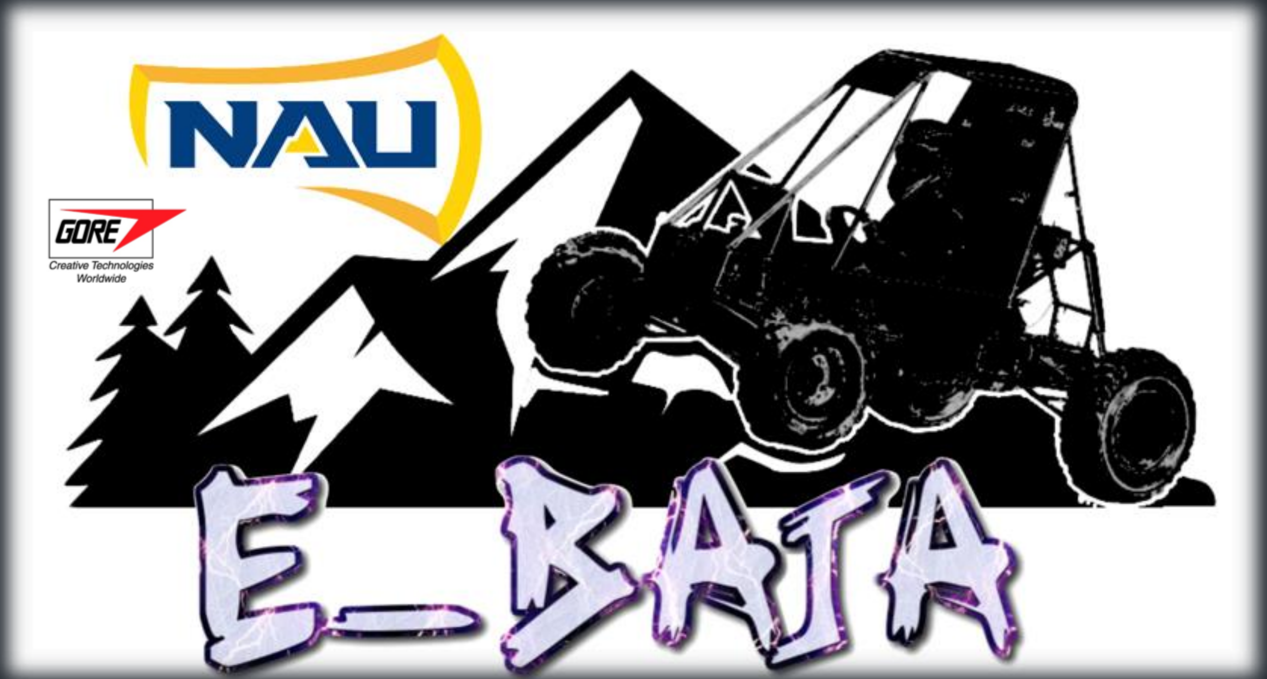


Andres Parra

Drew Stringer

Fahad Alhowaidi

LeAlan Kinlecheenie

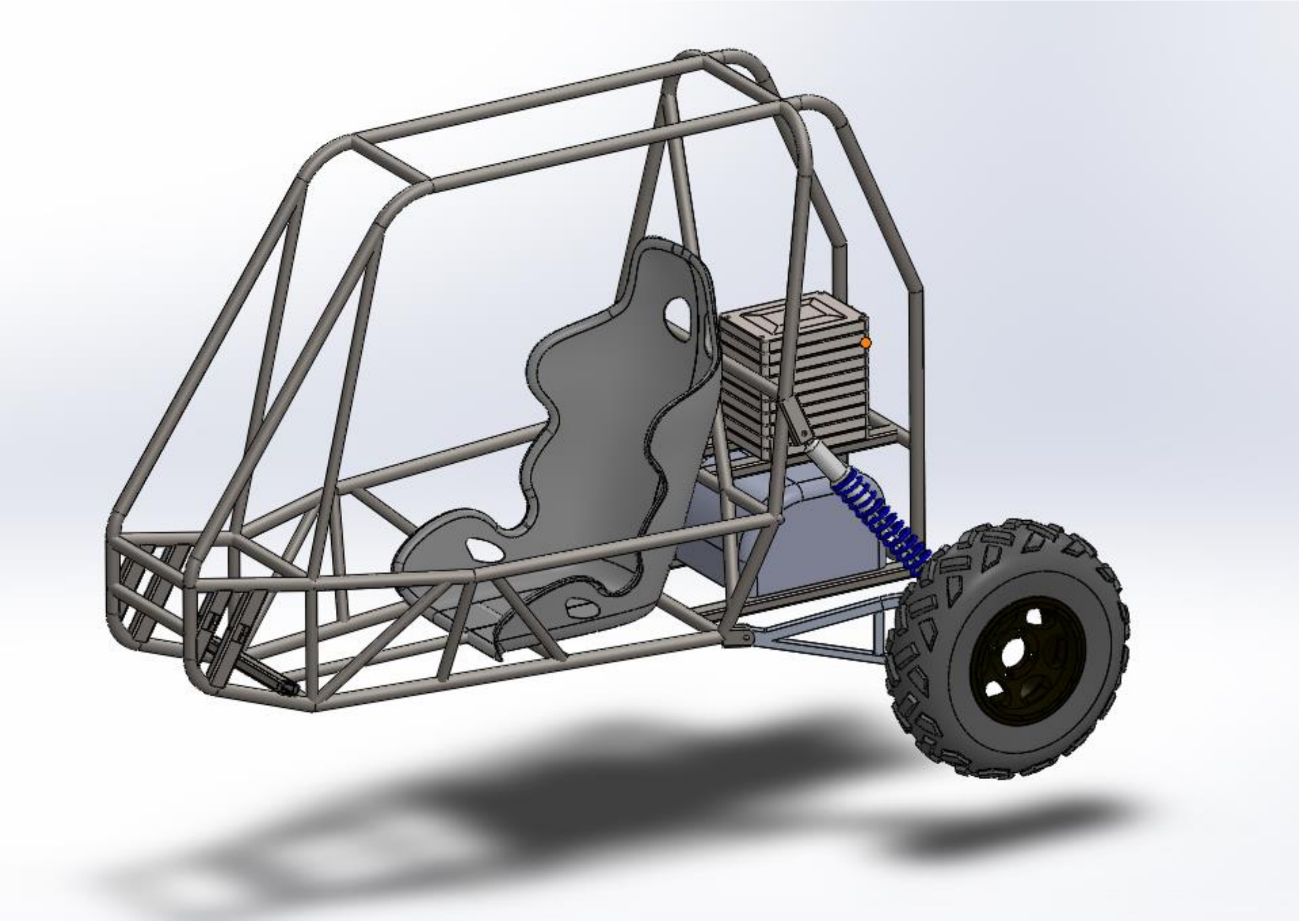
Shamlan Albahar

PROJECT DESCRIPTION

- Transform 2015-2016 Baja Car to Full Electric
- Work along EE Capstone team
- Conform to E-Baja Safety Rules
- Compete against 2019 Baja Car
- Client is David Willy
- Financially sponsored by W.L. Gore

CAD Model

- Need To Add
  - Front Suspension
  - Electronic Components
  - Steering Components



Subsystem Component Designs

- Rear Suspension (Trailing Arm)
- Steering (Front Knuckle)
- Front Suspension (Heim and Bolts)
- Brakes
- Gear Box

CUSTOMER NEEDS

Customer Needs	
Safety of User	5
Follow SAE E-Baja Rules / Industry Standards	5
Redesign Rear Suspension System	5
Redesign and Provide a Functioning Brake System	5
Electric Compatible Drive Terrain	4
Reinforcing Front suspension	4
Provide Space for Battery Mount	3
Redesign Steering	3
Ease of Fabrication of Components	2

High – 5
Low – 1

ENGINEERING REQUIREMENTS
RANKED ACCORDING TO RELATIVE TECHNICAL IMPORTANCE:

