SAE MINI BAJA – FRAME AND DRIVETRAIN

Riley Karg, Jacob Kelley, Kaleb Brunmeier, Jacob Najmy, Tye Jorgenson

Project Description: General

SAE Mini Baja Team:

- Build a single-seat, all terrain vehicle that fully contains its passenger capable

Frame:

- Ensure driver protection and provide a mounting structure for suspension geometry and drive train components.

Drive Train:

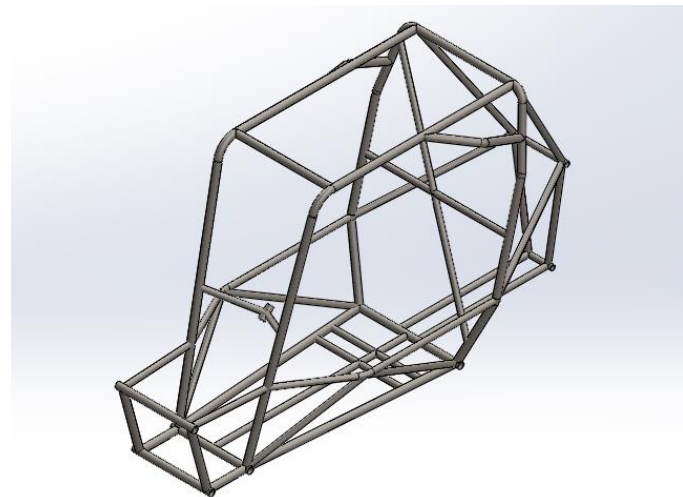- Ensure efficient translation of engine power output to final vehicle propulsion.

Figure 1. SAE Baja Frame Structure

Background & Benchmarking: General

- Utilized analysis compiled by Zachary Rischar
- Data from 2015 Portland, OR competition
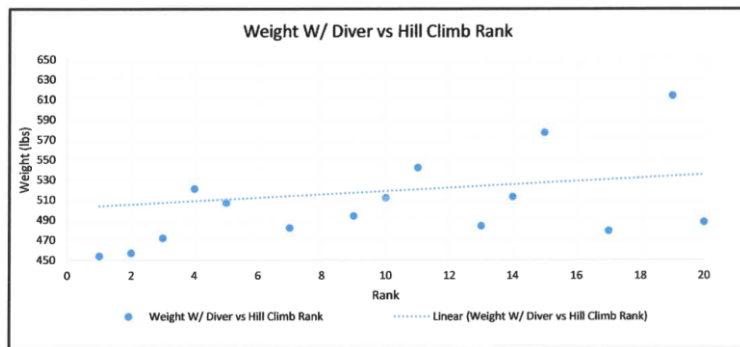- Decided upon desired Max/Min values

Figure 2. Weight vs Hill Climb Rank [2]

Table 1. General Characteristics Desired Values

Characteristic	Desired Max/Min	
	Front	Rear
Wheelbase	60" (Max)	
Track Width	53" (Max)	50" (Max)
Weight w/driver	525 lbs (Max)	
Ground Clearence	10" (Min)	9" (Min)

- Looked at geometry of top 5 teams
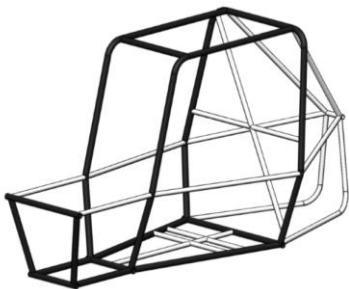- 50/50 split on RB vs FB
- Cockpits designed for max clearance

	Compairison	
Frame	60% RB	40% FB
RRH	60% Wide	40% Typical
RHO	100% Wide	
SIM	60% Bent	40% Straight
FBM angle	66% > RRH	33% = RRH
RRH to RHO Bracing	75% Bent	25% Straight

Table 2. Frame Geometry Comparisons

Figure 2. Rear Braced Frame [1]   **Figure 3. Front Braced Frame [1]**
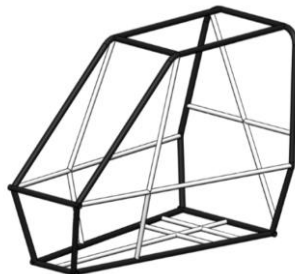
- Uses weights and springs to change gear ratio between engine and gearbox

