Preliminary Design Review

MAE151A Lab 5: ABR Rolling Chassis

Introduction

Project Mission: Design, test, and manufacture a rolling chassis—including the suspension, steering, brakes, and human interface subsystems—that will be integrated with the powertrain subsystem into the final vehicle, which will compete at the 2025 Baja SAE Arizona competition.

Objectives: Pass technical inspection at competition. Finish in the Top 20 overall.

2023-2024 Anteater Baja Racing Vehicle: “Scoundrel”

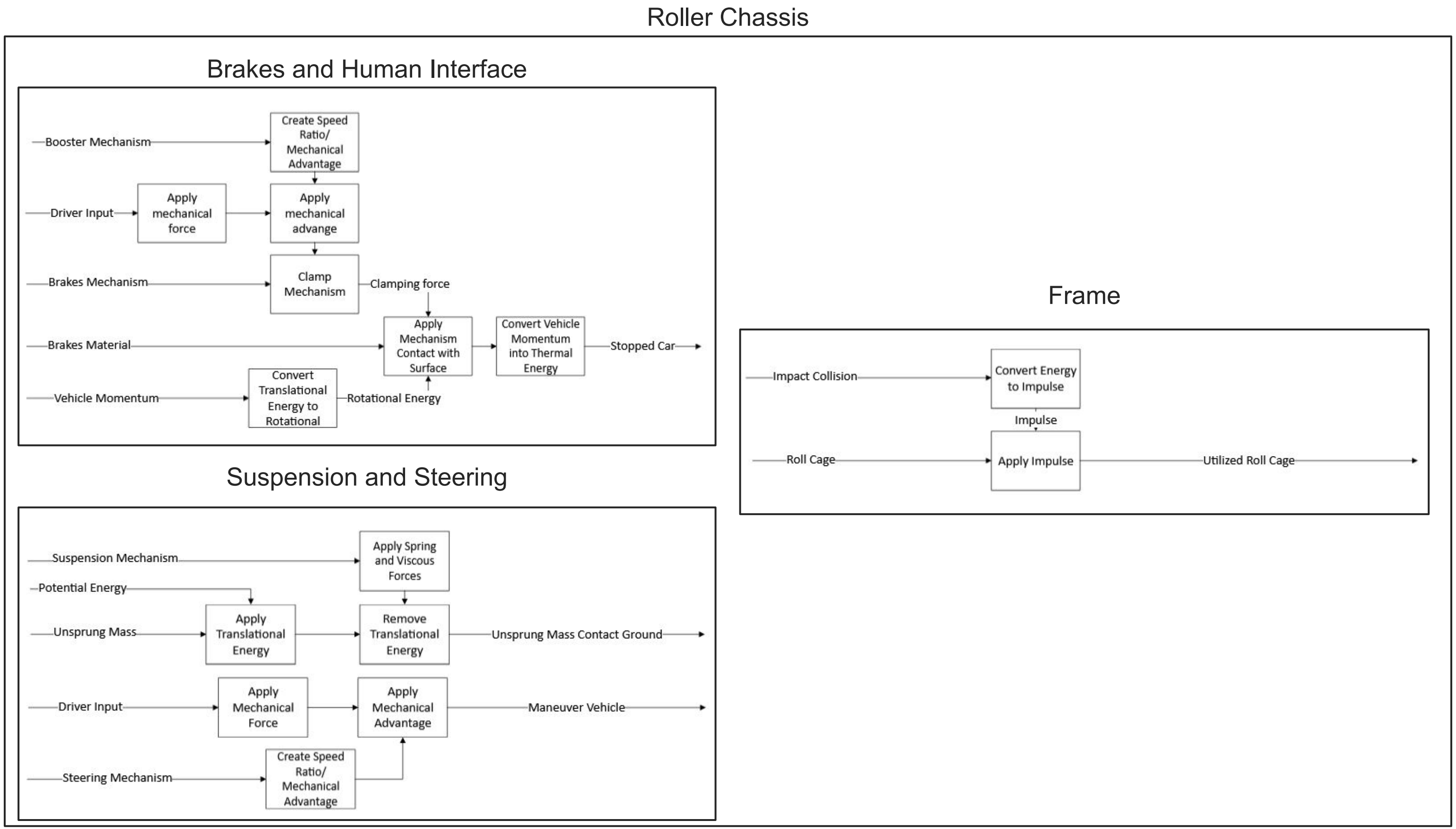
Mary

Design Attributes (OCFM Table)

