Critical Design Review

ZotSun: Front Suspension Subteam

Nicholas, Patrick, Quan, Sebastian, Tiffany

Overview

This presentation shows and justifies our design decisions, and outlines our testing plans for them.

Nicholas
- Parameters being tested
  - Broken down by person

Patrick
- List design attributes
- Outline vehicle requirements

Nicholas
- Final Design
  - Exploded view of suspension, steering for test jig
  - Finalized mounting plate
  - Finalized test jig

Quan
- Compliance table
  - Current regulation compliance
- Design Decisions
  - Ride height
  - Natural frequency
  - KAZ Steering Rack Assembly

Sebastian
- BOM, Manufacturing expectations, and final cost estimates

Nicholas
- Technical Risk Analysis (FMEA)

Tiffany
- Gantt Chart

Parameters Being Tested

Parameter to Test	**Requirement**	**Individual Responsible**	**Relevant Regulation**
Steering Ratio, Maximum Steering Angle	> 17 degrees	Nicholas	10.7.C: U-Turn requirement
Steering Backlash	< 10 degrees at the steering wheel.	Nicholas	10.7.D: Steering backlash
Spring Rate	> 250 lbf / in. (550 lbf / in. expected), Linear to within R^2 > 0.70, for the first half of suspension travel (1.2”).	Quan	9.3: All components > 100mm from ground, except wheels. 10.7.B: Wheel clearance under full suspension compression.
Rocker & Rocker Mount Testing	Withstand 2g bump (330 lbf) at an angle of 8° (46 lbf lateral, 327 lbf vertical), at any rocker configuration.	Patrick	D.1: “analysis shall include … 1g turn, 2g bump, and 1g braking”
A-Arm yield strength	Withstand 2g bump, 1g turn, 1g brake, and combined	Sebastian, Tiffany	D.1: “analysis shall include … 1g turn, 2g bump, and 1g braking”

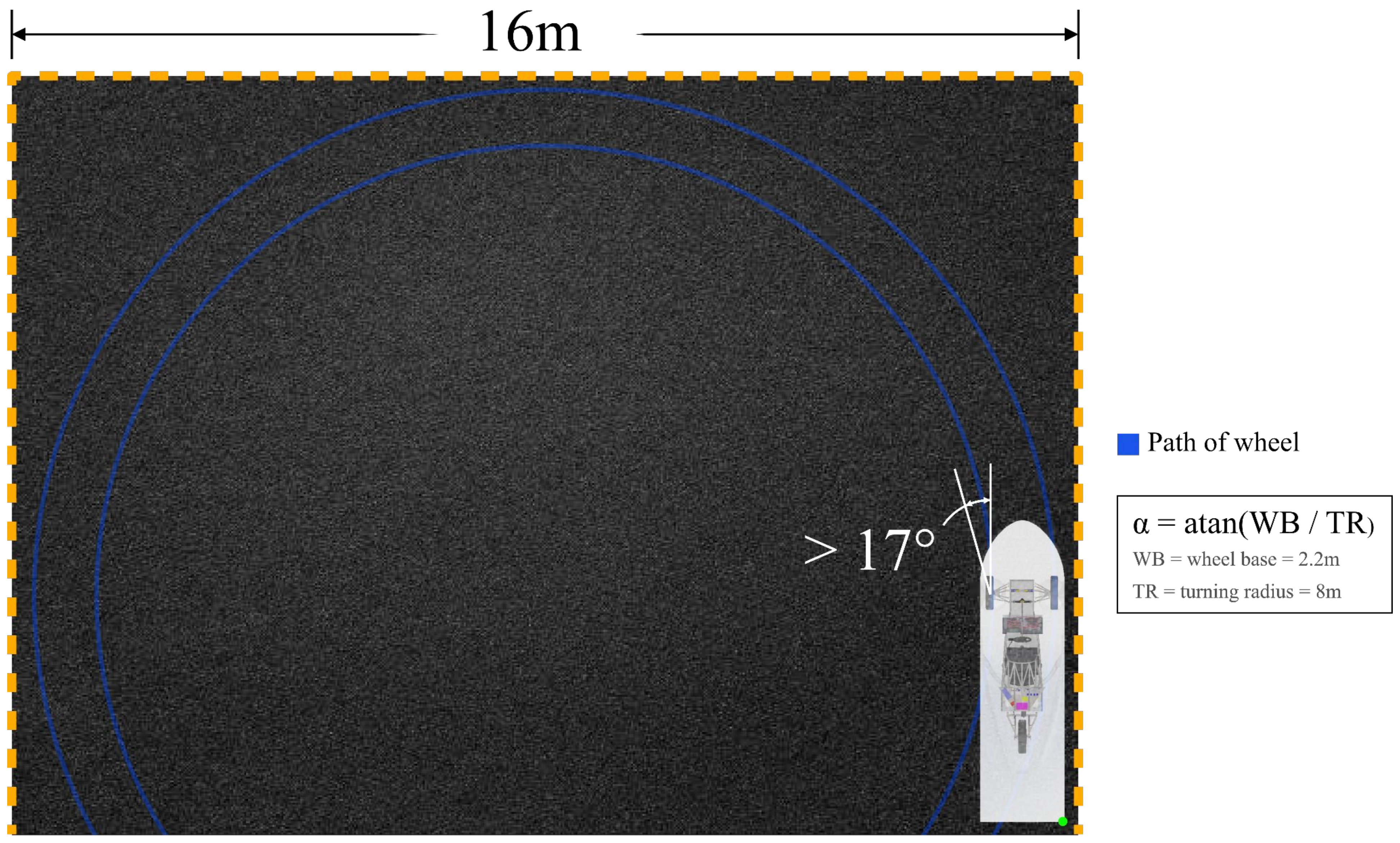


Illustration of the FSGP 10.7.C U-turn regulation, with our car. Drawn to scale.

Design Attributes

Attribute	O	C	F	M
Regulations: Compliance with racing and safety standards		x		
Minimize Weight: Essential for maximizing efficiency and performance	x			
Support Vehicle Load: Support the weight of the vehicle, driver, and subsystems			x	
Budget: Costs should be kept within the funding available for the project		x		
Test: Analysis of 3 unique loading conditions (1G turn, a 2G bump, and 1G braking)		x		
Material Selection: Parts will be manufactured out of 4130 alloy steel or OTS				x

Requirements

01 Functional Requirements

- 10.7.D: Minimal Steering Backlash
- 10.7.C: U-Turn Radius Requirement
- 10.6.D: Non-Contact Parking Brake

02 Performance Requirements

- 10.9.B: Stability Under Crosswinds
- 10.5.C: Minimum Deceleration
- 10.5.B: Brake Pad Thickness
- 10.9.A: Figure-8 Course Completion
- 10.5.C: Brake Fade Resistance

03 Physical Requirements

- 10.8: Towing Requirements
- 10.2.A: Wheel Configuration Requirement
- 10.2.B: Tire Load Capacity(Dynamic)
- 10.2.D.5: Tire Load Capacity(Static)
- 10.2.D.6: Defect-Free, Speed-Rated Tires
- 9.3: Ride Height(>100 mm)