- Fully automatic, very little human input

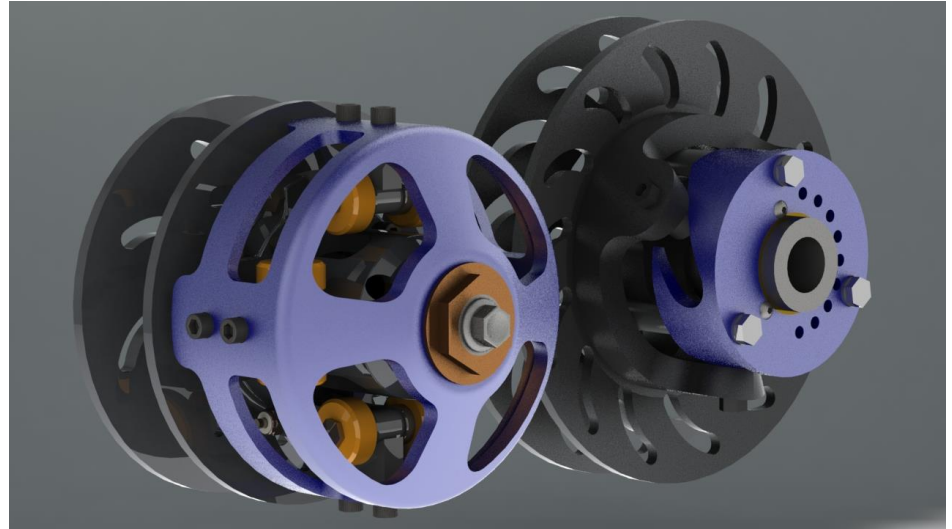- Mass produced CVT with company support

Figure 6. 2018 and 2019 NAU Gaged CVT [5]
"The CVT in Figure 2 uses centripetal motion to change the gear ratios by the tension on the belt. By tuning the CVT right, the Baja can get more acceleration. The problem with the CVT is we can't change the weights during competition." [5]

-NAU Baja Team 2018

Benchmarking: Electrically Controlled Continuously Variable Transmission

• Current ECVT on the market

Usually installed aftermarket on side-by-sides (Polaris Ranger)

• Programmable Stepper motor lets user fully control system

• Automatic mode uses computer and RPM reading to determine gear ratio

• Selectable terrain mode helps user in different situations
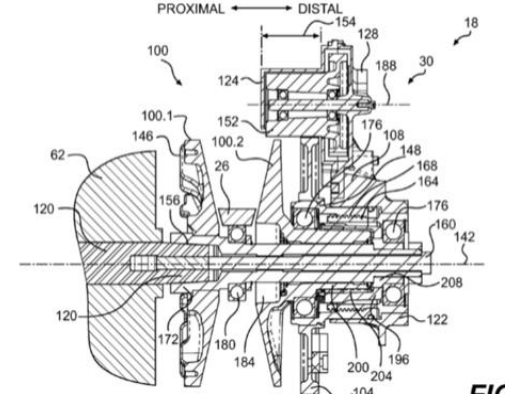
Figure 7. ECVT Concept [4]

Figure 8. ECVT Concept [4]

- Differentials help distribute power proportionally to drive wheels during a turn
- User input is not required
- Used in 99% of road driven vehicle

Figure 9. Standard Vehicle Differential [6]

Figure 10. Differential Concept for trikes [6]

Benchmarking: Drivetrain (Four-Wheel Drive)

