SAE Baja

Proposal

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NORTHERN ARIZONA UNIVERSITY

SAE INTERNATIONAL

Introduction

- Review of the Client’s needs, requirements, goals, and constraints
- Review of the Gantt chart, Quality Function Deployment, and House of Quality
- Functional Diagram of the Baja: how the baja works and its main sources of energy used
- Decision criteria and outcomes for the shifter, suspension, and clutch
- Design problems encountered since the last deliverable
- New designs, design solutions, and components to design
- Bill of Materials for each design component so far

Client’s Needs and Team Goals

Clients: NAU’s SAE club and Dr. Tester

Need Statement: The NAU SAE club does not have a Baja vehicle for competition

Goals:

- Build an operational Baja vehicle
- Inspire teamwork related to engineering design and practices
- Participate in competition

Project Objectives

Objectives	Measurement
Light Weight	lb
High Traction	lb
Quick Acceleration	ft/s^2
Safe	No Units
Endurance	hr
Ergonomic Cockpit	ft

Project Constraints

- Fully operational by March 1st, 2016
- Must have at minimum 2 forward gears and 1 reverse gear
- Cannot exceed 108” in length or 64” in width
- Weigh between 400 and 800 pounds
- Must use a 10 horse power Briggs and Stratton engine
- Utilize previous year’s transmission design

Quality Function Deployment

Engineering Requirements / Customer Requirements	Young's Modulus	Body Weight	Transmission	Dimensions	Frame Thickness	Factor of Safety	Total Cost	Exhaust Pipe Length	Engine Power	Spring Stiffness	Velocity	Maximum Steer Angle
Follow the 2016 SAE Baja Rules		9	9	9				9	9			
Safety	9				9	9						9
Inexpensive	9	9		9	9		9			9		
Aesthetic				3	3			1				
Maneuverability	9	9	9	1	1				9	9	9	9
Ergonomic Cockpit				3								
Traction		9	9	9					9			9
Robust	9			3	9		3			9	9	9
Endurance	9	9			9	9	1			3		9

Legend	
Strong Relationship	9
Moderate Relationship	3
Weak Relationship	1

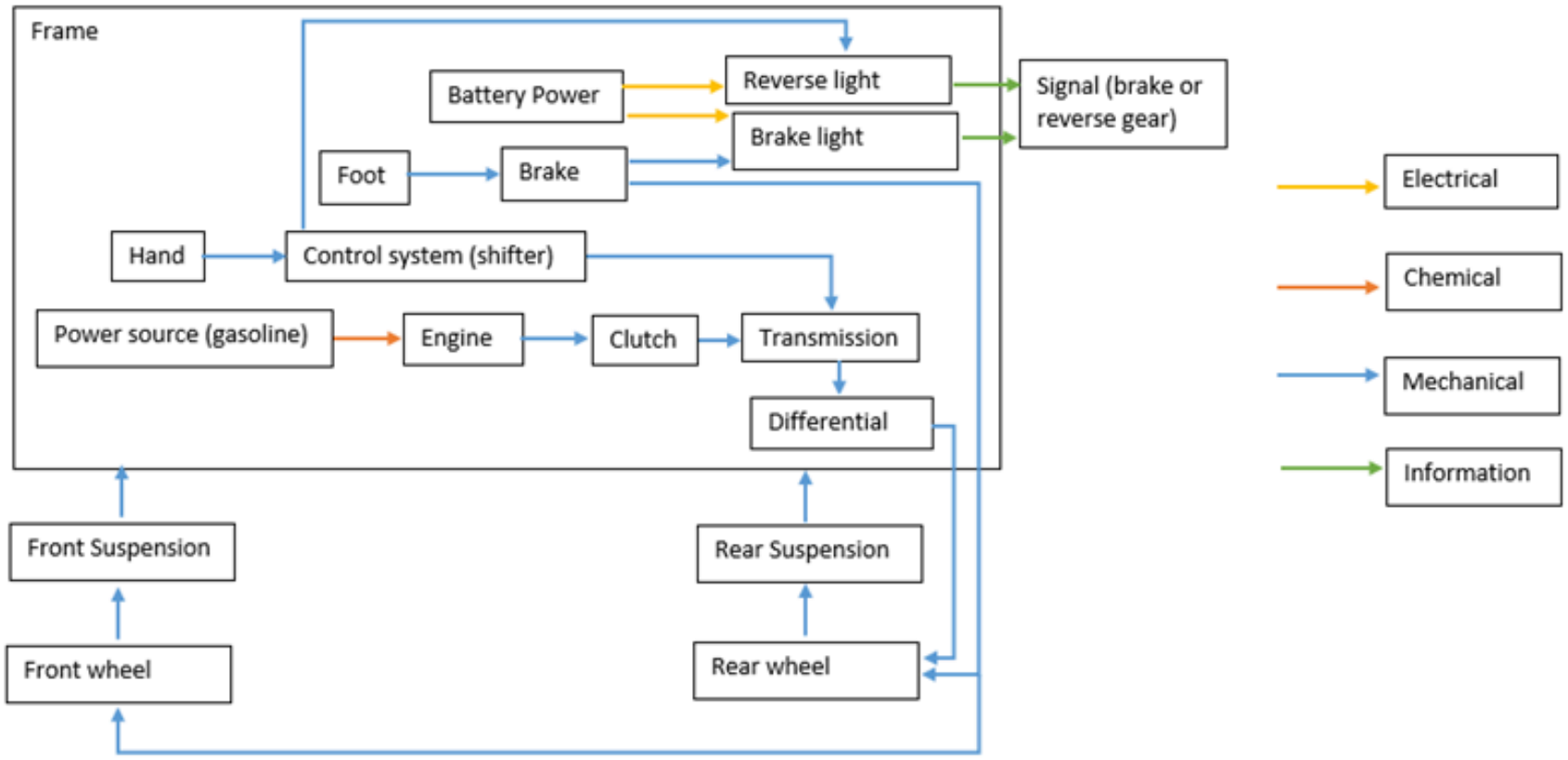
House of Quality

Young's Modulus												
Body Weight												
Transmission		-										
Dimensions		+										
Frame Thickness	-	+		+								
Factor of Safety	+	+			+							
Total Cost	+	+		+								
Exhaust Pipe Length				+								
Engine Power							+					
Spring Stiffness						+	+					
Velocity												
Maximum Steer Angle		-	+						+			
Engineering Requirements	Young's Modulus	Body Weight	Transmission	Dimensions	Frame Thickness	Factor of Safety	Total Cost	Exhaust Pipe Length	Engine Power	Spring Stiffness	Velocity	Maximum Steer Angle
Column#	1	2	3	4	5	6	7	8	9	10	11	12
Direction of improvements	↑↑↑	◊	↑↑↑	◊	◊	↑↑↑	↓	◊	◊	↑↑↑	↑↑↑	↑↑↑

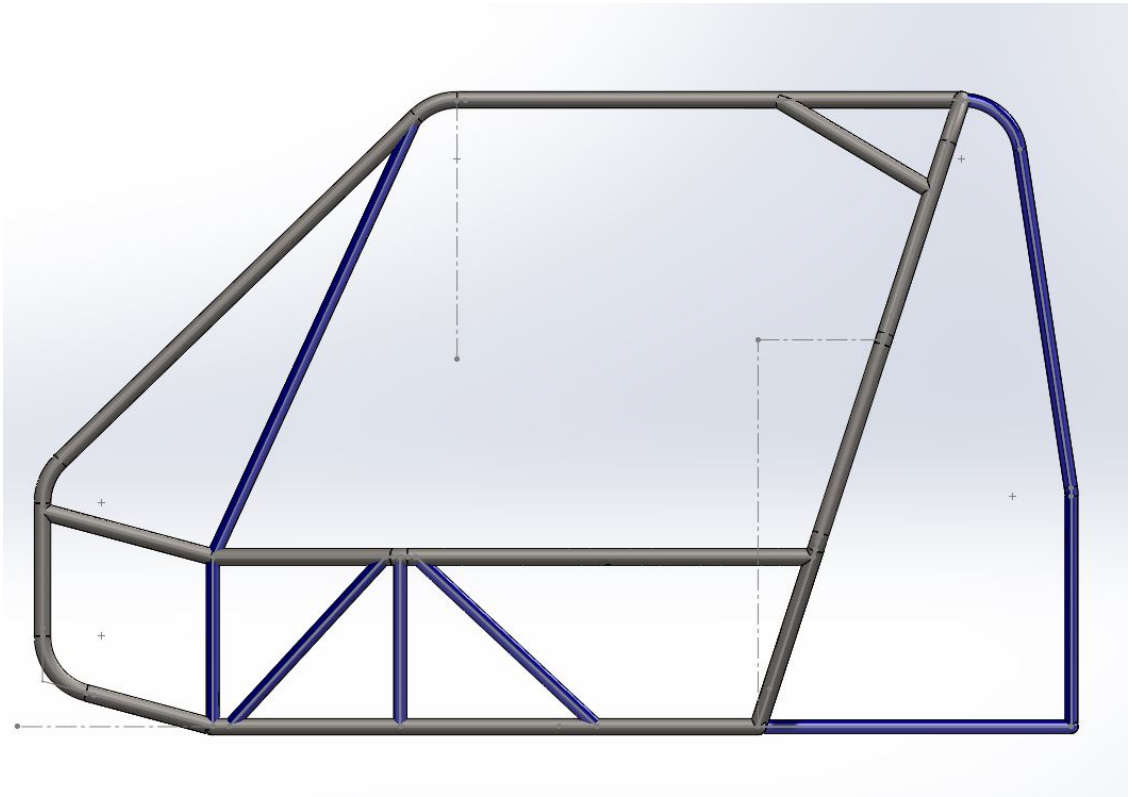
Positive Correlation	+
Negative Correlation	-

