure 14 in the appendix.

1.2 Design Changes

There are multiple changes to the car that need to be done in order to have an operating car and to meet the requirement of converting the car to full electric.

1.2.1 Design Iteration 1: Change in Front Suspension

The original design of the front suspension needs some improvement. The old design has had issues with the components snapping or bending. By increasing the size of the supports and the modifications of the heims joint, for which the calculations have been done and shown in appendix #, the suspension will hold up much better. None of the angles or main front suspension need to be changed due to already being a great base design. With small improvements, changing heim and bolts this design work great for the vehicle. Based on the calculations, the team agreed on having M8 heims for the upper front suspension and M10 Rod ends for the bottom suspension because more load will be on the bottom part. The factor of safety for the M8 size is 1.67 and for the the M10 is 1.8. FEA For new heims are shown in figure 15.

New M8 heims | New M10 Rod ends | Old heims size M6

Figure 1. Old and new heims

1.2.2 Design Iteration 2: Change in Rear suspension for the Trailing Arm

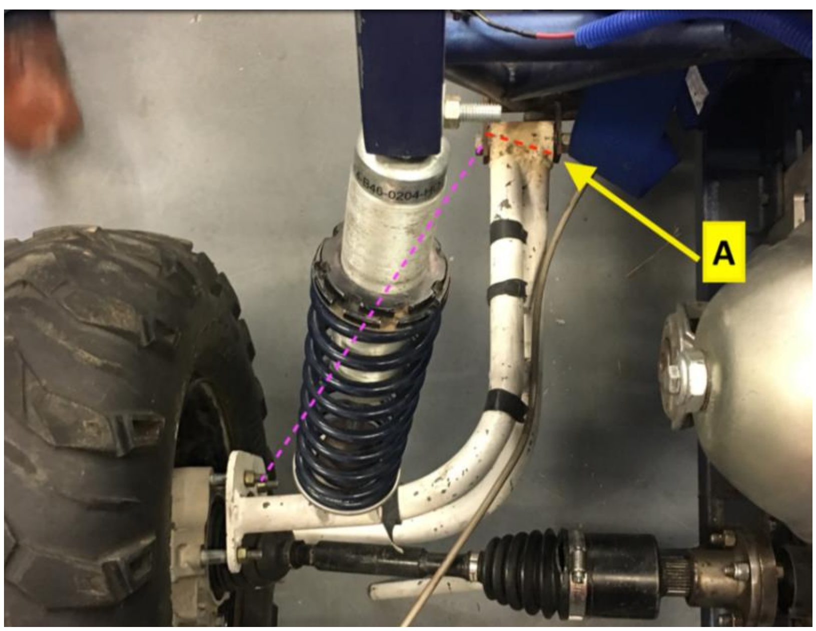

Figure 2. Original Design L-shaped Trailing Arm.

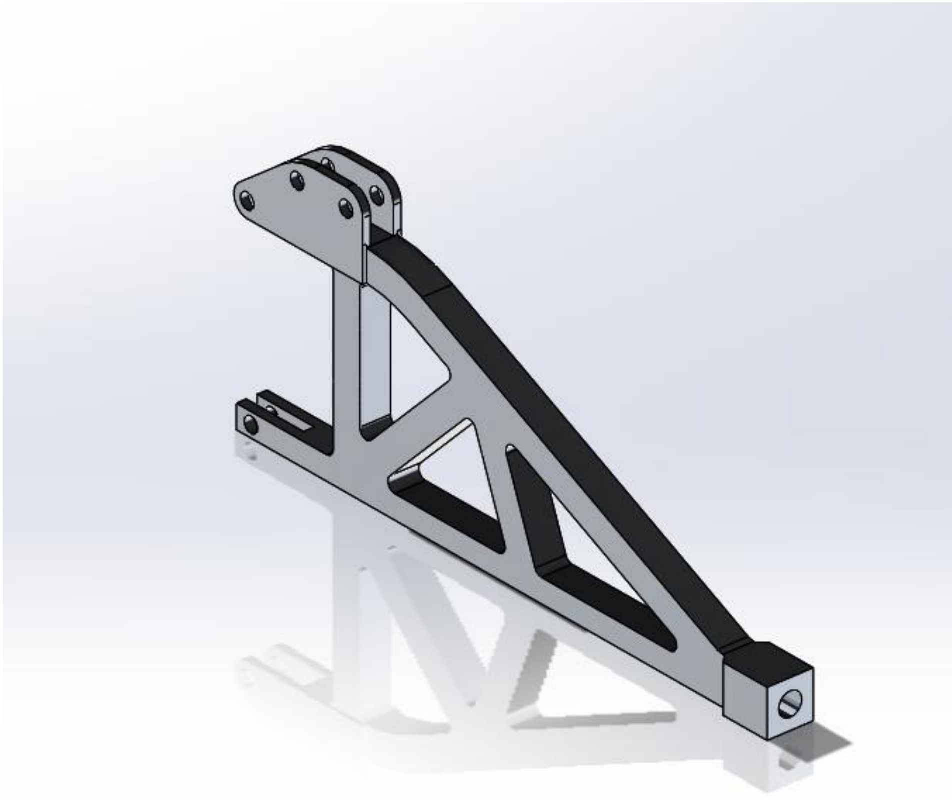

Figure 3. The Newly Designed Trailing Arm.