- Allows vehicle to have power running to all four wheels

- User can change between two-wheel drive or four-wheel drive

- Engine distributes power using a transfer case
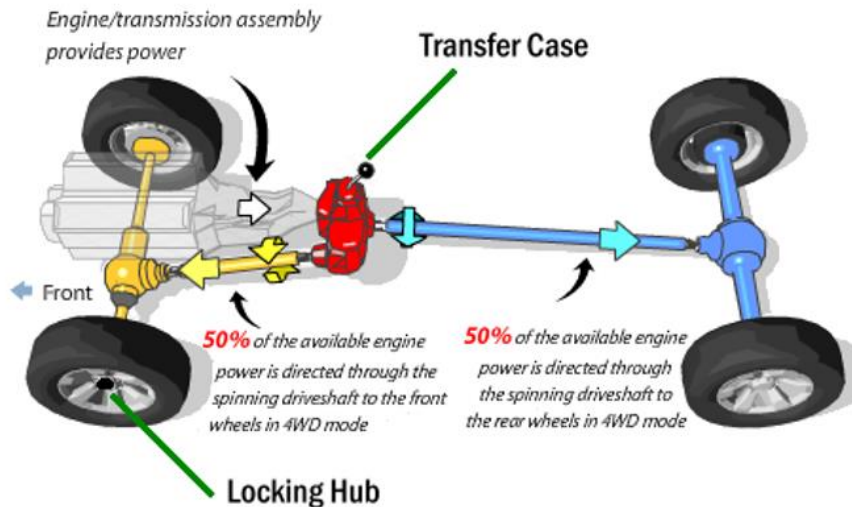
Figure 11. Baseline 4x4 Design [3]

Literature Review: Drivetrain
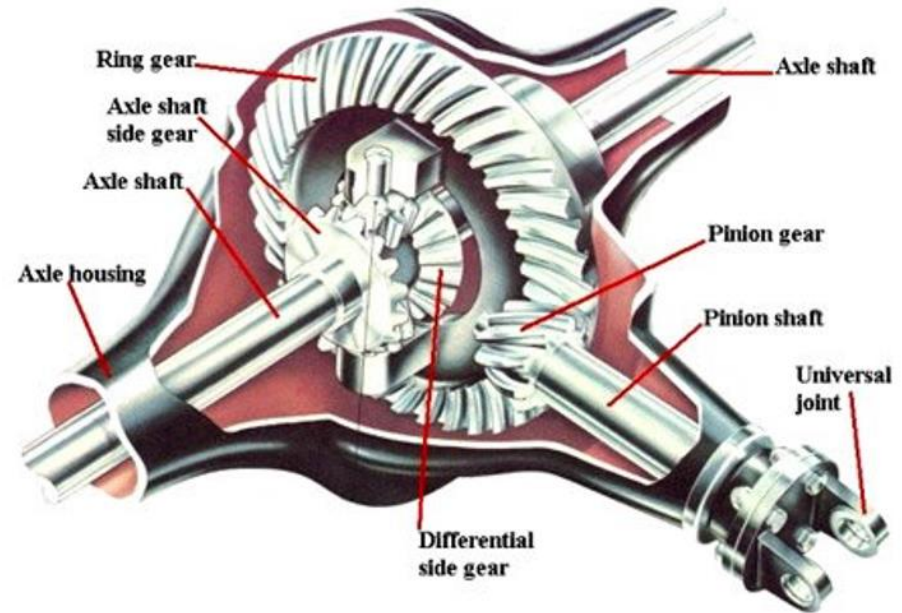
- **BAJA RULES 2020 Revision A – September 8, 2019**
  - Design drivetrain in accordance with rules
  - 4WD/AWD incentives and stipulations found here
- **Shigley's Mechanical Engineering Design, 10th Edition**
  - Reference for all drivetrain designs
  - All components will be designed using AGMA standards
  - Gear geometry, kinematic relations, and forces transmitted
- **Construction Mechanic Basics: Chapter 11**
  - Fundamentals of operation for Drive lines, differentials, drive axles, and powertrain accessories
  - Maintenance procedures
  - Advantages/disadvantages to different drive systems
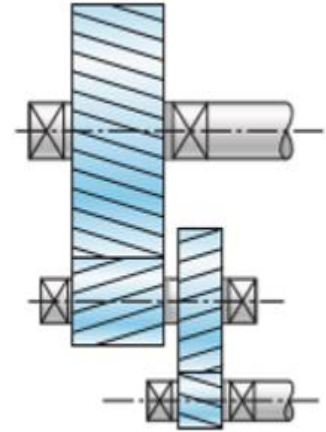
Figure 12: Two-Stage Compound Gear Train[9]

