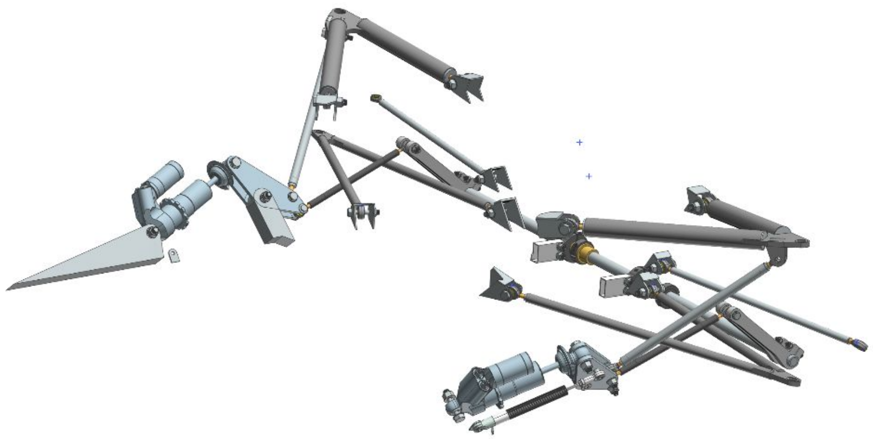
MY24 Suspension



Eric Zhou, Sean Boerhout, Alena Hu, Andy Li

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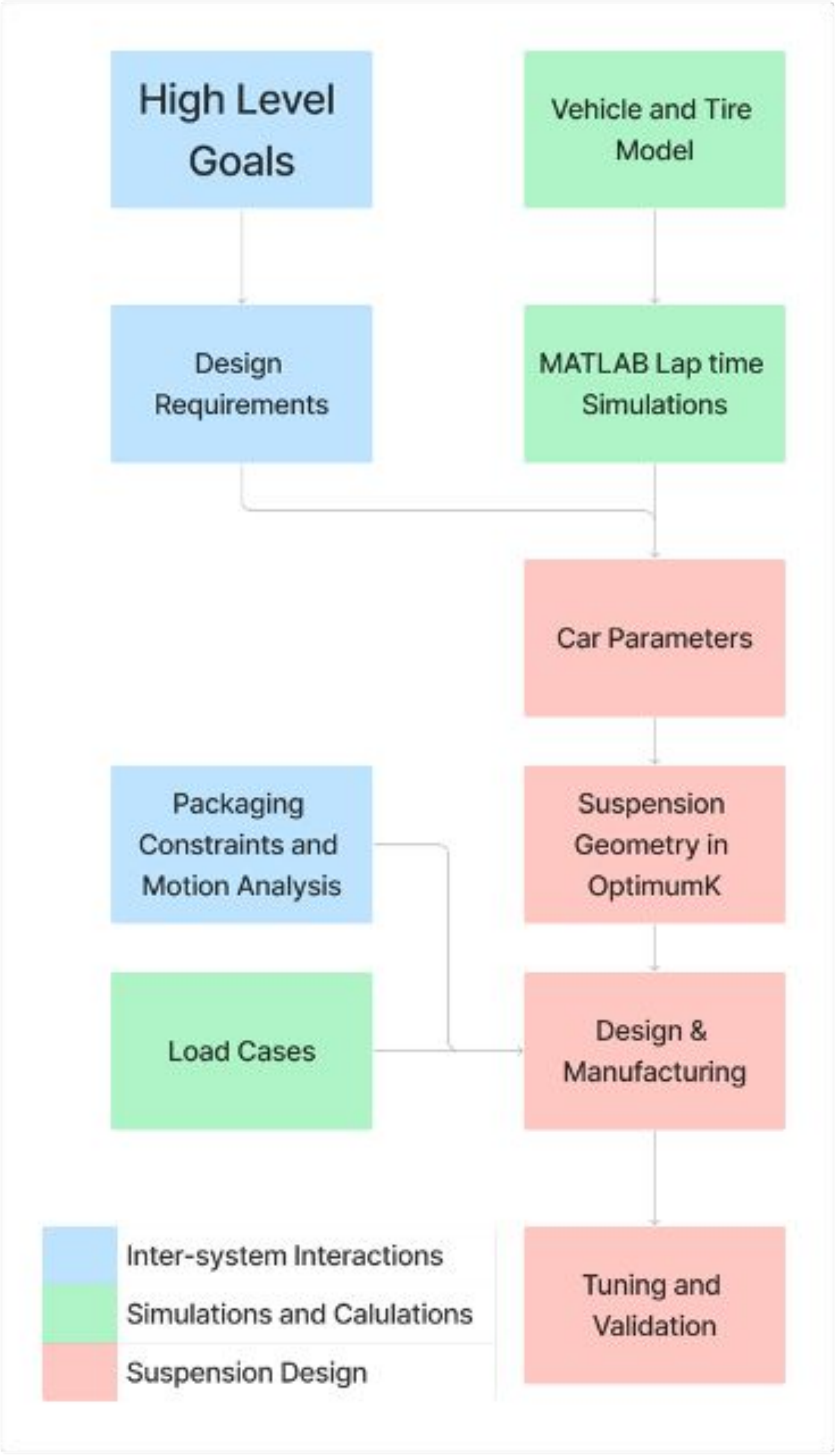
High-Level Design Goals

The entire purpose of the suspension system is to **maximize the acceleration potential of the tires during dynamic events while providing consistent driver feedback and adhering to rules.** This is done through:

1. Maximize lateral and longitudinal acceleration while maintaining stability
2. Consistent and predictable driver feedback
3. Withstand all maximum load cases with minimal compliance

Design Overview

- Double Wishbone SLA with adjustable Pull Rod, Camber, and Toe
- Double U-Joint Steering
  - 14.4 Nm driver feedback
  - 74.5% Ackermann
  - 4.45 Steering Ratio
- Adjustable Anti-Roll Bars
- Twin Tube Shocks with 4 Way Adjustable Dampers
  - 175 lb/in Front Springs
  - 150 lb/in Rear Springs
- 16x6 R20 Tires


High Level Goals
Vehicle and Tire Model
Design Requirements
MATLAB Lap time Simulations
Car Parameters
Packaging Constraints and Motion Analysis
Suspension Geometry in OptimumK
Load Cases
Design & Manufacturing
Tuning and Validation
Inter-system Interactions
Simulations and Calulations
Suspension Design

Design Requirements

Requirement	Metric	Priority
Car is steerable and stable	Ride frequency: 2.7-2.9 Hz Roll Gradient: 0.5-0.8°/g; Mechanical Trail: 0.5”; Scrub Radius: 0.3” TLLTD: 0.53; Toe: 0 with adjustability; Bump steer: 0; Roll Center: TBD”; Camber: < 0; Toe-base maximized to minimize compliance;	HIGH
Lateral Acceleration Maximized	Static Camber: -1°; Camber Change in Roll: -1° TLLTD: 0.53	HIGH
Car provides good driver feedback	Adjustable ARBs; Steering torque < 20 N*m; Scrub radius: 0.3”; Mechanical trail: 0.35"; Roll Center movement: ~0	HIGH
No packaging conflicts	> 0.1” clearance for all parts; > 0.2” for high range of motion parts	HIGH
System withstands all load cases	>= 1.5 MOS for all parts under maximum cornering, braking, accel, bump loads, dampers sized correctly	HIGH
Car doesn’t bottom out	Wheel rate, spring rate, and motion ratio result in sprung mass travel less than the ride height	HIGH
System meets mass allocations	Inboard: 4.25; kg A-arms: 5.5 kg; Steering: 2.3 kg	MEDIUM
Adjustability	Camber, ARB, and toe adjustability for driver preference and to account for manufacturing/simulation error	MEDIUM
Wheel travel must be at least 50 mm	Shocks should have enough travel when considering rocker motion ratio, Shcok preload, and ride rate	HIGH

Car Parameters

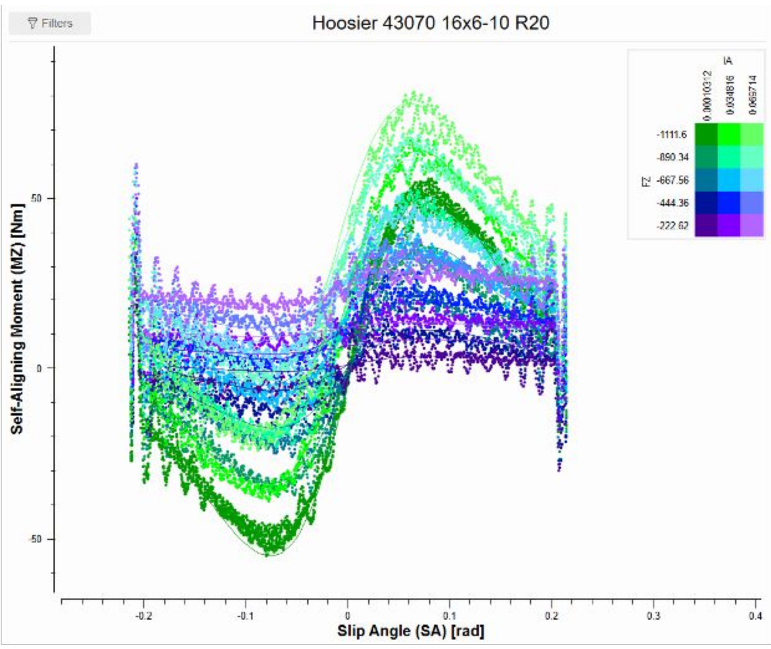
Car Parameter	Front	Rear
Wheel Rate	32 N/mm	24 N/mm
TLLTD	0.53	
Tire size, Compound, Make	Hoosier 16x6-10 R20	Hoosier 16x6-10 R20
Suspension Type	SLA Double-Wishbone with Pull Rod	SLA Double-Wishbone with Pull Rod
Suspension Travel	Jounce: 25.4 mm Rebound: 25.4 mm	Jounce: 25.4 mm Rebound: 25.4 mm
Steering Ratio	4.46	
Static Toe	0	0
Static Camber	-2	-1
Scrub Radius	8.565	
Roll Rate	627 Nm/deg	492 Nm/deg
Roll Center Height	12.86 mm	41.73 mm
Roll Camber	0.9 deg/deg	0.6 deg/deg

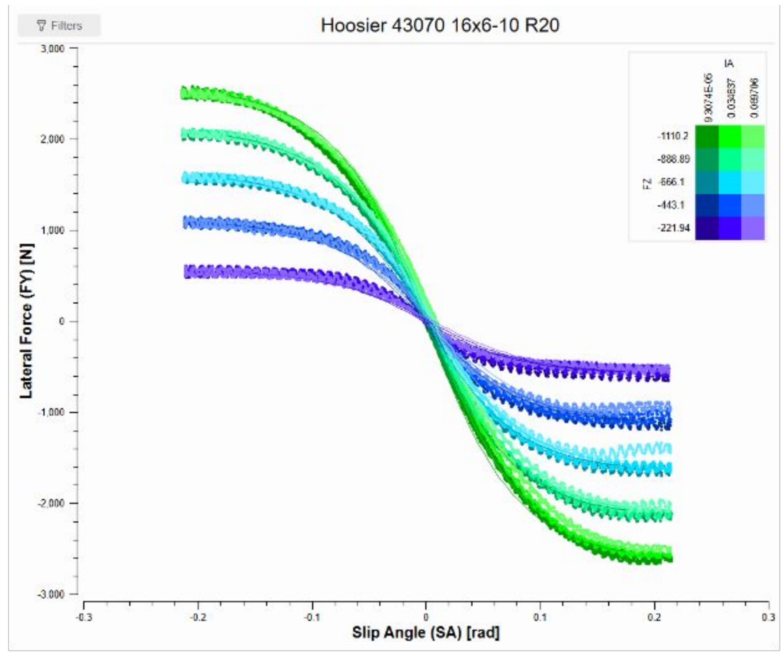
Car Parameters Cont.

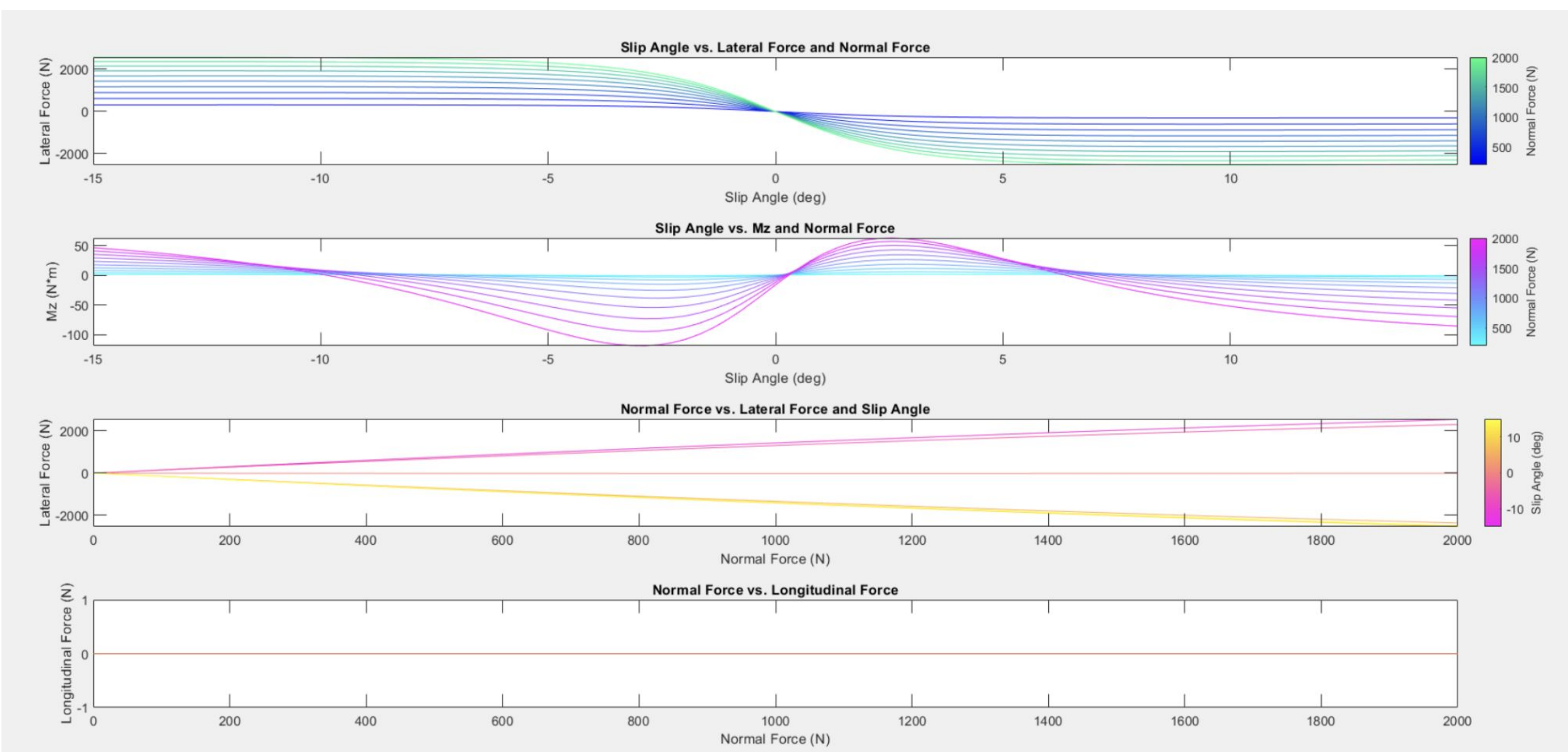
Car Parameter	Front	Rear
Ride Frequency	3.2 Hz	2.9 Hz
Ride Camber	0 deg/m	0 deg/m
Rebound Damping		
Pitman Arm Length	73.66 mm	
Motion Ratio	1.02 Progressive	0.96 Progressive
Mechanical Trail	7.493 mm	
Jounce Damping		
Caster	4.828 degree	N/A
C-factor	87.88 mm	
Anti Dive/Anti Squat	8.518%	41.33%
Ackermann Percentage	68%	

