BAJA SAE
FRONT END & REAR END

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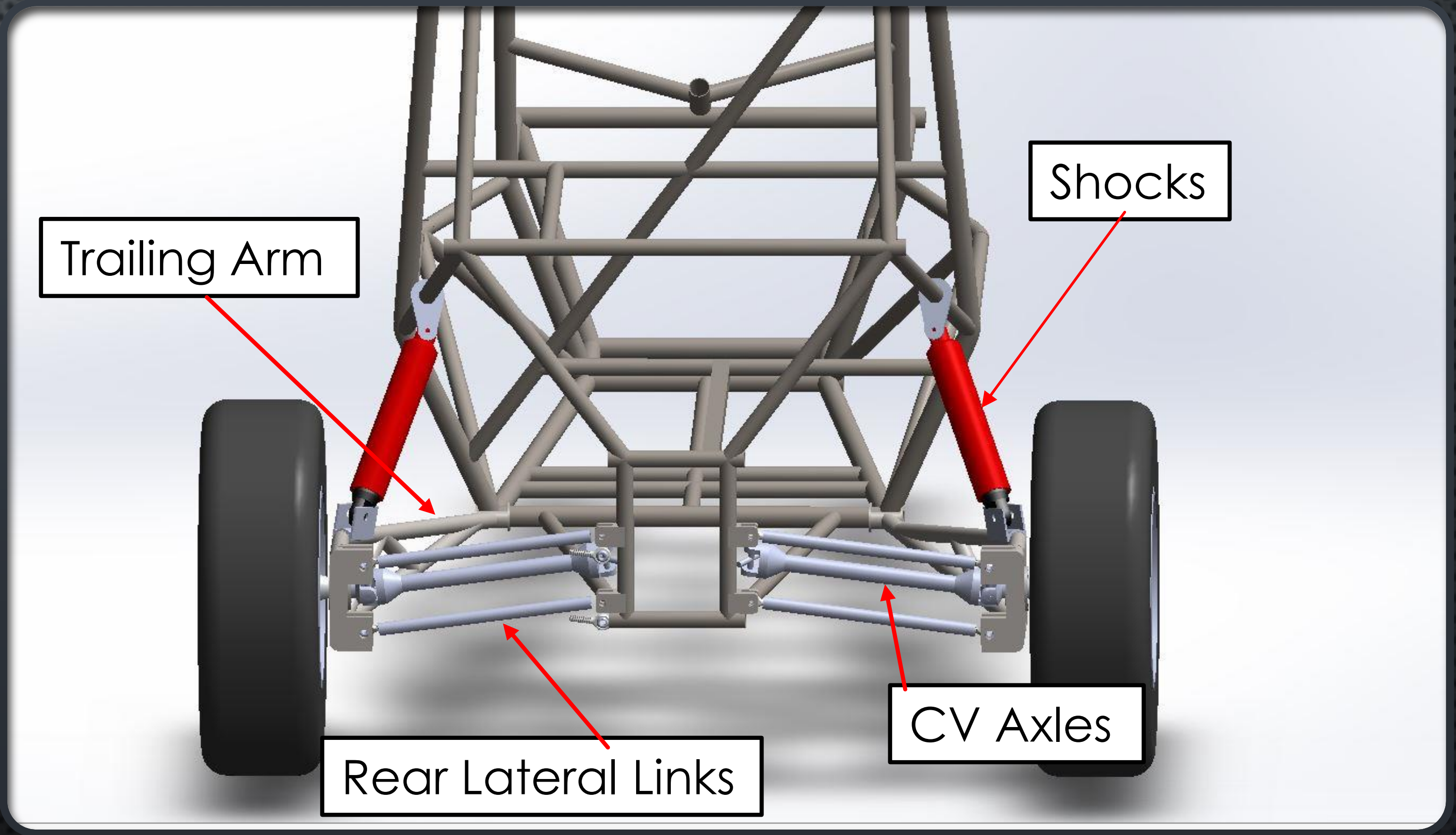
PROJECT DESCRIPTION

- SAE Baja is a collegiate competition in which teams design, build, and test off-roading vehicles
- Vehicles are presented in competition to a fictitious firm for possible manufacturing
- Designs must abide by Baja SAE competition rules in order to compete
- Must be able to perform well in Dynamic and Static events
    - Acceleration Test
    - Braking Test
    - Hillclimb
    - Endurance
- Sponsors include W.L. Gore, NAU and SAE International