1- Safety (Tbd Factor of Safety)

2- Speed of the Vehicle (30 Mph)

3- Cost ($3000)

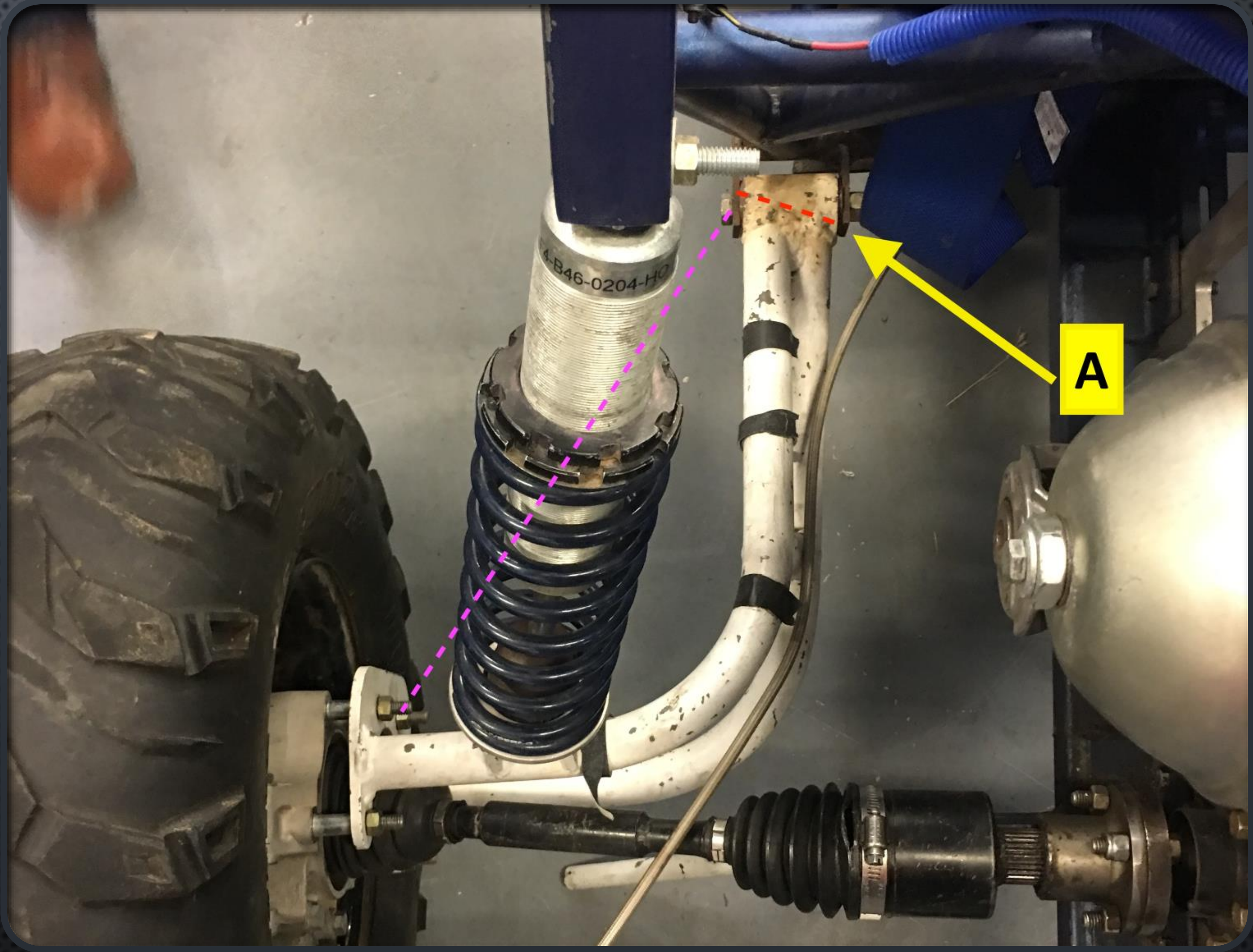
4- Torque of the Vehicle(TBD Nm)

5- Range of Motion of the Steering System(60 Degrees)

6- Weight of the Vehicle (363kg = 800lbs)

