SAE Baja

2024-2025

Project Description

Design, Fabricate, and Race a 4WD, off-road Vehicle

- 3 Subteams (Chassis, Drivetrain, Suspension, Steering, and Brakes)
- Everything is standardized in correspondence with the Society of Automotive Engineers (SAE)
- Outreach: Continue getting sponsorships
- Race and compete against other universities at the end of the year

NAU SAE Baja Car from 2024

Nolan S.

Budget

	Category	Description	Approximate Cost
1	Chassis	Cost from Bill of Materials	$1889.72
2	Drivetrain	Cost from Bill of Materials	$5169.63
3	Steering, Suspension, and Brakes	Cost from Bill of Materials	$3515.19
4	Travel and Contingencies	Estimated Cost from First Presentation	$5,200
		Total Cost :	$15,526.54

Potential Sponsors:

Gore, Copper State, Mother Road, NAPA HAAS, Harsh Co., Poba Medical, Discount Tire, H&S Field Services, Dylan and Ryan’s Dad, Novakinetics, Weiner Foundation, Dale Family, KC HiLiTES

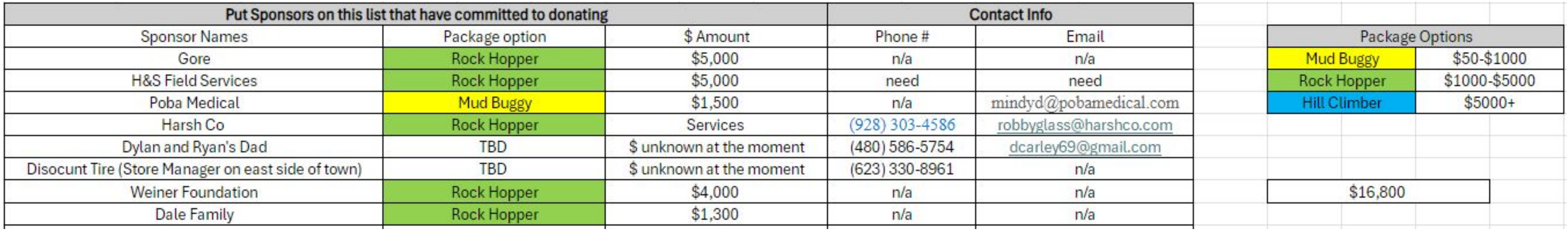
Sponsor Methodology:

Reach out to all of the team’s personal connections, and any local businesses to raise money.

Dylan C.

Team Finance

Income:



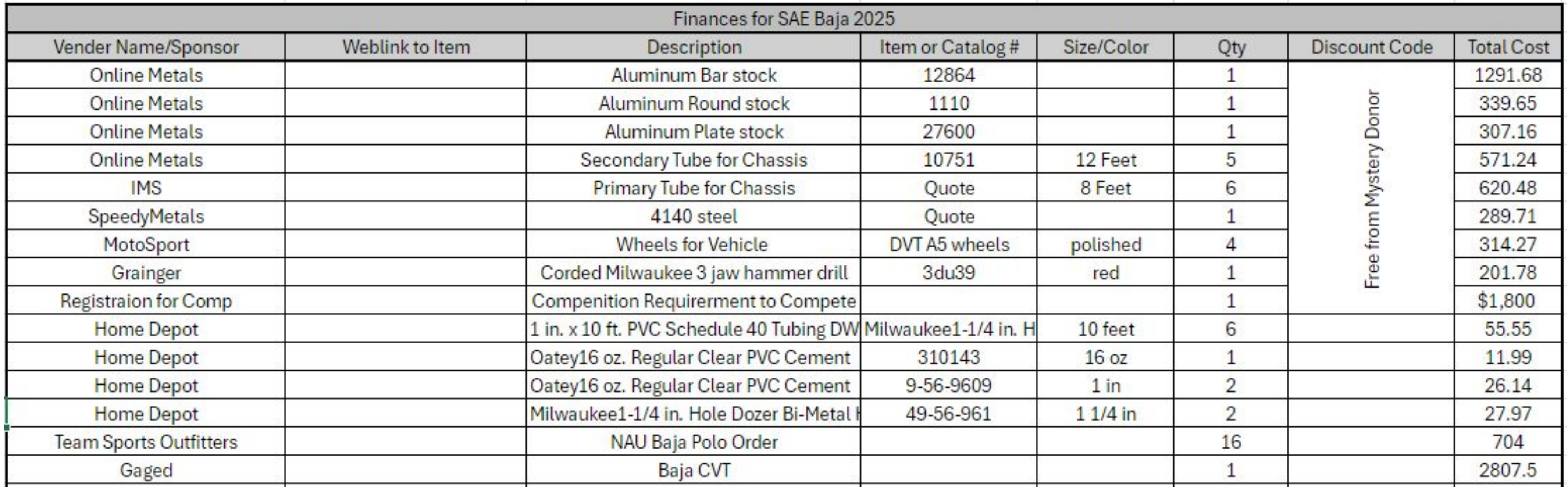
Put Sponsors on this list that have committed to donating			Contact Info	
Sponsor Names	Package option	$ Amount	Phone #	Email
Gore	Rock Hopper	$5,000	n/a	n/a
H&S Field Services	Rock Hopper	$5,000	need	need
Poba Medical	Mud Buggy	$1,500	n/a	mindyd@pobamedical.com
Harsh Co	Rock Hopper	Services	(928) 303-4586	robbyglass@harshco.com
Dylan and Ryan's Dad	TBD	$ unknown at the moment	(480) 586-5754	dcarley69@gmail.com
Disocunt Tire (Store Manager on east side of town)	TBD	$ unknown at the moment	(623) 330-8961	n/a
Weiner Foundation	Rock Hopper	$4,000	n/a	n/a
Dale Family	Rock Hopper	$1,300	n/a	n/a

Package Options	
Mud Buggy	$50-$1000
Rock Hopper	$1000-$5000
Hill Climber	$5000+

$16,800

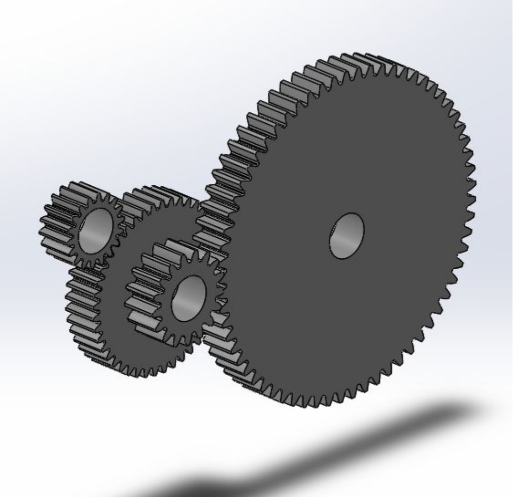
Expenses:

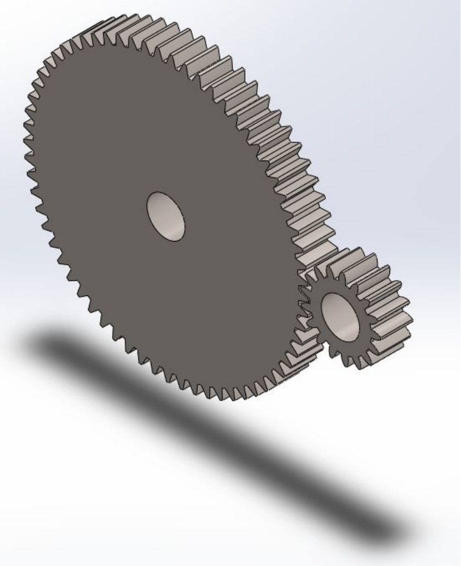
Total Cost	3633.15



Finances for SAE Baja 2025							
Vender Name/Sponsor	Weblink to Item	Description	Item or Catalog #	Size/Color	Qty	Discount Code	Total Cost
Online Metals		Aluminum Bar stock	12864		1	Free from Mystery Donor	1291.68
Online Metals		Aluminum Round stock	1110		1		339.65
Online Metals		Aluminum Plate stock	27600		1		307.16
Online Metals		Secondary Tube for Chassis	10751	12 Feet	5		571.24
IMS		Primary Tube for Chassis	Quote	8 Feet	6		620.48
SpeedyMetals		4140 steel	Quote		1		289.71
MotoSport		Wheels for Vehicle	DVT A5 wheels	polished	4		314.27
Grainger		Corded Milwaukee 3 jaw hammer drill	3du39	red	1		201.78
Registraion for Comp		Compenition Requirerment to Compete			1		$1,800
Home Depot		1 in. x 10 ft. PVC Schedule 40 Tubing DW	Milwaukee1-1/4 in. H	10 feet	6		55.55
Home Depot		Oatey16 oz. Regular Clear PVC Cement	310143	16 oz	1		11.99
Home Depot		Oatey16 oz. Regular Clear PVC Cement	9-56-9609	1 in	2		26.14
Home Depot		Milwaukee1-1/4 in. Hole Dozer Bi-Metal	49-56-961	1 1/4 in	2		27.97
Team Sports Outfitters		NAU Baja Polo Order			16		704
Gaged		Baja CVT			1		2807.5

Dylan





Drivetrain

Dylan Carley
Matthew Dale
Ethan Niemeyer

Reduction Box,
Axles, and Hubs

Rowan Jones
Nolan Stomp

4WD System

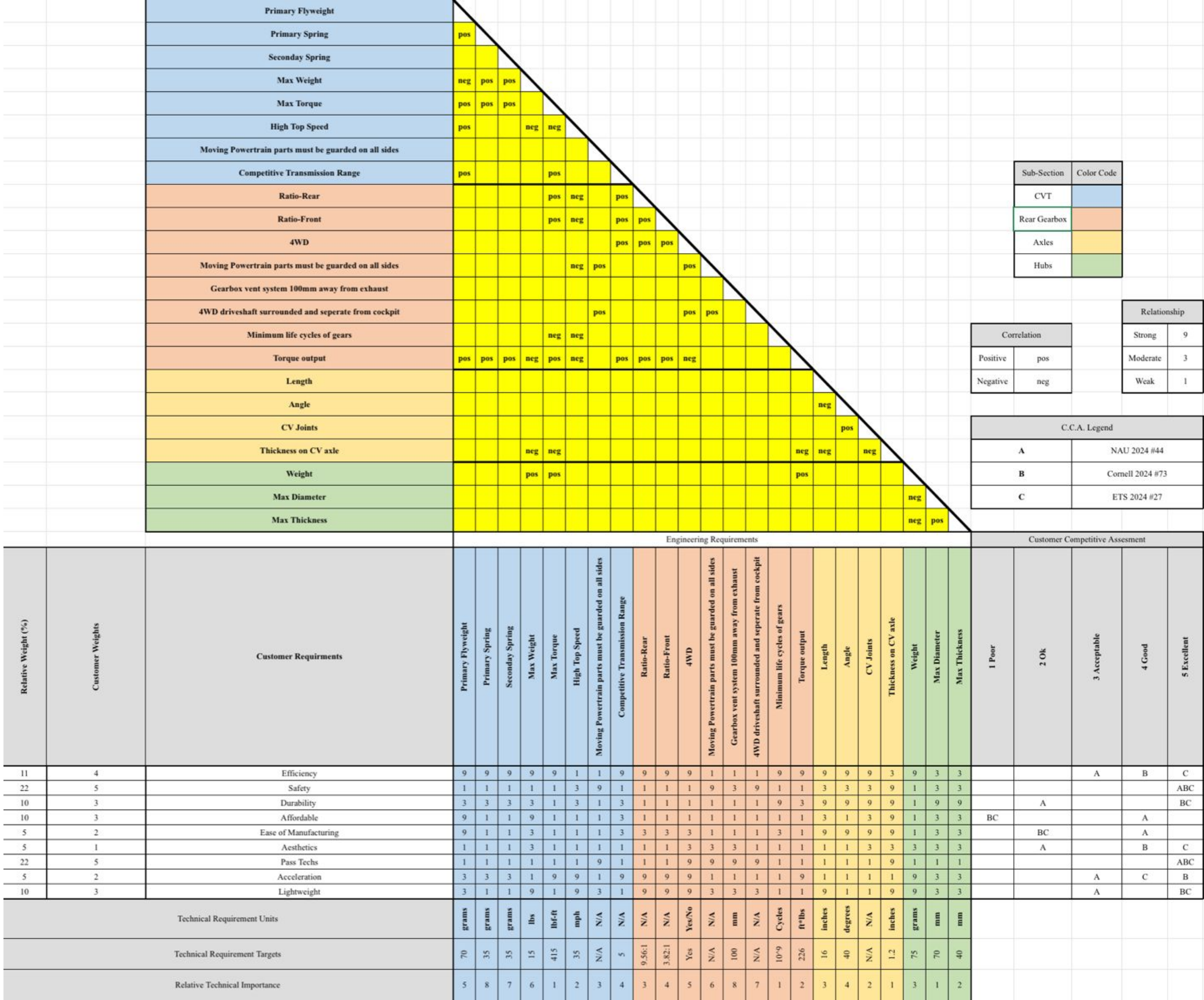
Seth Scheiwiller

Subteam lead

QFD

Customer Requirements

- Efficiency
- Safety
- Durability
- Affordable
- Ease of Manufacturing
- Aesthetics
- Pass Techs
- Acceleration
- Lightweight



Primary Flyweight																						
Primary Spring	pos																					
Seconday Spring																						
Max Weight	neg	pos	pos																			
Max Torque	pos	pos	pos																			
High Top Speed	pos			neg	neg																	
Moving Powertrain parts must be guarded on all sides																						
Competitive Transmission Range	pos				pos																	
Ratio-Rear					pos	neg		pos														
Ratio-Front					pos	neg		pos	pos													
4WD								pos	pos	pos												
Moving Powertrain parts must be guarded on all sides						neg	pos				pos											
Gearbox vent system 100mm away from exhaust																						
4WD driveshaft surrounded and seperate from cockpit							pos				pos	pos										
Minimum life cycles of gears					neg	neg																
Torque output	pos	pos	pos	neg	pos	neg		pos	pos	pos	neg											
Length																						
Angle																	neg					
CV Joints																		pos				
Thickness on CV axle				neg	neg											neg	neg		neg			
Weight				pos	pos											pos						
Max Diameter																					neg	
Max Thickness																					neg	pos

Sub-Section	Color Code
CVT	🟦
Rear Gearbox	🟧
Axles	🟨
Hubs	🟩

Correlation	
Positive	pos
Negative	neg

Relationship	
Strong	9
Moderate	3
Weak	1

C.C.A. Legend	
A	NAU 2024 #44
B	Cornell 2024 #73
C	ETS 2024 #27

			Engineering Requirements																							Customer Competitive Assesment				
Relative Weight (%)	Customer Weights	Customer Requirments	Primary Flyweight	Primary Spring	Seconday Spring	Max Weight	Max Torque	High Top Speed	Moving Powertrain parts must be guarded on all sides	Competitive Transmission Range	Ratio-Rear	Ratio-Front	4WD	Moving Powertrain parts must be guarded on all sides	Gearbox vent system 100mm away from exhaust	4WD driveshaft surrounded and seperate from cockpit	Minimum life cycles of gears	Torque output	Length	Angle	CV Joints	Thickness on CV axle	Weight	Max Diameter	Max Thickness	1 Poor	2 Ok	3 Acceptable	4 Good	5 Excellent
11	4	Efficiency	9	9	9	9	9	1	1	9	9	9	9	1	1	1	9	9	9	9	9	3	9	3	3			A	B	C
22	5	Safety	1	1	1	1	1	3	9	1	1	1	1	9	3	9	1	1	3	3	3	9	1	3	3					ABC
10	3	Durability	3	3	3	3	1	3	1	3	1	1	1	1	1	1	9	3	9	9	9	9	1	9	9		A			BC
10	3	Affordable	9	1	1	9	1	1	1	3	1	1	1	1	1	1	1	1	3	1	3	9	1	3	3	BC			A	
5	2	Ease of Manufacturing	9	1	1	3	1	1	1	3	3	3	3	1	1	1	3	1	9	9	9	9	1	3	3		BC		A	
5	1	Aesthetics	1	1	1	3	1	1	1	1	1	1	3	3	3	1	1	1	1	1	3	3	3	3	3		A		B	C
22	5	Pass Techs	1	1	1	1	1	1	9	1	1	1	9	9	9	9	1	1	1	1	1	9	1	1	1					ABC
5	2	Acceleration	3	3	3	1	9	9	1	9	9	9	9	1	1	1	1	9	1	1	1	1	9	3	3			A	C	B
10	3	Lightweight	3	1	1	9	1	9	3	1	9	9	9	3	3	3	1	1	9	1	1	9	9	3	3			A		BC
Technical Requirement Units			grams	grams	grams	lbs	lbf-ft	mph	N/A	N/A	N/A	N/A	Yes/No	N/A	mm	N/A	Cycles	ft*lbs	inches	degrees	N/A	inches	grams	mm	mm					
Technical Requirement Targets			70	35	35	15	415	35	N/A	5	9.56:1	3.82:1	Yes	N/A	100	N/A	10^9	226	16	40	N/A	1.2	75	70	40					
Relative Technical Importance			5	8	7	6	1	2	3	4	3	4	5	6	8	7	1	2	3	4	2	1	3	1	2					

Ethan

Engineering Requirements

CVT

- Primary Flyweight - 70 grams
- Primary Springs – 35 grams
- Secondary Springs – 35 grams
- Max weight – 15 lbs.
- Max torque – 415 lbf-ft
- Top speed – 35 mph
- Moving powertrain parts must be guarded on all sides – Yes
- Competitive transmission range – 5

Axles

- Length - <16 inches
- Angle – 40 degrees
- CV Joints – Yes
- Thickness of CV axle – 1.2 inches

Hubs

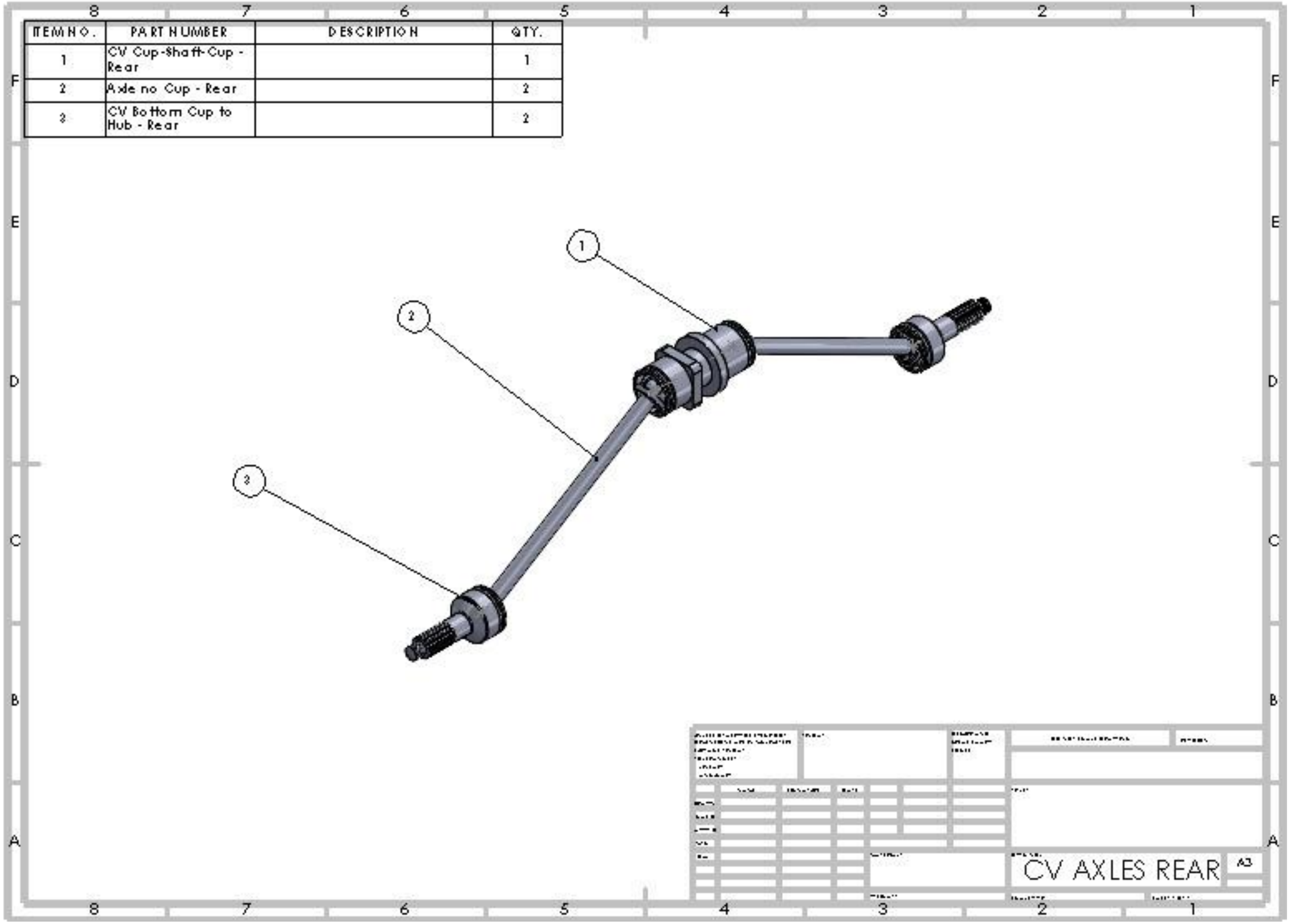
- Weight – 75 grams
- Max diameter – 70mm
- Max Thickness – 40mm

Reduction gearbox

- Rear Ratio – 6.98:1
- Front Ratio – 2.90:1
- 4WD – Yes
- Moving powertrain parts must be guarded on all sides – Yes
- Gearbox vent system 100mm away from exhaust – 100mm
- 4WD driveshaft surrounded and separate from cockpit – Yes
- Minimum life cycle of gears – 10^9 cycles
- Torque output – 503.61 ft*lbs

Ethan

Design Description - Rear CV assembly

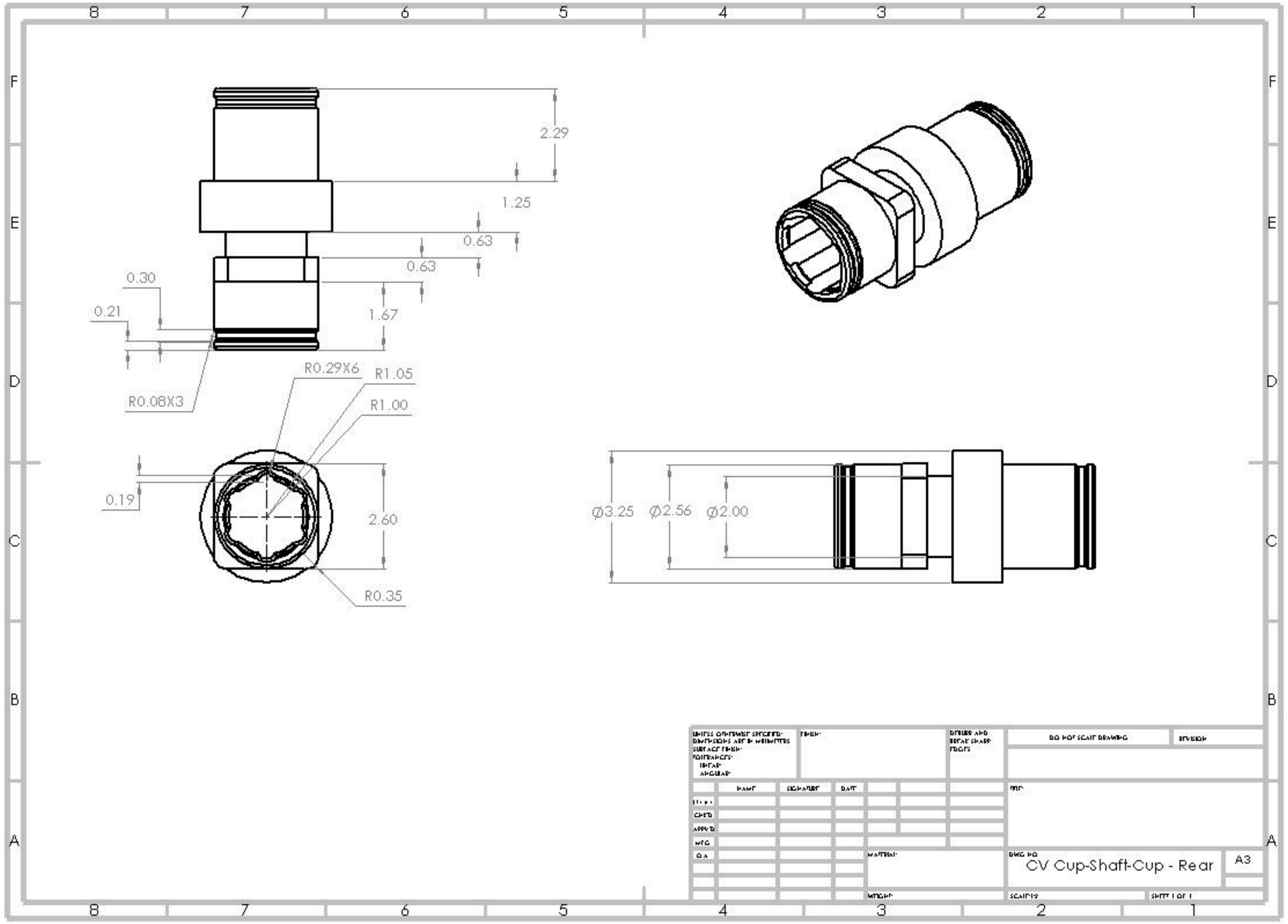


ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	CV Cup-Shaft-Cup - Rear		1
2	Axle no Cup - Rear		2
3	CV Bottom Cup to Hub - Rear		2

- Lower CV splines mesh to female hub spline
- Center Cup-shaft-cup press fits to driving gear in reduction box
- Brake mount for inboard brakes

Ethan

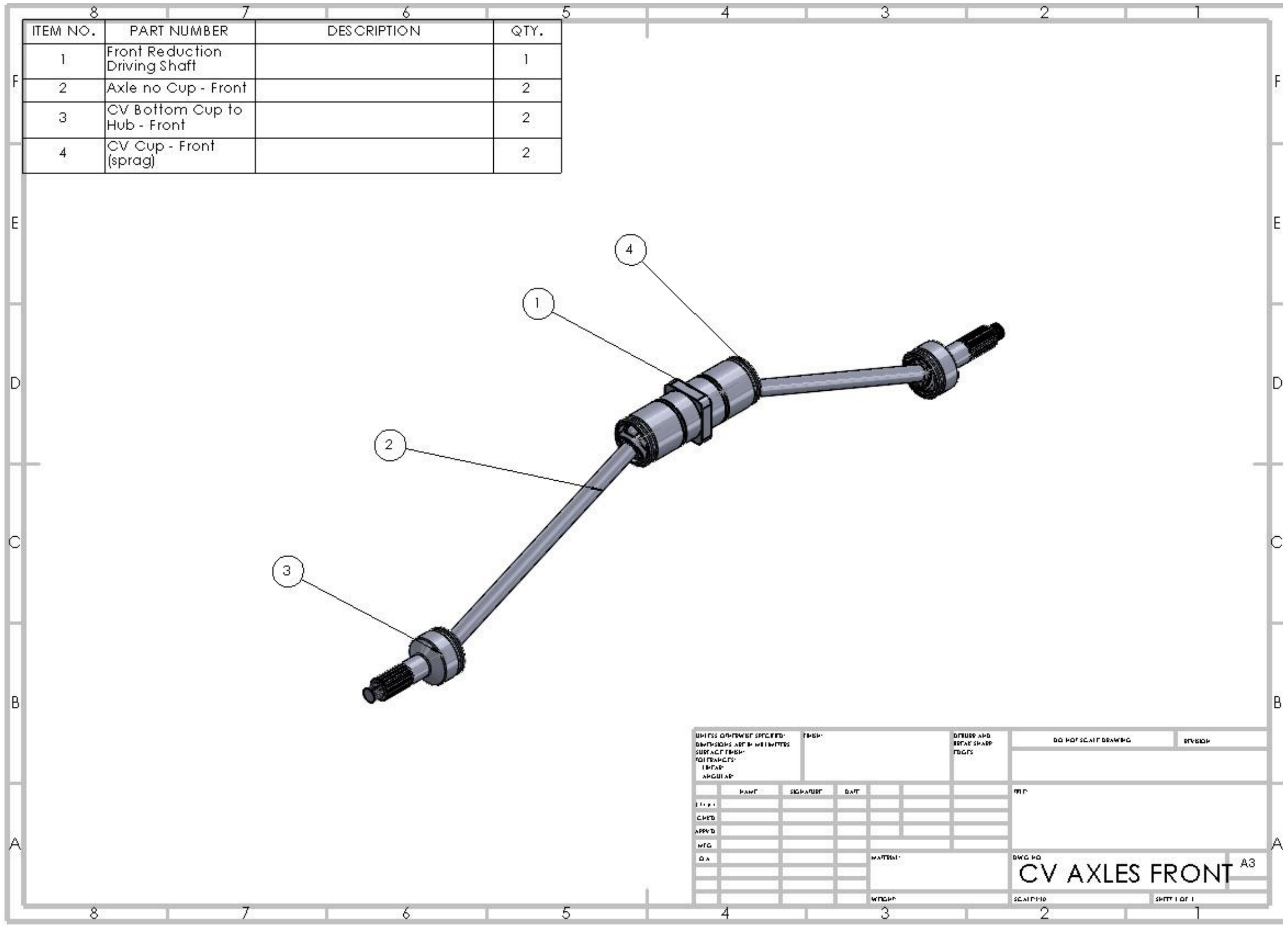
Design description - Cup-Shaft-Cup



- Integrated CV Cup and shaft design
- Increases strength
- Lowers weight
- Less moving parts that can break
- Table driven in solidworks for adjustments as necessary