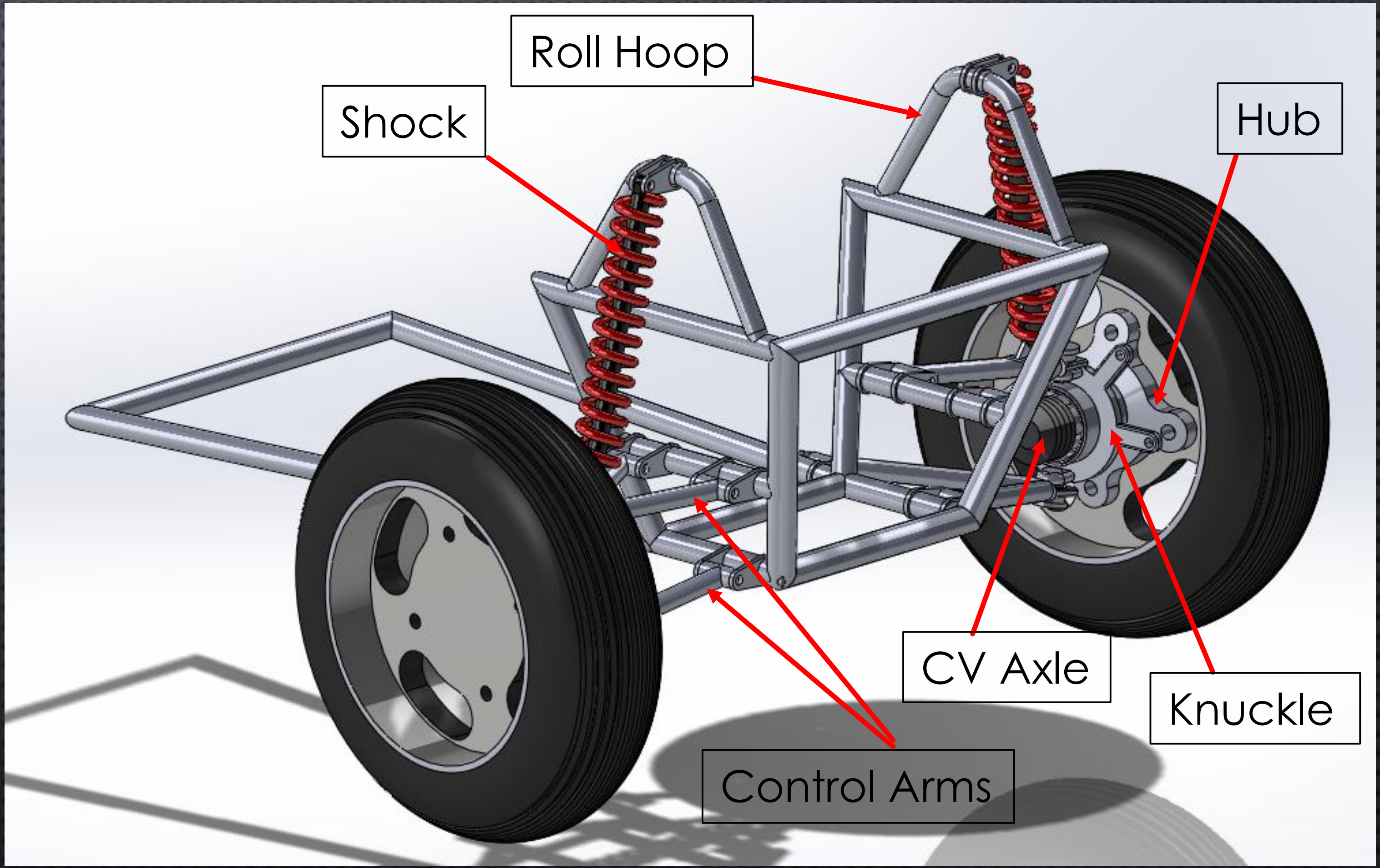
DESIGN DESCRIPTION (REAR END)

- Subsystems
  - Trailing Arm
    - Connect wheel to vehicle
  - Rear lateral links
    - Control wheel movement
  - Shocks
    - Keep Wheels on ground
    - Make ride smoother
  - CV Axles
    - Provide power to wheels