Design Attributes	O	C	F	M
Must adhere by rules and safety regulations laid out in the 2025 Baja SAE rulebook		X		
Should have braking system capable of locking all 4 wheels			X	
Should be lightweight	X			
Could use composite materials to manufacture vehicle body panels				X
Should be able to land smoothly from jumps			X	
Must be under the budget that the team is allocated		X		
Should be able to withstand impact with minimal deformation	X			
Should protect driver in the case of a rollover			X	
Should be easy to maneuver over rough terrain and around tight corners	X			
Should have a clear, minimally obstructed field of view for the driver	X			
Should require an appropriate amount of force on brake pedal to activate the brakes			X	
Should have easy access to components for quick maintenance and repair	X			

Victorio

Grey Box Diagram



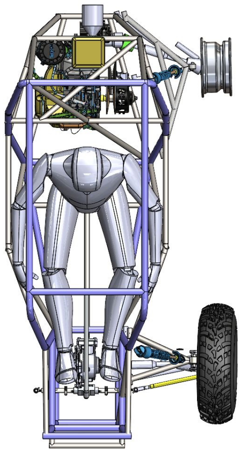
Justin

Requirements

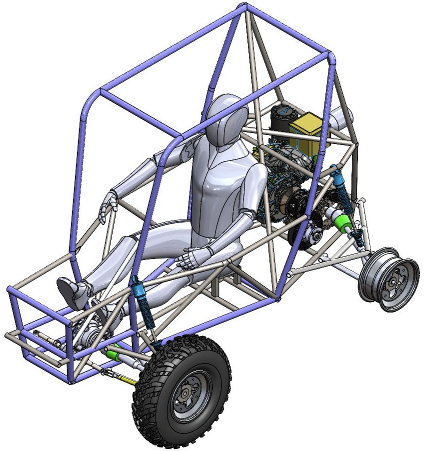
Type of Requirement	ID	Requirement
Overall System	OSR-001	The vehicle shall comply to the rules stated within the 2025 SAE Baja Rulebook
Overall System	OSR-002	The vehicle shall be able to withstand a 5G impact at the wheels without deforming or failing
Overall System	OSR-003	The Rolling Chassis must weigh 270 pounds or less
Chassis	CHR-001	The chassis shall be able to withstand a 5G impact without deforming
Chassis	CHR-002	The chassis shall be able to withstand suspension loading scenarios up to ~2000 lbf without deforming
Chassis	CHR-003	The chassis must provide adequate mounting locations and members for suspension and powertrain components
Suspension	SUR-001	The suspension shall be able to accommodate for 10 inches of suspension travel
Suspension	SUR-002	The suspension shall be able to absorb the energy from a 3 foot drop without bottoming out or binding
Steering	STR-001	The steering shall have a lock-to-lock rotation of 270 degrees or less
Steering	STR-002	The vehicle's turning radius shall be less than 11 feet
Brakes	BRR-001	The brakes must lock up all four wheels when fully activated
Human Interface	HIR-001	The driver must be positioned as low as possible while still being able to see and maneuver the vehicle
Human Interface	HIR-002	The driver shall have a way to communicate with team members within a ~¾ mile radius

Victorio

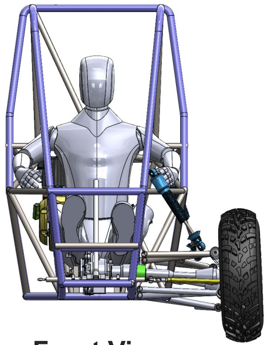
Proposed Design: Orthogonal Views



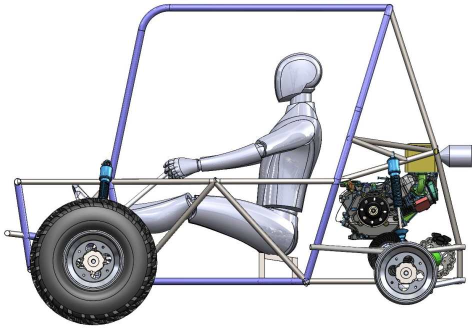
Top View



Isometric View



Front View



Side View

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Proposed Design: Detailed Exploded Views