Ethan

Design Description - Front CV assembly

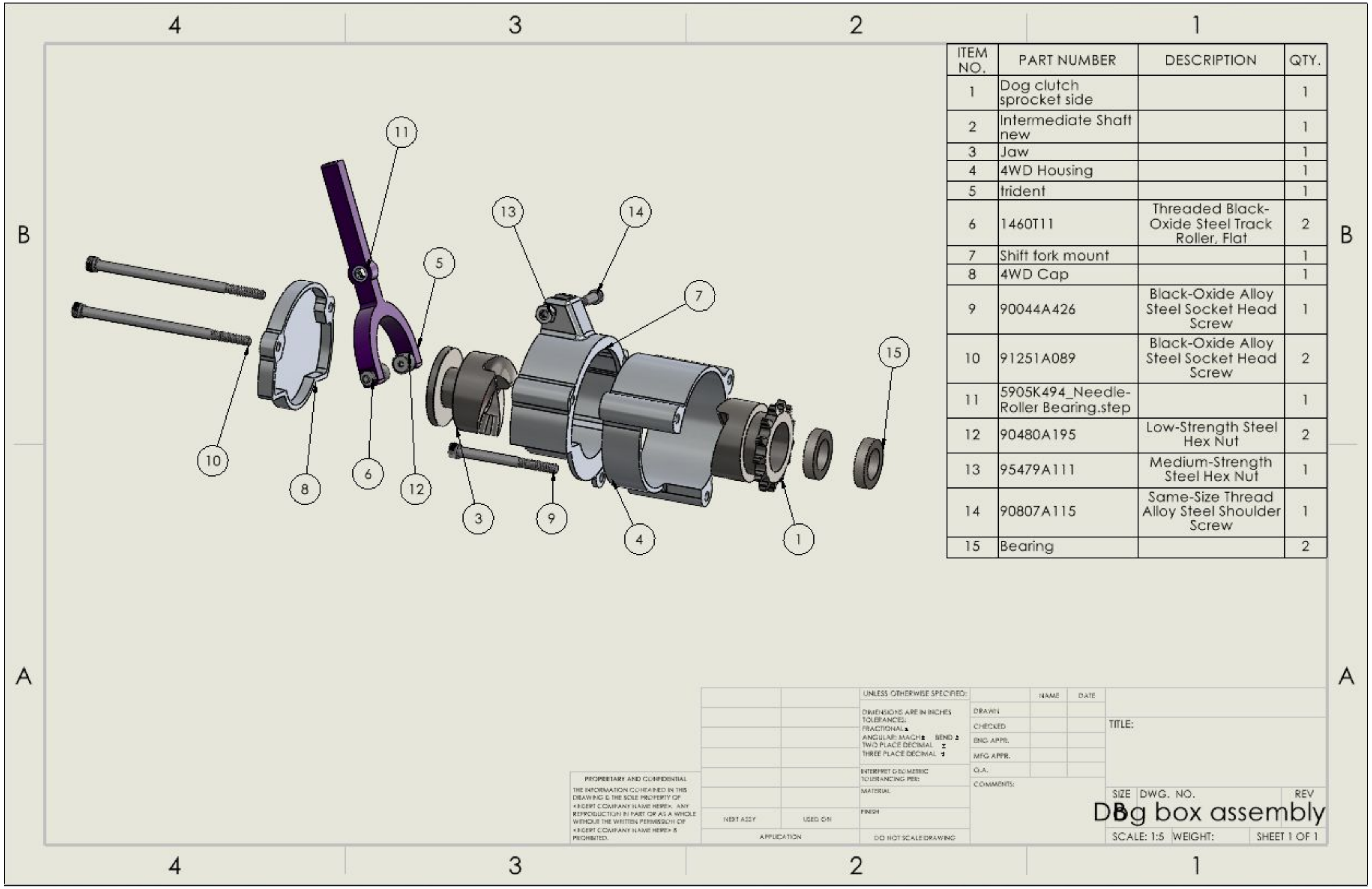


ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Front Reduction Driving Shaft		1
2	Axle no Cup - Front		2
3	CV Bottom Cup to Hub - Front		2
4	CV Cup - Front (sprag)		2

- Front drive shaft is press fit into driving gear
- Two sprag bearing press fit into driveshaft
- Two CV Cups press fit into sprag bearings
- Acts as a front hub for chain drive to move freely when needed

Ethan

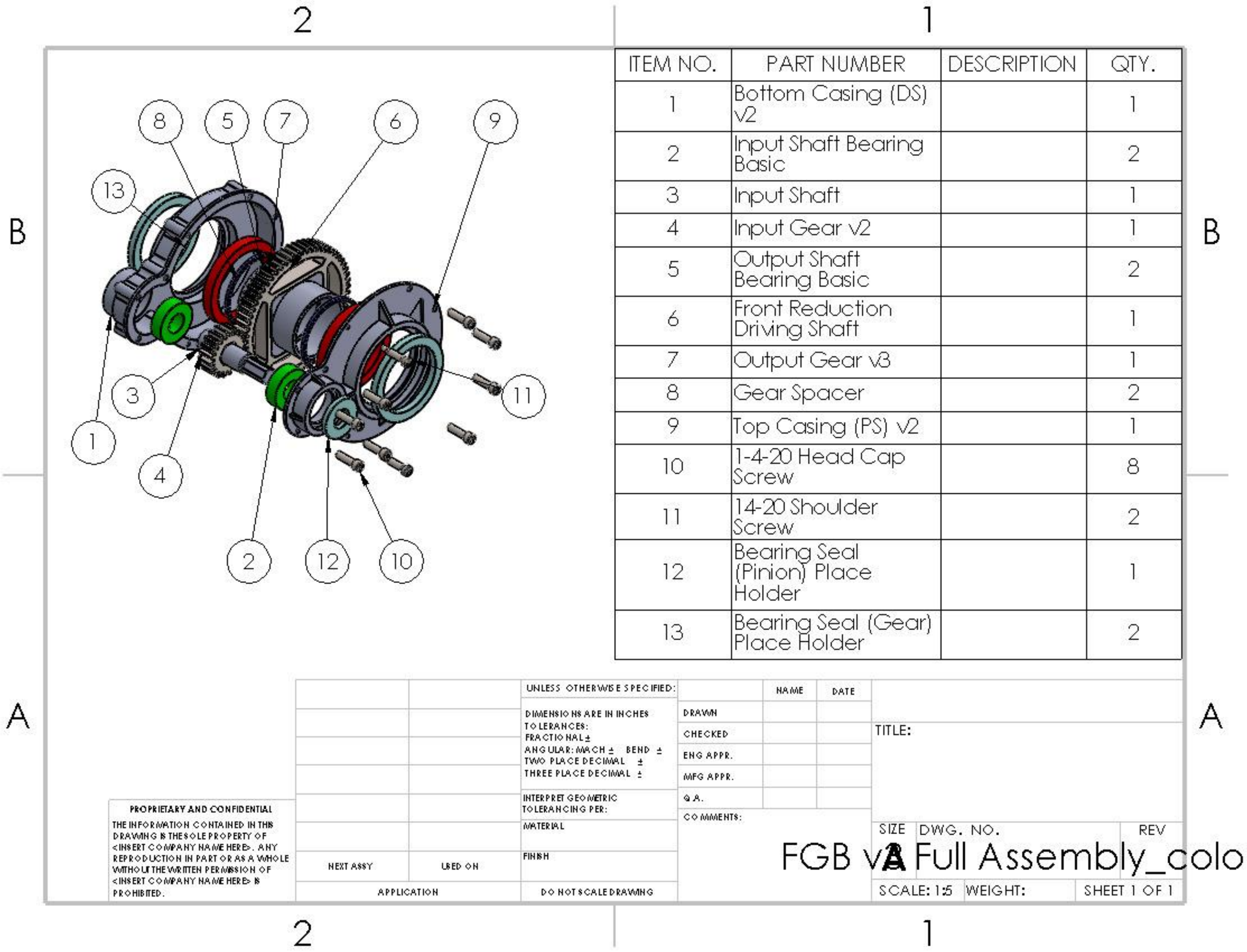
Design Description - Dog Box



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Dog clutch sprocket side		1
2	Intermediate Shaft new		1
3	Jaw		1
4	4WD Housing		1
5	trident		1
6	1460T11	Threaded Black-Oxide Steel Track Roller, Flat	2
7	Shift fork mount		1
8	4WD Cap		1
9	90044A426	Black-Oxide Alloy Steel Socket Head Screw	1
10	91251A089	Black-Oxide Alloy Steel Socket Head Screw	2
11	5905K494_Needle-Roller Bearing.step		1
12	90480A195	Low-Strength Steel Hex Nut	2
13	95479A111	Medium-Strength Steel Hex Nut	1
14	90807A115	Same-Size Thread Alloy Steel Shoulder Screw	1
15	Bearing		2

- Jaw clutches and bearings are assembled onto rear gearbox intermediate shaft.
- Housing units are bolted to rear gearbox casing.
- Shift fork is bolted onto shift fork housing with needle bearing attached to allow for ease of movement.
- Cable mounts are still in development. Awaiting finalized bolt placements.

Design Description - Front Gearbox



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Bottom Casing (DS) v2		1
2	Input Shaft Bearing Basic		2
3	Input Shaft		1
4	Input Gear v2		1
5	Output Shaft Bearing Basic		2
6	Front Reduction Driving Shaft		1
7	Output Gear v3		1
8	Gear Spacer		2
9	Top Casing (PS) v2		1
10	1-4-20 Head Cap Screw		8
11	14-20 Shoulder Screw		2
12	Bearing Seal (Pinion) Place Holder		1
13	Bearing Seal (Gear) Place Holder		2

PROPRIETARY AND CONFIDENTIAL

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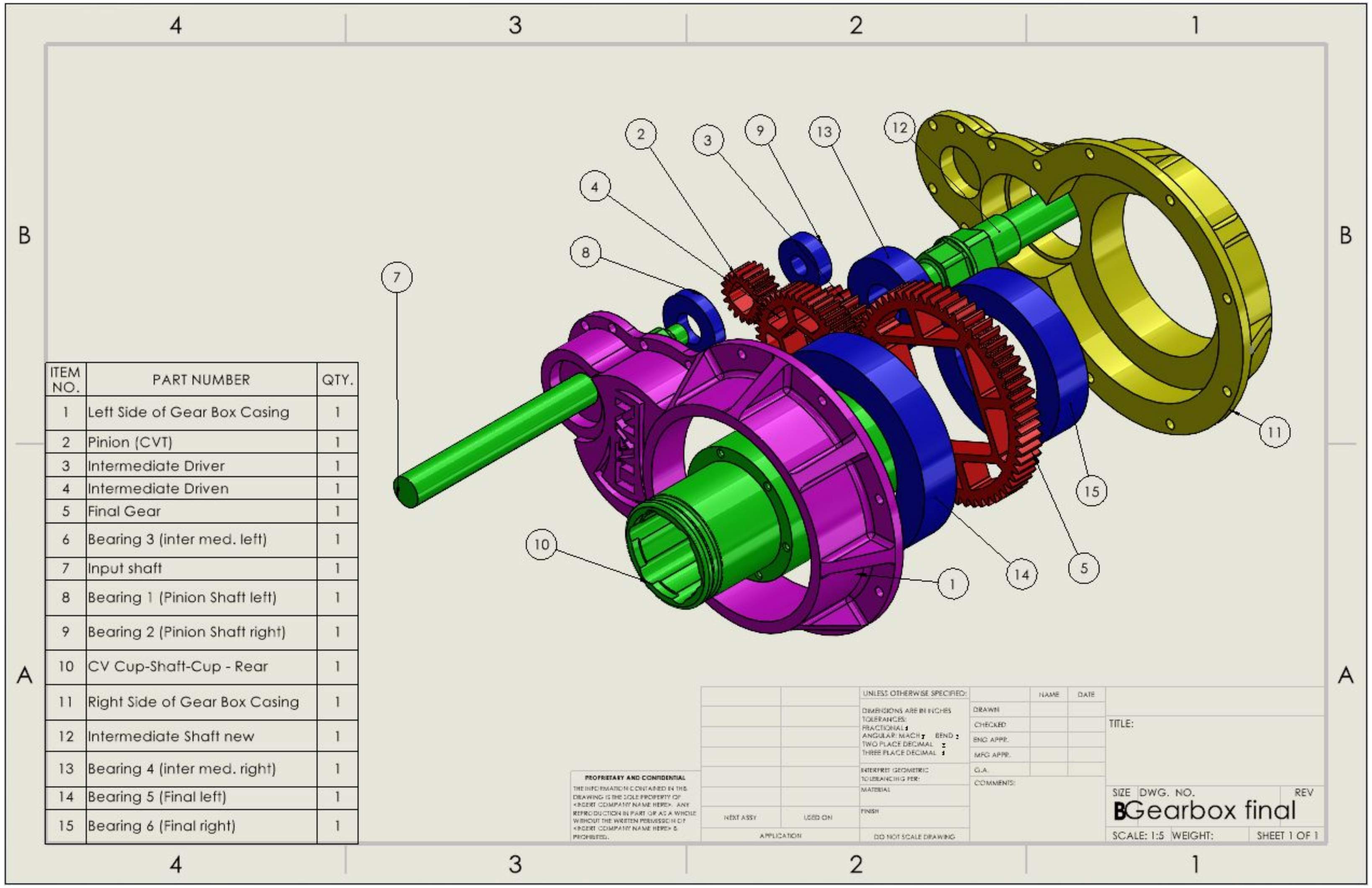
- Gears are press fitted onto shafts
- Same with ball bearings
- Bearings fit into both sides of the casing, keeping the casing in place
- Screw bolts used to secure casing sides together
- Bearing seals fitted into outside of casing to protect from dirt and debris

Rowan J.

Design Description - Rear Gearbox



ITEM NO.	PART NUMBER	QTY.
1	Left Side of Gear Box Casing	1
2	Pinion (CVT)	1
3	Intermediate Driver	1
4	Intermediate Driven	1
5	Final Gear	1
6	Bearing 3 (inter med. left)	1
7	Input shaft	1
8	Bearing 1 (Pinion Shaft left)	1
9	Bearing 2 (Pinion Shaft right)	1
10	CV Cup-Shaft-Cup - Rear	1
11	Right Side of Gear Box Casing	1
12	Intermediate Shaft new	1
13	Bearing 4 (inter med. right)	1
14	Bearing 5 (Final left)	1
15	Bearing 6 (Final right)	1

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NEXT ASSY | USED ON

APPLICATION

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:

SIZE B DWG. NO. Gearbox final REV

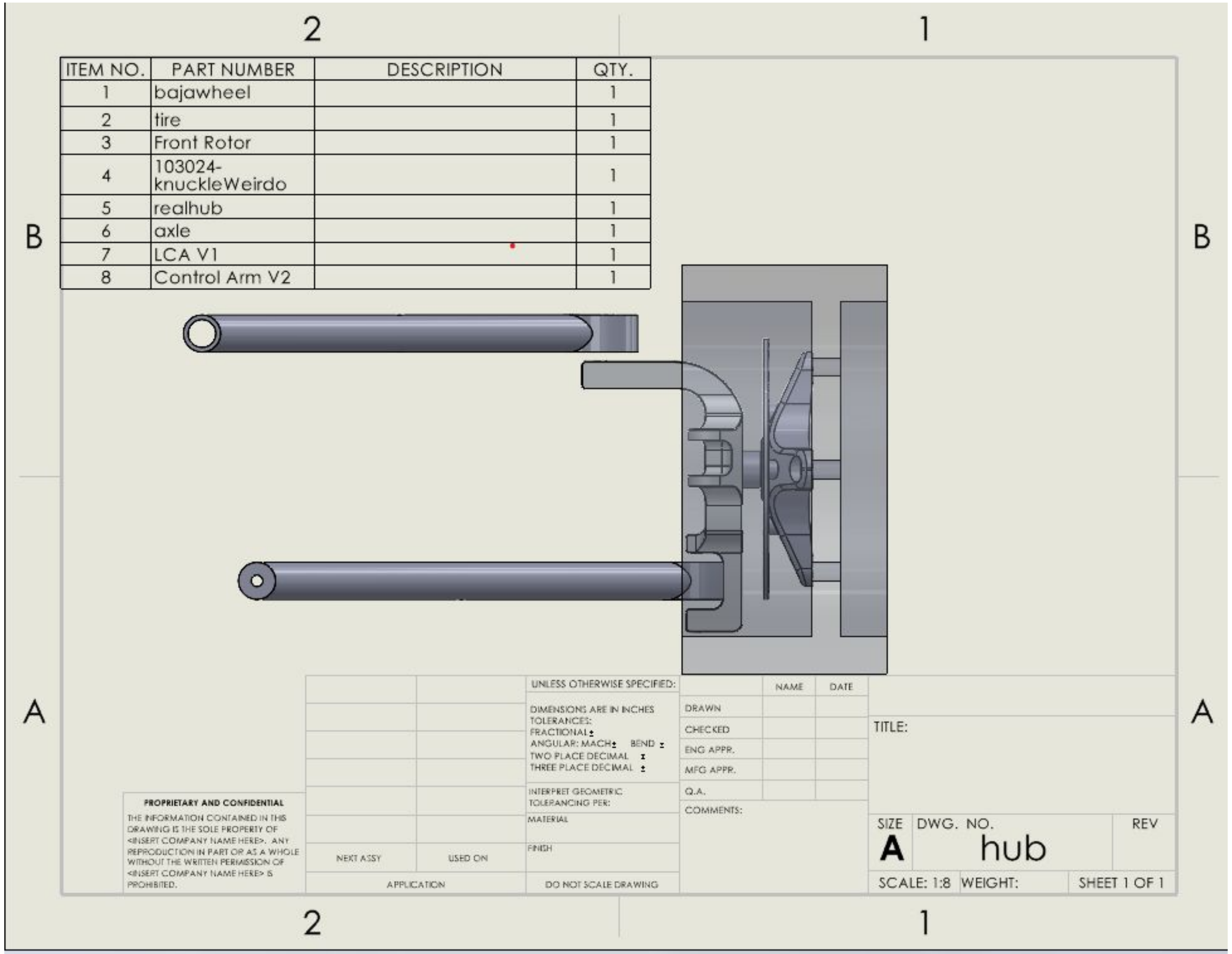
SCALE: 1:5 WEIGHT: SHEET 1 OF 1

- Red = Gears
- Blue = Bearings
- Green = Shafts
- Pink = Left Side of Gearbox
- Yellow = Right Side of Gearbox

- Gears and Bearings will be press-fitted to respective shafts
- Casings will be press-fitted together to close gearbox
- A seal will be used around external bearings and where casings meet to keep oil in gearbox
- Bolts will be used to keep press-fit together
- 4WD comes off of right side of casing

Dylan

Design Description - Front Hub



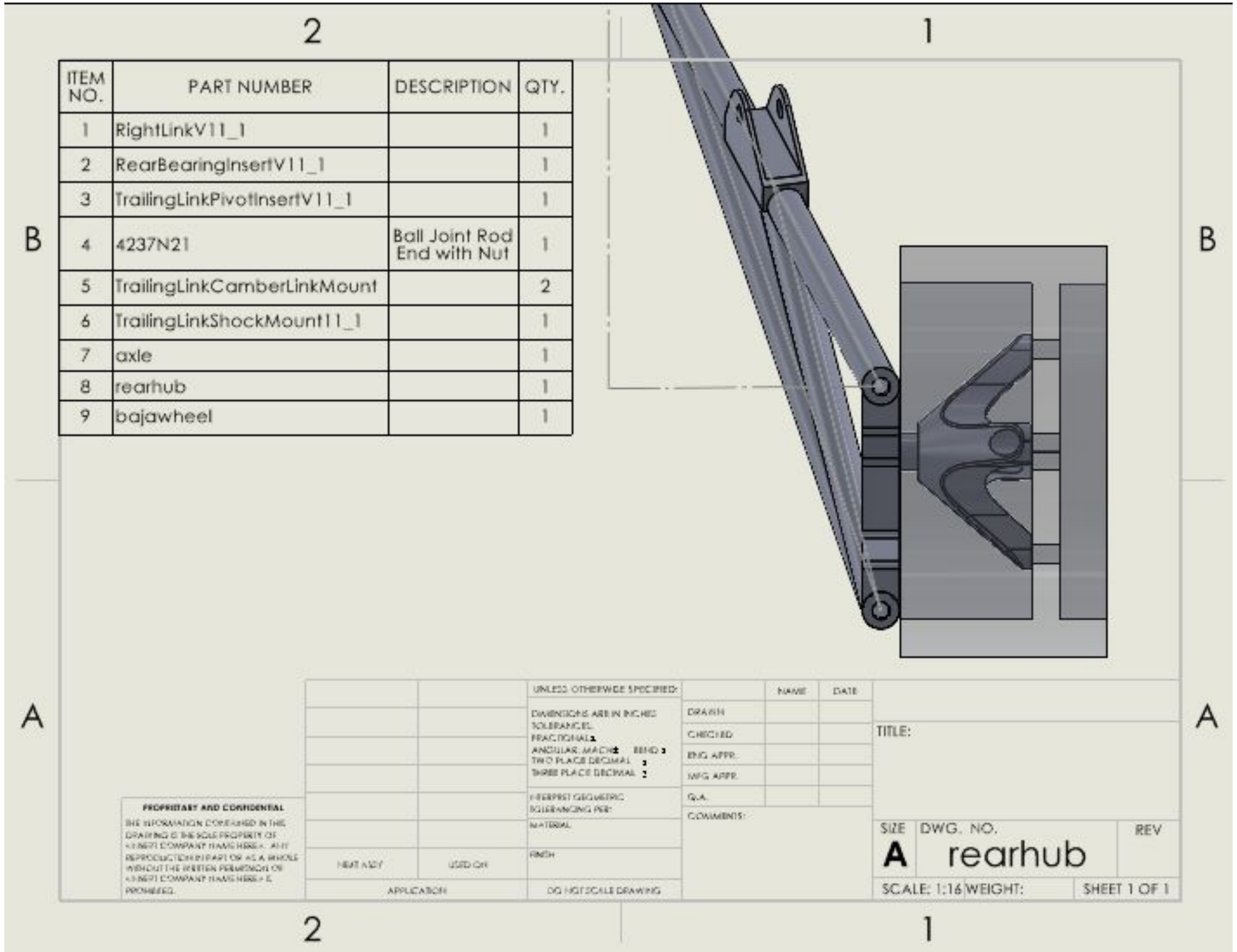
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	bajawheel		1
2	tire		1
3	Front Rotor		1
4	103024-knuckleWeirdo		1
5	realhub		1
6	axle		1
7	LCA V1		1
8	Control Arm V2		1

SIZE A
DWG. NO. hub
SCALE: 1:8
WEIGHT:
SHEET 1 OF 1

- Hub as flat as possible to decrease part thickness and thus weight
- Thickness depends on wheel geometry and axle length, as well as knuckle geometry
- Impacts front brake fitment

Matthew

Design Description - Rear Hub



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	RightLinkV11_1		1
2	RearBearingInsertV11_1		1
3	TrailingLinkPivotInsertV11_1		1
4	4237N21	Ball Joint Rod End with Nut	1
5	TrailingLinkCamberLinkMount		2
6	TrailingLinkShockMount11_1		1
7	axle		1
8	rearhub		1
9	bajawheel		1

NEXT ASSY
USED ON
APPLICATION

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:

SIZE A
DWG. NO. rearhub
REV
SCALE: 1:16
WEIGHT:
SHEET 1 OF 1

- Hub as flat as possible to decrease part thickness and thus weight
- Thickness depends on wheel geometry and axle length, as well as trailing arm geometry
- With current rear suspension set up, huge sweep angle needed to accommodate wheel geometry
- Will likely use a spacer

Matthew

Engineering Calculations - Rear Gearbox

First two gears

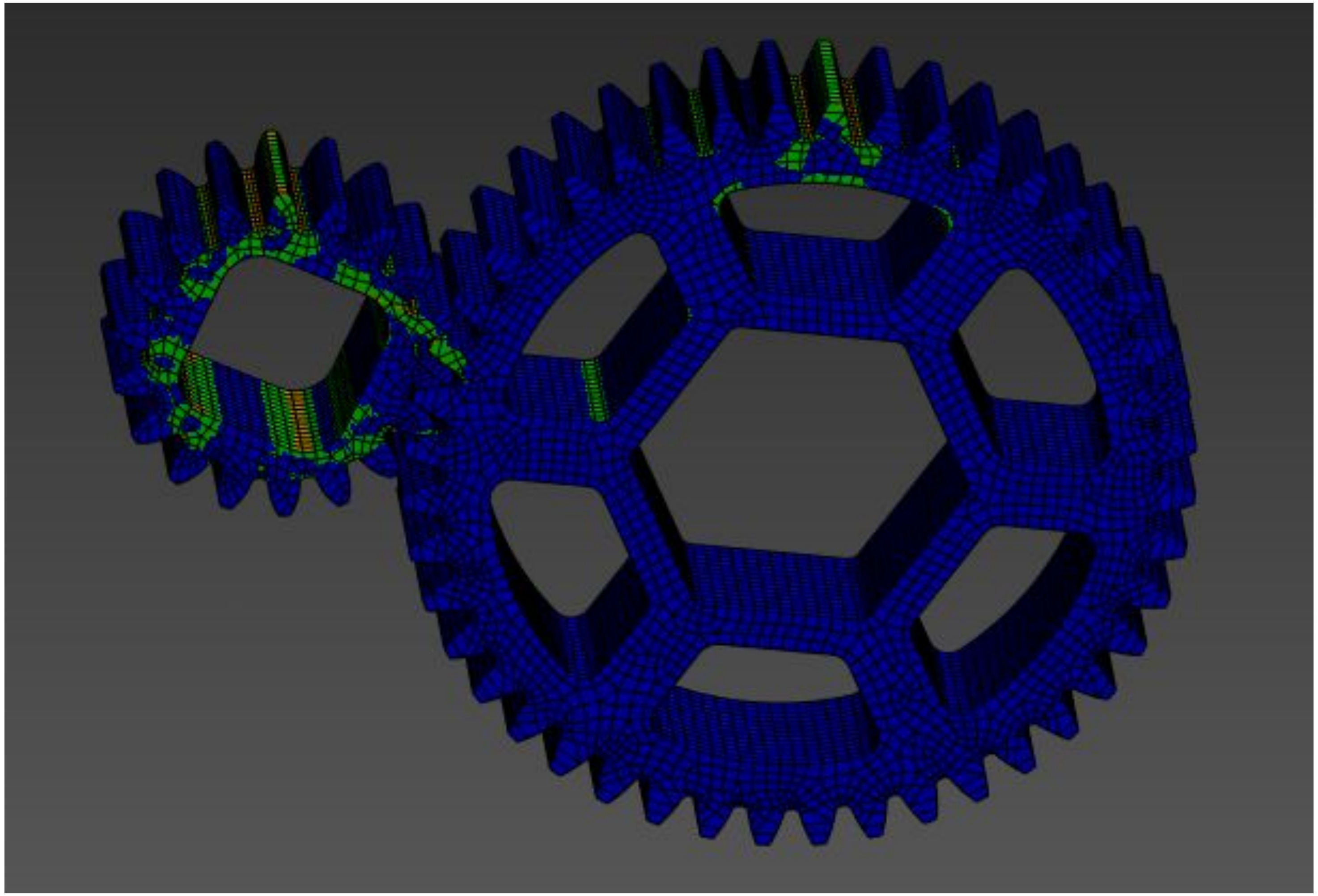


Figure of safety factor analysis

Total Deformation:

- .00074 in

Max Strain:

- .0011

Max Stress:

- 33145 psi

Safety Factor:

- 1.767

Moment:

- 865.8 ft-lbf

Radial Force on Both Gears:

- 545.5 lbf

Supports:

Gear: Fixed Support

Pinion: Frictionless Support

Dylan

Engineering Calculations - Rear Gearbox

Second two gears

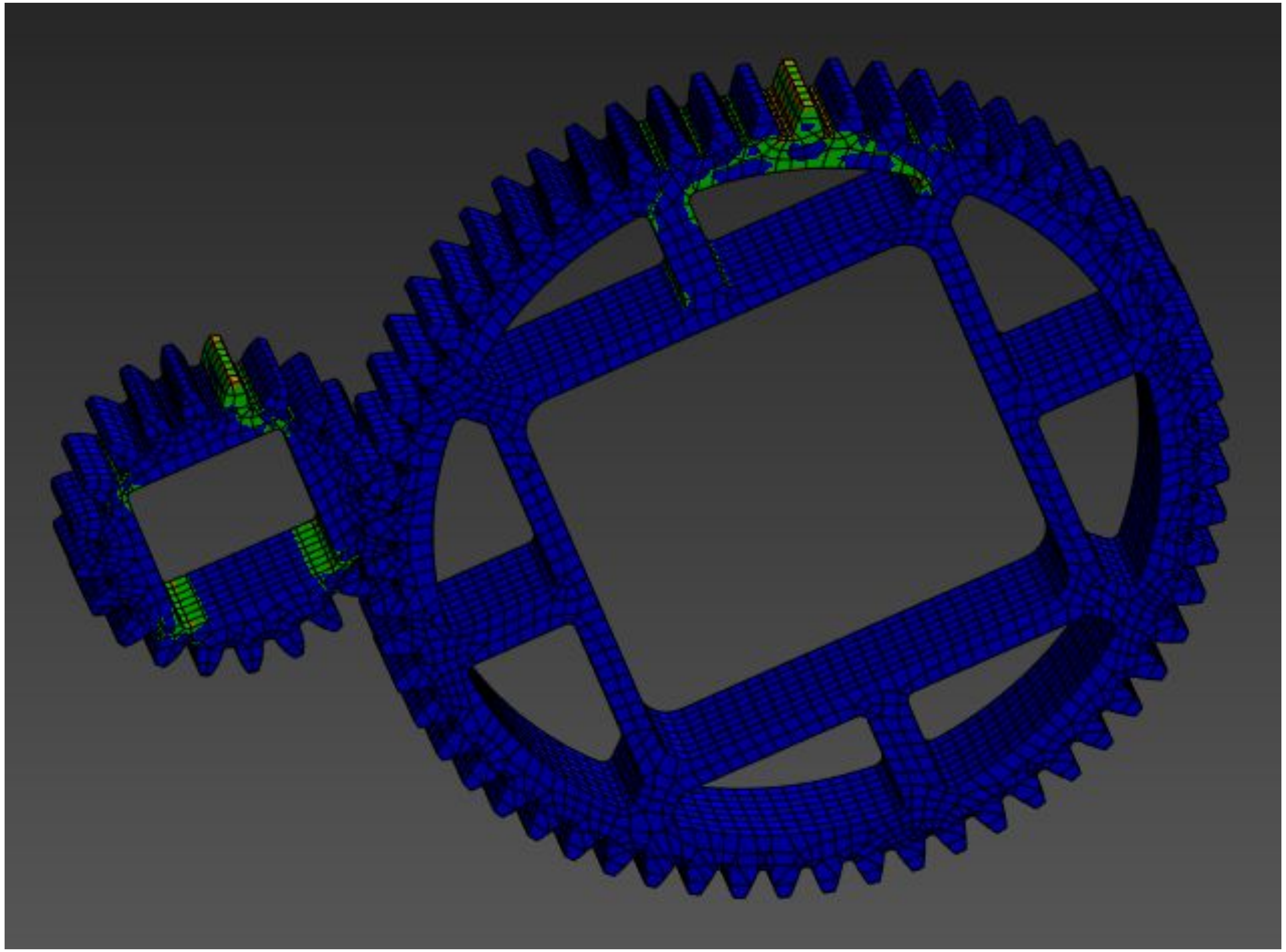


Figure of safety factor analysis

Total Deformation:

- .0013 in

Max Strain:

- .0008

Max Stress:

- 33532 psi

Safety Factor:

- 1.92

Moment:

- 2116.4 lbf*in

Radial Force on Both Gears:

- 857 lbf

Supports:

Gear: Fixed support

Pinion: Frictionless Support

Dylan

Engineering Calculations - Sprag Bearings

-Restricted Kohler CH440:

Max-torque = 18.5 ft-lb @ 2400 rpm

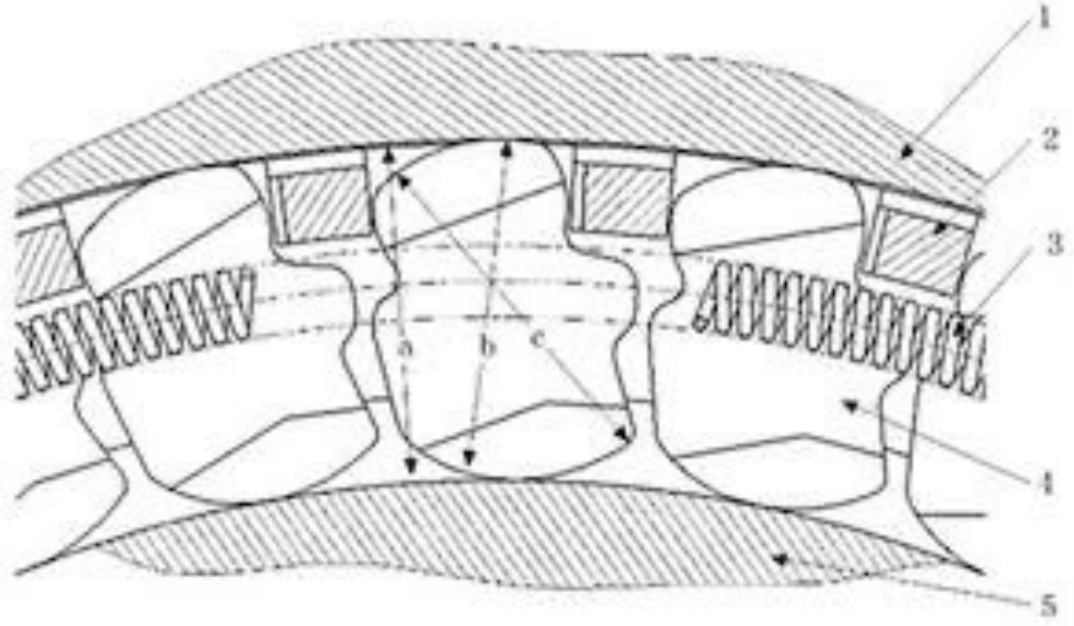
-Final drive gear ratio will be 3.9 * 6.98 = 27.22 with CVT and front gearbox

- 18.5 ft-lb torque * 27.22

=503.57 ft-lb

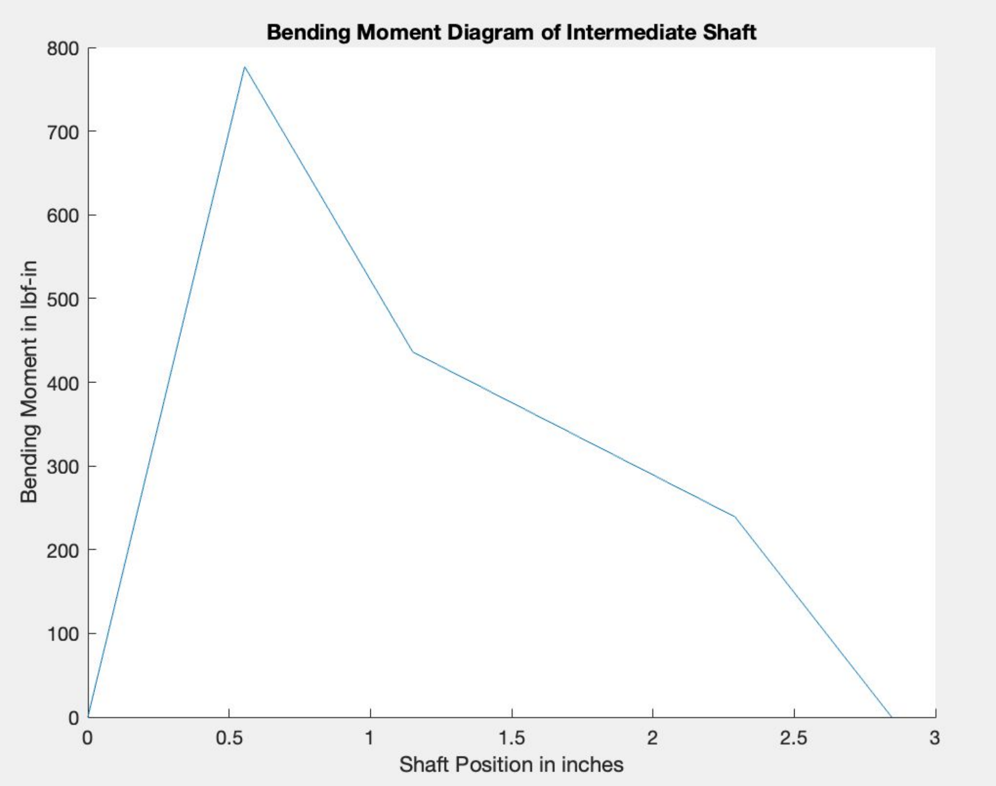
*.9 for mechanical loss = 453.23 ft-lb

Sprag rating must be higher than this value.