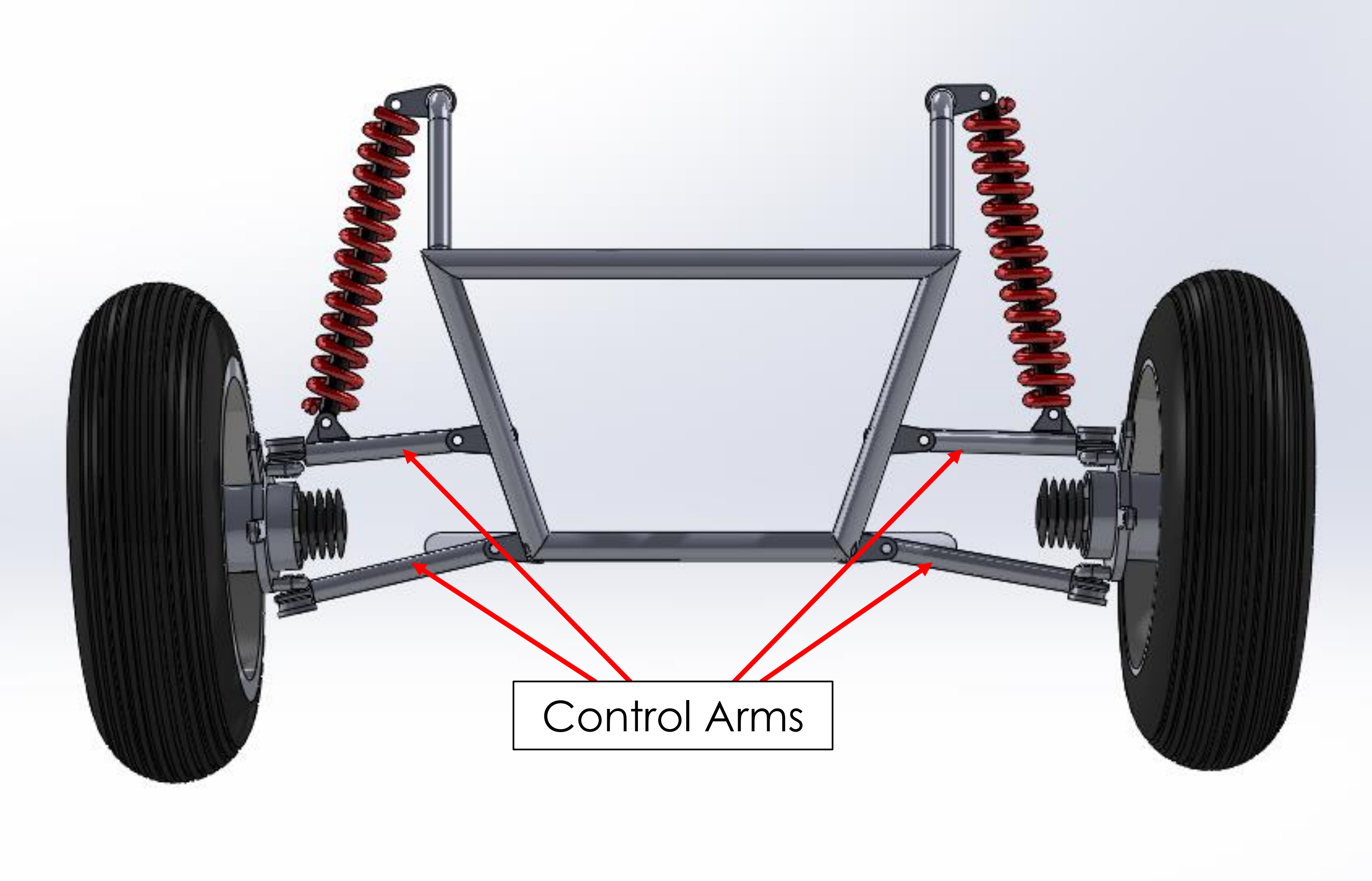


DESIGN DESCRIPTION (FRONT END)

- Subsystems
  - Control Arms
    - Connect wheel to vehicle
    - Center wheel laterally
  - Shocks
    - Keeps Wheels on ground
    - Absorbs ground terrain
  - Roll Hoop
    - Upper shock mount
  - CV Axles
    - Provides power to front wheels
  - Hub
    - Connects CV axle to wheel
  - Knuckle
    - Connects CV axle, brakes, and steering tie rod to wheel



DESIGN DESCRIPTION (FRONT END)



DESIGN REQUIREMENTS (FRONT & REAR END)

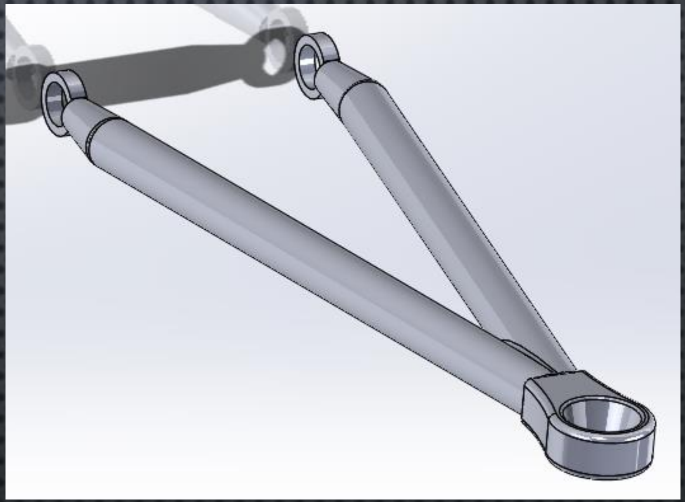
CR's	How CR's Met
Reliable	Designs are Steel
Durable and Robust	Designs are Steel
Lightweight	Designs are Tubes
Maneuverable	Designed Around Set Turning Radius
Low Cost	Within Planned Budget
Easy to repair	Most Parts are After-Market
Short Stopping Distance	Fixed Type Calipers
Short Wheelbase	58 inches
Ride Height	10 inches
Track Width	55 inches
Safe to Operate	Followed All SAE Rules

DESIGN VALIDATION (1 OF 3)

- FMEA
  - Cv axle failure
    - Twisted axle – Strong material
  - Brake system
    - Master Cylinder Leak – Integrated Master Cylinder
    - Brake line rupture – stainless steel brake lines
  - Control arms
    - Weld or tube failure – ensure strong welds through testing and accurate wall thickness in tubing
  - Steering
    - rack and pinion failure – sealed rack and pinion housing

Design Validation (2 of 3)

- Control/Trailing Arms
  - Driving tests
  - Weight Test
  - Maneuverability Tests
  - FEA
- Shocks
  - Mounting Locations (Same Plane)
  - Ensuring shock doesn't bind at current location
  - Compression Test (Pushing/Pulling)
  - Hooke's Law: deflection proportional to load force



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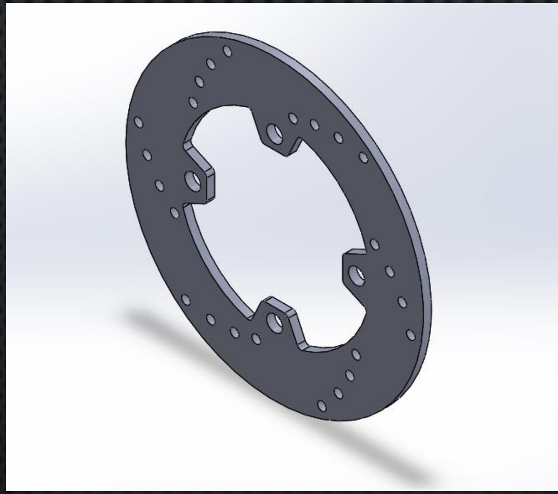
DESIGN VALIDATION (3 OF 3)