Tire Model

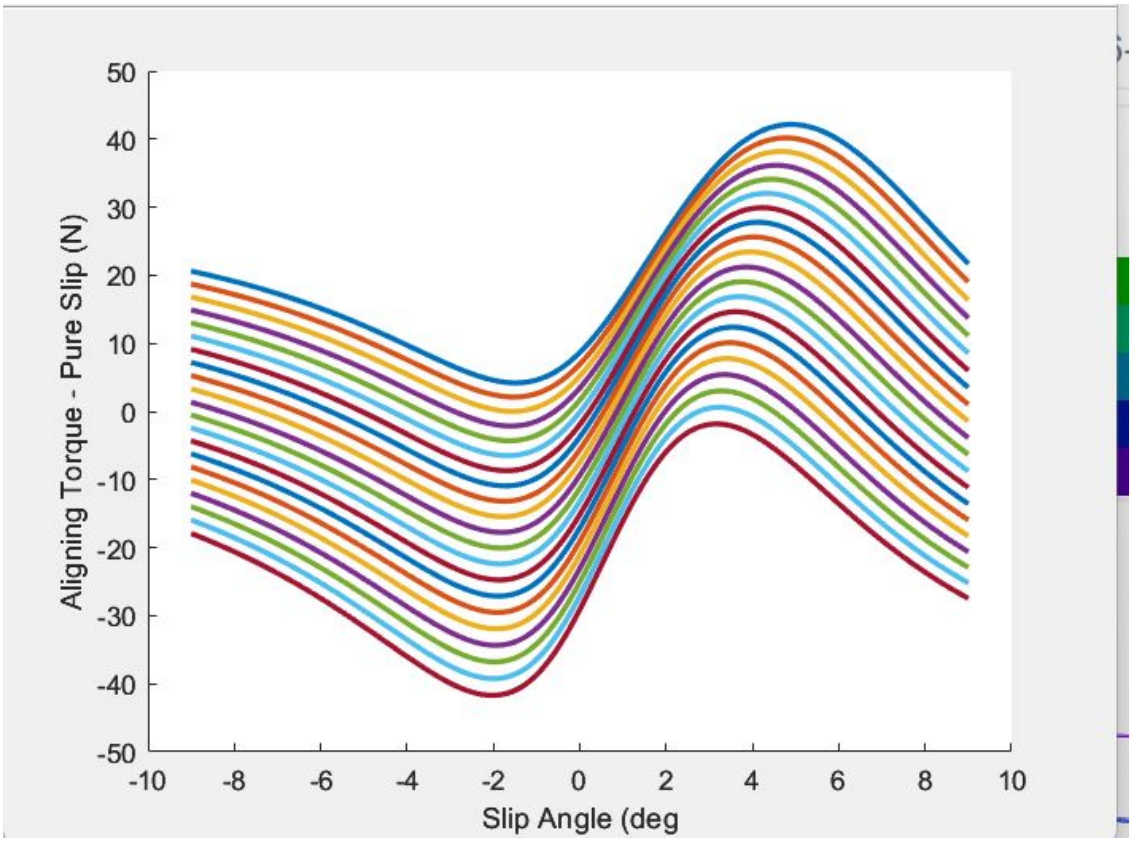
Tire Selection



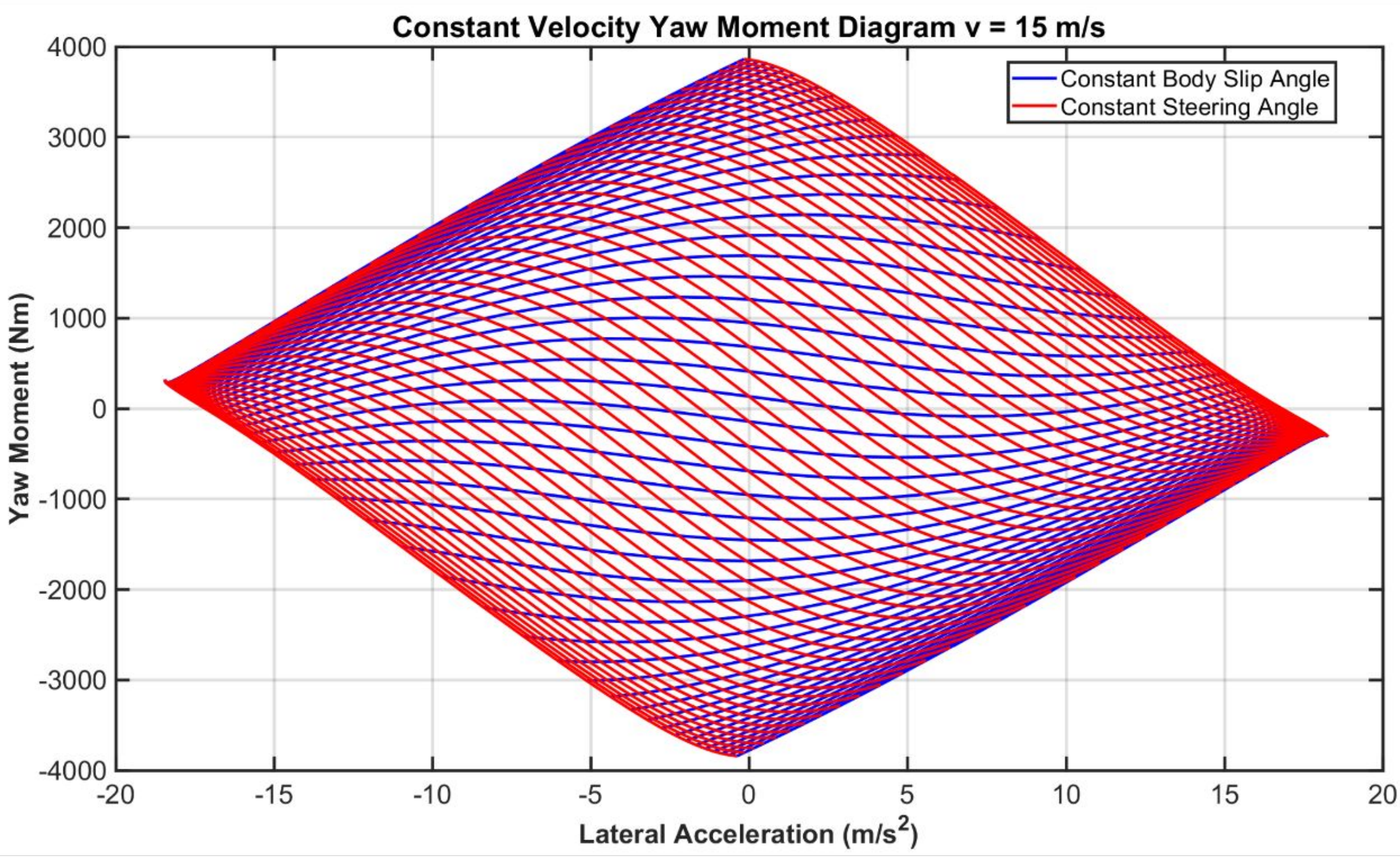




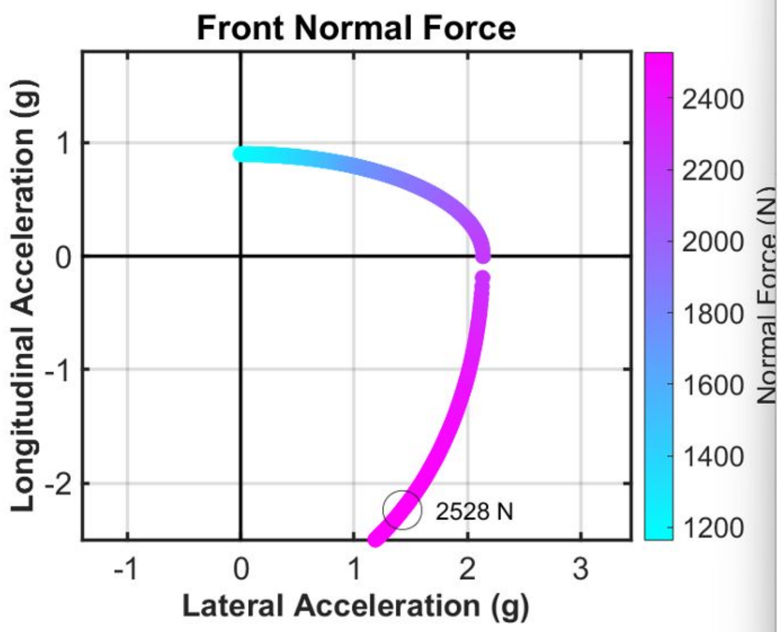
Slip Angle vs Aligning Torque

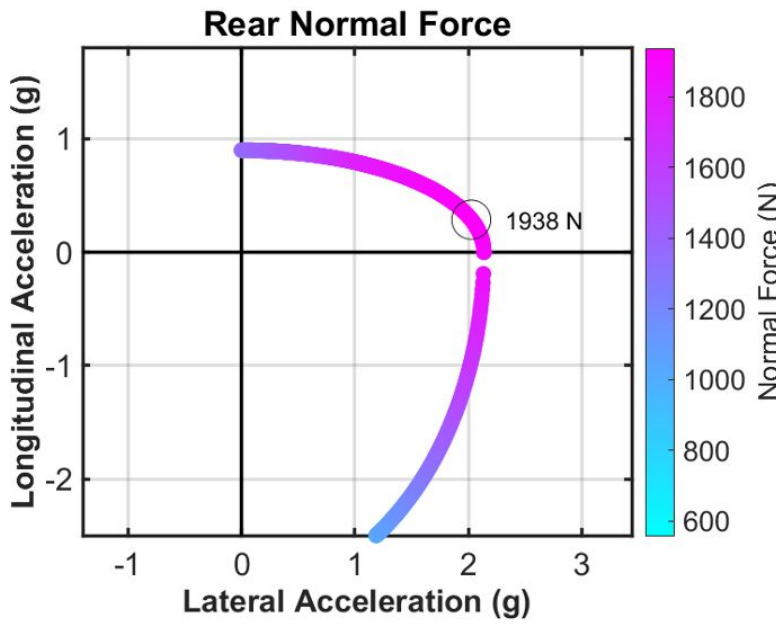


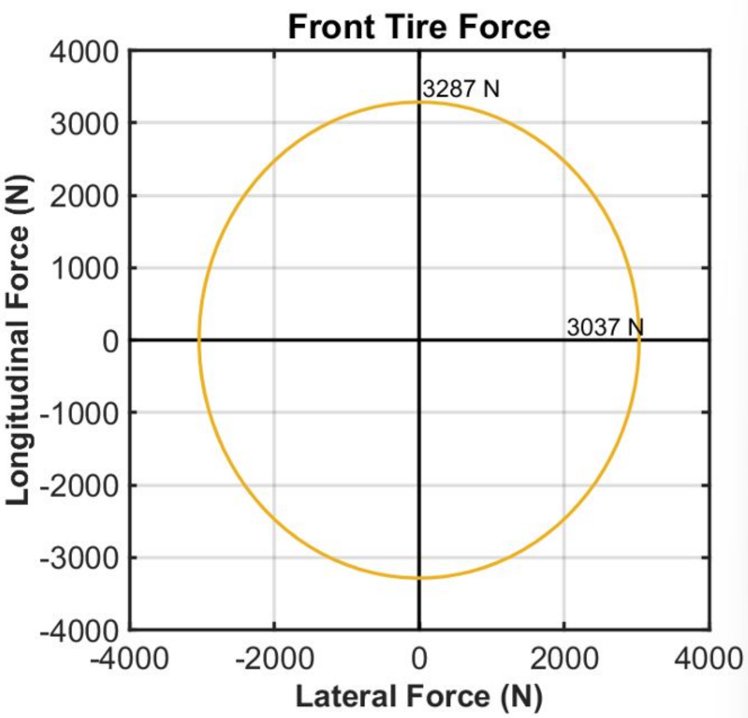
Yaw Moment Diagram

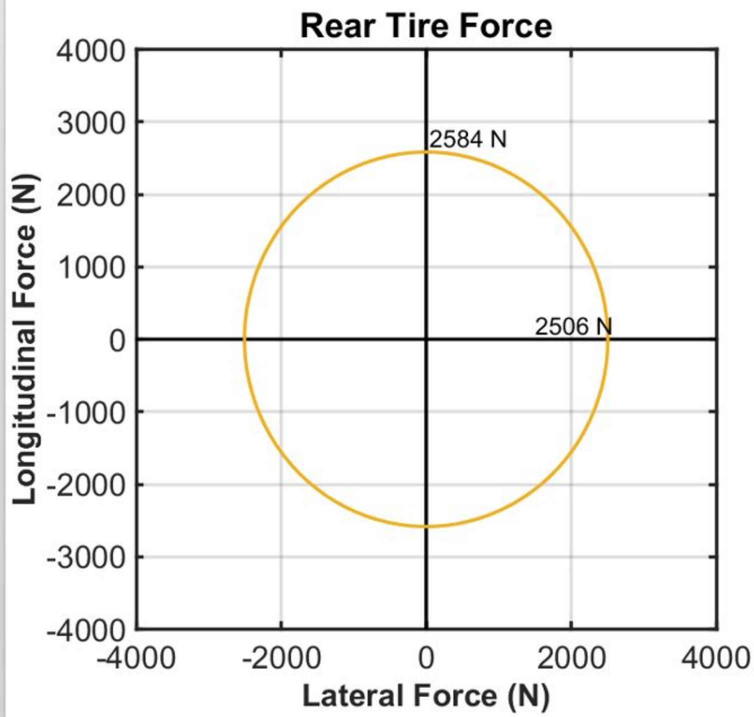


Force CAN





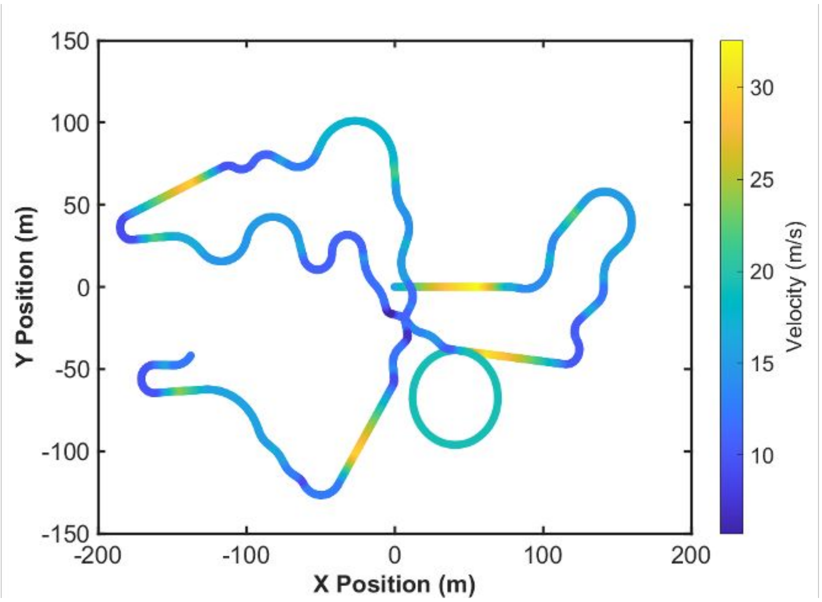


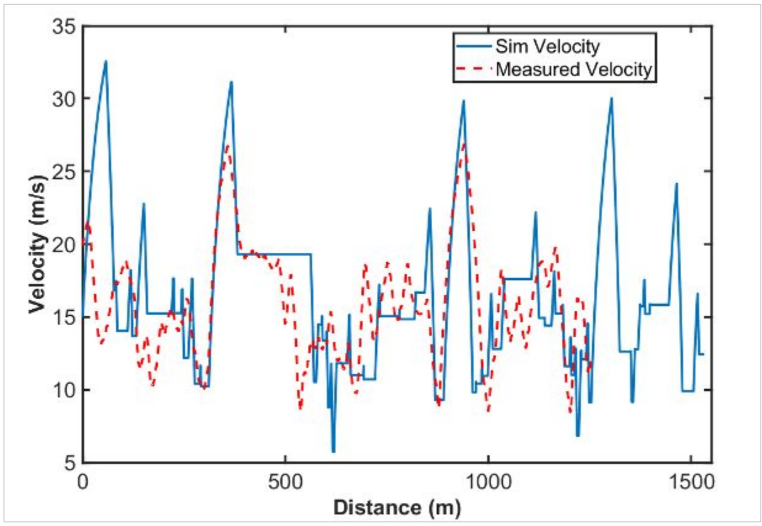


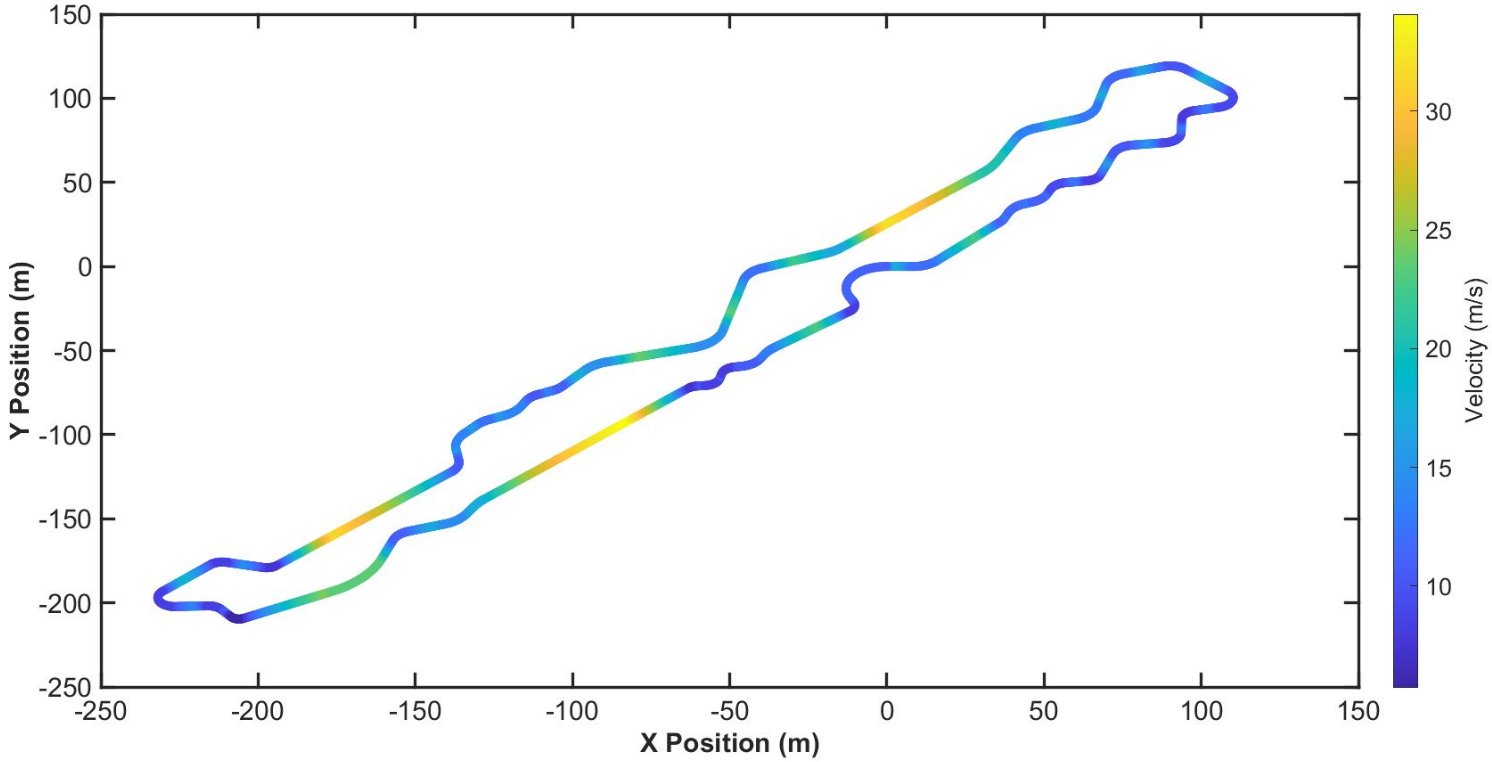
- Max a_y from skidpad sim, Max a_x from accel sim → g-g plot ellipse
- Car parameters + combined accelerations → load transfer and maximum normal forces on tires → plug into tire models to get your max lat and long forces.

Suspension Geometry and A-arms

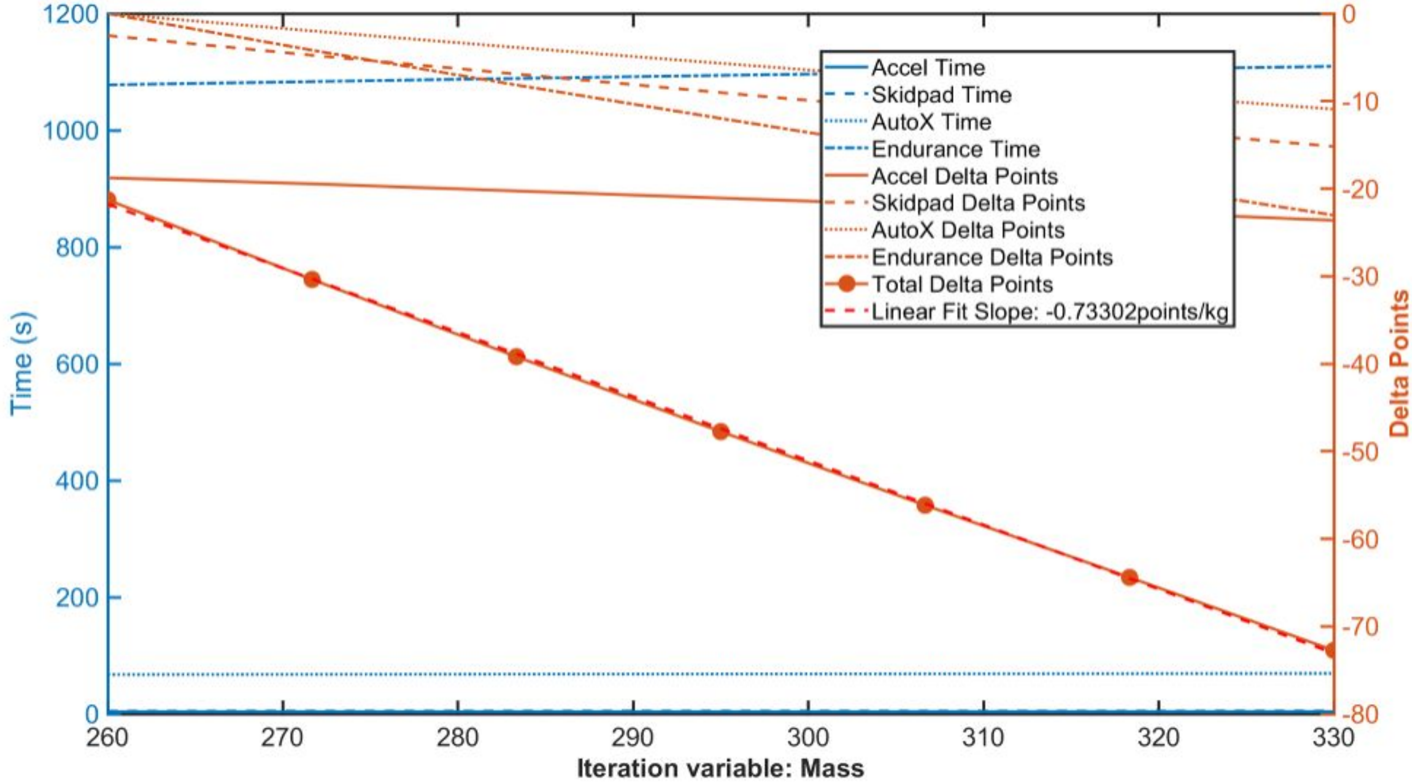
Lap Time Simulations

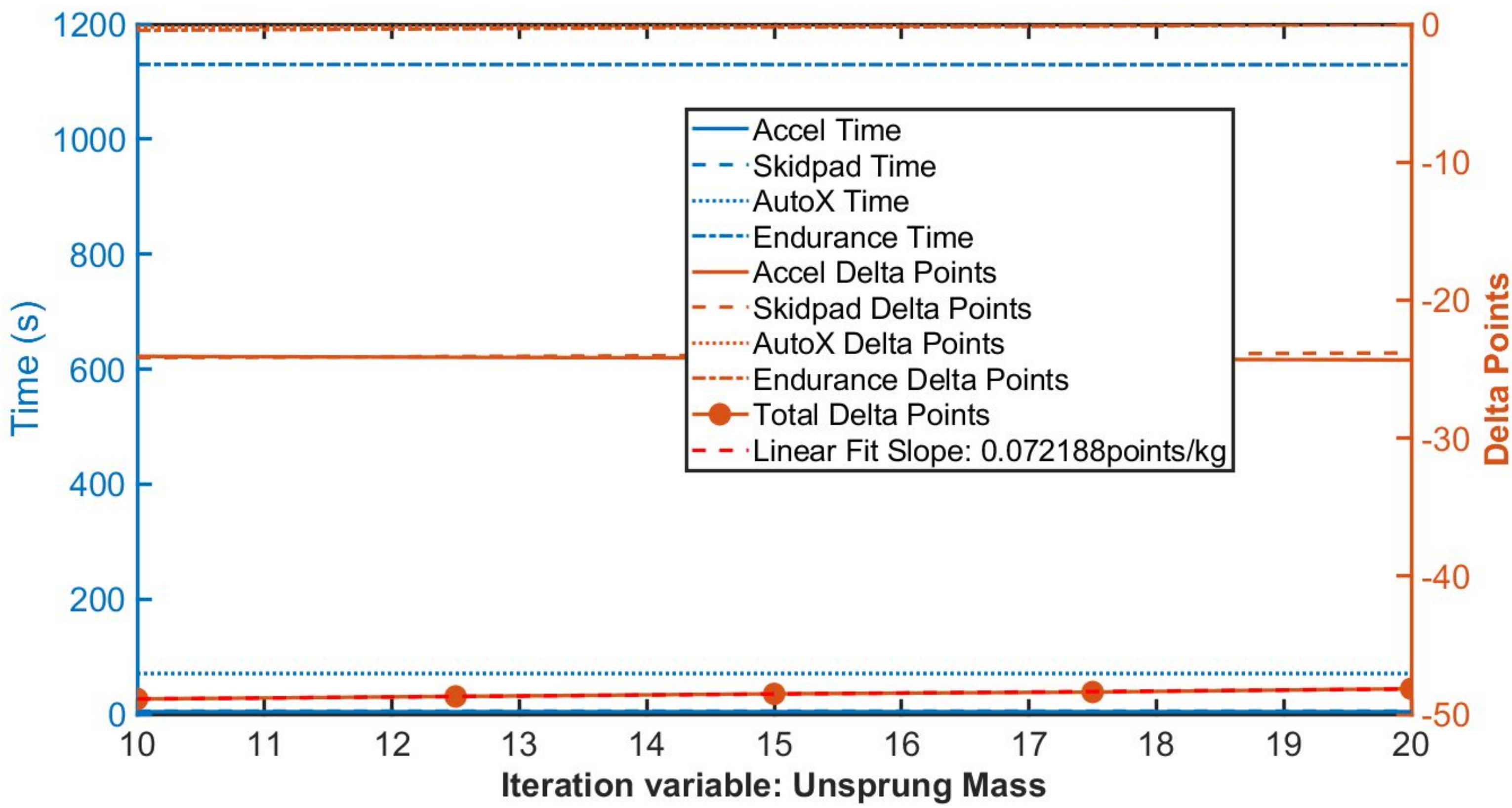






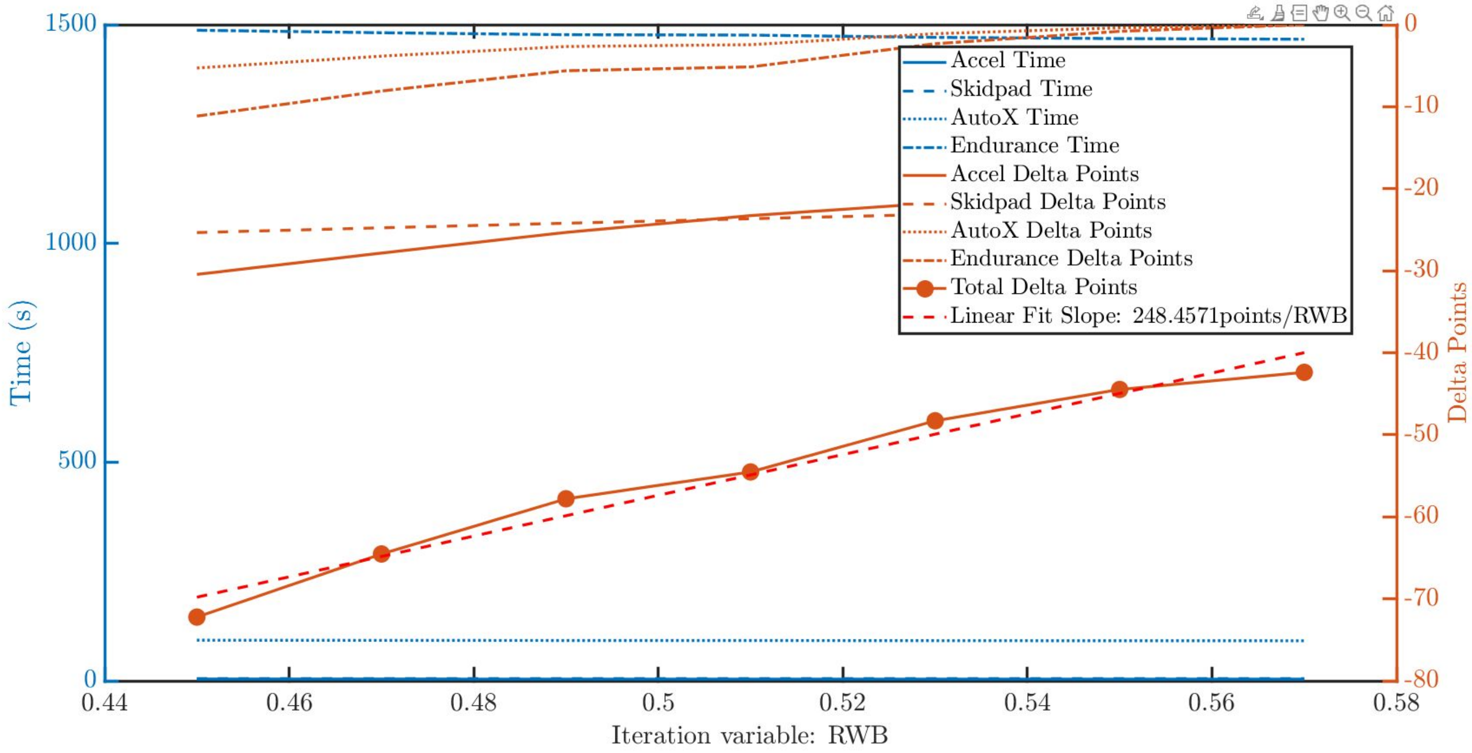
Mass Sensitivity

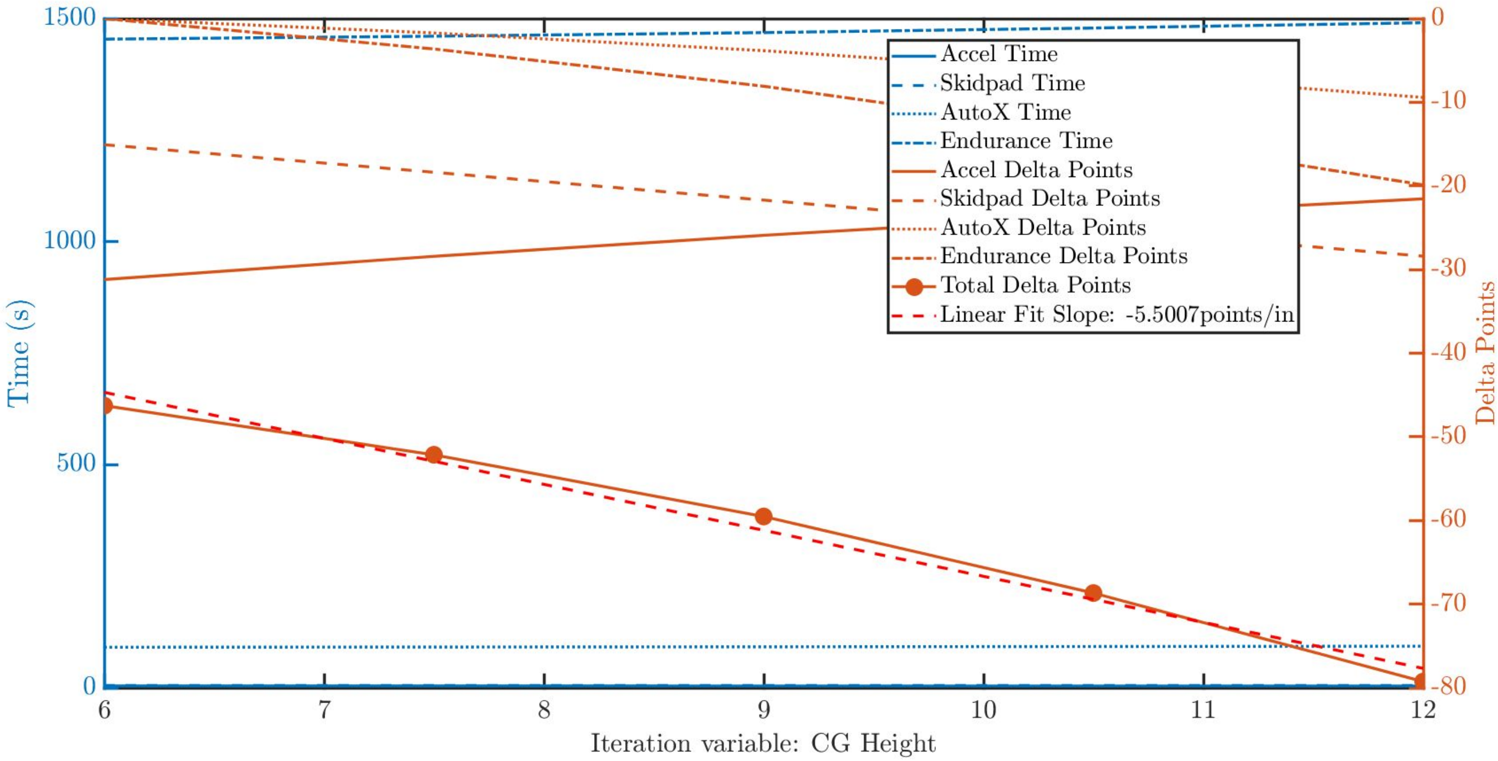




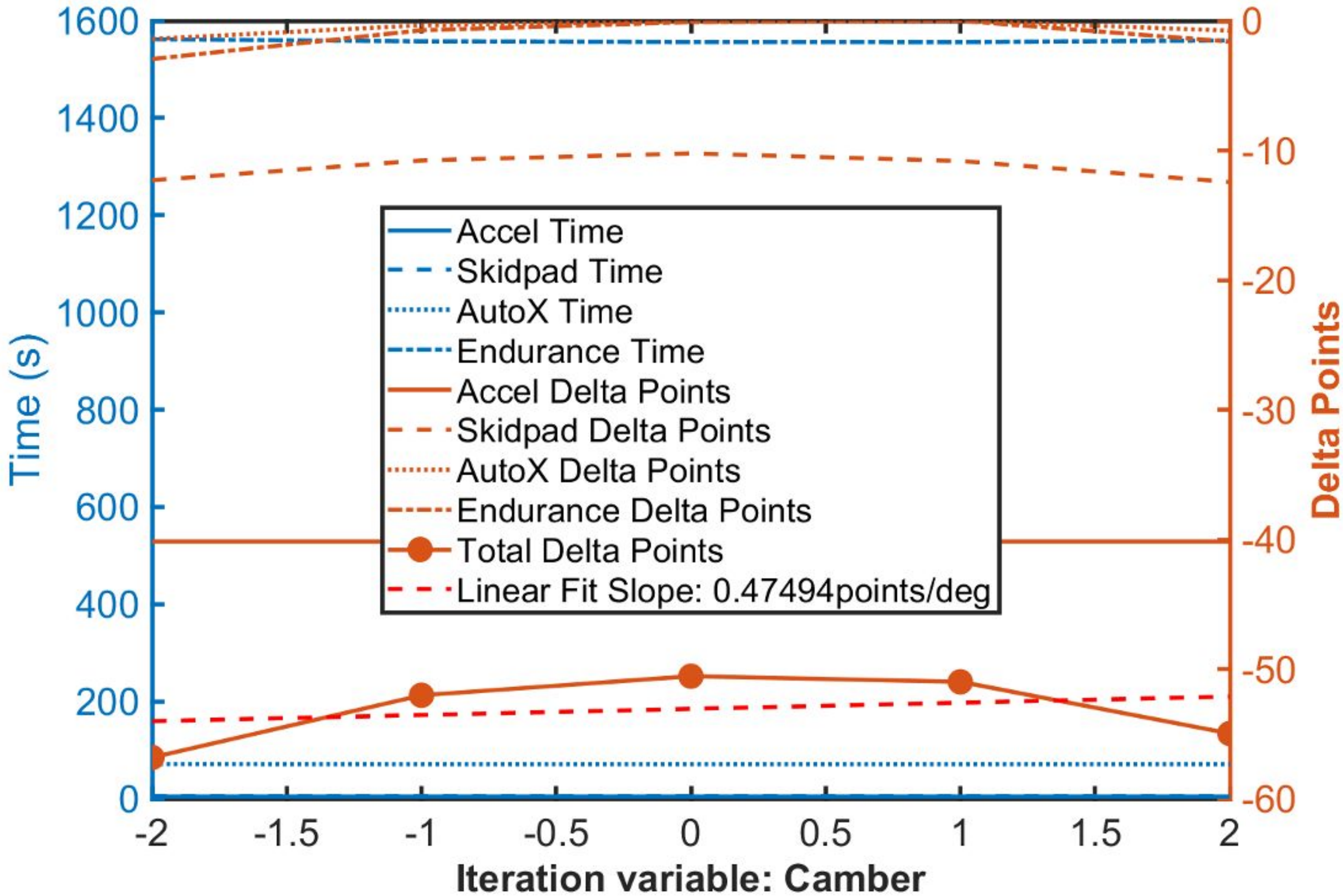
- Does not take into account unsprung mass effects on handling, or increased loads on suspension members