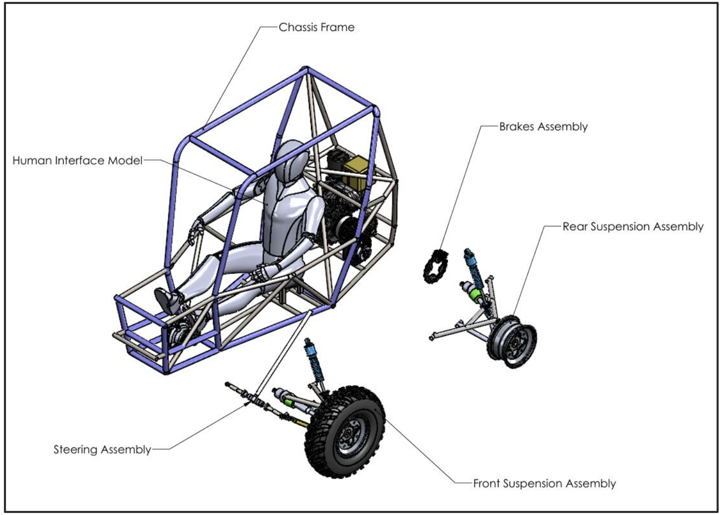
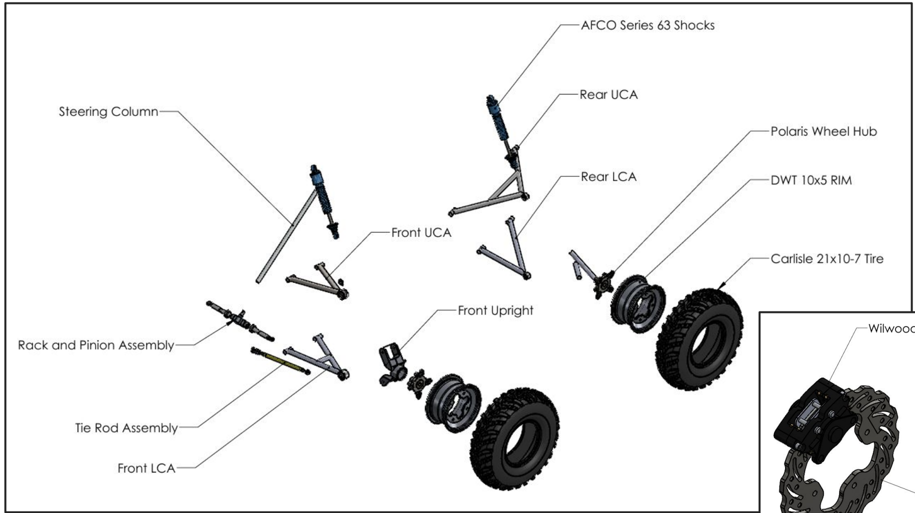


Fig 1: Exploded view of Master CAD with the Frame, Brakes, Human Interface, Suspension, and Steering subsystems



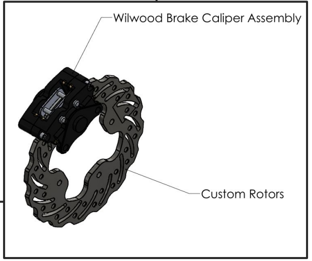


Fig 2-3: Exploded view of the Suspension, Steering, and Brakes with all major components.

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System Decomposition

Subsystem	Form	Function
Chassis	Steel Frame ● Body panels	Protect the driver ● Mount Steering, suspension, brakes, and human interface components
Steering	Rack and Pinion Steering (Ackerman Geometry) ● Rack and pinion ● Tie rods ● Steering column	Control the turning of the vehicle
Suspension	Double A-Arm Independent Suspension ● Shocks ● Control Arms ● Upright ● Wheel assembly	Transverse rocky and desert terrain ● Keep wheels contacting the ground at all times ● Keep vehicle stable through maneuvers ● Absorbs irregularities on the road
Brakes	Hydraulic Disc Brakes ● Brake Pedal ● Master Cylinders ● Brake Lines and Fittings ● Calipers ● Rotors	Lock all 4 wheels
Human Interface	Steering wheel	Provide means of driver input for maneuvering the vehicle