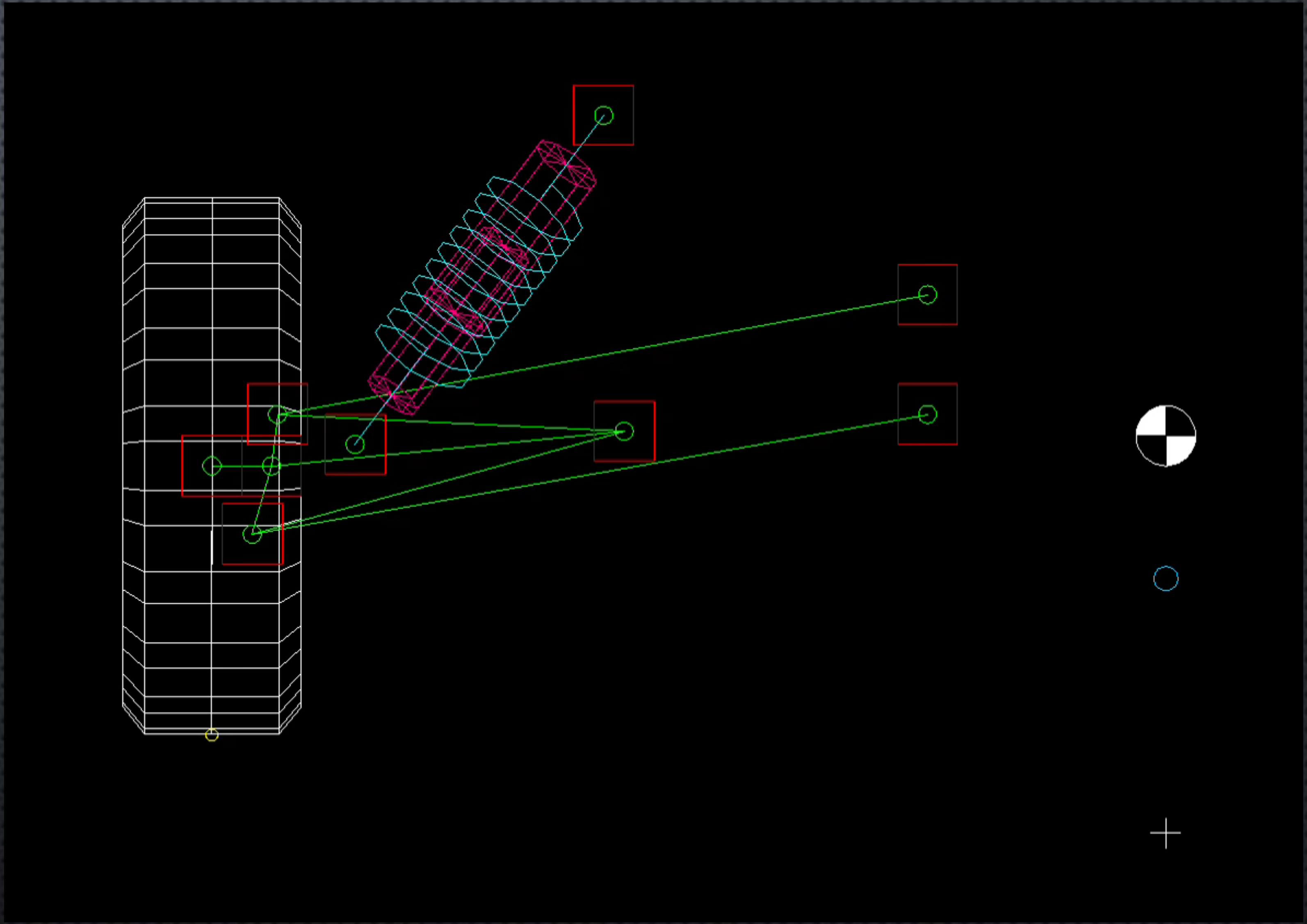
Rear Suspension Problem

- L-Shaped Trailing Arm
- Low Degree of Freedom
- Limits space
- Lacks Stability

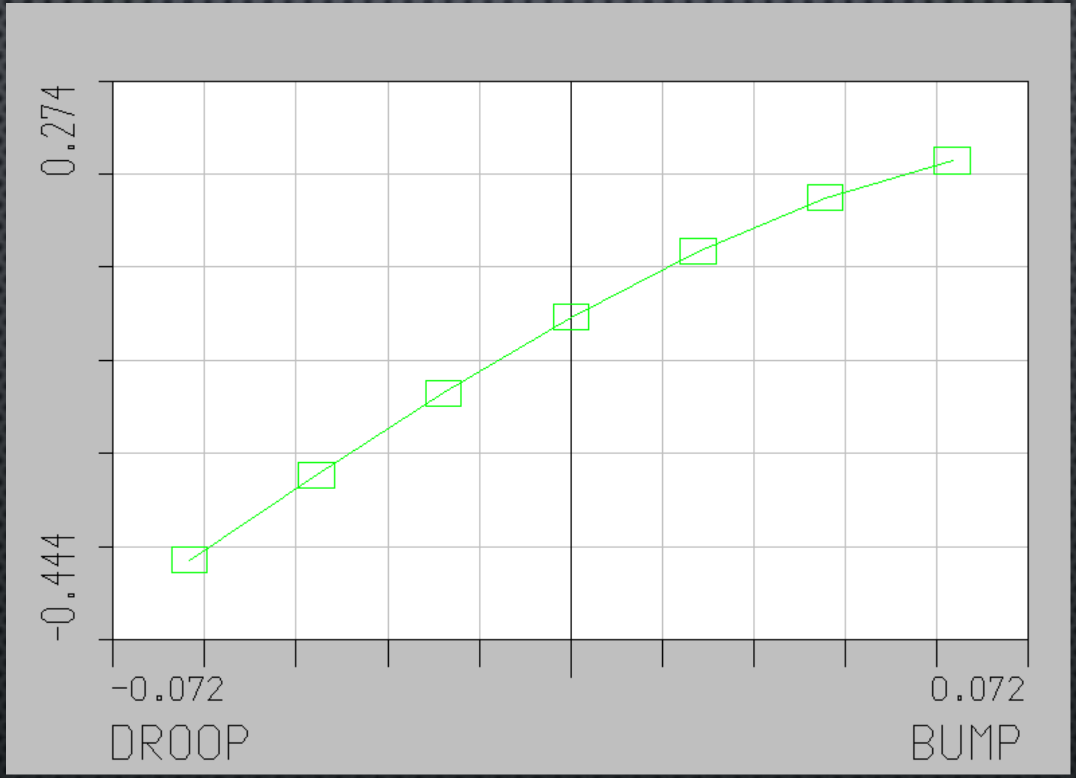


REAR SUSPENSION VIA LOTUS

- A-Shaped Trailing Arm
- Two stabilizers
- High Degree of Freedom
- Controls Camber
- Stable



LOTUS RESULTS

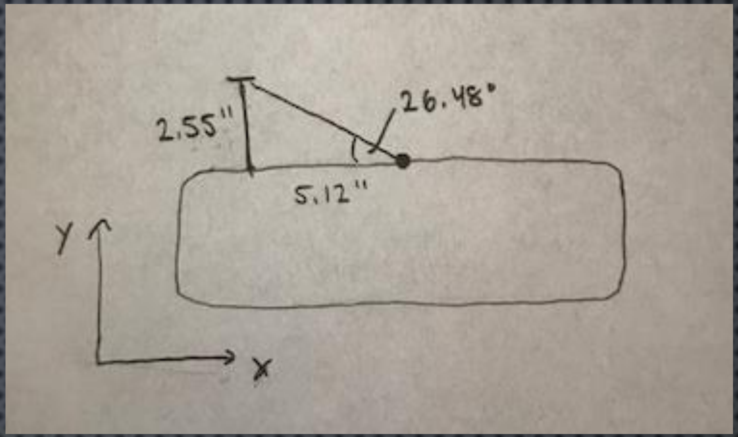


Camber (degrees)

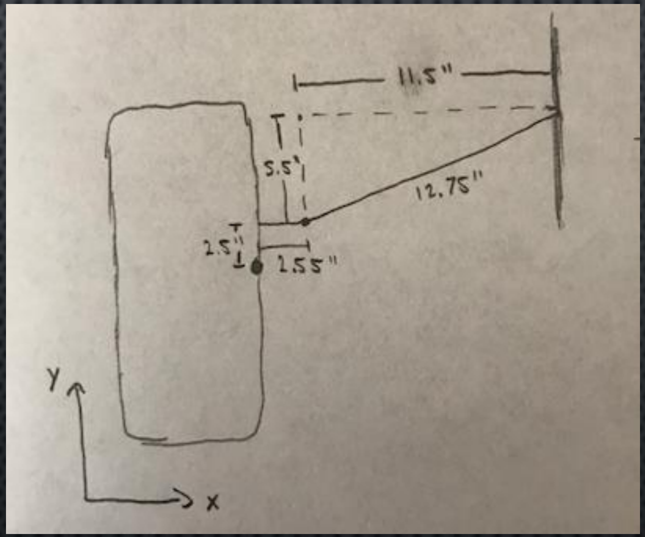
Steering Problem

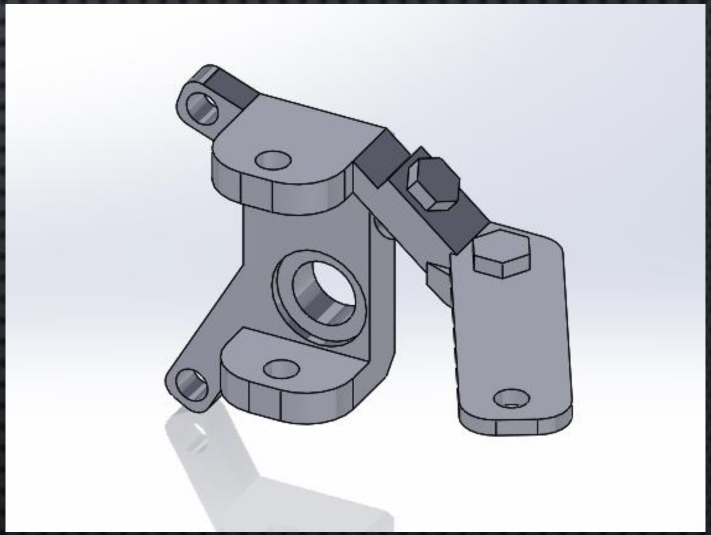
- Poor Ackermann Angle
- Long Tie Rods
- Right Lower Ball Joint Is Out of Alignment