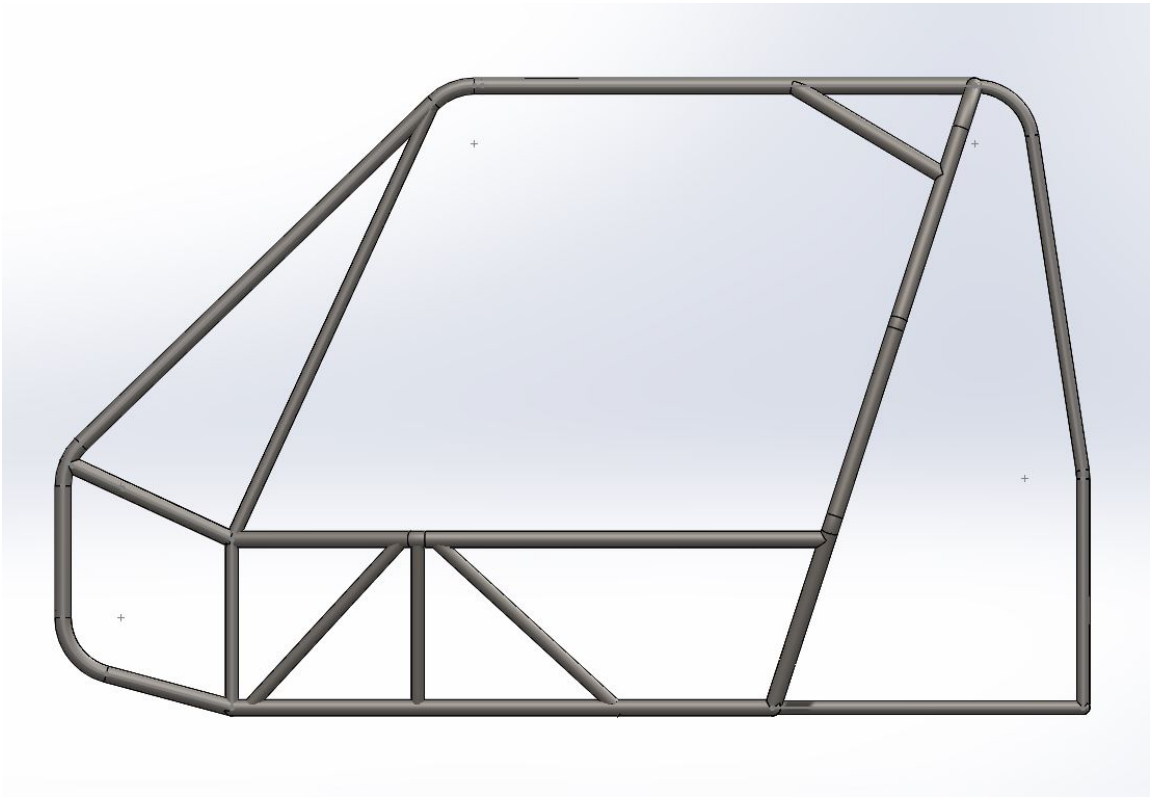
Maximize	↑↑
Target	◊
Minimize	↓

Functional Diagram

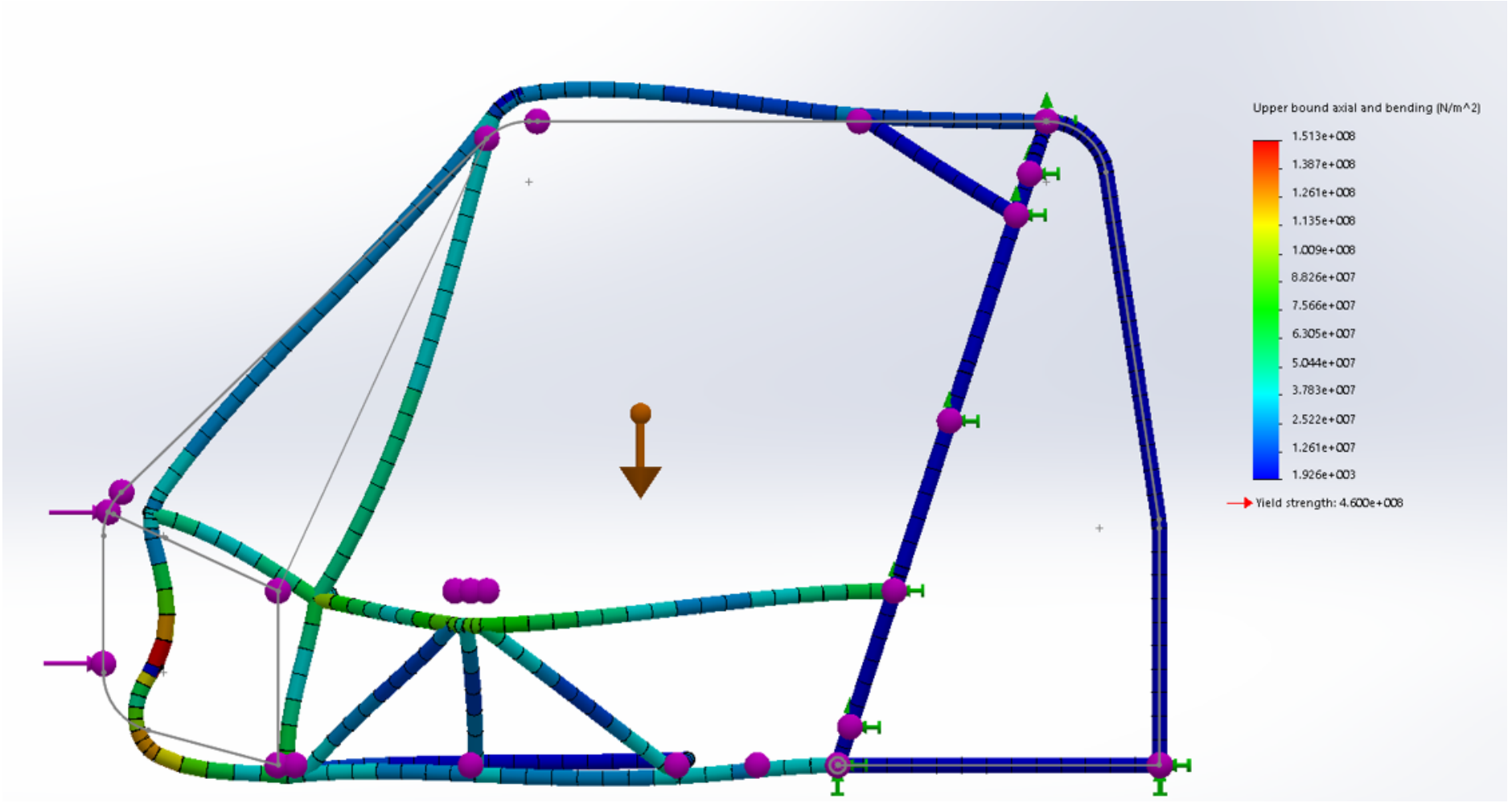


Frame: Modification 1





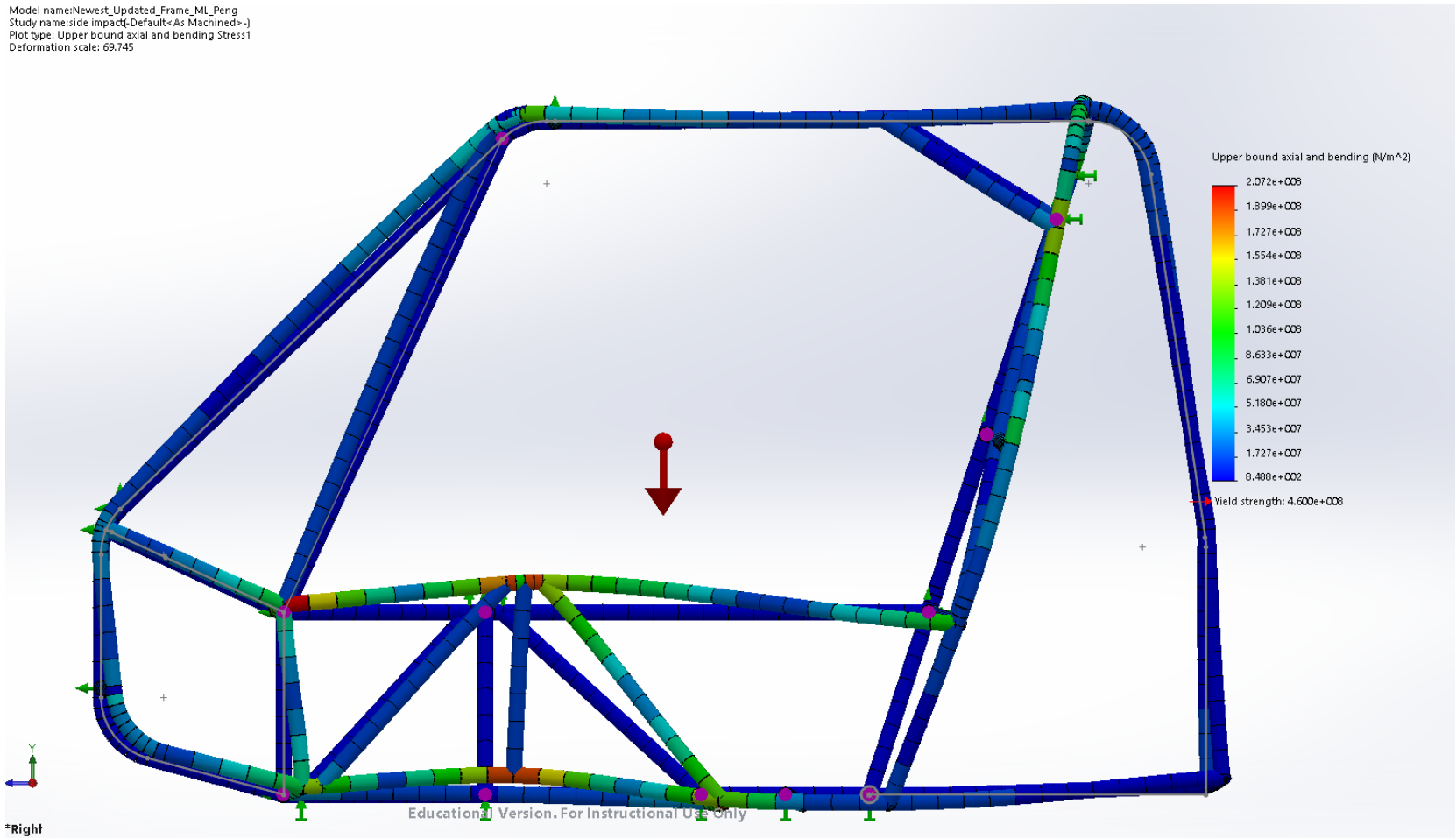
Frame: FEA for Front Impact



Test Result:
Pass

Minimum Factor of safety:
3.04