The original design for the vehicle was an L-shaped trailing arm seen in figure #. The original design has only one degree of freedom. The team agreed on replacing the trailing arm with a new design. The newly designed trailing arm have a degree of freedom on the X,Y,and Z axis. This is due to the attachment of the HMX10G series heims. The heims have been tested thru FEA on Solid Works and factor of safety is 2.1 which is within the customer requirements. In addition, the newly designed trailing arm can withstand the situation where the car is in a trajectory mod and the speed of impact is 30 mph. The load on each tire will be 57,000 newtons and the factor of safety is 1.8 which is within the customer requirements. The newly trailing arm will be made of 6061 T6 aluminum. The decision of changing the trailing arm came with the team doing the Pugh chart and decision matrix. This method helped the team to decide on the final design will be. The team also designed a rear attachment to the trailing arm to angle it towards the wheel hub. The rear attachment will be made of alloy steel. And the factor of safety of it will be 2.3 which is also with in the customer requirements.

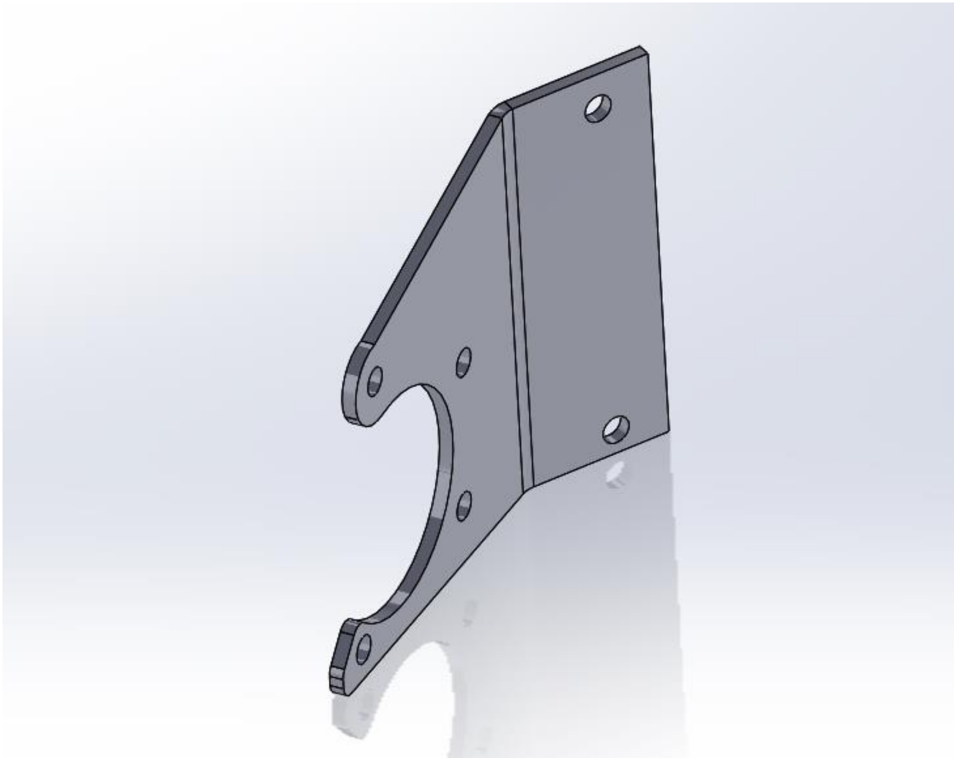

Figure 4. Rear Attachment.

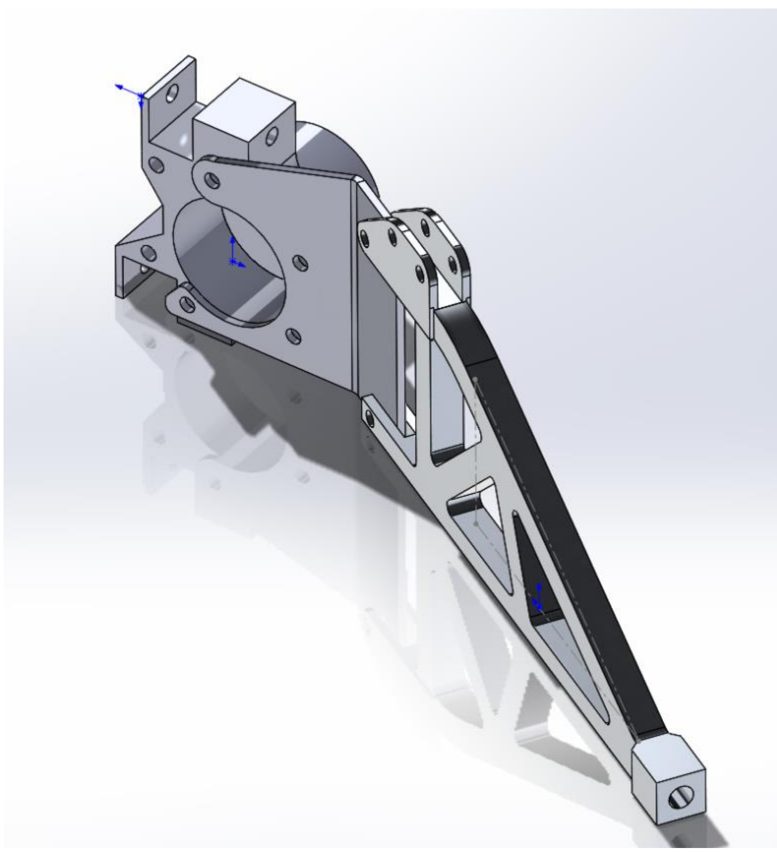

Figure 5. Complete Assembly of the trailing arm, Rear attachment, and wheel hub.