Steering Calculation



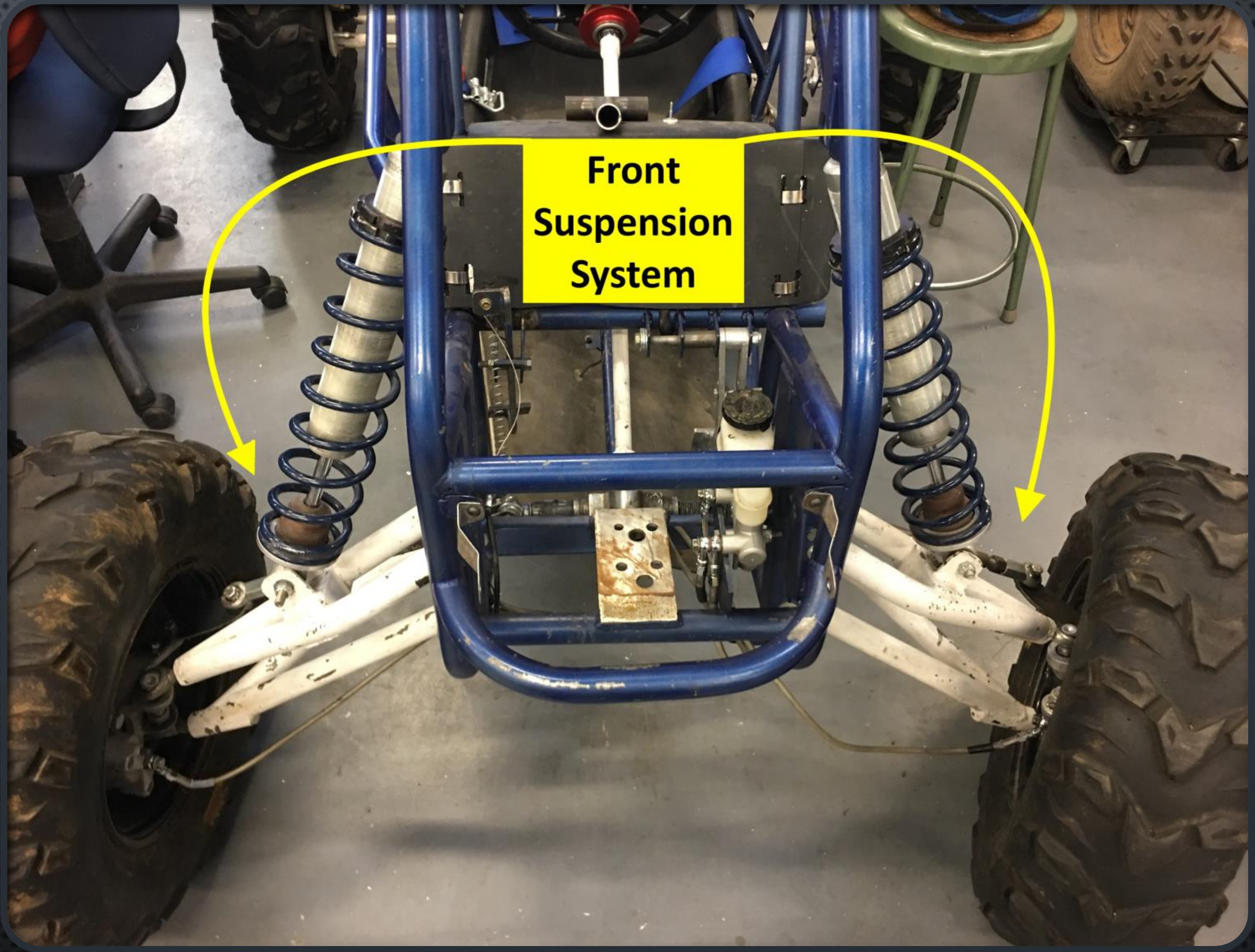
- Ackermann Angle = 26.48 degrees
- New Tie Rod Length = 12.75 inches