Literature Review: Frame

- **Design and optimization of a SAE Baja Chassis [7]**
  - Worcester Polytechnic Institute document
  - Describes optimization of a similar frame design project
  - Frame sub team will use but potentially useful to other sub teams
- **Design, analysis and optimization of a multi-tubular space frame [8]**
  - Online article
  - Material selection and FEA modification steps
  - Frame team alone could use
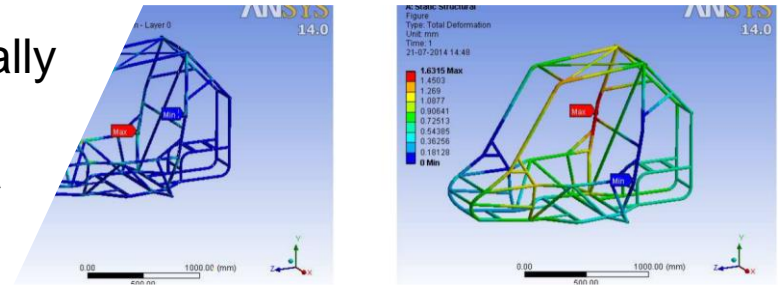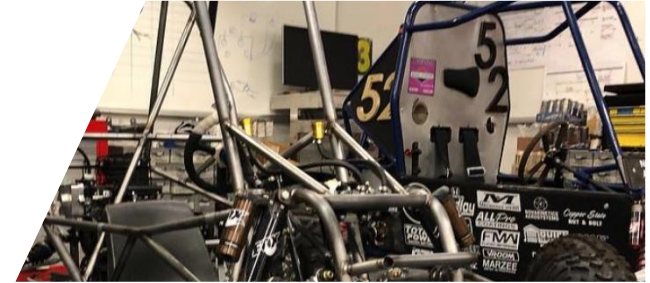
Figure 5. Accompanying Baja Frame Visuals

Customer Requirements to Engineering Requirements

Customer Requirements

- Reliability

- Durability

- Low weight

- Withstand impact

- Ergonomic Cockpit

- High Torque Output

- High Power Output

- Safe

Engineering Requirements

- Bending Stiffness   (2,620 Nm^2)

- Torsional Stiffness   (374 Nm)

- Material Type   (Tubing 0.984" X 0.118")

- Egress Time   (within 5s)

- Effective Gear Ratio   (2.24:1 reduction)

- Low Center Mass   (below 20 inches)

Table 3. House of Quality

Customer Requirement	Weight	Engineering Requirement	Material Ultimate Strength	Material Torsional Stiffness	Approximate Size (inches)	Weight of Material (lbs)	Driver Exit Speed (Seconds)	Cost of FR &DT (USD)	Highest Gear Ratio	Lowest Gear Ratio	Effective Gear Ratio	DT Component Location (inche
Absolute Technical Importance (ATI)			216	189	189	171	108	108	99	99	117	63
Relative Technical Importance (%)			16	14	14	13	7.9	7.9	7.3	7.3	8.6	4.6
Target ER values					108x64x60	300	5	6000	3.9	0.9	2.4	36x48x24
Tolerances of ERs					MAX	MAX	MAX	MAX	MAX	MAX	N/A	MAX
Testing Procedure (TP#)			1	2	2	4	6	6	8	8	5	10

Budget: Frame and Drivetrain

Table 4. Estimated Frame Budget

Part	Cost	Quantity	Total Cost
Steel Tubing	~$5.75 / foot	~100 feet	$575
Carbon Fiber Panels	~$42 / 36"x50" sheet	~4	$168
Labor	~$15 / hour	Mostly volunteer	$0
Seat and Seat Belt	~$60	1	$60
Welding supplies	~$50	1	$50
Miscellaneous brackets and tabs	~$150	1	$150
		Total	$1,003

Table 5. Estimated Drive Train Budget

Bill of Materials

			Team			Drive Train			
Part #	Part Name	Qty	Description	Functions	Material	Dimensions	Cost	Link to Cost estimate
1.1	Vanguard Model 19 Briggs & Stratton Motor	1	Manufacturer direct supply	Vehicle Propulsion	N/A	24"x24"x24"	$ 434.08	The Home Depot
1.2	Fuel Tank	1	1.5 Gallon tank by Pyrotect	Store fuel	6061-T6 Al	1.5 Gal	$ 225.00	Pyrotect Racing Safety Equipment
1.3	Continuously Variable Transmission	1	Gaged Engineering	changes shaft rotational speeds between engine and wheels	N/A	3.9:1 - 0.9:1	$ 1,596.00	Gaged Engineering
1.4	Shaft Material	3	Speedy Metals round stock	Machined to tolerance(s)	1018 RCF Steel	1"ODx36"	$ 81.00	Speedy Metals Round Stock
1.5	Gear Material	3	Speedy Metals flat stock	Machined to tolerance(s)	1018 RCF Steel	1/2"x10"x24"	$ 433.08	Speedy Metals Flat Stock
			Total Cost Estimate:				$ 2,769.16	