1.2.3 Design Iteration 3: Change in Steering

The original steering did not have a good turning radius and wheels were not aligned properly while turning. This was due to small links from the front knuckles to the tie rods. To fix this problem, the team decided to redesign the steering links from the original design. The original design was smaller and did not have a good Ackermann angle, which allows the car to turn with proper turning radius of 60 degrees. The new design created the ideal Ackermann angle and strengthen the link to a factor of safety to 2.4 with 1,000 lbf into the front of the wheel, shown in appendix A. The original design was welded pieces of sheet metal and the new design is one whole piece of sheet metal, figure 6. This allows the one piece to withstand more stress if the car is to be hit from the wheel of the car.

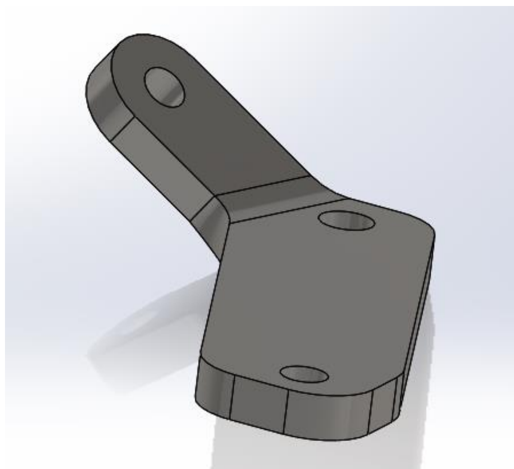

Figure 6. New design for steering link

1.2.4 Design Iteration 4: Change in Braking System

The braking system had to be mostly replaced since the majority of the system was not on the vehicle when we got it. Some of the components were reused such as the calipers, rotors, and brake pads. The other components such as brake pedal, master cylinders, and brake fluid reservoirs had to be added to the car. Since these parts needed to be added, they also needed mounts to attach them all the car. The mount for these systems is what had to be manufactured for the braking system.

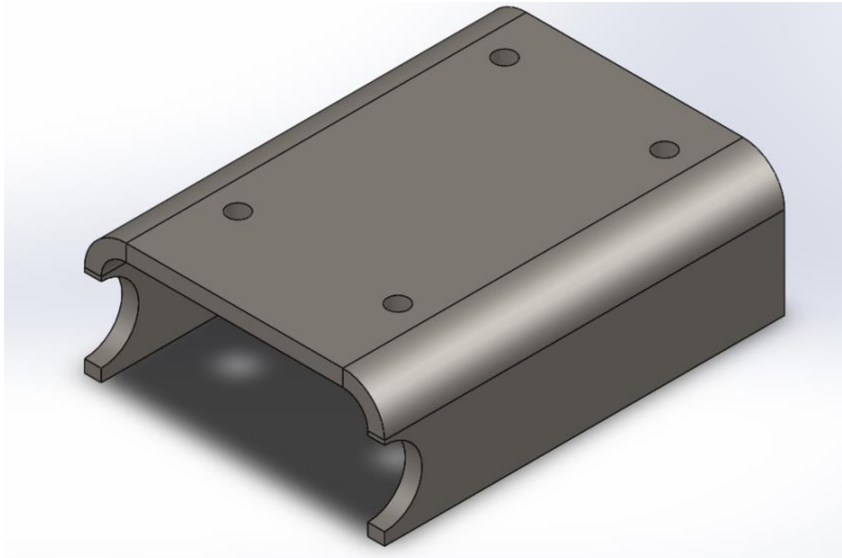

Figure 7. Brake Pedal Mount

The brake pedal mount was manufactured out of ¼ in sheet steel. The pedal mount isn't a part that will have a lot of stress on it, so this piece of steel had a factor of safety of way higher than we needed on our car. We could have used thinner material, but we were given this sheet, so we used it to keep costs down.