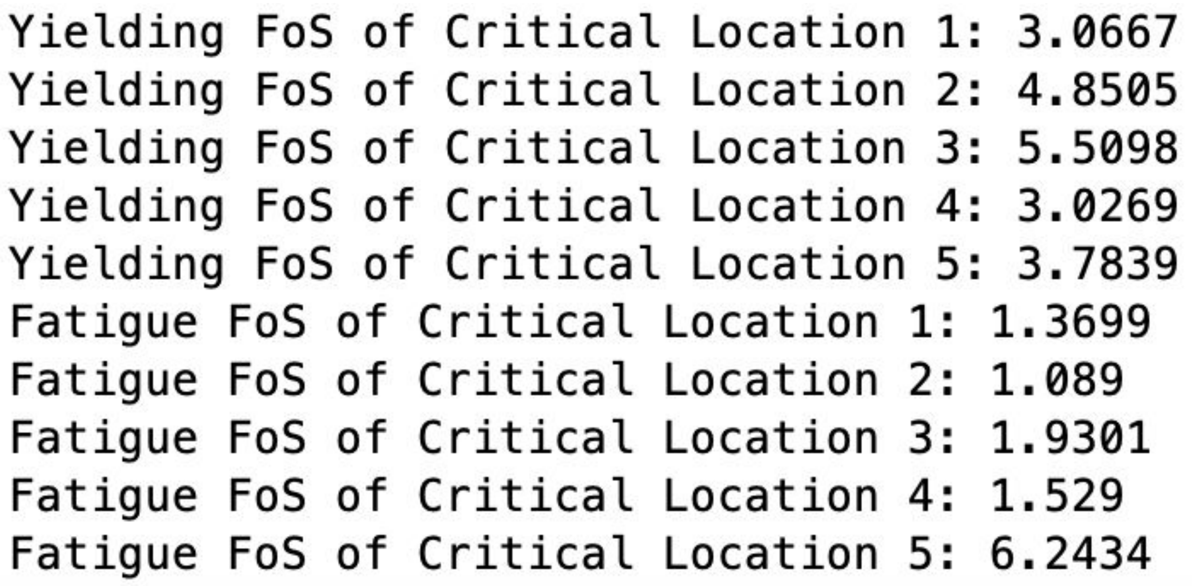


Ethan

Engineering Calculations - Shaft FOS



- MATLAB was utilized to determine most ideal locations of shaft components and shaft diameters to ensure shaft critical locations had a yielding and fatigue FOS greater than 1.
- Shigley’s Equations from Chapters 6,7, and 18 were used for this analysis.



```
Yielding FoS of Critical Location 1: 3.0667
Yielding FoS of Critical Location 2: 4.8505
Yielding FoS of Critical Location 3: 5.5098
Yielding FoS of Critical Location 4: 3.0269
Yielding FoS of Critical Location 5: 3.7839
Fatigue FoS of Critical Location 1: 1.3699
Fatigue FoS of Critical Location 2: 1.089
Fatigue FoS of Critical Location 3: 1.9301
Fatigue FoS of Critical Location 4: 1.529
Fatigue FoS of Critical Location 5: 6.2434
```

Engineering Calculations - Chain Drive

$T_1=F(1+(1/e^{\mu\alpha}-1)$

$T_2=F(1/e^{\mu\alpha}-1)$

$T_1=1884.6(1+(1/e^{0.3636\pi}-1)$

$T_2=1884.6(1/e^{0.3636\pi}-1)$

$T_1=2767.74$ N=**622.21 lbf**

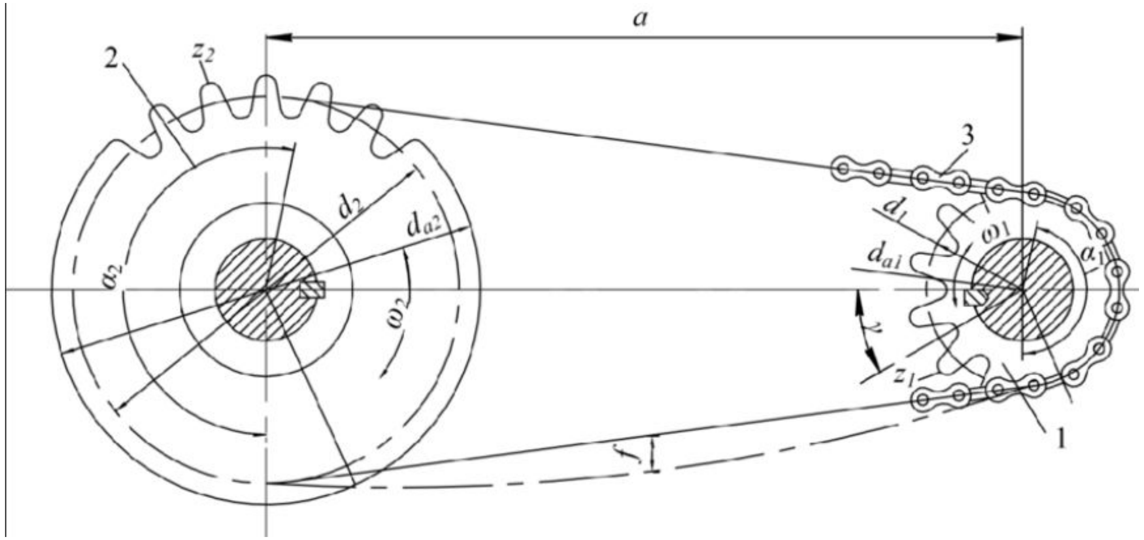
$T_2=883.16$ N= **198.67 lbf**

$\mu=(0.26+(\mu_f d))/D+1.64/D$

$\mu=0.1573+0.2063=$**0.3636**

F=(7084.15 Nm/s)/(3.759 m/s)

=1884.584 N= **423.68 lbf**



P=9.5hp=7084.15 Nm/s

V=739.981 ft/min=3.759 m/s

μ=coeff. of friction

α= angle subtended by contact surface at center of sprocket, in radians

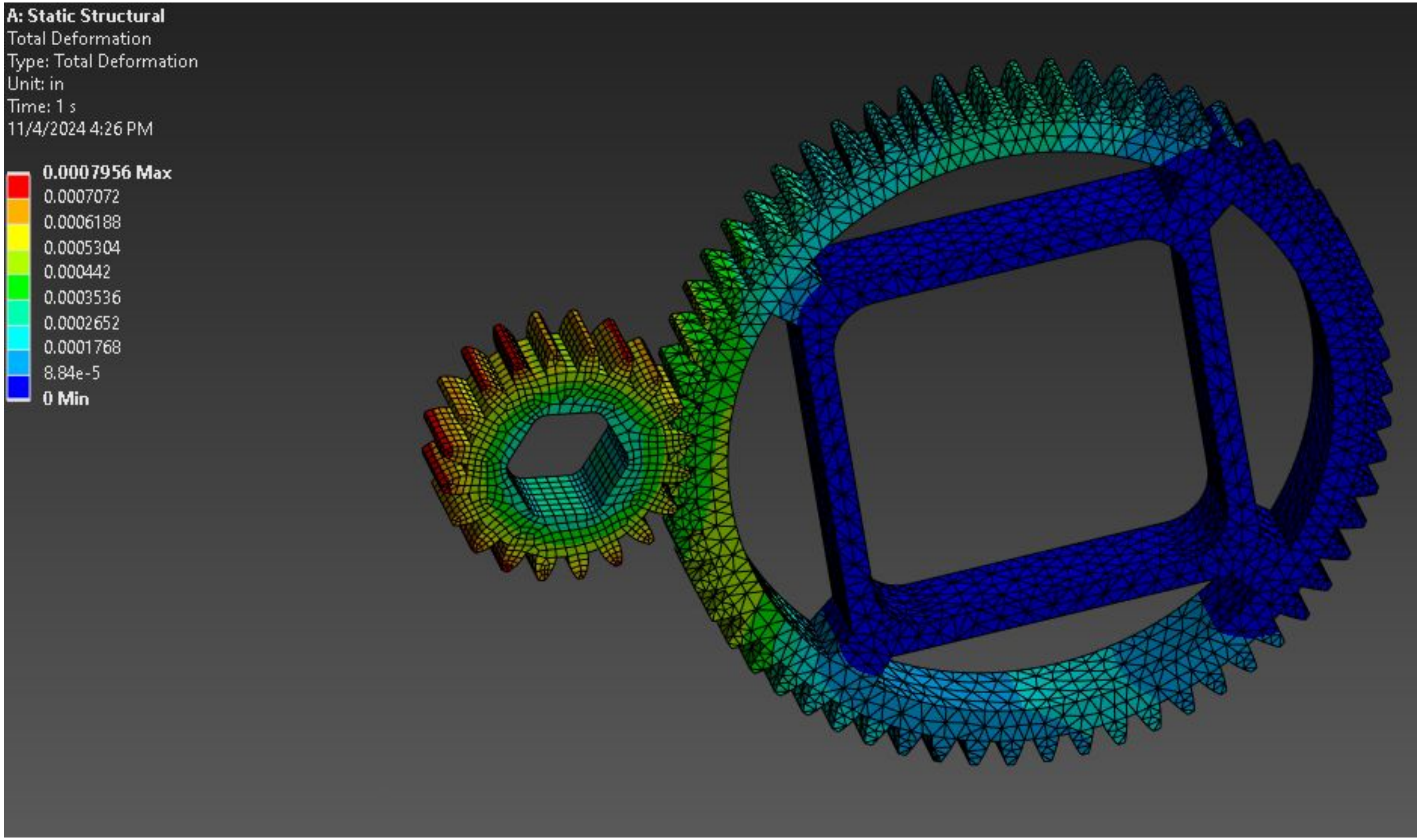
F= moving force in chain driver

d= roller bore (mm)

D= roller OD (mm)

Nolan S.

Engineering Calculations - Front Gearbox



Maximum Deformation

Maximum - 7.956E-04 inches

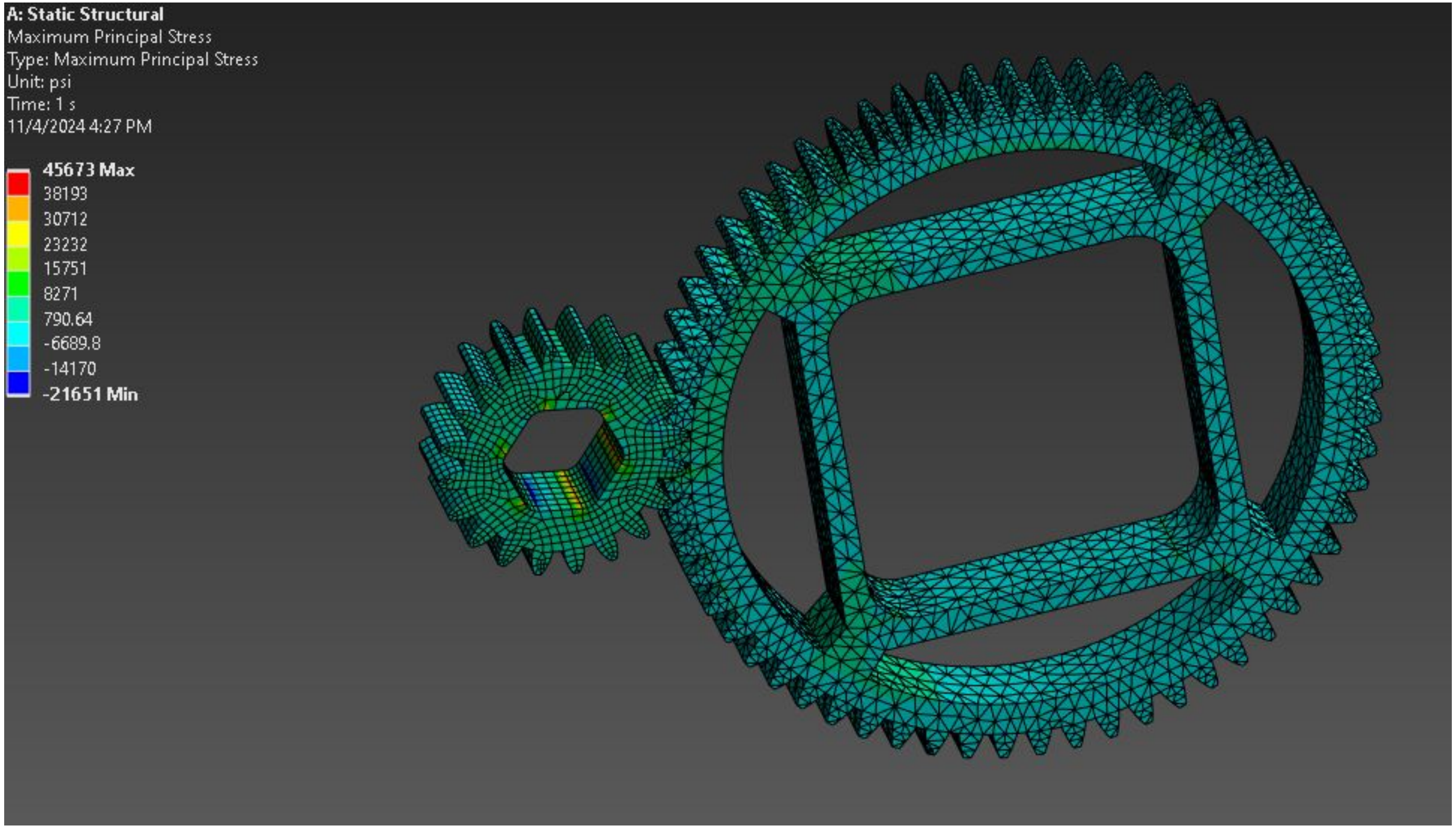
- Occurs at the tips of the teeth where the majority of the torque will be felt.
- Extremely small deformation

Minimum - 0 inches

- Occurs on the large gear, in which the torque is not felt as much

Rowan J.

Engineering Calculations - Front Gearbox



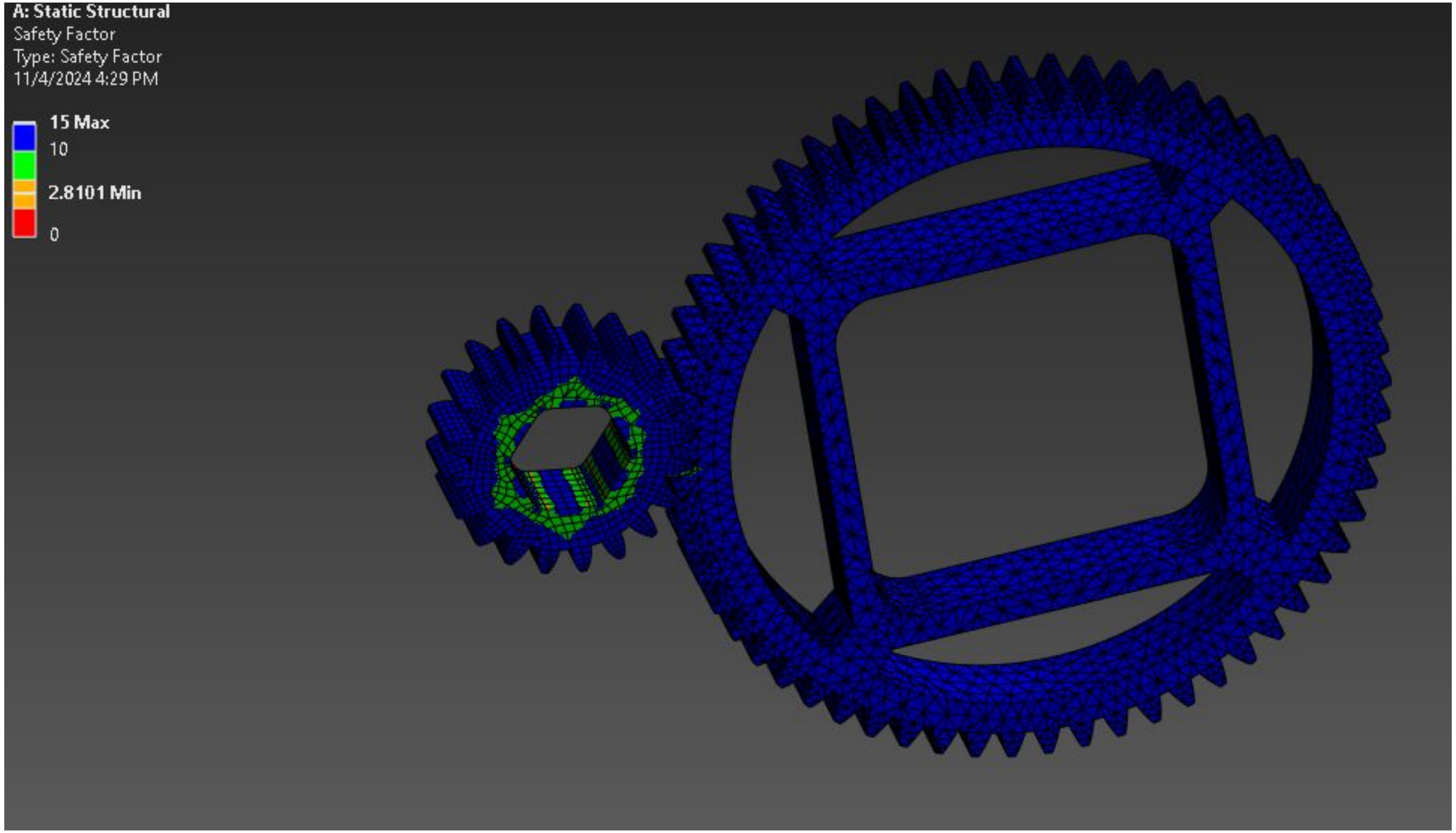
Maximum Principal Stress

Maximum - 45,673 psi

- Occurs in the interior filleted corners of the pinion and at the contact point of the teeth
- Below allowable contact stress of 65,982 psi previously calculated

Rowan J.

Engineering Calculations - Front Gearbox



ANSYS Safety Factor

Maximum - FoS = 15

- Most places on the large gear

Minimum - Fos = 2.81

- Occurs in the interior filleted corners of the pinion and at the contact point of the teeth

Rowan J.

Engineering Calculations - Spline Cuff Fit

$P = (E \times \delta) / (2 \times d)$

Where: P = Contact pressure (psi)

$E = 10{,}000{,}000$ psi (6061 Al)

δ = Radial interference (in)

d = Diameter (in)

For 0.75 inch hole using 0.001" interference:

$P = (10{,}000{,}000 \times 0.001) / (2 \times 0.75)$ $P = 6{,}667$ psi

Shrink Fit Temperature: $\Delta T = \delta / (\alpha \times d)$ $\Delta T = 0.001 / (13.1 \times 10^{-6} \times 0.75)$ $\Delta T = 102°\mathrm{F}$ rise

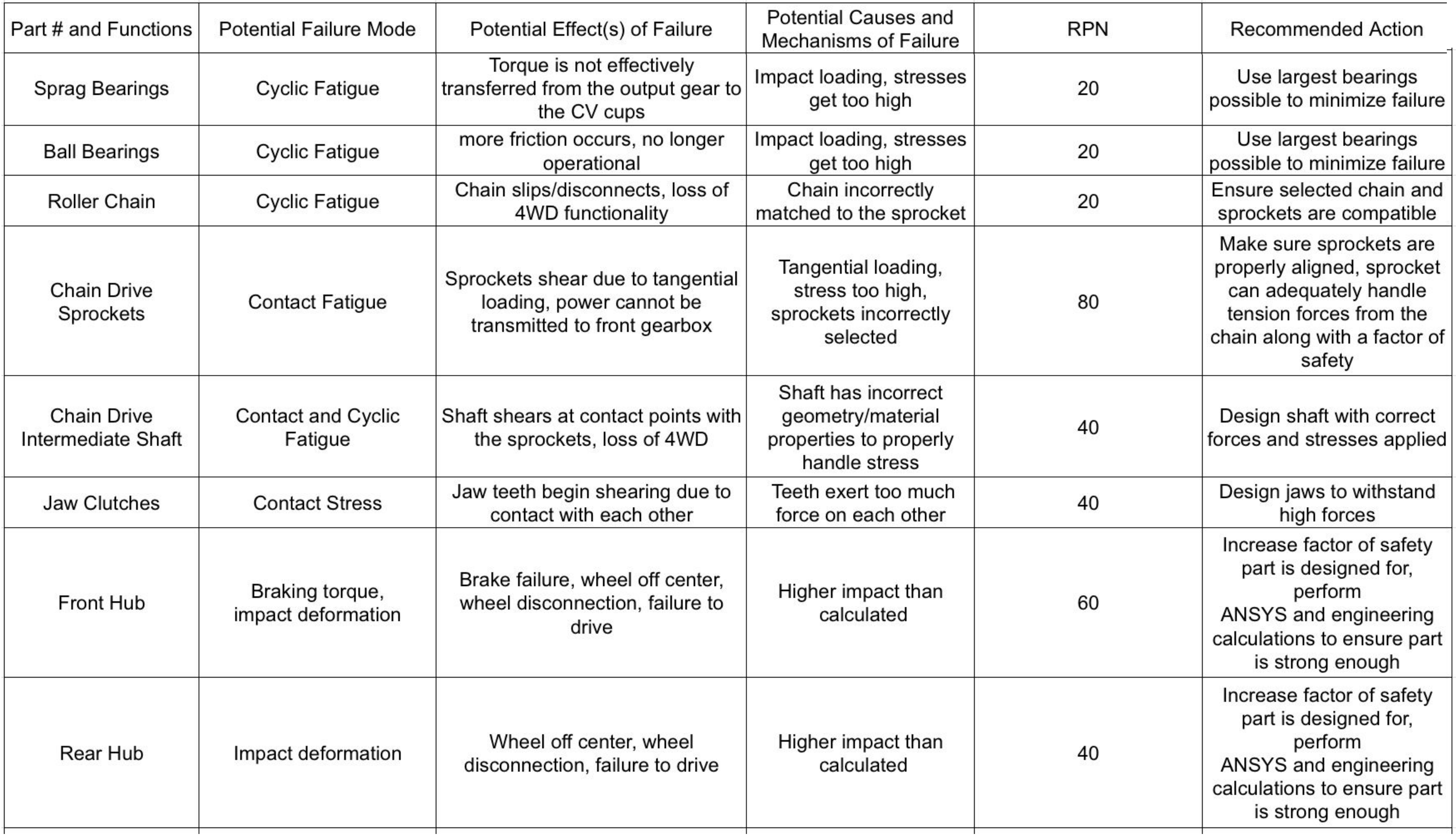
Matthew

FMEA

Part # and Functions	Potential Failure Mode	Potential Effect(s) of Failure	Potential Causes and Mechanisms of Failure	RPN	Recommended Action
Rear CV Cup-Shaft-Cup	Impact deformation	Rear CV Cup failing/ineffectiveness, CV Axle shaft failing/ineffetcivness, Damage to rear gearbox	Car bottoming out, Faulty suspension setup	9	Design suspension effectively
Front CV Cup	Impact deformation	Front CV Cup failing/ineffectiveness, CV Axle shaft failing/ineffetcivness, Damage to front gearbox	Car bottoming out, Faulty suspension setup	15	Design suspension effectively
Axle Shaft	High-Cycle Fatigue	Failure of CV axle shaft	Weakly designed axle shaft; small diameter or weak material	20	Perform FEA and do engineering calcs to ensure shafts are strong enough
Hub Spline	Slipping	Failure of transmission of power to wheels through hubs	Faulty press fit	140	Study up on press fits, ensure parts are manufacture to correct tolerance
Front gearbox Output Shaft	Temperature induced deformation	Deformation leading to damage of contained bearings	To much friction between gears, faulty gearbox design	20	Ensure center to centers on gears are correct, incorporate bearings effectively
Front gearbox Input Shaft	Contact and Cyclic Fatigue and Temperature induced deformation	Shaft shearing, Bearings overheating	Too much contact stress at the fillets in the shaft, friction between the gears too high	36	Ensure shaft calculations incorporate real world stresses, heat treat shaft to increase strength
Input Gear	Contact Fatigue	Teeth Shearing at contact point, Gearbox becomes not functional, no 4WD	Applied torque is too much, causing shearing of the gears	60	Make sure center to centers are correct, use ANSYS, and heat treat the entire gear to provide thew maximum strength
Output Gear	Contact Fatigue	Teeth Shearing at contact point, Gearbox becomes not functional, no 4WD	Applied torque is too much, causing shearing of the gears	60	Make sure center to centers are correct, use ANSYS, and heat treat the entire gear to provide thew maximum strength

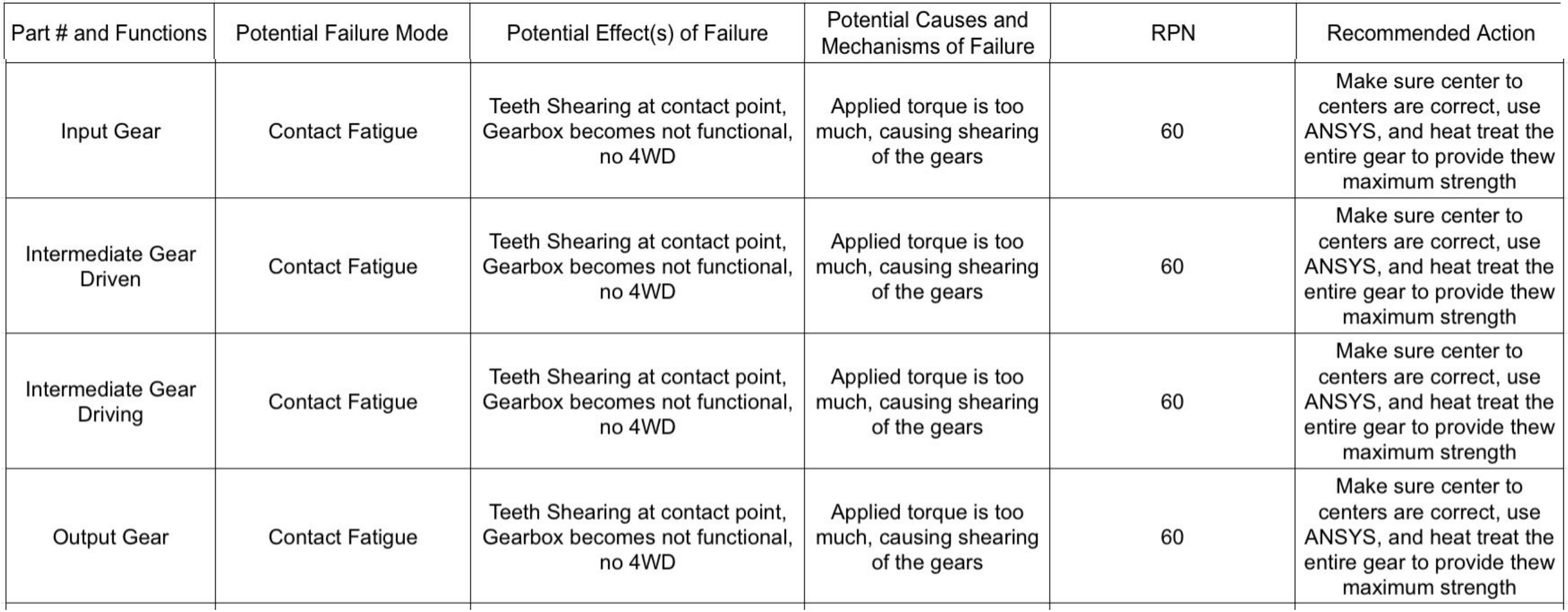
FMEA

Nolan S.