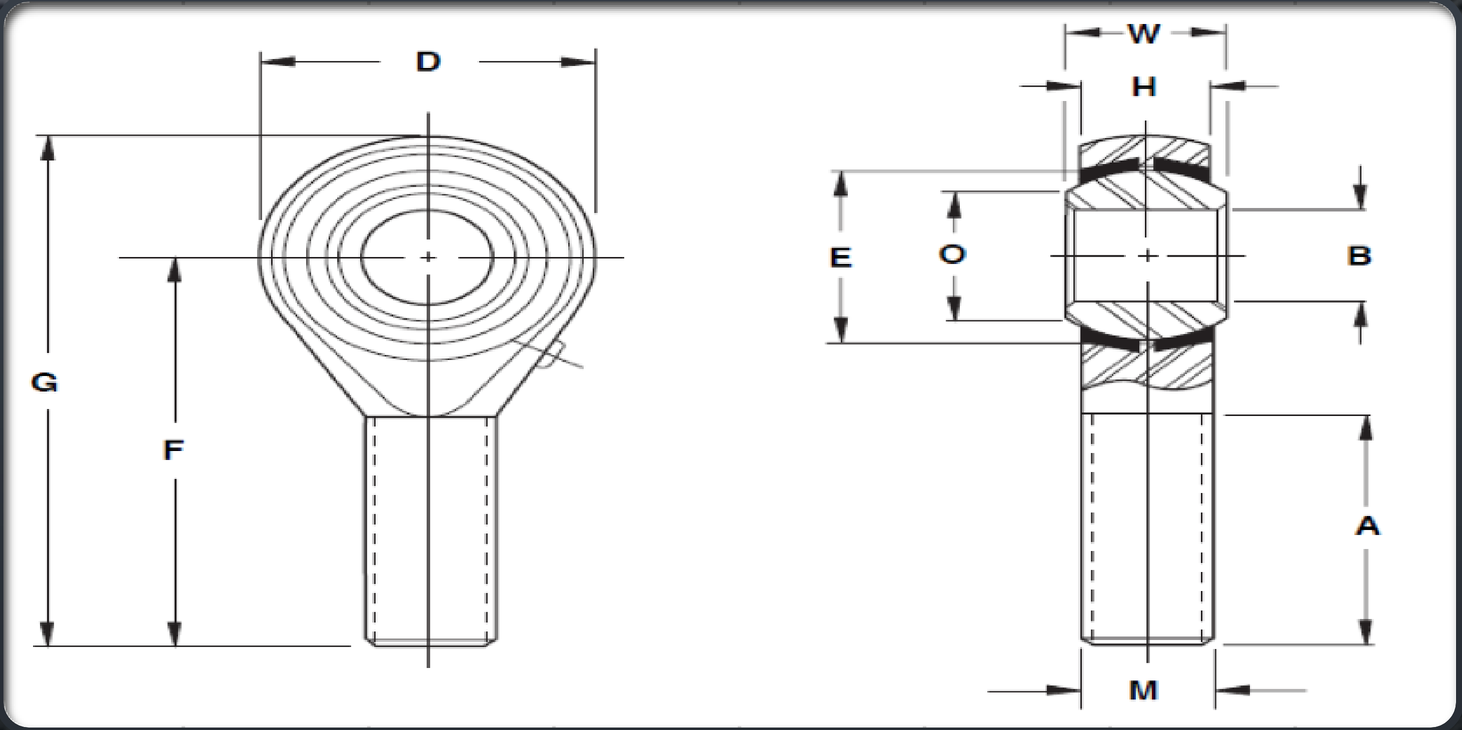
FRONT SUSPENSION

- Suspension is good
- Minor replacements for heims and bolts



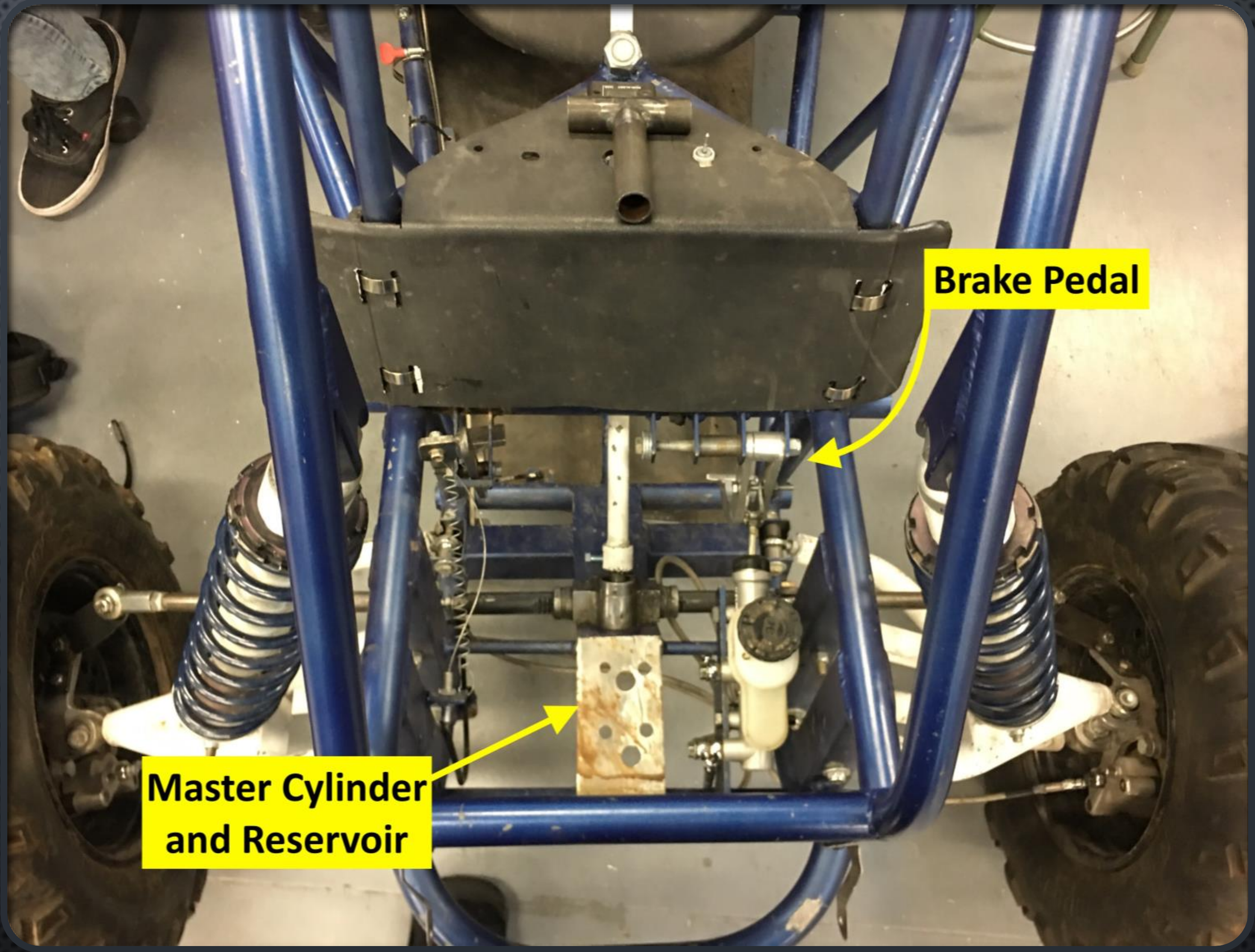
HEIM JOINTS CALCULATIONS

- STATICS AND DYNAMIC CALCULATIONS
- MAX RADIAL LOAD = 6535 LBF
- MAX STATIC LOAD = 7766 LBF



Brake System Problem

- Missing two master cylinder and the reservoir
- Need to replace Brake pedal



BRAKE VALIDATION CALCULATIONS

Left Side Specs

Front Cylinder	
# of Calipers on Cylinder	2
Force from Cylinder (lbs)	272
Force/Caliper (lbs)	136
LF Brake	
Caliper D (in)	1.25
# of piston	2
Net Bore Area (in^2)	2.5
Braking Force (lbs)	333.33
LR Brake	
Caliper D (in)	1.75
# of piston	1
Net Bore Area (in^2)	2.4
Braking Force (lbs)	326.67

Cylinder Size

Front Cylinder			Rear Cylinder	
Cylinder Size (in)	Bore Area (in2)		Cylinder Size (in)	Bore Area (in2)
5/8	0.31		5/8	0.31
Pedal Dimesions				
A (in)	B (in)	F (lbs)	Pedal Ratio	Pedal Force Out
7.5	2.25	50	3.33	167

Output Force Total

Clamp Force Needed (lbs)		1031
Total Clamping Force (lbs)		1320

GEARBOX

- Still looking into optimal gear ratios
- Need to perform stress calculations on gears
- Find gears for current gearbox

Tire Diameter (in)	25						
Tire Circumference (in)	78.54						
Target Speed (mph)	35						
Motor Speed (rpm)	3000						
Gear Ratio 1:	6		Spur Gear Teeth	18	20	22	24
Output Gear Speed (rpm	500		Gear 2 Teeth	108	120	132	144
Tire Speed (in/min)	39269.91		Spur Diameter (in	2.5	2.75	3	3.25
Tire Speed (mph)	37		Face Width (in)	1.5	1.5	1.5	1.5

DESIGN VALIDATION

- Several areas that are crucial to an operational vehicle
  - Brakes
    - Redundancies built in
    - Need all 4 brakes for safety
  - Suspension Arms
    - One breaks, won't drive right
    - Bending is possible
  - Connection Points
    - Any welds, bolts that break can endanger driver
    - Bending is possible

Risk Trade

- Adding stronger components adds weight
- Braking Factor of safety keeps driver safe but adds weight
- Adding weight keeps driver safe which is number 1 priority

FAILURE MODES AND EFFECTS ANALYSIS

Master Cylinder

15	Creates Pressure in lines when peddle is pressed	Piston gasket is blown from excess pressure	No braking ability	Rough handling to terrain	300	Prepare driver for vehicle control

Brake Lines

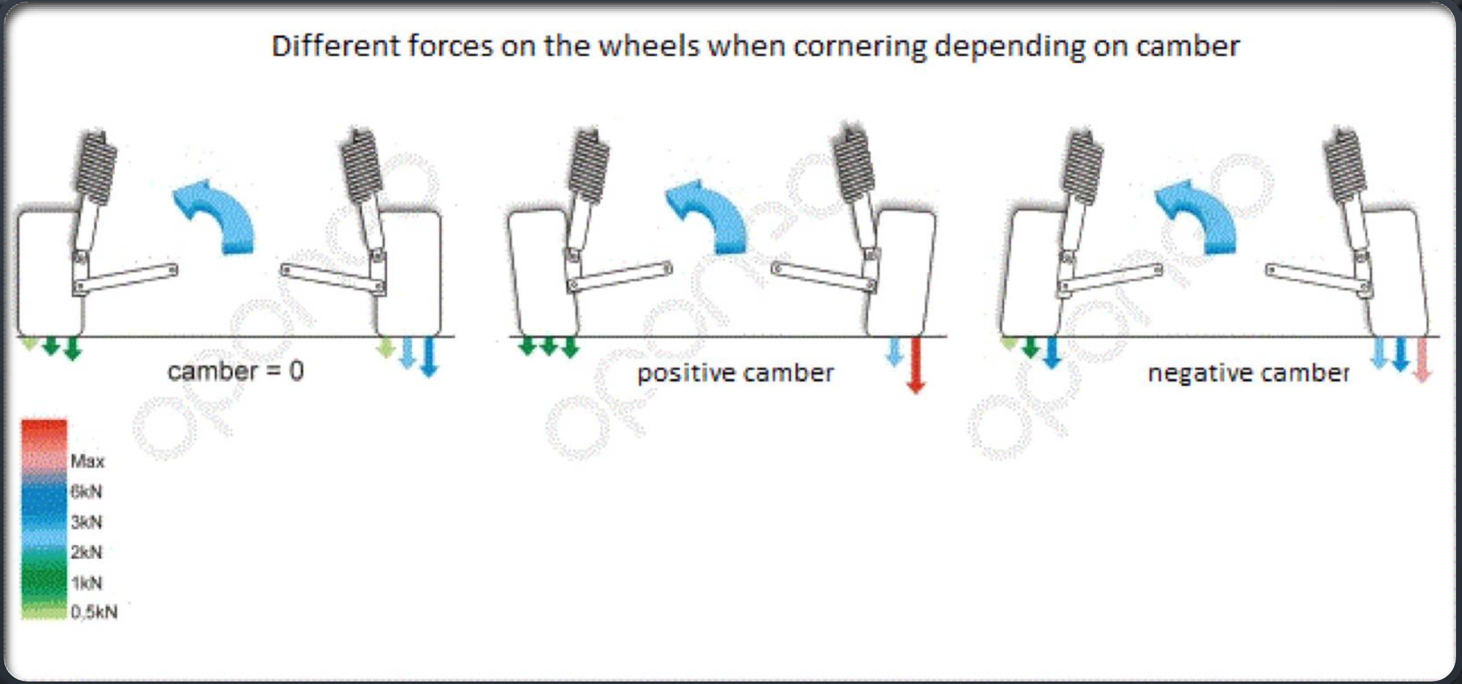
14	Allows fluid to create pressure to close caliper	Line gets cut causing loss of pressure	No braking ability	Pinched in suspension or caught on terrain	270	Protect brake lines by tying them to safe places along the way to caliper