RWB and CG Height

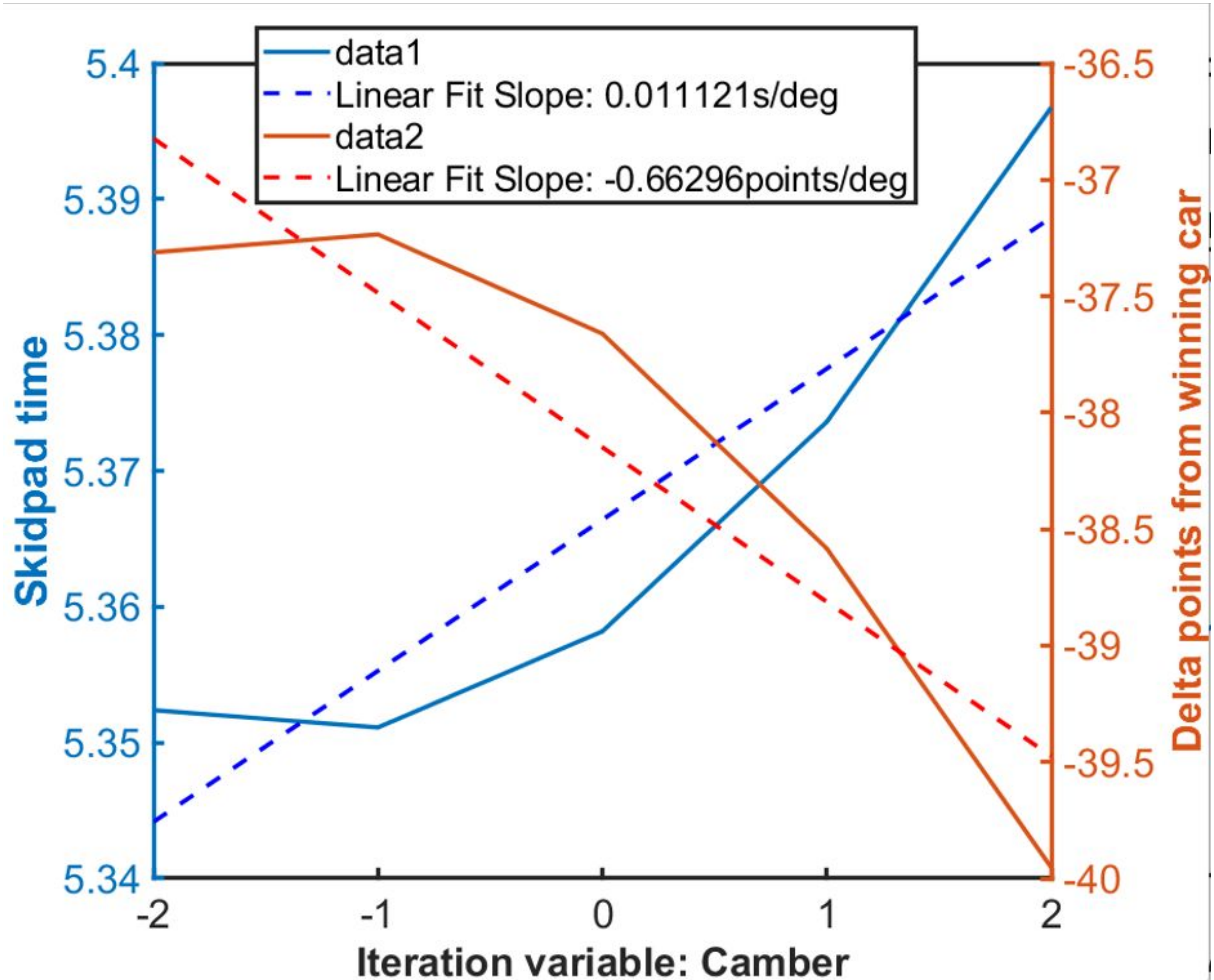




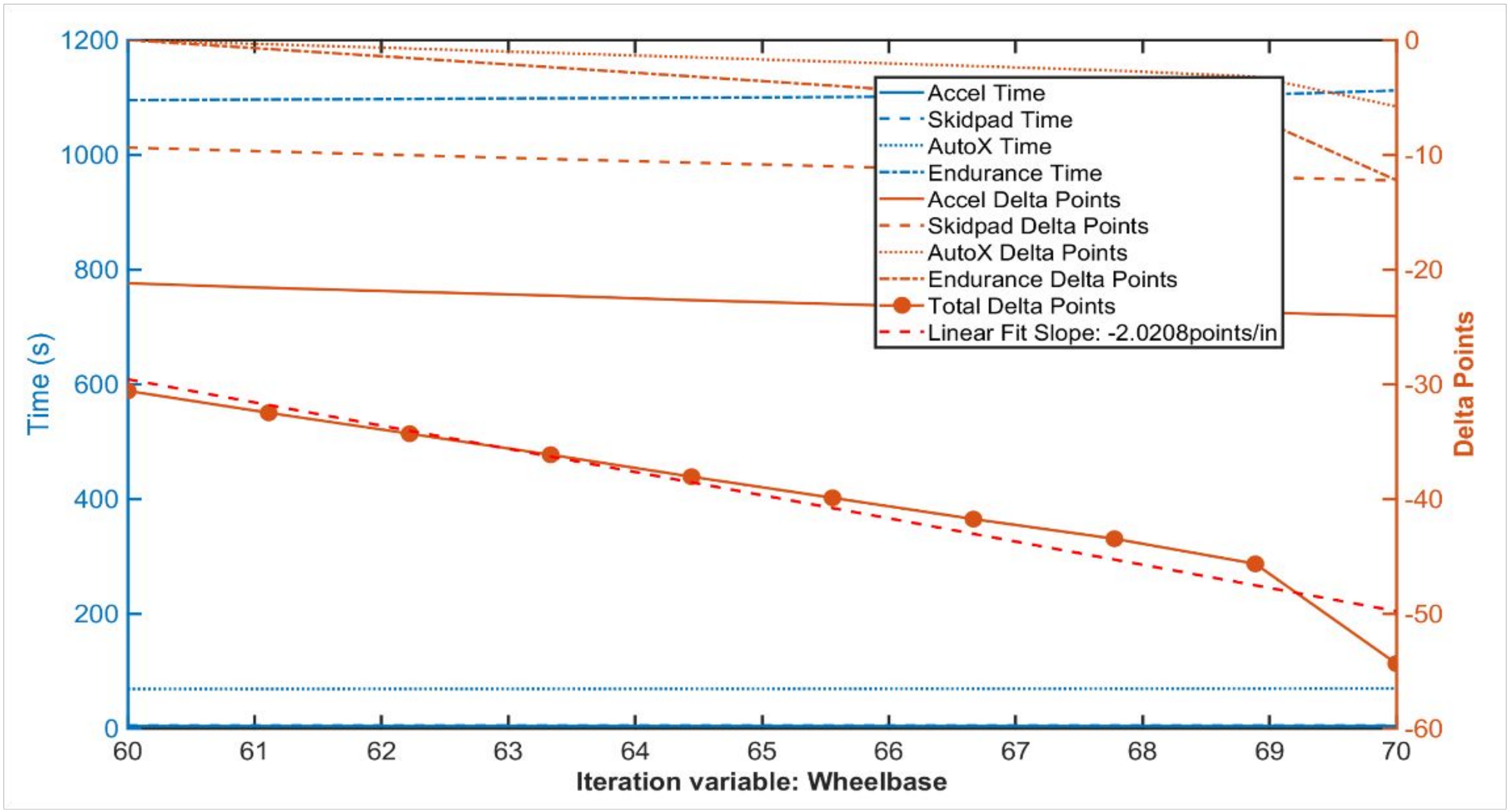
Static Camber

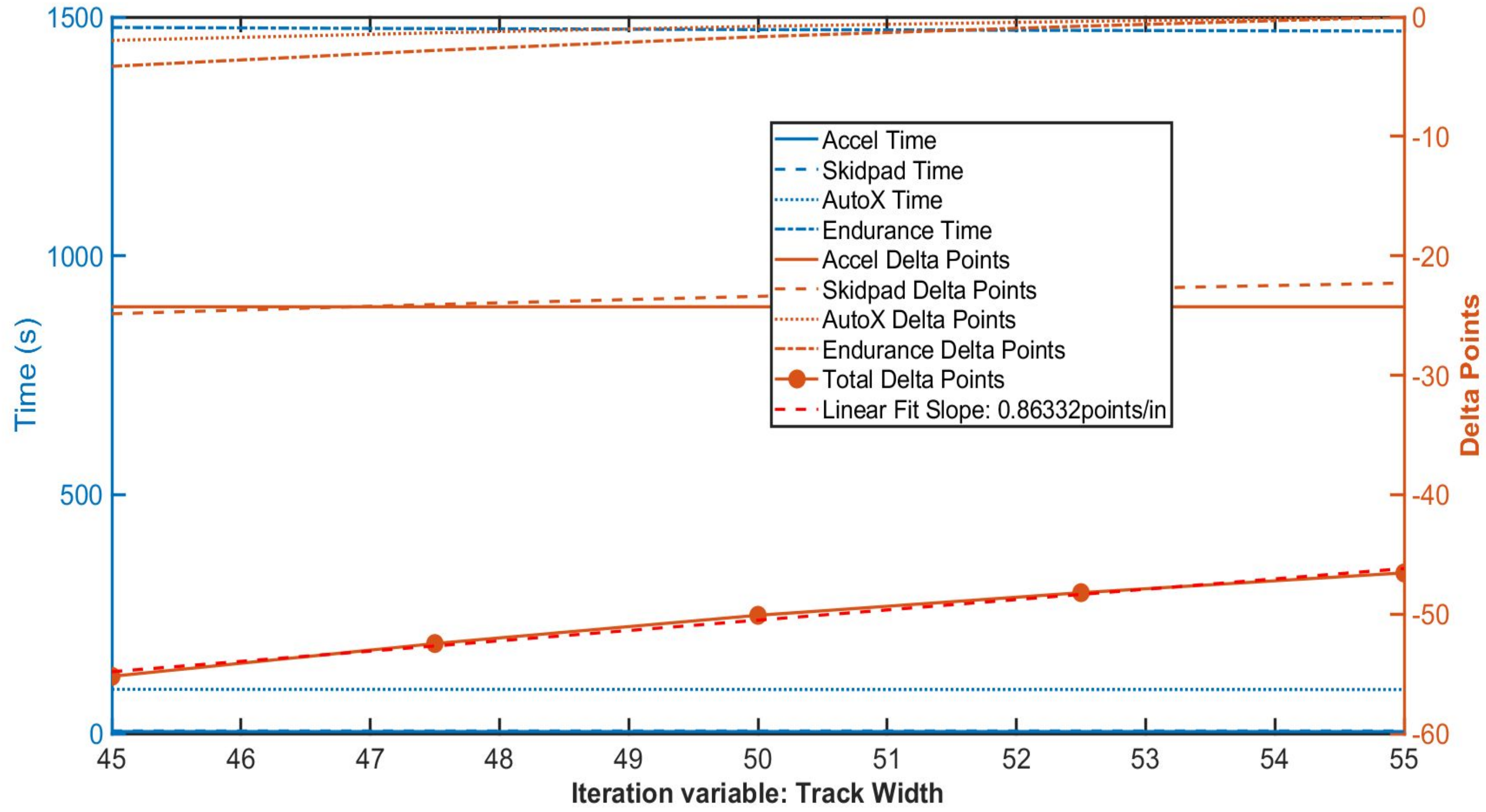


Camber Gain


data1
Linear Fit Slope: 0.011121s/deg
data2
Linear Fit Slope: -0.66296points/deg
Skidpad time
Delta points from winning car
Iteration variable: Camber
5.4
5.39
5.38
5.37
5.36
5.35
5.34
-36.5
-37
-37.5
-38
-38.5
-39
-39.5
-40
-2
-1
0
1
2

Wheel Base and Track Width





Load Cases + Forces Spreadsheet

	Inputs (MY24 SusP) (in mm and z swapped)			**Inputs (MY24 Suspension Points) (in)**		
	Inboard (P1)			Inboard (P1)		
	x	y	z	x	y	z
Up-Fore	1716.469	254.000	284.632	67.578	10.000	-11.206
Up-Aft	1418.651	254.000	282.128	55.852	10.000	-11.107
Low-Fore	1724.563	186.690	139.979	67.896	7.350	-5.511
Low-Aft	1435.786	186.690	139.997	56.527	7.350	-5.512
Push/Pull	1770.431	242.733	203.876	69.702	9.556	-8.027
Tie/Toe	1460.497	144.667	190.798	57.500	5.696	-7.512
	Outboard (P2)			Outboard (P2)		
Up-Fore	1532.400	523.494	290.068	60.331	20.610	-11.420
Up-Aft	1532.400	523.494	290.068	60.331	20.610	-11.420
Low-Fore	1544.899	569.595	141.986	60.823	22.425	-5.590
Low-Aft	1544.899	569.595	141.986	60.823	22.425	-5.590
Push/Pull	1550.187	502.844	272.225	61.031	19.797	-10.718
Tie/Toe	1469.390	521.208	190.800	57.850	20.520	-7.512
	Locations of Applied Forces from Tire					
Fx	1549.400	622.500	0.000			
Fy	1549.400	622.500	0.000		0.901	
Fz	1549.400	622.500	0.000		0.803	
	Calculations					
	Unit Vectors					
Up-Fore	-0.564	0.826	0.017	-326.401	-326.401	-326.401
Up-Aft	0.389	0.921	0.027	-292.624	-292.624	-292.624
Low-Fore	-0.425	0.905	0.005	-422.965	-422.965	-422.965
Low-Aft	0.274	0.962	0.005	-398.153	-398.153	-398.153
Push/Pull	-0.634	0.748	0.197	-347.616	-347.616	-347.616
Tie/Toe	0.024	1.000	0.000			
	Moment Arm (Dist to Moment Cente					
Moment Center	1549.400	0.000	0.000			
Up-Fore	167.069	254.000	284.632			
Up-Aft	-130.749	254.000	282.128			
Low-Fore	175.163	186.690	139.979			
Low-Aft	-113.614	186.690	139.997			
Push/Pull	221.031	242.733	203.876			
Tie/Toe	-88.903	144.667	190.798			
Fx	0.000	622.500	0.000			
Fy	0.000	622.500	0.000			
Fz	0.000	622.500	0.000			
	Applied Forces					
	Force Vectors					
Loadcase #:	18.000	**Combined 2**		Change Load Cases (From 2.000 to 22.000!)		
	x	y	z			
Fx	285.870	0.000	0.000			
Fy	0.000	2858.696	0.000			
Fz	0.000	0.000	1429.348			
	Mx	My	Mz			
M from Fx	0.000	0.000	-177953.807			
M from Fy	0.000	0.000	0.000			
M from Fz	889769.036	0.000	0.000			

Forces Spreadsheet Cont.

=MMULT(MINVERSE(C135:H140),L135:L140)

	Up-Fore	Up-Aft	Low-Fore	Low-Aft	Push/Pull	Tie/Toe						
ΣFx	-0.564	0.389	-0.425	0.274	-0.634	0.024		F_Up-Fore		-285.870	9010.791	Up-Fore
ΣFy	0.826	0.921	0.905	0.962	0.748	1.000		F_Up-Aft		-2858.696	2012.800	Up-Aft
ΣFz	0.017	0.027	0.005	0.005	0.197	0.000		F_Low-Fore		-1429.348	-818.130	Low-Fore
ΣMx	-230.777	-252.936	-125.836	-133.703	-104.828	-190.744	*	F_Low-Aft	=	-889769.036	-5465.820	Low-Aft
ΣMy	-163.296	113.217	-60.291	38.934	-172.632	4.505		F_Push/Pull		0.000	-8151.870	Push/Pull
ΣMz	281.180	-219.149	237.874	-160.425	319.183	-92.294		F_Tie/Toe		177953.807	-55.232	Tie/Toe
			A				*	X	=	b (applied forces)	X = A-1 * b	

Inputs		
m_carPlusDriver	286.750	kg
h_centerOfGravity	0.297	m
Track Width	1.245	m
Wheelbase	1.524	m
r_tireLoaded	0.240	m
gravity constant	9.810	m

2.000	3.000	4.000	5.000	6.000	7.000	8.000	9.000	10.000	11.000	12.000	13.000	14.000	15.000	16.000	17.000	
Loadcase Name	**Failure Mode**	**Long (Gs)** + for accel	**Lat (Gs)** +outside for wheel	**Velocity**	**Aero Down**	**Aero Drag**	**WT_lateral**	**WT_long**	**Fz_%**	**Fx_car**	**Fy_car**	**Fx**	**Fy**	**Fz**	**Fx-Added Height For Driveshafts**	
None	Fatigue											0.000	0.000	0.000	0.000	
Static	Fatigue						0.000	0.000	0.250	0.000	0.000	0.000	0.000	703.254	0.000	
Max Braking	Fatigue	-1.250	0.000				0.000	-685.258	0.128	-3516.272	0.000	-450.782	0.000	360.626		
Max Turn	Fatigue	0.000	2.000				1342.546	0.000	0.489	0.000	5626.035	0.000	2749.054	1374.527		
Max Speed	Fatigue	0.000	0.000				0.000	0.000	0.250	0.000	0.000	0.000	0.000	703.254		
Max Accel	Fatigue	1.000	0.000				0.000	548.206	0.347	2813.018	0.000	977.357	0.000	977.357		
Combined 1	Fatigue	-1.000	1.000				**671.273**	**-548.206**	**0.272**	**-2813.018**	**2813.018**	**-764.788**	**764.788**	**764.788**		
Combined 2	Fatigue	0.200	1.000				671.273	109.641	0.389	562.604	2813.018	218.742	1093.711	1093.711		
	Fatigue						0.000	0.000	0.250	0.000	0.000	0.000	0.000	703.254		
	Fatigue						0.000	0.000	0.250	0.000	0.000	0.000	0.000	703.254		
	Fatigue						0.000	0.000	0.250	0.000	0.000	0.000	0.000	703.254		
	Fatigue						0.000	0.000	0.250	0.000	0.000	0.000	0.000	703.254		
Max Braking	Yield/Buckle	-2.300	0.000				0.000	-1260.874	0.026	-6469.940	0.000	-167.480	0.000	72.817		
Max Turn	Yield/Buckle	0.000	2.000				1342.546	0.000	0.489	0.000	5626.035	0.000	2749.054	1374.527		
Max Speed	Yield/Buckle	0.000	0.000				0.000	0.000	0.250	0.000	0.000	0.000	0.000	703.254		
Max Accel	Yield/Buckle	1.500	0.000				0.000	822.309	0.396	4219.526	0.000	1671.613	0.000	1114.409		
FROM FORCE CAN	Yield/Buckle	0.000	0.000				0.000	0.000	0.508	0.000	0.000	3287.000	3037.000	5000.000		takes f_z f
Combined 2	Yield/Buckle	0.200	2.000				1342.546	109.641	0.508	562.604	5626.035	285.870	2858.696	1429.348		
Max Bump	Yield/Buckle	1.500	0.000				0.000	822.309	0.000	4219.526	0.000	0.000	0.000	5000.000		
	Yield/Buckle						0.000	0.000	0.250	0.000	0.000	0.000	0.000	703.254		
Inside No WT	Yield/Buckle	0.000	-2.000				0.000	0.000	0.250	0.000	-5626.035	0.000	-1406.509	703.254		
Reverse Braking	Yield/Buckle	1.750	0.000				0.000	959.361	0.421	4922.781	0.000	2070.136	0.000	1182.935		

	Up-Fore	**Up-Aft**	**Low-Fore**	**Low-Aft**	**Push/Pull**	**Tie/Toe**	
	9010.791	2012.800	-818.130	-5465.820	-8151.870	-55.232	
1.000	81.068	21.817	35.521	-69.032	-90.355	-0.185	
2.000	3812.228	-65.856	289.163	-600.565	-3882.198	133.846	
3.000	2398.112	-468.393	-1161.486	885.474	-1967.052	123.204	
4.000	8935.489	1670.551	-1585.502	-4528.376	-7824.750	-19.836	
5.000	3812.228	-65.856	289.163	-600.565	-3882.198	133.846	
6.000	4337.136	850.796	3241.624	-3422.188	-5446.769	67.703	
7.000	5310.708	-308.432	-2505.981	438.417	-4247.545	159.840	
8.000	6304.328	824.319	229.629	-2847.736	-6143.413	69.709	
9.000	3812.228	-65.856	289.163	-600.565	-3882.198	133.846	
10.000	3812.228	-65.856	289.163	-600.565	-3882.198	133.846	
11.000	3812.228	-65.856	289.163	-600.565	-3882.198	133.846	
12.000	3812.228	-65.856	289.163	-600.565	-3882.198	133.846	
13.000	559.401	-168.295	-456.679	381.217	-393.163	34.133	
14.000	8935.489	1670.551	-1585.502	-4528.376	-7824.750	-19.836	
15.000	3812.228	-65.856	289.163	-600.565	-3882.198	133.846	
16.000	4397.462	1507.330	5315.169	-5377.264	-6239.872	9.745	
17.000	25512.217	4688.671	9230.471	-16678.127	-28036.350	242.799	
18.000	9010.791	2012.800	-818.130	-5465.820	-8151.870	-55.232	
19.000	27104.191	-468.224	2055.890	-4269.897	-27601.665	951.619	
20.000	3812.228	-65.856	289.163	-600.565	-3882.198	133.846	
21.000	3052.760	-986.422	1389.521	1115.740	-3760.991	277.841	
22.000	4377.093	1885.148	6501.271	-6490.868	-6639.128	-25.455	
Fatigue (only in tensio	81.068	-468.393	-2505.981	-4528.376	-7824.750	-19.836	N
Buckling	27104.191	4688.671	9230.471	1115.740	0.000	951.619	N
Compression	27104.191	4688.671	9230.471	1115.740	0.000	951.619	N
Tens	0.000	-986.422	-2505.981	-16678.127	-28036.350	-55.232	N
OD	**0.500**	**0.500**	**0.625**	**0.625**	**0.500**	**0.500**	in
Wall	**0.065**	**0.065**	**0.065**	**0.065**	**0.065**	**0.065**	in
Length						m	

Load Case 19

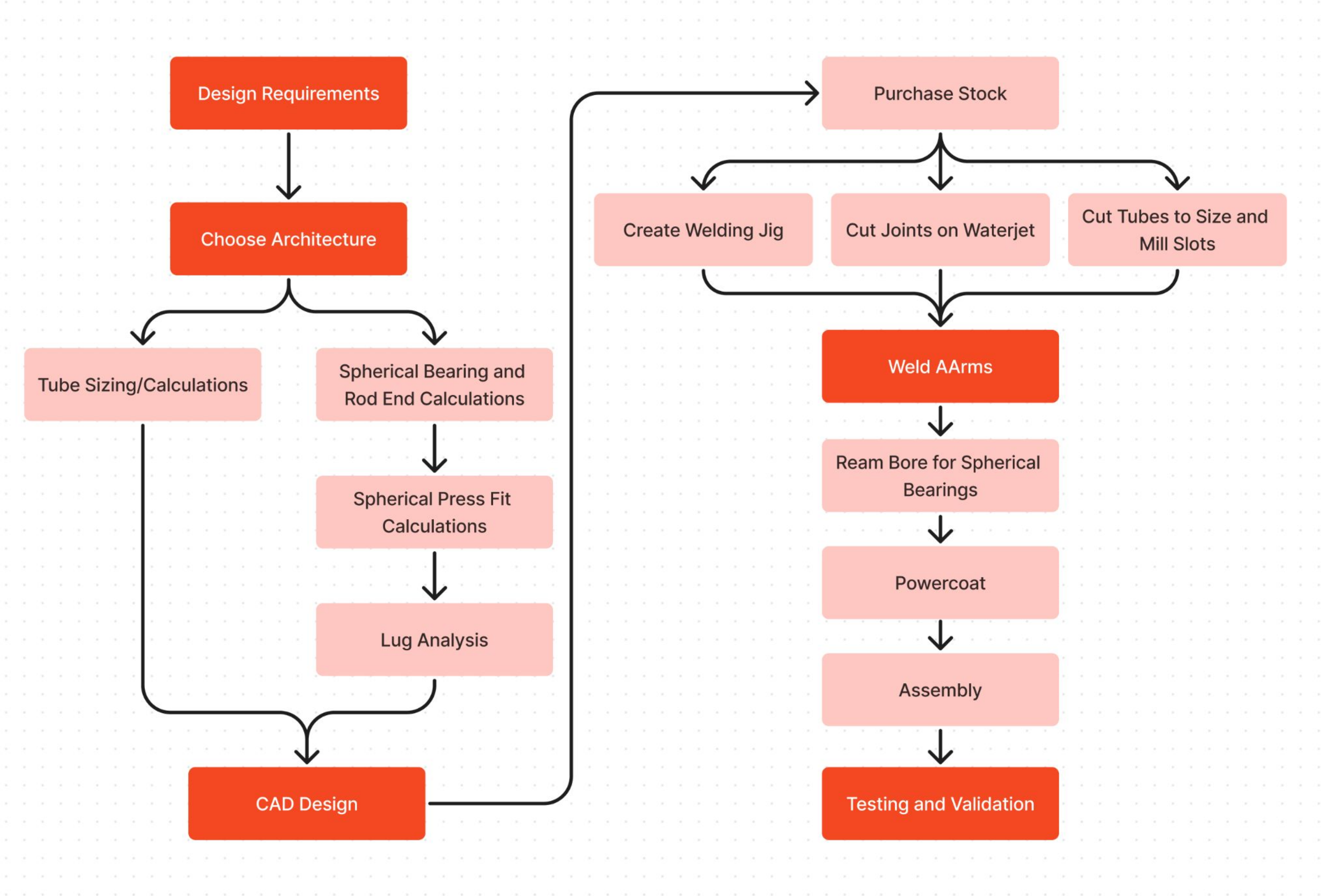
Force Components

	Up-Fore	Up-Aft	Low-Fore	Low-Aft	Push/Pull	Tie/Toe	Units
X	-14387.198	1822.580	-3920.859	-4570.618	17763.362	5.733	N
Y	21064.217	4318.061	8356.228	-16039.402	-20978.835	242.731	N
Z	424.858	127.222	43.791	-83.309	-5512.563	0.001	N

MAX LOADS		**UBJ**	**LBJ**	Units
	X	5198.744	-8491.476	N
	Y	4403.443	-7683.174	N
	Z	-4960.483	-39.519	N

Sanity Check	UBJ+LBJ+toe
	-3287.000
	-3037.000
	-5000.000

AArms Flow Chart



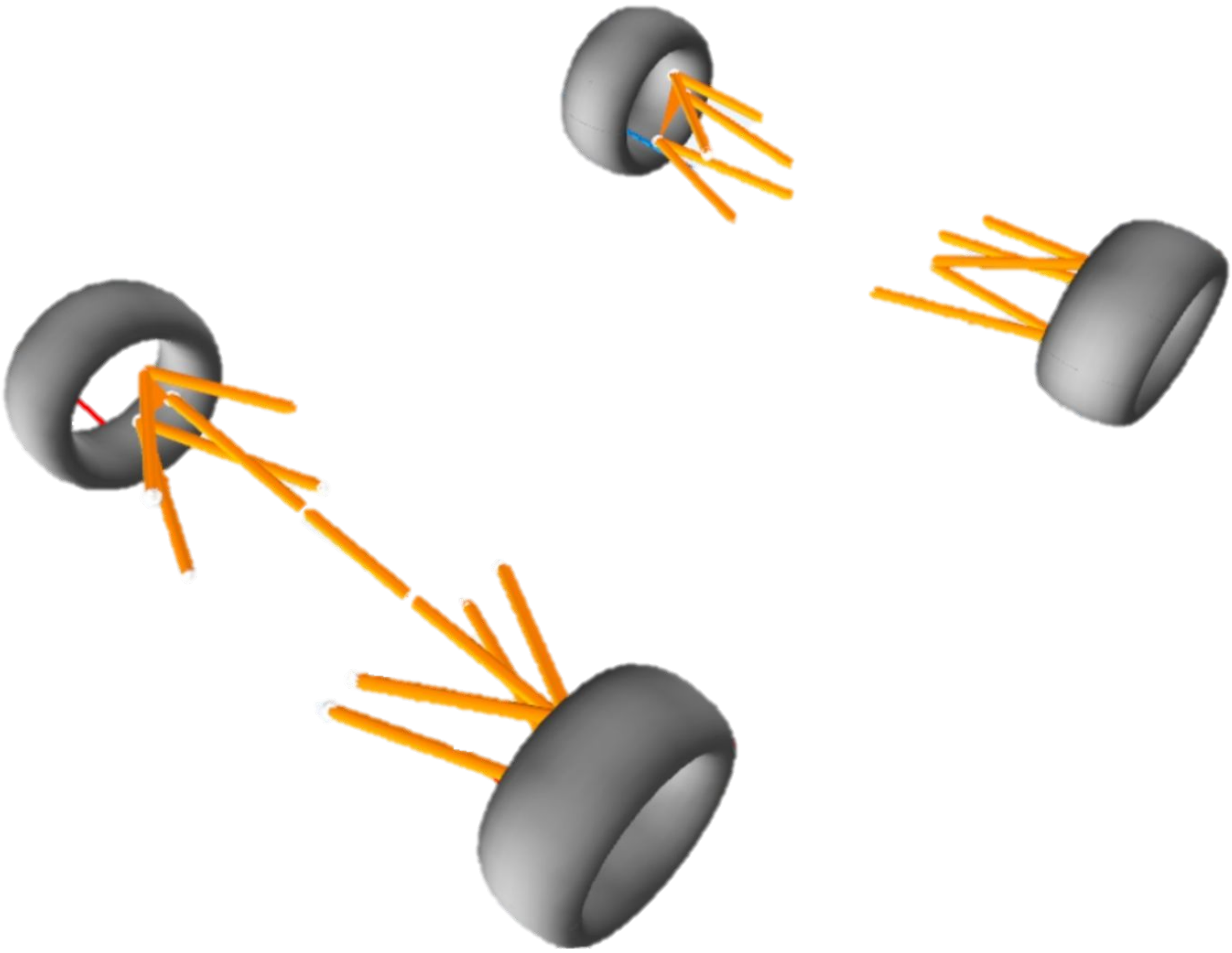
A-arm Sizing Spreadsheet

STEEL	STEEL	STEEL	STEEL	STEEL	STEEL	STEEL
Elastic/Youngs Modulus (Pa)	Yield Strength (Pa)	Factor of Safety	Pullrod Moment Arm (in)	Pullrod Moment Arm (m)	Density (kg/m^3)	Pi
2E+11	4.14E+08	1.5	1.08	0.027432	7833.413	3.1415
	x		x			
A-Arm Member Data	**Tensile Load (N)**	**Compressive Load (N)**	**Length From CAD (mm)**	**Length (m)**	**Z Component of Pull-rod**	**Max Vertical Force Exerted By Pullrod Moment (N)**
Up-Fore	0.000	27104.191	237.510	0.238	0.180	582.765
Up-Aft	986.422	4688.671	210.060	0.210	0.169	620.547
Low-Fore	2505.981	9230.471	353.162	0.353		
Low-Aft	16678.127	1115.740	328.310	0.328		
Pullrod	28036.350	0.000	302.200	0.302	0.000	
Tierod	55.232	951.619	335.890	0.336		
	x	x	x	x	x	
Stress Type By Member	**Axial Stress (Pa)**	**Bending Stress Due to Pullrod (Pa)**	**Shear Stress Due to Pullrod (Pa)**	**Von Mises Stress (Pa)**		**Von Mises Margin**
Up-Fore	1.266E+08	1.291E+08	2.723E+06	2.54E+08		0.085
Up-Aft	2.691E+07	1.423E+08	3.561E+06	1.68E+08		0.648
Low-Fore	2.725E+08			2.72E+08		0.013
Low-Aft	2.502E+08			2.50E+08		0.103
Pullrod	1.891E+08			1.89E+08		0.460
Tierod	2.404E+07			2.40E+07		10.481
	F/A	My/E	F_z/A	$\sigma' = (\sigma_x^2 - \sigma_x\sigma_y + \sigma_y^2 + 3\tau_{xy}^2)^{1/2}$		
Stress Type By Member	**Euler Buckling SMA Required (m^4)**	$P_{cr} = \frac{\pi^2 EI}{l^2}$	**Euler Buckling Margin**		**Adjusted Lengths for Weight (m)**	**Weight of Each Tube (kg)**
Up-Fore	7.746E-10		10.717		0.199	0.334
Up-Aft	1.048E-10		73.009		0.172	0.235
Low-Fore	5.833E-10		0.115		0.315	0.084
Low-Aft	6.093E-11		18.106		0.290	0.152
Pullrod	0.000E+00		#DIV/0!			
Tierod	5.439E-11		20.401			
	x		x			
Stress Type By Member (Eccentric Buckling)	**Max stress for eccentricity 0.005**	**Max stress for eccentricity 0.015**	**Max stress for eccentricity 0.025**	Units	**Eccentric Buckling Margin**	
Up-Fore	1.279E+08	1.305E+08	1.345E+08	Pa	1.053	
Up-Aft	2.213E+07	2.257E+07	2.301E+07	Pa	10.996	
Low-Fore	2.788E+08	2.916E+08	3.044E+08	Pa	-0.093	
Low-Aft	1.701E+07	1.689E+07	1.810E+07	Pa	14.246	