04 Safety Requirements

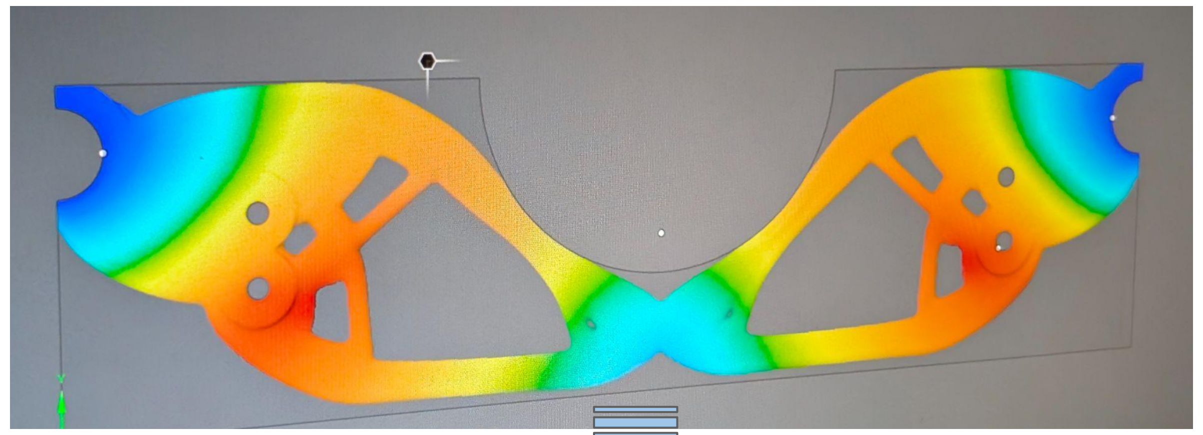
- 10.1.A: Shielding of Moving Parts
- 10.1.1: Suspension Clearance
- 10.4: Strength of Critical Fasteners
- 10.5.A: Dual Balanced Brake System
- 10.4.B: Locking Mechanisms for Safety Fasteners

Final Design

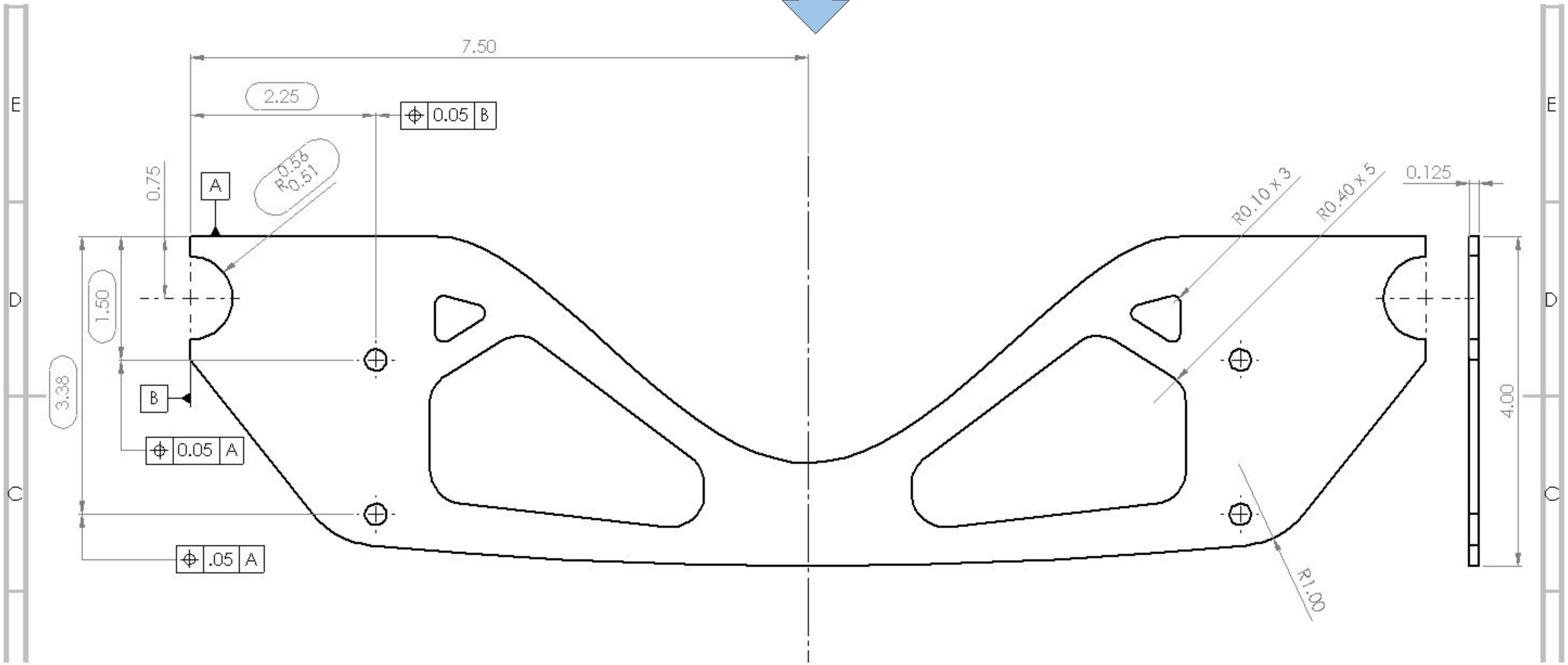
Collapse view of control arm and wheel mounting.

Collapse view of steering rack mounting solution for prototype.

Final Design

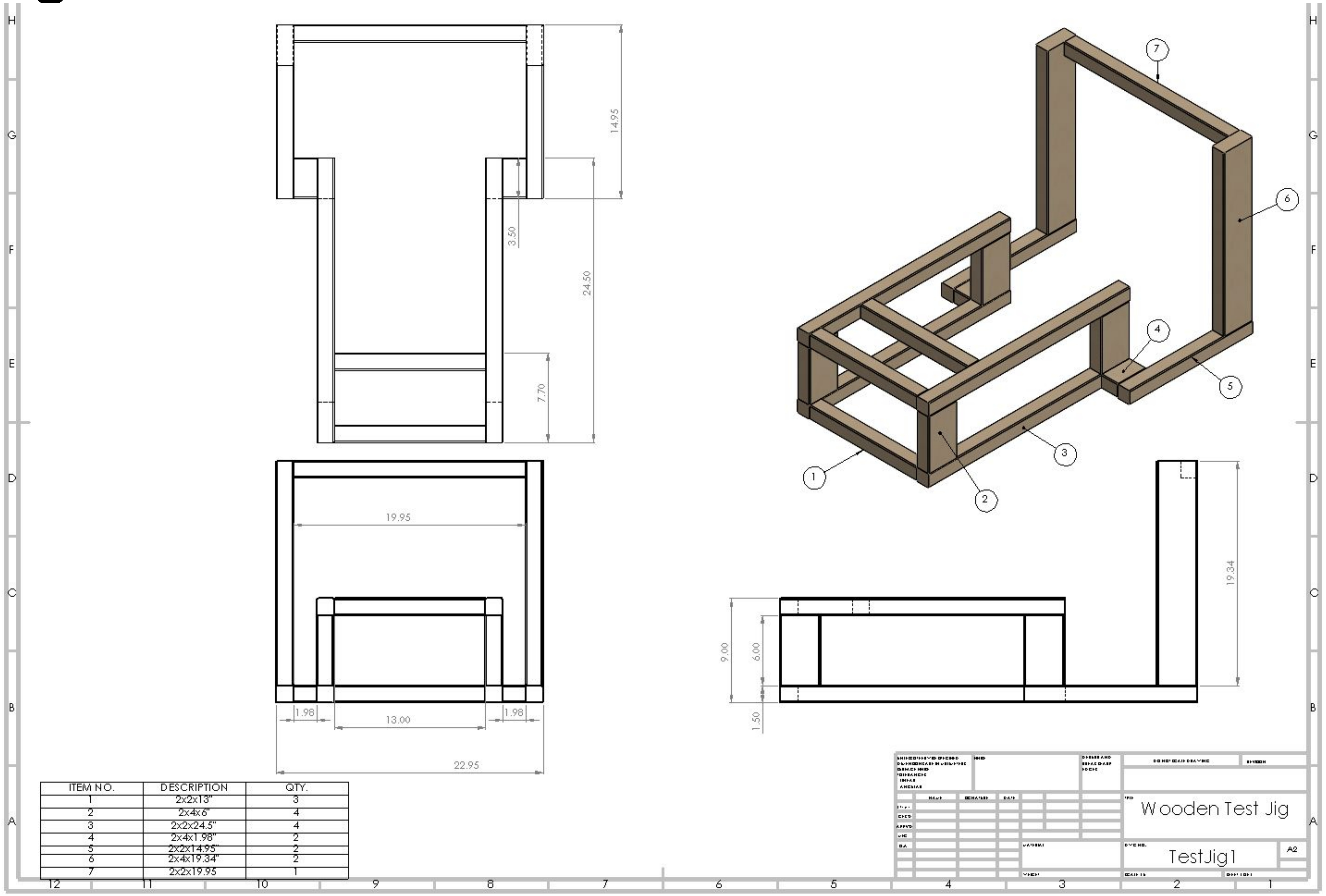


Generative design in ANSYS Discovery



Steering rack mounting plate; 0.125” carbon steel (A1008). Shape cut with CNC plasma cutting; drill holes to final size.