A-Arms

19	Absorb elastic deformation the knuckle and shock force onto the vehicle	Snaps due to excessive forces	Car no longer drives	Stress added when suspension compresses	252	Beware of terrain that can maximize suspension impact

TESTING PROCEDURES

- Camber/Caster angles
- Brake time and Full lock upon stopping
- Visually inspect four functional brakes
- Computer and Visual Inspection on Steering



BILL OF MATERIALS (BOM)

- Tentative BOM
- Specific components on vehicle, not whole vehicle
  - No electronics present
  - New components replacing old systems
- No dimensions due finalizing design
- Plan on reusing components
  - Bolts
  - Heims
  - Steering Components

Part #	Part Name	Qty	Description	Functions	Material
1	Steering - Knuckle Link	2	Extra attachment to the steering knu	For a better ste	Steel
2	Steering Knuckles	2	Multiaxis unit on wheel	Central place a	Steel
3	Tie Rod	2	Rod between the wheel and the rack	connects steer	Steel
4	Tie Rod Heims	2	joint with added degree of freedom	Connects rod t	Steel
5	Rack Heims	2	joint with added degree of freedom	connects rack	Steel
6	Kingpin Heim	4	joint with added degree of freedom	connects knucl	Steel
7	Rack and Pinion	1	Rod with teeth connected to pinion g	Connect wheels	Steel
8	Steering Shaft	1	Shaft directed from wheel to rack an	Connects whee	Steel
9	Steering Wheel	1	Wheel for rotation	Connected to s	Steel
10	Steering Heim	1	Support holding the steering shaft	Hold steering sl	Steel
11	Steering - Knuckle Link Bolts	4	Fasteners on link	Holds link toget	Steel
12	Brake Caliper	3	Clamp on brake rotor	Tightens to cre	Steel
13	Brake Rotors	4	Metal plate attached to wheel	Rotates until cl	Steel
14	Brake Peddle	1	Swing Mount Brake Pedal	Applies force to	Aluminum
15	Fluid Resevoir	2	Contains fluid for brake cylinder	Holds fluid	Plastic
16	Brake Cylinder	2	Compresses fluid to apply pressure to	Contains brake	Steel
17	Caliper Bolt	6	Fasteners on caliper	Connects calipe	Steel
18	A-Arm Heim	8	joint with added degree of freedom	connects A-Arr	Steel
19	A-Arm Heim Bolt	8	Fastener on frame for heim	Connects heim	Steel
20	Angle Trailing Arm	2	Arm attached to shock and to rear k	Absorb elastic (	Steel
21	Heim Joint	2	joint with added degree of freedom	Replaces hinge	Steel
22	Connecting Rods	4	parallel rods from frame to knuckle	Maintains stabi	Steel
23	Rear Shocks	2	Spring loaded rod supporting vehicle	Absorbs impact	Steel
24	Trailing Arm Bolt	8	Fastener on frame for heim	Connects heim	Steel
25	Support Bracket Bolt	8	Fastener for keeping in place	Connects supp	Steel
26	Heat Shield	1	Metal plate between driver and moto	Protects driver	Plastic
27	Frame Member	2	Added member in secondary section	Attachment of	Steel
28	Drive Line	2	Shaft connected to drive train	Power transfer	Steel
29	Tire	4	Offroad	offroad traction	Rubber
30	Pinion Gear	1	18 teeth	Connects moto	Steel
31	Gear 2	1	108 teeth	Connect spur g	Steel

CURRENT BUDGET

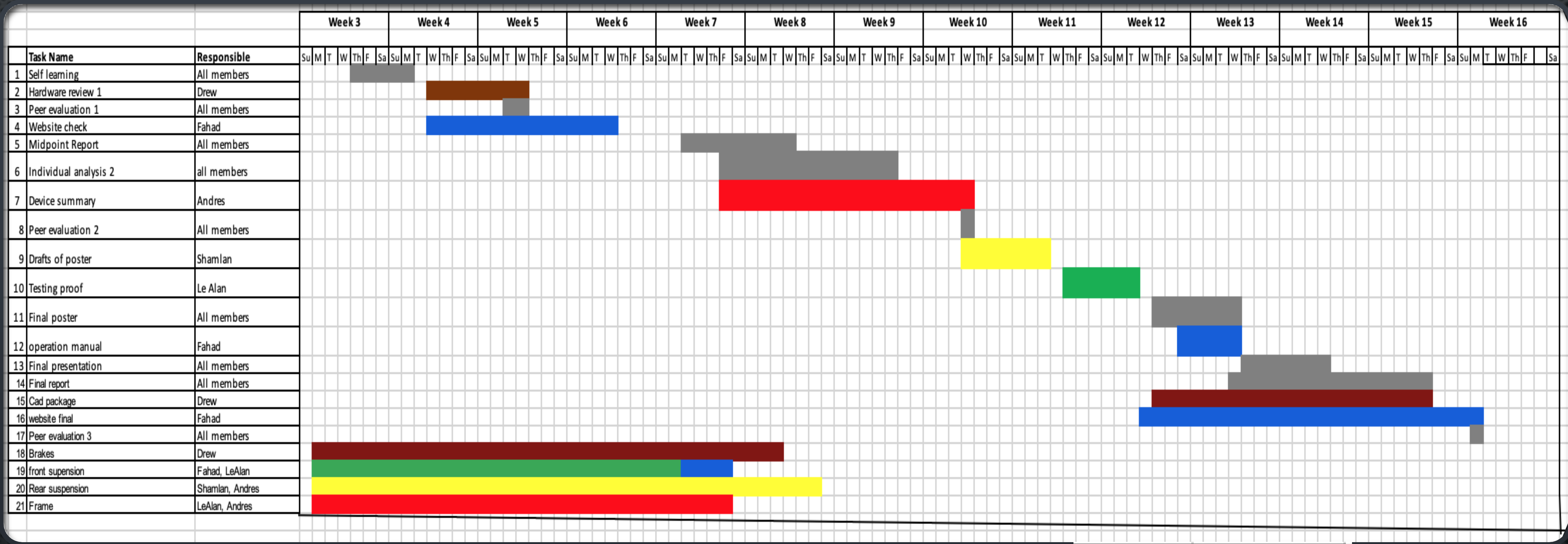
- Reusing Several Parts
- Prices are Tentative
- No Electrical components on BOM