Part # and Functions	Potential Failure Mode	Potential Effect(s) of Failure	Potential Causes and Mechanisms of Failure	RPN	Recommended Action
Sprag Bearings	Cyclic Fatigue	Torque is not effectively transferred from the output gear to the CV cups	Impact loading, stresses get too high	20	Use largest bearings possible to minimize failure
Ball Bearings	Cyclic Fatigue	more friction occurs, no longer operational	Impact loading, stresses get too high	20	Use largest bearings possible to minimize failure
Roller Chain	Cyclic Fatigue	Chain slips/disconnects, loss of 4WD functionality	Chain incorrectly matched to the sprocket	20	Ensure selected chain and sprockets are compatible
Chain Drive Sprockets	Contact Fatigue	Sprockets shear due to tangential loading, power cannot be transmitted to front gearbox	Tangential loading, stress too high, sprockets incorrectly selected	80	Make sure sprockets are properly aligned, sprocket can adequately handle tension forces from the chain along with a factor of safety
Chain Drive Intermediate Shaft	Contact and Cyclic Fatigue	Shaft shears at contact points with the sprockets, loss of 4WD	Shaft has incorrect geometry/material properties to properly handle stress	40	Design shaft with correct forces and stresses applied
Jaw Clutches	Contact Stress	Jaw teeth begin shearing due to contact with each other	Teeth exert too much force on each other	40	Design jaws to withstand high forces
Front Hub	Braking torque, impact deformation	Brake failure, wheel off center, wheel disconnection, failure to drive	Higher impact than calculated	60	Increase factor of safety part is designed for, perform ANSYS and engineering calculations to ensure part is strong enough
Rear Hub	Impact deformation	Wheel off center, wheel disconnection, failure to drive	Higher impact than calculated	40	Increase factor of safety part is designed for, perform ANSYS and engineering calculations to ensure part is strong enough

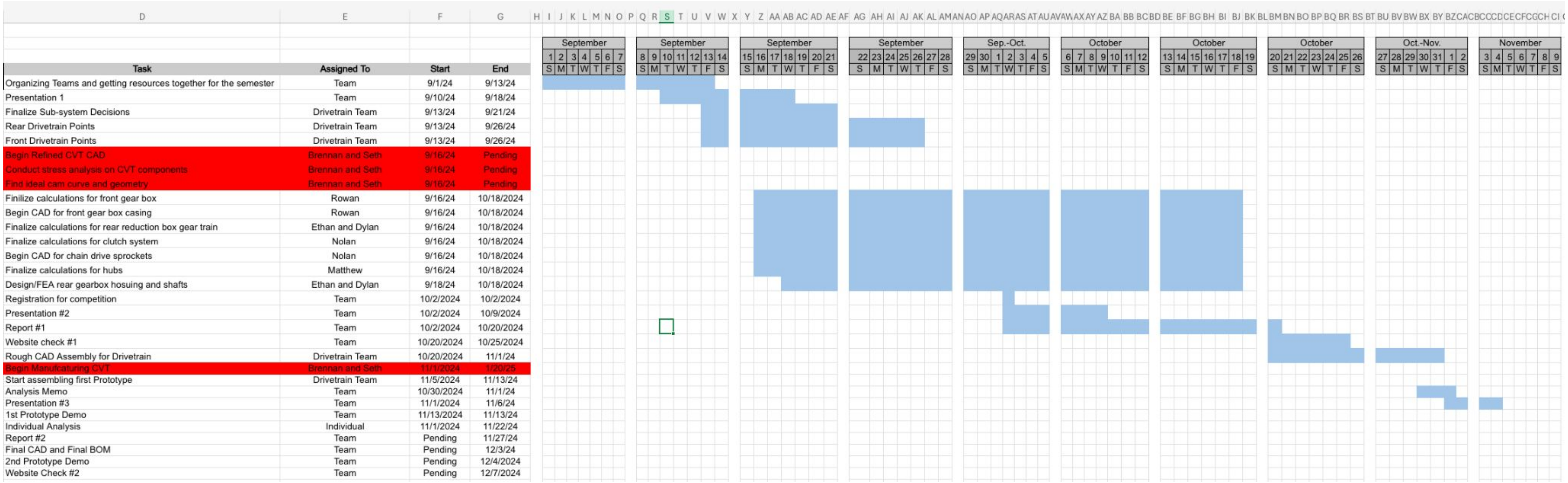
FMEA



Part # and Functions	Potential Failure Mode	Potential Effect(s) of Failure	Potential Causes and Mechanisms of Failure	RPN	Recommended Action
Input Gear	Contact Fatigue	Teeth Shearing at contact point, Gearbox becomes not functional, no 4WD	Applied torque is too much, causing shearing of the gears	60	Make sure center to centers are correct, use ANSYS, and heat treat the entire gear to provide thew maximum strength
Intermediate Gear Driven	Contact Fatigue	Teeth Shearing at contact point, Gearbox becomes not functional, no 4WD	Applied torque is too much, causing shearing of the gears	60	Make sure center to centers are correct, use ANSYS, and heat treat the entire gear to provide thew maximum strength
Intermediate Gear Driving	Contact Fatigue	Teeth Shearing at contact point, Gearbox becomes not functional, no 4WD	Applied torque is too much, causing shearing of the gears	60	Make sure center to centers are correct, use ANSYS, and heat treat the entire gear to provide thew maximum strength
Output Gear	Contact Fatigue	Teeth Shearing at contact point, Gearbox becomes not functional, no 4WD	Applied torque is too much, causing shearing of the gears	60	Make sure center to centers are correct, use ANSYS, and heat treat the entire gear to provide thew maximum strength

Matthew

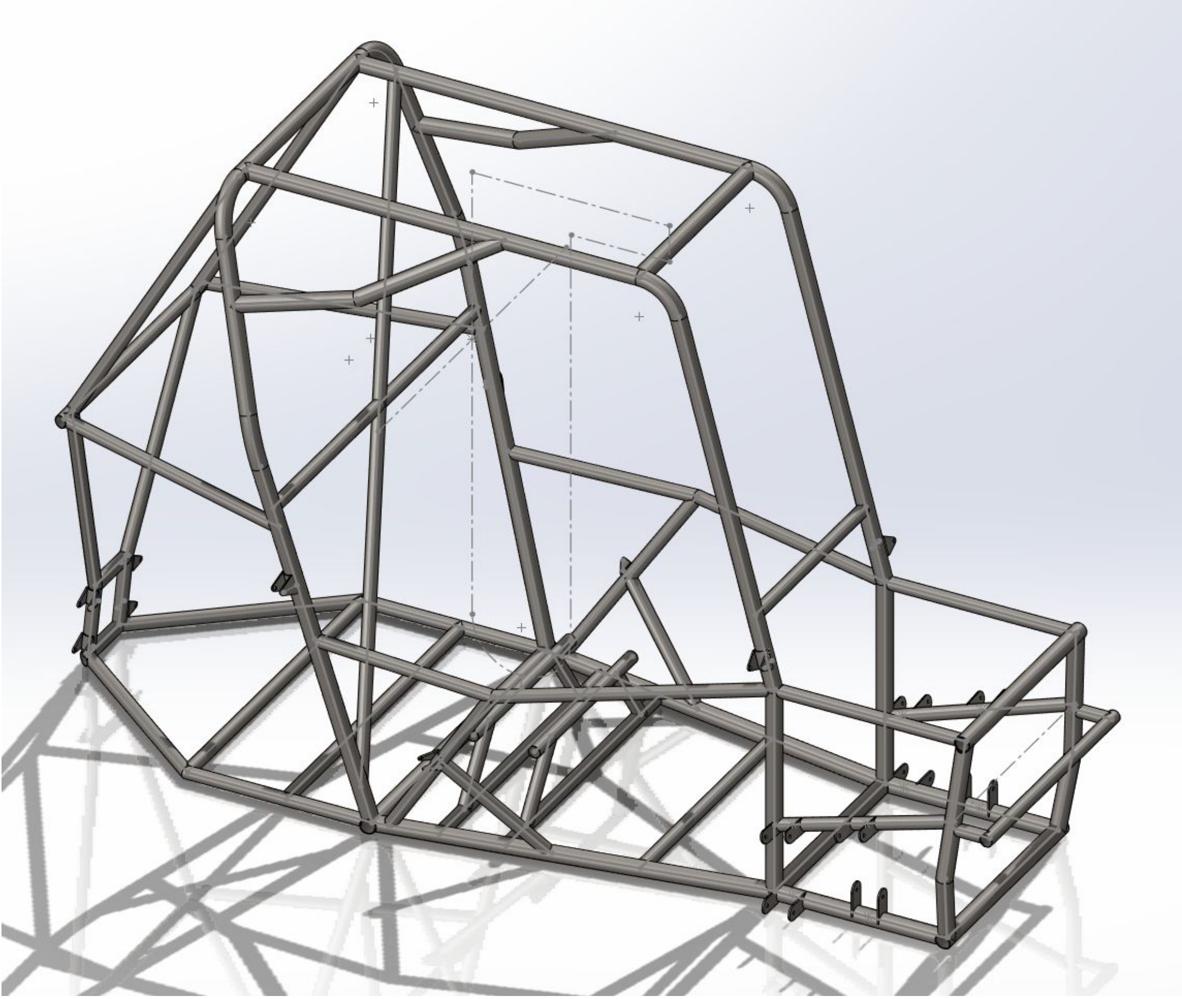
Schedule



Task	Assigned To	Start	End
Organizing Teams and getting resources together for the semester	Team	9/1/24	9/13/24
Presentation 1	Team	9/10/24	9/18/24
Finalize Sub-system Decisions	Drivetrain Team	9/13/24	9/21/24
Rear Drivetrain Points	Drivetrain Team	9/13/24	9/26/24
Front Drivetrain Points	Drivetrain Team	9/13/24	9/26/24
Begin Refined CVT CAD	Brennan and Seth	9/16/24	Pending
Conduct stress analysis on CVT components	Brennan and Seth	9/16/24	Pending
Find ideal cam curve and geometry	Brennan and Seth	9/16/24	Pending
Finilize calculations for front gear box	Rowan	9/16/24	10/18/2024
Begin CAD for front gear box casing	Rowan	9/16/24	10/18/2024
Finalize calculations for rear reduction box gear train	Ethan and Dylan	9/16/24	10/18/2024
Finalize calculations for clutch system	Nolan	9/16/24	10/18/2024
Begin CAD for chain drive sprockets	Nolan	9/16/24	10/18/2024
Finalize calculations for hubs	Matthew	9/16/24	10/18/2024
Design/FEA rear gearbox hosuing and shafts	Ethan and Dylan	9/18/24	10/18/2024
Registration for competition	Team	10/2/2024	10/2/2024
Presentation #2	Team	10/2/2024	10/9/2024
Report #1	Team	10/2/2024	10/20/2024
Website check #1	Team	10/20/2024	10/25/2024
Rough CAD Assembly for Drivetrain	Drivetrain Team	10/20/2024	11/1/24
Begin Manufcaturing CVT	Brennan and Seth	11/1/2024	1/20/25
Start assembling first Prototype	Drivetrain Team	11/5/2024	11/13/24
Analysis Memo	Team	10/30/2024	11/1/24
Presentation #3	Team	11/1/2024	11/6/24
1st Prototype Demo	Team	11/13/2024	11/13/24
Individual Analysis	Individual	11/1/2024	11/22/24
Report #2	Team	Pending	11/27/24
Final CAD and Final BOM	Team	Pending	12/3/24
2nd Prototype Demo	Team	Pending	12/4/2024
Website Check #2	Team	Pending	12/7/2024

Seth

Chassis & Frame

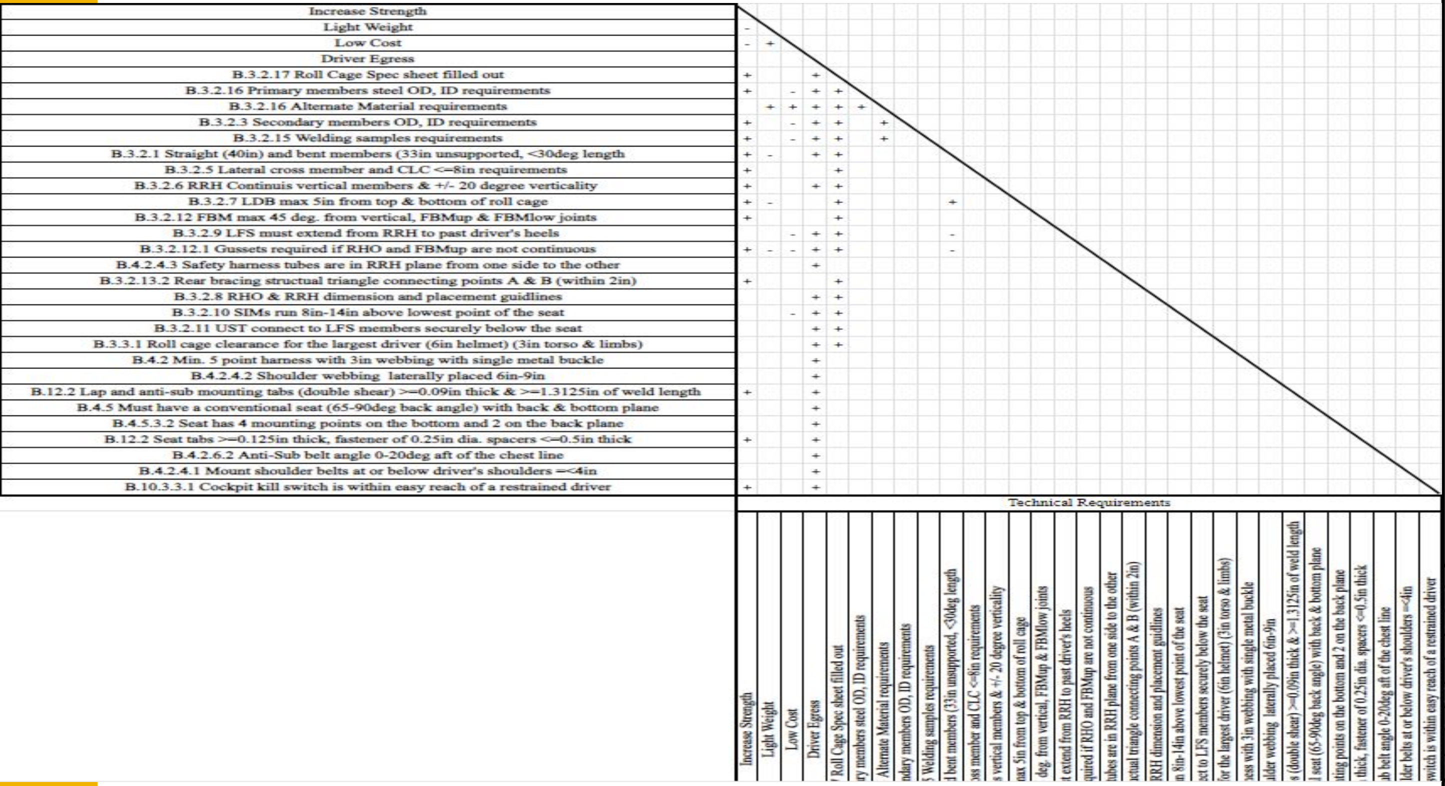


Ryan Carley - Front End, Team Lead

Wyatt Walker - Cockpit, CAD Manager

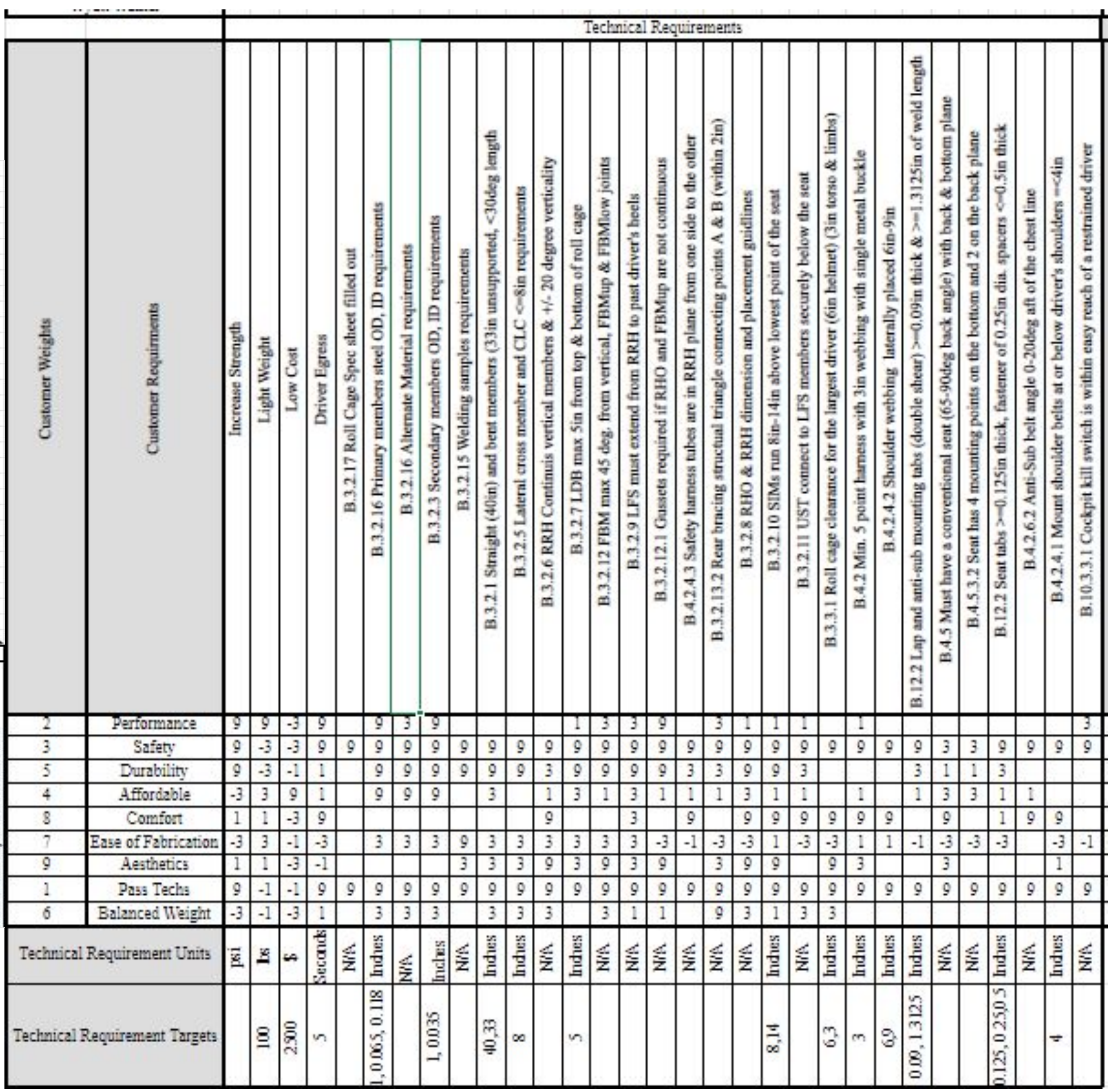
Charles Anderson- Rear End, Fabrication & Web Design

QFD



	Increase Strength	Light Weight	Low Cost	Driver Egress	Roll Cage Spec sheet filled out	ry members steel OD, ID requirements	Alternate Material requirements	ndary members OD, ID requirements	Welding samples requirements	d bent members (33in unsupported, <30deg length	oss member and CLC <=8in requirements	s vertical members & +/- 20 degree verticality	nax 5in from top & bottom of roll cage	deg. from vertical, FBMup & FBMlow joints	t extend from RRH to past driver's heels	quired if RHO and FBMup are not continuous	tubes are in RRH plane from one side to the other	uctual triangle connecting points A & B (within 2in)	RRH dimension and placement guidlines	n 8in-14in above lowest point of the seat	ect to LFS members securely below the seat	for the largest driver (6in helmet) (3in torso & limbs)	ness with 3in webbing with single metal buckle	ulder webbing laterally placed 6in-9in	s (double shear) >=0.09in thick & >=1.3125in of weld length	l seat (65-90deg back angle) with back & bottom plane	ting points on the bottom and 2 on the back plane	thick, fastener of 0.25in dia. spacers <=0.5in thick	ub belt angle 0-20deg aft of the chest line	lder belts at or below driver's shoulders =<4in	witch is within easy reach of a restrained driver
Increase Strength																															
Light Weight	-																														
Low Cost	-	+																													
Driver Egress																															
B.3.2.17 Roll Cage Spec sheet filled out	+			+																											
B.3.2.16 Primary members steel OD, ID requirements	+		-	+	+																										
B.3.2.16 Alternate Material requirements		+	+	+	+	+																									
B.3.2.3 Secondary members OD, ID requirements	+		-	+	+		+																								
B.3.2.15 Welding samples requirements	+		-	+	+		+																								
B.3.2.1 Straight (40in) and bent members (33in unsupported, <30deg length	+	-		+	+																										
B.3.2.5 Lateral cross member and CLC <=8in requirements	+				+																										
B.3.2.6 RRH Continuis vertical members & +/- 20 degree verticality	+			+	+																										
B.3.2.7 LDB max 5in from top & bottom of roll cage	+	-			+					+																					
B.3.2.12 FBM max 45 deg. from vertical, FBMup & FBMlow joints	+				+																										
B.3.2.9 LFS must extend from RRH to past driver's heels			-	+	+					-																					
B.3.2.12.1 Gussets required if RHO and FBMup are not continuous	+	-	-	+	+					-																					
B.4.2.4.3 Safety harness tubes are in RRH plane from one side to the other				+																											
B.3.2.13.2 Rear bracing structual triangle connecting points A & B (within 2in)	+				+																										
B.3.2.8 RHO & RRH dimension and placement guidlines				+	+																										
B.3.2.10 SIMs run 8in-14in above lowest point of the seat			-	+	+																										
B.3.2.11 UST connect to LFS members securely below the seat				+	+																										
B.3.3.1 Roll cage clearance for the largest driver (6in helmet) (3in torso & limbs)				+	+																										
B.4.2 Min. 5 point harness with 3in webbing with single metal buckle				+																											
B.4.2.4.2 Shoulder webbing laterally placed 6in-9in				+																											
B.12.2 Lap and anti-sub mounting tabs (double shear) >=0.09in thick & >=1.3125in of weld length	+			+																											
B.4.5 Must have a conventional seat (65-90deg back angle) with back & bottom plane				+																											
B.4.5.3.2 Seat has 4 mounting points on the bottom and 2 on the back plane				+																											
B.12.2 Seat tabs >=0.125in thick, fastener of 0.25in dia. spacers <=0.5in thick	+			+																											
B.4.2.6.2 Anti-Sub belt angle 0-20deg aft of the chest line				+																											
B.4.2.4.1 Mount shoulder belts at or below driver's shoulders =<4in				+																											
B.10.3.3.1 Cockpit kill switch is within easy reach of a restrained driver	+			+																											

Technical Requirements



		Technical Requirements														
Customer Weights	Customer Requirments	Increase Strength	Light Weight	Low Cost	Driver Egress	B.3.2.17 Roll Cage Spec sheet filled out	B.3.2.16 Primary members steel OD, ID requirements	B.3.2.16 Alternate Material requirements	B.3.2.3 Secondary members OD, ID requirements	B.3.2.15 Welding samples requirements	B.3.2.1 Straight (40in) and bent members (33in unsupported, <30deg length	B.3.2.5 Lateral cross member and CLC <=8in requirements	B.3.2.6 RRH Continuis vertical members & +/- 20 degree verticality	B.3.2.7 LDB max 5in from top & bottom of roll cage	B.3.2.12 FBM max 45 deg. from vertical, FBMup & FBMlow joints	B.3.2.9 LFS must extend from RRH to past driver's heels
2	Performance	9	9	-3	9		9	3	9					1	3	3
3	Safety	9	-3	-3	9	9	9	9	9	9	9	9	9	9	9	9
5	Durability	9	-3	-1	1		9	9	9	9	9	9	3	9	9	9
4	Affordable	-3	3	9	1		9	9	9		3		1	3	1	3
8	Comfort	1	1	-3	9								9			3
7	Ease of Fabrication	-3	3	-1	-3		3	3	3	9	3	3	3	3	3	3
9	Aesthetics	1	1	-3	-1					3	3	3	9	3	9	3
1	Pass Techs	9	-1	-1	9	9	9	9	9	9	9	9	9	9	9	9
6	Balanced Weight	-3	-1	-3	1		3	3	3		3	3	3		3	1
Technical Requirement Units		psi	lbs	$	Seconds	N/A	Inches	N/A	Inches	N/A	Inches	Inches	N/A	Inches	N/A	N/A
Technical Requirement Targets			100	2500	5		1, 0.065, 0.118		1, 0.035		40,33	8		5		

		Technical Requirements															
Customer Weights	Customer Requirments	B.3.2.12.1 Gussets required if RHO and FBMup are not continuous	B.4.2.4.3 Safety harness tubes are in RRH plane from one side to the other	B.3.2.13.2 Rear bracing structual triangle connecting points A & B (within 2in)	B.3.2.8 RHO & RRH dimension and placement guidlines	B.3.2.10 SIMs run 8in-14in above lowest point of the seat	B.3.2.11 UST connect to LFS members securely below the seat	B.3.3.1 Roll cage clearance for the largest driver (6in helmet) (3in torso & limbs)	B.4.2 Min. 5 point harness with 3in webbing with single metal buckle	B.4.2.4.2 Shoulder webbing laterally placed 6in-9in	B.12.2 Lap and anti-sub mounting tabs (double shear) >=0.09in thick & >=1.3125in of weld length	B.4.5 Must have a conventional seat (65-90deg back angle) with back & bottom plane	B.4.5.3.2 Seat has 4 mounting points on the bottom and 2 on the back plane	B.12.2 Seat tabs >=0.125in thick, fastener of 0.25in dia. spacers <=0.5in thick	B.4.2.6.2 Anti-Sub belt angle 0-20deg aft of the chest line	B.4.2.4.1 Mount shoulder belts at or below driver's shoulders =<4in	B.10.3.3.1 Cockpit kill switch is within easy reach of a restrained driver
2	Performance	9		3	1	1	1		1								3
3	Safety	9	9	9	9	9	9	9	9	9	9	3	3	9	9	9	9
5	Durability	9	3	3	9	9	3				3	1	1	3			
4	Affordable	1	1	1	3	1	1		1		1	3	3	1	1		
8	Comfort		9		9	9	9	9	9	9		9		1	9	9	
7	Ease of Fabrication	-3	-1	-3	-3	1	-3	-3	1	1	-1	-3	-3	-3		-3	-1
9	Aesthetics	9		3	9	9		9	3			3				1	
1	Pass Techs	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
6	Balanced Weight	1		9	3	1	3	3									
Technical Requirement Units		N/A	N/A	N/A	N/A	Inches	N/A	Inches	Inches	Inches	Inches	N/A	N/A	Inches	N/A	Inches	N/A
Technical Requirement Targets						8,14		6,3	3	6,9	0.09, 1.3125			0.125, 0.25, 0.5		4	

Wyatt

Customer and Engineering Requirements

Customer Requirements

- Performance
- Safety
- Durability
- Affordable
- Comfort
- Ease of Fabrication
- Aesthetics
- Pass Tech. Inspection
- Balanced Weight Distribution

Engineering Requirements

- Increased Strength
- Lightweight
- Low Cost
- Driver Egress
- Rulebook/Tech. Inspection Requirements*

Wyatt

QFD

General:

Straight members <=40in, Bent members at most <=33in and <=30 deg

6in Helmet clearance and 3in clearance for limbs

Harness: 5 point system, Shoulder harness must be no lower than 4in below drivers shoulders

Member Requirements:

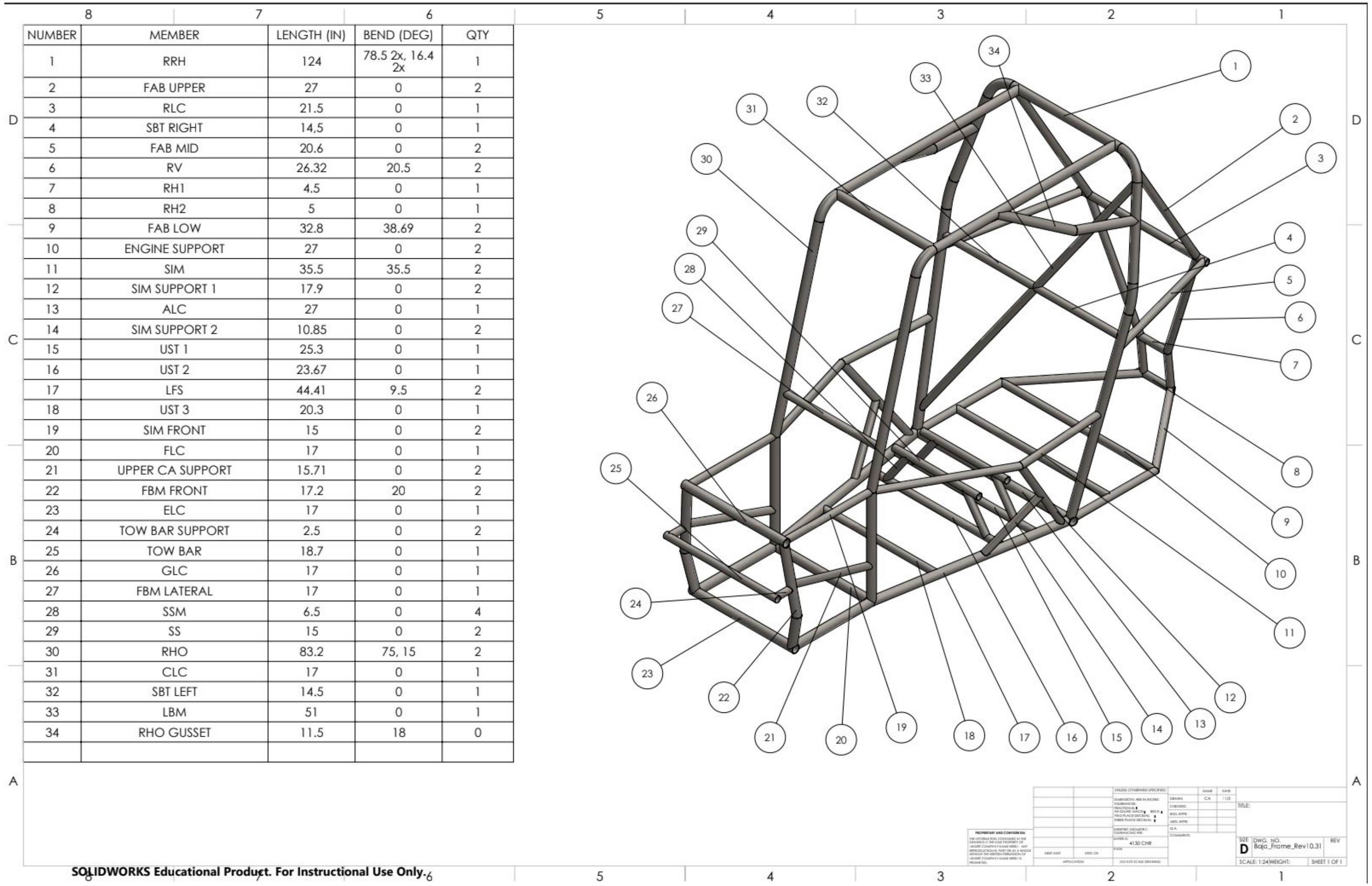
Lateral members: >=8in in length and no bends (RLC, FLC, CLC, BLC, and ALC)

Rear Roll Hoop: Angled at most 20 deg, continuous member except bottom and Min width of 29in measured 27in above seat bottom

Side Impact Members: Must be within 8in-14in above the inside seat bottom

Wyatt

Design Description (Cut List)



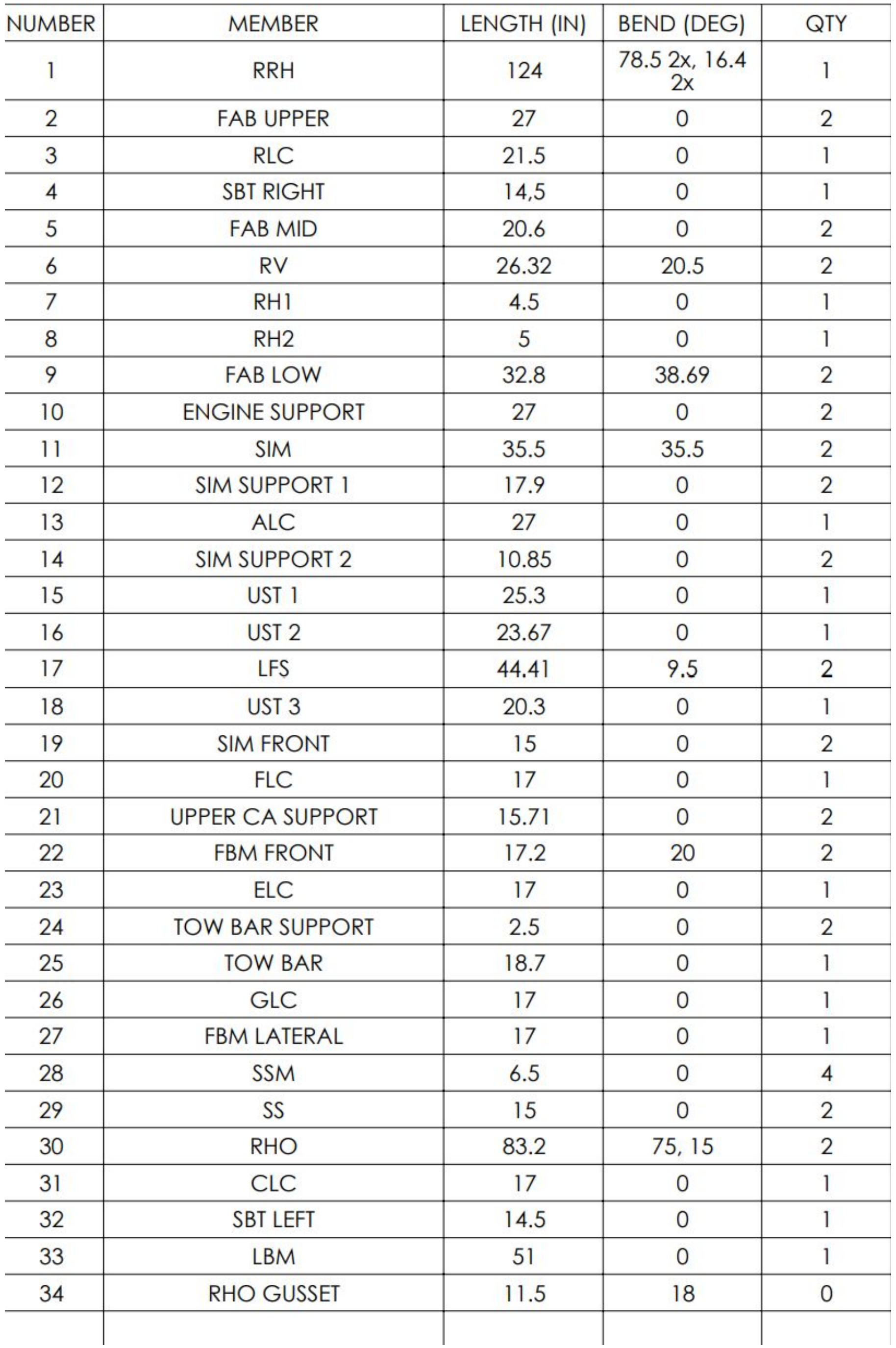
NUMBER	MEMBER	LENGTH (IN)	BEND (DEG)	QTY
1	RRH	124	78.5 2x, 16.4 2x	1
2	FAB UPPER	27	0	2
3	RLC	21.5	0	1
4	SBT RIGHT	14,5	0	1
5	FAB MID	20.6	0	2
6	RV	26.32	20.5	2
7	RH1	4.5	0	1
8	RH2	5	0	1
9	FAB LOW	32.8	38.69	2
10	ENGINE SUPPORT	27	0	2
11	SIM	35.5	35.5	2
12	SIM SUPPORT 1	17.9	0	2
13	ALC	27	0	1
14	SIM SUPPORT 2	10.85	0	2
15	UST 1	25.3	0	1
16	UST 2	23.67	0	1
17	LFS	44.41	9.5	2
18	UST 3	20.3	0	1
19	SIM FRONT	15	0	2
20	FLC	17	0	1
21	UPPER CA SUPPORT	15.71	0	2
22	FBM FRONT	17.2	20	2
23	ELC	17	0	1
24	TOW BAR SUPPORT	2.5	0	2
25	TOW BAR	18.7	0	1
26	GLC	17	0	1
27	FBM LATERAL	17	0	1
28	SSM	6.5	0	4
29	SS	15	0	2
30	RHO	83.2	75, 15	2
31	CLC	17	0	1
32	SBT LEFT	14.5	0	1
33	LBM	51	0	1
34	RHO GUSSET	11.5	18	0

Charles

Design (Cut List)

- The length is based on the centerline

- The bend angle is based in the exterior angle on the centerline.