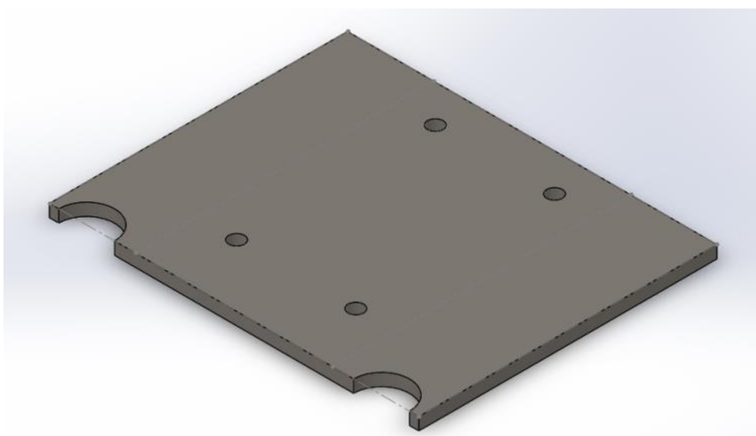

Figure 8. Brake Pedal Mount Sheet Metal

As seen in the picture above, the features were all cut into a piece of sheet metal and then the bend was applied. Due to the size of the piece, a grinder was used to cut in the half circles which is what attaches to the frame by a weld. The holes in the center are used for mounting the brake pedal to the car. On the side members of the bracket, the holes will be drilled and tapped to attach the brake fluid reservoirs. This allows for minimal hoses and connections since the cylinders will be mounted right next to the reservoirs.

1.2.5 Design Iteration 5: Change in Drive Train System

Due to the car being converted to electric and is now utilizing an electric motor the team is in need of creating a new gearbox. The gearbox will be used to get the gear ratio required and to distribute the power to both wheels. Using gears from the old gearbox, we have designed a new gearbox to get the proposed gear ratio.

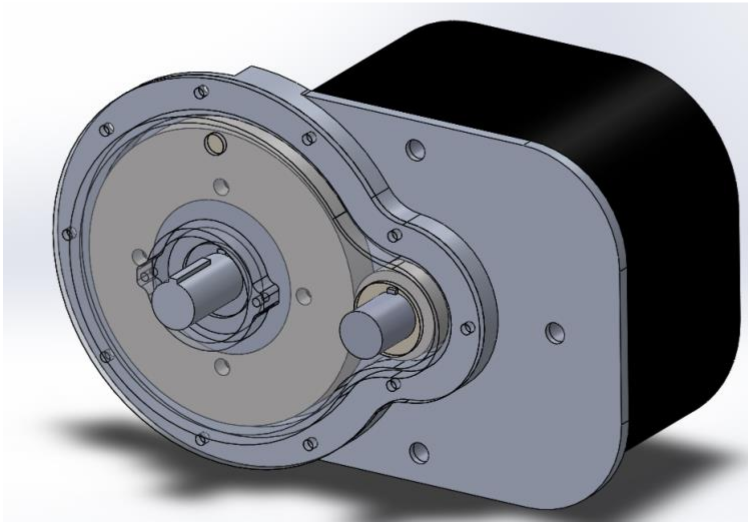

Figure 9. Gearbox and Motor Assembly

In the figure above, it shows how the motor attaches to the new gearbox with the two gears inside. The gearbox is going to be machined out of billet 1 in thick Aluminum. There are going to be two sides to the gearbox which will have features on either side of them which will complicate the machining. These two parts are going to be manufactured on the CNC Haas Mill at the school.

2 Future Implementation

The team is on track with the schedule. A Gantt chart have been provided in the appendix which shows the team tasks, timeline, responsibility and goal for delivering the final product. The budget and a simple schedule breakdown are provided in the following sections.

2.1 Further Manufacturing and Design

The team has the majority of their parts on their way to be manufactured. We have several parts submitted to the manufacturers and are waiting on them to be manufactured and on quotes. Some parts such as the Trailing arm mount, we are going to make ourselves which will be done this next week when the front suspension is all finished. The trailing arms have been submitted to Marzee to be manufactured. These are going to be finished at the end of next week (3/6). The gearbox is in the final design stage and will be submitted to be manufactured at the start of next week (3/3).

2.2 Schedule Breakdown

Table 1: Timeline of Remaining Project

NAU eBaja Capstone Project		
Action	**Parties Involved**	**Month/Year**
Preparation	ME Subteams	February/2020
Begin manufacturing parts for front and rear suspension, begin front suspension build and adding brakes	ME Subteams	February/2020
Await manufacture time for rear suspension parts, finalize adding brakes	ME Subteams, Machine Shop	March/2020
Begin build of rear suspension, finalize front suspension, allow EE team to add electrical components	ME Subteams, Machine Shop, EE Team	March/2020
Finalize rear suspension build, finalize electrical components	ME Subteams, EE Team	March/2020
Present at UGRADS the results of vehicle	ME Subteams, EE Teams	April/2020
Hand off vehicle to client	ME Subteams, EE Team, Client	April/2020

This capstone project will be finalized fully by April of 2020. Before that, the teams still have to finish manufacturing the pieces and assembling the vehicle. The front suspension will be finalized by February 28th and the EE team will be able to mount their items soon after. All parts are in the process of being manufactured or delivered. The due date for the capstone class is March 25th and the vehicle should be completed barring major setbacks which will be communicated to the client and advisor.