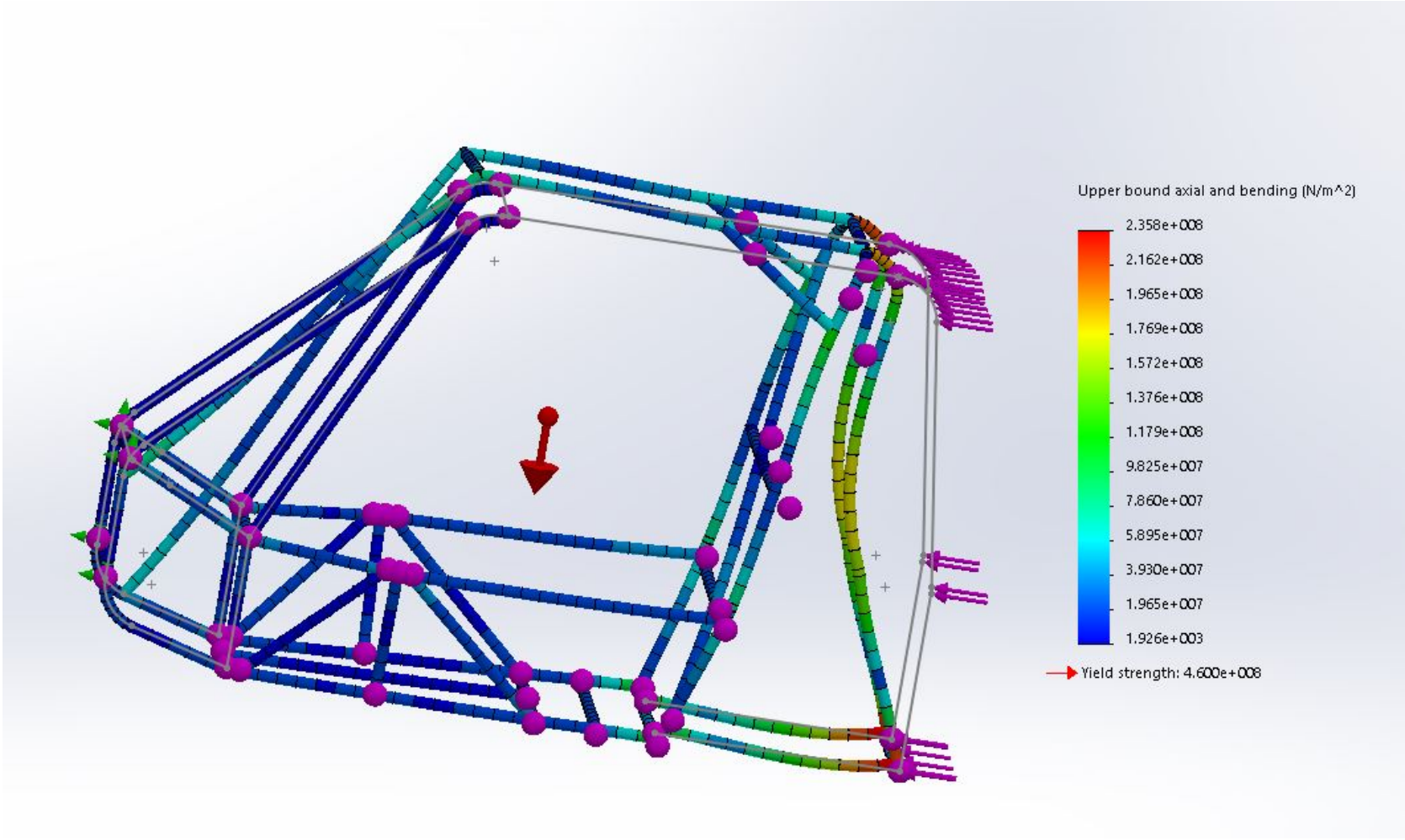
Frame: FEA for Side Impact



Test Result:
Pass

Minimum
Factor
of safety:
2.22

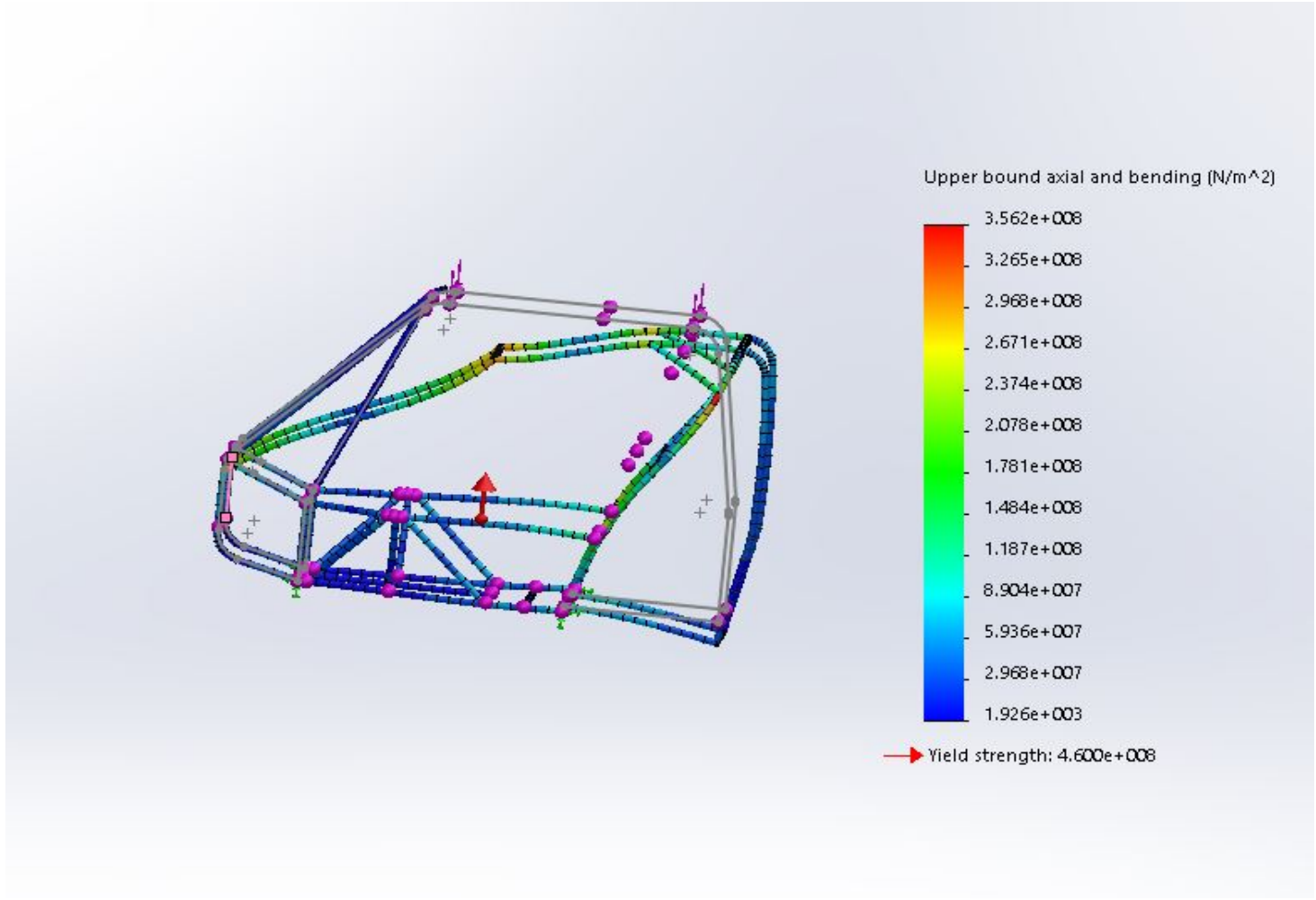
Frame: FEA for Rear Impact



Test Result:
Pass

Minimum
Factor
of safety:
1.95

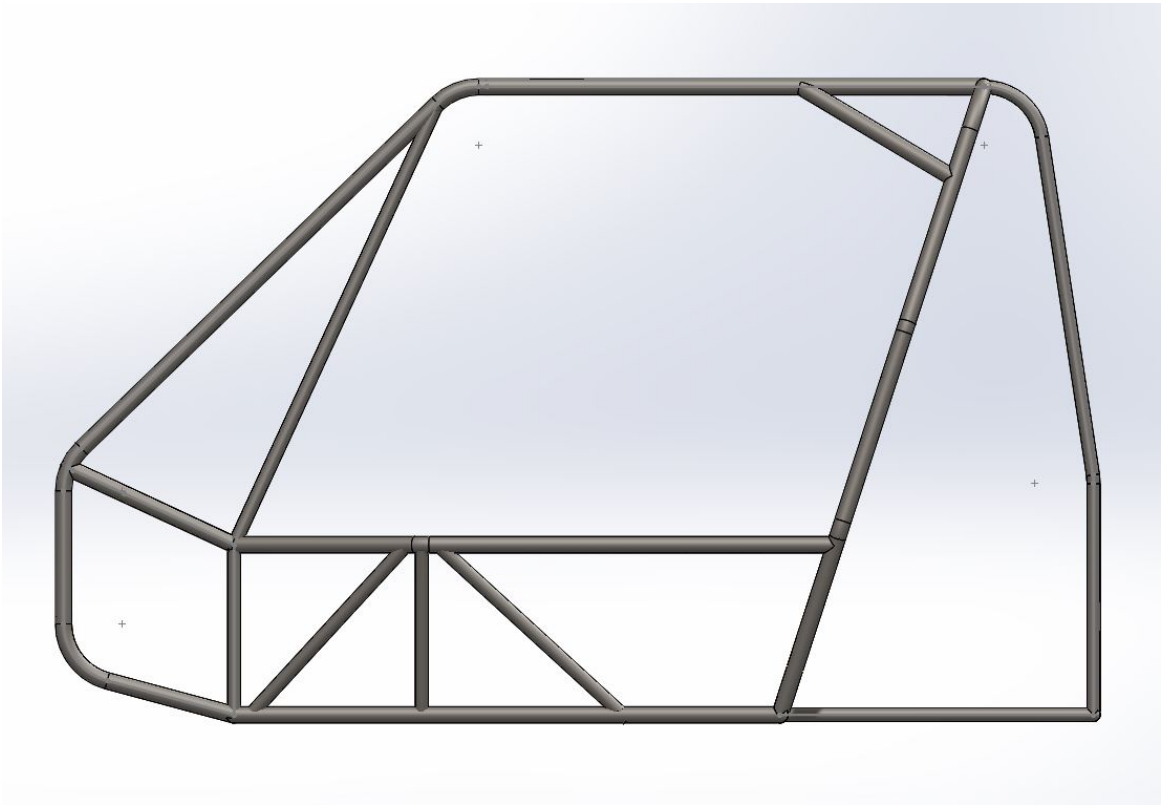