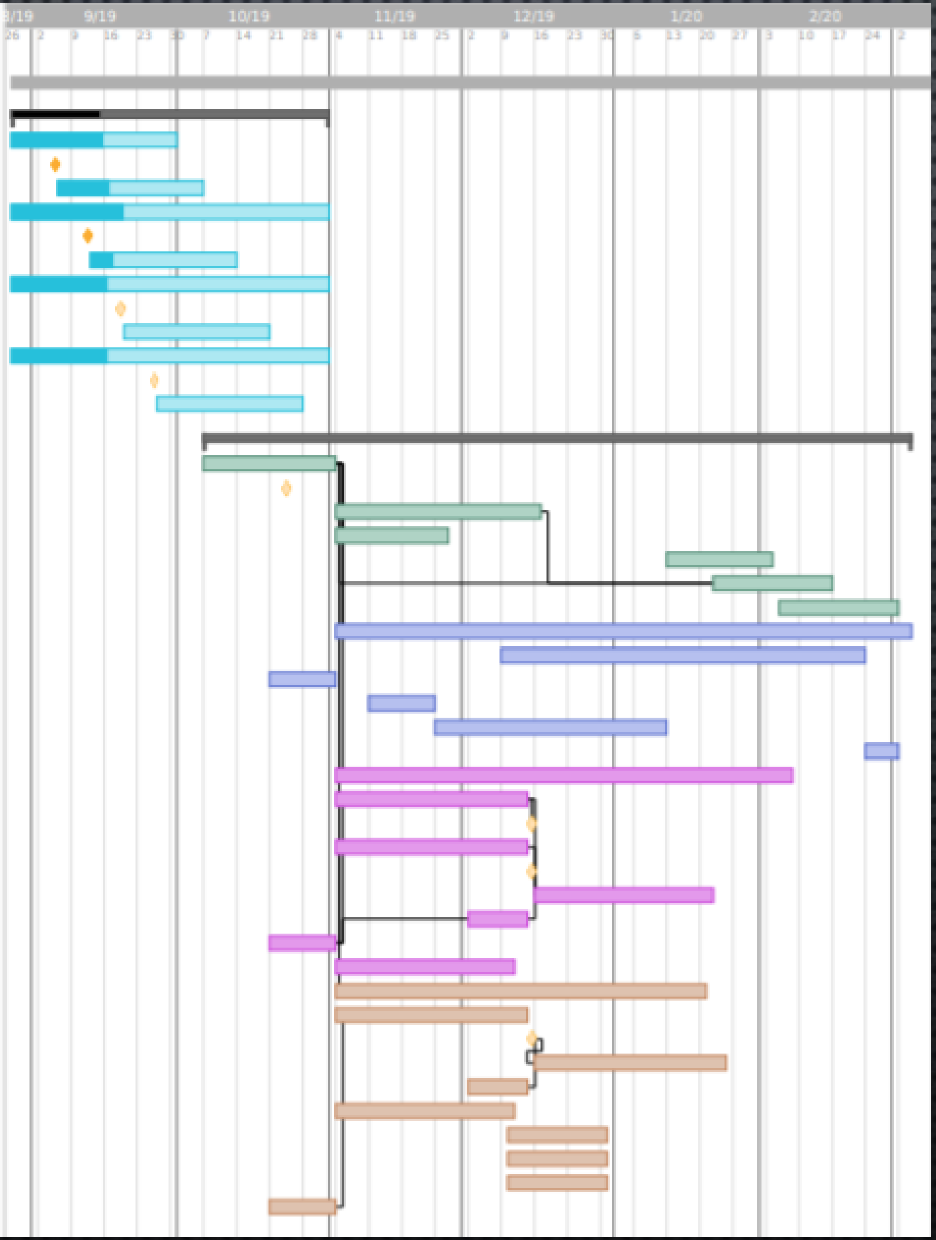
- Steering
  - Ackermann Analysis – Physical measurement of tire angles
  - Rigorous steering on rough terrain – Test the ability to withstand stresses