Rod End Sizing

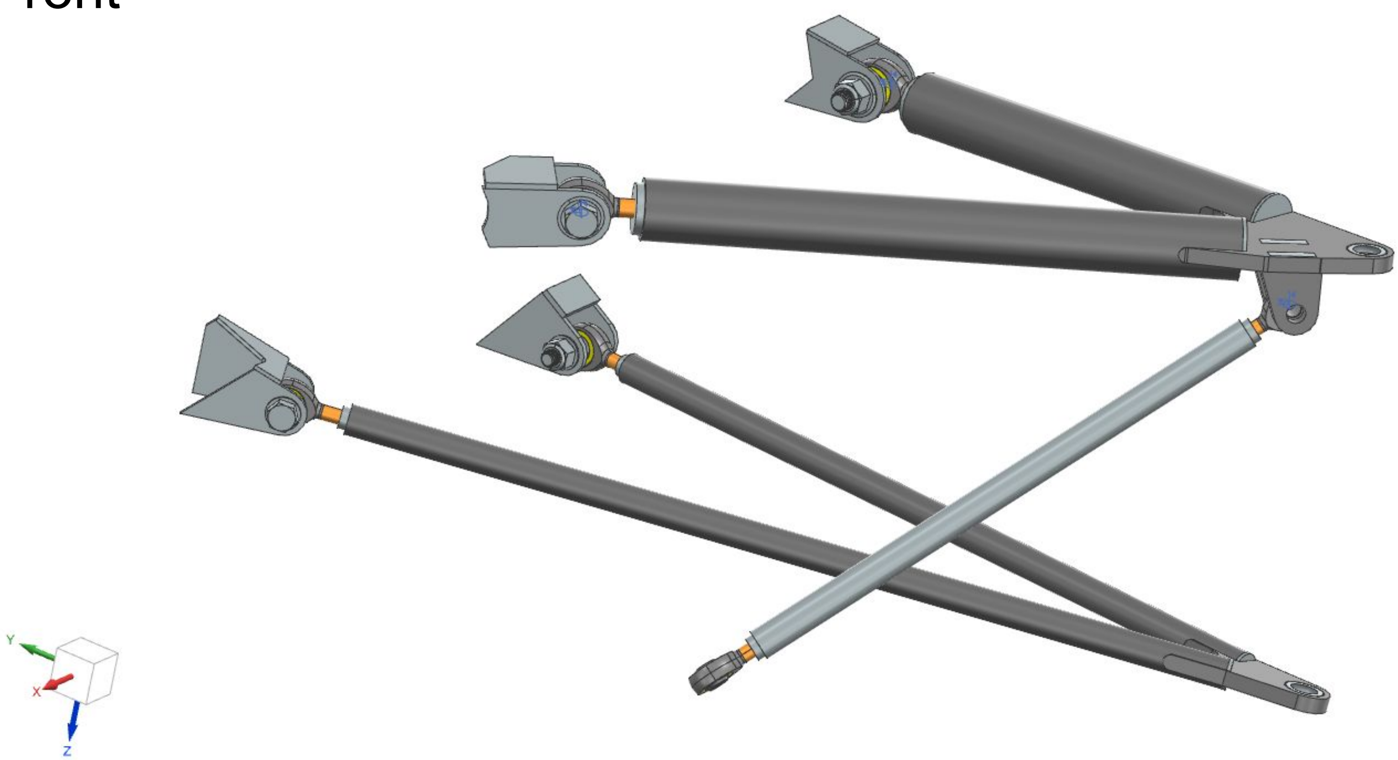
Calculations	Front Up-Fore	Front Up_Aft	Rear Up-Fore	Rear Up-Aft	Units
Yield Strength	7.65E+08	4.15E+08	6.87E+08	6.87E+08	Pa
Tab Distance d from CAD	1.08	0.5538	1.12	0.696	in
Tab Distance d from CAD	0.0274	0.0141	0.0284	0.0177	m
Control Arm Length Point-to-Point from CAD	12.8508	11.52	12.33	10.09	in
Control Arm Length Point-to-Point from CAD	0.3264	0.2926	0.3132	0.2563	m
Lowercase L **from Rod End Specs**	0.0273	0.0246	0.0222	0.0222	m
Rod End Minor Radius **from Rod End Specs**	0.0048	0.0041	0.0033	0.0033	m
Maximum Pull Rod Tension	28036	28036	9089	9089	N
Pull Rod Z component	5046	4752	5068	4675	N
Maximum Tube Force	27104	9230	9817	2696	N
Area Moment of Inertia	4.09E-10	2.25E-10	9.54E-11	9.54E-11	m^4
Cross Sectional Area	7.17E-05	5.32E-05	3.46E-05	3.46E-05	m^2
R_z Reaction Force	262	87	87	261	N
Bending Moment at Cross-Section	7.2	2.1	1.9	5.8	N*m
Bending Stress	8.35E+07	3.93E+07	6.75E+07	2.02E+08	Pa
Shear Stress	3.65E+06	1.64E+06	2.52E+06	7.55E+06	Pa
Normal Stress	3.78E+08	1.74E+08	2.84E+08	7.79E+07	Pa
Von Mises Stress	4.62E+08	2.13E+08	3.51E+08	2.80E+08	Pa
Factor of Safety	1.5	1.5	1.5	1.5	
Margin	0.104470087	0.298103381	0.304838672	0.634090017	
Test	**RSMX6**	**JMX6**	**JMX5**	**JMX5**	