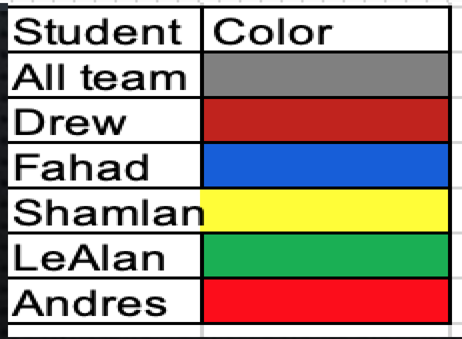
Part #	Part Name	Qty	Unit Cost	Total Cost
1	Steering - Knuckle Link	2	N/A	$ -
2	Steering Knuckles	2	N/A	$ -
3	Tie Rod	2	$ 35.00	$ 70.00
4	Tie Rod Heims	2	$ 19.48	$ 38.96
5	Rack Heims	2	$ 19.48	$ 38.96
6	Kingpin Heim	4	$ 60.00	$ 240.00
7	Rack and Pinion	1	N/A	$ -
8	Steering Shaft	1	N/A	$ -
9	Steering Wheel	1	N/A	$ -
10	Steering Heim	1	N/A	$ -
11	Steering - Knuckle Link Bolts	4	$ 1.36	$ 5.44
12	Brake Caliper	3	N/A	$ -
13	Brake Rotors	4	N/A	$ -
14	Brake Peddle	1	$176.94	$ 176.94
15	Fluid Resevoir	2	$ 64.74	$ 129.48
16	Brake Cylinder	2	$ 70.19	$ 140.38
17	Caliper Bolt	6	N/A	$ -
18	A-Arm Heim	8	$ 7.98	$ 63.84
19	A-Arm Heim Bolt	8	$ 1.36	$ 10.88
20	Angle Trailing Arm	2	N/A	$ -
21	Heim Joint	2	$120.00	$ 240.00
22	Connecting Rods	4	$ 20.00	$ 80.00
23	Rear Shocks	2	N/A	$ -
24	Trailing Arm Bolt	8	$ 1.36	$ 10.88
25	Support Bracket Bolt	8	$ 1.36	$ 10.88
26	Heat Shield	1	$120.00	$ 120.00
27	Frame Member	2	N/A	$ -
28	Drive Line	2	N/A	$ -
29	Tire	4	$ 78.00	$ 312.00
30	Pinion Gear	1	$ 68.00	$ 68.00
31	Gear 2	1	$132.00	$ 132.00
Total Cost				$1,888.64

BUDGET PLAN

- Budget given: $3,000
- Budget Allocated: $1888.64
- Certain items to be machined and reused
- Currently looking for more sponsors
- EE has their own budget

GANTT CHART


Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10
Week 11
Week 12
Week 13
Week 14
Week 15
Week 16
Task Name
Responsible
1 Self learning | All members
2 Hardware review 1 | Drew
3 Peer evaluation 1 | All members
4 Website check | Fahad
5 Midpoint Report | All members
6 Individual analysis 2 | all members
7 Device summary | Andres
8 Peer evaluation 2 | All members
9 Drafts of poster | Shamlan
10 Testing proof | Le Alan
11 Final poster | All members
12 operation manual | Fahad
13 Final presentation | All members
14 Final report | All members
15 Cad package | Drew
16 website final | Fahad
17 Peer evaluation 3 | All members
18 Brakes | Drew
19 front supension | Fahad, LeAlan
20 Rear suspension | Shamlan, Andres
21 Frame | LeAlan, Andres


Student
Color
All team
Drew
Fahad
Shamlan
LeAlan
Andres

Thank You!

Questions?

APPENDIX A: FULL FMEA

	Part #	Functions	Potential Failure Mode	Potential Effect(s) of Failure	Potential Causes and Mechanisms of Failure	RPN	Recommended Action
Steering	1	For a better steering angle	Shears/Bends due to impact	Faulty Steering and Driving	Stress added when suspension compresses	168	Remove and add directly to knuckle
	2	Central place at wheel connecting the supports, rack and pinion, brakes, etc	Bends due to impact	"Rougher" ride	Stress added when suspension compresses	72	None
	3	Connects steering wheel to the knuckles for steering	Bends due to impact	Improper steering angles	Stress added when suspension compresses	150	Add to heim to release stress from end point
	4	Connects rod to knuckle	Shears/Bends due to impact	Faulty Steering and Driving	Stress added when suspension compresses	140	None
	5	Connects rack to tie rod	Shears/Bends due to impact	Faulty Steering and Driving	Stress added when suspension compresses	108	None
	6	Connects knuckle to A-Arms	Shears/Bends due to impact	No longer able to drive	Stress added when suspension compresses	162	None
	7	Connect wheels to steering wheel	Strip Gears from excessive force	No longer able to steer	Strip Gears from excessive force when steering	126	None
	8	Connects wheel to pinion	Shears/Bends due to excessive steering force	No longer able to steer	Bent shaft from excessive force when steering	98	None
	9	Connected to steering shaft	Comes of steering shaft from impact	No longer able to steer	Lock fails and comes loose	147	None
	10	Hold steering shaft in place for steering	Shears/Bends due to impact	No longer able to steer	Tensile yield from excessive steering force	112	None
	11	Holds link together to knuckle and tie rods	Shears/Bends due to impact	No longer able to steer	Stress added when suspension compresses	126	None
Braking	12	Tightens to create friction and stop rotation	Loss of Pressure to lines	No braking ability	Punctured brake lines or broken master cylinder	210	Protect brake lines and place cylinder in proper location
	13	Rotates until clamped	Warped upon impact	Pulsing braking	Worn out and not maintained	64	None
	14	Allows fluid to create pressure to close caliper	Line gets cut causing loss of pressure	No braking ability	Pinched in suspension or caught on terrain	270	Protect brake lines by tying them to safe places along the way to caliper
	15	Creates Pressure in lines when peddle is pressed	Piston gasket is blown from excess pressure	No braking ability	Rough handling to terrain	300	Prepare driver for vehicle control
	16	Connects caliper to knuckle	Shears from excess braking force	Minimal braking ability	Continuous brake slamming	216	Check on wear after every use
Suspension	17	connects A-Arm to vehicle frame	Shears due to impact	Faulty Steering and Driving	Stress added when suspension compresses	216	Check on wear after every use
	18	Connects heim to frame	Bends due to impact	Faulty Steering and Driving	Stress added when suspension compresses	180	Check on wear after every use
	19	Absorb elastic deformation the knuckle and shock force onto the vehicle	Snaps due to excessive forces	Car no longer drives	Stress added when suspension compresses	252	Beware of terrain that can maximize suspension impact
	20	Replaces hinge joint to release force resistance	Shears due to impact	Faulty Steering and Driving	Stress added when suspension compresses	216	Prepare driver for vehicle control and examine after use
	21	Maintains stability of wheel	Shears/Bends due to impact	Faulty Steering and Driving	Exposed and beaten by terrain	210	Examine after every use
	22	Absorbs impact from ground	Shears/Bends due to impact	"Rougher" ride	Impact beyond fabrication point	84	None
	23	Connects heim to frame	Shears/Bends due to impact	Faulty Steering and Driving	Stress added when suspension compresses	216	Examine after every use
	24	Connects support bracket to frame and knuckle	Shears/Bends due to impact	Faulty Steering and Driving	Excessive camber	252	Examine after every use

APPENDIX B: BRAKE CALCULATIONS

Front Cylinder	
Cylinder Size (in)	Bore Area (in2)
5/8	0.31

Rear Cylinder	
Cylinder Size (in)	Bore Area (in2)
5/8	0.31

Pedal Dimesions				
A (in)	B (in)	F (lbs)	Pedal Ratio	Pedal Force Out
7.5	2.25	50	3.33	167

A = Distance from pivot point to middle of push/pull point
B = Distance from pivot to point of push on master cylinder
P = Pivot point
F = Force or push

Force Required	
Car Weight (lbs)	800
Stopping Acceleration ft/s^2	15
Braking Force Required	12000.00

Brake Torque	
Braking Force/wheel (lbs)	3000
Radius of Tire (in)	12.5
Disc brake radius (in)	4
Speed ratio btwn wheel/bra	3.1
Braking Torque (Ftlbs)	12000

Disc Outer Diameter	8
Disc Inner Diameter	6.5
Effective Radius	3.6

Coefficient of Friction	0.4
Number of friction faces	2
Clamp Load (lbs)	4123

Clamp Force Needed (lbs)	1031

Total Clamping Force (lbs)	1320

http://www.engineeringinspiration.co.uk/brakecalcs.html

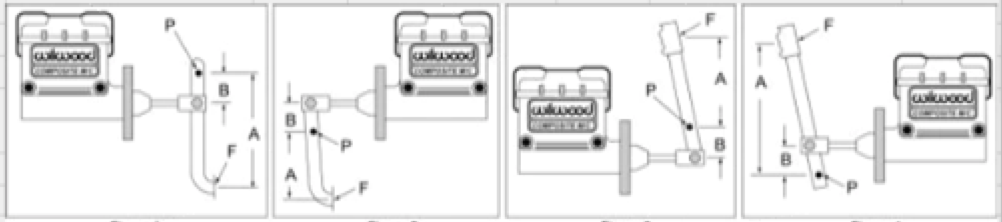


Figure 1 Figure 2 Figure 3 Figure 4

Front Cylinder	
# of Calipers on Cylinder	2
Force from Cylinder (lbs)	272
Force/Caliper (lbs)	136