Schedule

Table 6. Gantt Chart
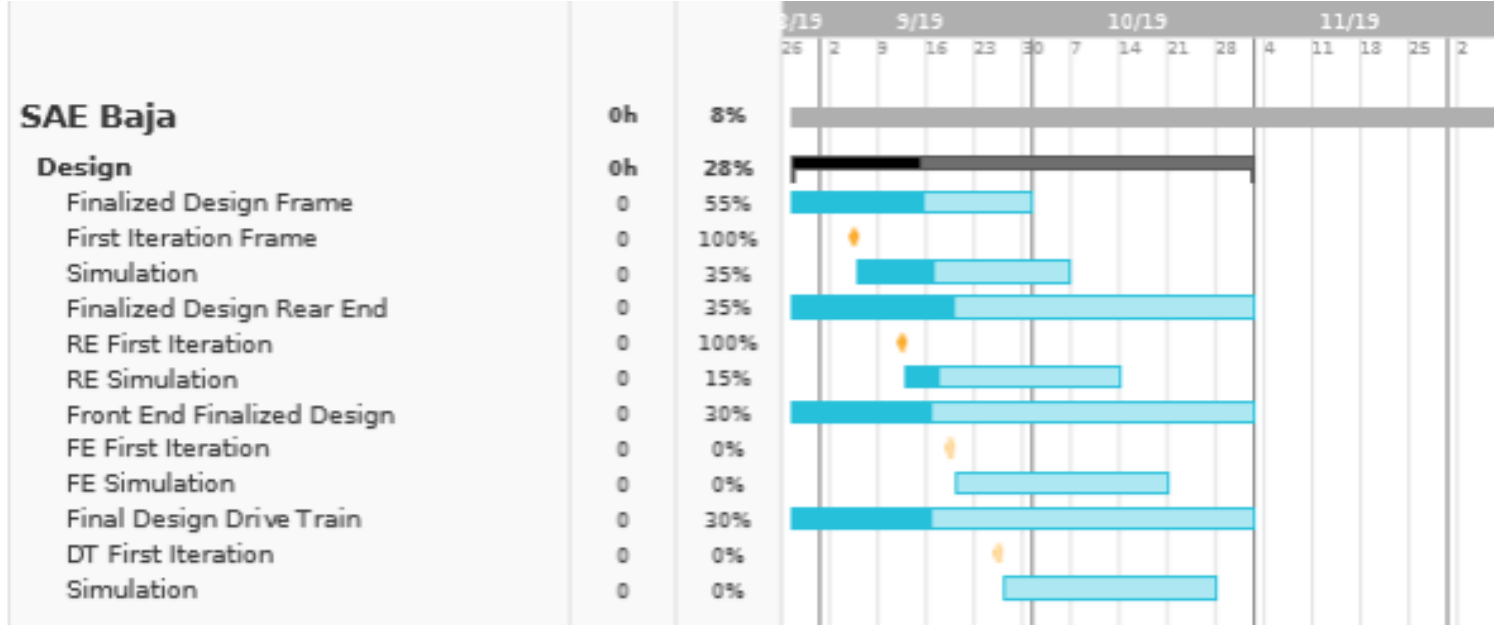
Questions?

References

[1]   Baja SAE Rules, Collegiate Design Series, Revision A, Baja SAE, Sep. 8 2019

[2]   Zachary Rischar, "2015 SAE Mini Baja Portland, OR Results and Analysis,"   Lumberjack Motorsports, Northern Arizona Univ., Sep. 8 2017

[3] 9. Media, "www.therangerstation.com," The Ranger Station, 2019. [Online]. Available: https://www.therangerstation.com/stock-ranger-specifications/the-ford-ranger-4wd-system/. [Accessed 15 September 2019].

[4] H. Roberge, D. Levasseur and C. Mercier, "Electronically Controlled Continuously Variable Transmission With Torque Limiting System and Method Thereof". United States of America Patent US 8682549 B2, 22 December 2010.