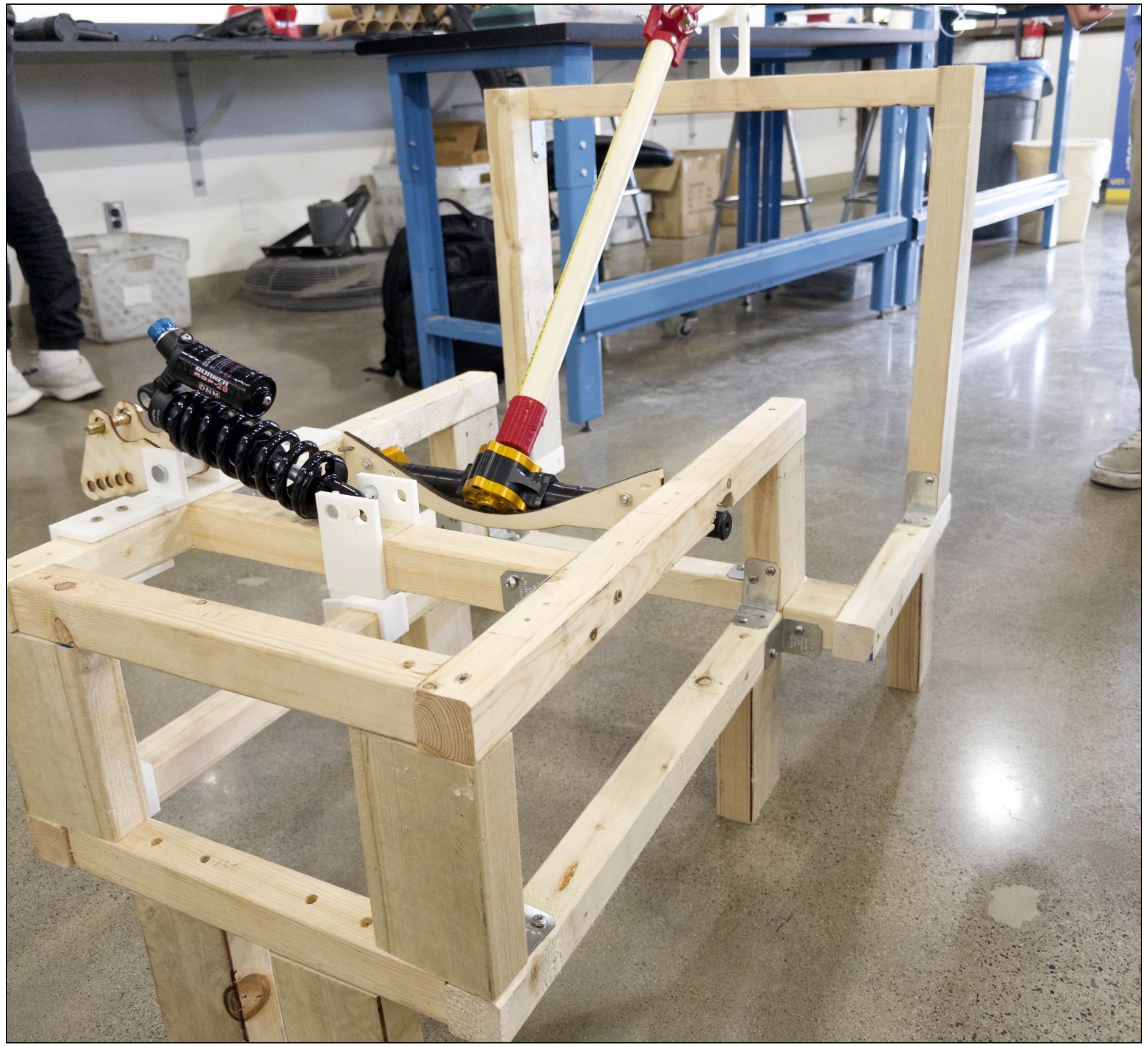
Final Design



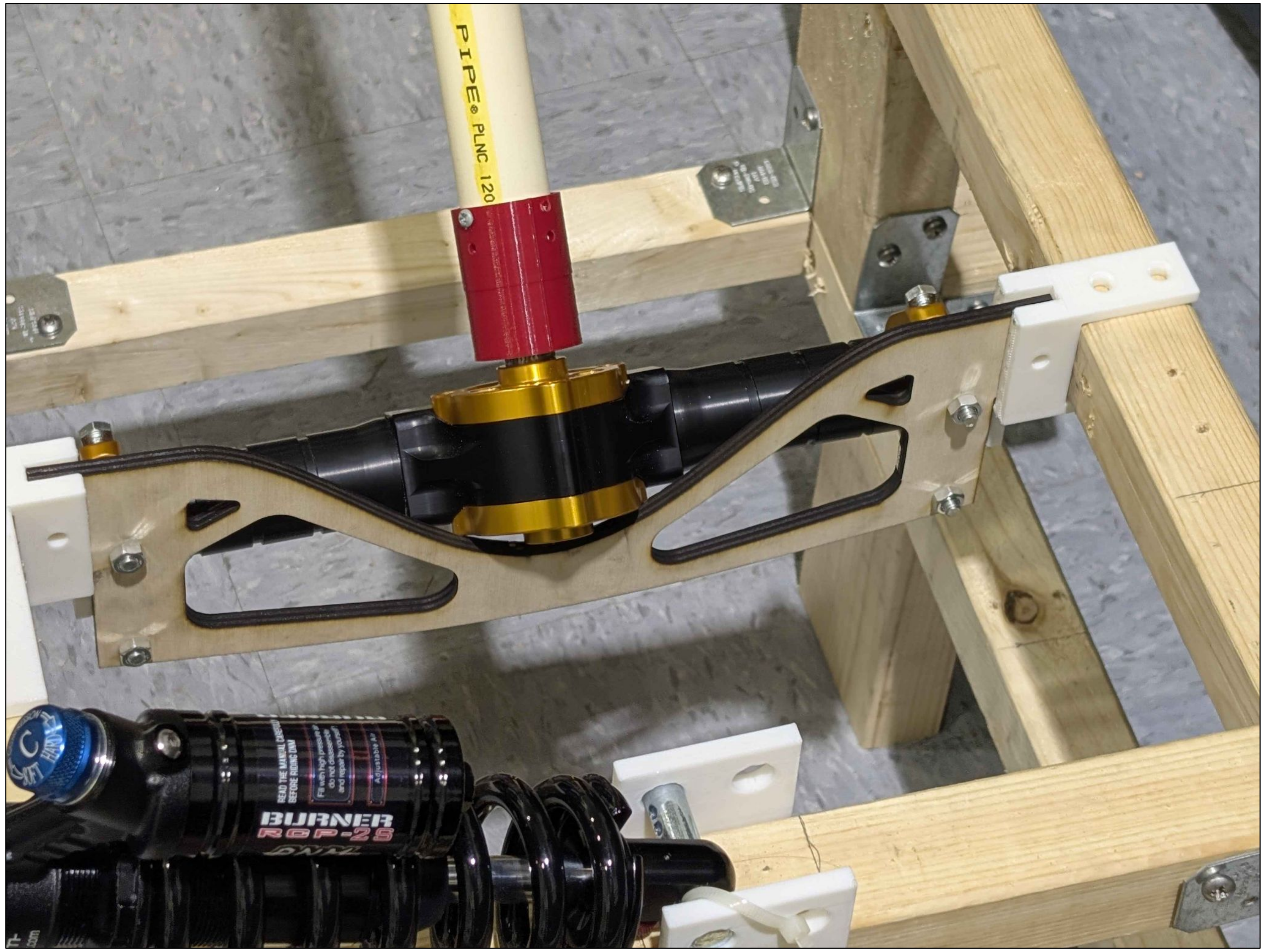
ITEM NO.	DESCRIPTION	QTY.
1	2x2x13"	3
2	2x4x6"	4
3	2x2x24.5"	4
4	2x4x1.98"	2
5	2x2x14.95"	2
6	2x4x19.34"	2
7	2x2x19.95	1

Drawing for wood testing jig, with dimensions and BOM.