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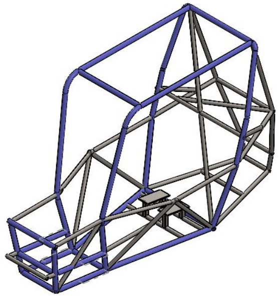
Chassis-Frame Material Trade Study



Primary → 4130 Chromoly Steel

Primary Member Materi	1018 DOM Steel (SAE Ru	4140 Steel	A513 Steel	304 Steel	A36 Steel	1018 DOM	4140 Steel	1020 DOM !	1020 DOM !	1026 DOM !	1026 DOM Ste	4130 Chromol	4130 Chromol	4130 Chromol	1045	15B30 Steel	1540 Steel
Outer Diameter (in.)	0.984	1.1	1.25	1.25	1.25	1.18	1.18	1.25	1	1.25	1	**1.25**	1	1	1		
Wall Thickness (in.)	0.118	0.078	0.065	0.065	0.065	0.078	0.078	0.0625	0.065	0.065	0.065	**0.065**	0.065	0.049	0.065		
Inner Diameter (in.)	0.748	0.944	1.12	1.12	1.12	1.024	1.024	1.125	0.87	1.12	0.87	**1.12**	0.87	0.902	0.87		
Moment of Inertia (in^4)	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.02	0.04	0.02	**0.04**	0.02	0.02	0.0210		
Moment of Inertia (m^4)	1.28E-08	1.37E-08	1.77E-08	1.77E-08	1.77E-08	1.71E-08	1.71E-08	1.72E-08	8.73E-09	1.77E-08	8.73E-09	**1.77E-08**	8.73E-09	6.91E-09	0.0000000087		
Density (lb/in^3)	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	**0.28**	0.28	0.28	0.284	0.284	0.284
Elastic Modulus (GPa)	205.00	205.00	205.00	205.00	205.00	205.00	205.00	205.00	205.00	205.00	205.00	**205.00**	205.00	205.00	205	205	205
Yield Strength (MPa)	365.00	415.00	170.00	205.00	250.00	365.00	415.00	350.00	350.00	415.00	415.00	**435.00**	435.00	435.00	515		
Ultimate Ten.Strength (MPa)	440.00	655.00	275.00	515.00	400.00	440.00	655.00	420.00	420.00	490.00	490.00	**670.00**	670.00	670.00	620		
Bending Strength (N/m)	*372.66*	*406.65*	*189.89*	*228.99*	*279.25*	*417.65*	*474.86*	*378.21*	*240.49*	*463.56*	*285.16*	***485.90***	*298.90*	*236.58*	*354.0*		
Bending Stiffness (N/m^2)	*2,615.61*	*2,806.20*	*3,635.15*	*3,635.15*	*3,635.15*	*3,515.27*	*3,515.27*	*3,516.66*	*1,788.92*	*3,635.15*	*1,788.92*	***3,635.15***	*1,788.92*	*1,415.92*	*1789.7*		
Weight (lb/ft)	*1.13*	*0.85*	*0.82*	*0.82*	*0.82*	*0.92*	*0.92*	*0.82*	*0.65*	*0.82*	*0.65*	***0.82***	*0.65*	*0.50*	*0.651*		
Relative Cost ($)	*128.00*	*163.00*	*6.97*	*16.84*	*13.16*	*138.00*	*163.00*	*53.40*		*22.84*		***29.00***	*26.89*				
Ben Stre. to wei. ratio	329.50	476.45	230.26	277.67	338.62	453.82	515.99	461.23	369.60	562.11	438.23		459.35	474.18	5.44E+02		
Ben Stif. To wei. ratio	2,312.66	3,287.94	4,407.99	4,407.99	4,407.99	3,819.73	3,819.73	4,288.61	2,749.26	4,407.99	2,749.26	**4,407.99**	2,749.26	2,837.99	2.75E+03		
Weldability	Good	Easy	Medium	Tough	Easy	Easy	Easy	Easy	Easy	Easy	Easy	**Easy**	Easy				
Cost to Weight Ratio	113.17	190.98	8.45	20.42	15.96	*149.95*	177.12	65.12		27.70		**35.17**	41.33				
Carbon Content	0.18%	0.38%-0.43%	0.18%	0.08 %	0.29%	0.18%	0.38%-0.43%	0.17-0.23%	0.17-0.23%	0.22-0.28%	0.22-0.28%	**0.30%**	0.30%				
Pass or Fail	Pass	FAIL	FAIL	FAIL	FAIL	Possible	Possible	Pass	FAIL	Pass	FAIL	**Pass**	FAIL	FAIL	FAIL	FAIL	FAIL
Reason for Fail	N/A	Too expensive	Too Thick for mass	Carbon Content	Not come in tube	Too expensiv	Too expensive	N/A	Properties		Properties		Properties	Wall Thickness	Not sold	Not sold	Not sold
												Best Choice					