[5] N. S. B. C. T. 2018, "www.cefns.nau.edu," 7 October 2017. [Online]. Available: https://www.cefns.nau.edu/capstone/projects/ME/2018/SAEBaja/documents/drivetrainprelim.pdf. [Accessed 17 September 2019].

[6] Pizzaman711, "www.ChevroletForum.com," www.ChevroletForum.com, 8 June 2015. [Online]. Available: https://chevroletforum.com/how-tos/a/chevrolet-silverado-1999-2006-how-to-test-rear-differential-390147. [Accessed 15 September 2019].

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[7] H. Selmer, S. Shweiki and P. Tencati, "2016-2017 Design and Optimization of a SAE Baja Chassis", *Web.wpi.edu*, 2019. [Online]. Available: https://web.wpi.edu/Pubs/E-project/Available/E-project-042517-094544/unrestricted/Design_and_Optimization_of_a_SAE_Baja_Chassis.pdf. [Accessed: 17- Sep- 2019].

[8] V. Jadhav, "DESIGN, ANALYSIS AND OPTIMIZATION OF A MULTI-TUBULAR SPACE FRAME", *researchgate*, 2014. [Online]. Available: https://www.researchgate.net/publication/274702070_DESIGN_ANALYSIS_AND_OPTIMIZATION_OF_A_MULTI-TUBULAR_SPACE_FRAME. [Accessed: 17- Sep- 2019].

[9] Budynas, R. and Nisbett, K. (2014). *Shigley's Mechanical Engineering Design*. 10th ed. McGraw Hill.

Rank (2019 California)	1	2	3	4	5
Team/School	Uof Michigan Ann Arbor	RIOT RACING	Oregan State	Baja ETS	University of Arkon
Frame	RB	RB	FB	RB	FB
RRH	Typical	Wide	Wide hardly narrowed at top	Typical	Wide
RHO	One piece, wide	One piece, wide	One piece, wide	One piece, wide	One piece, wide
SIM	One piece, straight	One piece, bent	One piece, bent	One piece, bent (bend is close to front)	One piece, straight
RHO angle	Steeper than RRH	Steeper than RRH	N/A	Same as RRH	N/A
RRH to RHO Bracing?	Yes, straight member	Yes, bent member	None	Yes, bent member	Yes, bent member

Rank (2019 Tennesee)					
Team/School	Oregan State	Uof Michigan Ann Arbor	Baja ETS	RIOT RACING	UMBC Racing
Frame	FB	RB	RB	RB	FB
RRH	Wide at top	Typical	Typical	Wide at top	Typical
RHO	One piece, wide	One piece, wide	One piece, wide	One piece, wide	One piece, wide
SIM	One piece, bent	One piece, straight	One piece, bent (bend is close to front)	One piece, bent	One piece, straight
RHO angle	N/A	Steeper than RRH	Same as RRH	Steeper than RRH	N/A
RRH to RHO Bracing?	None	Yes, straight member	Yes, bent member	Yes, bent member	Same mistake as 44

| Rank (2019 Rochester)					
Team/School	Uof Michigan Ann Arbor	Baja ETS	SDSU Aztec Baja	Cornell Baja	Université Laval
Frame	RB	RB	RB	FB	FB
RRH	Typical	Typical	Typical	Typical	Typical
RHO	One piece, wide	One piece, wide	One piece, angled in	One piece, wide	One piece, wide
SIM	One piece, straight	One piece, bent (bend is close to fron	One piece, two bends	One piece, bent	One piece, two bends
RHO angle	Steeper than RRH	Same as RRH	Same as RRH	N/A	Steeper than RRH
RRH to RHO Bracing?	Yes, straight member	Yes, bent member	Yes, bent member	Yes, bent member	Yes, straight member

FR & DT House of Quality (HoQ)