Final Design



Old rack plate mount



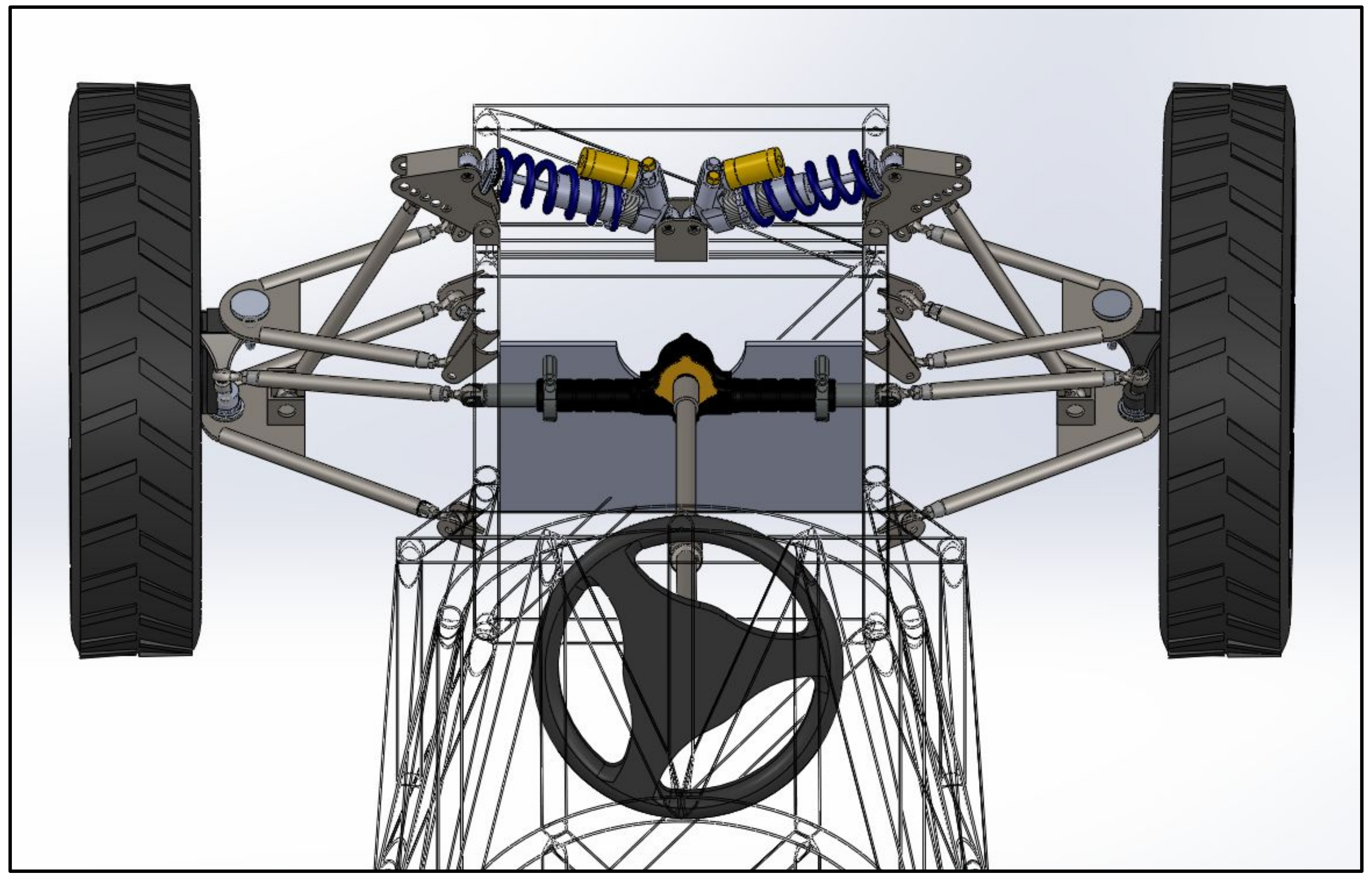
New rack plate mount

Compliance Table

Technical Specifications	Compliant	Noncompliant	Not Tested Yet
1. Functional			
0 Degrees of Camber, +- 2 degrees	x		
12 degrees of KPI, +- 1 degree	x		
10.7.C: U-Turn Radius Requirement			x
2. Performance			
10.5.C: Minimum Deceleration of 4.72 m/s^2			x
10.5.B: Brake Pad Thickness Minimum of 6mm	x		
3.Physical			
10.2.B: Tire Load Capacity(Dynamic)			x
4. Safety			
10.1.1: Suspension Clearance	x (calculated)		