2.3 Budget breakdown

Table 2: Gore Budget Bill of Materials

Gore Budget $3,000.00				
Part #	Part Name	Qty	Unit Cost	Total Cost
1	Front Hub Link	2	$50	$100.00
2	Rear Hub Link	2	$50	$100.00
3	Support Rods	4	$40	$160.00
4	Trailing Arm	2	$500.00	$1,000.00
5	Front Heim	8	$11.99	$95.92
6	Trailing Arm Heim	2	$17.50	$35.00
7	Rear Heim	4	$11.99	$47.96
8	Tire	4	$75	$300
9	Firewall UV94-V0	1	$400.00	$400
10	Brake Pedal	1	$176.94	$177
11	Fluid Reservoir	2	$64.74	$129
12	Brake Cylinder	2	$70.19	$140
13	Pinion Gear	1	$68.00	$68
14	Gear 2	1	$132.00	$132
15	Rack and Pinion Boots	2	$29.95	$60
Subtotal				$2,945.58
Shipping and Handling				-
Tax				-

Total Cost	$2,945.58

The Gore budget sustains all the important parts and manufacturing. The team has maxed out and been decisive on what is needed. Shocks are an opportunity cost the team must take due to the expensive price of the fire-resistant plastic hat will work as a heat shield. It will keep the driver safe. The total price has left a small surplus in case shipping and handling becomes an issue. However, most places the team will order from will first ask for part donations. This will allow the team more flexibility.

Table 3: Mechanical Engineering Department Budget Bill of Materials

ME Department Budget $1,000.00				
Part #	Part Name	Qty	Unit Cost	Total Cost
1	Titanium Split Point Drill Bit Set, 29 PC	1	$24.99	$24.99
2	Safety Glasses with Clear Lenses	1	$11.94	$11.94
3	10 Person First Aid Kit	1	$14.99	$14.99
4	20V Hypermax Lithium 1/2 in. Drill/Driver Kit	1	$69.99	$69.99
5	17 PC Professional Saw Set	1	$14.99	$14.99
6	3 Lb. Neon Orange Dead Blow Hammer	1	$9.99	$9.99
7	6 in. Swivel Vise with Anvil	1	$62.99	$62.99
8	44 x 22 in. Double Bank Red Roller Cabinet	1	$499.99	$499.99
9	7 pc. Metric Combination Ratcheting Wrench Set	1	$24.99	$24.99
10	7 pc. SAE Combination Ratcheting Wrench Set	1	$24.99	$24.99
11	301 pc. Mechanic's Tool Set	1	$199.99	$199.99
Subtotal				$959.84
Shipping and Handling				$96.94
Tax				$53.75
Total Cost				$1,110.53

The ME department has given the team a personal space at building 47A to work in. They also took another step in buying new equipment to work with. This includes safety gear and hand tools. This money has already been accounted for and is in no need of further action.

Table 4: Green Fund Budget bill of Materials

Green Fund Budget				
Part #	Part Name	Qty	Unit Cost	Total Cost
1	Fire Extinguisher - Class ABC 10lb	1	$100.00	$100.00
2	Fire Extinguisher - Class D 30lb	1	$650	$650.00
3	Class 0 High Voltage Gloves	4	$90.00	$360.00
4	First Aide Cabinet	1	$200.00	$200.00
5	Earplugs	1	$25.00	$25.00
6	Safety Glasses	1	$15.00	$15.00
7	Trash Bags	1	$15.00	$15.00
8	Respirators	1	$20.00	$20.00
9	Kitty Litter	1	$15.00	$15.00
10	Hazardous Material Cabinet	1	$600	$600.00
11	5% Contingency	-	-	$100.00
Subtotal				$2,100.00
Shipping and Handling				-
Tax				-
Total Cost				$2,100.00

The Green Fund will be used to order the remaining safety necessities of room 47A. Things such as fire extinguishers and high voltage gloved are necessary if the team will be working with electrical components. Kitty Litter allows the team to clean leaky oils and hazardous material to prevent slip and fire hazards. This list has been sent alongside a letter of support and the Green Fund application to Dr. Ciocanel for approval. Since this money is still uncertain, it has been focused with the items the team does not immediately need if taken the right precautions.

Appendix:

Mass	kg	363		
Gravity	m/s	9.81		
Height	m	1		
Velocity	m/s^2	13		
Work	kj	34234.53		
X (distance)	m	0.3		
Force	N	114115.1	FOS	1.1
F on one side	N	57057.55	FOS	2.142
T Bone	FOS 0.053	F=114115.1		
T Bone	FOS 0.11	F=57057.55		

Figure 10. Excel calculation for vehicles trajectory and impact.