NUMBER	MEMBER	LENGTH (IN)	BEND (DEG)	QTY
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3	RLC	21.5	0	1
4	SBT RIGHT	14,5	0	1
5	FAB MID	20.6	0	2
6	RV	26.32	20.5	2
7	RH1	4.5	0	1
8	RH2	5	0	1
9	FAB LOW	32.8	38.69	2
10	ENGINE SUPPORT	27	0	2
11	SIM	35.5	35.5	2
12	SIM SUPPORT 1	17.9	0	2
13	ALC	27	0	1
14	SIM SUPPORT 2	10.85	0	2
15	UST 1	25.3	0	1
16	UST 2	23.67	0	1
17	LFS	44.41	9.5	2
18	UST 3	20.3	0	1
19	SIM FRONT	15	0	2
20	FLC	17	0	1
21	UPPER CA SUPPORT	15.71	0	2
22	FBM FRONT	17.2	20	2
23	ELC	17	0	1
24	TOW BAR SUPPORT	2.5	0	2
25	TOW BAR	18.7	0	1
26	GLC	17	0	1
27	FBM LATERAL	17	0	1
28	SSM	6.5	0	4
29	SS	15	0	2
30	RHO	83.2	75, 15	2
31	CLC	17	0	1
32	SBT LEFT	14.5	0	1
33	LBM	51	0	1
34	RHO GUSSET	11.5	18	0

Charles

Updated Engineering Calculations FEA

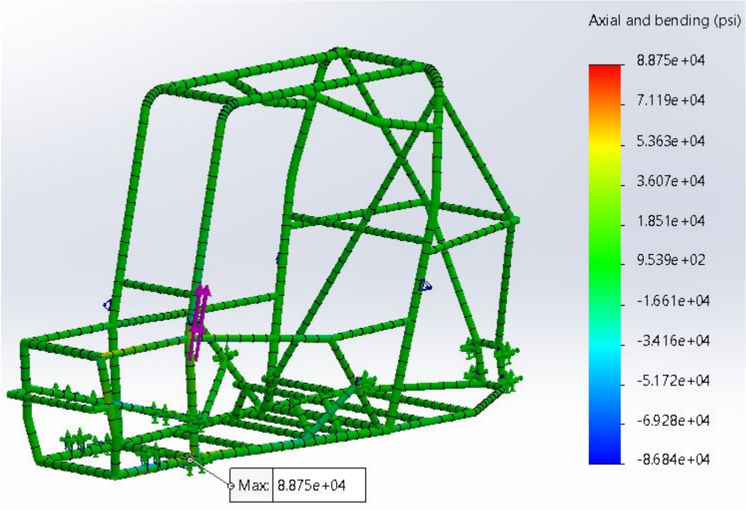
Suspension Fully Compressed:

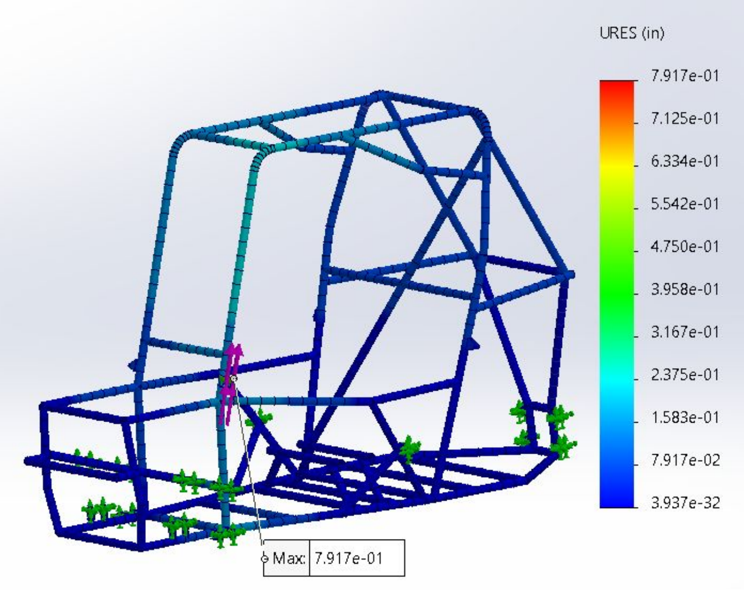
Car is falling from 5 ft and landing on one front wheel

F = 1250 lbf

Max Deformation: .79 in

Max Stress: 88.8 kpsi





Ryan

Updated Engineering Calculations FEA

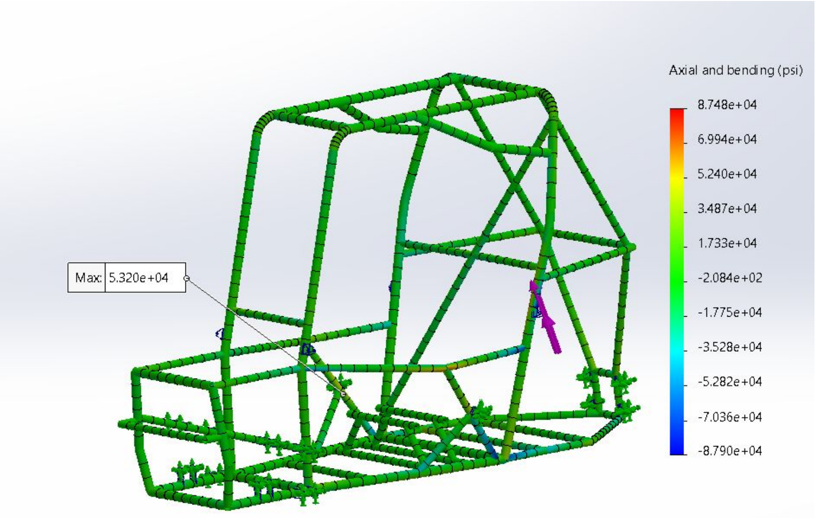
Suspension Fully Compressed:

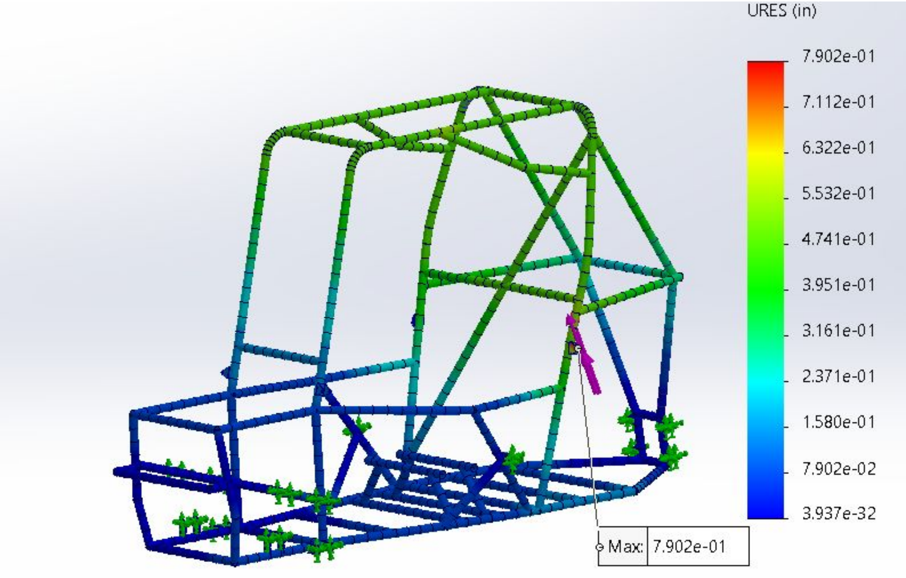
Car is falling from 5 ft and landing on one rear wheel

F = 1250 lbf

Max Deformation: .79 in

Max Stress: 53.2 kpsi





Ryan

Updated Engineering Calculations FEA

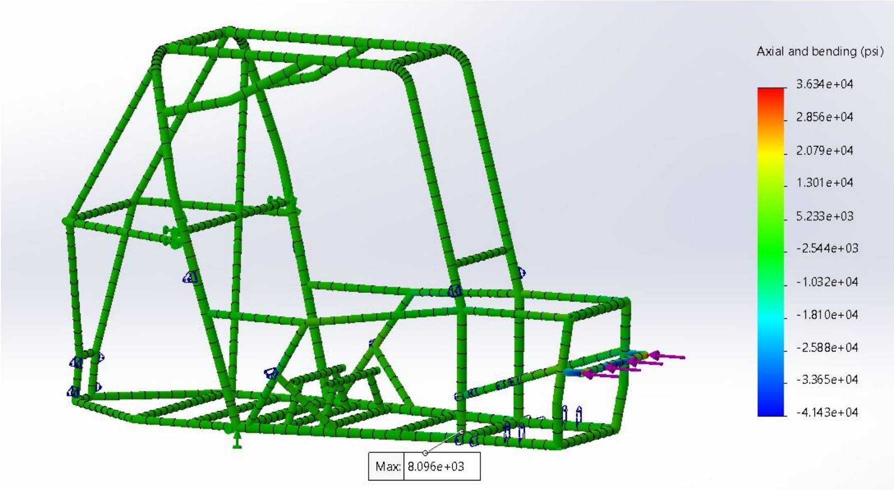
Head on Collision:

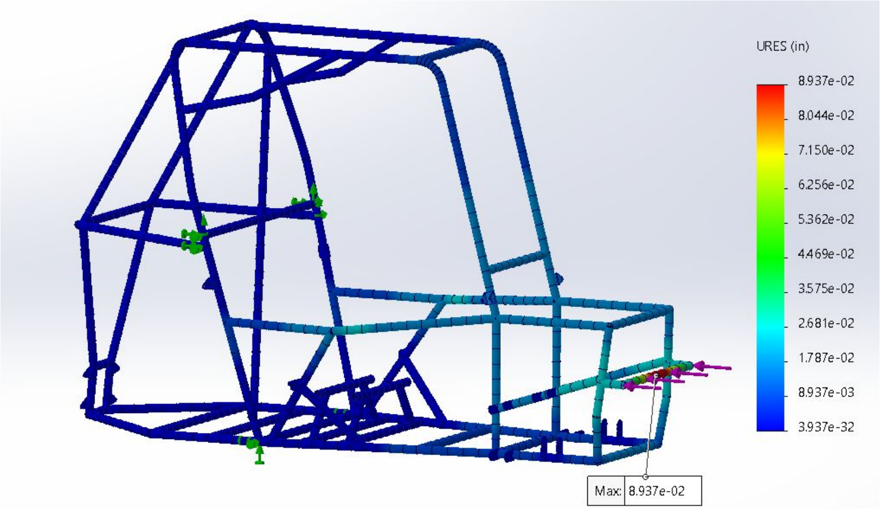
Car is moving 20 mph our car hits the rear of another competitor.

F = 750 lbf

Max Deformation: .089 in

Max Stress: 8.1 kpsi



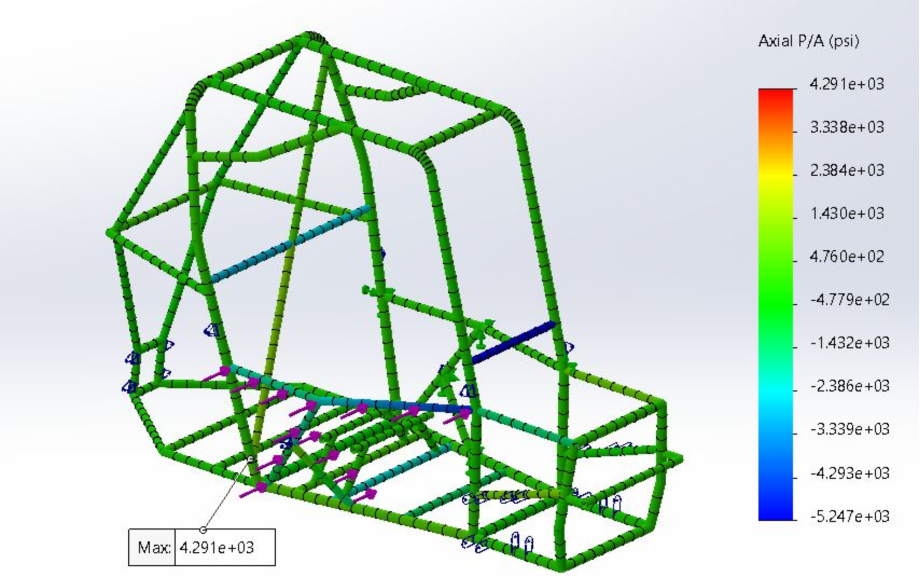


Wyatt

Updated Engineering Calculations FEA

Side Impact:

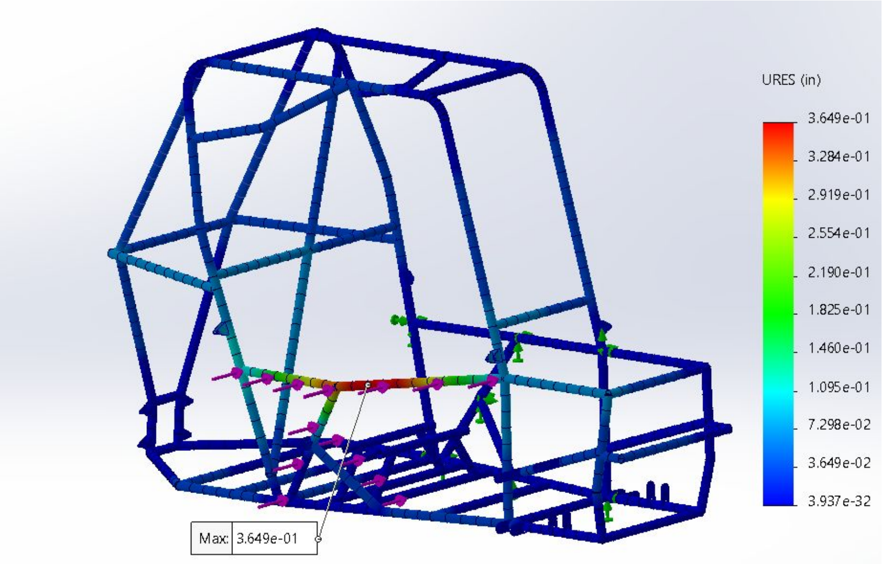
Car is T-Boned by another car which is moving at 20 mph, and hits our side impact member



F = 750 lbf

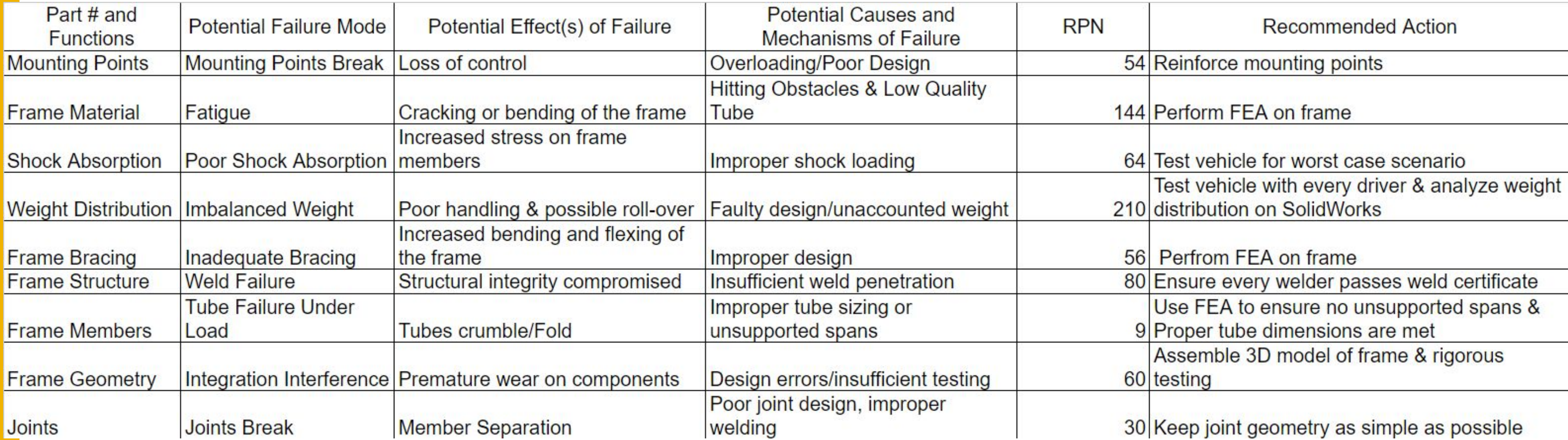
Max Deformation: .36 in

Max Stress: 4.3 kpsi



Charles

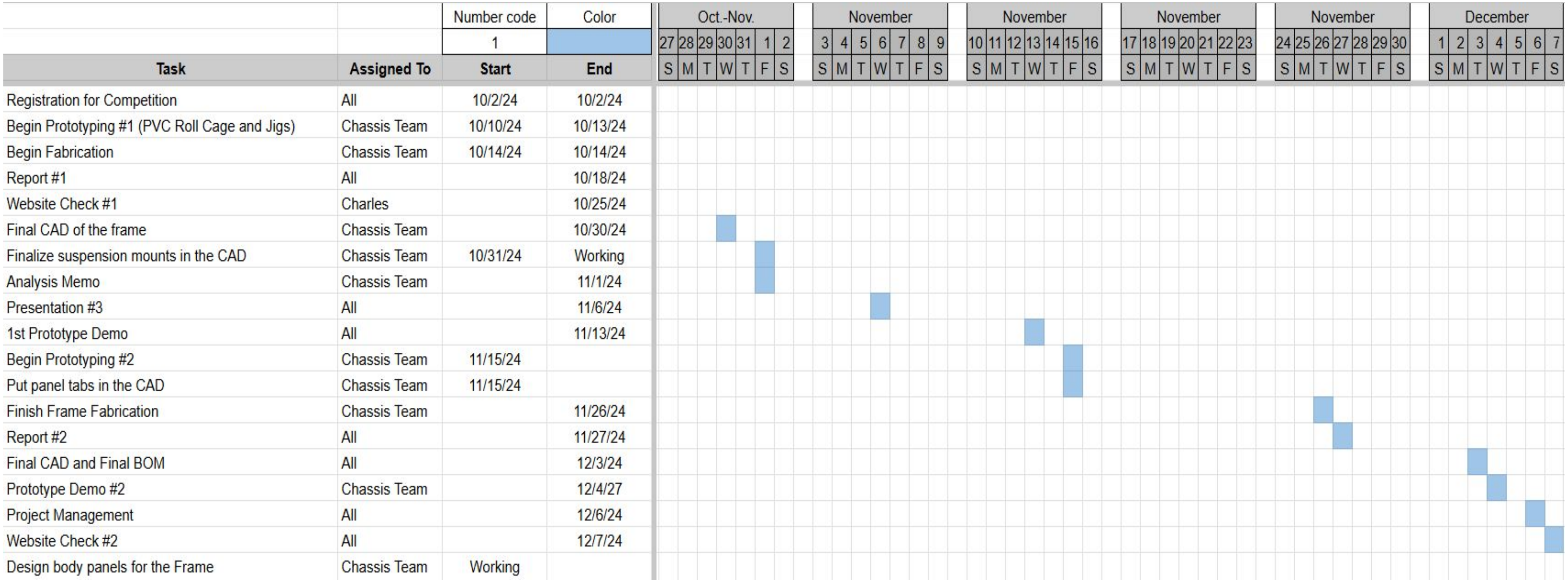
Design Validation



Part # and Functions	Potential Failure Mode	Potential Effect(s) of Failure	Potential Causes and Mechanisms of Failure	RPN	Recommended Action
Mounting Points	Mounting Points Break	Loss of control	Overloading/Poor Design	54	Reinforce mounting points
Frame Material	Fatigue	Cracking or bending of the frame	Hitting Obstacles & Low Quality Tube	144	Perform FEA on frame
Shock Absorption	Poor Shock Absorption	Increased stress on frame members	Improper shock loading	64	Test vehicle for worst case scenario
Weight Distribution	Imbalanced Weight	Poor handling & possible roll-over	Faulty design/unaccounted weight	210	Test vehicle with every driver & analyze weight distribution on SolidWorks
Frame Bracing	Inadequate Bracing	Increased bending and flexing of the frame	Improper design	56	Perfrom FEA on frame
Frame Structure	Weld Failure	Structural integrity compromised	Insufficient weld penetration	80	Ensure every welder passes weld certificate
Frame Members	Tube Failure Under Load	Tubes crumble/Fold	Improper tube sizing or unsupported spans	9	Use FEA to ensure no unsupported spans & Proper tube dimensions are met
Frame Geometry	Integration Interference	Premature wear on components	Design errors/insufficient testing	60	Assemble 3D model of frame & rigorous testing
Joints	Joints Break	Member Separation	Poor joint design, improper welding	30	Keep joint geometry as simple as possible

Ryan

Schedule



Number code	Color
1	🟦

Task	Assigned To	Start	End
Registration for Competition	All	10/2/24	10/2/24
Begin Prototyping #1 (PVC Roll Cage and Jigs)	Chassis Team	10/10/24	10/13/24
Begin Fabrication	Chassis Team	10/14/24	10/14/24
Report #1	All		10/18/24
Website Check #1	Charles		10/25/24
Final CAD of the frame	Chassis Team		10/30/24
Finalize suspension mounts in the CAD	Chassis Team	10/31/24	Working
Analysis Memo	Chassis Team		11/1/24
Presentation #3	All		11/6/24
1st Prototype Demo	All		11/13/24
Begin Prototyping #2	Chassis Team	11/15/24	
Put panel tabs in the CAD	Chassis Team	11/15/24	
Finish Frame Fabrication	Chassis Team		11/26/24
Report #2	All		11/27/24
Final CAD and Final BOM	All		12/3/24
Prototype Demo #2	Chassis Team		12/4/27
Project Management	All		12/6/24
Website Check #2	All		12/7/24
Design body panels for the Frame	Chassis Team	Working	

Wyatt

Bill of Materials/Budget

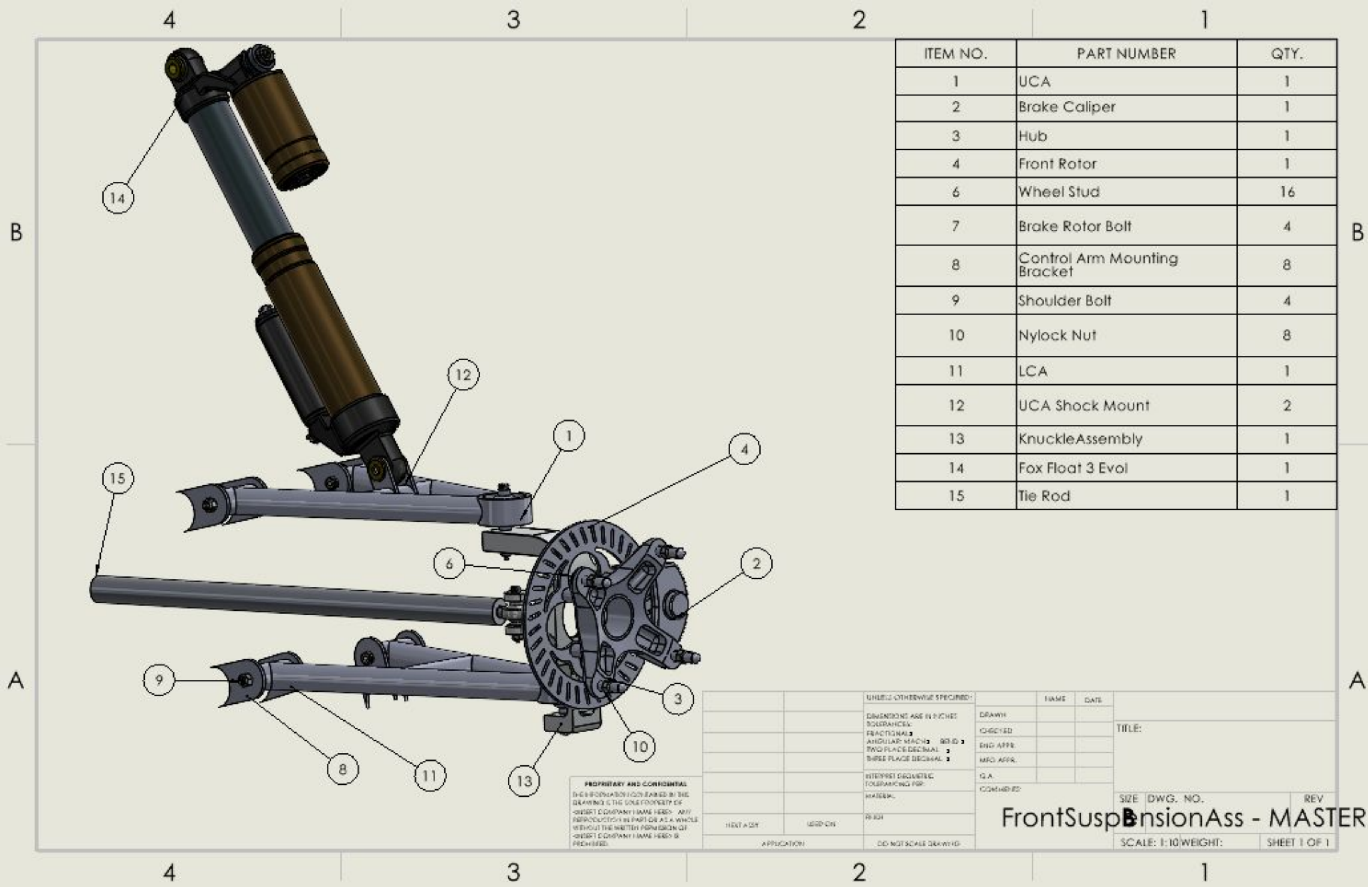
Item	Quantity	Estimated Cost	Actual Cost
4130 Chromoly Steel Round Tubing 1.25OD x 0.065Wall	60 ft	620.48	0
4130 Chromoly Steel Round Tubing 1.00OD x 0.035Wall	48 ft	571.24	0
Carbon Fiber	TBD	200	TBD
Seat Belts	5	100	TBD
Fasteners & Tabs	~50	150	TBD
Filler rod 1/16in Diameter	10 lbs	120	120
Firewall Sheet Metal	4 ft x 4 ft	128	TBD
Total		1889.72	120

Charles

Steering, Brakes, and Suspension

David Polkabla Jr.	Steering, Brakes
Taylor Hewitt	
Ryan Key	Suspension
Ryan Latulippe	
Oliver Husmann	
Brennan Pongratz	

Design Description - Sub-System



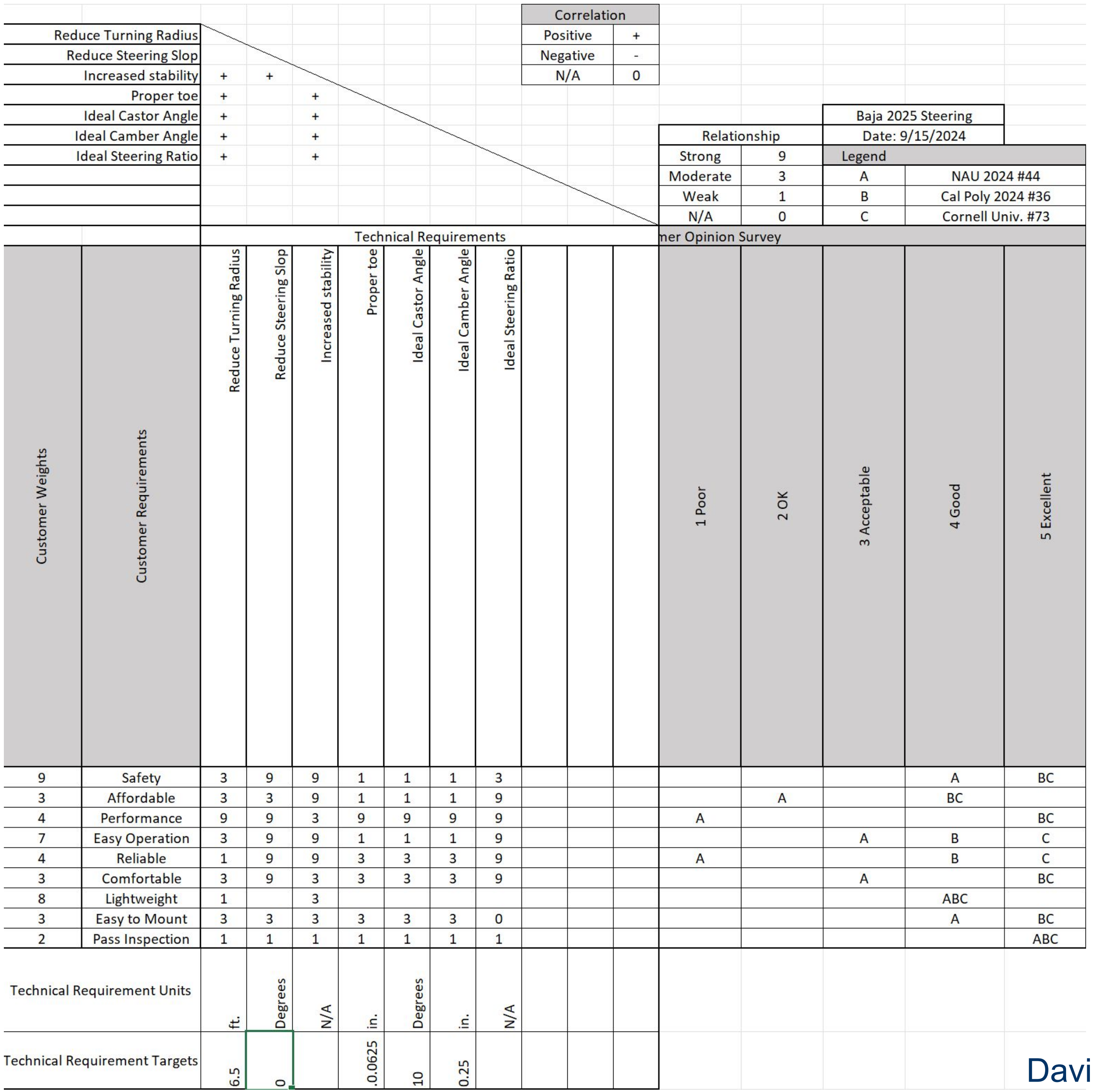
ITEM NO.	PART NUMBER	QTY.
1	UCA	1
2	Brake Caliper	1
3	Hub	1
4	Front Rotor	1
6	Wheel Stud	16
7	Brake Rotor Bolt	4
8	Control Arm Mounting Bracket	8
9	Shoulder Bolt	4
10	Nylock Nut	8
11	LCA	1
12	UCA Shock Mount	2
13	KnuckleAssembly	1
14	Fox Float 3 Evol	1
15	Tie Rod	1

Ryan K.