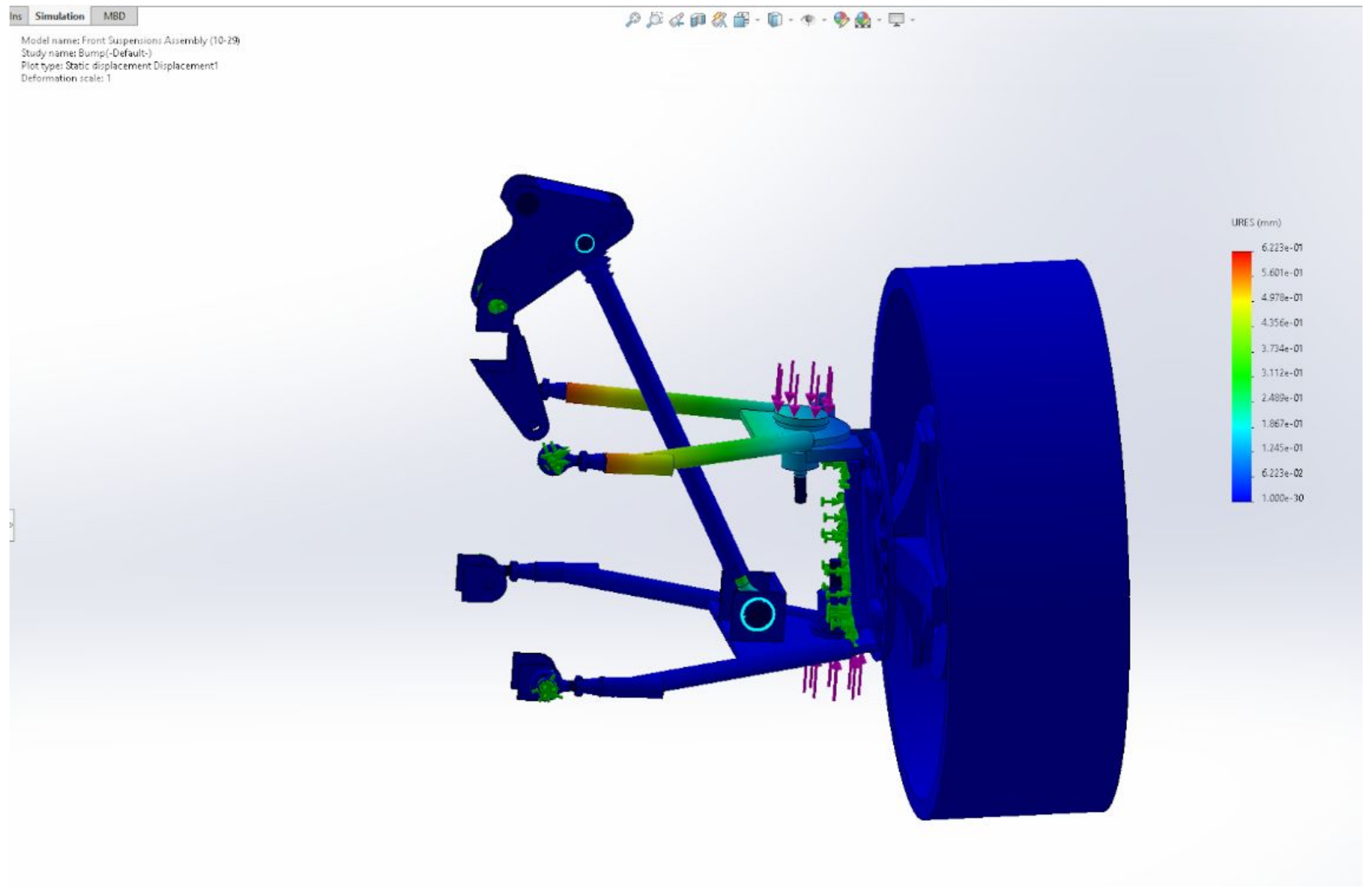
Quan

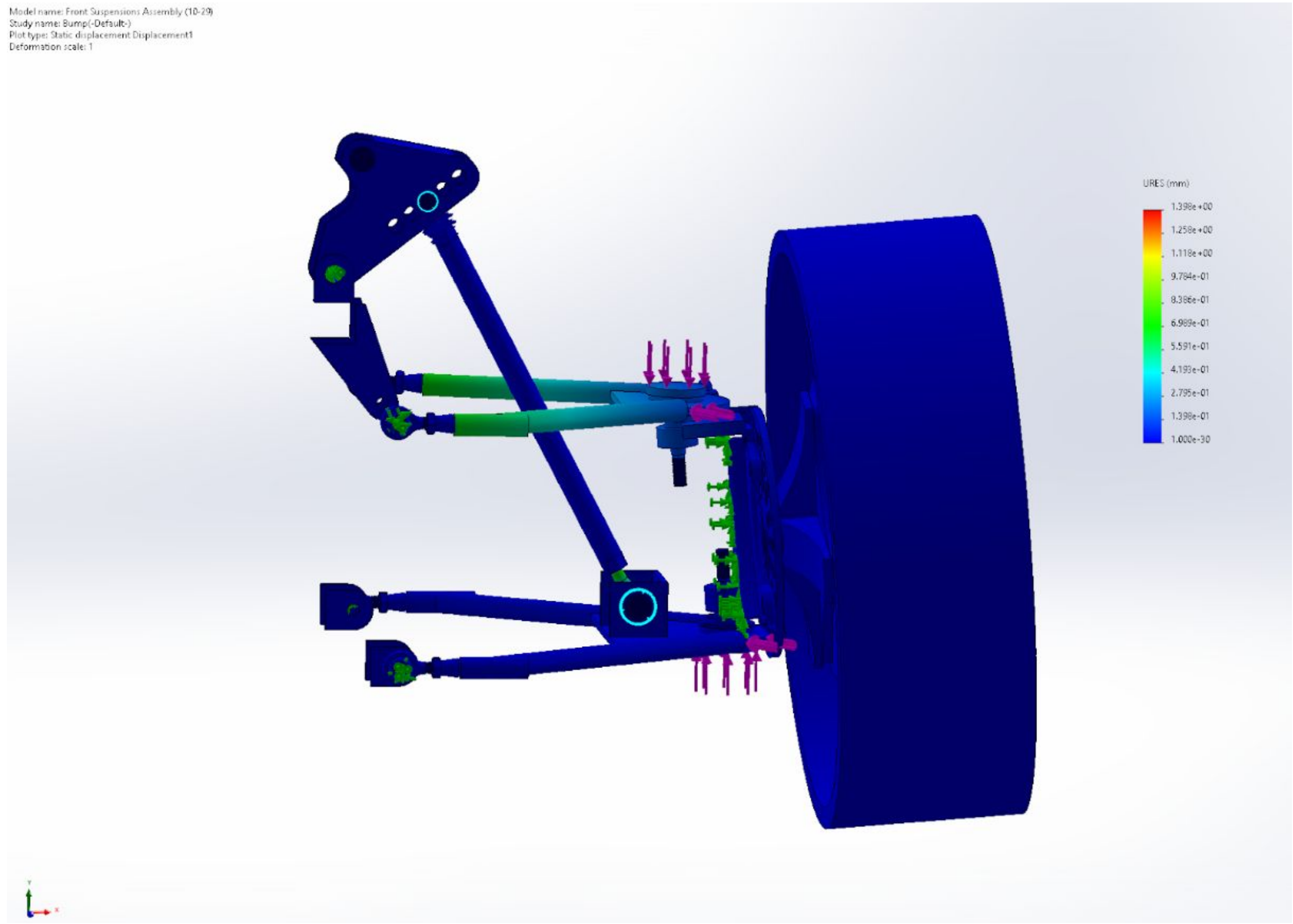
Final Key Decisions - Suspension Type: Double Wishbone