Suspension Geometry

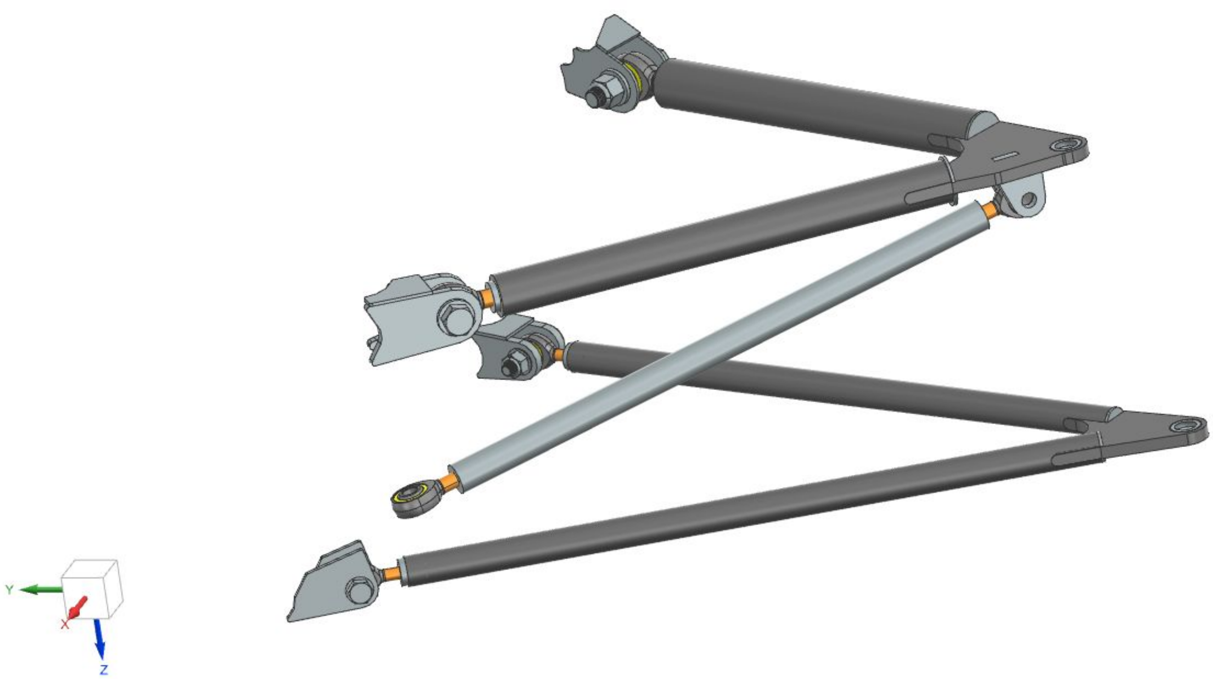


A-arm CAD

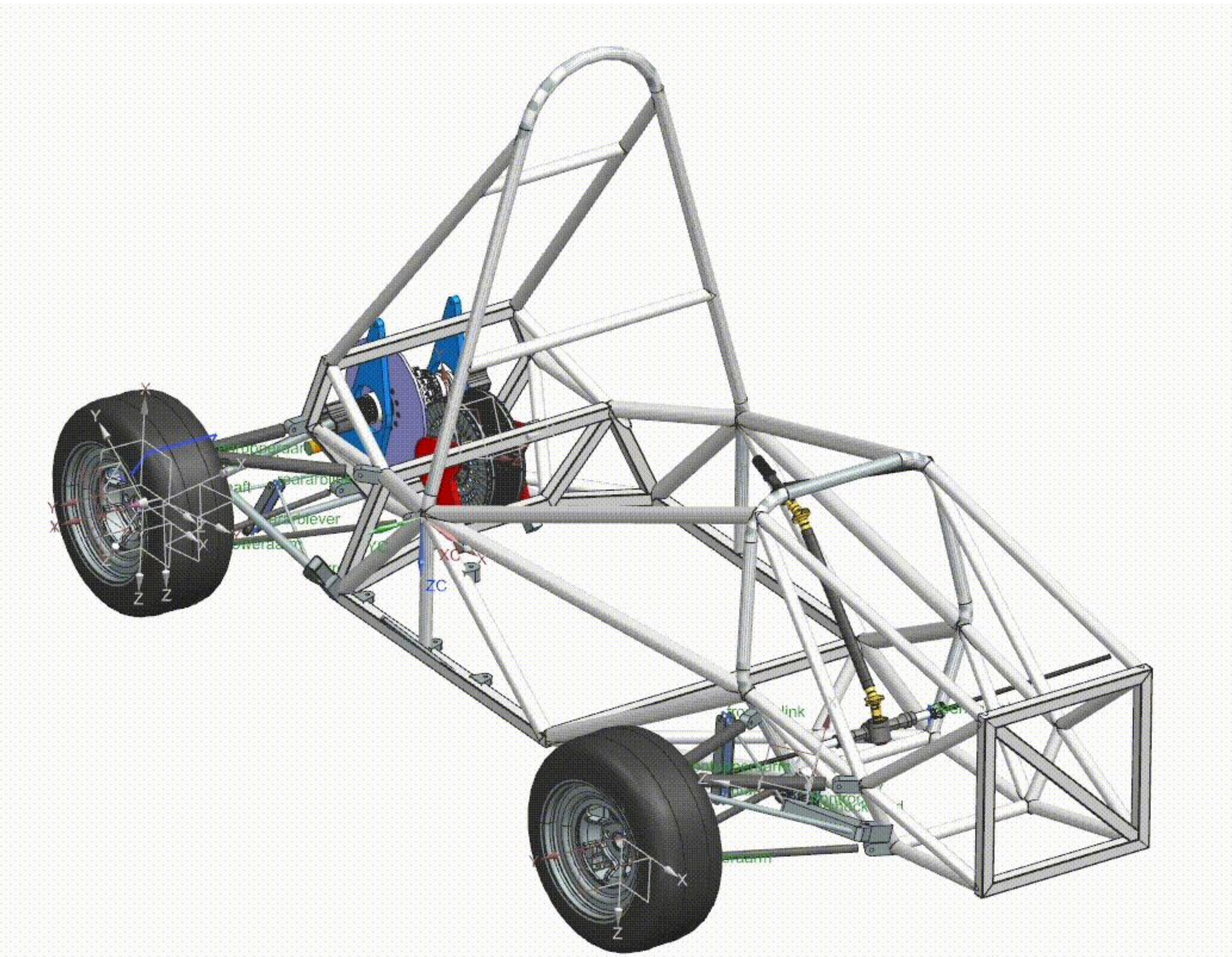
Front



Rear

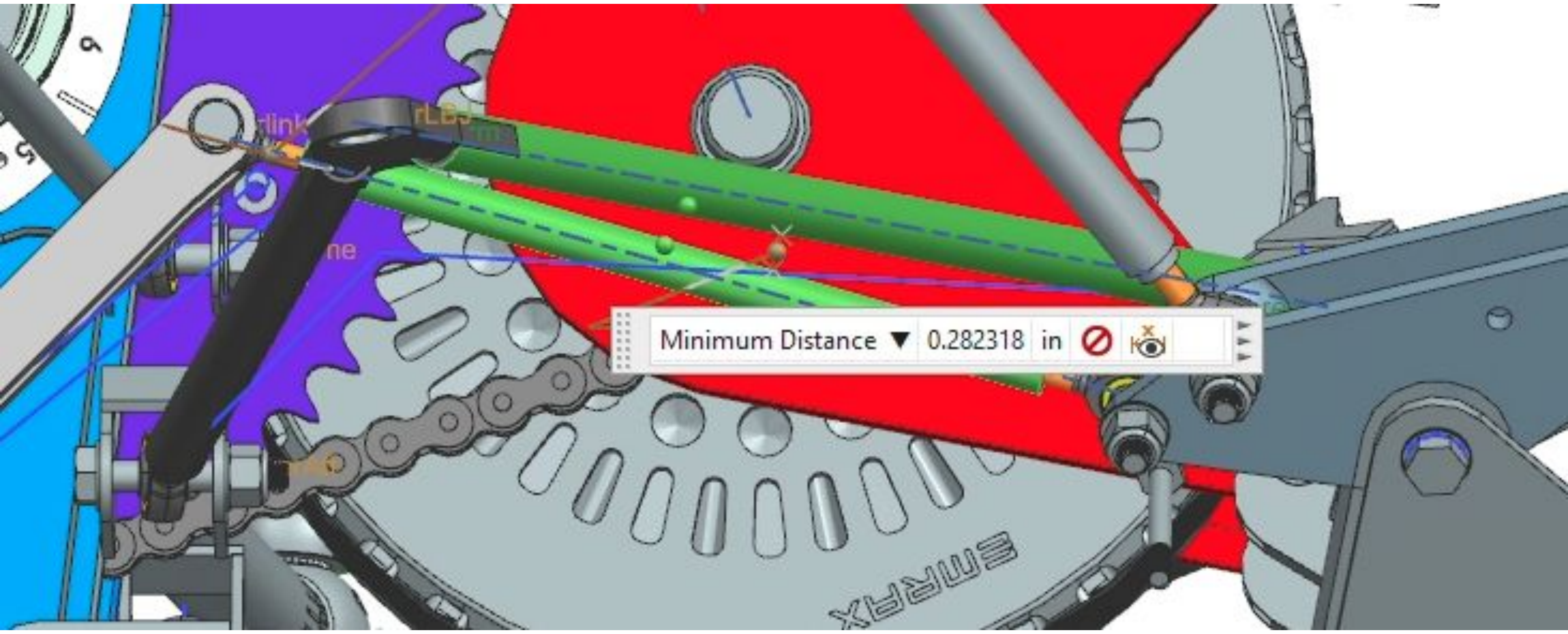


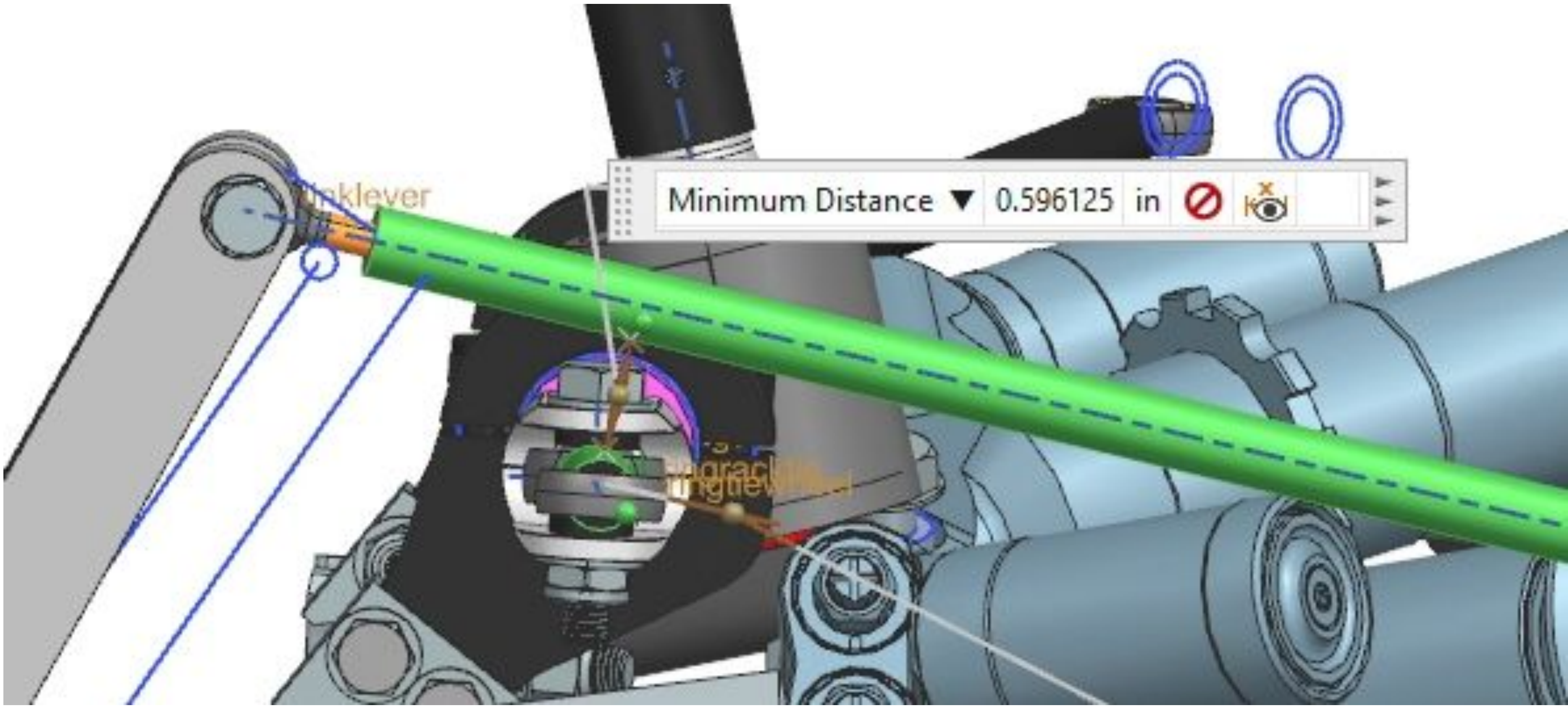
Motion Analysis



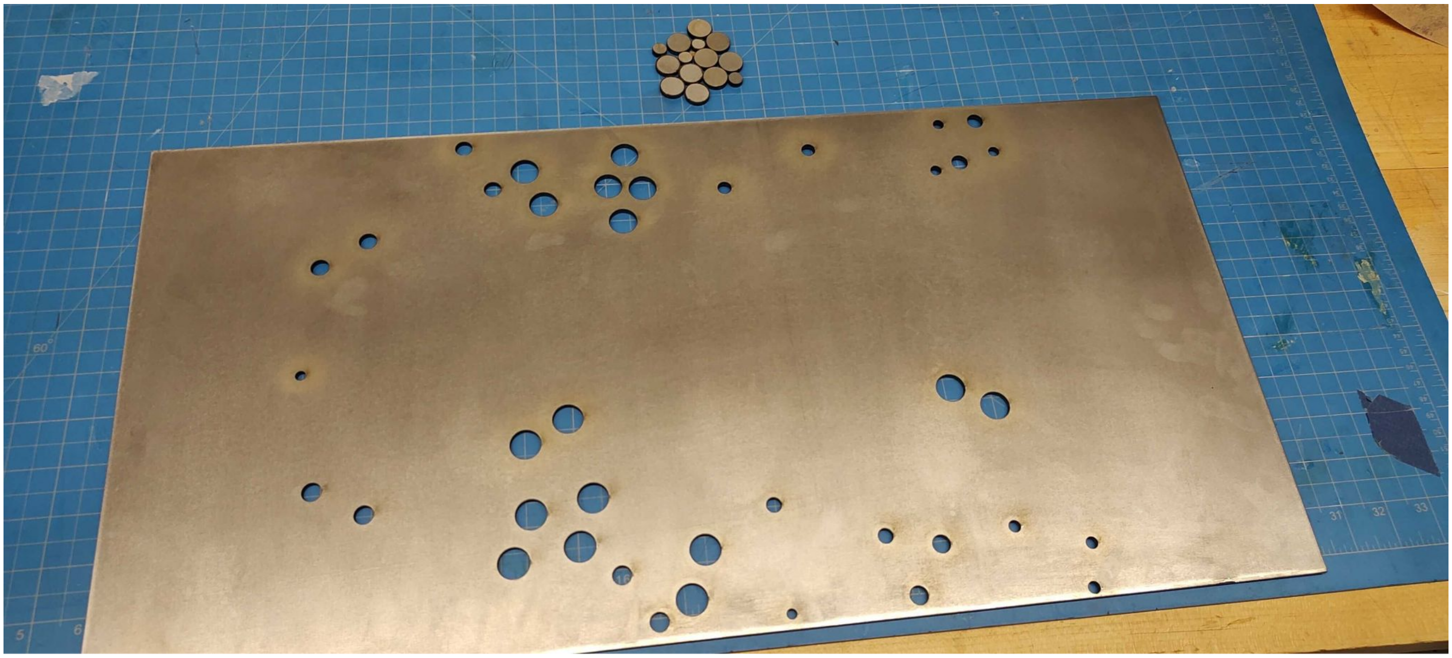
Clearances

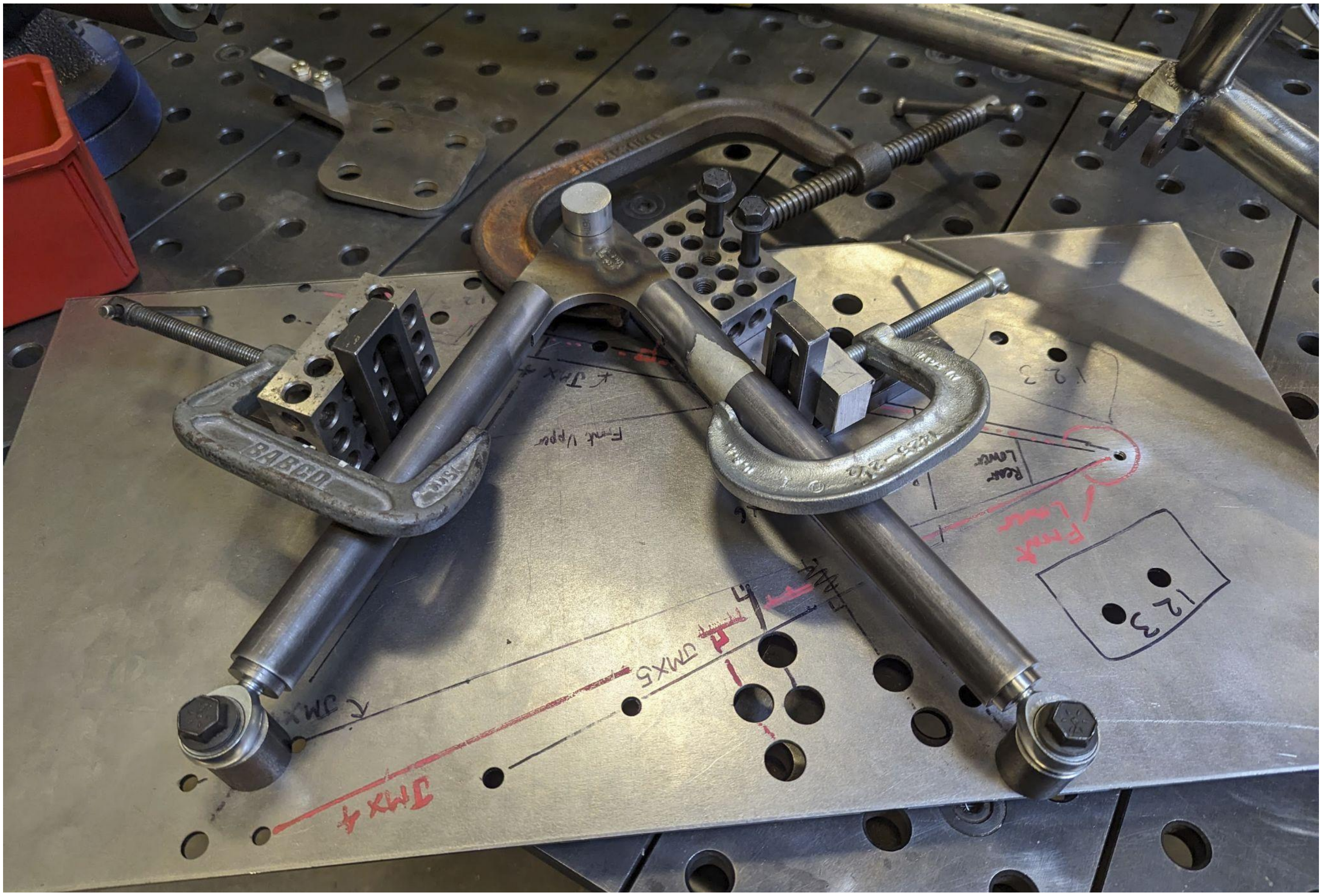
- .1” static parts, .2” dynamic parts





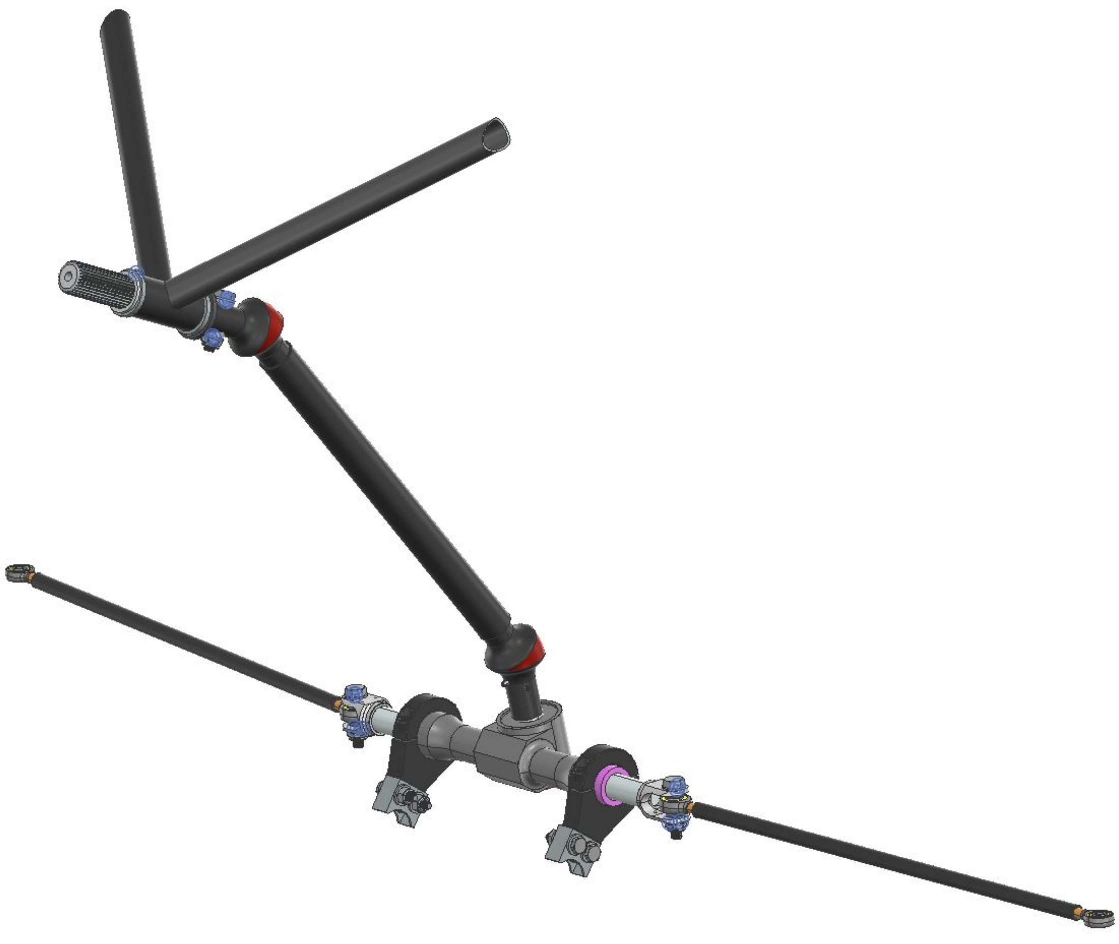
Manufacturing - A-arm Jig





Manufacturing

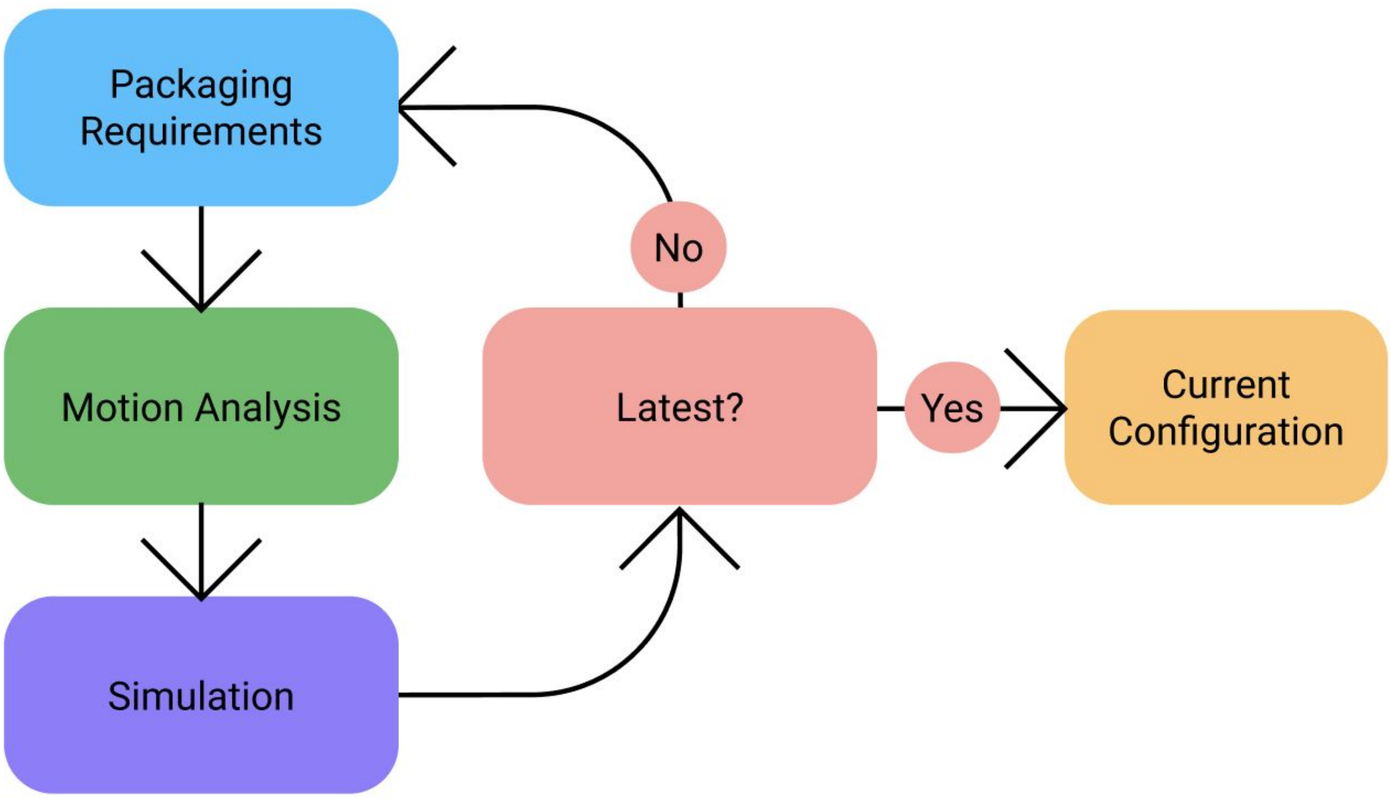
Steering



Design Requirements

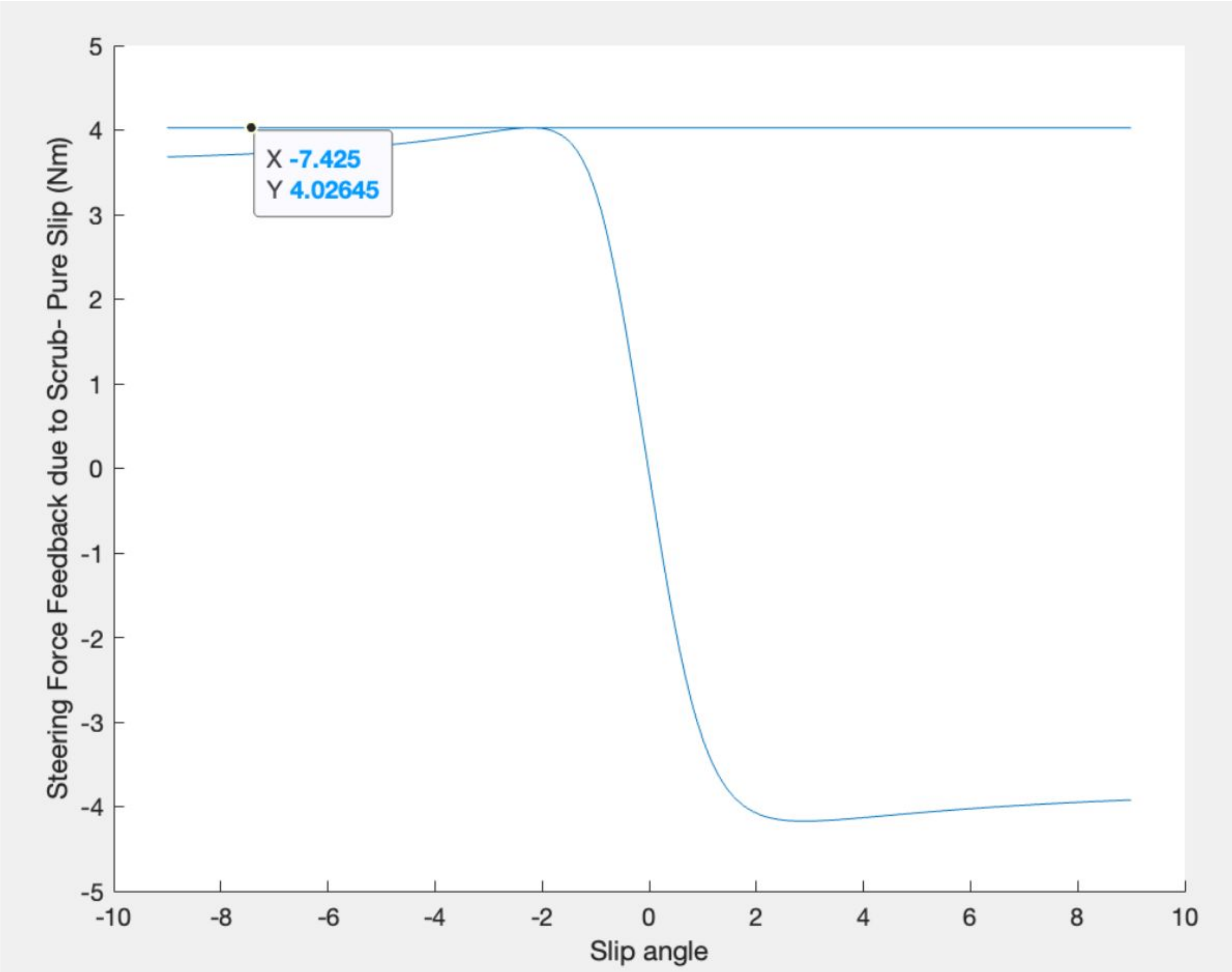
Requirement	**What does this requirement impact?**	**Verification**
Minimize driver fatigue	Steering torque < 11 N*m, steering ratio between 3.0-5.0	Use hand calcs and sims to validate. Use scales to measure required force after manufacturing
Car provides driver feedback	Optimal mechanical trail and scrub radius - ~1Nm corner aligning torque (scrub) - ~5Nm pure slip	Get feedback from drivers during testing trips
Doesn't fail under load	All parts can withstand maximum loading of 100 Nm from driver	Hand calcs, scrutineering and MOS of 1.5
Vehicle is controllable	Ackerman steering of ~80% at maximum turn angle	Calcs and sims to determine if ackermann steering is necessary. Testing trips to verify no slip.
Ergonomic for driver	Arms @ 100 degree angle on steering wheel, steering wheel can't hit driver's legs. Steering wheel should be perpendicular to drivers neck	Ergonomics jig to measure, reverify in CAD and during manufacturing
Rules legal	Below front roll hoop, 250mm max away front roll hoop and physical covers over moving components, < 7 degrees of backlash in steering wheel	Verify in CAD and during manufacturing using jig and visual inspections
Under mass allocation	2.3 kg	Measure in CAD and in real life
Under budget	$3,000	Layout budget and track purchases
No packaging conflicts	> 0.1" clearance for all parts; > 0.2" for high range of motion parts	Design in CAD

Design Workflow



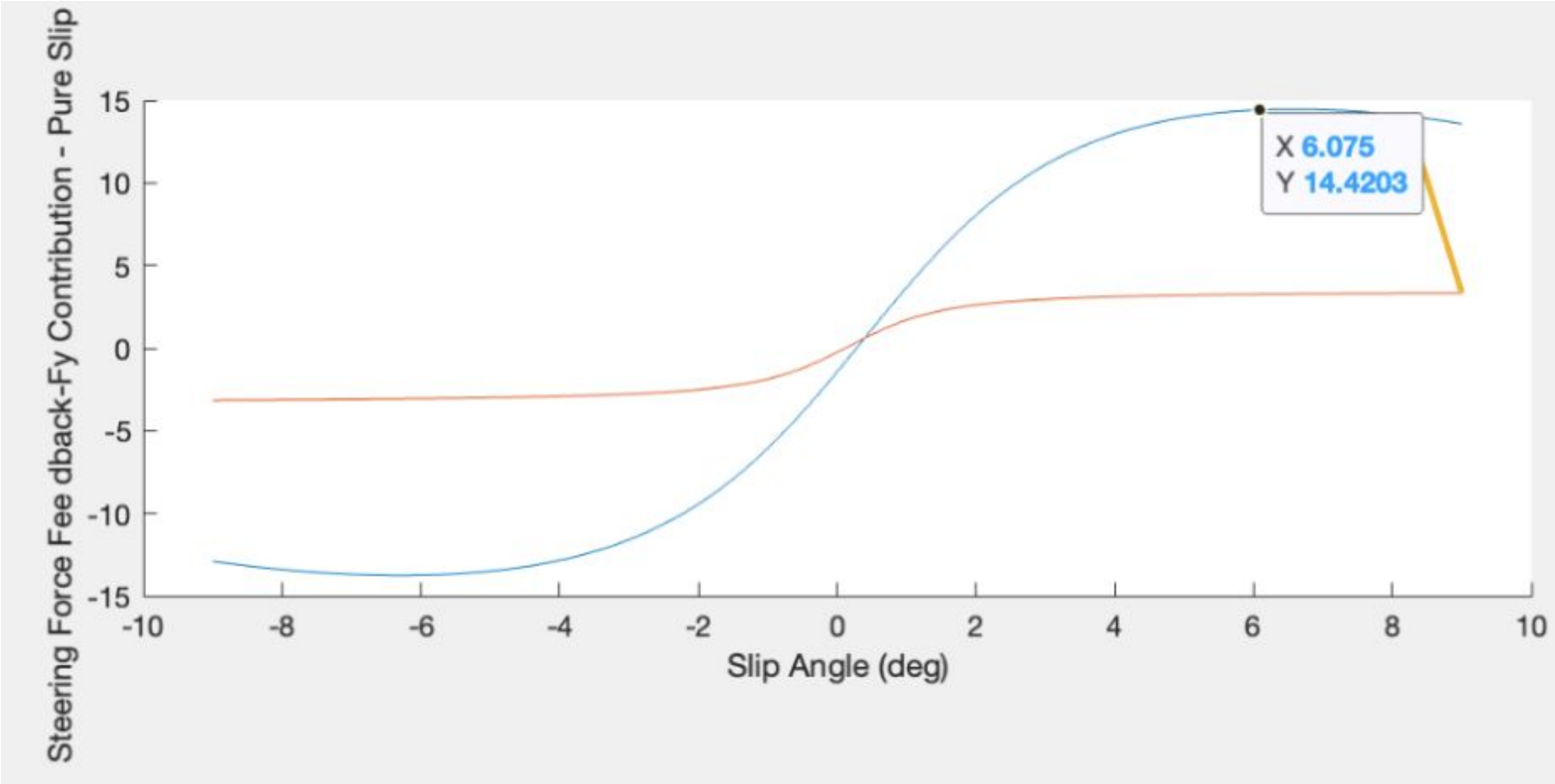
Scrub Radius Sensitivity

- Optimization done for lateral force feedback over scrub radii of 0.25" - 0.4", yielded ~0.35" to be optimal. Force vs slip angle graph for a scrub radius of 0.35 (mechanical trail = 0):



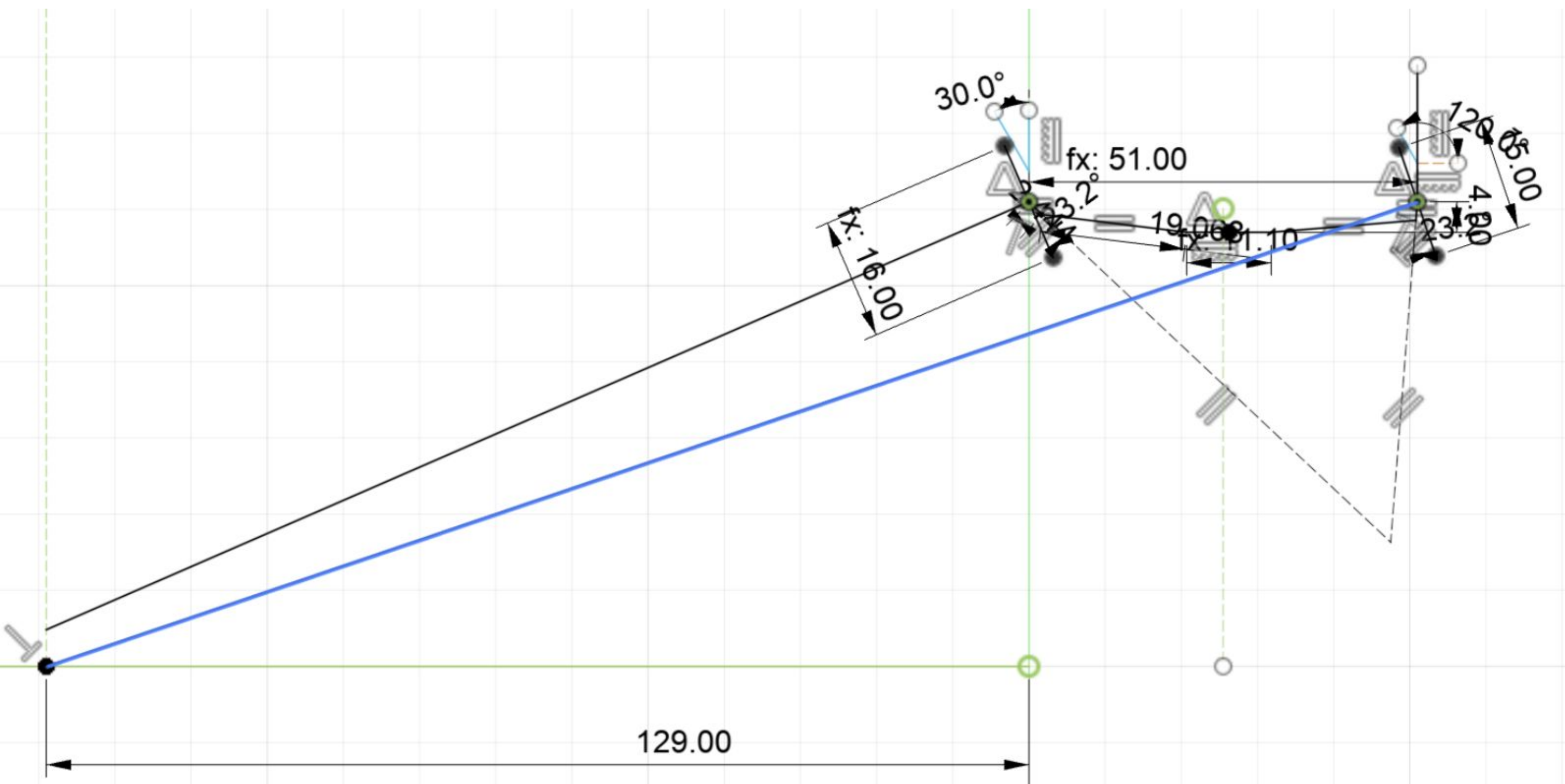
Mechanical Trail Sensitivity

- Again, optimization done for lateral force feedback over mechanical trails of 0.25" - 0.6" yielded ~0.3" to be optimal. Force vs slip angle graph for a mechanical trail of 0.3,



Ackermann Steering

- Ackermann - calculated 74.5% at 4.5m radius turn given car geometry
- "Correct" percentage determined using rule of thumb of 60% - 80% Ackermann (Claude Royale, RCVD, forums, etc.)



Steering Ratio

- 4.45 - calculated based on geometry in cad
- C-factor: 3.46 in/rev, 87.884 mm/rev

Steering Angle Stuff						
Rack Dist / Rev (c-factor)	3.46	in/rev				
Rack Lockout Angle	130	Deg				
Max Rack Dist	1.249444444	in			Old:	1
Rack Pinion Radius	0.55	in				
Rack Length	11.1	in				
Rack offset	3.5	in	Rack offset from wheel centers			
Pitman Length	2.9	in	~ Based on other years			
Pitman Angle	20.1	deg				
Ackmerman Static Angle	20.1	deg	Angle between pitman arm and wheel			
Pushrod length	14.97	in				
Max Demand Steer	30	deg	Based on skidpad previous years - we can turn further			
Demand Steer	35	deg	This is the variable calculations are on			
Math simplification in far columns						
Demand steer rack shift	1.284834355	in	See math			
Steer due to wheel angle	133.6821872	deg				
Steering ratio	4.456072908		Seems about right			

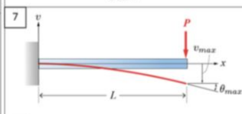
```
pitman_len = 2.444
pitman_angle = 23.2
pushrod_len = 19.068
track_length = 51
rack_length = 11.1
rack_offset = 4

steering_angle = 30

rho = np.sqrt(2*(pitman_len**2) * (1 - np.cos(np.deg2rad(steering_angle))))
beta = pitman_angle + steering_angle/2
d_y = rho * np.sin(np.deg2rad(beta))
d_x = rho * np.cos(np.deg2rad(beta))
x = (track_length - rack_length) / 2 - pitman_len * np.sin(np.deg2rad(pitman_angle))
y = rack_offset - pitman_len * np.cos(np.deg2rad(pitman_angle))
x_new = np.sqrt(pushrod_len ** 2 - (y + d_y) ** 2) - (x - d_x)
print(rho, beta, d_y, d_x, x, y, x_new)
```

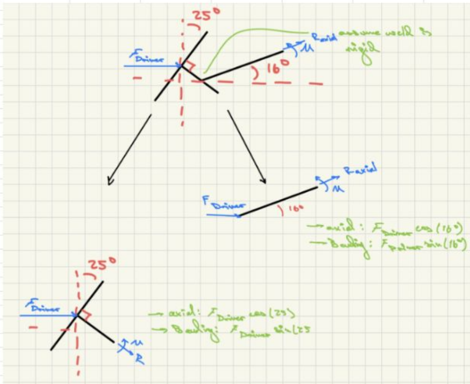
Packaging Constraints

- High Risk Areas:
  - Tie rod frame interference
  - Rockers interference
  - Arbs interference

Mounting and Steering Column Math

Neck Mounts (PN: 2)				Source
Length	10.4429	in		
	0.26524966	m		
ID	0.37	in		
	0.00925	m		
OD	0.5	in		
	0.0127	m		
Area	0.000059476239	m^2		
Young's modulus	27557	ksi	Source	
	1.90E+11	Pa		
Ic	0.000000000917	m^4		
Axial Force	440.5152861	N		
Bending Force	500	N		
Bending				
Deflection	1.78E-02	m		
	1.78E+01	mm	Good	
Axial Loading				
Stress	7406575.977	Pa		
FOS	2.57E+04	Good		
Displacement	1.03E-05	m		
	1.03E-02	mm	Good	
Volume	0.000015776057	m^3		
	15.77605228	cm^3		
Density	7.85	g/cm^3		
Mass	123.8420104	g		
	0.1238420104	kg		0.1238420104

Cantilevered Beam Slopes and Deflections				
	Beam	Deflection Field	Slope	Deflection w/ Max Magnitude
7		$v(x) = \frac{-Px^2}{6EI}(3L - x)$	$\theta_{max} = \frac{-PL^2}{2EI}$	$v_{max} = \frac{-PL^3}{3EI}$



Vertical Shaft (PN: 1)			Notes		
Verify no yielding					
ID	0.745	in	Based on insert OD	Source	N/A
	0.018625	m			
OD	0.875	in			
	0.022225	m			
J	0.000000194235	m^4			
t	11442299.78	Pa			
tensile yield	1110000000	Pa	Source, Another Source		
torsional yield	666000000	Pa	Rule of Thumb		
Safety Factor	58.20508226		Good		
Verify low compliance					
Shear Modulus	80000000000	Pa			
Compliance	0.000029063441	Rad	Good		
Length	8	in	From Cad		
	0.2032	m			
Volume	0.000093878931	m^3			
	93.8789315	cm^3			
Density	7.85	g/cm^3			
Mass	736.9496123	g			
	0.7369496123	kg		0.7369496123	May turn down the outer face of the tube to conserve weight - calcs show that this is ok

Global	Value	Unit	Notes	Weight (kg)	Link	CAD
Max Steering Torque	100	Nm	based on paper and past years			
Steering Lateral load	500	N	Guess, this is the force with which the driver leans on the wheel			
Wheel angle	65	deg				
	1.134464014	rad				
Neck Mount angle	19.4	deg	Measured in cad			
	0.49276	rad				
Quick release Diameter	20	mm				
U Joint OD	0.745					
U Joint ID	0.625					
e/d	1.5					
AN Bolt (PN: 6)					Source	
OD	0.25	in				
	0.00635	m				
Force Radius	0.3125	in	ID of vertical column, ID = smaller to be conservative			
	0.0078125	m				
Bolt Yield stress	180	ksi	Source			
	1241100000	pa				
Shear Stress	930825000	pa	Rule of thumb			
Lateral Force	12800	N				
Shear Stress	404177969.4	N/m^2	Assumption made here is that each half of the bolt is in single shear, not double shear; if anything this is then conservative			
	404177969.4	pa				
FOS	2.30300776					
Necessary Edge	0.375	in	Based on E/D = 1.5		The shaft assembly should never be in tension so there isn't really a risk of tearout, but whatevs	
Inner Column (PN: 16)					Source	
Verify no yielding			Main Failure mode is torsion			
ID	0.56	in				
	0.014224	m	Note that the ID is **less than the spline** OD (20mm) and this needs to be turned down			
OD	0.625	in	**Minimum OD** of the tube (it's being faced down for a slip-fit with the u-joint)			
	0.015875	m				
J	0.000000035464	m^4				
t	44762655.74	Pa				
tensile yield	1110000000	Pa	Source, Another Source			
torsional yield	666000000	Pa	Rule of Thumb			
Safety Factor	14.87847379		Good			
Verify low compliance						
Shear Modulus	80000000000	Pa				
Compliance	0.000056848572	Rad	Good			
Length	8	in	From Cad			
	0.2032	m				
Volume	0.000031722887	m^3				
	31.7228879	cm^3				
Density	7.85	g/cm^3				
Mass	249.02467	g				
	0.24902467	kg		0.24902467		
Outer column	https://www.mcmaster.com/89955K639/					
Inner Column	https://www.mcmaster.com/89955K298/					

Bushings (PN: 3)					Source
Dynamic Radial l	1650	lbs			
	748.2993197	kg	Good		
Dynamic Thrust	1050	lbs			
	476.1904762	kg	Good		

Inner Column (PN: 16)					Source
Verify no yielding			Main Failure mode is bending - not inhibiting the bushings		
ID	0.87	in			
	0.022098	m			
OD	1	in	Minimum OD of the tube (it's being faced down for a slip-fit with the u-joint)		
	0.0254	m			
I	0.000000139622	m^4	Second moment of area - bending		
tensile yield	1110000000	Pa	Source, Another Source		
Bending Stress	1046951.115	N/m^2			
FOS	1060.221422		Good		
Verify low compliance					
Young's modulus	27557	ksi	Source		
	1.90E+11	Pa			
Displacement	3.01E-11	m	Good		
Length	1	in	From Cad - max lever distance		
	0.0254	m			
Volume	-0.0797964534	m^3			
	-79796.4534	cm^3			
Density	7.85	g/cm^3			
Mass	-626402.1592	g			
	-626.4021592	kg		-626.4021592	

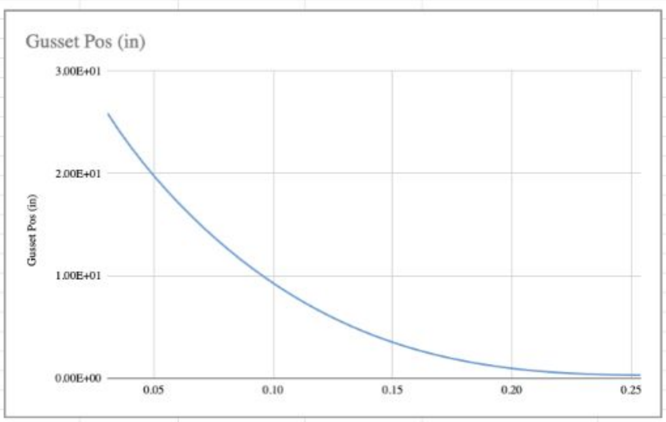
Assumption: axial load results in ~0 compliance + not a concern because the tube will be preloaded for bushings anyway

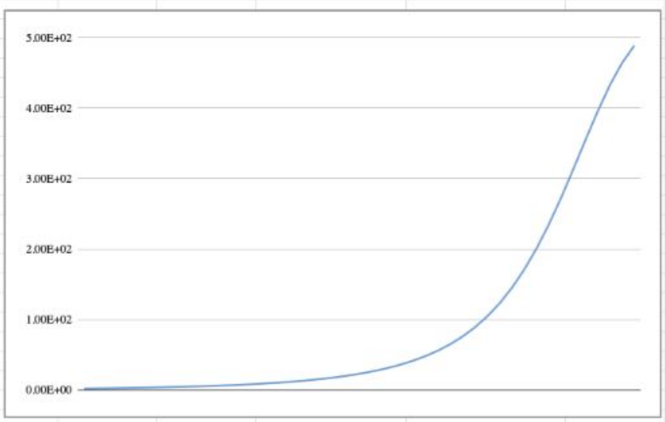
Neck Gusset Optimization

Value	Value	Unit	Comment				Constants		
Load	900	N	Sam you're not breaking my shit				Area	0.00005947623	m^2
	865.5671786						Young's Modulu	1.90E+11	Pa
					Moment of area	0.000000000917	Mount - frame a	116.928	deg
ID	0.37	in	Same tube as the current mount					2.040778588	rad
	0.00925	m					Mount length	10.7776	in
OD	0.5	in		Angular deflecti	1.60E-03			0.27375104	m
	0.0127	m					Density	7.85	g/cm^3
Area	0.00005947623	m^2					Moment of area	0.000000000917	m^4
Neck - Gusset angle	31.536	deg	Going for isoceles rn						
	0.5504070329	rad							
Young's Modulus	1.90E+11	Pa	Source, Another Source				Variables		
							Gusset - frame le	4.5	in
Neck Mount length	10.7776	in	From cad					0.1143	m
	0.27375104	m					Load	200	lbs
Gusset pos on moun	5	in	The distance along the mount at which the gusset connects					889.644	N
	0.127	m							
Gusset length	8.523	in							
	0.2164842	m							
Deflection Angle	1.03E-03	rad							
	0.05894414757	deg							
Deflection	2.82E-04	m	Deflection at gus	1.31E-04	m				
	2.82E-01	mm		1.31E-01	mm				
Gusset Stress	14553159.16	Pa							
Volume	0.00001287566	m^3							
	12.87566611	cm^3							
Density	7.85	g/cm^3							
Mass	101.073979	g/cm^3							
FOS	1.5								
Margin	8.70E+03		yay						
Deflection due to be	5.23E-03	m	Assume that bending only occurs after the gusset for simplicity						
	5.23E+00	mm							
Total Deflection	5.51E+00	mm	sum of truss model and bending after the gusset						

Neck Gusset Optimization Cont.