QFD-Steering

Customer Requirements

- No Performance Issues
- Minimum Turning Radius
- Maximum Steering Angle
- Ideal Toe, Caster, Camber
- Increased Stability
- Ideal Steering Ratio
- Minimal Steering Slop



Correlation	
Positive	+
Negative	-
N/A	0

	Reduce Turning Radius	Reduce Steering Slop	Increased stability	Proper toe	Ideal Castor Angle	Ideal Camber Angle	Ideal Steering Ratio
Reduce Turning Radius							
Reduce Steering Slop							
Increased stability	+	+					
Proper toe	+		+				
Ideal Castor Angle	+		+				
Ideal Camber Angle	+		+				
Ideal Steering Ratio	+		+				

Baja 2025 Steering
Date: 9/15/2024

Relationship	
Strong	9
Moderate	3
Weak	1
N/A	0

Legend	
A	NAU 2024 #44
B	Cal Poly 2024 #36
C	Cornell Univ. #73

		Technical Requirements										mer Opinion Survey				
Customer Weights	Customer Requirements	Reduce Turning Radius	Reduce Steering Slop	Increased stability	Proper toe	Ideal Castor Angle	Ideal Camber Angle	Ideal Steering Ratio				1 Poor	2 OK	3 Acceptable	4 Good	5 Excellent
9	Safety	3	9	9	1	1	1	3							A	BC
3	Affordable	3	3	9	1	1	1	9					A		BC	
4	Performance	9	9	3	9	9	9	9				A				BC
7	Easy Operation	3	9	9	1	1	1	9						A	B	C
4	Reliable	1	9	9	3	3	3	9				A			B	C
3	Comfortable	3	9	3	3	3	3	9						A		BC
8	Lightweight	1		3											ABC	
3	Easy to Mount	3	3	3	3	3	3	0							A	BC
2	Pass Inspection	1	1	1	1	1	1	1								ABC
Technical Requirement Units		ft.	Degrees	N/A	in.	Degrees	in.	N/A								
Technical Requirement Targets		6.5	0		.0.0625	10	0.25									

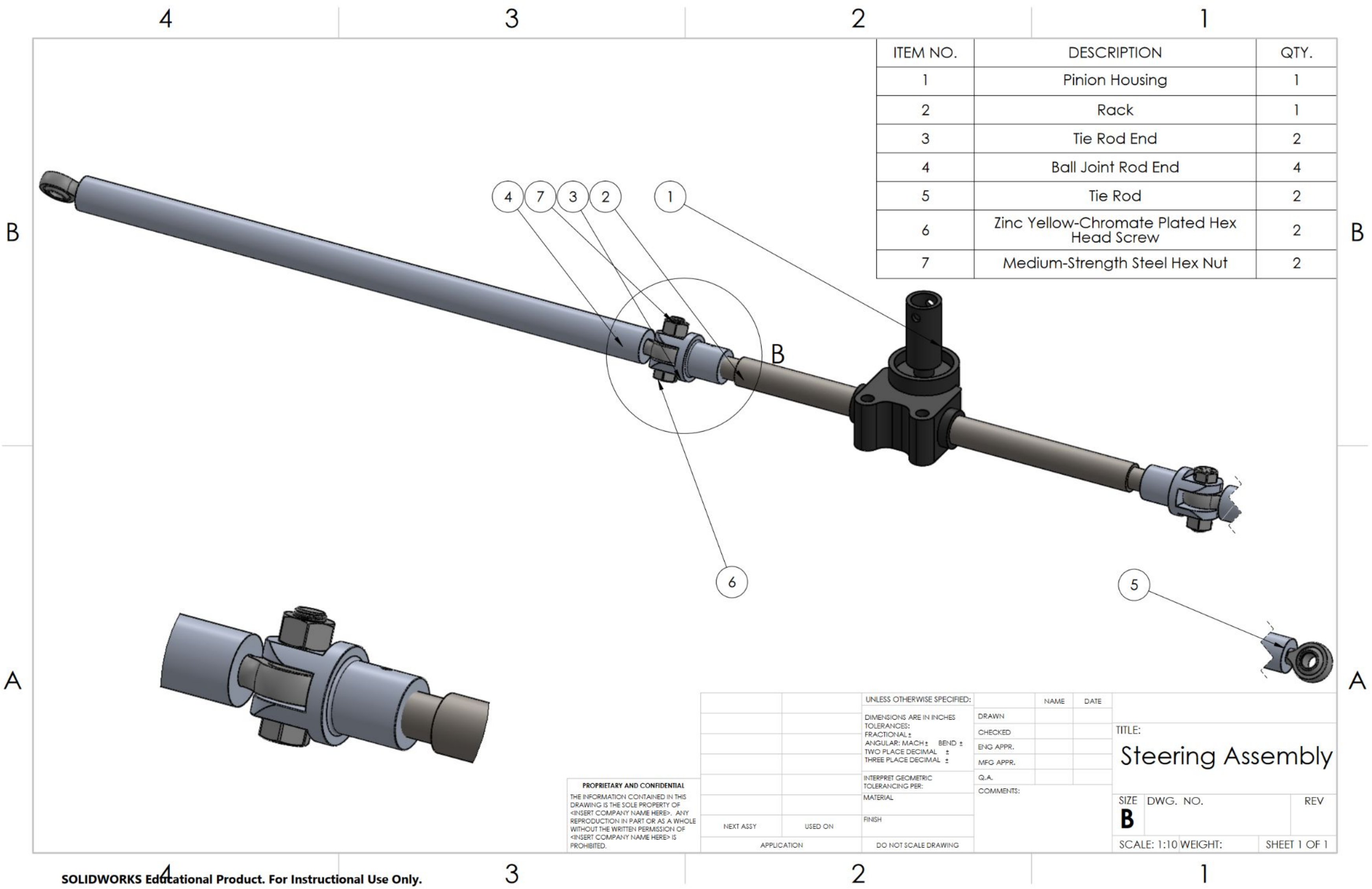
David

Engineering Requirements-Steering

- Minimize Turn Radius: <7 feet
- Minimize Steering Slop
- Strong Steering Components: Steel Rack, Aluminum Tie Rods & Tie Rod Ends
- Ideal Tire Angles
- Tie Rod Thickness: TBD
- Maximum Rack Travel: TBD

David

Design Description- Steering



ITEM NO.	DESCRIPTION	QTY.
1	Pinion Housing	1
2	Rack	1
3	Tie Rod End	2
4	Ball Joint Rod End	4
5	Tie Rod	2
6	Zinc Yellow-Chromate Plated Hex Head Screw	2
7	Medium-Strength Steel Hex Nut	2

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NEXT ASSY
USED ON
APPLICATION

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:
Steering Assembly

SIZE B
DWG. NO.
REV
SCALE: 1:10
WEIGHT:
SHEET 1 OF 1

SOLIDWORKS Educational Product. For Instructional Use Only.

- Tie rods mounted to rack with bolted tie rod end and heim joint.
- Tie rods mounted to knuckle via heim joint.
- In-house rack, tie rods, & tie rod ends.

David

Engineering Calculations- Steering

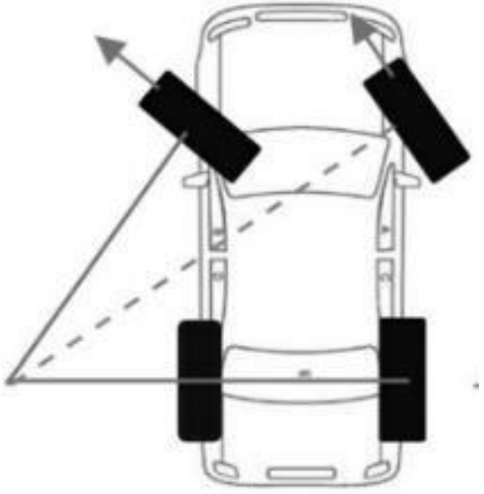
Wheelbase L = 60in

Track Width = 62in

Inner Steering Angle θ_{in} = 50°

Outer Steering Angle θ_{out} = 28.15°

Estimated Turn Radius R = 81in or 6.75ft



$$R_{in} = \frac{L}{\tan(\theta_{in})}$$

$$R = R_{in} + \frac{Track\ width}{2}$$

$$R_{out} = R + \frac{Track\ width}{2}$$

$$\theta_{out} = \tan^{-1}(\frac{L}{R_{out}})$$

David

Design Validation- Steering

Part	Failure Mode	Effects of Failure	Cause of Failure	Severity (1-10)	Action Taken
Tie Rod Mounts	Fatigue	Breaks due to impact or collision	Large Impact	9	Tie Rod calculations
Rack and Pinion	Fatigue	Breaks due to impact or collision	Large Impact	9	Tie Rod calculations
Rack and Pinion	Interference	Dust or mud gets into rack	Dust from other divers, mud build up	4	Use boots to cover the rack
Tie Rod Mounts	Bending	Tie rod bends or buckles	Large Impact	4	Tie Rod calculations

Biggest Priority:

- Rack & Pinion
- Tie Rod Mounts

Failures Avoided By:

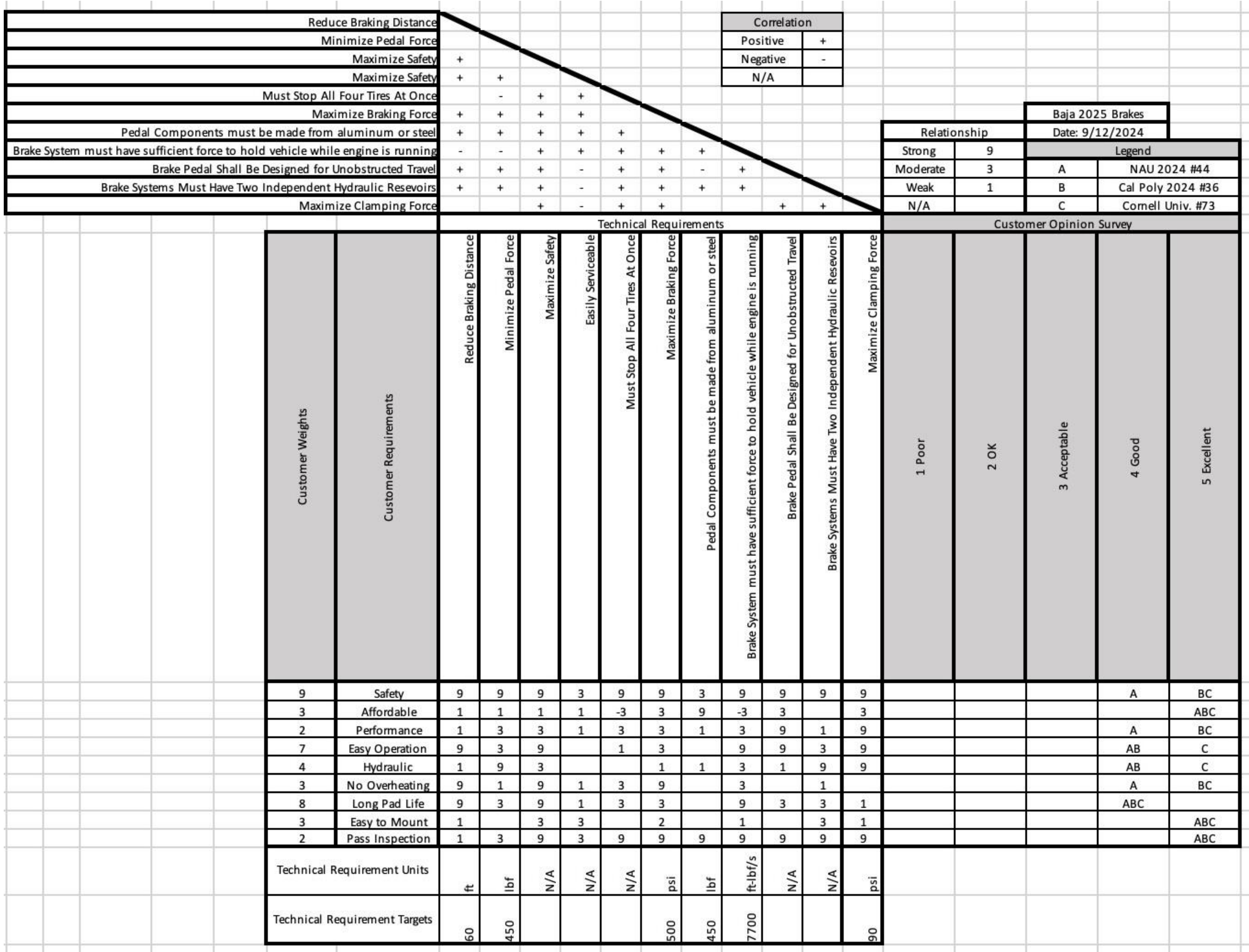
- Ideal Sizing and Material Selection
- FEA & Tie Rod Calculations

David

QFD-Brakes

Customer Requirements

- Safe
- Affordable
- No Performance Issues
- No Hydraulic Issues
- Doesn’t Overheat
- Long Pad Life
- Passes SAE Inspection
- Easy to Engage Brake
- Easy Installation



Reduce Braking Distance										
Minimize Pedal Force										
Maximize Safety	+									
Maximize Safety	+	+								
Must Stop All Four Tires At Once		-	+	+						
Maximize Braking Force	+	+	+	+						
Pedal Components must be made from aluminum or steel	+	+	+	+	+					
Brake System must have sufficient force to hold vehicle while engine is running	-	-	+	+	+	+	+			
Brake Pedal Shall Be Designed for Unobstructed Travel	+	+	+	-	+	+	-	+		
Brake Systems Must Have Two Independent Hydraulic Resevoirs	+	+	+	-	+	+	+	+		
Maximize Clamping Force			+	-	+	+			+	+

Correlation	
Positive	+
Negative	-
N/A	

Baja 2025 Brakes
Date: 9/12/2024

Relationship	
Strong	9
Moderate	3
Weak	1
N/A	

Legend	
A	NAU 2024 #44
B	Cal Poly 2024 #36
C	Cornell Univ. #73

Technical Requirements

Customer Opinion Survey

Customer Weights	Customer Requirements	Reduce Braking Distance	Minimize Pedal Force	Maximize Safety	Easily Serviceable	Must Stop All Four Tires At Once	Maximize Braking Force	Pedal Components must be made from aluminum or steel	Brake System must have sufficient force to hold vehicle while engine is running	Brake Pedal Shall Be Designed for Unobstructed Travel	Brake Systems Must Have Two Independent Hydraulic Resevoirs	Maximize Clamping Force	1 Poor	2 OK	3 Acceptable	4 Good	5 Excellent
9	Safety	9	9	9	3	9	9	3	9	9	9	9				A	BC
3	Affordable	1	1	1	1	-3	3	9	-3	3		3					ABC
2	Performance	1	3	3	1	3	3	1	3	9	1	9				A	BC
7	Easy Operation	9	3	9		1	3		9	9	3	9				AB	C
4	Hydraulic	1	9	3			1	1	3	1	9	9				AB	C
3	No Overheating	9	1	9	1	3	9		3		1					A	BC
8	Long Pad Life	9	3	9	1	3	3		9	3	3	1				ABC	
3	Easy to Mount	1		3	3		2		1		3	1					ABC
2	Pass Inspection	1	3	9	3	9	9	9	9	9	9	9					ABC
Technical Requirement Units		ft	lbf	N/A	N/A	N/A	psi	lbf	ft-lbf/s	N/A	N/A	psi					
Technical Requirement Targets		60	450				500	450	7700			90					

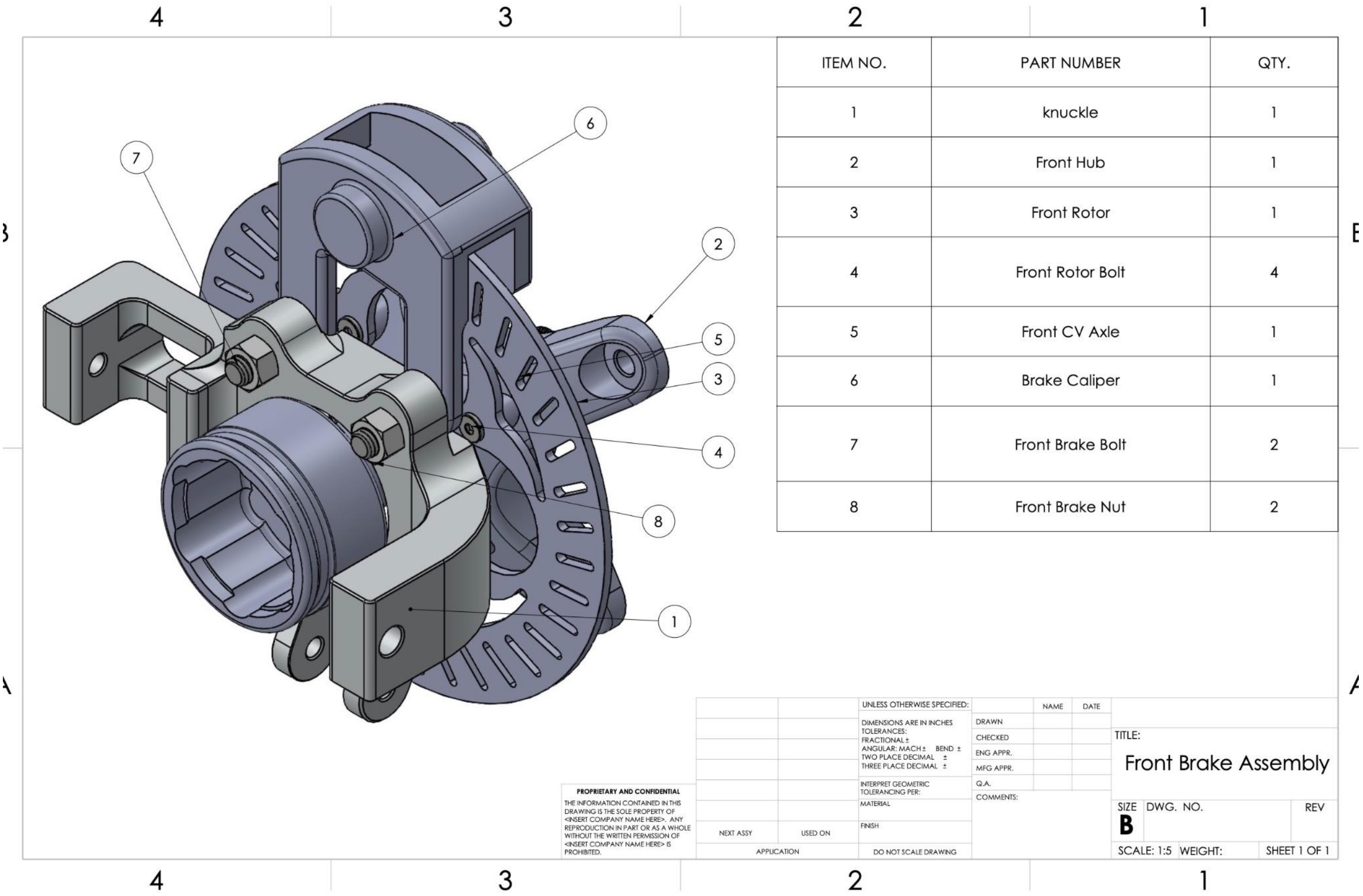
Taylor

Engineering Requirements-Brakes

- Max Diameter for front brakes: 7 inches
- Max Diameter for rear brake: 9 inches
- Light weight
- Min Thickness for both brakes: 1/8 in
- All Four Wheels Must Lock up
- Pedal must withstand minimum force of 450 lbs
- Brake system must have 2 hydraulic reservoirs

Taylor

Design Description - Front Brakes



ITEM NO.	PART NUMBER	QTY.
1	knuckle	1
2	Front Hub	1
3	Front Rotor	1
4	Front Rotor Bolt	4
5	Front CV Axle	1
6	Brake Caliper	1
7	Front Brake Bolt	2
8	Front Brake Nut	2

NEXT ASSY
USED ON
APPLICATION

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:
Front Brake Assembly

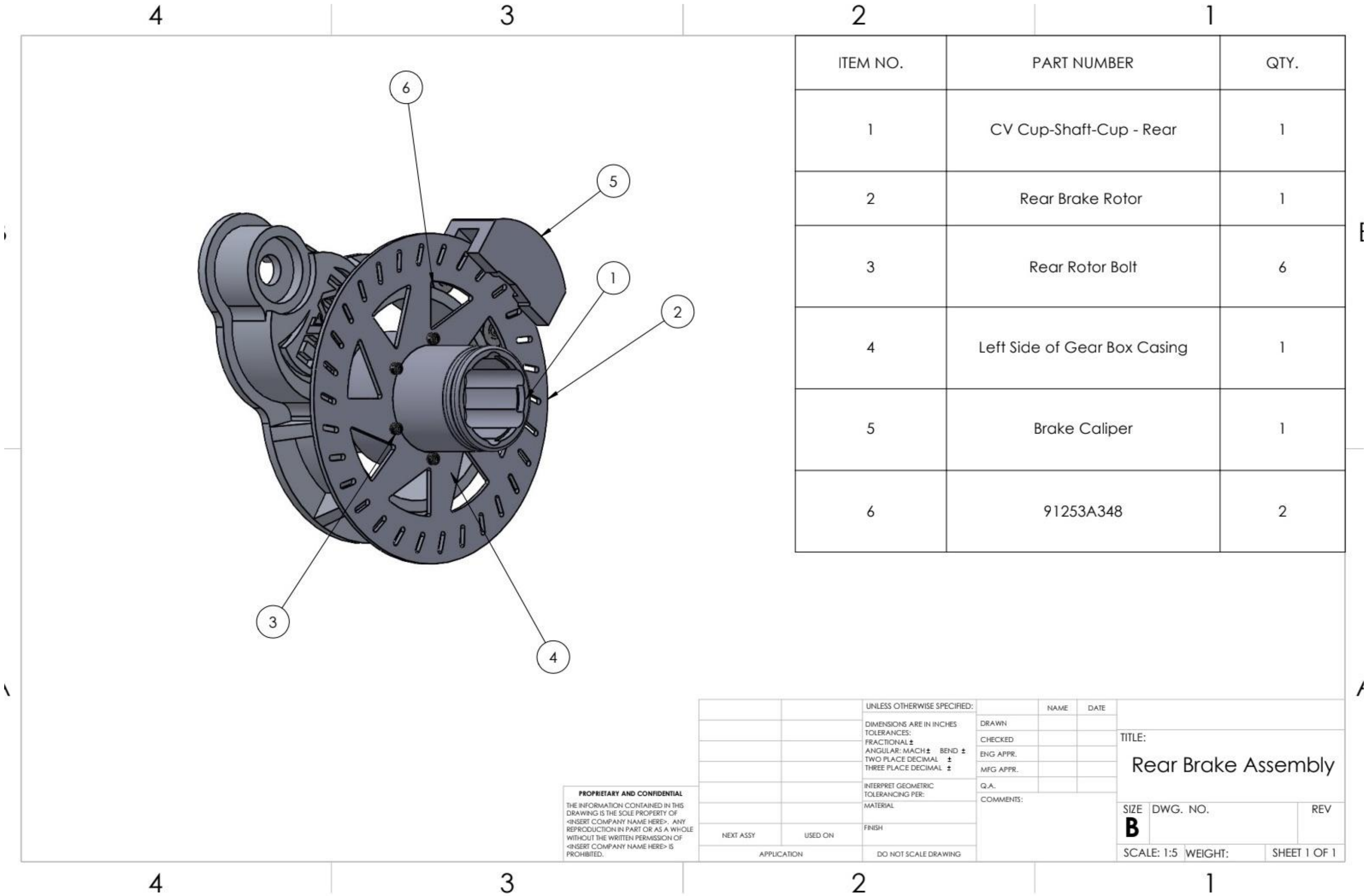
SIZE B
DWG. NO.
REV

SCALE: 1:5
WEIGHT:
SHEET 1 OF 1

- **Lower profile bolts for brake rotor**
- **Mounted caliper on the backside of the knuckle**
- **Make through holes on knuckle instead of threaded**

Taylor

Design Description - Rear Brakes



ITEM NO.	PART NUMBER	QTY.
1	CV Cup-Shaft-Cup - Rear	1
2	Rear Brake Rotor	1
3	Rear Rotor Bolt	6
4	Left Side of Gear Box Casing	1
5	Brake Caliper	1
6	91253A348	2

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DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:
Rear Brake Assembly

SIZE **B**
DWG. NO.
REV
SCALE: 1:5
WEIGHT:
SHEET 1 OF 1

SOLIDWORKS Educational Product. For Instructional Use Only.