Customer Requirement	Weight	Engineering Requirement	Material Ultimate Strength	Material Torsional Stiffness	Approximate Size (inches)	Weight of Material (lbs)	Driver Exit Speed (Seconds)	Cost of FR &DT (USD)	Highest Gear Ratio	Lowest Gear Ratio	Effective Gear Ratio	DT Component Location (inche
Reliability	9		9									
Durability	9		3	9	3	3						
Withstand Impact	9		3	3	9	3						
Low Weight	6				6	9						
Ergonomic Cockpit	6				3		9	3				
Operational Safety	6				3		9	9	3	3	6	6
High Power Output	6		6	6		3		3	9	3	6	
High Torque Output	6		6	6		3		3	3	9	6	
Low Center of Mass	3		3	3	3	9			3	3	3	9
Absolute Technical Importance (ATI)			216	189	189	171	108	108	99	99	117	63
Relative Technical Importance (%)			16	14	14	13	7.9	7.9	7.3	7.3	8.6	4.6
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Tolerances of ERs					MAX	MAX	MAX	MAX	MAX	MAX	N/A	MAX
Testing Procedure (TP#)			1	2	2	4	6	6	8	8	5	10

Approval (print name, sign, and date):

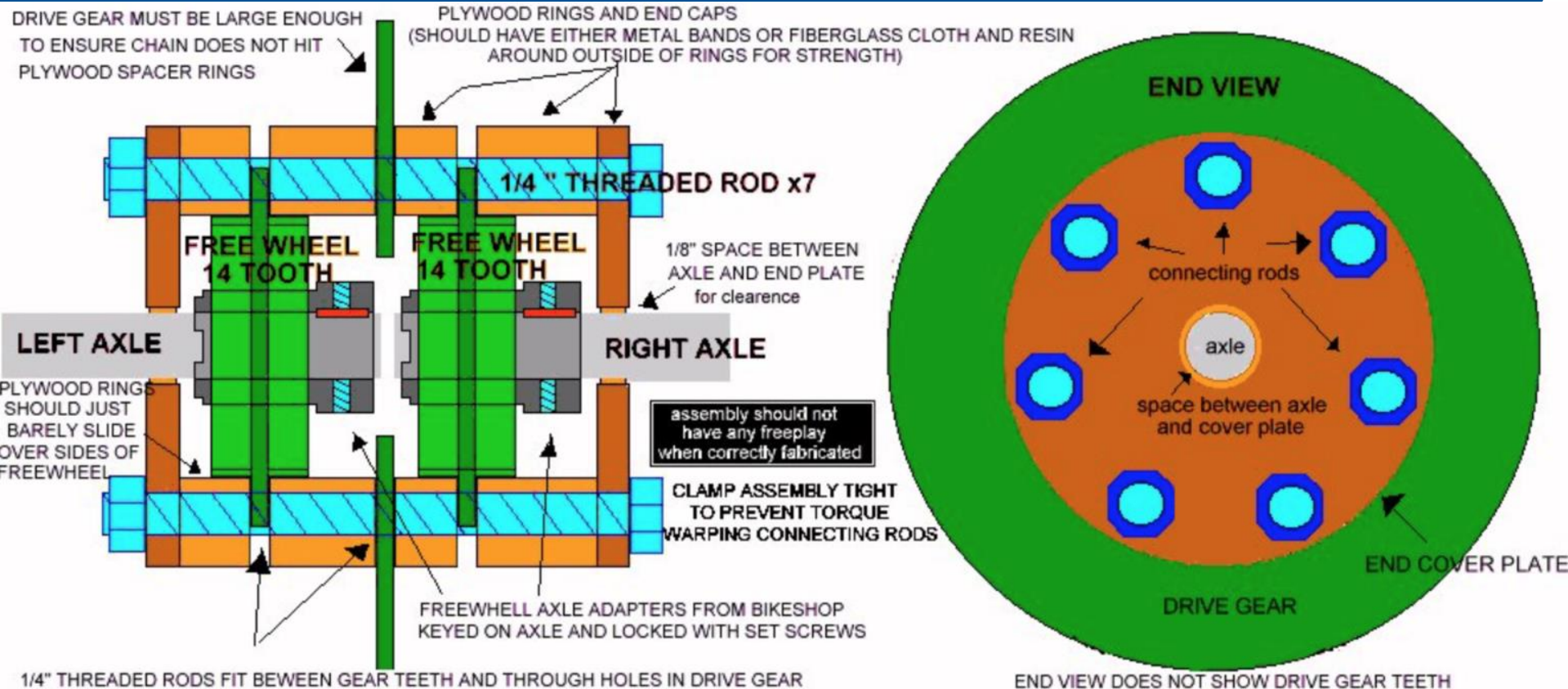| |
|---|
| Team member 1: Kaleb Brunmeier |
| Team member 2: Riley Karg |
| Team member 3: Tye Jorgenson |
| Team member 4: Jacob Najmy |
| Team member 5: Jacob Kelley |
| Client Approval: Dr. John Tester |
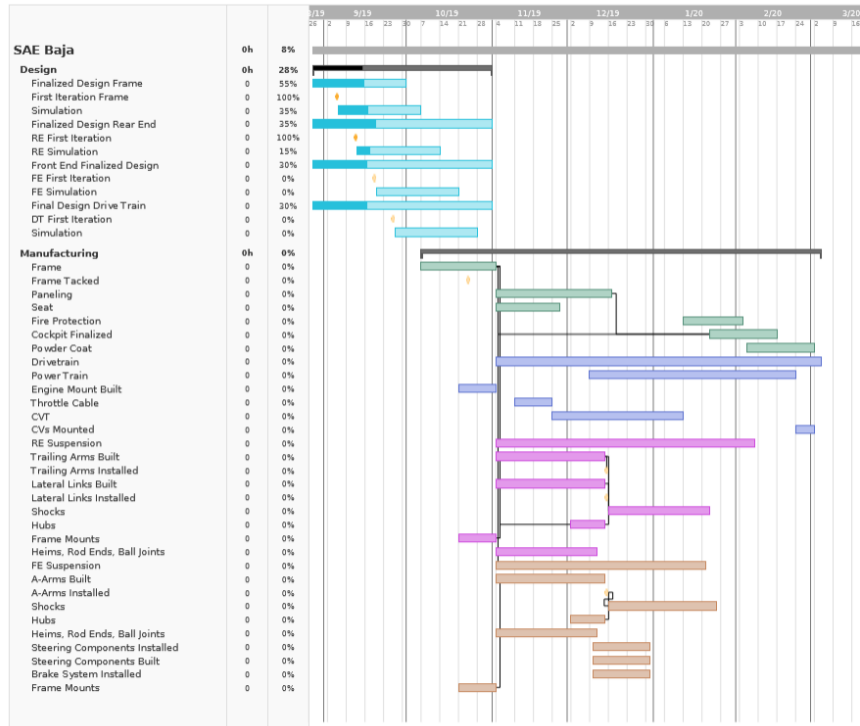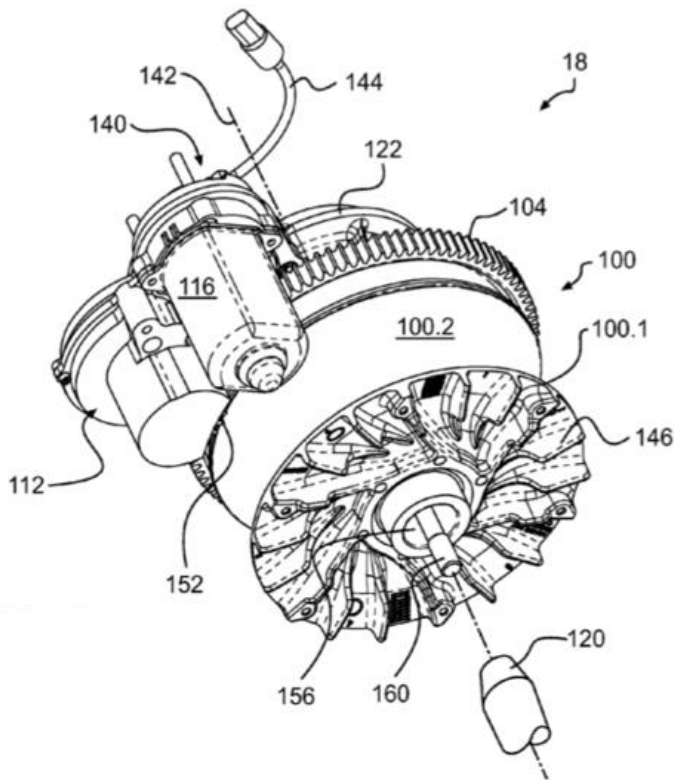
Figure 8. ECVT Concept [4]

Figure 7. ECVT Concept [4]

Figure 10. Differential Concept [6]