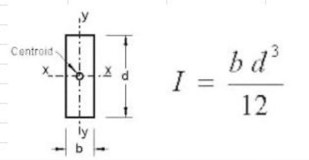
Gusset Pos (in)	Gusset Pos (m)	Gusset Length (in)	Gusset Length (m)	Gusset - Mount angle (rad)	Deflection angle (rad)	Deflection (m)	Deflection (mm)	Bending deflection (m)	Bending Deflection (mm)	Total Deflection	Mass (g)	Mass / Deflectior
1	0.0254	5.032477941	0.1278249397	0.9227094645	6.72E-03	1.84E-03	1.84E+00	2.61E-02	2.61E+01	2.79E+01	59.67999173	2.14E+00
1.2	0.03048	5.155676587	0.1309541853	0.891777839	5.02E-03	1.37E-03	1.37E+00	2.45E-02	2.45E+01	2.59E+01	61.14100046	2.36E+00
1.4	0.03556	5.283575297	0.1342028125	0.8623166483	3.97E-03	1.09E-03	1.09E+00	2.30E-02	2.30E+01	2.41E+01	62.65774708	2.60E+00
1.6	0.04064	5.415841095	0.1375623638	0.8342710858	3.27E-03	8.95E-04	8.95E-01	2.15E-02	2.15E+01	2.24E+01	64.22628287	2.86E+00
1.8	0.04572	5.552161886	0.1410249119	0.8075825616	2.78E-03	7.62E-04	7.62E-01	2.02E-02	2.02E+01	2.09E+01	65.84290668	3.15E+00
2	0.0508	5.692246345	0.1445830572	0.7821902698	2.43E-03	6.65E-04	6.65E-01	1.88E-02	1.88E+01	1.95E+01	67.50416371	3.46E+00
2.2	0.05588	5.835823447	0.1482299155	0.7580324662	2.16E-03	5.93E-04	5.93E-01	1.76E-02	1.76E+01	1.82E+01	69.20683988	3.81E+00
2.4	0.06096	5.982641736	0.1519591001	0.7350474859	1.96E-03	5.36E-04	5.36E-01	1.64E-02	1.64E+01	1.69E+01	70.94795319	4.19E+00
2.6	0.06604	6.132468426	0.155764698	0.7131745365	1.80E-03	4.92E-04	4.92E-01	1.52E-02	1.52E+01	1.57E+01	72.72474301	4.62E+00
2.8	0.07112	6.285088372	0.1596412446	0.6923542978	1.67E-03	4.57E-04	4.57E-01	1.42E-02	1.42E+01	1.46E+01	74.53465796	5.10E+00
3	0.0762	6.440302996	0.1635836961	0.6725293617	1.56E-03	4.28E-04	4.28E-01	1.31E-02	1.31E+01	1.35E+01	76.37534313	5.64E+00
3.2	0.08128	6.597929185	0.1675874013	0.6536445396	1.48E-03	4.05E-04	4.05E-01	1.21E-02	1.21E+01	1.25E+01	78.24462696	6.24E+00
3.4	0.08636	6.75779819	0.171648074	0.6356470631	1.41E-03	3.85E-04	3.85E-01	1.12E-02	1.12E+01	1.16E+01	80.14050828	6.92E+00
3.6	0.09144	6.919754564	0.1757617659	0.6184867013	1.35E-03	3.69E-04	3.69E-01	1.03E-02	1.03E+01	1.07E+01	82.06114363	7.69E+00
3.8	0.09652	7.083655135	0.1799248404	0.6021158096	1.30E-03	3.55E-04	3.55E-01	9.47E-03	9.47E+00	9.82E+00	84.00483516	8.55E+00
4	0.1016	7.249368035	0.1841339481	0.5864893299	1.26E-03	3.44E-04	3.44E-01	8.68E-03	8.68E+00	9.02E+00	85.97001904	9.53E+00
4.2	0.10668	7.416771788	0.1883860034	0.5715647507	1.22E-03	3.34E-04	3.34E-01	7.93E-03	7.93E+00	8.27E+00	87.95525468	1.06E+01
4.4	0.11176	7.585754452	0.1926781631	0.5573020404	1.19E-03	3.25E-04	3.25E-01	7.23E-03	7.23E+00	7.56E+00	89.95921458	1.19E+01
4.6	0.11684	7.756212829	0.1970078059	0.5436635594	1.16E-03	3.18E-04	3.18E-01	6.57E-03	6.57E+00	6.89E+00	91.98067491	1.34E+01
4.8	0.12192	7.928051734	0.201372514	0.5306139604	1.14E-03	3.12E-04	3.12E-01	5.95E-03	5.95E+00	6.27E+00	94.01850688	1.50E+01
5	0.127	8.101183317	0.2057700563	0.5181200784	1.12E-03	3.07E-04	3.07E-01	5.38E-03	5.38E+00	5.68E+00	96.07166868	1.69E+01
5.2	0.13208	8.275526448	0.2101983718	0.506150818	1.10E-03	3.02E-04	3.02E-01	4.84E-03	4.84E+00	5.14E+00	98.13919818	1.91E+01
5.4	0.13716	8.451006143	0.214655556	0.4946770381	1.09E-03	2.99E-04	2.99E-01	4.33E-03	4.33E+00	4.63E+00	100.2202062	2.16E+01
5.6	0.14224	8.627553053	0.2191398475	0.4836714375	1.08E-03	2.95E-04	2.95E-01	3.87E-03	3.87E+00	4.16E+00	102.3138702	2.46E+01
5.8	0.14732	8.805102982	0.2236496157	0.4731084435	1.07E-03	2.93E-04	2.93E-01	3.44E-03	3.44E+00	3.73E+00	104.419429	2.80E+01
6	0.1524	8.983596461	0.2281833501	0.4629641032	1.06E-03	2.91E-04	2.91E-01	3.04E-03	3.04E+00	3.33E+00	106.5361774	3.20E+01
6.2	0.15748	9.162978348	0.23273965	0.4532159798	1.05E-03	2.89E-04	2.89E-01	2.67E-03	2.67E+00	2.96E+00	108.6634613	3.67E+01
6.4	0.16256	9.343197475	0.2373172159	0.4438430534	1.05E-03	2.87E-04	2.87E-01	2.34E-03	2.34E+00	2.63E+00	110.8006741	4.22E+01
6.6	0.16764	9.524206314	0.2419148404	0.4348256272	1.05E-03	2.86E-04	2.86E-01	2.03E-03	2.03E+00	2.32E+00	112.947252	4.87E+01
6.8	0.17272	9.705960681	0.2465314013	0.4261452386	1.04E-03	2.85E-04	2.85E-01	1.75E-03	1.75E+00	2.04E+00	115.1026711	5.64E+01
7	0.1778	9.888419469	0.2511658545	0.4177845762	1.04E-03	2.85E-04	2.85E-01	1.50E-03	1.50E+00	1.79E+00	117.2664439	6.56E+01
7.2	0.18288	10.07154439	0.2558172276	0.4097274015	1.04E-03	2.84E-04	2.84E-01	1.28E-03	1.28E+00	1.56E+00	119.4381164	7.65E+01
7.4	0.18796	10.25529977	0.2604846141	0.4019584757	1.04E-03	2.84E-04	2.84E-01	1.07E-03	1.07E+00	1.36E+00	121.6172654	8.95E+01
7.6	0.19304	10.4396523	0.2651671684	0.3944634917	1.04E-03	2.84E-04	2.84E-01	8.94E-04	8.94E-01	1.18E+00	123.8034961	1.05E+02
7.8	0.19812	10.62457091	0.2698641011	0.3872290105	1.04E-03	2.84E-04	2.84E-01	7.36E-04	7.36E-01	1.02E+00	125.9964398	1.23E+02
8	0.2032	10.81002654	0.2745746741	0.380242402	1.04E-03	2.85E-04	2.85E-01	5.97E-04	5.97E-01	8.82E-01	128.1957521	1.45E+02
8.2	0.20828	10.99599203	0.2792981975	0.3734917898	1.04E-03	2.85E-04	2.85E-01	4.77E-04	4.77E-01	7.63E-01	130.4011107	1.71E+02
8.4	0.21336	11.18244193	0.284034025	0.3669660005	1.04E-03	2.86E-04	2.86E-01	3.75E-04	3.75E-01	6.61E-01	132.612214	2.01E+02
8.6	0.21844	11.36935242	0.2887815514	0.3606545157	1.05E-03	2.87E-04	2.87E-01	2.88E-04	2.88E-01	5.75E-01	134.8287794	2.35E+02
8.8	0.22352	11.55670114	0.2935402089	0.3545474285	1.05E-03	2.88E-04	2.88E-01	2.16E-04	2.16E-01	5.03E-01	137.0505418	2.72E+02
9	0.2286	11.74446713	0.298309465	0.3486354021	1.05E-03	2.89E-04	2.89E-01	1.57E-04	1.57E-01	4.45E-01	139.2772525	3.13E+02
9.2	0.23368	11.93263068	0.3030888192	0.3429096321	1.06E-03	2.90E-04	2.90E-01	1.09E-04	1.09E-01	3.99E-01	141.5086779	3.55E+02
9.4	0.23876	12.12117328	0.3078778014	0.3373618116	1.06E-03	2.91E-04	2.91E-01	7.29E-05	7.29E-02	3.64E-01	143.7445985	3.95E+02
9.6	0.24384	12.31007752	0.312675969	0.3319840979	1.07E-03	2.92E-04	2.92E-01	4.55E-05	4.55E-02	3.38E-01	145.9848077	4.32E+02
9.8	0.24892	12.499327	0.3174829058	0.3267690826	1.07E-03	2.93E-04	2.93E-01	2.60E-05	2.60E-02	3.19E-01	148.2291111	4.64E+02
10	0.254	12.68890627	0.3222982192	0.3217097635	1.08E-03	2.95E-04	2.95E-01	1.31E-05	1.31E-02	3.08E-01	150.4773255	4.89E+02

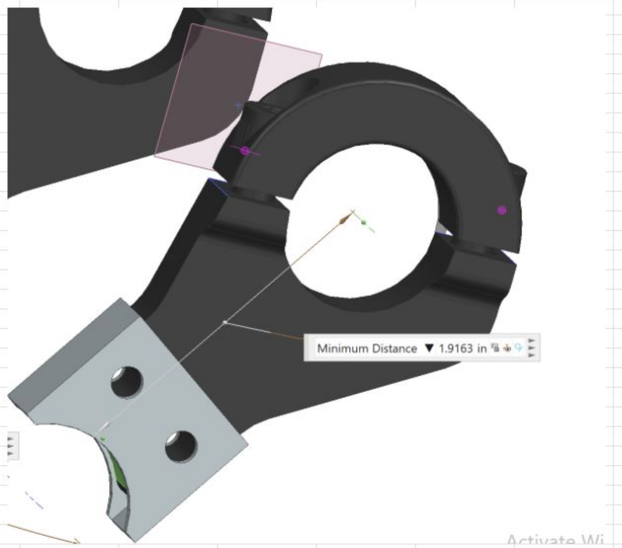




Rack Mount

Global	Value	Unit	Notes	Weight (kg)	Link	CAD	
Max Steering Torque	100	Nm	based on paper and past years				
Steering Lateral load	300	N	Guess, this is the force with which the driver leans on the wheel				
RE Max Tension	-342.355	N	From AARMS sheet				
RE Max Compression	387.849	N	From AARMS sheet				
Max Load	387.849						
Rack Mount							https://www.onlinemetals.com/en/buy/aluminum/0-5-aluminum-plat
4130 Steel Young's Modu	27557	ksi	Source				https://www.onlinemetals.com/en/buy/aluminum/-500-aluminum-60
	1.90E+11	Pa					
6061 Aluminum Young's I	10000	ksi	Source				
	68950000000	Pa					
Box tube Width	0.5	in					
	0.0127	m					
Tube Height	1	in					
	0.0254	m					
Tube Wall	0.049	in					
	0.0012446	m					
Tube / Insert Offset	0.01	in					
	0.000254	m					
Aluminum width	0.382	in					
	0.0097028	m					
Aluminum height	0.882	in					
	0.0224028	m					
Insert Length	1.9163	in	Measured in cad, assume that load is placed at center of rack				
	0.04867402	m					
Aluminum / Steel Overla	0.625	in	Measured in cad				
	0.015875	m					
Aluminum EI_eff	117.5835491	Nm^2					
Eleff_overlap	6.17E+02	Nm^2					
Bending							
Overlap displacement	3.43E-06	m					
Aluminum Displacement	0.00010875915	m					
Total Displacement	1.12E-04	m	Good				
Bolt Shear Stress							
Bending Moment	18.87816998	Nm					
Shear stress	2.67E+04	N	Good, 1 bolts is fine				
Bolt Yield stress	125000	psi	Source				
	856798750	pa					
Shear Stress	642599062.5	pa	Rule of thumb				
Factor of Safety	1.5						
Margin	1.61E+04						





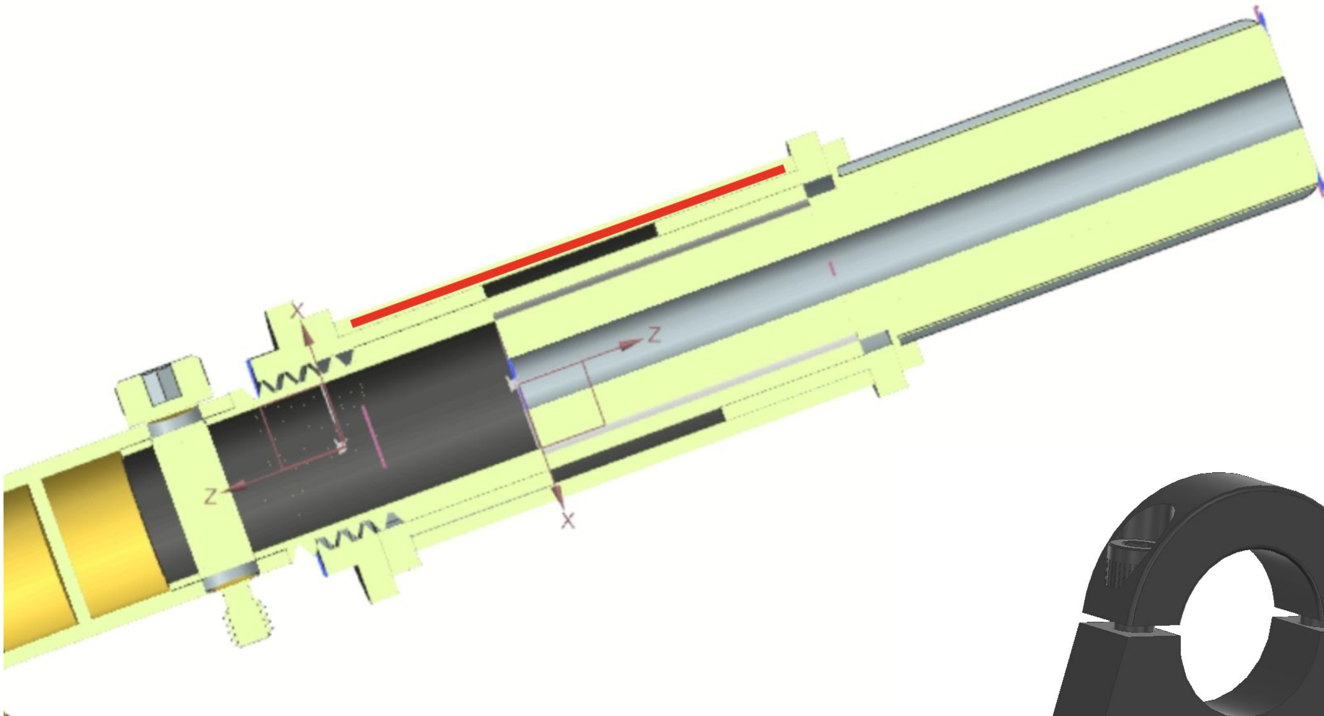
Tie Rods

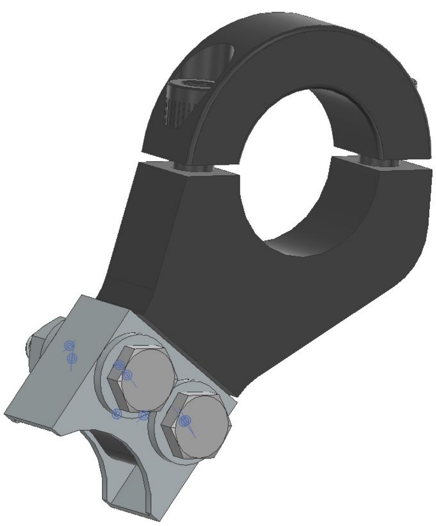
Global	Value	Unit	Notes	Weight (kg)	Link	CAD
Max Steering To	100	Nm	based on paper			
Steering Lateral	300	N	Guess, this is the			
RE Max Tension	-342.355	N	From AARMS sheet			
RE Max Compre	387.849	N	From AARMS sheet			
Max Load	387.849	N				
Tie Rod			Source			
Length	16.0359	in				
	0.4008975	m				
OD	0.3125	in				
	0.0078125	m				
ID	0.243	in				
	0.0061722	m				
Yield Stress	70000	psi				
	482633010.5	Pa				
Cross sectional A	0.000022939103	m^2				
Internal Stress	16907766.32	Pa				
FOS	28.54504856	FOS				
Compliance						
Young's modulus	27557	ksi	Source			
	1.90E+11	Pa				
Displacement	3.57E-05	m	Good			
Density	7.85	g/cm^3				
Volume	0.000009196229	m^3				
	9.196229209	cm^3				
	72.19039929	g				
	0.07219039929	kg		0.07219039929		
Rod End (PN: 14/21)						
JMX4			**JMX4 on inboard, 3 on outboard**			
Ult. Radial	5262	lbf				
	23406.53364	N				
Max Radial Load	387.849	N				
FOS	1.5					
Margin	39.23306947		Good			
Weight	0.04	lbs				
	0.01814058957	kg		0.01814058957		
Tie Rod Connection Bolt (PN: 6)						
OD	0.25	in	Source			
	0.00635	m				
Lateral Force	193.9245	N	Double Shear			
Yield Stress	120000	psi				
	827370875.2	Pa				
Shear Yield	620528156.4	Pa				
Shear Stress	1530859.583	Pa				
FOS	405.3462273		Good			

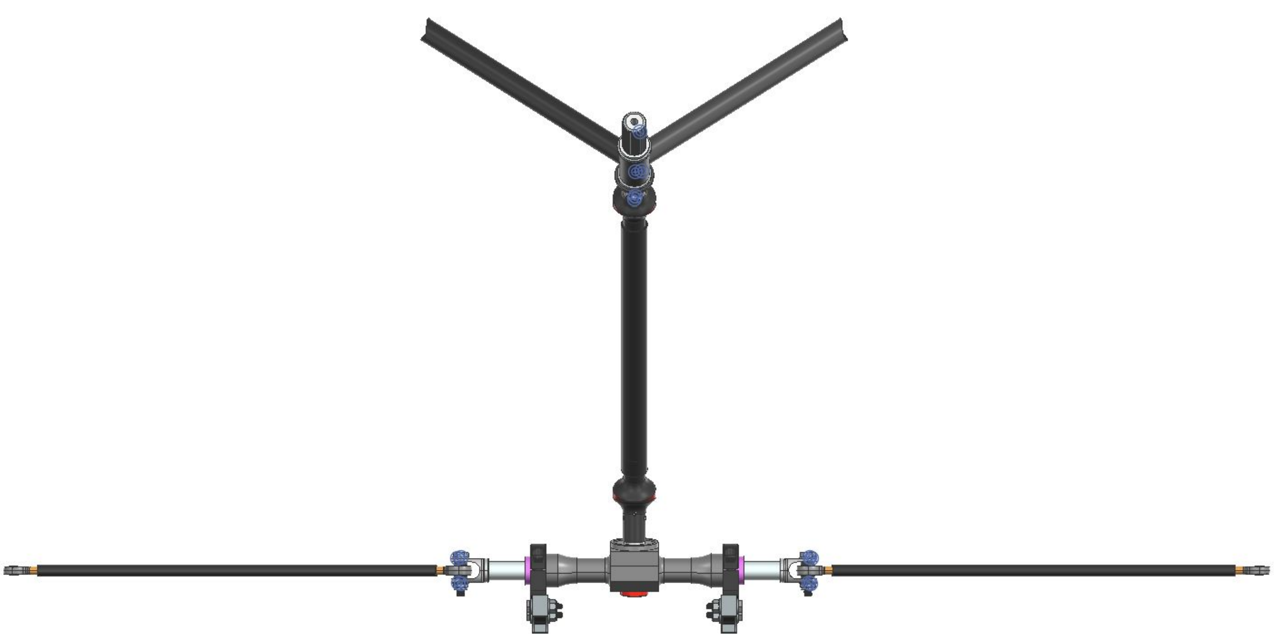
Tube Force Script Outputs	Front		Rear			
	Max Tension Forc	Max Compres	Max Tension F	Max Compression Forces [N]		Inches to mete
Up-Fore	.000	3357.405579	93.142	443.743		
Up-Aft	75.56823385746	115.6417047	67.419	616.912		
Low-Fore	405.2069111775	716.3030453	807.915	909.974		
Low-Aft	3950.06716450	308.7421989	1174.702	557.032		
Pull Rod	2050.36291116	0	745.337	.000		
Toe/Tie	-342.355	387.849	569	-449		
Bending Calcs						

JMX3			https://www.fkrodends.com/products/rod-ends/precision-series/jmx-jfx/
Ult. Radial	2855		
	12699.6681	N	
Max Radial Load	387.849	N	
FOS	1.5		
Margin	20.82923096		Good
Weight	0.04	lbs	
	0.01814058957	kg	