Frame: FEA for Roll Over Impact

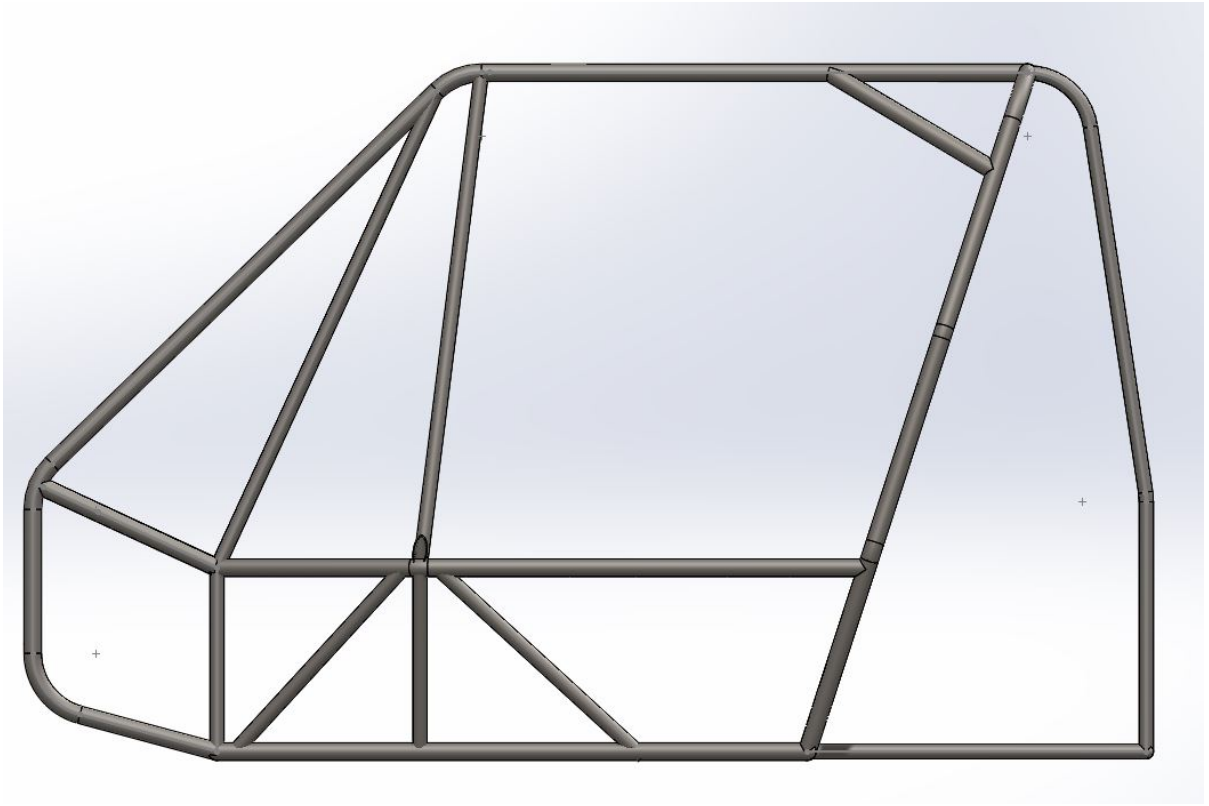


Test Result:
Failure

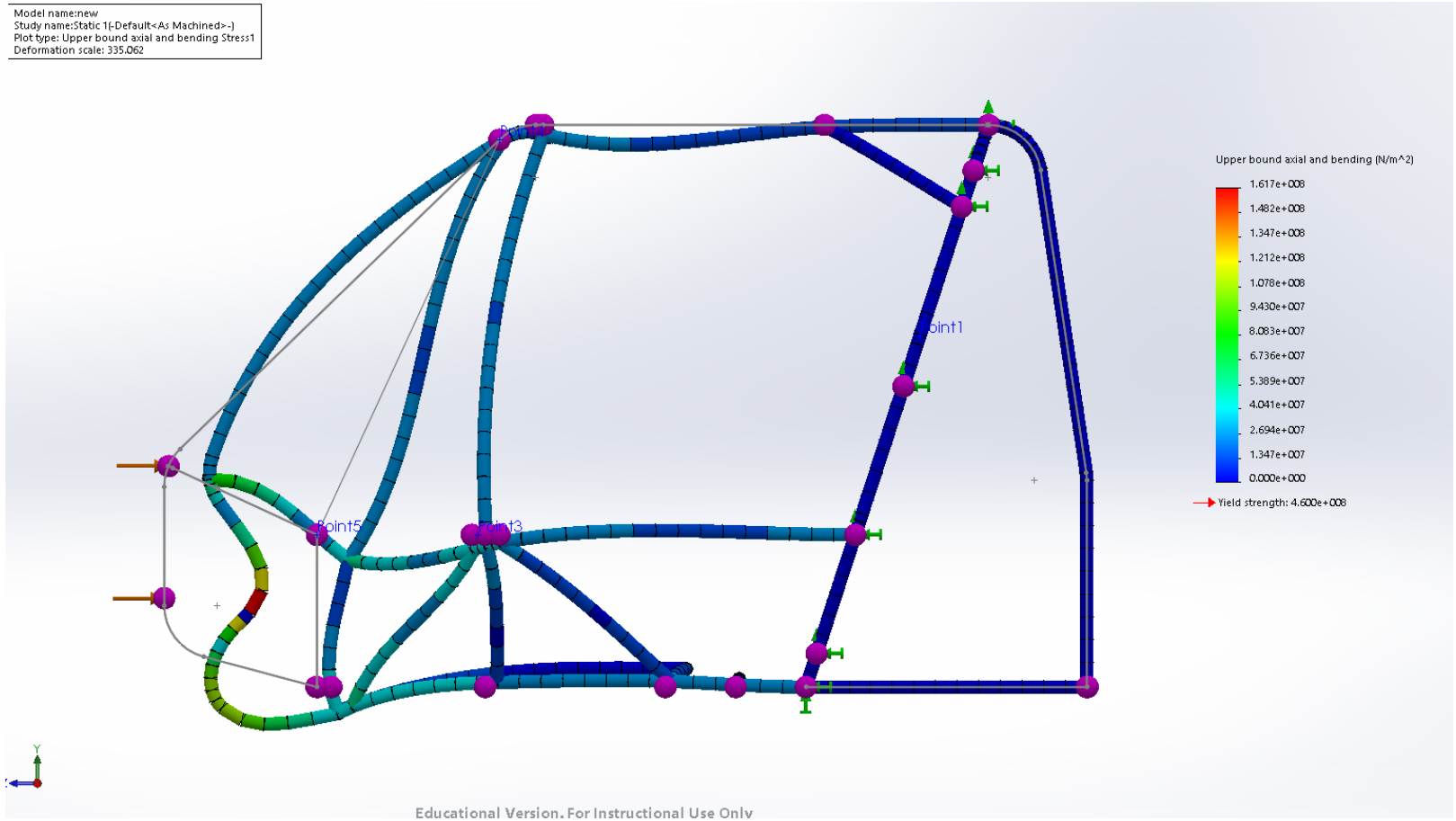
Minimum
Factor
of safety:
0.774

Frame: Modification 2





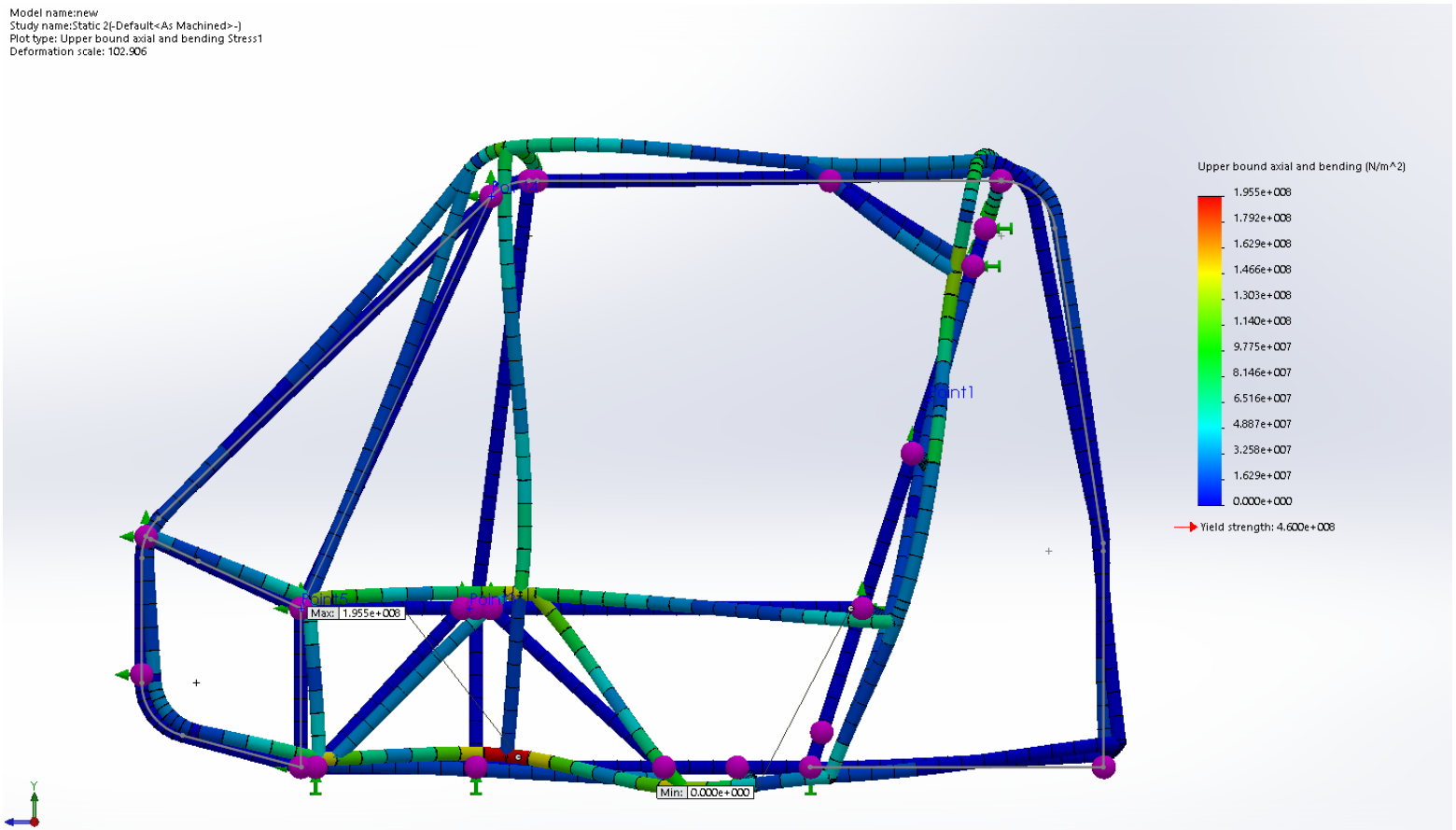
Frame: FEA for Front Impact (Final Design)