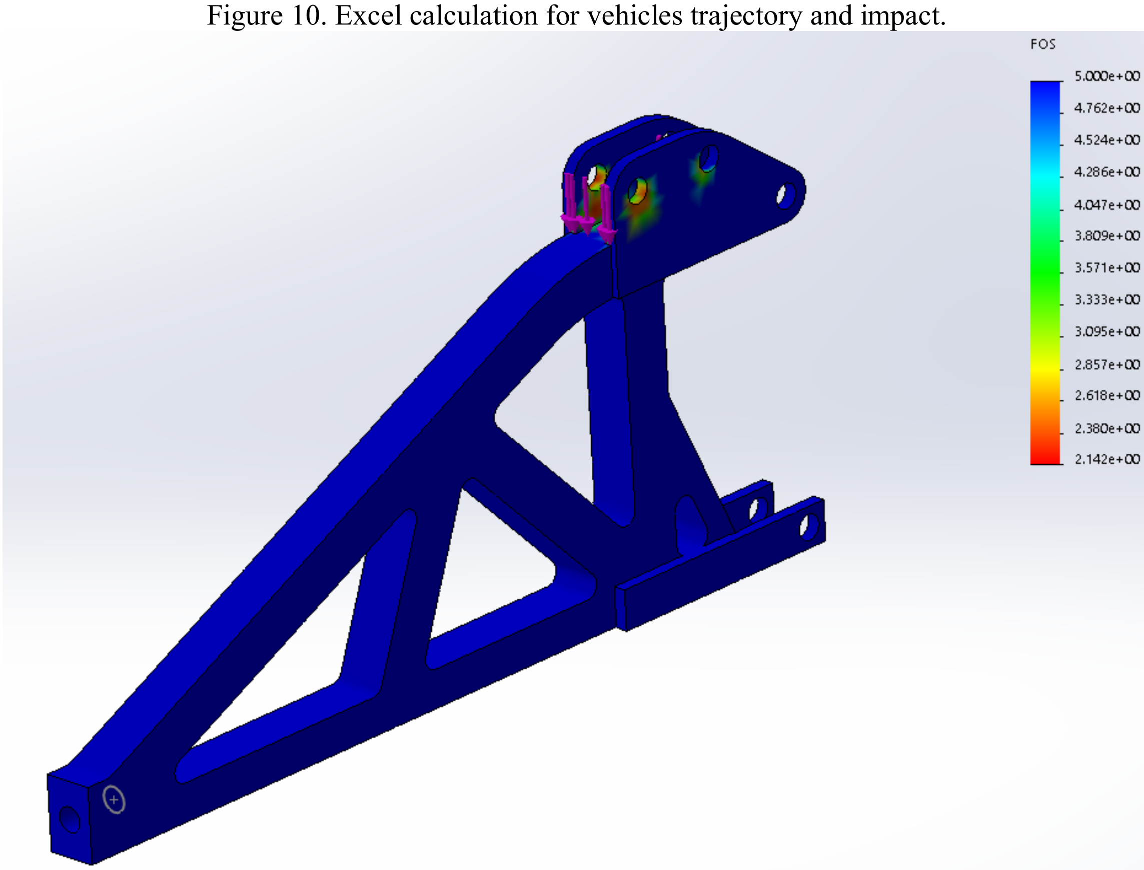

Figure 11. FEA on Trailing arm showing a FOS of 2.142

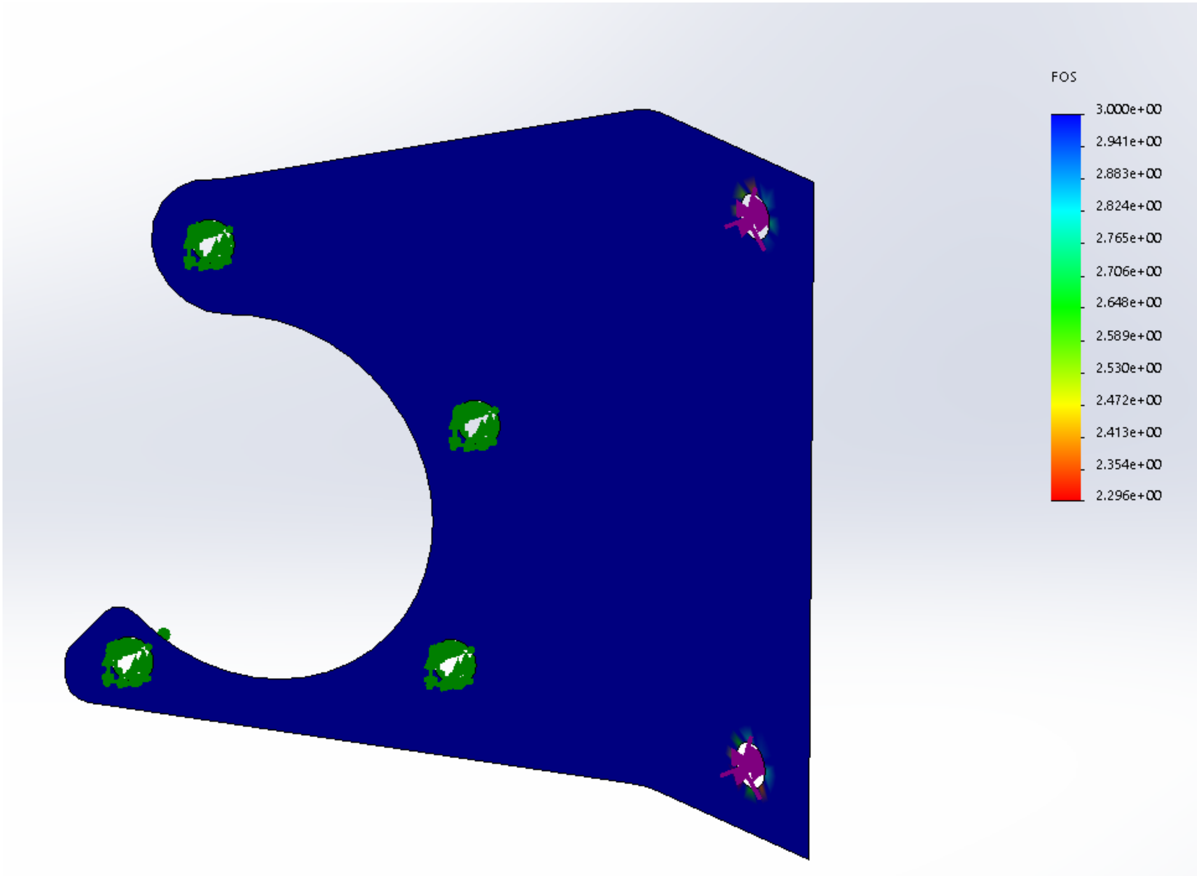

Figure 12. FEA on Rear attachment showing a FOS of 2.296

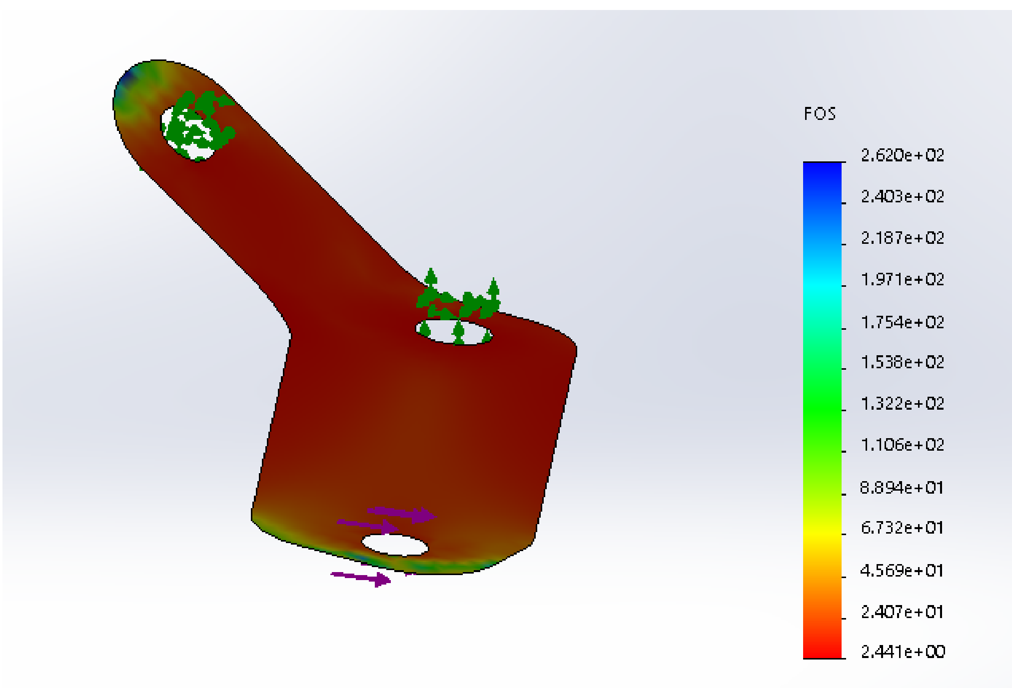

Figure 13. FEA on counter force if the wheel was hit from the front, FOS of 2.441

Given Parameters (Bottom Heim Joint)				
Ball Diamter	E	1.125	in	
Housing Width	H	0.562	in	
Head Diameter	D	1.500	in	
Minor Dia of thread	M	0.625	in	
Allowable Material Stress	X	52,000	PSI	(Material-SS 300 Series)
Calculated Values				
Race Material Compressive Strength	R	32877	lbf	
Rod End Head Strength	T	8068	lbf	
Male Thread Rod End Strength	S	15844	lbf	
Maximum Static Radial Load		8068	lbf	
Maximum Static Axial Load	A	9424	lbf	
	fs=	1.8		