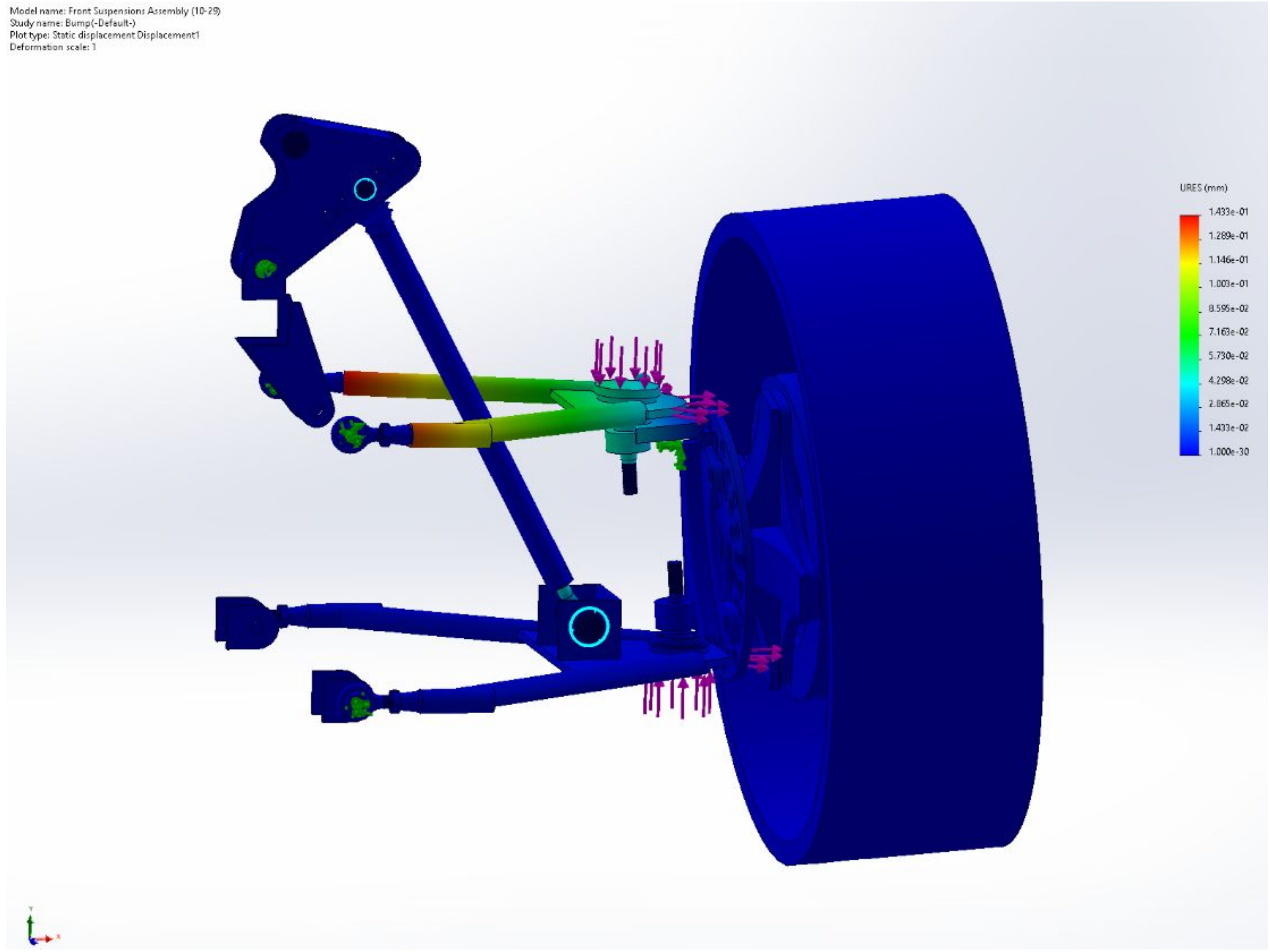


Front end top view

Scenario	A-arm	Vertical Load (lbs)	Longitudinal Load (lbs)	Lateral Load (lbs)
2-G Bump	Lower A-arm	316.8	0	0
2-G Bump	Upper A-arm	79.2	0	0
2.5-G Bump + Braking	Lower A-arm	456	158.4	0
2.5-G Bump + Braking	Upper A-arm	114	39.6	0
1-G Braking	Lower A-arm	218.4	158.4	0
1-G Braking	Upper A-arm	54.6	39.6	0
1-G Cornering	Lower A-arm	158.4	0	99
1-G Cornering	Upper A-arm	39.6	0	99

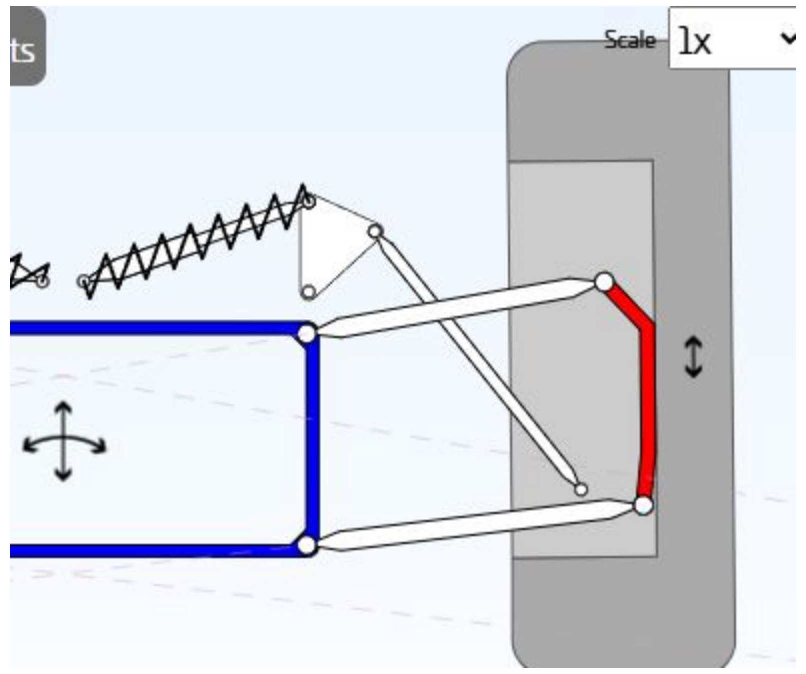






Bump, brake, and cornering loads

Final Key Decisions - Shock Mounting



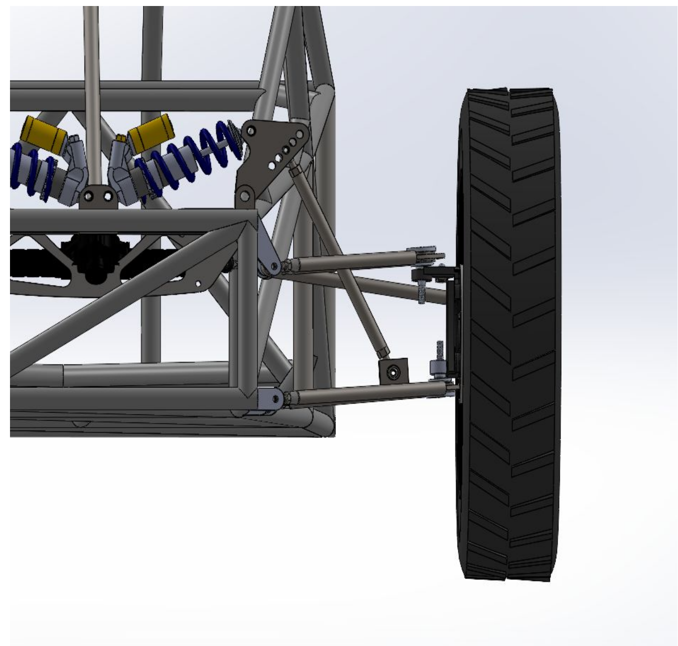
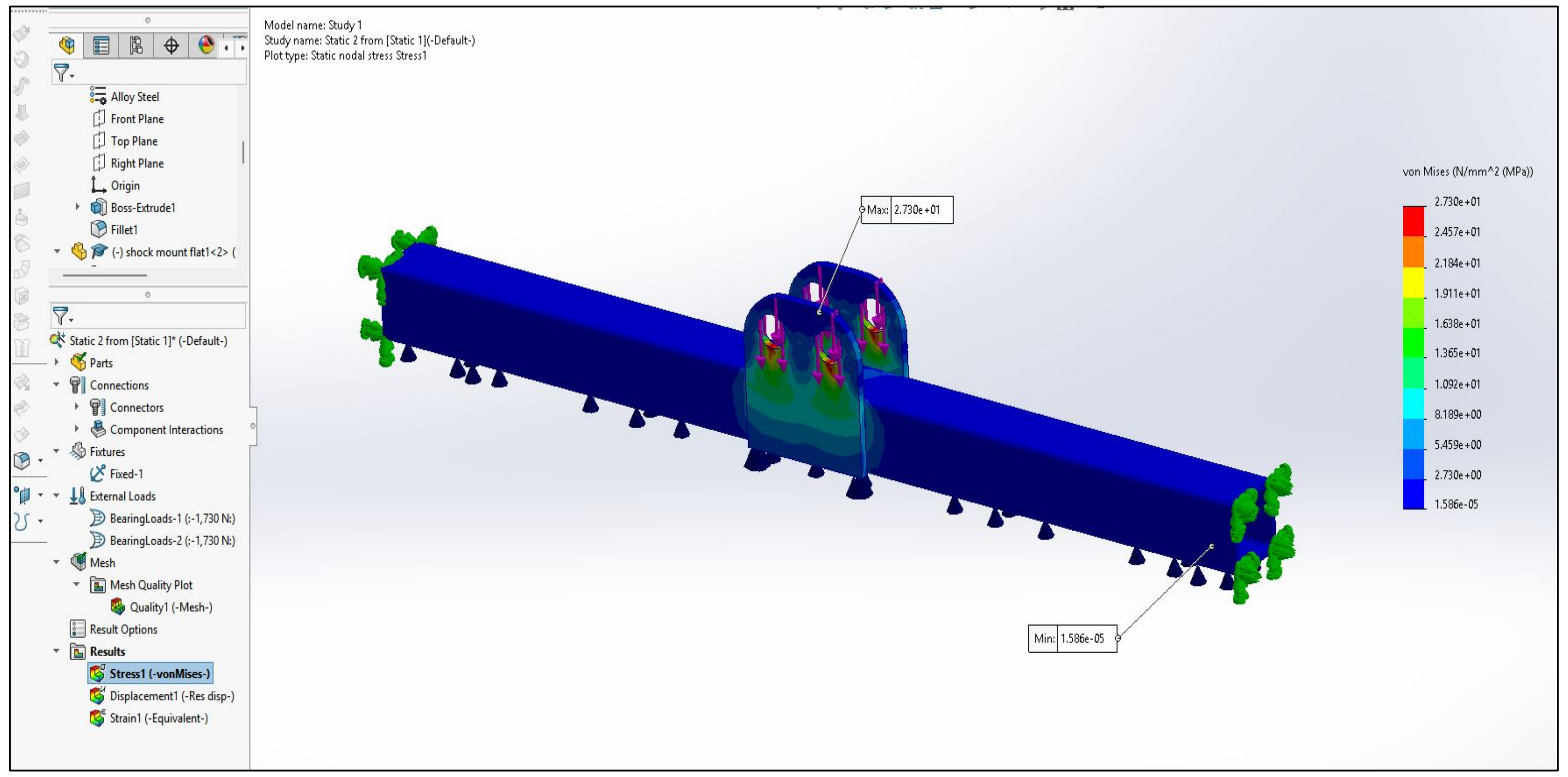