Test Result:
Pass

Minimum
Factor
of safety:
2.84

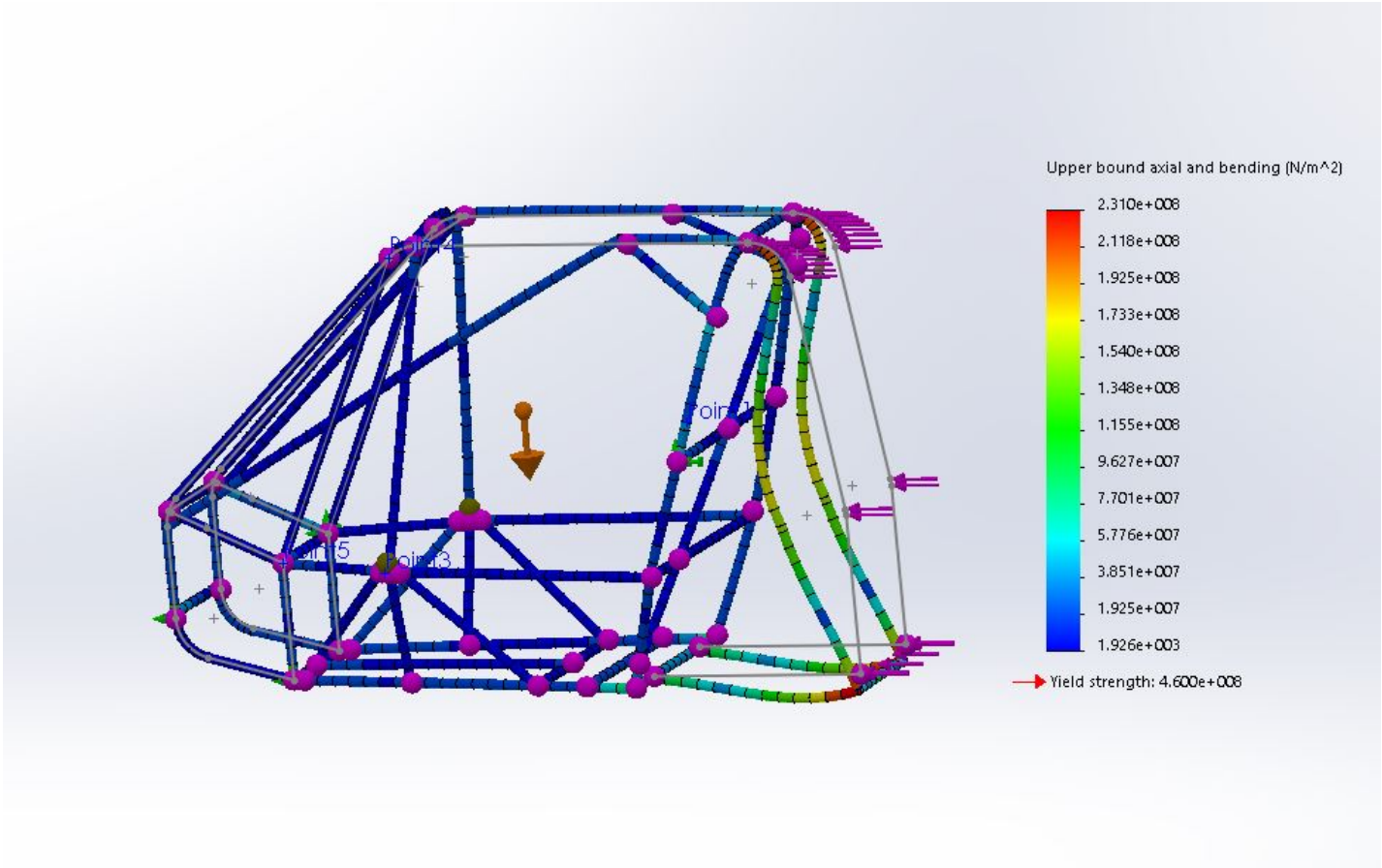
Frame: FEA for Side Impact (Final Design)



Test Result:
Pass

Minimum
Factor
of safety:
2.35

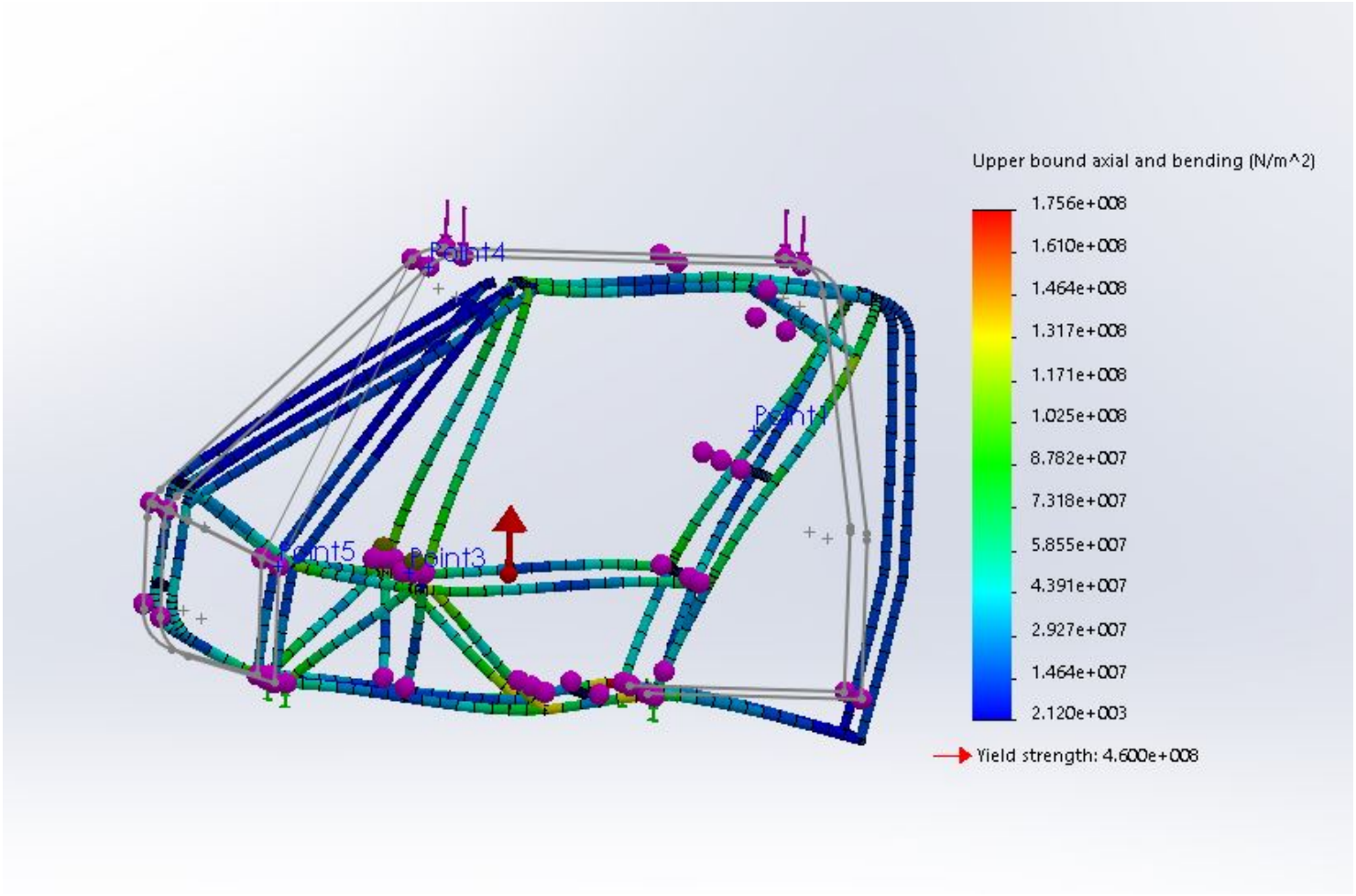
Frame: FEA for Rear Impact (Final Design)



Test Result:
Pass

Minimum
Factor
of safety:
1.99

Frame: FEA for Roll Over Impact (Final Design)



Test Result:
Pass

Minimum
Factor
of safety:
2.62

Suspension: Criteria Rating

Rear Suspension						
Level	**Rating**	**Travel (in)**	**Deflection (in)**	**Durability (hours)**	**Cost**	**Maint./Repair (min)**
Perfect	**10**	20	0	30	≤ $150	≤ 15
Excellent	**9**	18	0.25	27	$300	30
Very Good	**8**	16	0.5	24	$450	45
Good	**7**	14	0.75	21	$600	60
Satisfactory	**6**	12	1	18	$750	75
Adequate	**5**	10	1.25	15	$900	90
Tolerable	**4**	8	1.5	12	$1,050	105
Poor	**3**	6	1.75	9	$1,200	120
Very Poor	**2**	4	2	6	$1,350	135
Inadequate	**1**	2	2.25	3	$1,500	150
Useless	**0**	0	≥ 2.5	0	> $1500	> 150

Suspension: Criteria Weight and Decision Outcomes

Criteria Weight	
Criteria	**Normalized Weight**
Travel	0.14
Deflection	0.13
Durability	0.37
Cost	0.12
Maint./Repair	0.24
Total	**1.00**