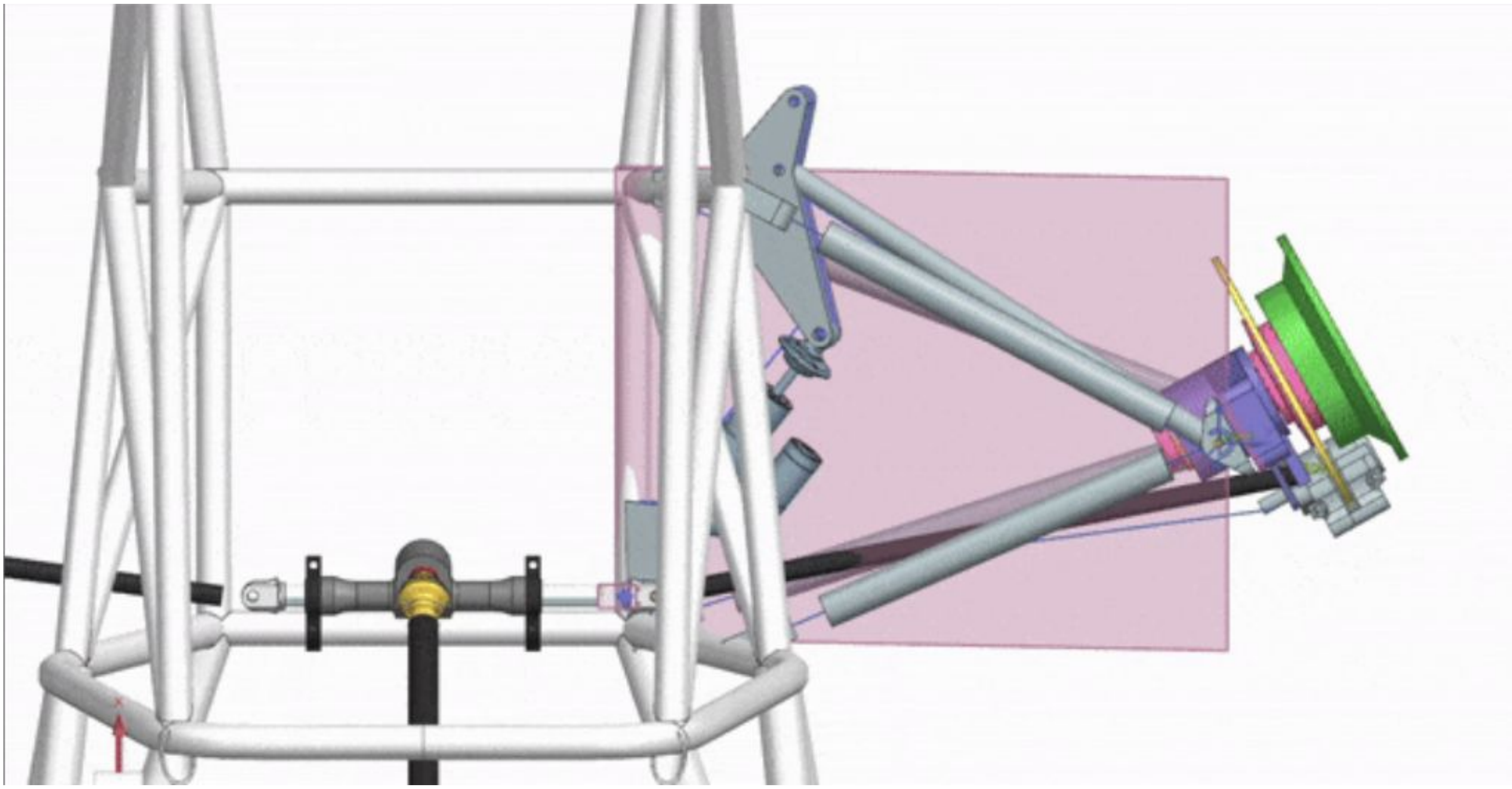
Design

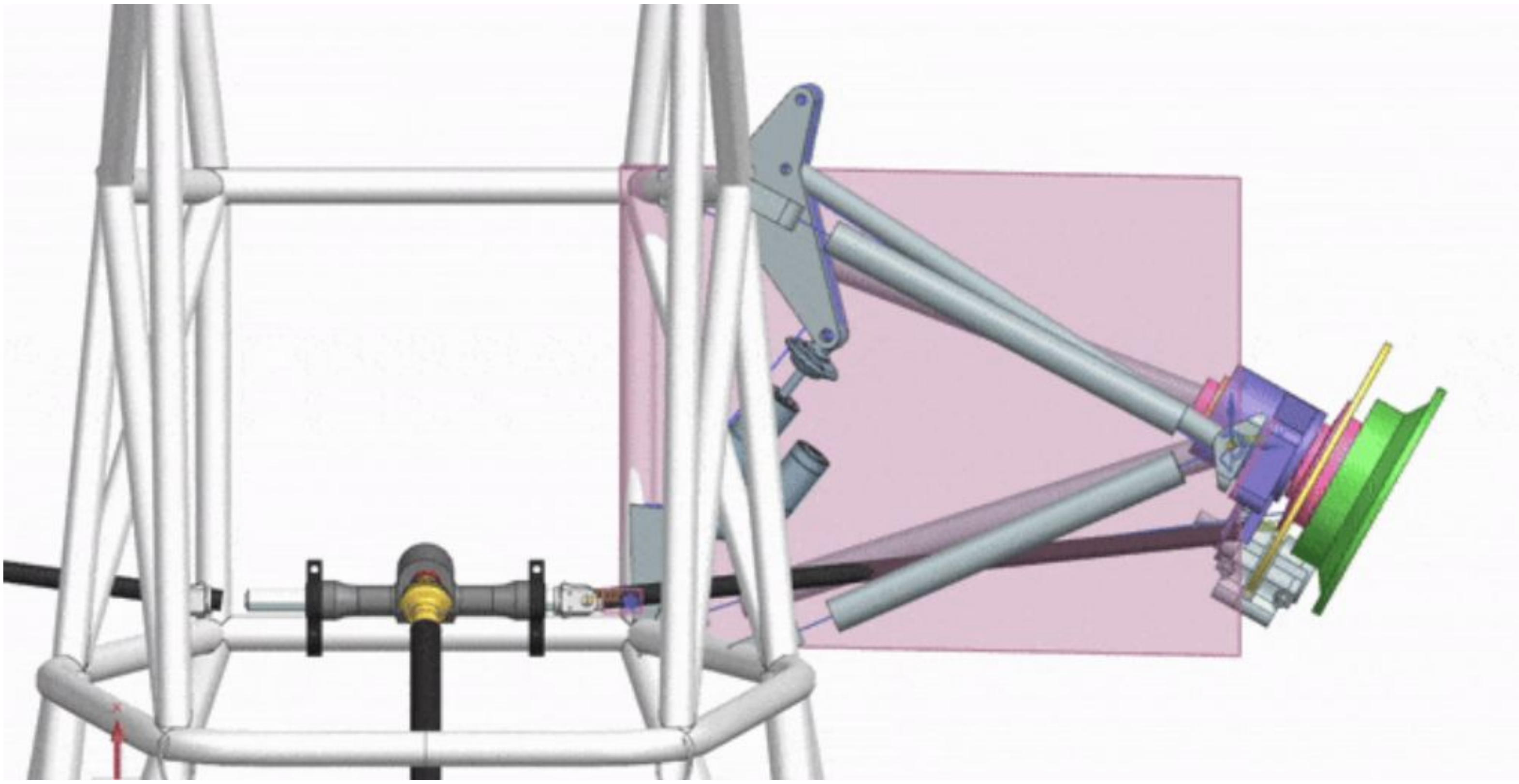






Motion Analysis



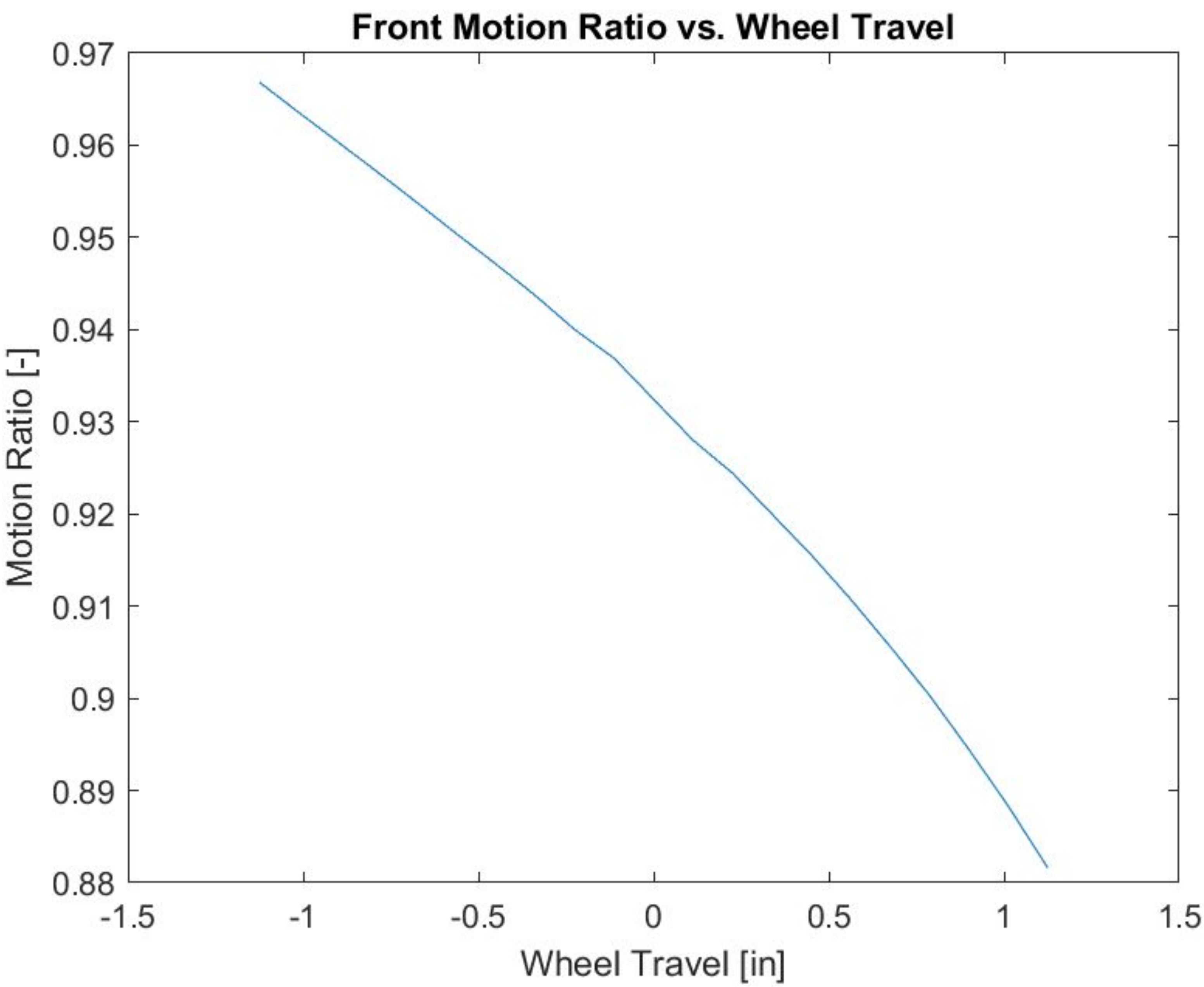


Rockers

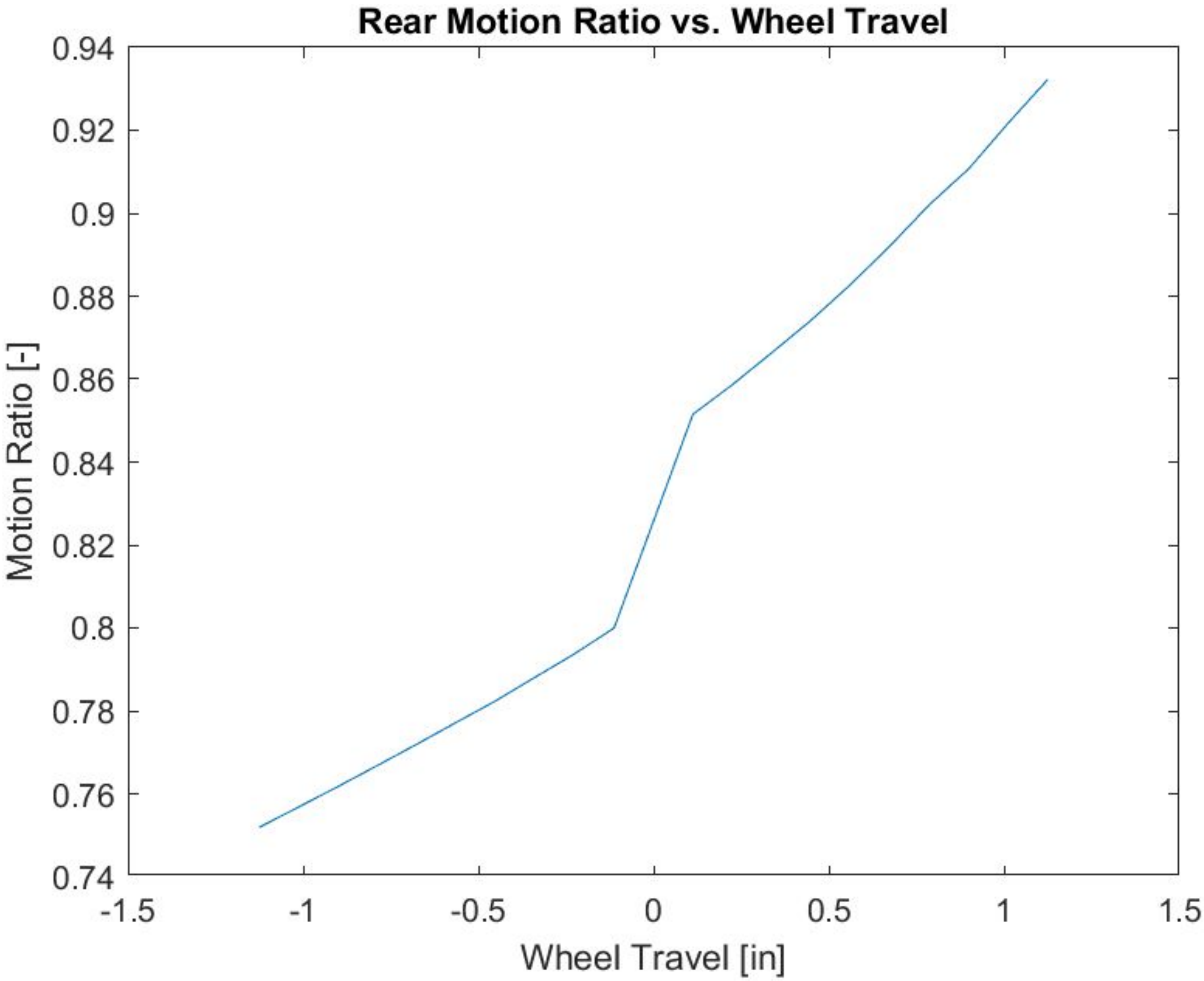
Design Requirements

Requirement	What does this requirement impact?	Verification
Motion ratio close to 1 Linearity	• Full use of shocks • Affects wheel travel distance/bottoming out • 1 in up, 1 in down for wheel travel	• Hand calcs • Motion analysis • FEA for shock forces
Mass + Budget	• 4.25 kg, $3000 (rockers + arbs + shocks) • 1.5 kg? Weigh old rockers, try to keep similar	• Measurement in CAD, machining decisions
Manufacturable		• minimize machining operations • Can be manufactured within a month
Packaging	• Interference with other systems	• Motion analysis

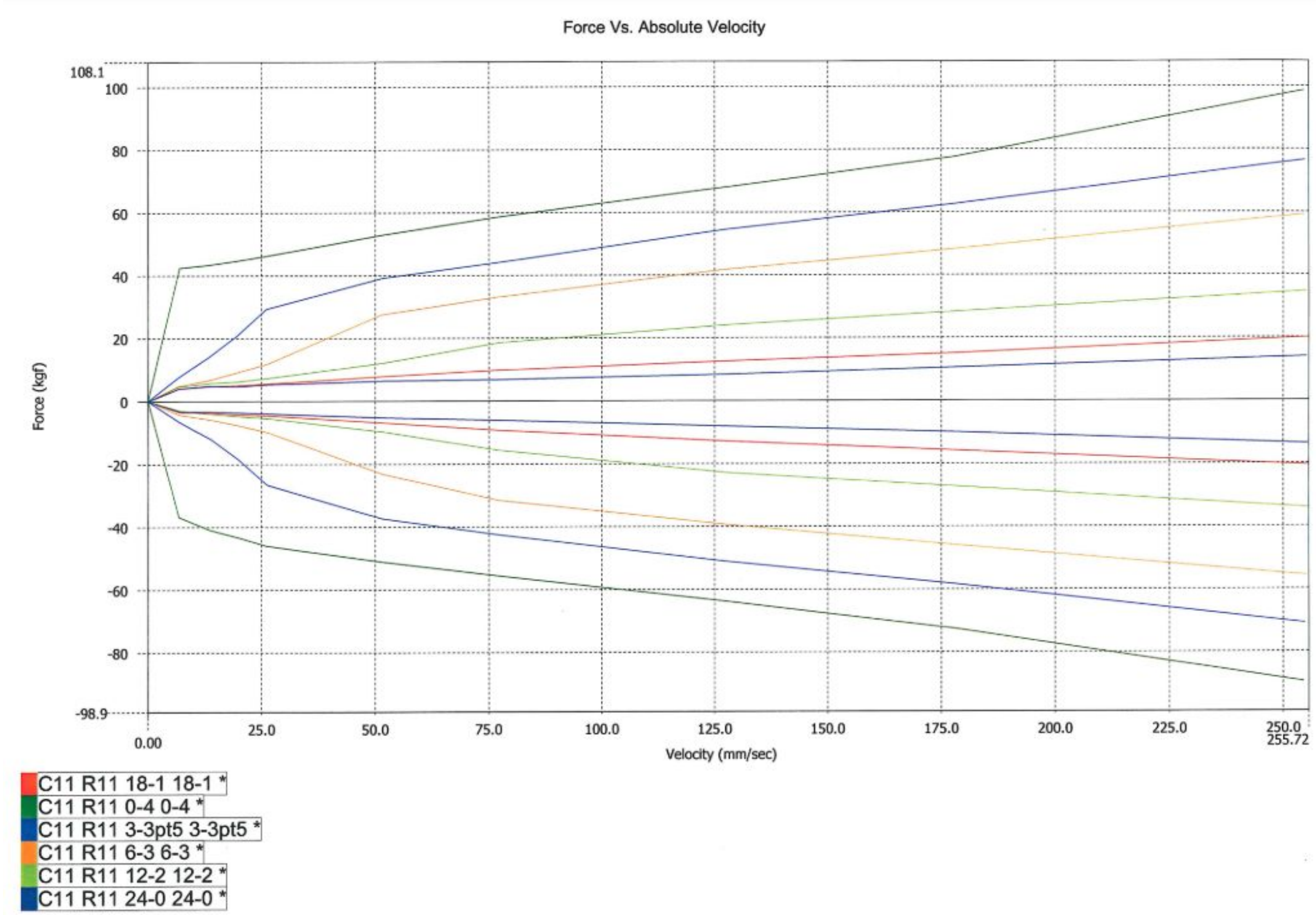
Front Motion Ratio



Rear Motion Ratio



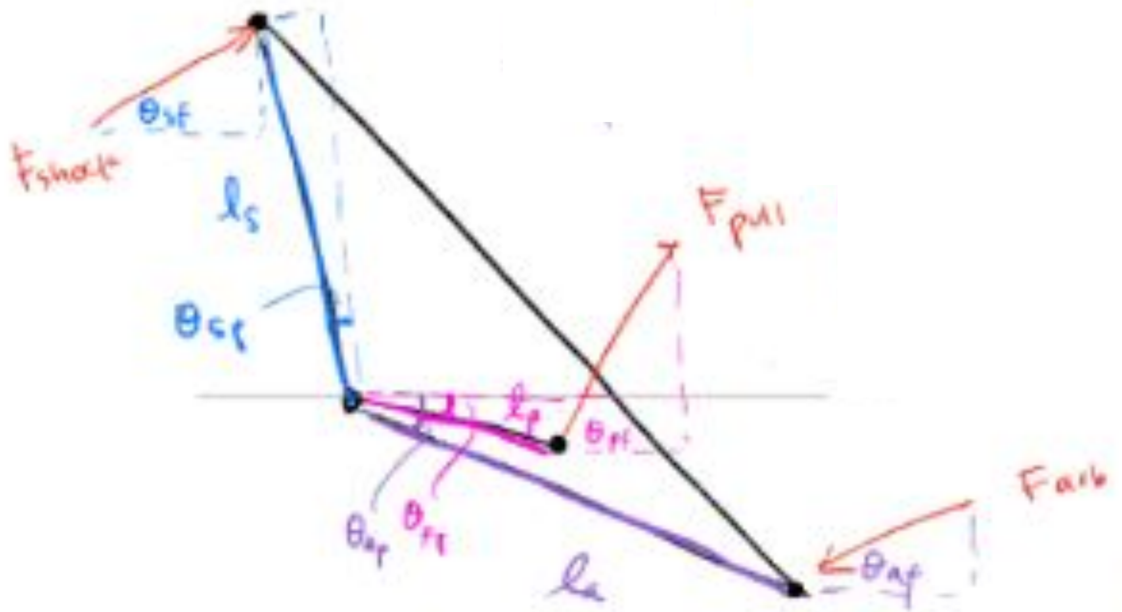
Damper Curve



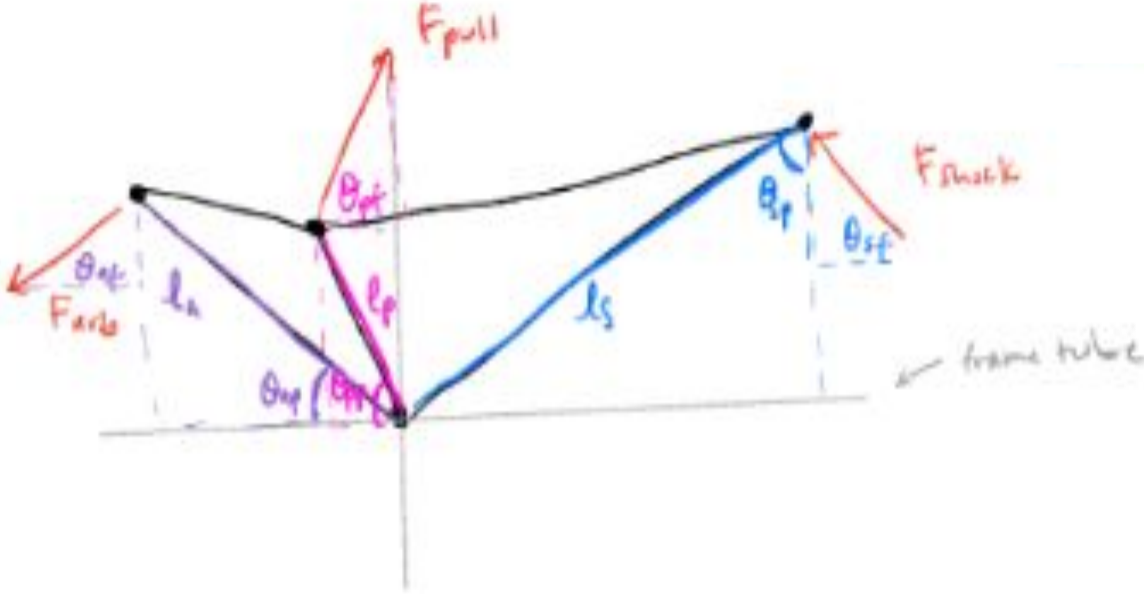
TTX 25 FSAE - (LSC-HSC LSR-HSR) Low speed clicks counted from fully closed (clockwise), High speed turns counted from fully open (counter clockwise)

Rocker FBDs

Rear Rocker



Front rocker



Front Rocker Hand Calcs

Front Rocker

Pullrod				
Dh	0.0082042	m	0.323	in
F	14018.17475	N		
Dp	0.0079375	m	0.312	in
Bearing Failure				
FS	1.5			
Sbru	6.70E+08	Pa		
t_min	0.0039538864	m	0.155	in
t_chosen	0.00711199616	m	0.28	in
A_br	0.0000564514	m^2		
Stress	248322583.5	N/m		
MoS	0.798735582			
Shear Tearout				
FS	1.5			
Ssu	193000000	Pa		
R	0.0117616615	m	0.463	in
R_chosen	0.0121919934	m	0.48	in
As	0.0001150705	m^2		
Stress	121822402.6	N/m		
MoS	0.0561823103			
Tensile Failure				
FS	1.5			
Stu	296000000	Pa		
w	0.0181926822	m	0.716	in
w_chosen	0.0243839868	m	0.96	in
At	0.0001150705	m^2		
Stress	121822402.6	N/m		
MoS	0.6198443723			

Shock				
Dh	0.0079375	m	0.3125	in
F	419.1796561	N		
Dp	0.0079375	m	0.3125	in
Bearing Failure				
FS	1.5			
Sbru	670000000	Pa		
t_min	0.000118231422	m	0.00465478293	in
t_chosen	0.0031749982	m	0.125	in
A_br	0.0000252015	m^2		
Stress	16633091	N/m		
MoS	25.85409865			
Shear Tearout				
FS	1.5			
Ssu	193000000	Pa		
R	0.00448180113	m	0.176448959	in
R_chosen	0.0076199958	m	0.3	in
As	0.0000231853	m^2		
Stress	18079467.12	N/m		
MoS	6.11672893			
Tensile Failure				
FS	1.5			
Stu	296000000	Pa		
w	0.00860654641	m	0.3388405931	in
w_chosen	0.01523999177	m	0.6	in
At	0.0000231853	m^2		
Stress	18079467.12	N/m		
MoS	9.914775975			

Pivot				
Dh	0.0111506	m	0.439	in
F	13625.41632	N		
Dp	0.0111506	m	0.439	in
Bearing Failure				
FS	1.5			
Sbru	228000000	Pa		
t_min	0.00803910972	m	0.3165005537	in
t_chosen	0.00736599602	m	0.29	in
A_br	0.0000821352	m^2		
Stress	165889945.4	N/m		
MoS	-0.08372988096			
Shear Tearout				
FS	1.5			
Ssu	193000000	Pa		
R	0.01276353481	m	0.5025016419	in
R_chosen	0.012953993	m	0.51	in
As	0.00010870284	m^2		
Stress	125345533.7	N/m		
MoS	0.02649582239			
Tensile Failure				
FS	1.5			
Stu	296000000	Pa		
w	0.02052444675	m	0.8080495209	in
w_chosen	0.02590798601	m	1.02	in
At	0.00010870284	m^2		
Stress	125345533.7	N/m		
MoS	0.5743148364			

ARB				
Dh	0.0065278	m	0.257	in
F	750	N		
Dp	0.00635	m	0.25	in
Bearing Failure				
FS	1.5			
Sbru	670000000	Pa		
t_min	0.00026442590	m	0.0104104742	in
t_chosen	0.0031749982	m	0.125	in
A_br	0.0000201612	m^2		
Stress	37200094.49	N/m		
MoS	11.00713796			
Shear Tearout				
FS	1.5			
Ssu	193000000	Pa		
R	0.0041818556	m	0.1646400771	in
R_chosen	0.005079997257	m	0.2	in
As	0.000011532211	m^2		
Stress	65035228.46	N/m		
MoS	0.9784149255			
Tensile Failure				
FS	1.5			
Stu	296000000	Pa		
w	0.007724863851	m	0.3041286623	in
w_chosen	0.01015999451	m	0.4	in
At	0.000011532211	m^2		
Stress	65035228.46	N/m		
MoS	2.034252943			