Sources: Onlinemetals.com, Coremarkmetals.com, Wicksaircraft.com https://www.metalsupermarkets.com/product/mild-steel-round-tube-1026-dom/

AISI 4140 Steel, normalized at 870°C (1600°F), air cooled, 13 mm (0.5 in.) round (matweb.com)

The Top row is another possible source

Andrew

Tire Selection Trade Study

Tire Trade Study (size 10 rim)

Relevant Factors*: Make sure it fits on the rim. Lightweight (2 ply should be good). Suitable for Arizona terrain. Research what the comp was like last time it was there and take note of the terrain. Tires are extremely important and a bad choice can make an otherwise good car run horribly.

Features	Option 1	Option 2	Option 3	Option 4
Name/Link	Kenda Bearclaw	Holeshot ITP Tire	Carlisle AT489	Trail Wolf
Manufacturer	Kenda	ITP	Carlstar	Carlstar
Image				
Ply	6	2	4	4
Weight per tire (lbs)	15.2 (22x8-10) 15.1 (23x7-10) 17.86 (23x10-10)	12	11.52	11.19
Size	22x8-10 and 23x7-10 and 23x10-10	21x7-10	23x7-10	22x7-10
Price per tire	$75.16 (22x8-10) $79.96 (23x7-10) $83.96 (23x10-10)	$76.18	$119.38	$111.42
Tread pattern	Mud (17,17,19/32" depth)	intermediate (14/32" depth)	All terrain (19/32" depth)	Intermediate all terrain
other	Some sizes suggested for front / back	Also might struggle in mud	Bandit's tire, many sizes	Not rated for mud, more sizes

Pravir

Brake Caliper Part Selection

Wilwood GP200 Brake Caliper

- Dual piston, floating
- Lightweight, small size, durable

Decision Matrix:

Criterion	Description	Weight (0-5)	Ranking (1-10)	Score (Weight * Ranking)	Ranking (1-10)	Score (Weight * Ranking)	Ranking (1-10)	Score (Weight * Ranking)	Ranking (1-10)	Score (Weight * Ranking)	Ranking (1-10)	Score (Weight * Ranking)
Name:	Cooler is always better :)		Wilwood PS1 Caliper		Wilwood SC10 2 Piston		Wilwood GP200 Caliper		Wilwood D154 Single & Dual Piston Floater		Brembo P34 Brake Caliper	
Price:	Cheaper is better (usually)	2	7	14	7	14	7	14	4	8	6	12
Piston Size:	More piston area = more force on rotor	2	5	10	7	14	6	12	7	14	7	14
Durability:	Forged and machined > cast	3	8	24	6	18	8	24	8	24	6	18
Mounting:	Any potential issues?	2	5	10	5	10	5	10	5	10	5	10
Weight:	Lighter is better (reduce unsprung mass)	5	8	40	5	25	8	50	2	10	6	30
Size:	Smaller is better	4	8	32	6	24	8	32	5	20	7	28
Availability:	Available and more common	3	5	15	5	15	6	18	6	18	4	12
			Total:	145	*Total:*	120	*Total:*	160	*Total:*	104	*Total:*	124
			Notes:	2nd Place	*Notes:*	Okay	*Notes:*	BEST	*Notes:*	Not Good	*Notes:*	Okay

Mary

Brake Rotor Design & Material Selection

Custom Rotor Design:

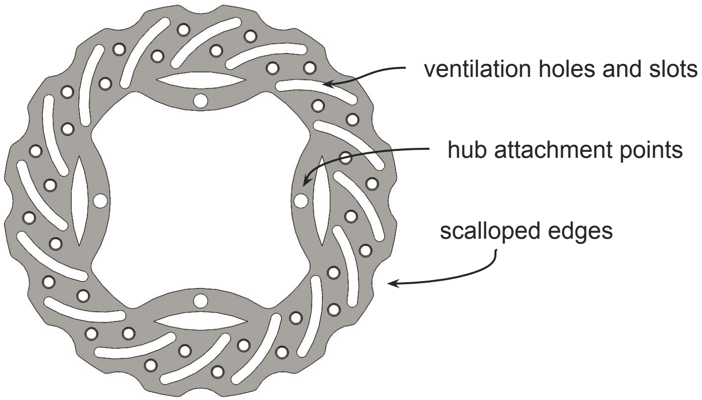
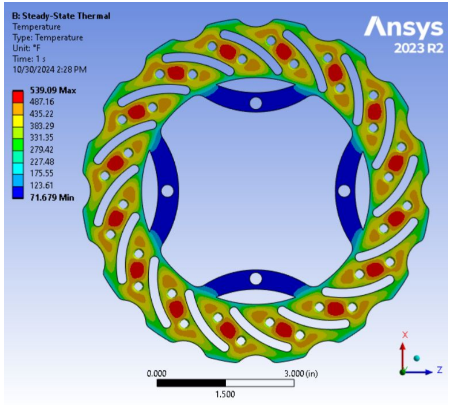


Fig 4

Steady-State Thermal FEA Results for 1018 Steel Rotor:

Max Temperature: 539.09 °F

Max Total Heat Flux: 1.9192 BTU/s · in^2



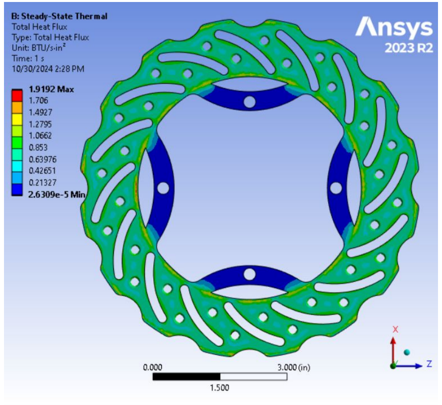


Fig 5.1, 5.2

Material Options Pros and Cons:

	Gray Cast Iron (GG20)	Mild Steel (1018)	Aluminum
Pros	best machinability, low cost, good thermal conductivity, easy to finish	less prone to cracking, good thermal conductivity, good machinability, high hardness, high compressive strength	most lightweight
Cons	very brittle (prone to cracking), bad corrosion resistance	can be more expensive, moderate corrosion resistance	warps easily, worse heat dissipation, low melting temperature

Mary

Work Breakdown Structure (WBS)

I. Problem Definition
   A. Understand SAE Rulebook
   B. Identify Project Constraints (Time, Budget, Technical)
   C. Develop Project Objectives and Milestones
   D. Define System Requirements
II. Design and Analysis
   A. Conceptual Design
      1. Brainstorming and Concept Generation
      2. Evaluate Design Alternatives and Off-the-Shelf Parts Options
         a) Trade Studies & Decision Matrices
   B. Detailed Design and Analysis
      1. OTS Parts Selection
      2. Finalize Materials Selection of Design Components
      3. CAD Modeling of Components and Subsystems
      4. Create Master CAD
      5. Perform Analysis (FEA) on System Components
         a) Design Calculations (Stress, Thermal, etc.)
III. Prototype Fabrication
   A. Acquire Materials and Secure Access to Facilities, Machinery, etc.
   B. Weld and Assemble Chassis Frame
   C. Integrate Subsystems onto Chassis
      1. Complete Subsystem (Steering, Suspension, Brakes) Prototypes
      2. Manufacture Composite Body Panels and Number Panel
IV. Prototype Testing
   A. Develop Testing Procedures
   B. Static Testing
      1. Chassis Structural Load Tests
      2. Brake System Pressure and Response Test
   C. Record Testing Data and Document Results