Criteria	Three Link	Single Trailing Arm	A-Arm
Travel	10(0.14)	10(0.14)	6(0.14)
Deflection	8(0.13)	0(0.13)	8(0.13)
Durability	7(0.37)	3(0.37)	7(0.37)
Cost	6(0.12)	10(0.12)	7(0.12)
Maint./Repair	6(0.24)	8(0.24)	5(0.24)

Criteria	Three Link	Single Trailing Arm	A-Arm
Travel	1.4	1.4	0.84
Deflection	1.04	0	1.04
Durability	2.59	1.11	2.59
Cost	0.72	1.2	0.84
Maint./Repair	1.44	1.92	1.2
Total	**7.19**	**5.63**	**6.51**

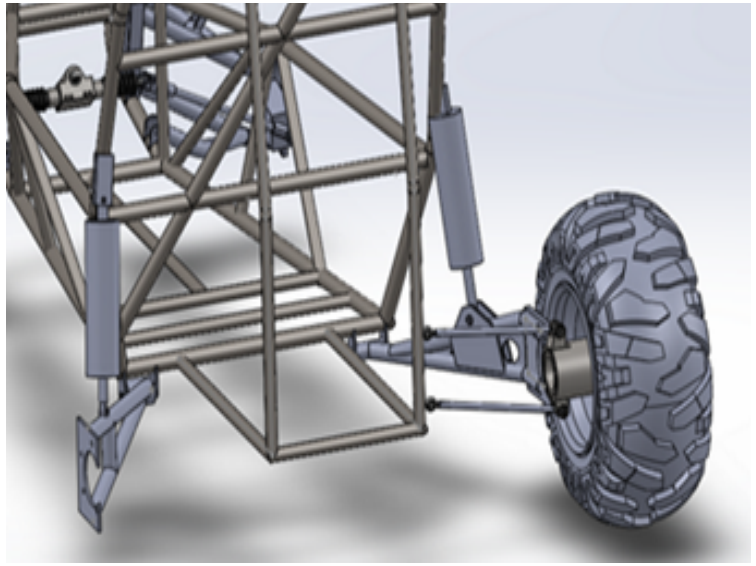
Suspension: Design Changes

Current Design: Single Trailing Arm

Desired Outcome: Three Link Representation

Suspension: Concept Implementation and Cost

CAD Comparative Representation



Initial Implementation/Mock-Up

Front View of Mock-Up

Transmission: Clutch Criteria Rating

Clutch					
Level	**Rating**	**Durability**	**Maint./Repair**	**Torque (ft-lb)**	**Cost**
Perfect	**10**	100 hrs.	≤ 15 min.	≥ 30	≤ $150
Excellent	**9**	90 hrs.	30 min.	28.5	$300
Very Good	**8**	80 hrs.	45 min.	27	$450
Good	**7**	70 hrs.	60 min.	25.5	$600
Satisfactory	**6**	60 hrs.	75 min.	24	$750
Adequate	**5**	50 hrs.	90 min.	22.5	$900
Tolerable	**4**	40 hrs.	105 min.	21	$1,050
Poor	**3**	30 hrs.	120 min.	19.5	$1,200
Very Poor	**2**	20 hrs.	135 min.	18	$1,350
Inadequate	**1**	10 hrs.	150 min.	16.5	$1,500
Useless	**0**	0 hrs.	> 150 min.	≤ 15	> $1500

Transmission: Clutch Criteria Weight and Decision Outcomes

Criteria Weight	
Criteria	**Normalized Weight**
Durability	0.30
Maint./Repair	0.12
Torque	0.21
User Friendly	0.13
Cost	0.24
Total	**1.00**

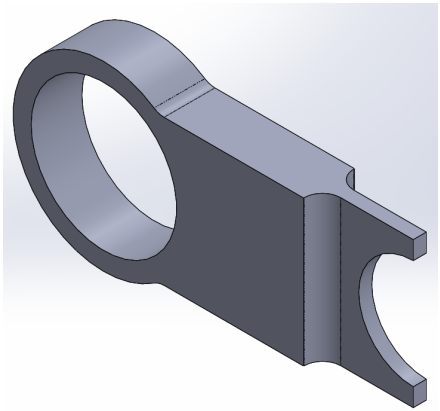
Criteria	Centrifugal	Basket Clutch
Durability	7(0.30)	10(0.30)
Maint./Repair	10(0.12)	2(0.12)
Torque	10(0.21)	10(0.21)
User Friendly	10(0.13)	5(0.13)
Cost	9(0.24)	3(0.24)

Criteria	Centrifugal	Basket Clutch
Durability	2.1	3
Maintenance/Repair	1.2	0.24
Torque	2.1	2.1
User Friendly	1.3	0.65
Cost	2.16	0.72
Total	**8.86**	**6.71**

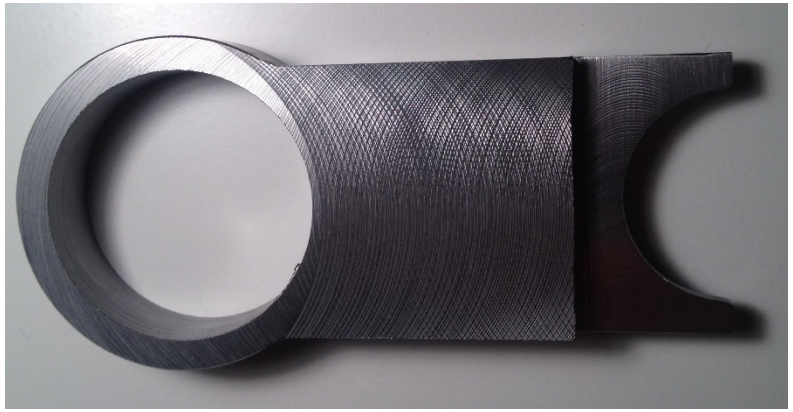
Transmission: Shifting Fork Design

- Previous shifting forks were incompatible
- New design is made from one solid piece
- One steel part and Two 3D printed parts have been fabricated
- Fadec code for the shift fork will be developed over break

Shift Fork CAD



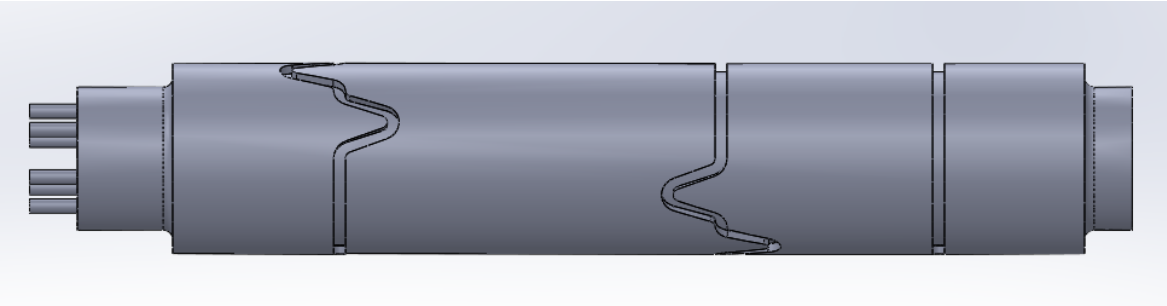
Manual Milled Shift Fork



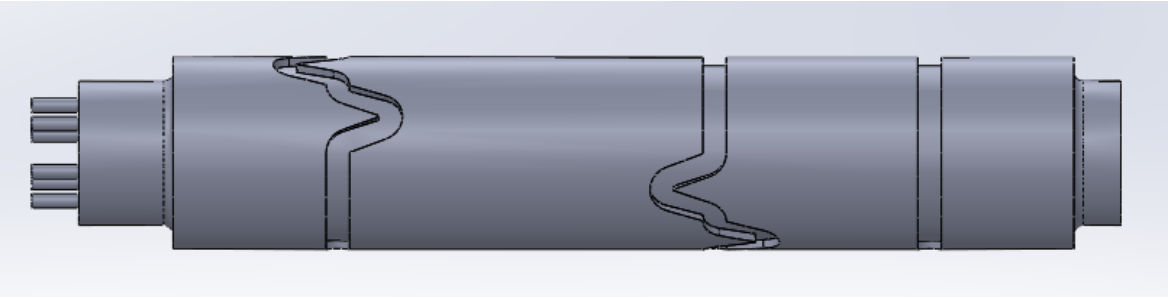
Transmission: Shift Rod Design and Transmission Cost Analysis

- Grooves and corners on the shift rod need to be widened
- 3D printed rod exists and will be used as test model
- Modification will allow for analysis of shifting force

Current Shift Shaft



Proposed Shift Shaft Change



Shifting Mechanism: Criteria Rating

Shifter					
Level	**Rating**	**Deg. of Throw**	**Shifting Speed (s)**	**Shifting Force (lb)**	**Cost**
Perfect	**10**	<10	1	<4	≤ $100
Excellent	**9**	10	2	4	$125
Very Good	**8**	20	3	6	$150
Good	**7**	30	4	8	$175
Satisfactory	**6**	40	5	10	$200
Adequate	**5**	50	6	12	$225
Tolerable	**4**	60	7	14	$250
Poor	**3**	70	8	16	$275
Very Poor	**2**	80	9	18	$300
Inadequate	**1**	90	10	20	$325
Useless	**0**	>90	> 10	>20	>$325

Shifting Mechanism: Criteria Weight and Decision Outcomes

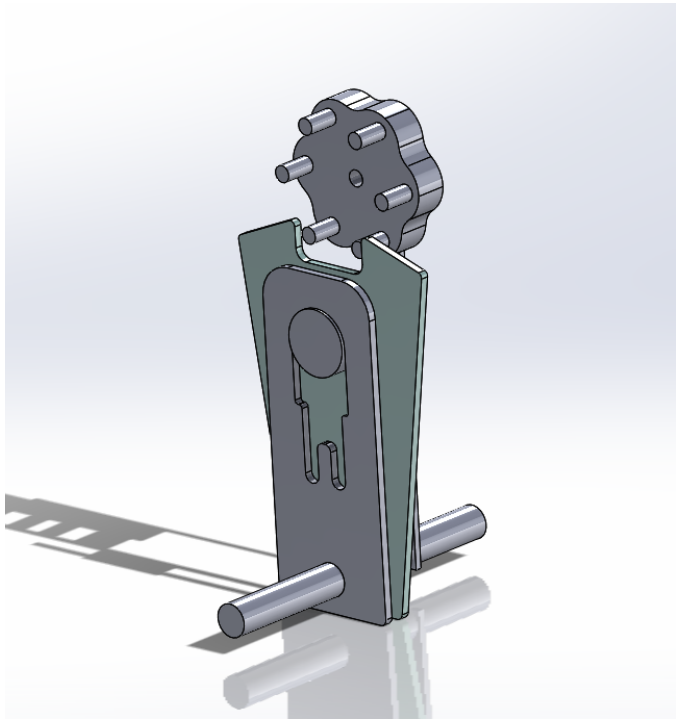
Shifter	
Criteria	**Normalized Weight**
Degrees of Throw	0.18
Shifting Speed	0.13
Shifting Force	0.45
Cost	0.15
Simplicity	0.09
Total	**1.00**