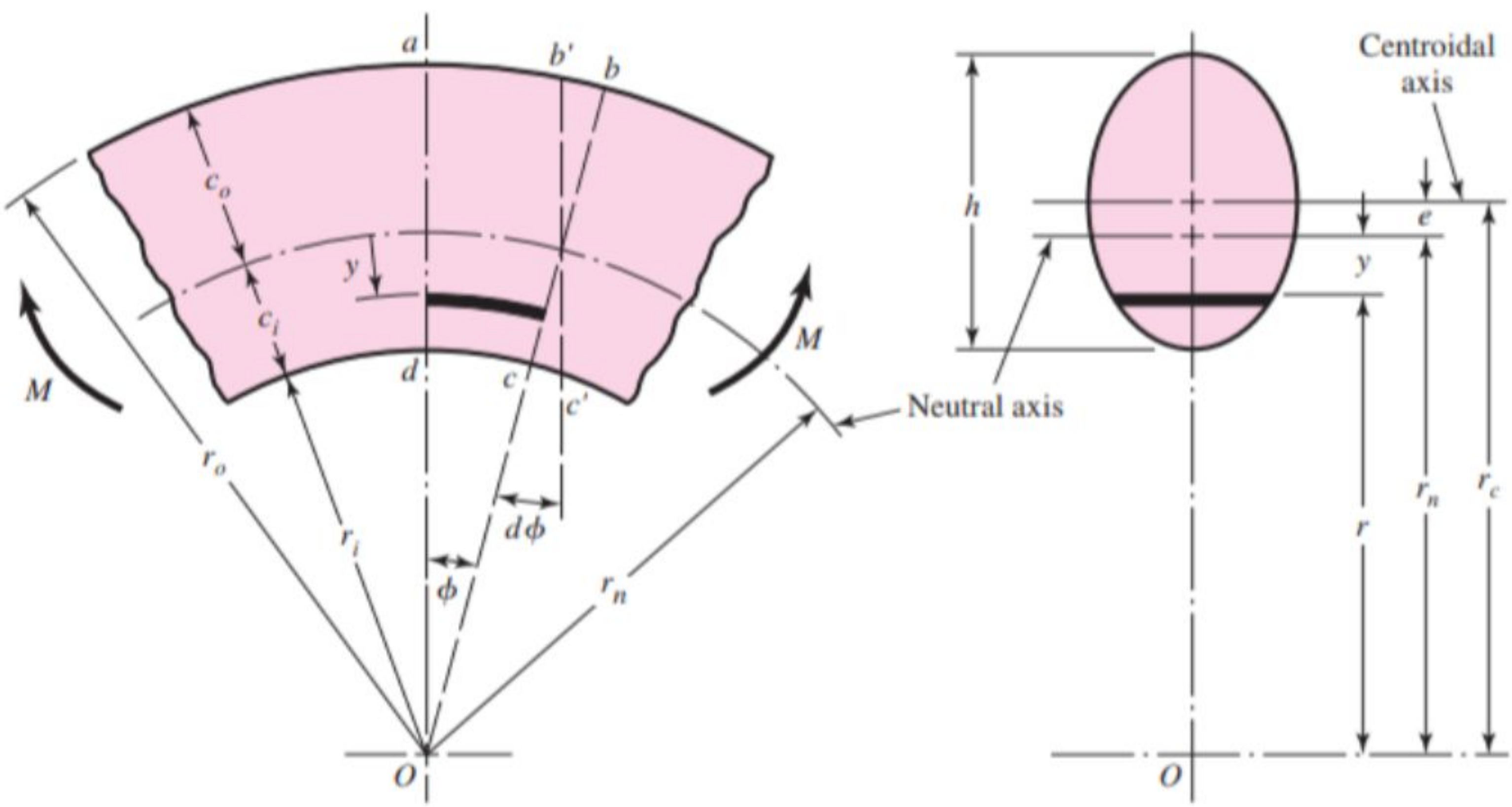
Front Rocker Hand Calcs

Curved				
M	339.447			
r_i	0.114	m	4.5	in
r_o	0.152	m	6	in
h	0.038	m	1.5	in
A	0.000	m^2		
r_n	0.132	m		
e	0.001	m		
c_i	0.018	m		
c_o	0.020	m		
s_i	2.10E+08	Pa		
s_o	1.74E+08	Pa		
Ultimate Tensile	2.96E+08	Pa		
FoS_i	1.407			
FoS_o	1.704			

$$r_n = \frac{A}{\int \frac{dA}{r}}$$

$$\sigma_i = \frac{Mc_i}{Aer_i}$$

$$\sigma_o = -\frac{Mc_o}{Aer_o}$$



Rear Rocker Hand Calcs

Rear Rocker

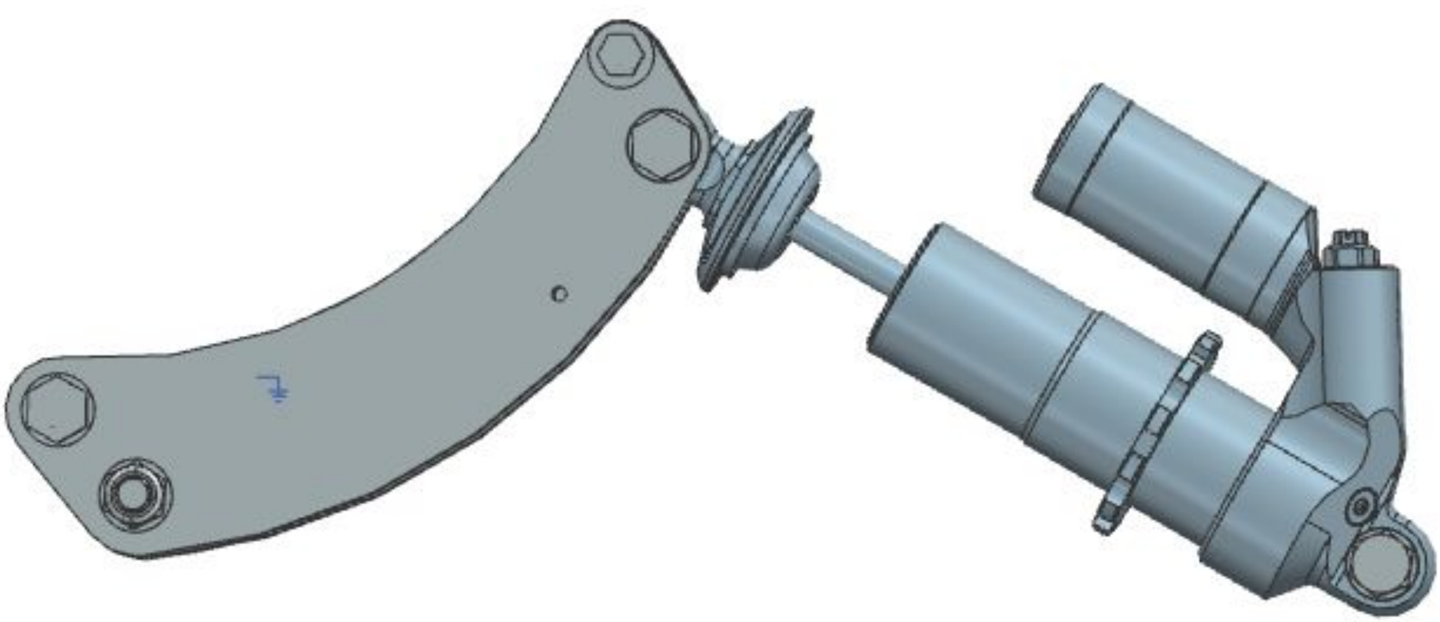
Pullrod				
Dh	0.0065278	m	0.257	in
F	4544.5415	N		
Dp	0.00635	m	0.25	in
Bearing Failure				
FS	1.5			
Sbru	670000000	Pa		
t_min	0.00160225931	m	0.063	in
t_chosen	0.00482599739	m	0.19	in
A_br	0.00003064508	m^2		
Stress	148295941.4	N/m		
MoS	2.01199522			
Shear Tearout				
FS	1.5			
Ssu	193000000	Pa		
R	0.00692327523	m	0.272	in
R_chosen	0.00761999588	m	0.3	in
As	0.00004204501	m^2		
Stress	108087523	N/m		
MoS	0.1903933327			
Tensile Failure				
FS	1.5			
Stu	296000000	Pa		
w	0.01129982311	m	0.444	in
w_chosen	0.01523999177	m	0.6	in
At	0.00004204501	m^2		
Stress	108087523	N/m		
MoS	0.8256809662			

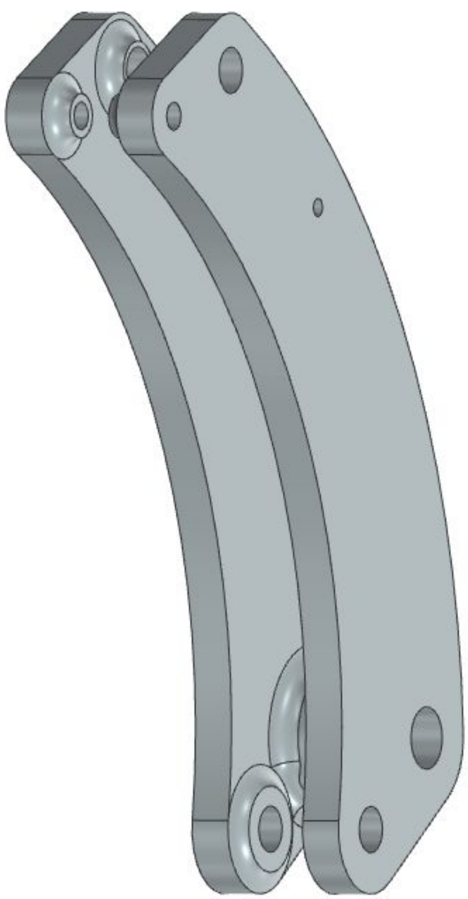
Shock				
Dh	0.0079375	m	0.3125	in
F	3804.720744	N		
Dp	0.0079375	m	0.3125	in
Bearing Failure				
FS	1.5			
Sbru	670000000	Pa		
t_min	0.001073137829	m	0.04224954364	in
t_chosen	0.003124198313		0.123	
A_br	0.000024798324	m^2		
Stress	153426527	N/m		
MoS	1.911274049			
Shear Tearout				
FS	1.5			
Ssu	193000000	Pa		
R	0.008701223025	m	0.3425680206	in
R_chosen	0.009524994857	m	0.375	in
As	0.000034717621	m^2		
Stress	109590477.9	N/m		
MoS	0.1740679403			
Tensile Failure				
FS	1.5			
Stu	296000000	Pa		
w	0.01410890063	m	0.5554688288	in
w_chosen	0.01904998971	m	0.75	in
At	0.000034717621	m^2		
Stress	109590477.9	N/m		
MoS	0.8006430586			

Pivot				
Dh	0.0095504	m	0.376	in
F	6447.812471	N		
Dp	0.0095504	m	0.376	in
Bearing Failure				
FS	1.5			
Sbru	228000000	Pa		
t_min	0.004441679813	m	0.1748693784	in
t_chosen	0.004825997394		0.19	
A_br	0.000046090205	m^2		
Stress	139895502.7	N/m		
MoS	0.08652527796			
Shear Tearout				
FS	1.5			
Ssu	193000000	Pa		
R	0.00996713527	m	0.3924071123	in
R_chosen	0.01015999451	m	0.4	in
As	0.000051974008	m^2		
Stress	124058402.4	N/m		
MoS	0.03714592614			
Tensile Failure				
FS	1.5			
Stu	296000000	Pa		
w	0.01632096424	m	0.6425579941	in
w_chosen	0.02031998903	m	0.8	in
At	0.000051974008	m^2		
Stress	124058402.4	N/m		
MoS	0.5906486743			

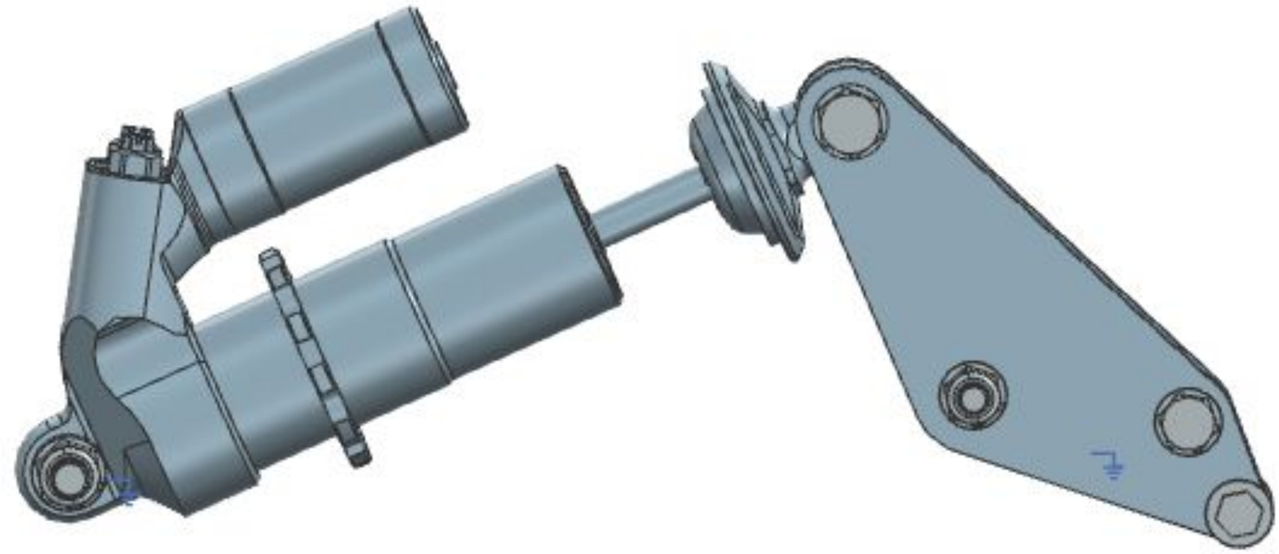
ARB				
Dh	0.0049784	m	0.196	in
F	750	N		
Dp	0.004826	m	0.19	in
Bearing Failure				
FS	1.5			
Sbru	670000000	Pa		
t_min	0.000347928818	m	0.01369799237	in
t_chosen	0.004825997394	m	0.19	in
A_br	0.000023290263	m^2		
Stress	32202297.86	N/m		
MoS	12.87064577			
Shear Tearout				
FS	1.5			
Ssu	193000000	Pa		
R	0.003093118223	m	0.1217763738	in
R_chosen	0.005079997257	m	0.2	in
As	0.000025006361	m^2		
Stress	29992368	N/m		
MoS	3.28998026			
Tensile Failure				
FS	1.5			
Stu	296000000	Pa		
w	0.005765942007	m	0.2270057134	in
w_chosen	0.01015999451	m	0.4	in
At	0.000025006361	m^2		
Stress	29992368	N/m		
MoS	5.57945159			

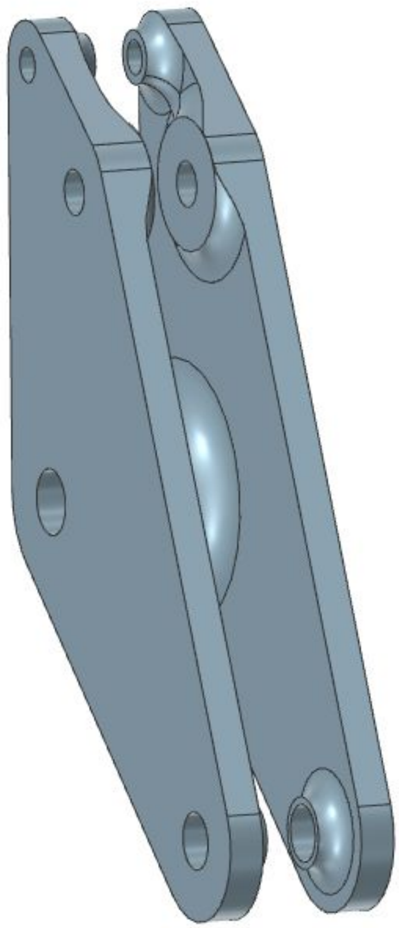
Front Rocker Design

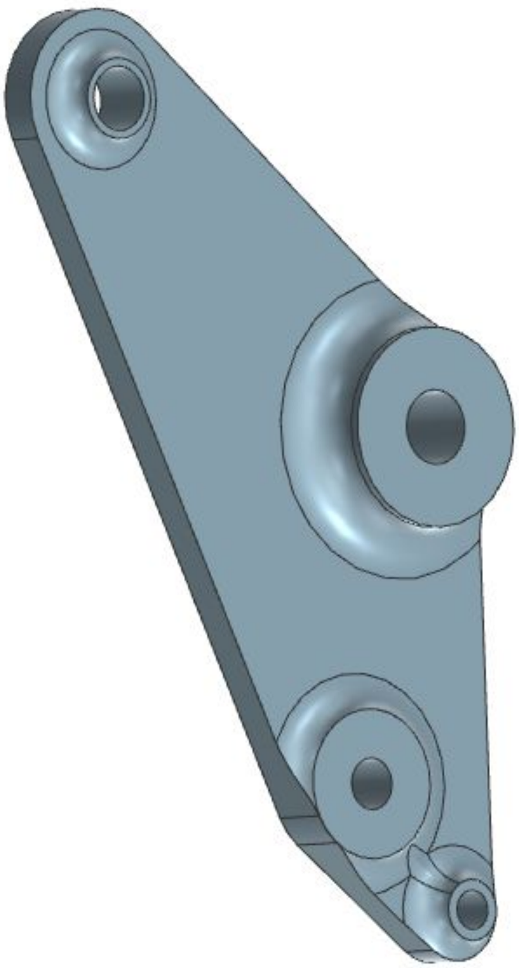




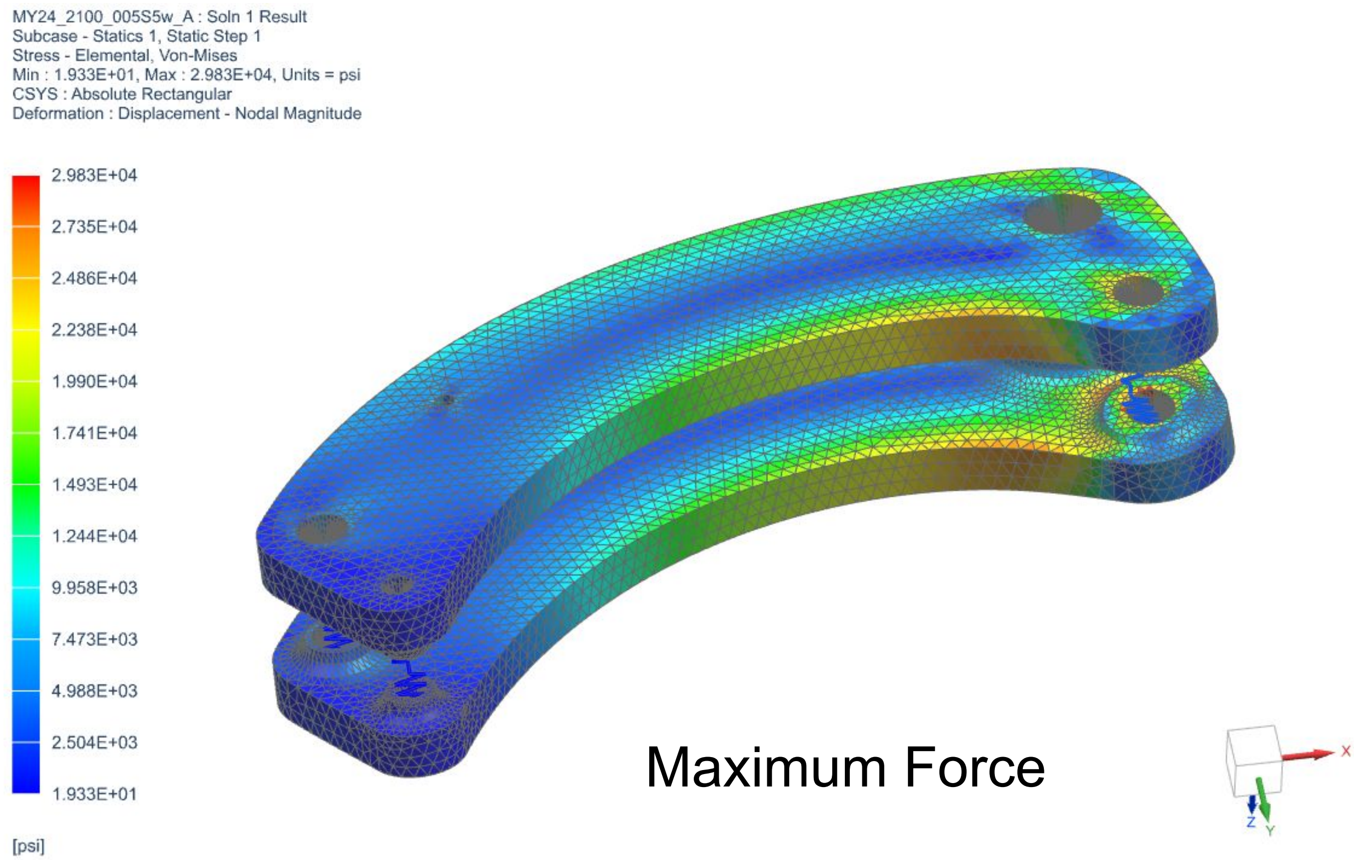
Rear Rocker Design

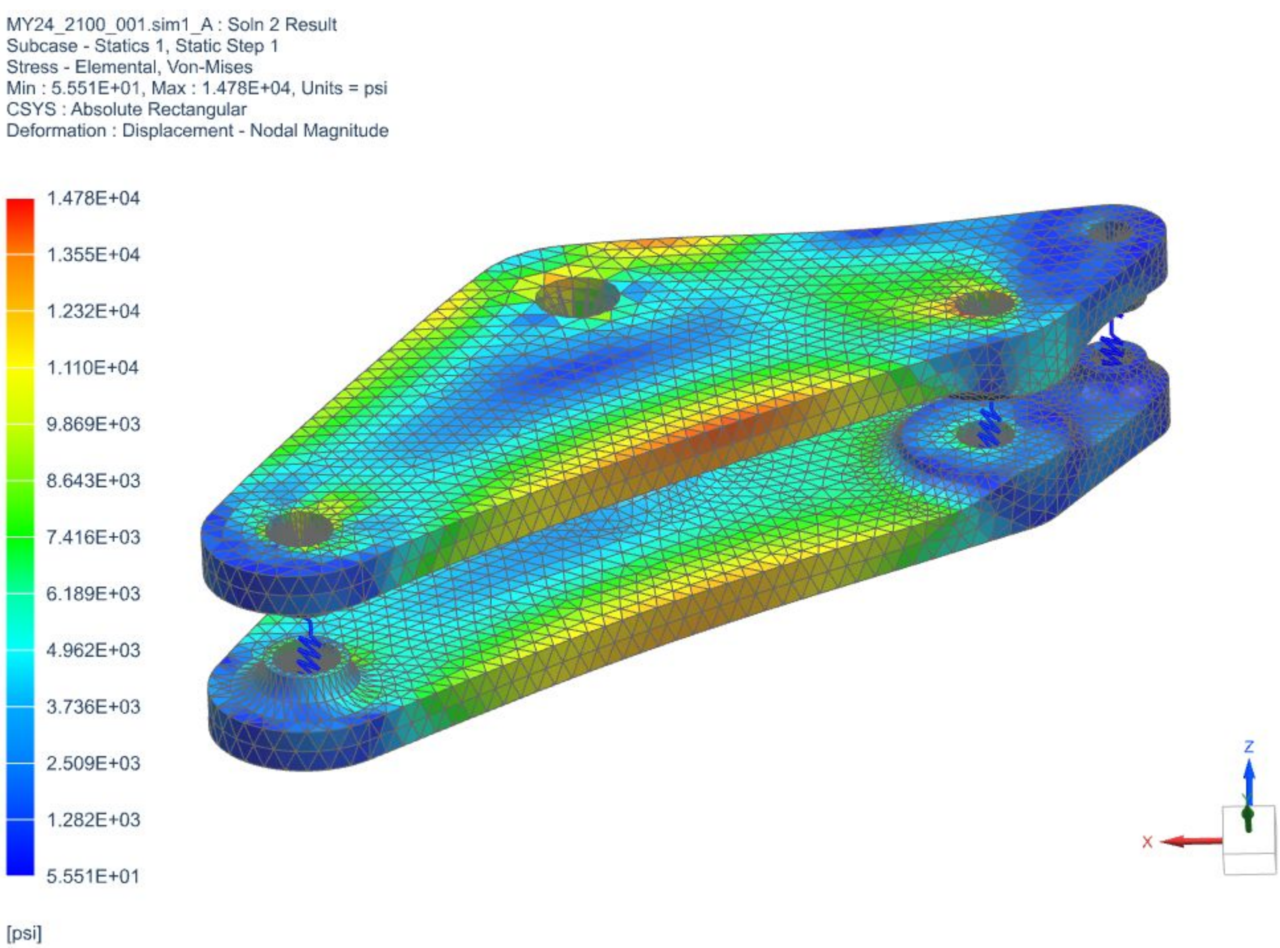




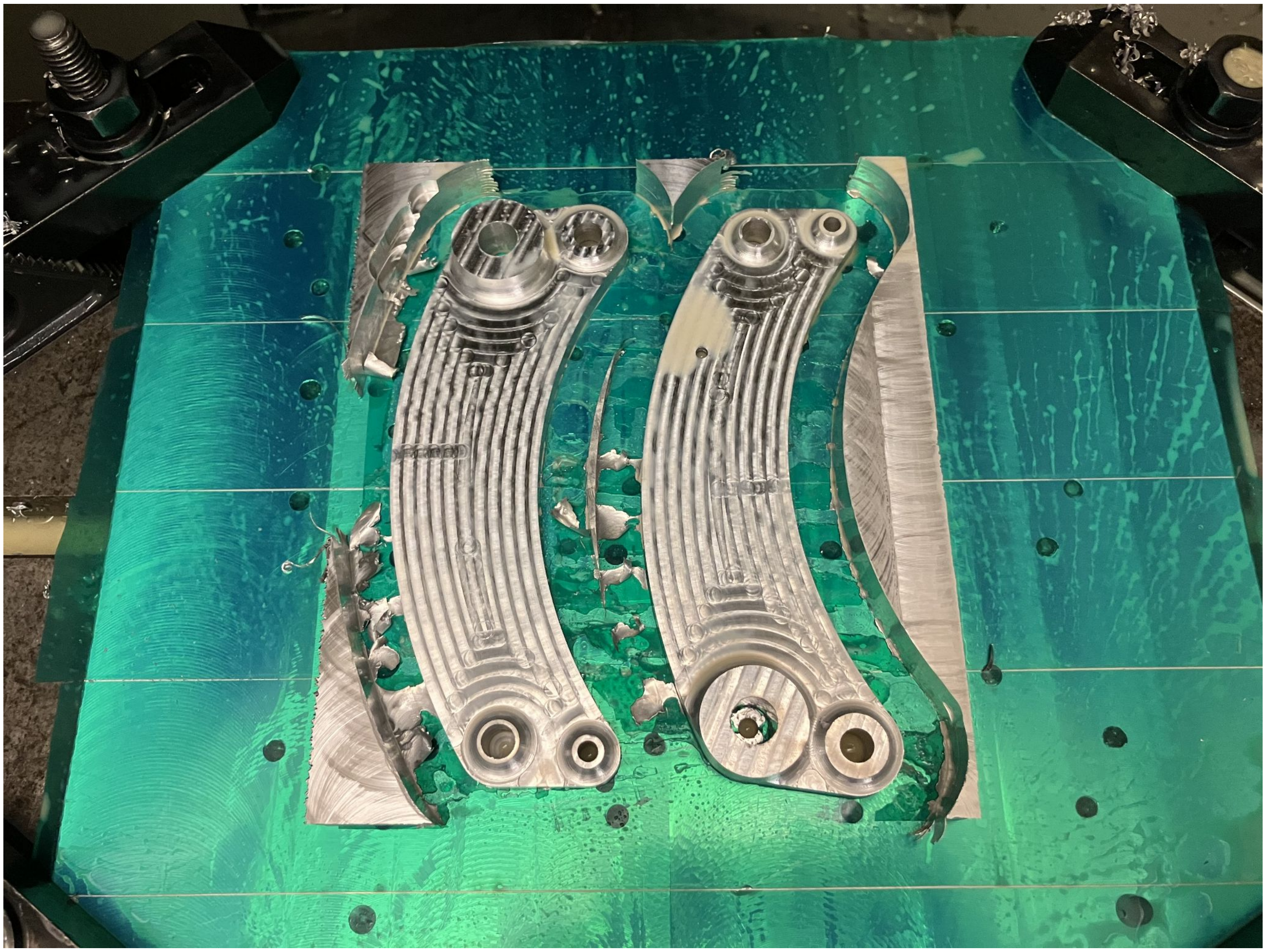


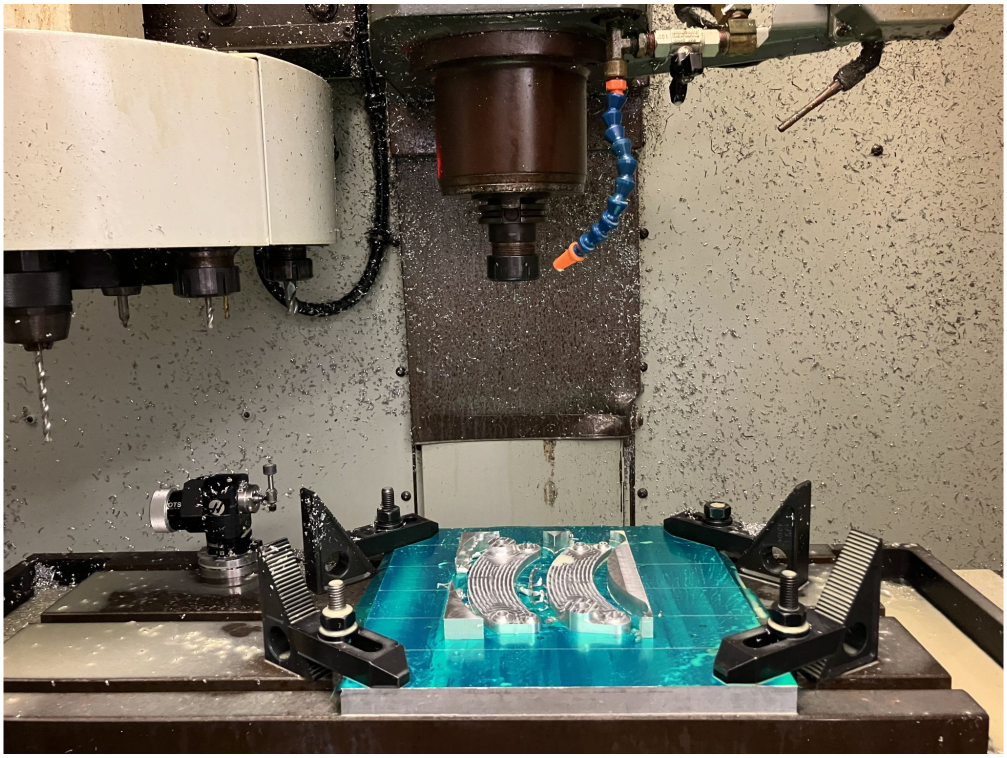
Rocker FEA


MY24_2100_005S5w_A : Soln 1 Result
Subcase - Statics 1, Static Step 1
Stress - Elemental, Von-Mises
Min : 1.933E+01, Max : 2.983E+04, Units = psi
CSYS : Absolute Rectangular
Deformation : Displacement - Nodal Magnitude
2.983E+04
2.735E+04
2.486E+04
2.238E+04
1.990E+04
1.741E+04
1.493E+04
1.244E+04
9.958E+03
7.473E+03
4.988E+03
2.504E+03
1.933E+01
[psi]
Maximum Force
X
Z
Y


MY24_2100_001.sim1_A : Soln 2 Result
Subcase - Statics 1, Static Step 1
Stress - Elemental, Von-Mises
Min : 5.551E+01, Max : 1.478E+04, Units = psi
CSYS : Absolute Rectangular
Deformation : Displacement - Nodal Magnitude
1.478E+04
1.355E+04
1.232E+04
1.110E+04
9.869E+03
8.643E+03
7.416E+03
6.189E+03
4.962E+03
3.736E+03
2.509E+03
1.282E+03
5.551E+01
[psi]
Z
X

Manufacturing





Manufacturing