Figure: Racing aspirations calculator for vehicle suspension.



Simulation with Theoretical load of 550 lbs or 2G

$$WR = (0.86)^2 * 500\frac{lbf}{in} = 369.8\frac{lbf}{in}$$

$$F_s = -k_{eq}x$$

$$-162lbf = 369.8\frac{lbf}{in}x$$

$$0.44in = x$$

- Chassis ride height with no load = 213mm; with vehicle weight, 202mm.
- With k_{eq} = 369 lbf / in = 64700 N/m, **the natural frequency of the front is 4.7 Hz (very stiff).**

Front Load Condition	Droop	Chassis Ride Height	Pass? (> 100mm)
0g (no load)	0mm	213mm	yes
1g (vehicle weight)	11mm	202mm	yes
2g (bump)	22mm	191mm	yes
≅ 2.45g (bump + brake)	27mm	186mm	yes

BOM, Manufacturing expectations, and final cost estimates

Purpose of Order:
Solar Car Front End Subsystem Prototype

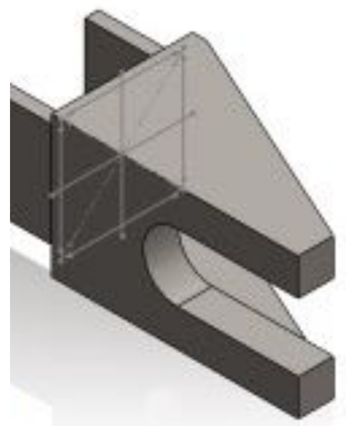
VENDOR*	DESCRIPTION*	WEBSITE/LINK*	ITEM #/PART #* (if applicable)	QTY*	UNITS	UNIT PRICE*	EXTENDED PRICE	NOTES/LINK TO THE QUOTE in PDF
Aircraft Spruce	4130 STEEL TUBE	https://www.aircraftspru	03-08500-1	1		8.5	$8.50	
Aircraft Spruce	4130 STEEL TUBE 3/4X.058	https://www.aircraftspr	03-04500-4	1		26.6	$26.60	
Aircraft Spruce	4130 STEEL TUBE 5/8X.058	https://www.aircraftspr	03-03800-8	1		52	$52.00	
Summit Racing	Summit Racing™	https://www.summitraci	SUM-420303	2		38.79	$77.58	
Home Depot	2x2 and 1x2 lumber	https://www.homedepot		1		15	$15.00	
Home Depoit	wood screws	https://www.homedepot	11598	1		7.99	$7.99	
McMaster Carr	rod-end (right)	https://www.mcmaster.		4		7.95	$31.80	
McMaster Carr	rod-end (left)	https://www.mcmaster.		4		7.95	$31.80	
McMaster Carr	tie rod	https://www.mcmaster.		2		19.4	$38.80	

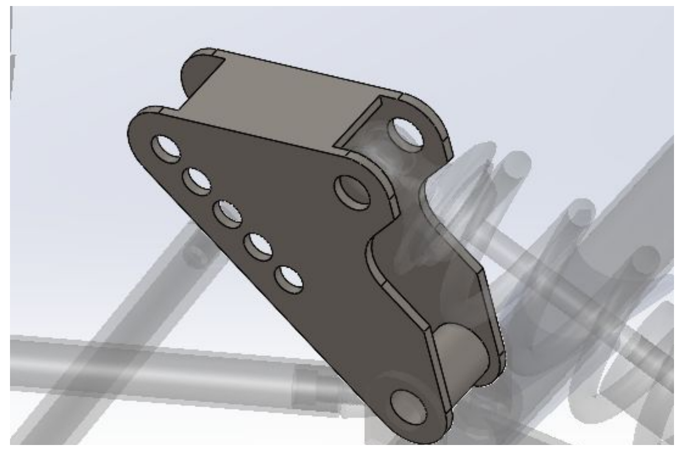
Other Comments or Special Instructions:		
	SUBTOTAL	$290.07
		$22.48
	Shipping	
	TOTAL	$312.55

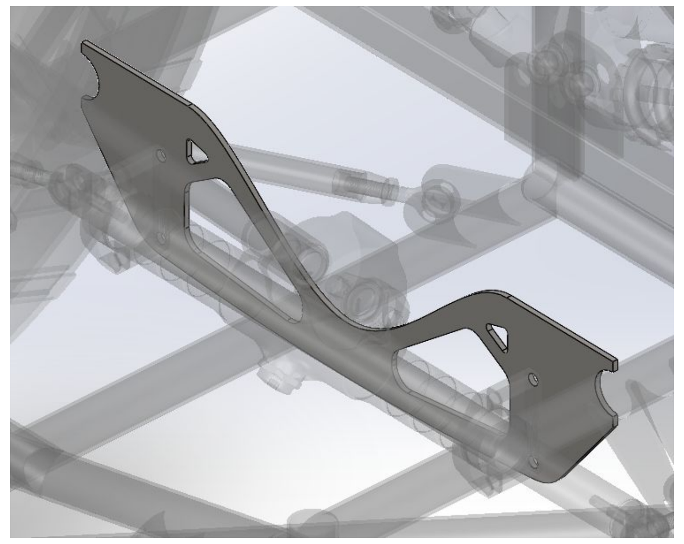
2025 UCI Race Car Engineering

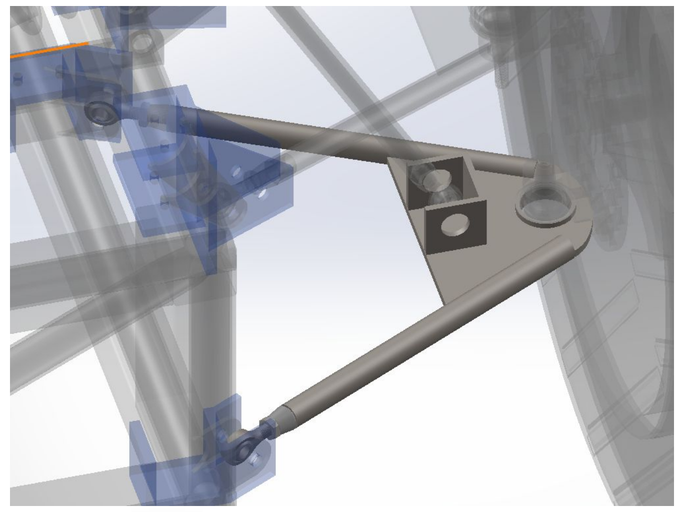
Sebastian

Technical Risk Analysis (FMEA)