- **Smaller bolt head diameters**
- **9 inch diameter for easier packaging**
- **Different caliper for rear rotor**

Taylor

Engineering Calculations - Brakes

Braking Force

- W = Work (ft-lb)
- d = distance (ft)

$$F_{brake} = \frac{W}{d} \quad => \quad \frac{29460}{88} = 335\ lb$$

Clamping Force

- μ = coefficient of friction

$$F_{clamp} = \frac{F_{brake}}{2} * \mu \quad => \quad \frac{335}{2} * 0.7 = 117.25\ lb$$

Front Brake Calcs

- θ = length of brake pad (radians)
- r = radius (in)
- f = frictional force coefficient
- pa = normal pressure

$$T = \bar{r} * F_{Clamp} => \frac{(2.63)(117.3)}{12} = 25.6\ ft - lb$$

$$p_a = \frac{T}{(\theta_2 - \theta_1) f r_i (r_o^2 - r_i^2)} => \frac{12(25.6)}{(1.885)(0.37)(2.6875)(3.4375^2 - 2.6875^2)} = 36\ psi$$

Rear Brake Calcs

- θ = length of brake pad (radians)
- r = radius (in)
- f = frictional force coefficient
- pa = normal pressure

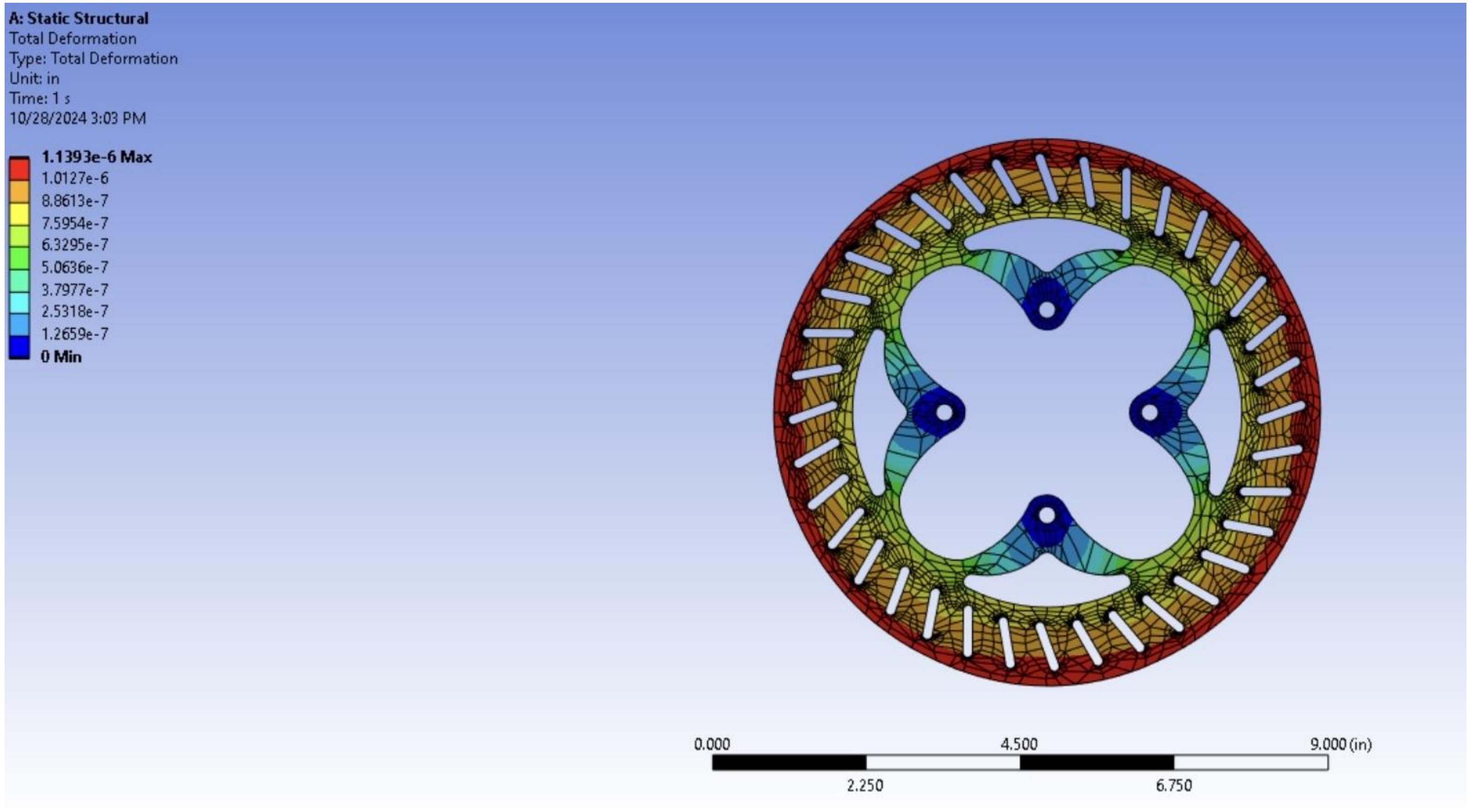
$$T = \bar{r} * F_{Clamp} => \frac{(3.326)(117.3)}{12} = 32.5\ ft - lb$$

$$p_a = \frac{2T}{(\theta_2 - \theta_1) f r_i (r_o^2 - r_i^2)} => \frac{12(32.5)}{(1.885)(0.37)(3.3125)(4.4375^2 - 3.3125^2)} = 19\ psi$$

Taylor

Engineering Calculations - Brakes

FEA-Front Rotor



Max Deformation

- 1.139*10^-6 in

Max Stress

- 68.3 Psi

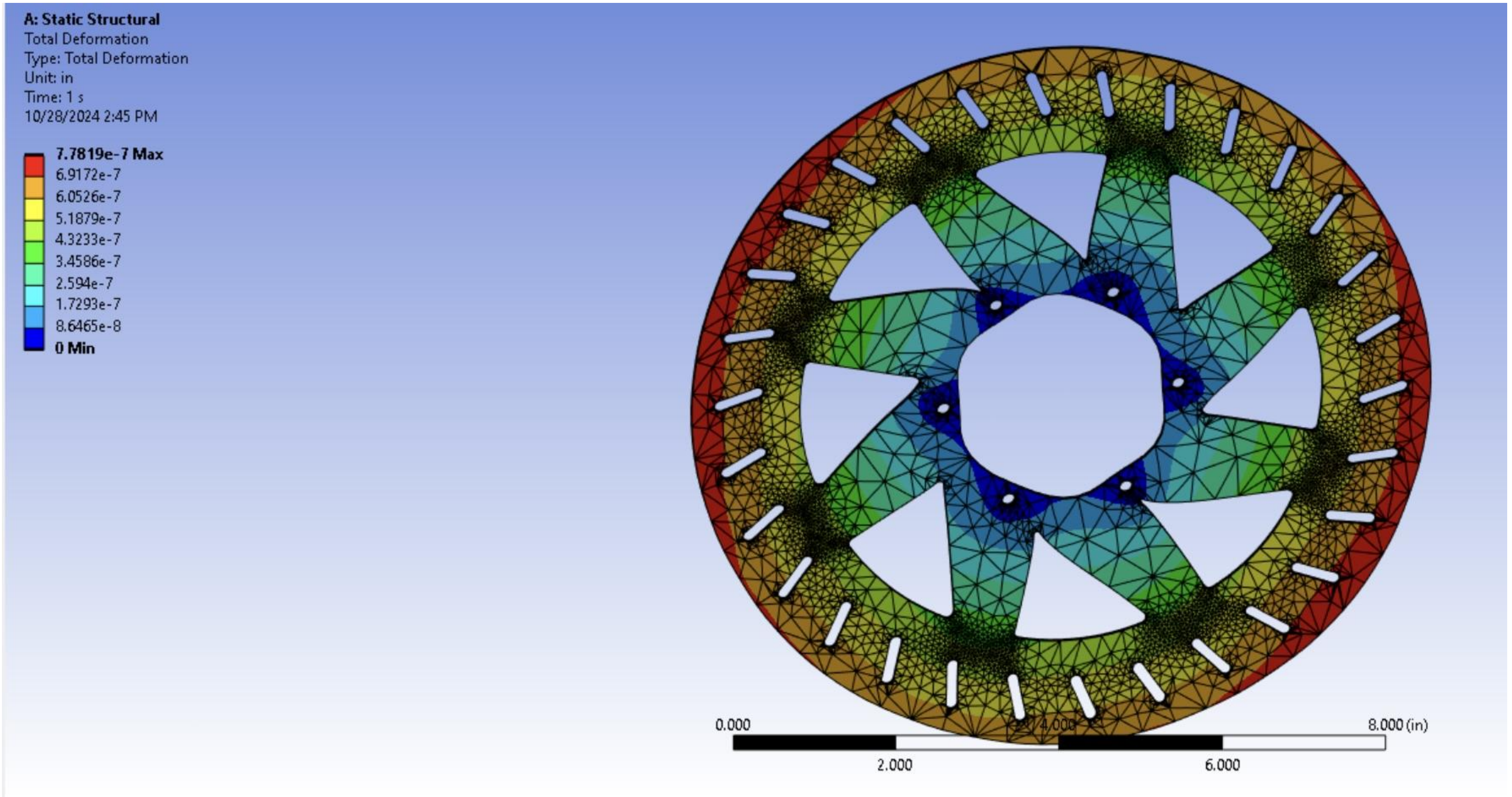
Safety Factor

- 15

Taylor

Engineering Calculations - Brakes

FEA-Rear Rotor



A: Static Structural
Total Deformation
Type: Total Deformation
Unit: in
Time: 1 s
10/28/2024 2:45 PM

Max Deformation

- 7.7819*10^-7 in

Max Stress

- 57.7 Psi

Safety Factor

- 15

Taylor

Design Validation - Brakes

Part	Failure Mode	Effects of Failure	Cause of Failure	Severity (1-10)	Action Taken
Rotors	Fatigue	Breaks due to large braking force	Slamming on the brakes	9	Use high strength steel
Calipers	Fatigue	Breaks due to large braking force	Slamming on the brakes	8	Use quality calipers
Front Rotor Bolts	Fatigue	Shears from torque	Driver has to slam on the brakes	8	Use bolts with high yield strength
Rear Rotor Bolts	Fatigue	Shears from torque	Driver has to slam on the brakes	8	Use bolts with high yield strength
Front Caliper Bolt	Fatigue	Shears from torque	Driver has to slam on the brakes	8	Use bolts with high yield strength
Rear Caliper Bolt	Fatigue	Shears from torque	Driver has to slam on the brakes	8	Use bolts with high yield strength

Biggest Priority:

- Rotors
- Rotor bolts

Failures Avoided By:

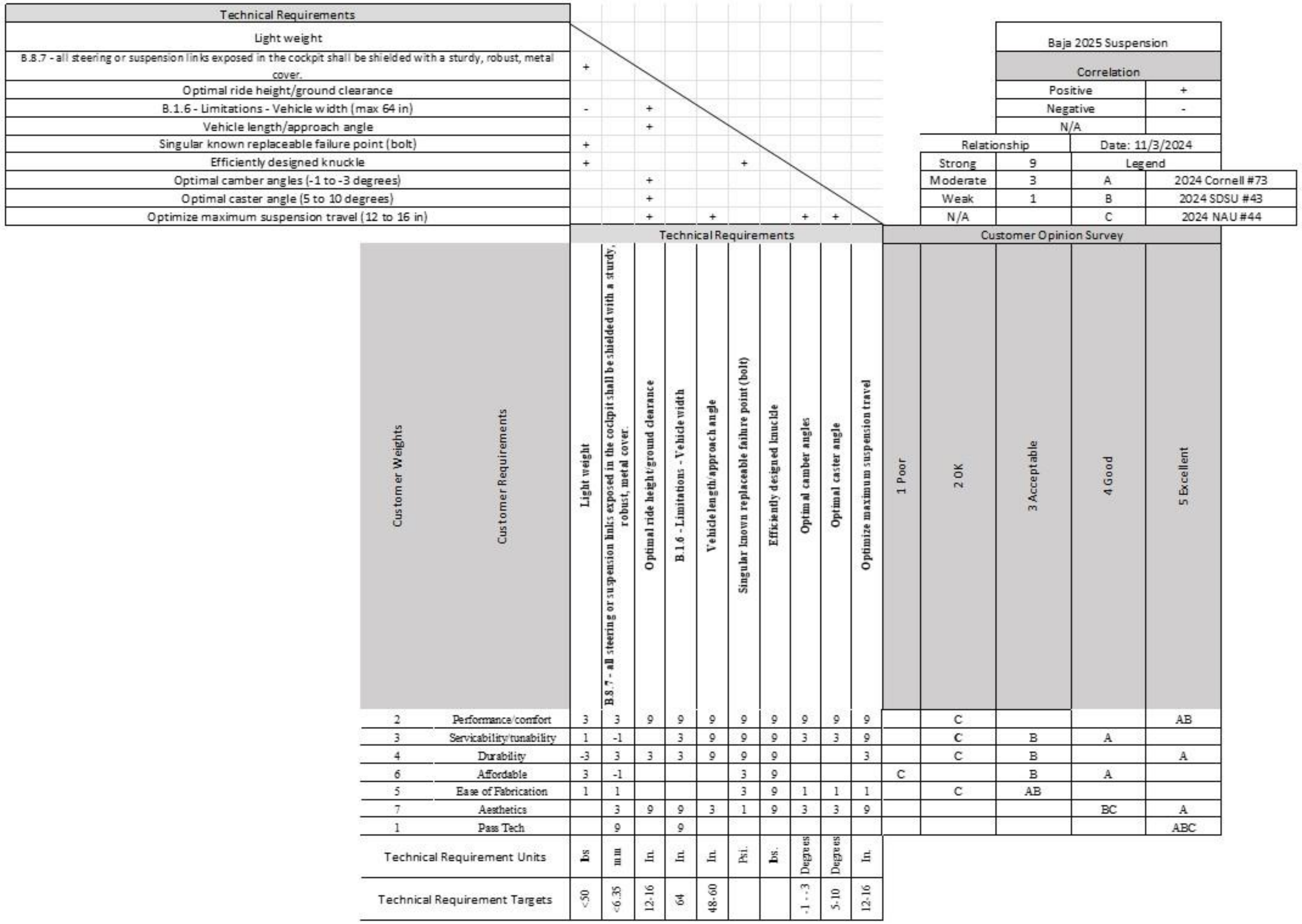
- FEA testing
- Appropriate material selection

Taylor

QFD-Suspension

Customer Requirements

- Performance/comfort
- Serviceability/tunability
- Durability
- Affordable
- Ease of fabrication
- Aesthetics
- Pass tech



Baja 2025 Suspension

Correlation	
Positive	+
Negative	-
N/A	

Relationship		Date: 11/3/2024	
Strong	9	Legend	
Moderate	3	A	2024 Cornell #73
Weak	1	B	2024 SDSU #43
N/A		C	2024 NAU #44

Technical Requirements	Light weight	B.8.7	Optimal ride height/ground clearance	B.1.6 - Limitations - Vehicle width	Vehicle length/approach angle	Singular known replaceable failure point (bolt)	Efficiently designed knuckle	Optimal camber angles	Optimal caster angle	Optimize maximum suspension travel
Light weight										
B.8.7 - all steering or suspension links exposed in the cockpit shall be shielded with a sturdy, robust, metal cover.	+									
Optimal ride height/ground clearance										
B.1.6 - Limitations - Vehicle width (max 64 in)	-		+							
Vehicle length/approach angle			+							
Singular known replaceable failure point (bolt)	+									
Efficiently designed knuckle	+					+				
Optimal camber angles (-1 to -3 degrees)			+							
Optimal caster angle (5 to 10 degrees)			+							
Optimize maximum suspension travel (12 to 16 in)			+		+			+	+	

Customer Weights	Customer Requirements	Light weight	B.8.7 - all steering or suspension links exposed in the cockpit shall be shielded with a sturdy, robust, metal cover.	Optimal ride height/ground clearance	B.1.6 - Limitations - Vehicle width	Vehicle length/approach angle	Singular known replaceable failure point (bolt)	Efficiently designed knuckle	Optimal camber angles	Optimal caster angle	Optimize maximum suspension travel	1 Poor	2 OK	3 Acceptable	4 Good	5 Excellent
2	Performance/comfort	3	3	9	9	9	9	9	9	9	9		C			AB
3	Servicability/tunability	1	-1		3	9	9	9	3	3	9		C	B	A	
4	Durability	-3	3	3	3	9	9	9			3		C	B		A
6	Affordable	3	-1				3	9				C		B	A	
5	Ease of Fabrication	1	1				3	9	1	1	1		C	AB		
7	Aesthetics		3	9	9	3	1	9	3	3	9				BC	A
1	Pass Tech		9		9											ABC
Technical Requirement Units		lbs	mm	In.	In.	In.	Psi.	lbs.	Degrees	Degrees	In.					
Technical Requirement Targets		<50	<6.35	12-16	64	48-60			-1 - -3	5-10	12-16					

Oliver H.

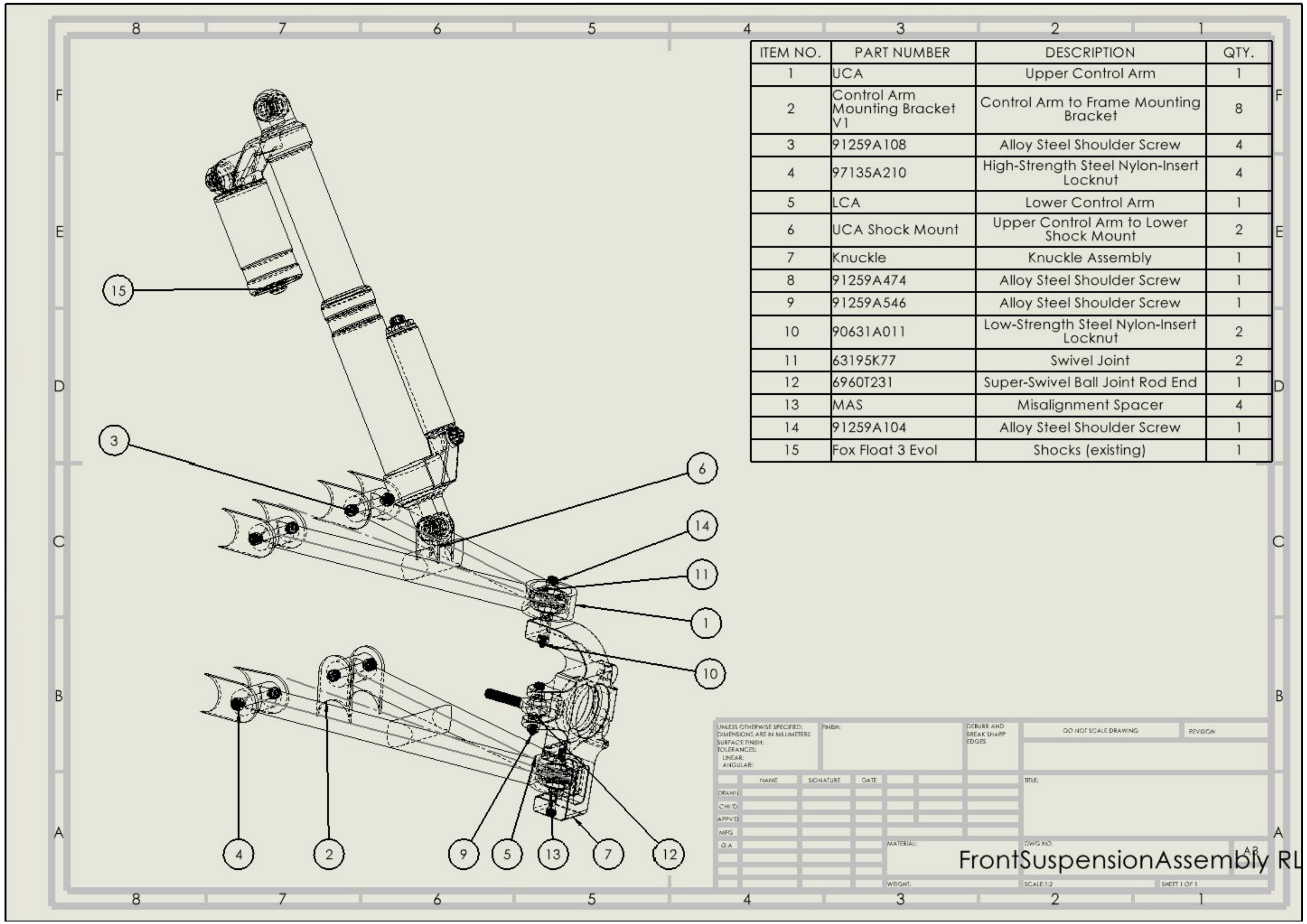
Engineering Requirements

- Light weight
- B.8.7 - cockpit shielding for steering/suspension links
- Optimal ride height/ground clearance (12-13in.)
- B.1.6 - Vehicle width (62in)
- Vehicle length/approach angle
- Singular known replaceable failure point (Bolt)
- Efficiently designed knuckle (lightweight)
- Optimize maximum suspension travel (F - 12in. | R - 14in.)

Oliver H.

Design Description - Control Arms and Mounting

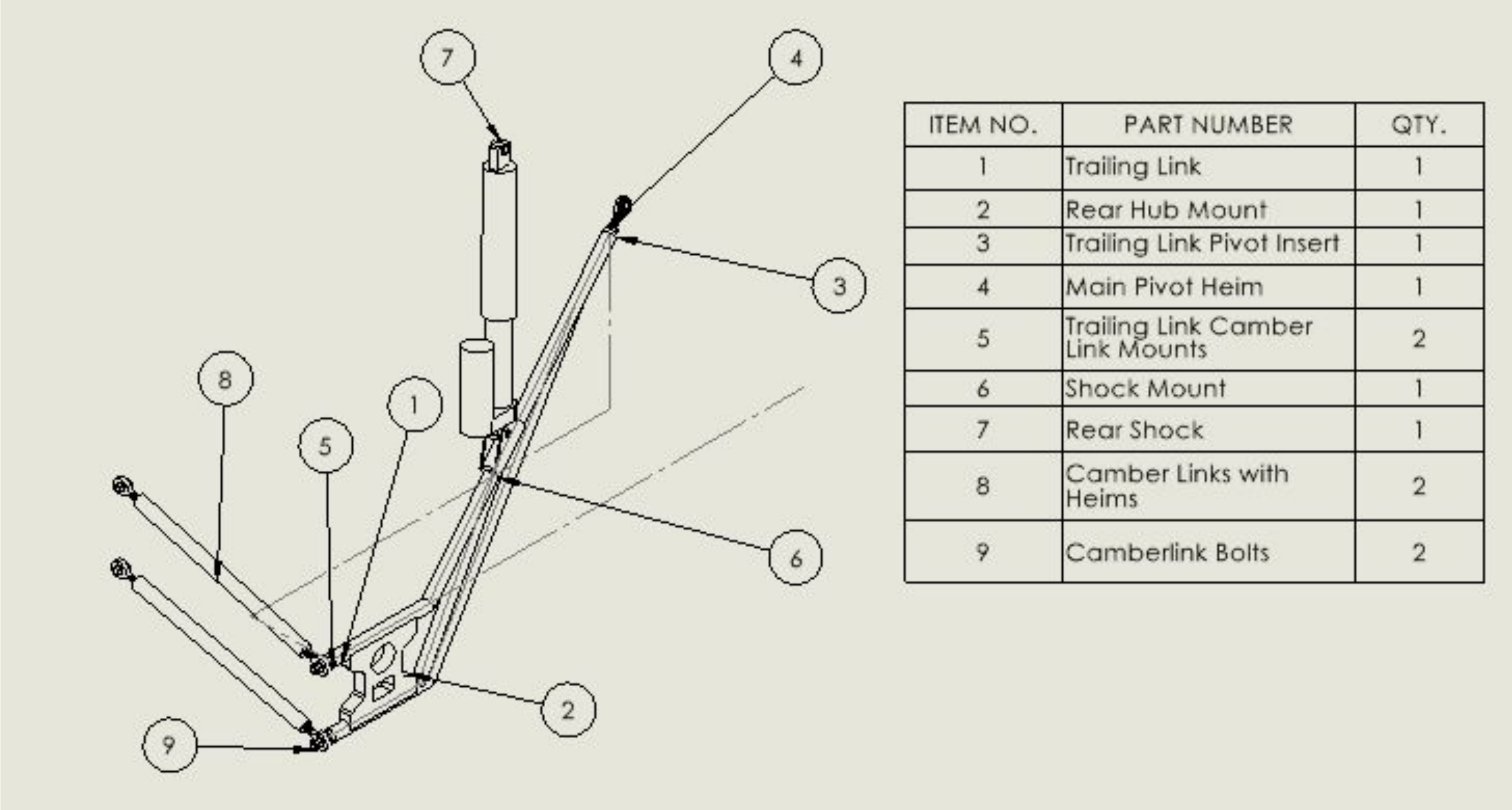
- Robust CA to frame mounting tab, UCA to lower shock mount tabs
- Narrower design, reducing bending moment on UCA with shock mount



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	UCA	Upper Control Arm	1
2	Control Arm Mounting Bracket V1	Control Arm to Frame Mounting Bracket	8
3	91259A108	Alloy Steel Shoulder Screw	4
4	97135A210	High-Strength Steel Nylon-Insert Locknut	4
5	LCA	Lower Control Arm	1
6	UCA Shock Mount	Upper Control Arm to Lower Shock Mount	2
7	Knuckle	Knuckle Assembly	1
8	91259A474	Alloy Steel Shoulder Screw	1
9	91259A546	Alloy Steel Shoulder Screw	1
10	90631A011	Low-Strength Steel Nylon-Insert Locknut	2
11	63195K77	Swivel Joint	2
12	6960T231	Super-Swivel Ball Joint Rod End	1
13	MAS	Misalignment Spacer	4
14	91259A104	Alloy Steel Shoulder Screw	1
15	Fox Float 3 Evol	Shocks (existing)	1

Ryan L.

Design Description - Rear Suspension

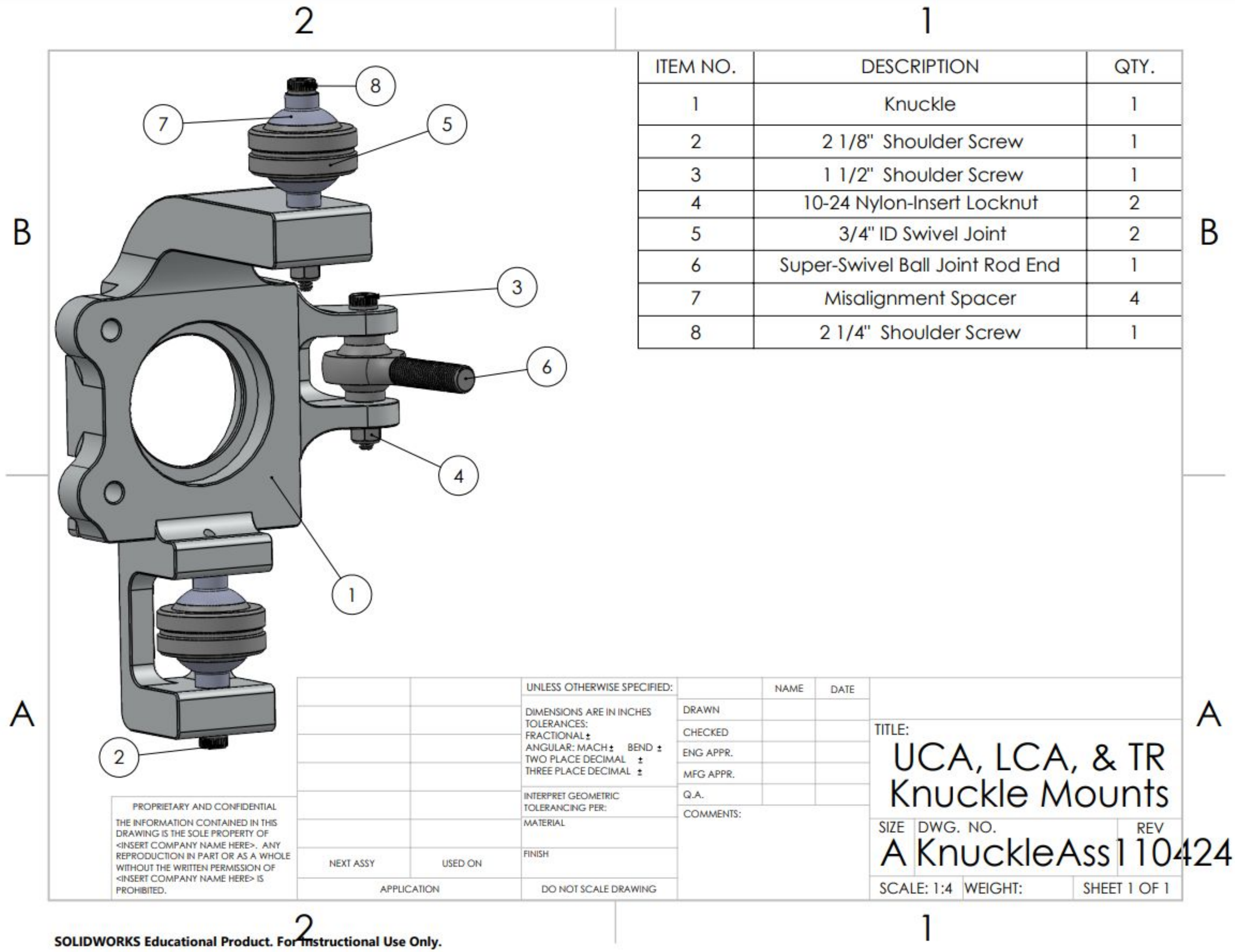


ITEM NO.	PART NUMBER	QTY.
1	Trailing Link	1
2	Rear Hub Mount	1
3	Trailing Link Pivot Insert	1
4	Main Pivot Heim	1
5	Trailing Link Camber Link Mounts	2
6	Shock Mount	1
7	Rear Shock	1
8	Camber Links with Heims	2
9	Camberlink Bolts	2

- **Tubular design to reduce weight and reduce manufacturing time.**
- **Equal length rear camber links to minimize binding and CV plunge.**
- **Adjustable heim joints for alignment adjustment**

Ryan K.

Design Description - Knuckle Mounts



ITEM NO.	DESCRIPTION	QTY.
1	Knuckle	1
2	2 1/8" Shoulder Screw	1
3	1 1/2" Shoulder Screw	1
4	10-24 Nylon-Insert Locknut	2
5	3/4" ID Swivel Joint	2
6	Super-Swivel Ball Joint Rod End	1
7	Misalignment Spacer	4
8	2 1/4" Shoulder Screw	1

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NEXT ASSY | USED ON
APPLICATION

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:
UCA, LCA, & TR Knuckle Mounts

SIZE A
DWG. NO. KnuckleAss1
REV 10424

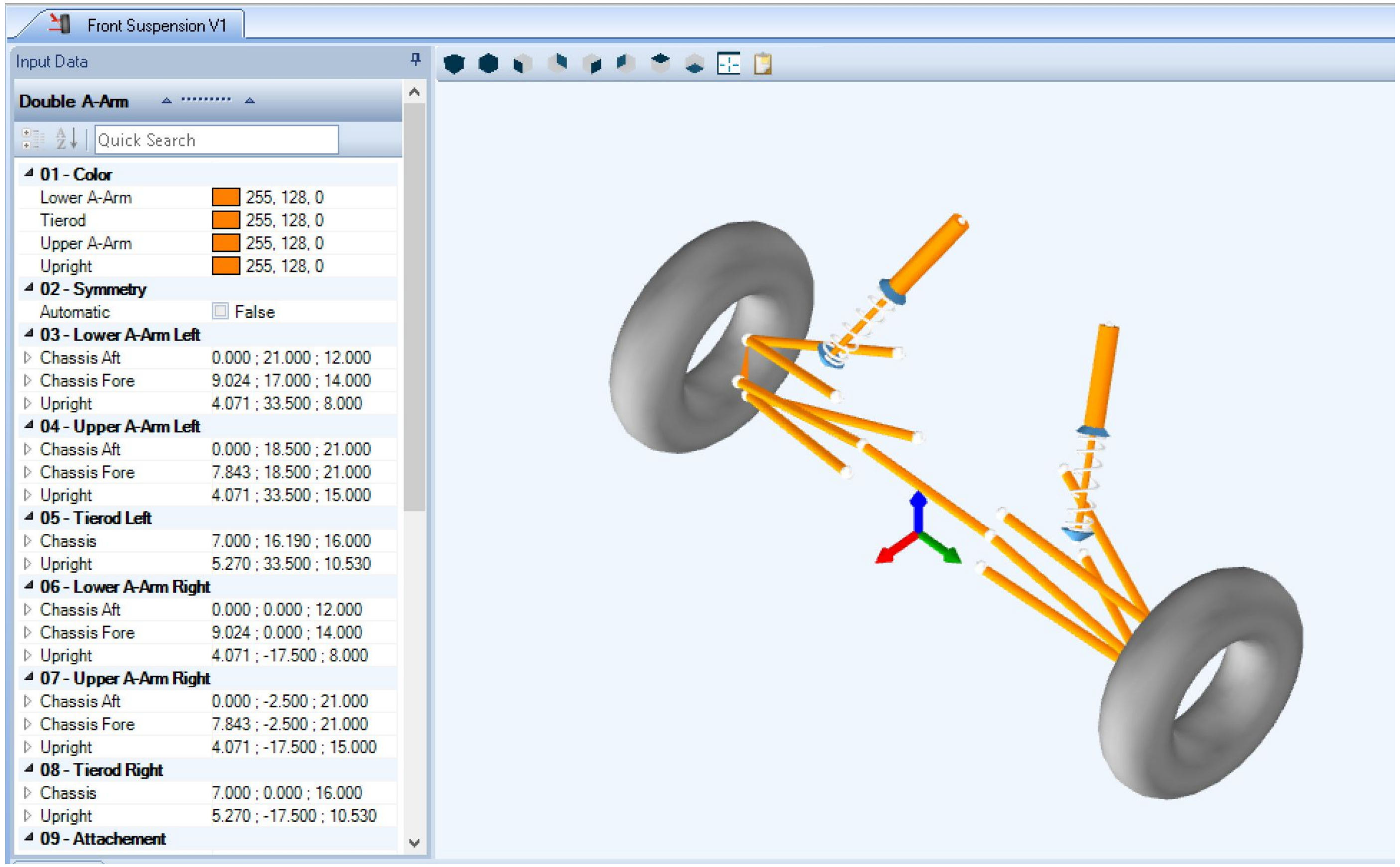
SCALE: 1:4 WEIGHT: SHEET 1 OF 1

SOLIDWORKS Educational Product. For Instructional Use Only.

- **Robust UCA, LCA, & Tie Rod Mounts**
- **Minimal threads in the knuckle itself**
- **¼” vs ⅜” shoulder bolts**

Brennan P.