Rear Cylinder	
# of Calipers on Cylinder	2
Force from Cylinder (lbs)	272
Force/Caliper (lbs)	136

LF Brake	
Caliper D (in)	1.25
# of piston	2
Net Bore Area (in^2)	2.5
Braking Force (lbs)	333.33

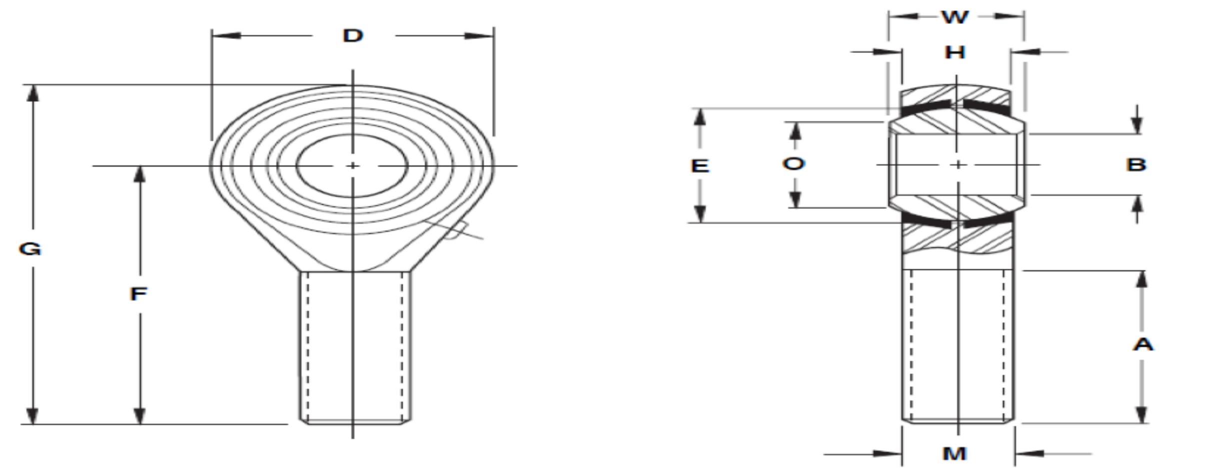
RF Brake	
Caliper D (in)	1.25
# of piston	2
Net Bore Area (in^2)	2.5
Braking Force	333.33

LR Brake	
Caliper D (in)	1.75
# of piston	1
Net Bore Area (in^2)	2.4
Braking Force (lbs)	326.67

LR Brake	
Caliper D (in)	1.75
# of piston	1
Net Bore Area (in^2)	2.4
Braking Force	326.67

APPENDIX C: HEIM JOINTS CALCULATIONS

Given Parameters (Bottom Heim Joint)			
Ball Diamter	E	1.312	in
Housing Width	H	0.687	in
Head Diameter	D	1.750	in
Minor Dia of thread	M	0.750	in
Allowable Material Stress	X	30,000	PSI
Calculated Values			
Rod End Head Strength	T	6535	lbf
Male Thread Rod End Strength	S	13163	lbf
Maximum Static Radial Load		6535	lbf
Maximum Static Axial Load	A	7766	lbf



APPENDIX D: STEERING CALCULATIONS

E-Baja: Steering calculations and update report

Finding the ideal Ackermann angle for the e-Baja, using equation 1.

$$\theta_{SIAI} = 0.8\frac{T}{L} \quad (1)$$

T is the wheel track, the distance between the center of the right and left wheel. L is the wheelbase, the distance between the center of the front and rear wheel.

For the e-Baja, T = 104 cm (40.95 inches) and L = 180 cm (70.87 inches). Using equation 1, the ideal Ackermann angle equals to approximate of 26.48°.

Using the Ackermann angle, figure 1 was drawn to help visualize the design of a new attachment.

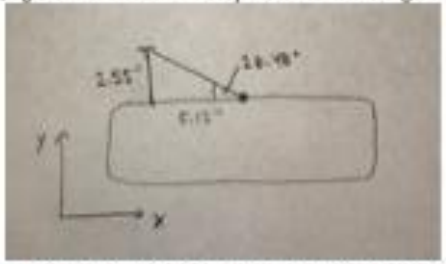


Figure 1. Location of new position for the connection from the tie rod.

The tie rods meet the tire at 13 cm (5.12 inches) from the kingpin; this gives the idea of where the new point for the tie rod to connect to the wheel. Using triangle relations, to find the proper location from the tire is given in equation 2.

$$\tan\theta = \frac{opposite}{adjacent} \quad (2)$$

$\theta = 26.48^{0}$ and the adjacent length = 13 cm (5.12 inches), rearranging equation 2 to solve for the opposite length, this gives the opposite length = 6.48 cm (2.55 inches). Using figure 1, the connection point of the tie rod should be 5.12 inches on the x-axis from the kingpin and 2.55 inches on the y-axis from the kingpin.

Figure 2 shows the repositioning of the tie rod; due to the new placement of the tie rod connection to the knuckle, the length of the tie rod needs to be updated. Using the Pythagorean theorem, the length of the tie rod could be found in equation 3.

$$c = \sqrt{a^2 + b^2} \quad (3)$$

c is the tie rod length, a = 5.5 inches and b = 11.5 inches from the car frame. Using equation 3, the tie rod length equals approximately 12.75 inches.

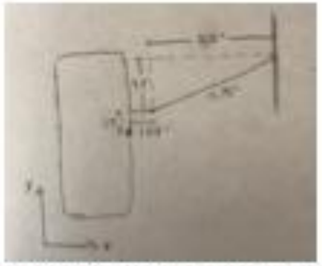


Figure 2. Image of the tie rod to the new location of the connection from the tie rod.

APPENDIX E: QFD

System QFD

Project:	E-BAJA
Date:	Sept. 16, 2019

	Weight of the Vehicle	Range of Motion of the Steering System	Torque of the Vehicle	Cost	Power of Motor	Safety
Weight of the Vehicle						
Range of Motion of the Steering System						
Torque of the Vehicle	-					
Cost						
Power of Motor	-	-	-			
Safety	+		+	-		
Speed (m/s)		-		-		

	Customer Needs	Customer Weights (5 Best to 1 Least)	Weight of the Vehicle	Range of Motion of the Steering System	Torque of the Vehicle	Cost	Power of Motor	Safety	Speed of the Vehicle
1	Safety of User	5	3	9	1	3	3	9	9
2	Follow SAE E-Baja Rules / Industry Standards	5	3	3	9		3	9	
3	Provide Space for Battery Mount	3	3		1	1		1	
4	Electric Compitable Drive Terrain	4	3	3	9	9	9	9	9
5	Redesign and Provide a Functioning Brake System	5	3	3	3	3	3	9	3
6	Reinforsing Front suspension	4	9	1	9	9	9	3	9
7	Ease of Fabrication of Components	2	9	9	3	9	9	9	3
8	Redesign Rear Suspension System	5	3	3	1	9		9	9
9	Redesign Steering (Rack and Pinion)	3	3	9	1	3		9	9
	Technical Requirement Units		Kg	Degrees	Newton Meters	$	KW	Factor of Safety	m/s
	Technical Requirement Targets		363	60	TBD	3000	7.5	TBD	16.667
	Absolute Technical Importance		144	151	154	177	135	276	210
	Relative Technical Importance		6	5	4	3	7	1	2