Component	Function	Failure Mode	Failure Cause	Effect	Corrective Action	Severity Rating
Fork End	Transmit forces from rear axle to the trailing arm.	Fatigue	Small radius of axle (R =)	Rear end falls to ground, causing significant chassis damage.	Fork end will be CNC machined; solid 4340 steel	8
Rocker	Transmit pushrod force into the shock, with a motion ratio < 1.	Fracture	Shear load from misaligned push rod.	Front end falls to ground, causing significant chassis damage.	Lateral support between two plates of rocker.	8
Steering rack mounting plate	Holds steering rack in place.	Fatigue (at welds)	The cyclic lateral loading and unloading provided by steering rack.	Sudden loss of steering control.	The plate is bridged, so that if a weld to the chassis fails, steering is still possible.	10
A-Arm	Constrain wheel path during suspension travel	Fatigue (at weld nuts)	Cyclic lateral loads from bumps; cyclic longitudinal loads from braking.	Front end falls to ground, causing significant chassis damage.	Scrutineer recommends horizontal rod end configuration.	8

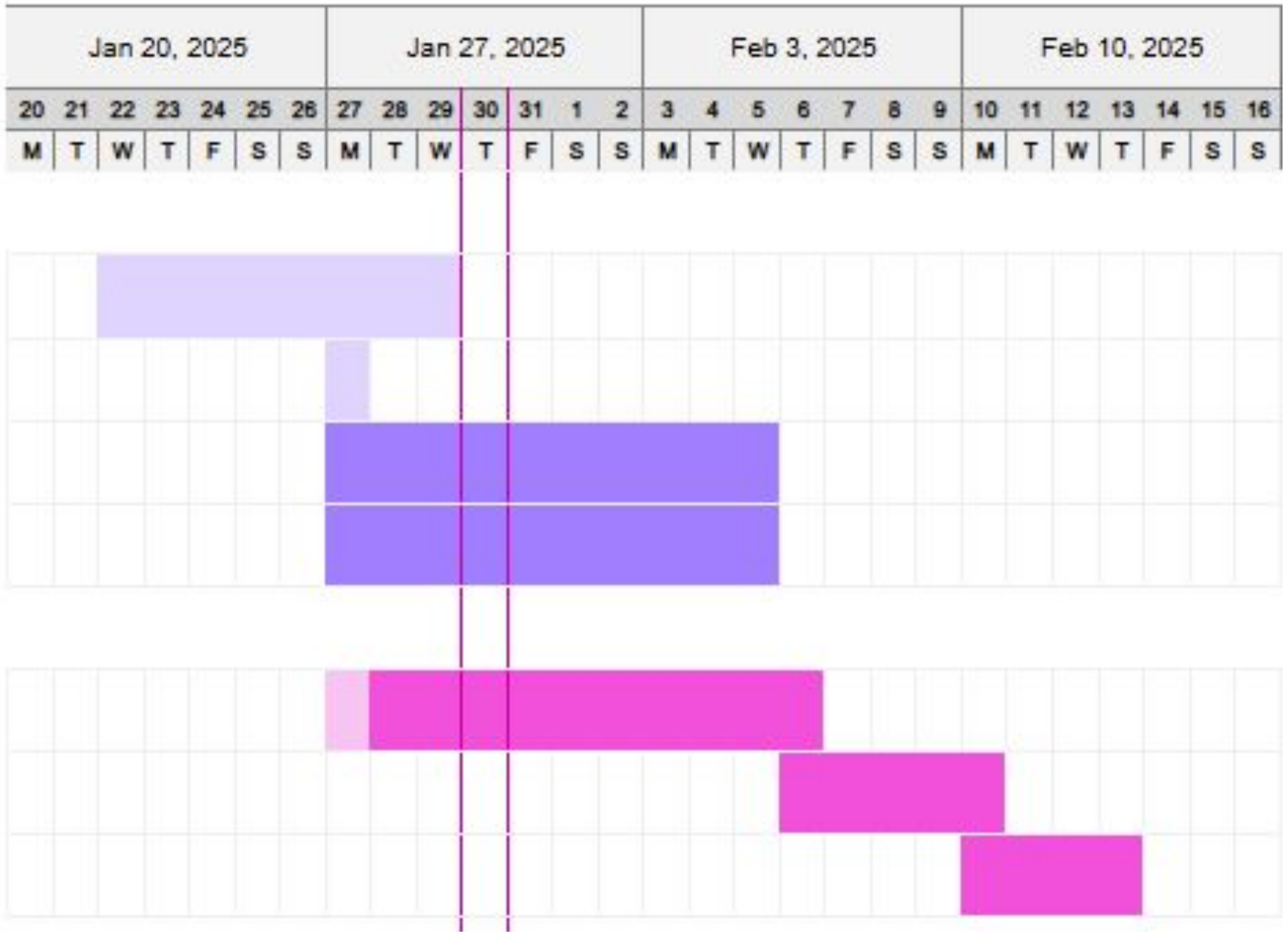
Missing Resources and Concerns

Manufacturing	Guidance in Analysis and Simulation	Material Selection
3D Printing and laser cutting: - Access to FABWORKS	Mentors/Instructors: - Access to experienced simulation engineers for support	Material Properties: - Access to materials properties database and published research papers
Machining Resources: - Access to the machine shop - Access to hydraulic press	Simulation Software: - Access to FEA software such as SolidWorks and ANSYS	Suppliers: - Direct access to local suppliers able to adhere to our material requirements
Welding Resources: - Access to welding facilities - Welding equipment - Assembly tools	Computational Resources: - Access to hardware capable of running simulations and analysis	Prototyping Materials: - Cheaper materials able to test the proof of concept - Simple to assemble
Budget: - Budget allocations for the manufacturing process		Testing Materials: - Materials intended to validify design of prototype

Gantt Chart

SIMPLE GANTT CHART by Vertex42.com
https://www.vertex42.com/ExcelTemplates/simple-gantt-chart.html

TASK	ASSIGNED TO	PROGRESS	START	END
Steering				
Redesign and Mount Steering Mount	Nicholas, Quan	100%	1/22/25	1/29/25
Reinforce Wooden Jig with L Brackets	Patrick, Tiffany	100%	1/27/25	1/27/25
Measure Steering Angle	Nicholas	0%	1/27/25	2/5/25
Measure Steering Backlash	NIcholas	0%	1/27/25	2/5/25
Control Arms				
Repurpose Metal Chassis for Testing	Sebastian, Tiffany	10%	1/27/25	2/6/25
Weld Mounts for Control Arm	Sebastian, Tiffany	0%	2/6/25	2/10/25
Perform Lateral Load Testing	Sebastian, Tiffany	0%	2/10/25	2/13/25



Tiffany

Gantt Chart

Spring Rate				
Determine Spring Resistance Under Load	Quan	0%	2/6/25	2/11/25
Ensure Structural Integrity is Maintained	Quan	0%	2/12/25	2/16/25
Ensure Correct Alignment Under Load	Quan	0%	2/17/25	2/22/25
Determine Suspension Travel	Quan	0%	2/23/25	2/27/25
Mounting Tabs/Rocker				
Complete Rockers/Mounts	Gyan	0%	1/28/25	2/10/25
Ensure it's able to Withstand 2G bump	Patrick	0%	2/10/25	2/18/25
Chassis Integration				
Integrate Components with Chassis	Everyone	0%	2/18/25	3/14/25