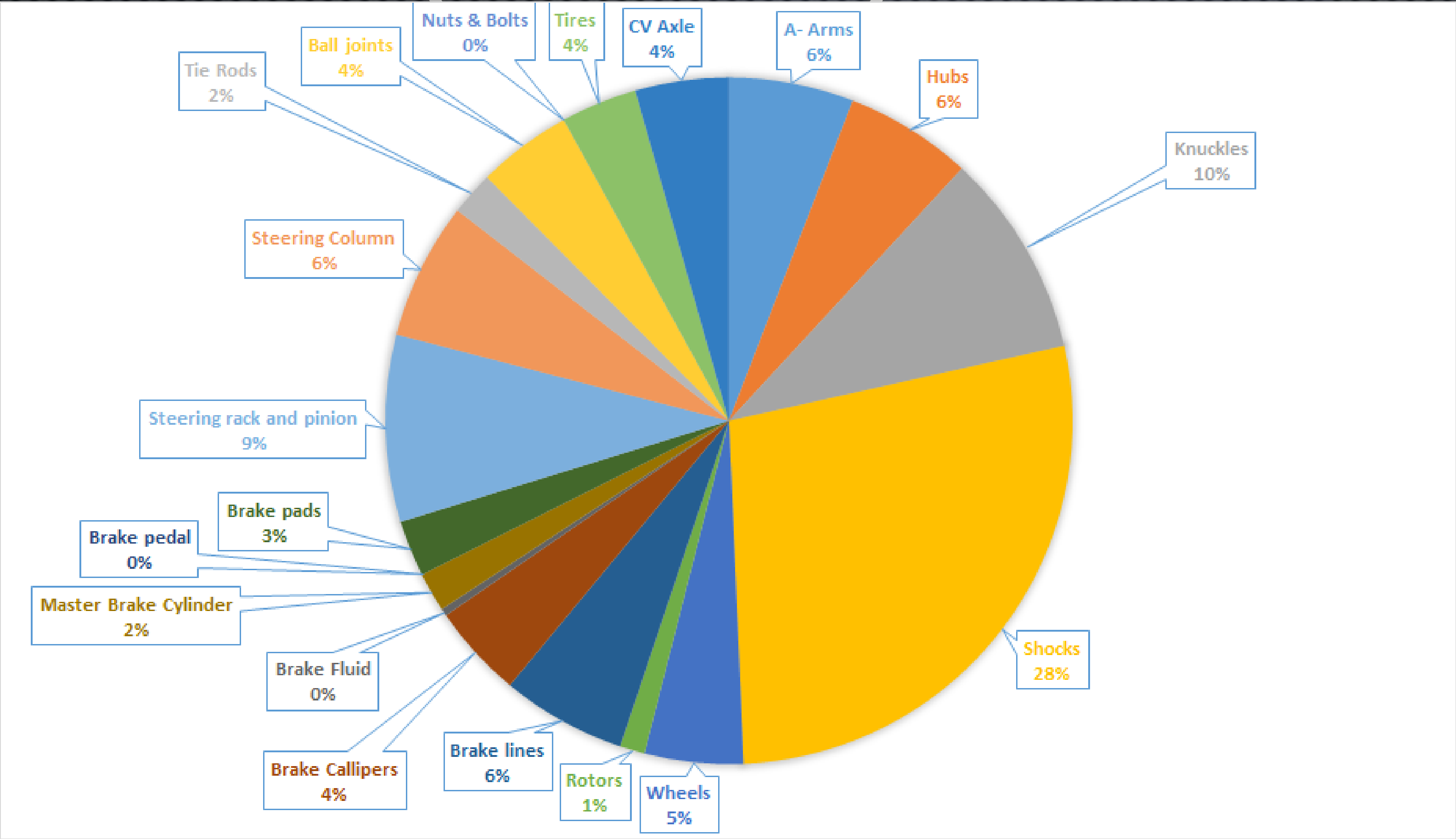
- Brakes
  - Pressure Test
    - Pascal's Law – Hydraulic pressure is transmitted equally throughout fluid in closed system
  - Dynamic Braking Test
    - Record stopping distance, brakes applied at max speed
    - Repeated tests of hard braking
    - Kinetic Energy – Required braking force acting over stopping distance

SCHEDULE

SAE Baja	**0h**	**8%**
Design	**0h**	**28%**
Finalized Design Frame	0	55%
First Iteration Frame	0	100%
Simulation	0	35%
Finalized Design Rear End	0	35%
RE First Iteration	0	100%
RE Simulation	0	15%
Front End Finalized Design	0	30%
FE First Iteration	0	0%
FE Simulation	0	0%
Final Design Drive Train	0	30%
DT First Iteration	0	0%
Simulation	0	0%
Manufacturing	**0h**	**0%**
Frame	0	0%
Frame Tacked	0	0%
Paneling	0	0%
Seat	0	0%
Fire Protection	0	0%
Cockpit Finalized	0	0%
Powder Coat	0	0%
Drivetrain	0	0%
Power Train	0	0%
Engine Mount Built	0	0%
Throttle Cable	0	0%
CVT	0	0%
CVs Mounted	0	0%
RE Suspension	0	0%
Trailing Arms Built	0	0%
Trailing Arms Installed	0	0%
Lateral Links Built	0	0%
Lateral Links Installed	0	0%
Shocks	0	0%
Hubs	0	0%
Frame Mounts	0	0%
Heims, Rod Ends, Ball Joints	0	0%
FE Suspension	0	0%
A-Arms Built	0	0%
A-Arms Installed	0	0%
Shocks	0	0%
Hubs	0	0%
Heims, Rod Ends, Ball Joints	0	0%
Steering Components Installed	0	0%
Steering Components Built	0	0%
Brake System Installed	0	0%
Frame Mounts	0	0%