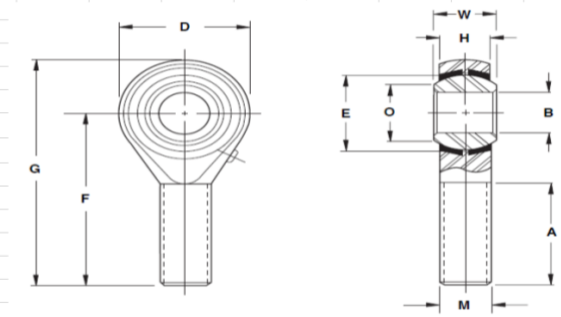

Figure 14. Front suspension calculation for M10 heims

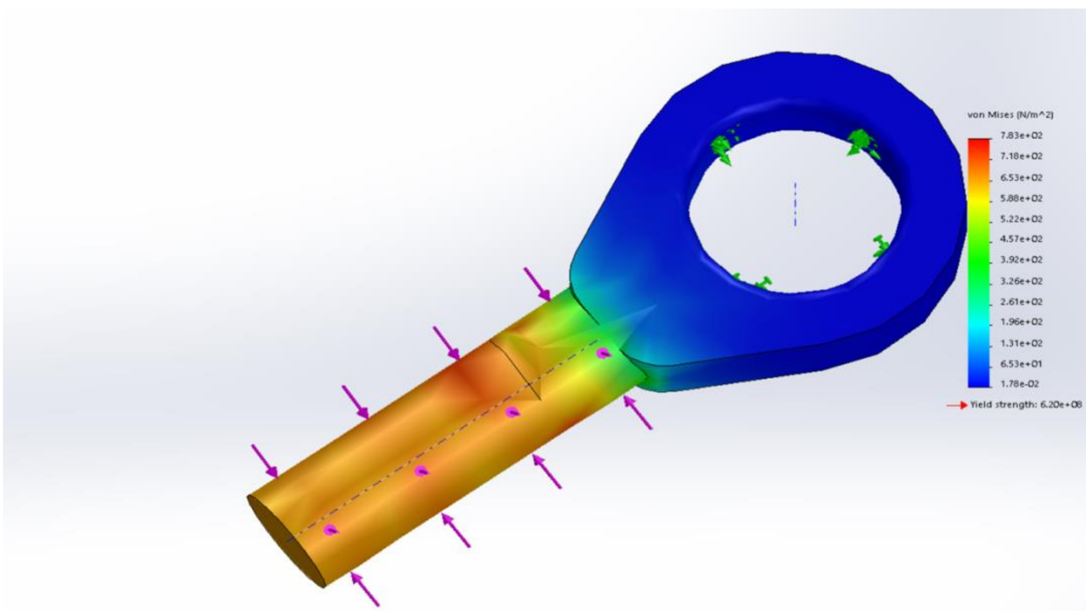

Figure 15. FEA on heim joints

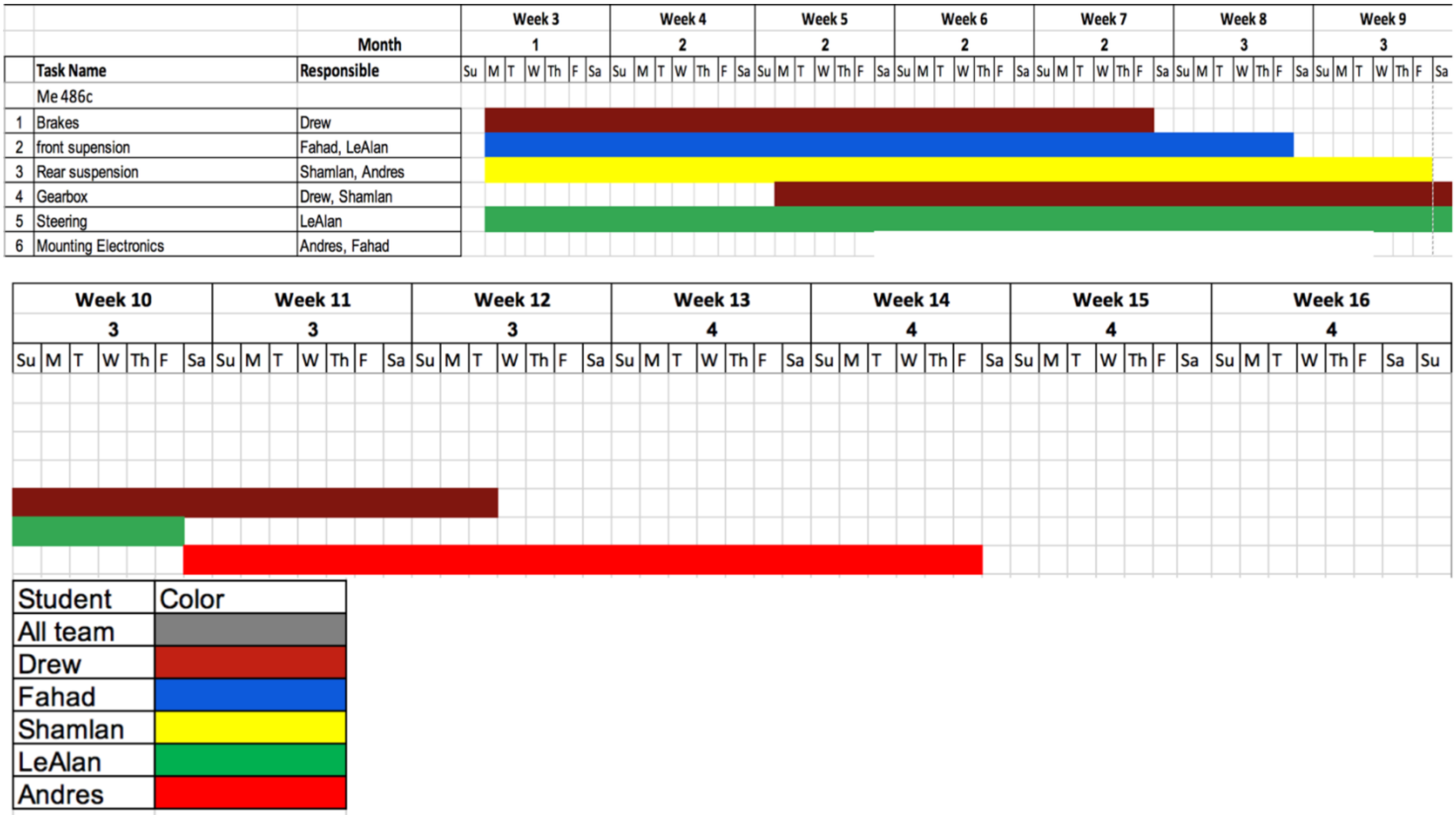

Figure 16. Gantt Chart