Criteria	Ratchet	Gate
Degrees of Throw	4(0.18)	8.5(0.18)
Shifting Speed	5(0.13)	5(0.13)
Shifting Force	7(0.45)	4(0.45)
Cost	3(0.15)	10(0.15)
Simplicity	4(0.09)	8(0.09)

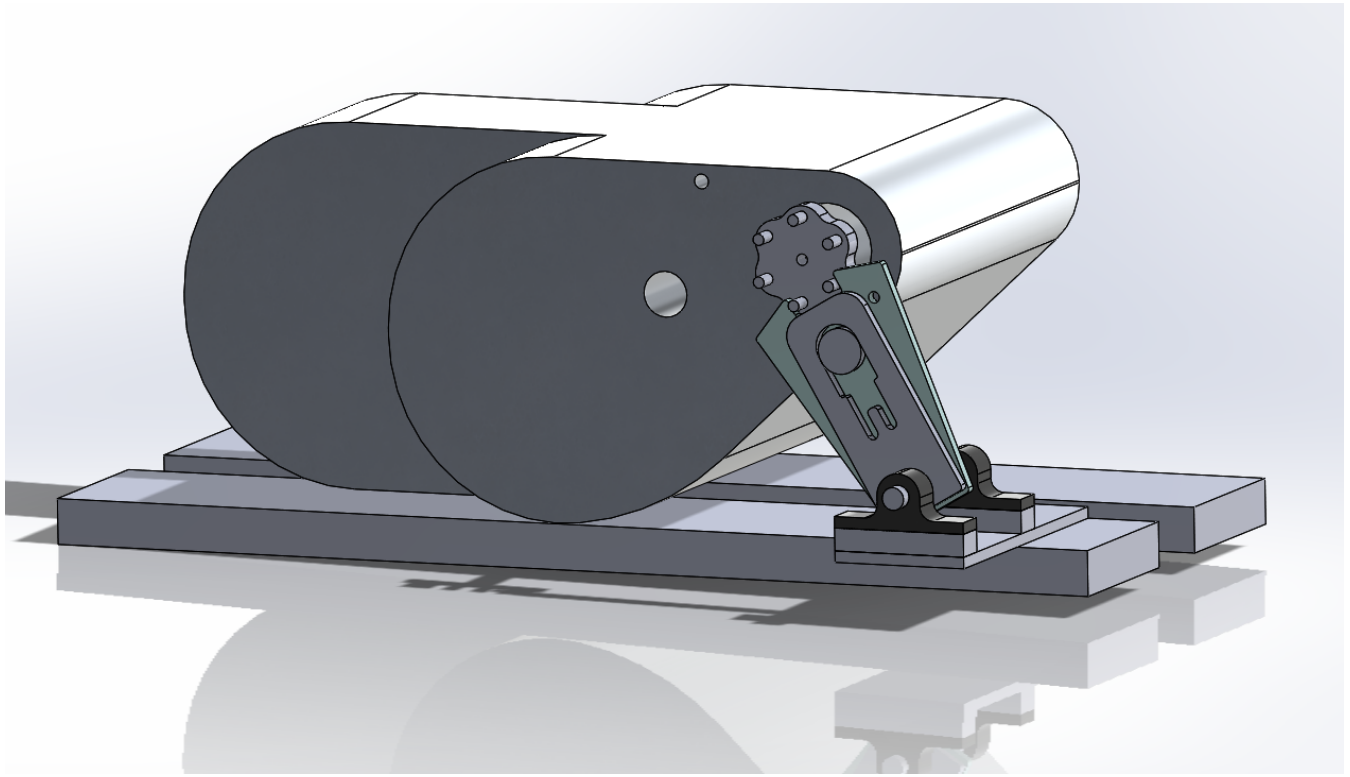
Criteria	Ratchet	Gate
Degrees of Throw	0.72	1.53
Shifting Speed	0.78	0.65
Shifting Force	3.15	1.8
Cost	0.45	1.5
Simplicity	0.36	0.72
Total	**5.46**	**6.2**

- Due to design compatibility issues, the ratchet shifter has been selected as the shifting mechanism

Shifting Mechanism: Design Progress

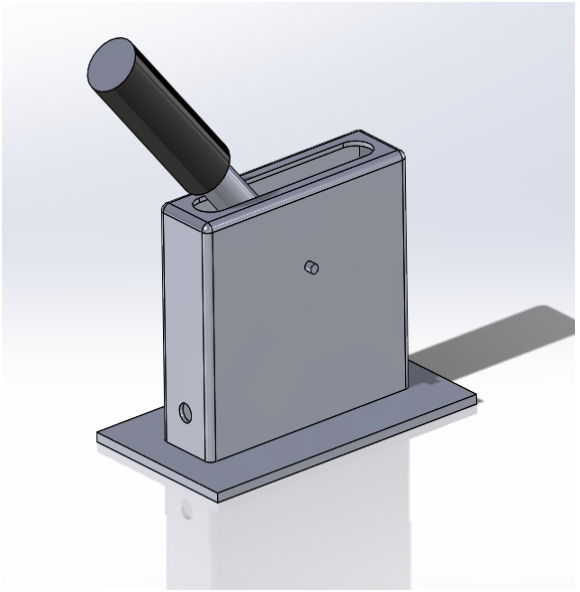


SolidWorks Model

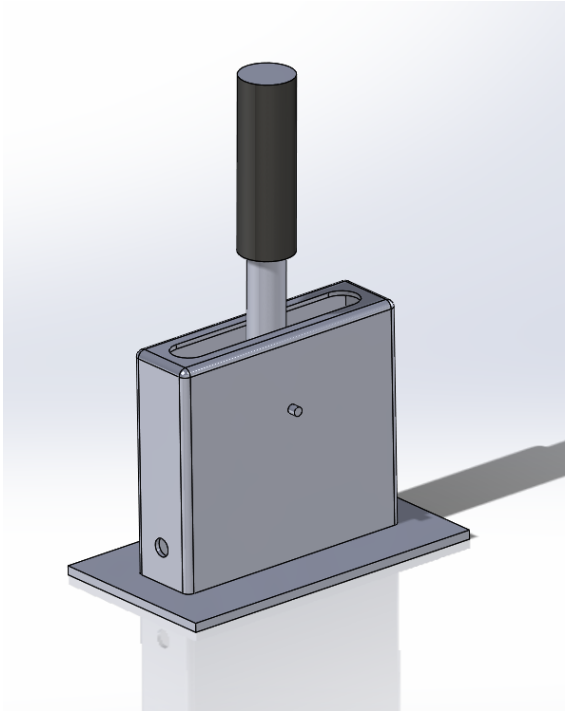


Mechanism Mated to Transmission

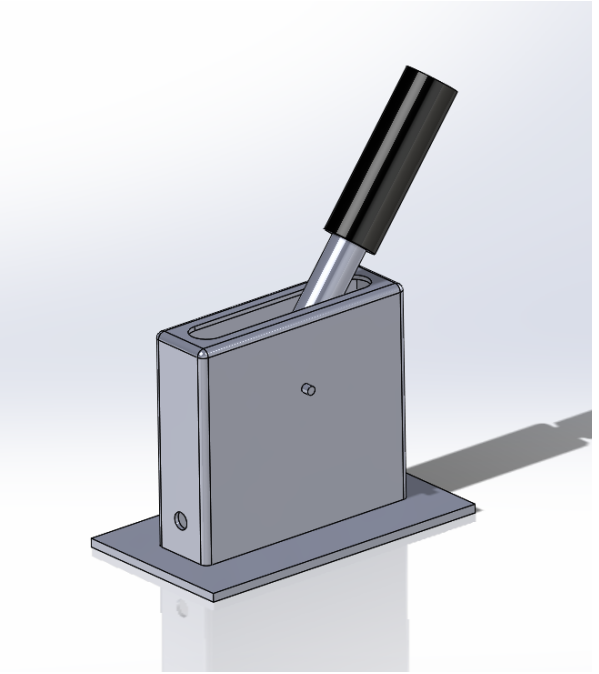
Shifter Design:



Down Shift Position

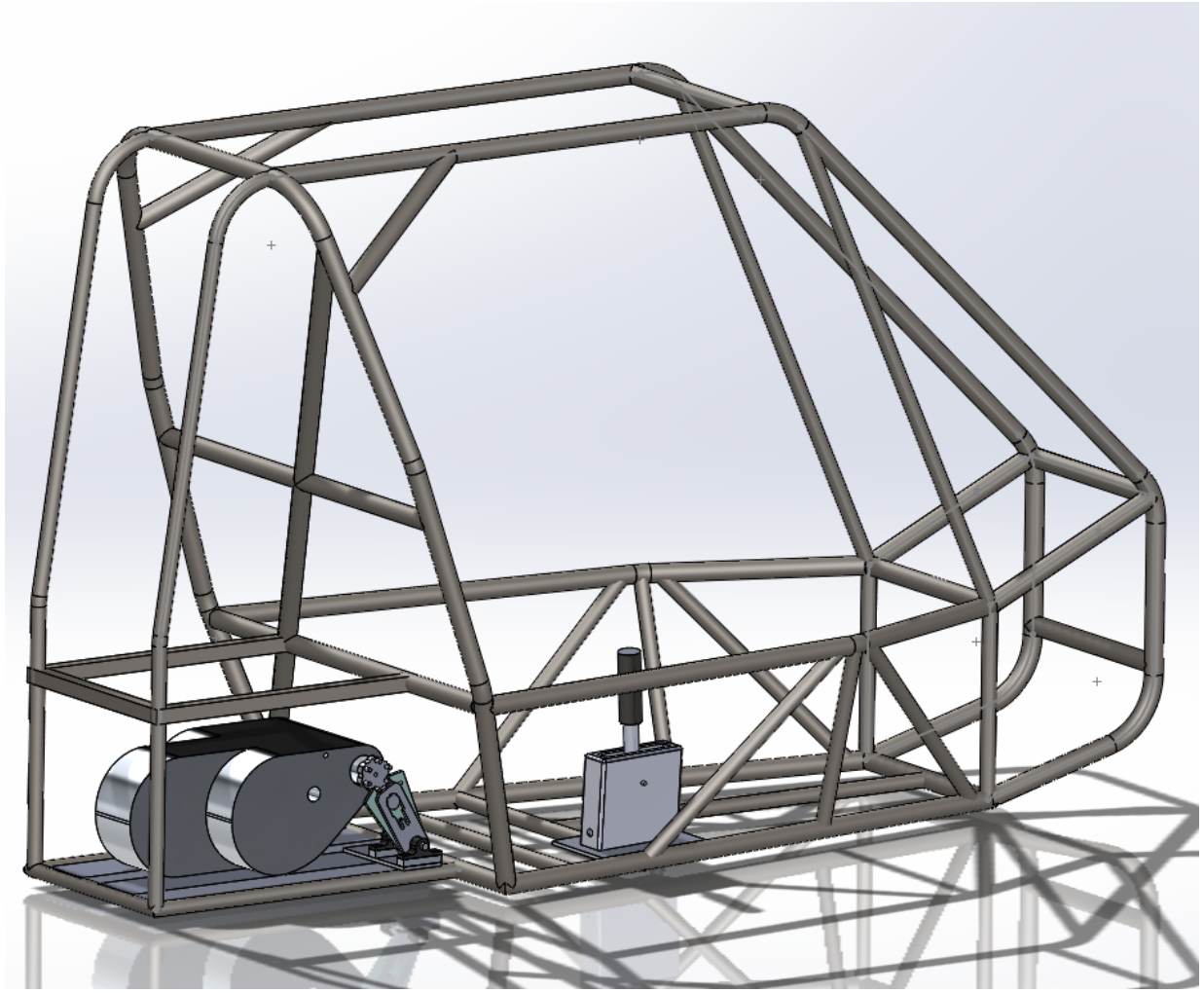


Resting Position

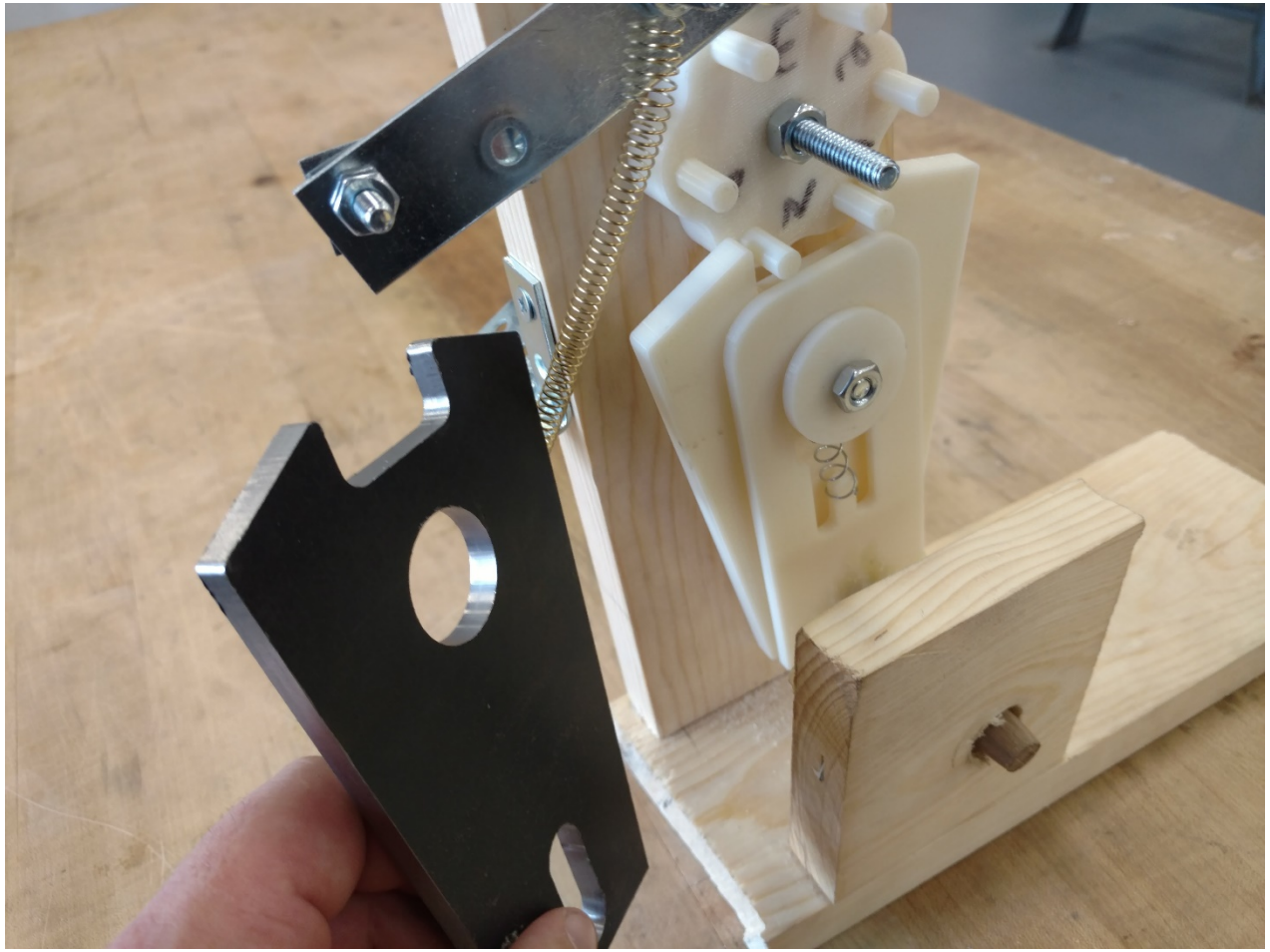


Up Shift Positon

- Shifting mechanism mounted to the frame and transmission
- Shifter mounted to bottom of frame next to seat position



- Shifting slide has been machined
- Shifting plate has been machined



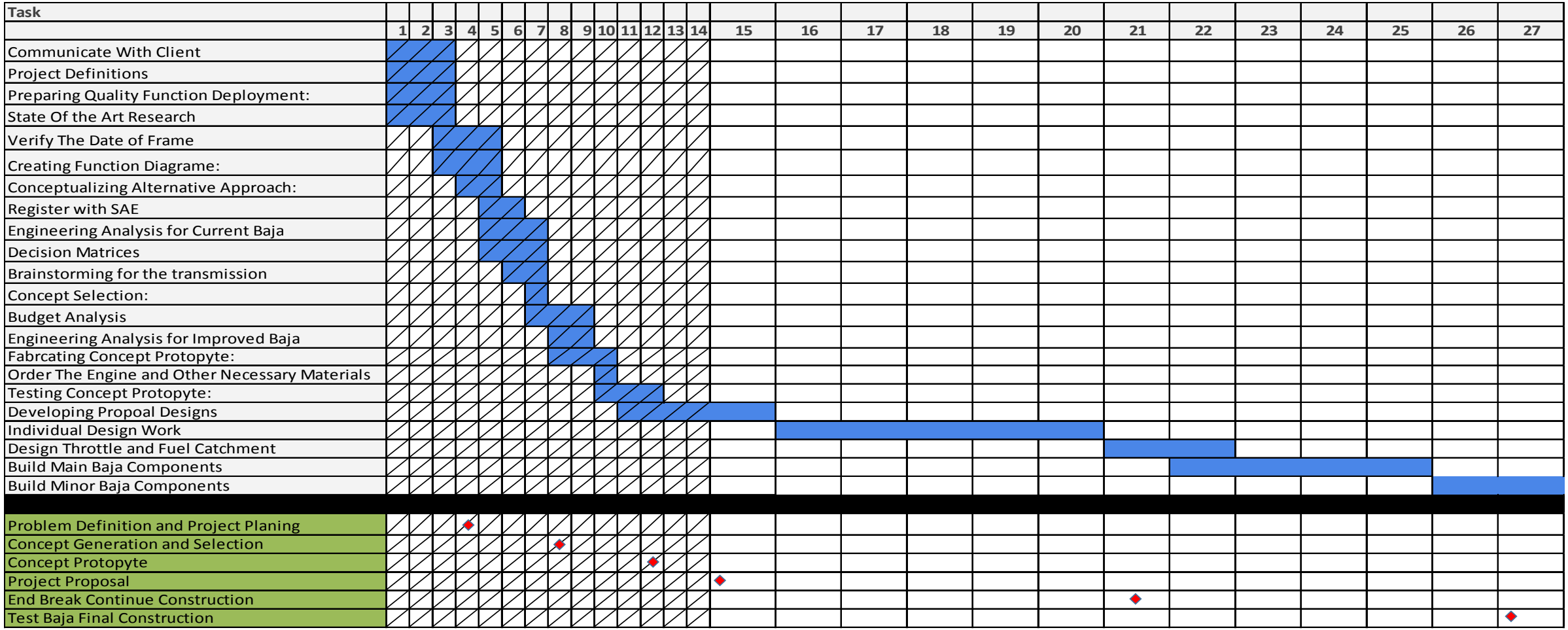
Designs in Progress

- Muffler location is our problem, Baja 2016 rules not allow to muffler comes out of frame from three directions of frame(right, back, left).
- Should be a muffler extension be in the straight direction or down, not in any other direction.
- Solving of our muffler problem, to make the muffler in 90 degree horizontal line, instead what we have now(55 degree).
- Dr.Tester request to re design throttle.
- Per SAE rules, a fuel catchment system must be designed that fits within the vehicles envelope.

Bill of Materials

Part Name	Sub-part/Material	Cost
Frame	AISI 4130 steel	$121.16
Suspension	Razor Half Shafts	$539.98
Transmission	Centrifugal Clutch	$500
	1018 Steel Forks	$80
Shifting	Linkage	$60
	Bearing/metal	$45
Muffler	Steel Pipe	$7
Gas Pedal		$15
Gas		$15
Total		$1383.14

Updated Project Plan



Conclusion

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- Functional Diagram of the Baja: how the baja works and its main sources of energy used
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Questions?