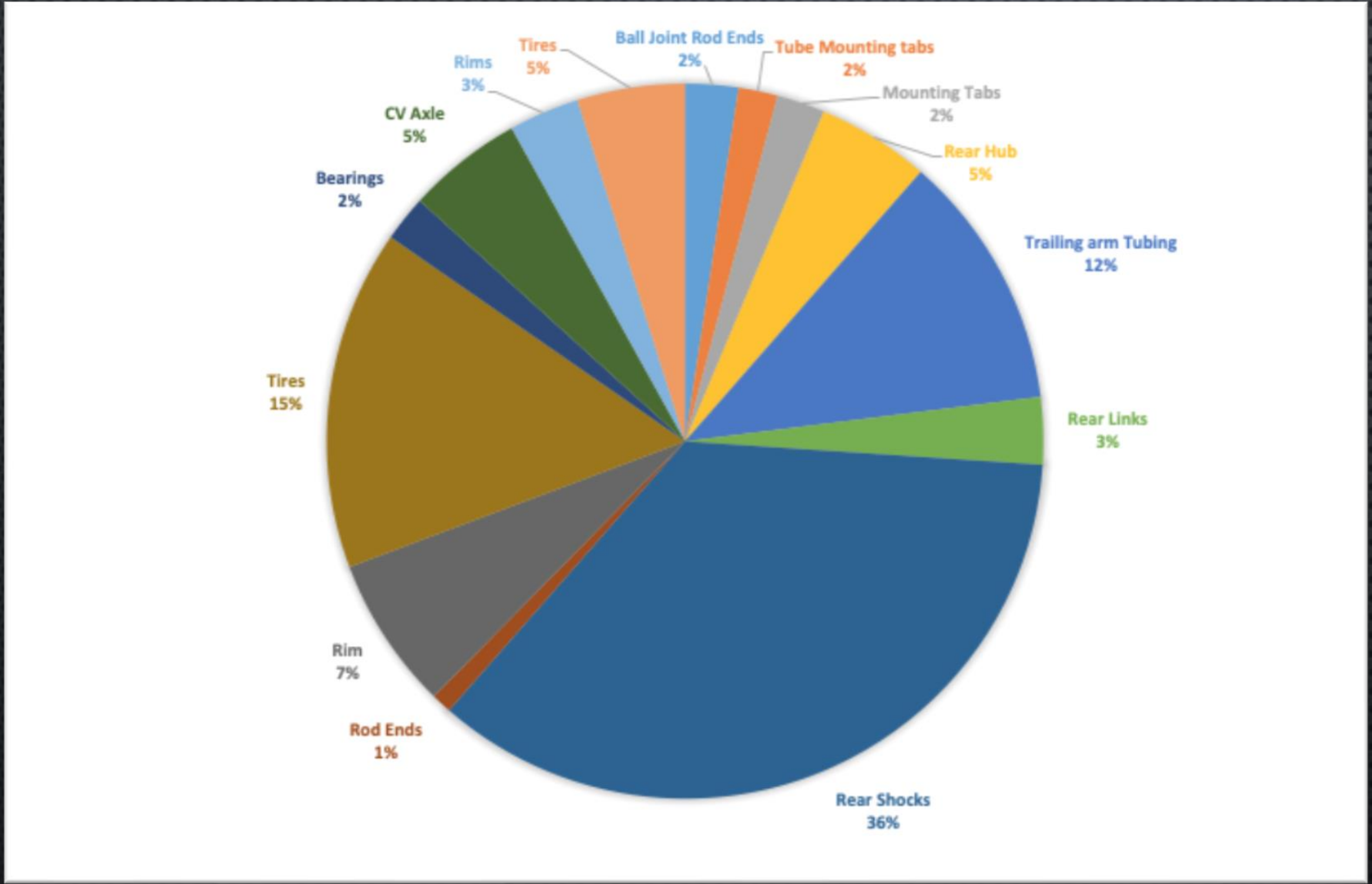


BUDGET - (FRONT END)



- Allocated Budget: $4000
- Total expected Cost: $3256.49

BUDGET (REAR END)



ALLOCATED BUDGET: $3,000

TOTAL EXPECTED COST: $2,678

QUESTIONS?

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APPENDIX A – BRAKE FORCE ANALYSIS

Knowns & Assumptions

Parameter	Value	Units
Curb Weight	375	lbs
Fully Laden Weight (+250 lb Driver)	625	lbs
Weight Distribution (FRONT) *(1-Y)*	0.4	--
Weight Distribution (REAR) *(Y)*	0.6	--
Top Speed	35	mph
Top Speed (Downhill)	40	mph
Wheelbase	58	in
Front Track Width	55	in
Rear Track Width	52	in
Ride Height	10	in
Tire Diameter	22	in
Rim Diameter	10	in
Rim Width	7	in
Average Pedal Force from Driver ****(1.4.1)	100	lbf
Maximum Pedal Force	450	lbf
Application Speed ****	3.5	ft/s
Theoretical Deceleration (fully laden), *a* (Ch.7, a = to tire-surf	1	g
Maximum Pedal Travel ****	3.5	in
Pedal Force/ Deceleration Ratio ****	100	lbf/g
Pedal Force Multiplier	6.2	--
Height of CG	22	in
Factor of Safety (FS)	1.75	--
4 Wheel Lock Force (Total Force)	1025.390625	lbf
Brake Bias		
Front Split	0.7	--
Rear Split	0.3	--
Brake Pad Type		
Coefficient of Friction**	0.4	--
Pad Area**	0.34	in^2

Component Design

Parameter	Value	Units
Rotor Design		
Front Rotor Diameter	7	in
Front Rotor Mean Radius	3.2	in
Rear Rotor Diameter	7	in
Rear Rotor Mean Radius	3.2	in
Front Caliper Design		
Number of Pistons	2	in
Piston Diameter	1.25	in
Single Piston Area	1.23	in^2
Total Piston Area	2.46	in^2
Rear Caliper Design		
Number of Pistons	2	in
Piston Diameter	1.25	in
Single Piston Area	1.23	in
Total Piston Area	2.46	in
Master Cylinder Dimensions		
Bore Diameter (Front)***	0.625	in
Bore Diameter (Rear)***	0.625	in
Max Pushrod Stroke	1.4	in
Brake Pedal Dimensions		
Foot Plate to Pivot Point	9.3	in
Pivot point to MC Pushrod	1.5	in
Average Pedal Force from Driver	100	lbf
Maximum Pedal Force	450	lbf
Pedal Ratio (Ip)	7	--
Brake Pedal Material	Aluminum	--