Mary

Timeline

		Name	Duration	Start	Finish	Predecessors	Resource Names
1		Rule Familiarization and Sy...	6 days	7/8/24 8:00 AM	7/15/24 5:00 PM		All Subteams
2		Trade Studies and Parts S...	6 days?	7/16/24 8:00 AM	7/23/24 5:00 PM	1	All Subteams
3		Working Subassemblies	76 days?	7/24/24 8:00 AM	11/6/24 5:00 PM	1;2	All Subteams
4		Front Suspension Chassis ...	15.5 days?	9/23/24 8:00 AM	10/14/24 1:00 PM		Suspension and Steering;Ch...
5		UPright Design Complete	11 days?	10/28/24 8:00 AM	11/11/24 5:00 PM		
6		Rear Suspension Integration	10.5 days?	10/28/24 8:00 AM	11/11/24 1:00 PM		Suspension and Steering[15...
7		Powertrain Transmission C...	10.5 days?	10/28/24 8:00 AM	11/11/24 1:00 PM		Powertrain Transmission;Po...
8		Powertrain Driveline Integ...	8.4 days?	10/28/24 8:00 AM	11/7/24 11:12 AM		Powertrain Driveline;Chassis...
9		Seat Location/Mounting C...	24 days?	10/29/24 8:00 AM	11/29/24 5:00 PM		
10		Pedal Box Routed	24 days?	10/29/24 8:00 AM	11/29/24 5:00 PM		
11		Brakes Intgration	5.25 days?	10/28/24 8:00 AM	11/4/24 10:00 AM		Suspension and Steering;Br...
12		Chassis Body Final Changes	4.875 days?	11/25/24 9:00 AM	11/29/24 5:00 PM		Chassis and Body
13		Final CAD Integration	4.875 days?	11/25/24 9:00 AM	11/29/24 5:00 PM		All Subteams
14		Subsystem Prototype Design	8.875 days?	11/4/24 9:00 AM	11/14/24 5:00 PM		All Subteams
15		Subsystem Prototypes Built	32.875 days?	11/18/24 9:00 AM	1/1/25 5:00 PM	14	All Subteams
16		Prototype Manufacturing	40.875 days?	1/1/25 9:00 AM	2/26/25 5:00 PM		All Subteams
17		Vehicle Testing and Re-ev...	27 days?	3/26/25 8:00 AM	5/1/25 5:00 PM	16	All Subteams

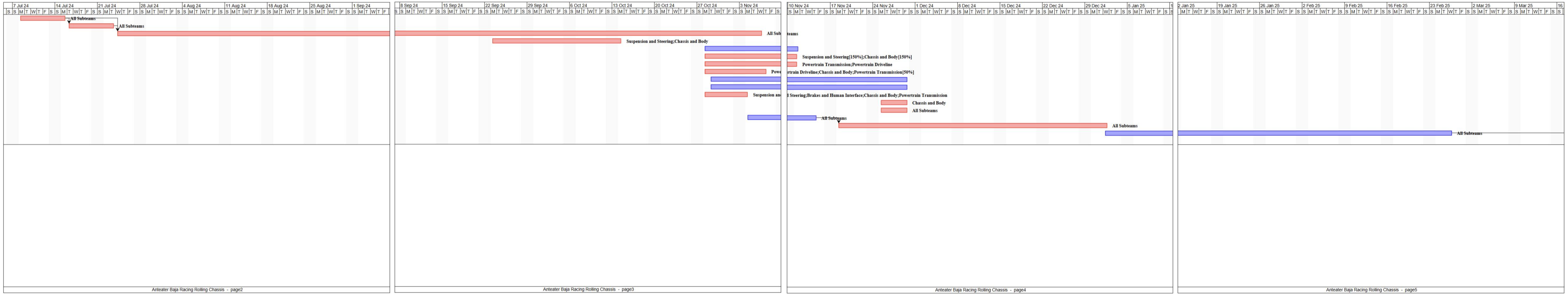


Fig 1: Project Timeline with Projectlibre

Yulun

Concerns

Technical Concerns	Plan to Resolve Concern
Oversized frame	Reduce chassis size and height by designing around designated driver(s)
Overweight vehicle	Reduce number of unnecessary members. Use lightweight composite materials for body panels. Reduce individual component weight in subsystems
Weak steering components	Stronger rack and pinion modifications and stronger and sturdier rack and pinion mounting
Lack of on-campus resources & facilities for composite manufacturing	Enroll in Cerritos Community College course and use their facilities
Difficulty finding OTS brake rotor that fits within wheel assembly	Will manufacture rotor in-house using CNC machine on campus

Mary