Engineering Calculations - Optimum Kinematics

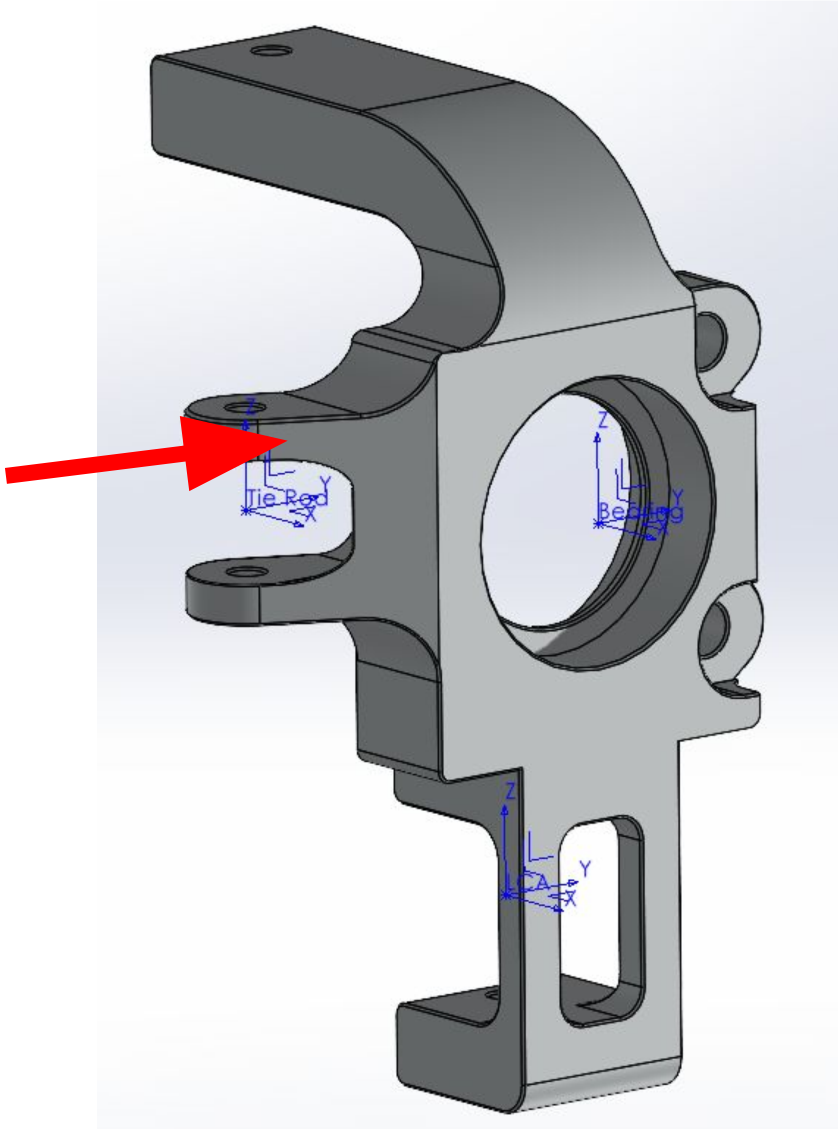


01 - Color	
Lower A-Arm	🟧 255, 128, 0
Tierod	🟧 255, 128, 0
Upper A-Arm	🟧 255, 128, 0
Upright	🟧 255, 128, 0
02 - Symmetry	
Automatic	☐ False
03 - Lower A-Arm Left	
Chassis Aft	0.000 ; 21.000 ; 12.000
Chassis Fore	9.024 ; 17.000 ; 14.000
Upright	4.071 ; 33.500 ; 8.000
04 - Upper A-Arm Left	
Chassis Aft	0.000 ; 18.500 ; 21.000
Chassis Fore	7.843 ; 18.500 ; 21.000
Upright	4.071 ; 33.500 ; 15.000
05 - Tierod Left	
Chassis	7.000 ; 16.190 ; 16.000
Upright	5.270 ; 33.500 ; 10.530
06 - Lower A-Arm Right	
Chassis Aft	0.000 ; 0.000 ; 12.000
Chassis Fore	9.024 ; 0.000 ; 14.000
Upright	4.071 ; -17.500 ; 8.000
07 - Upper A-Arm Right	
Chassis Aft	0.000 ; -2.500 ; 21.000
Chassis Fore	7.843 ; -2.500 ; 21.000
Upright	4.071 ; -17.500 ; 15.000
08 - Tierod Right	
Chassis	7.000 ; 0.000 ; 16.000
Upright	5.270 ; -17.500 ; 10.530
09 - Attachement	

- Optimum Kinematics
- Make suspension points in Solidworks frame CAD model, translate to Optimum.
- Work with frame team and iterate based on new changes/ideas.
- Final stages of optimum.

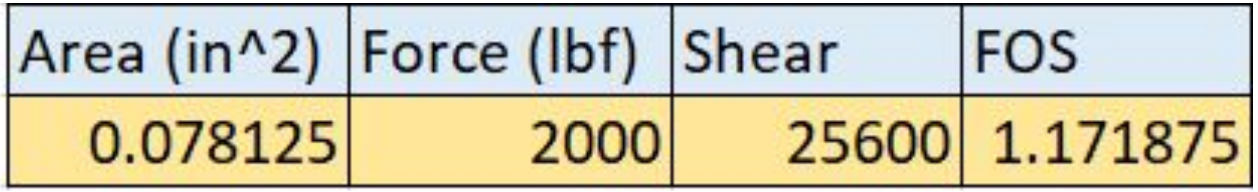
Ryan L.

Engineering Calculations



Shear Stress in Tie Rod Mount assuming 6061-T6 aluminum with 30kpsi shear strength

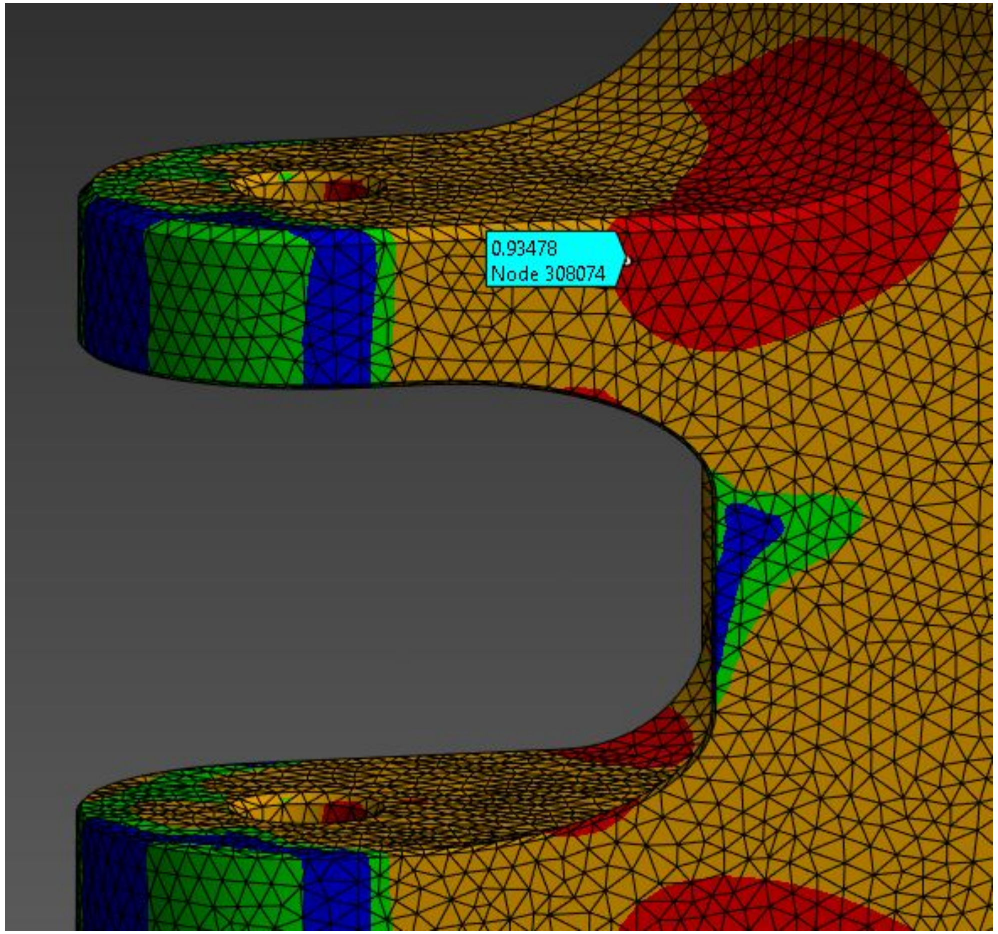
$$\sigma(\text{shear}) = F/A$$



Area (in^2)	Force (lbf)	Shear	FOS
0.078125	2000	25600	1.171875

Brennan P.

Engineer Calculations



Results from Ansys FEA:

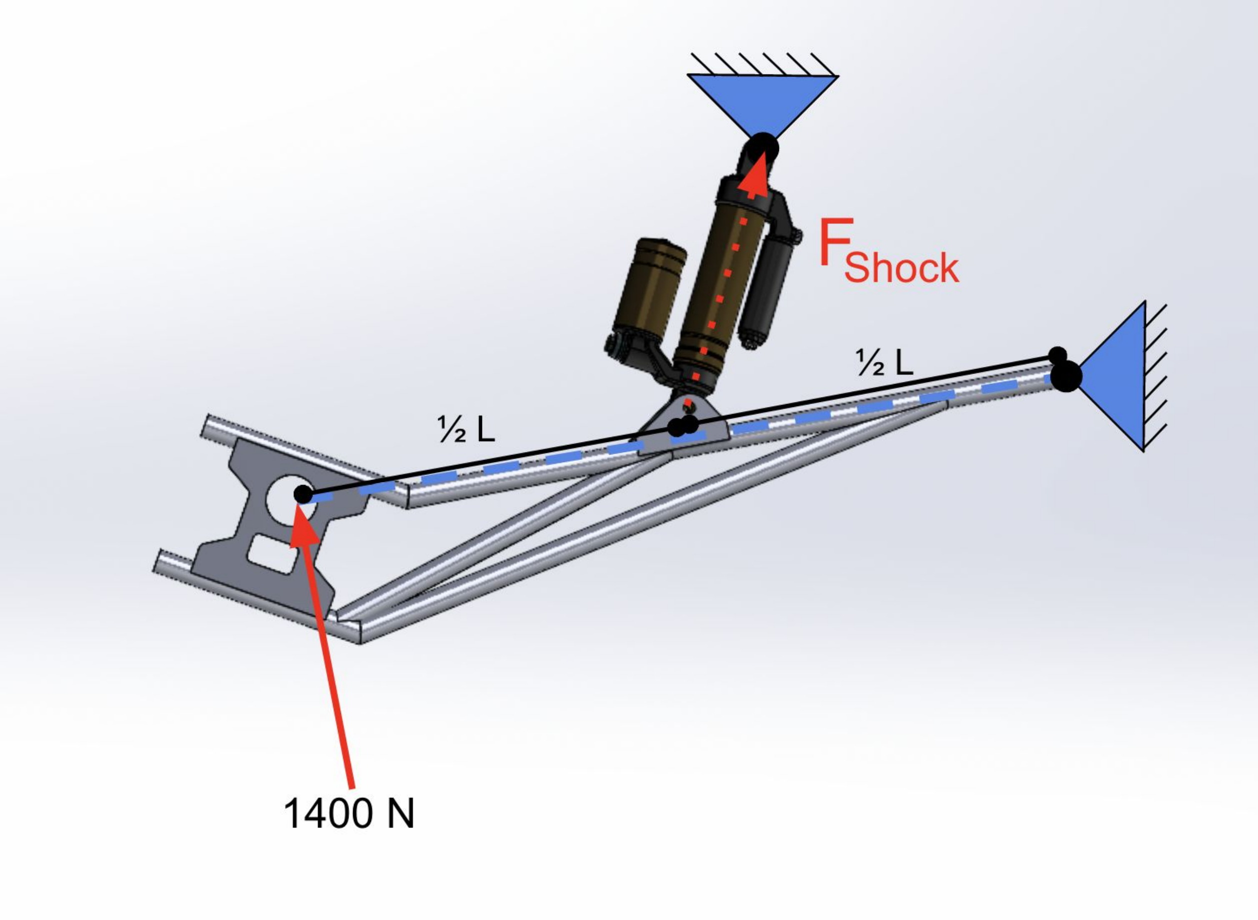
- 0.93 FOS

Moving Forward:

- Add material to increase FOS and dynamic testing

Brennan

Engineer Calculations - Rear Link



Rear link is treated as a lever arm, pivoting at the forwardmost mounting location.

- Worst case scenario impact
- 1400N acting on rear wheel
- Shock is compressed fully
- Need to find force on center of link, will also help with mount design

$$F_{Impact} = 1400N$$

$$L = 32" = 0.8128m$$

$$\Sigma M_{pivot} = 1400N\ x\ 0.8128m - F_{Shock}\ x\ 0.4064m = 0$$

$$F_{Shock} = \frac{1400N\ x\ 0.8128m}{0.4064m} = 2800N$$

Ryan K.

Engineering Calculations- Bolts

Minimum Shear Strength 84,000 psi

$$Shear = \frac{2000\ lbf}{\pi(0.125^2)} = 40{,}743\text{ psi}$$

$$Shear = \frac{2000\ lbf}{\pi(0.1875^2)} = 18{,}108\text{ psi}$$

$$FOS = \frac{84{,}000}{40{,}744} = 2.06$$

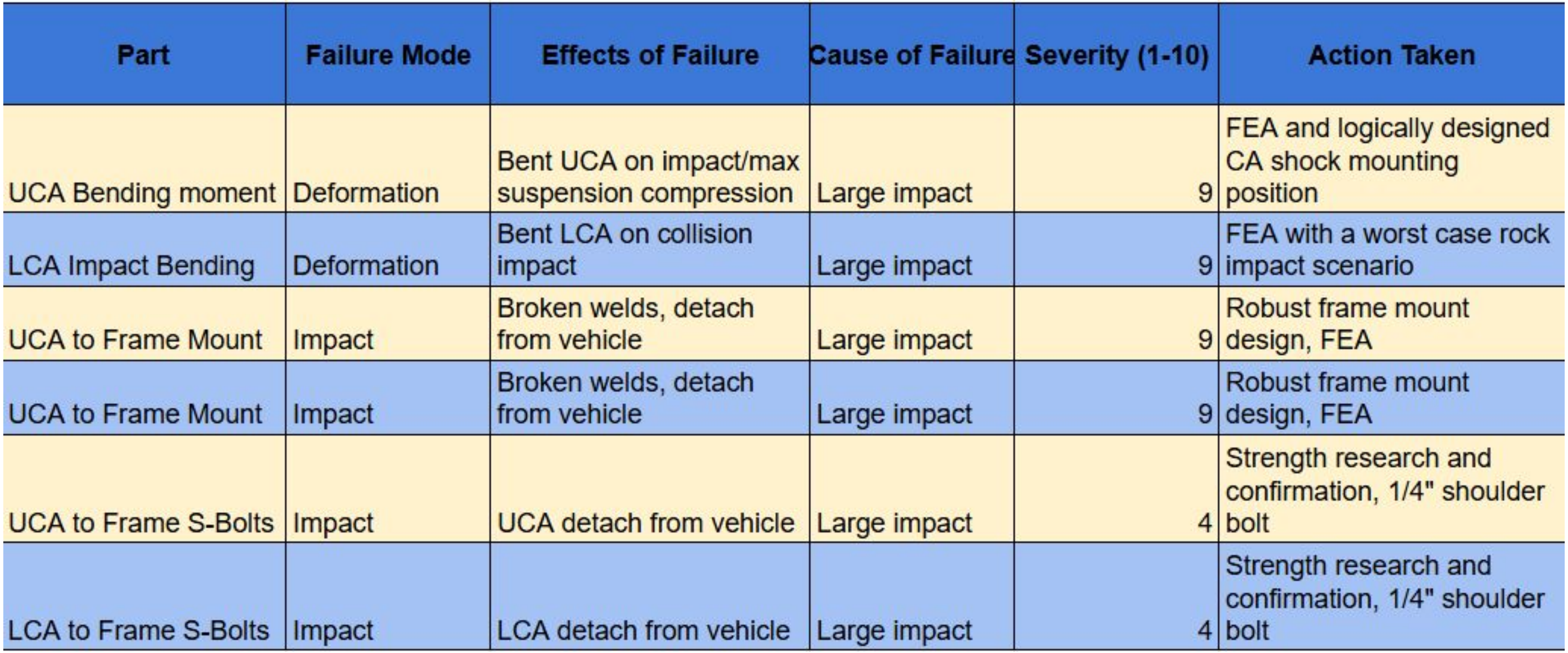
$$FOS = \frac{84{,}000}{18{,}108} = 4.63$$

Shoulder Diameter 1/4"

Shoulder Diameter 3/8"

Oliver H.

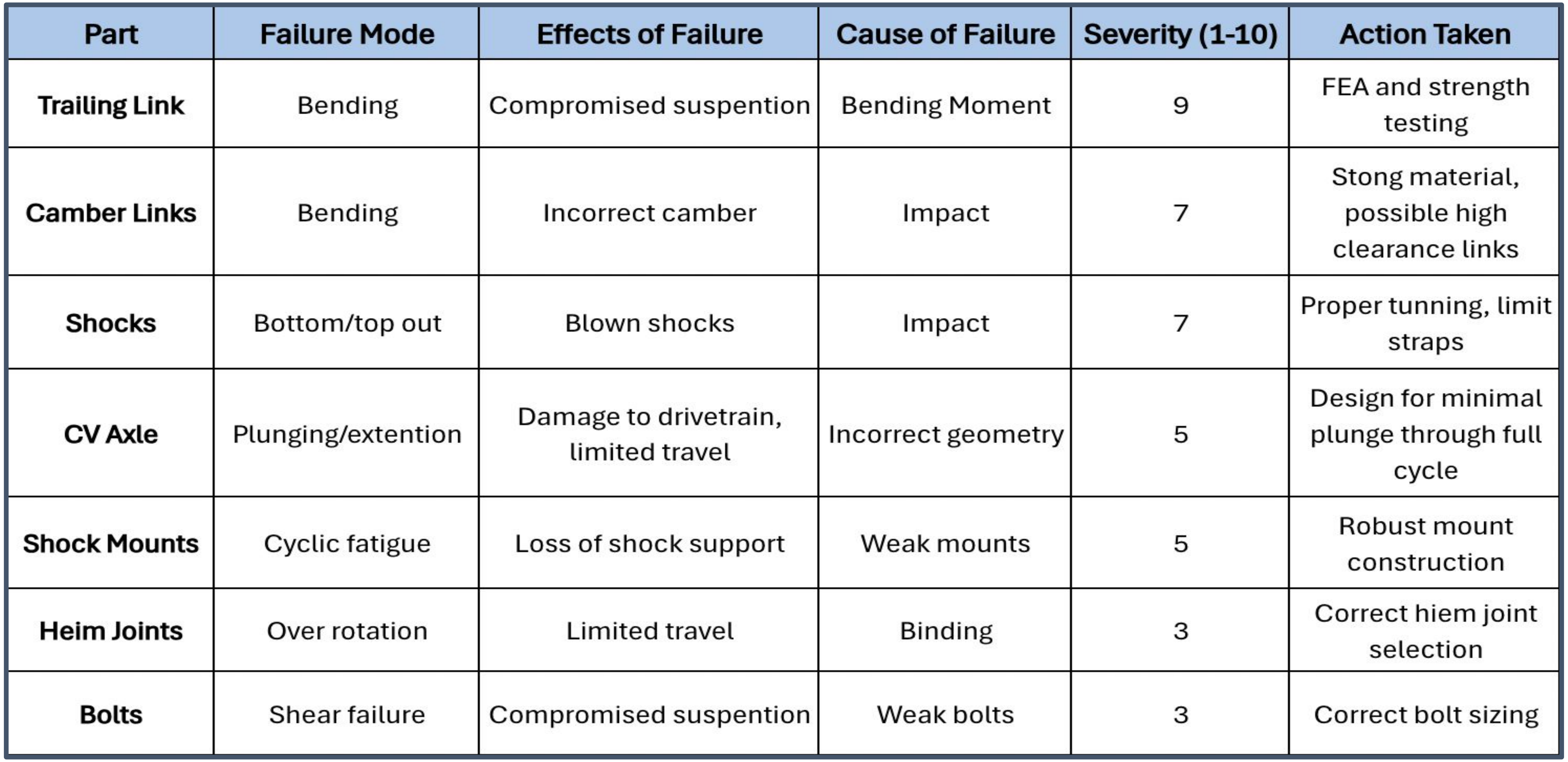
Design Validation - Control Arms



Part	Failure Mode	Effects of Failure	Cause of Failure	Severity (1-10)	Action Taken
UCA Bending moment	Deformation	Bent UCA on impact/max suspension compression	Large impact	9	FEA and logically designed CA shock mounting position
LCA Impact Bending	Deformation	Bent LCA on collision impact	Large impact	9	FEA with a worst case rock impact scenario
UCA to Frame Mount	Impact	Broken welds, detach from vehicle	Large impact	9	Robust frame mount design, FEA
UCA to Frame Mount	Impact	Broken welds, detach from vehicle	Large impact	9	Robust frame mount design, FEA
UCA to Frame S-Bolts	Impact	UCA detach from vehicle	Large impact	4	Strength research and confirmation, 1/4" shoulder bolt
LCA to Frame S-Bolts	Impact	LCA detach from vehicle	Large impact	4	Strength research and confirmation, 1/4" shoulder bolt

Ryan L.

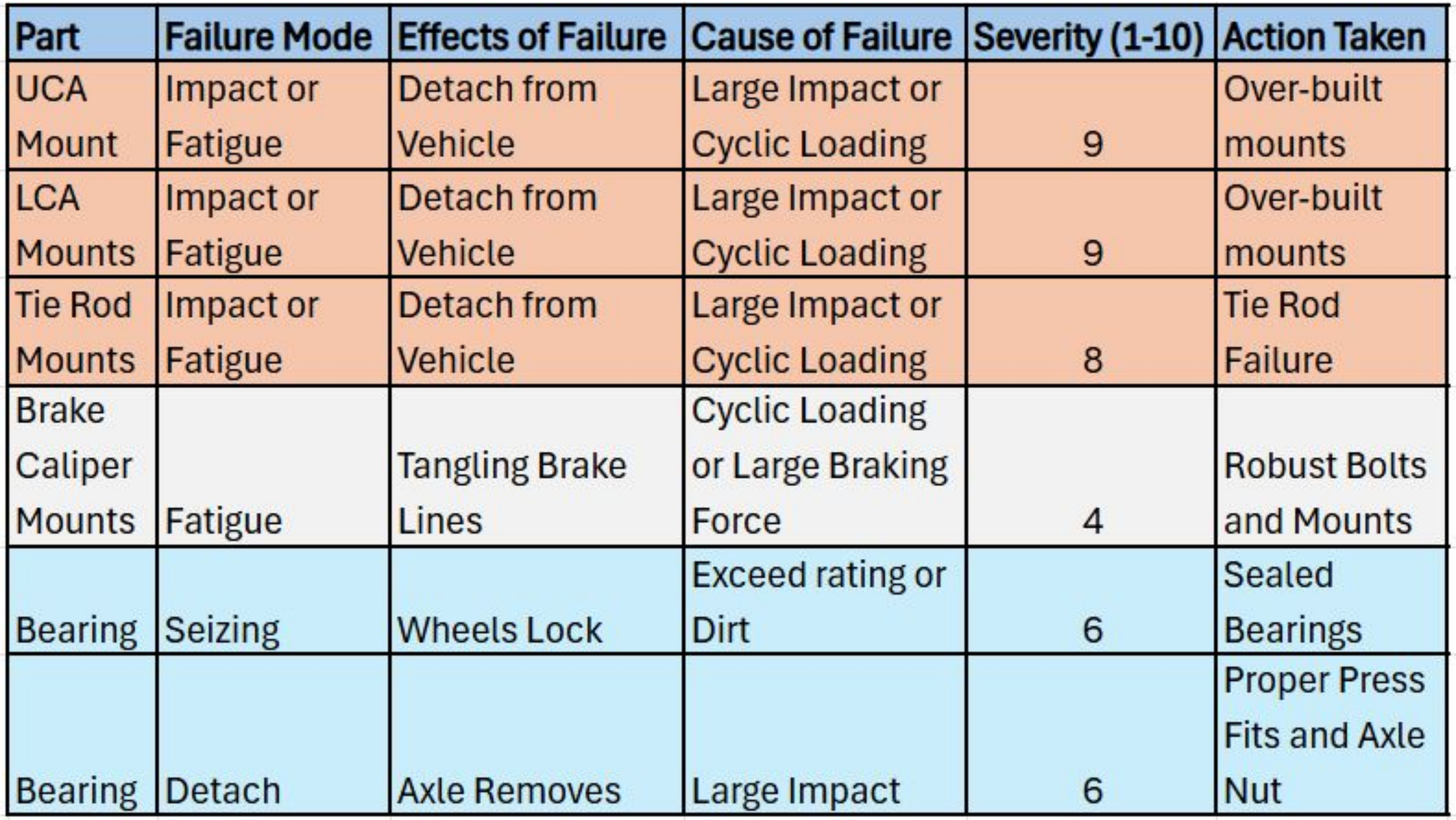
Design Validation - Rear Suspension



Part	Failure Mode	Effects of Failure	Cause of Failure	Severity (1-10)	Action Taken
Trailing Link	Bending	Compromised suspention	Bending Moment	9	FEA and strength testing
Camber Links	Bending	Incorrect camber	Impact	7	Stong material, possible high clearance links
Shocks	Bottom/top out	Blown shocks	Impact	7	Proper tunning, limit straps
CV Axle	Plunging/extention	Damage to drivetrain, limited travel	Incorrect geometry	5	Design for minimal plunge through full cycle
Shock Mounts	Cyclic fatigue	Loss of shock support	Weak mounts	5	Robust mount construction
Heim Joints	Over rotation	Limited travel	Binding	3	Correct hiem joint selection
Bolts	Shear failure	Compromised suspention	Weak bolts	3	Correct bolt sizing

Ryan K.

Design Validation - Knuckle



Part	Failure Mode	Effects of Failure	Cause of Failure	Severity (1-10)	Action Taken
UCA Mount	Impact or Fatigue	Detach from Vehicle	Large Impact or Cyclic Loading	9	Over-built mounts
LCA Mounts	Impact or Fatigue	Detach from Vehicle	Large Impact or Cyclic Loading	9	Over-built mounts
Tie Rod Mounts	Impact or Fatigue	Detach from Vehicle	Large Impact or Cyclic Loading	8	Tie Rod Failure
Brake Caliper Mounts	Fatigue	Tangling Brake Lines	Cyclic Loading or Large Braking Force	4	Robust Bolts and Mounts
Bearing	Seizing	Wheels Lock	Exceed rating or Dirt	6	Sealed Bearings
Bearing	Detach	Axle Removes	Large Impact	6	Proper Press Fits and Axle Nut

High Priority:

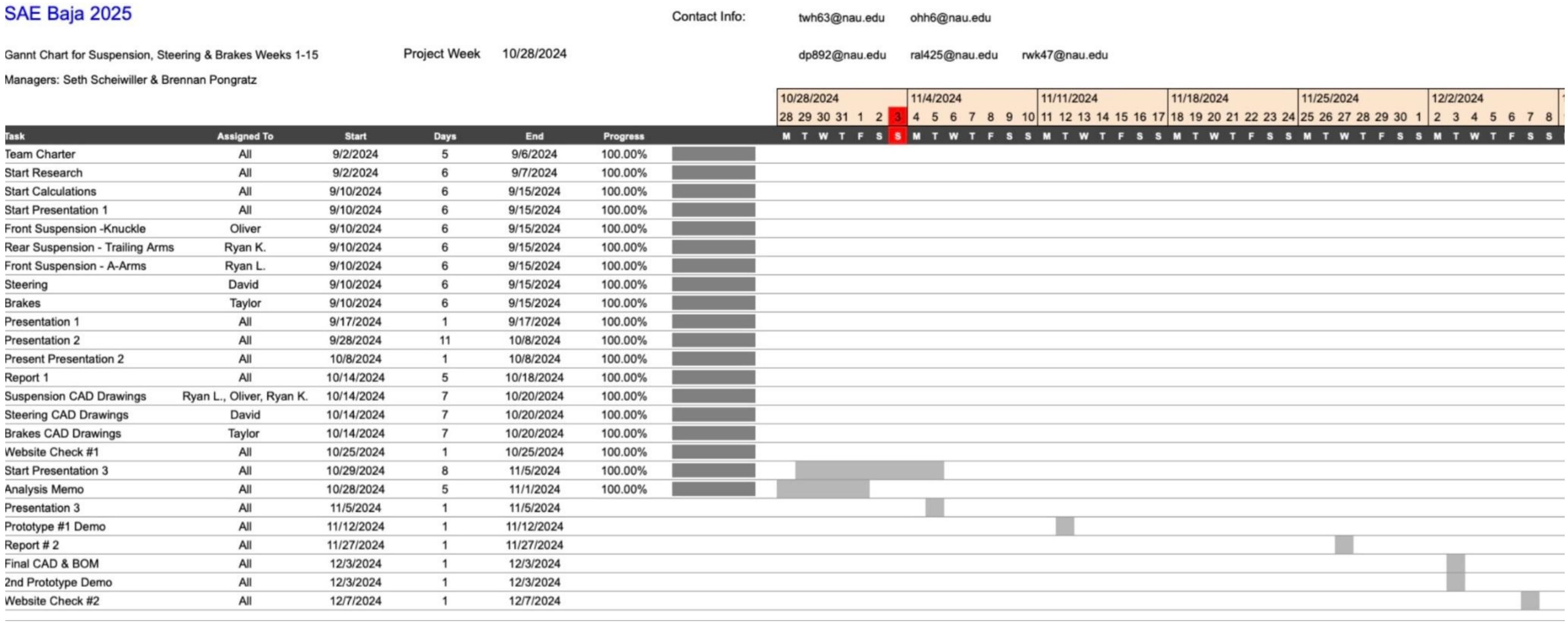
- UCA, LCA, and TR mounts

Failure Avoided By:

- Excess material in high stress areas (fillets)
- FEA testing before manufacturing

Brennan P.

Schedule



SAE Baja 2025

Contact Info: twh63@nau.edu ohh6@nau.edu

Gannt Chart for Suspension, Steering & Brakes Weeks 1-15

Project Week 10/28/2024

dp892@nau.edu ral425@nau.edu rwk47@nau.edu

Managers: Seth Scheiwiller & Brennan Pongratz

Task	Assigned To	Start	Days	End	Progress
Team Charter	All	9/2/2024	5	9/6/2024	100.00%
Start Research	All	9/2/2024	6	9/7/2024	100.00%
Start Calculations	All	9/10/2024	6	9/15/2024	100.00%
Start Presentation 1	All	9/10/2024	6	9/15/2024	100.00%
Front Suspension -Knuckle	Oliver	9/10/2024	6	9/15/2024	100.00%
Rear Suspension - Trailing Arms	Ryan K.	9/10/2024	6	9/15/2024	100.00%
Front Suspension - A-Arms	Ryan L.	9/10/2024	6	9/15/2024	100.00%
Steering	David	9/10/2024	6	9/15/2024	100.00%
Brakes	Taylor	9/10/2024	6	9/15/2024	100.00%
Presentation 1	All	9/17/2024	1	9/17/2024	100.00%
Presentation 2	All	9/28/2024	11	10/8/2024	100.00%
Present Presentation 2	All	10/8/2024	1	10/8/2024	100.00%
Report 1	All	10/14/2024	5	10/18/2024	100.00%
Suspension CAD Drawings	Ryan L., Oliver, Ryan K.	10/14/2024	7	10/20/2024	100.00%
Steering CAD Drawings	David	10/14/2024	7	10/20/2024	100.00%
Brakes CAD Drawings	Taylor	10/14/2024	7	10/20/2024	100.00%
Website Check #1	All	10/25/2024	1	10/25/2024	100.00%
Start Presentation 3	All	10/29/2024	8	11/5/2024	100.00%
Analysis Memo	All	10/28/2024	5	11/1/2024	100.00%
Presentation 3	All	11/5/2024	1	11/5/2024	
Prototype #1 Demo	All	11/12/2024	1	11/12/2024	
Report # 2	All	11/27/2024	1	11/27/2024	
Final CAD & BOM	All	12/3/2024	1	12/3/2024	
2nd Prototype Demo	All	12/3/2024	1	12/3/2024	
Website Check #2	All	12/7/2024	1	12/7/2024	

Taylor

Budget

Category	Items	Approximate Cost
System Components	Knuckles Control Arms Shocks Brake System Steering System Hardware and Bearings	\$200 \$150 \$0 (on hand, saves us \$6000) \$500 \$450 \$800
Spare Parts/Hardware	Hardware Knuckles Tie Rods Brake Rotors	\$80 \$200 \$100 \$80
Travel (Suspension, Steering, and Brakes)	Hotel, Gas, Food, etc.	\$1500
Contingency	Unexpected Costs	\$205
	Total	~\$4300

Ryan K.

Thank You