Force Calculations

Parameter	Value	Units
Brake Pedal Force (Fp*Ip)	700	lbf
Front Master Cylinder Pressure	2281.645264	psi
Rear Master Cylinder Pressure	2281.645264	psi
Front Caliper Force	2806.423675	lbf
Rear Caliper Force	2806.423675	lbf
Brake Line Pressure P_lf (Front)	1825.316211	psi
Brake Line Pressure P_lr (Rear)	1825.316211	psi
MC Bore Area (F)	0.3067961576	in^2
MC Bore Area (R)	0.3067961576	in^2
Brake Factor (BF)****	0.8	--
Front Clamping Force Efficiency****	0.98	--
Front Clamping Force	5500.590403	lbf
Rear Clamping Force Efficiency****	0.98	--
Rear Clamping Force	5500.590403	lbf
Friction Force (Front)	2200.236161	lbf
Friction Force (Rear)	2200.236161	lbf
Brake Rotor Torque (Front)	7040.755716	lbf*in
Brake Rotor Torque (Rear)	7040.755716	lbf*in
Force at 1x Front tire	640.0687014	lbf
Force at 1x Rear tire	640.0687014	lbf
Front Force (No Balance Bar)	1280.137403	lbf
Rear Force (No Balance Bar)	640.0687014	lbf
Total Braking Force	**1920.206104**	lbf
Front Force (With Bias Bar)	1344.144273	lbf
Rear Force (With Bias Bar)	576.0618313	lbf
4 Wheel Lock Total Force	1025.390625	lbf
4 Wheel Lock Total Force (FS)	**1794.433594**	lbf

Sanity Checks

Will All 4 Wheels Lock?
Yes
Which Brakes will Lock First? Adjust bias accordingly.
Rears

Theoretical Braking Force Required

Parameter	Value	Units		
x (Ratio of Ycg to Wheelbase)	0.3793103448	--		
Dynamic Front Axle Normal Force (F_zFdyn)	487.0689655	lbf		
Dynamic Rear Axle Normal Force (F_zRdyn)	137.9310345	lbf		
Surface Coeff. of Friction *u (offroad tire on gravel/sand)*	0.6	--	http://hpwizard.com/tire-friction-coefficient.html	
Axle Braking force F_xf	292.2413793	lbf		
Axle Braking force F_xr	82.75862069	lbf		
Front Traction Coeff. (U_tf)	0.8982300885	--	*eq. 7-18b	
Rear Traction Coeff. (U_tr)	1.359375	--	*eq. 7-18a	
Front Braking Torque	1022.844828	lbf*in	http://www.engineeringinspiration.co.uk/brakecalcs.html	*v = rw
Rear Braking Torque	289.6551724	lbf*in	http://www.engineeringinspiration.co.uk/brakecalcs.html	*v = rw
Required Clamping Force (Front)	799.0975216	lbf	http://www.engineeringinspiration.co.uk/brakecalcs.html	*F_friction = T_rc F_friction = u_bmr * F_clamping
Required Clamping Force (Rear)	226.2931034	lbf	http://www.engineeringinspiration.co.uk/brakecalcs.html	*F_friction = T_rc F_friction = u_bmr * F_clamping
Total Clamping Force Required	1025.390625	lbf		

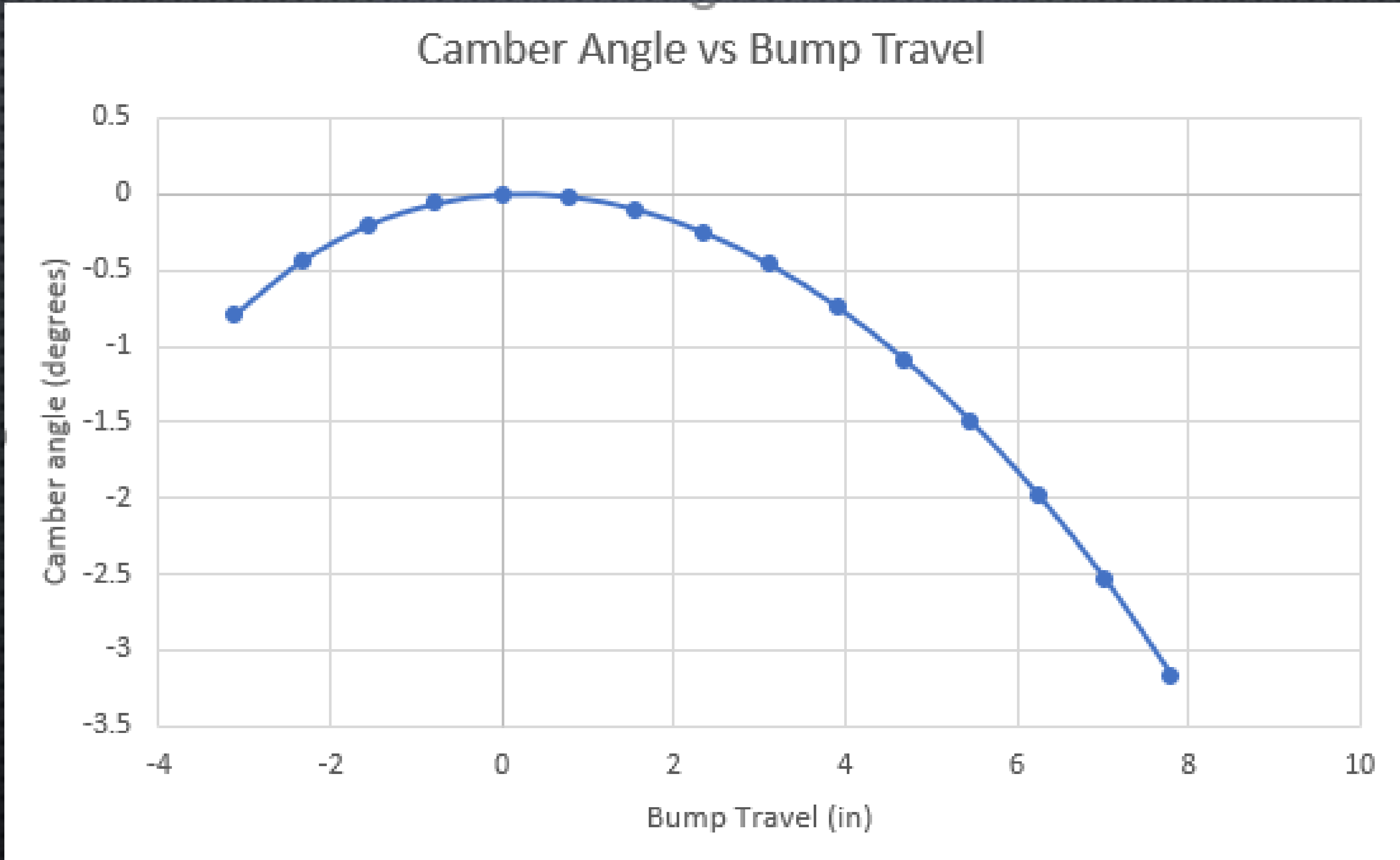
APPENDIX B – ACKERMANN ANALYSIS

R	96	in						
	Track Width (in)							
	52		53		54		55	
Wheel base (in)	L	R	L	R	L	R	L	R
50	35.53767779	22.28558765	35.73216374	22.20347853	35.92850242	22.12194197	36.12671577	22.04097233
51	36.07601156	22.68652667	36.27170359	22.60325748	36.46923439	22.5205656	36.66862524	22.43844541
52	36.60707481	23.08513367	36.80388871	23.00072724	37.00252653	22.91690262	37.20300889	22.83365418
53	37.13092445	23.48139068	37.32877852	23.39586984	37.52844082	23.31093504	37.72993135	23.22658063
54	37.64762064	23.87528085	37.84643568	23.78866841	38.04704253	23.70264595	38.24946054	23.61720785
55	38.15722659	24.26678843	38.3569259	24.17910715	38.5583999	24.09201953	38.76166731	24.00551997
56	38.65980825	24.65589874	38.8603176	24.56717132	39.0625839	24.47904099	39.26662524	24.39150214
57	39.15543412	25.04259818	39.35668172	24.95284725	39.55966797	24.86369657	39.76441034	24.77514057
58	39.64417496	25.42687417	39.84609144	25.33612229	40.04972777	25.24597356	40.25510079	25.15642244
59	40.12610358	25.80871518	40.32862196	25.7169848	40.53284094	25.62586023	40.73877676	25.53533595
60	40.60129465	26.1881107	40.80435031	26.09542416	41.0090869	26.00334584	41.21552009	25.91187026
61	41.06982445	26.56505118	41.27335508	26.47143071	41.47854662	26.37842063	41.68541418	26.2860155
62	41.53177074	26.93952806	41.73571628	26.84499575	41.94130243	26.75107578	42.14854371	26.65776271
63	41.9872125	27.31153375	42.19151512	27.21611156	42.3974378	27.1213034	42.60499448	27.0271039
64	42.43622979	27.68106157	42.64083387	27.58477129	42.84703721	27.48909653	43.05485324	27.39403194
65	42.8789036	28.04810575	43.08375563	27.95096903	43.29018596	27.85444908	43.49820748	27.7585406
66	43.31531568	28.41266144	43.52036423	28.31469974	43.72696998	28.21735585	43.93514531	28.12062453

APPENDIX C – FAILURE MODES AND EFFECTS ANALYSIS

Component	Potential Failure Mode	Potential Effects of Failure	Severity (1-5)	Occurance (1-5)	Detection (1-5)	How Design Mitigated	Risk Priority Number
CV Axles	Binding joint	Tire locks up	4	2	1	Use durable and heavy duty boots to seal the binding joints	8
	Spline failure	No power to the wheel	5	3	3	Ensure power through CV axle is appropriate splines	45
	Twisted axle	Risk of breaking and damaging other parts	3	1	5	Diameter of axle must withstand power output	15
Brake System	Master cylinder leak	Decreased braking system pressure, pedal will not retract	5	2	5	Integrated master cylinder	50
	Seized Caliper piston	Vehicle pulls to one direction during braking/ partial system failure	4	2	4	Brake Bias system to redirect braking force to either axle	32
	Brake line leak or rupture	Decreased deceleration, brake system failure	5	3	4	Stainless steel Brake lines to resist abrasion, expansion	60
	Brake fluid boils	Reduced brake system pressure	3	3	4	DOT 4 Brake fluid, higher fluid boiling point	36
	Brake rotor thermal deformation	Vibrations in steering system feedback, decreased braking efficiency	3	3	4	Cross drilled and slotted rotors to improve heat dissipation	36
Control Arms	Ball joint seize	Suspension dampening loss, separation from wheel knuckle/hub	3	2	3	Big enough ball joint for weight of vehicle	18
	Weld failure	Complete control arm failure, arm component separation	5	3	4	Ensuring all welds are strong through testing	60
	Tube failure	Complete control arm failure	5	2	5	Thick enough wall on tubing	50
Steering	Steering column failure	Detachment of the driver to control the vehicle	3	2	5	Stress analysis performed on Steering Column	30
	External interfrence in rack and pinion	Jammed steering system	5	2	4	Sealed rack and pinion set up.	40
	Tie rod bending	Steering alignment will be off	5	2	3	Stress analysis conducted prior to mounting	30
Shocks	Binding mount	Reduced shock mobility	3	1	3	Mounting geometry correct for movement of shock	9
	Blown shock	Decreased damping ability, soft or stiff ride quality	3	3	3	Purchase capable shock for our vehicle weight	27

APPENDIX D – FRONT END GEOMETRY ALIGNMENT SPECIFICATIONS (CAMBER)



APPENDIX E – FRONT END GEOMETRY ALIGNMENT SPECIFICATIONS (TOE ANGLE)