2021 SAE Baja

Final Proposal

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DISCLAIMER

This report was prepared by students as part of a university course requirement. While considerable effort has been put into the project, it is not the work of licensed engineers and has not undergone the extensive verification that is common in the profession. The information, data, conclusions, and content of this report should not be relied on or utilized without thorough, independent testing and verification. University faculty members may have been associated with this project as advisors, sponsors, or course instructors, but as such they are not responsible for the accuracy of results or conclusions.

EXECUTIVE SUMMARY

The SAE Baja competition requires collegiate teams to design, engineer, and build a lightweight off-road vehicle from the ground up over the course of two semesters. A 10hp Briggs and Stratton engine is provided to teams competing, but the rest of the components must be designed around that engine by the team. To be eligible to compete in the competition, each design must adhere to the guidelines laid out in the SAE 2021 Handbook. The team is broken up into four sub-teams: front end, rear end, drivetrain, and frame. The engineering and design phase takes place during the Fall 2020 semester. Using inspiration from previous successful designs and research pulled from many sources, each sub-team brainstorms several design concepts for various components of the vehicle. Through finite element analysis and benchmarking with other designs, final designs are chosen. The final designs will be manufactured during the Spring 2021 semester. After completion of the vehicle various tests will be ran to simulate what the car will be put through during competition. Data will be collected from these tests and will be used to iterate and improve the initial design. After the iteration process, the engineering cycle will be complete, and the vehicle will finally be ready to compete against several hundred other universities.

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1 BACKGROUND

1.1 Introduction

The SAE Baja project is competition based, with the goal to design and construct a fully functioning miniature Baja vehicle and rank against other schools across the country. The project sponsor David Trevas takes interest into this project to see our team do better in competition and provide aid in attempt to create a better vehicle. Dr. Trevas, along with other sponsors, provide both aid in design and financially, and upon completing the vehicle, performance and placement in competition will determine the effectiveness of the aid and the aid for future teams. It is important to emphasize the placement in competition, as the higher placement we achieve, would provide a better name for NAU in future competitions. This report will cover the concept generation processes for the overall vehicle, and within the four sub-teams, being frame, drivetrain, front end, and rear end.

1.2 Project Description

The Baja capstone team strives to compete in the annual West Coast SAE Baja Competition, where we can showcase our knowledge of the vehicle design to other universities and automotive industry representatives. There are thirteen undergraduate mechanical engineering students who have divided the project into four sub-teams: Frame, drive train, front end, and rear end. All design aspects of this project will be following the SAE Baja competition rule book. The sponsors of this project include the Society of Automotive Engineers, W.L Gore and Associates, Lucas Inc., Acre, Bro-Tools, and Home Depot. Our team anticipates un upwards cost around $30,000. The 2021 competition is slightly different compared to previous years, as they are adding a significant point incentive to using a four-wheel drive system. Therefore, our team will be designing a four-wheel drive Baja vehicle.

2 REQUIREMENTS

Before beginning any design process, the team needed to have a thorough understanding of the requirements needed for the competition. The customer requirements were provided for us via the SAE Baja 2021 Competition Rulebook. These customer requirements assisted in developing the engineering requirements, which are measurable parameters applied to the systems within the design. From there, the team created a functional decomposition model that broke down the entire vehicle into four subsystems: frame, drive train, front end, and rear end. Each subsystem team then created a black box model for their specific subsystem in order to identify their basic input and output elements.

2.1 Customer Requirements (CRs)

Along with the requirements of the competition, there are requirements the Baja team must meet provided by our sponsors. The first requirement is that we stay within the provided budget for the project. The team anticipates an upward cost of around $30,000. Much of the budget will be provided to us through the NAU capstone department, as well as Gore. Furthermore, in order to ensure that the final Baja design is durable and reliable, many FEA's and analysis must be performed. This will provide calculated evidence supporting or discrediting initial aspects of the Baja's design process. While maintaining a robust and reliable design is critical, the team must provide evidence that the Baja vehicle will be safe to operate. One of the ways this will be done will be through incorporating a factor of safety into all sub system design aspects. As a result, the customer requirements for the SAE Baja vehicle will be met and will help guide the team to engineering a competitive design.

2.2 Engineering Requirements (ERs)

After defining the customer needs of the Baja vehicle, the team converted each customer need to a quantifiable engineering requirement with a target value and tolerance. These engineering requirements would then be used to design each subsystem to fulfil the customer needs. Seen below in Table 1 are each engineering requirement and the associated unit to quantify the target goal. Further on, the engineering requirements are summarized in a Quality Functional Deployment, where each engineering requirement is given a target value and a tolerance.

Table 1: Engineering Requirements

Engineering Requirements	Units
Low Material Density	g/cm^3
Fatigue Life Cycles	n
Overal Weight	lbs
Frictional Coefficent	N/A
Turning Radius	deg.
Yeild Strength	MPa
Projected Cost to Manufacture	$
Number of Standardised Parts	n
Saftey	Injuries/Lifetime
Number of Adjustable parts	n

2.3 Functional Decomposition

Initially breaking down the function of the Baja into a Decomposition Model allowed our team to highlight each function of the sub teams. This is shown in the figure below.

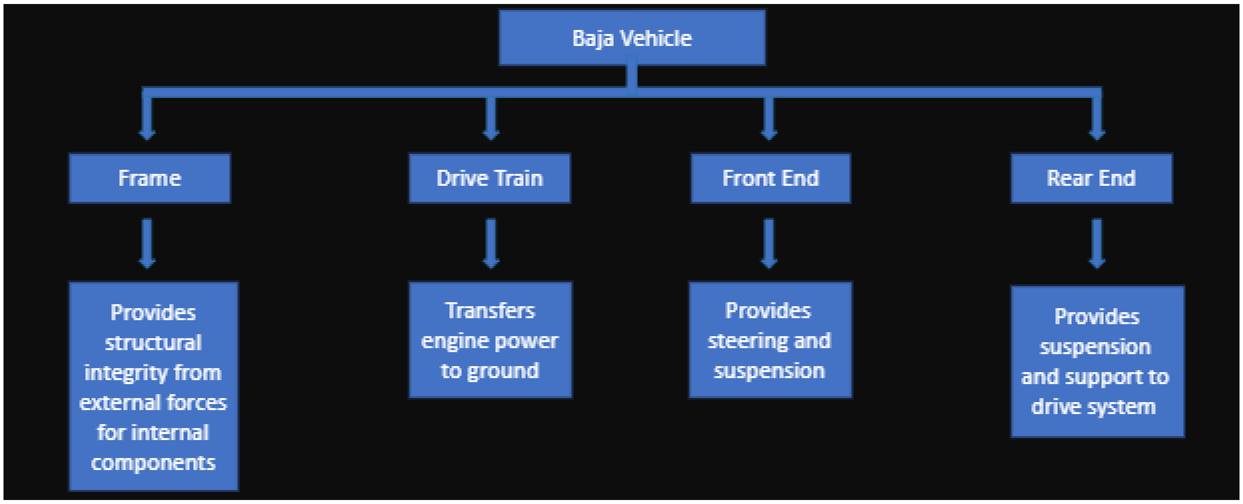


Figure 1: Baja Vehicle Decomposition Model

As shown in the figure above, each team will need to strive for optimum results for their specific performance requirement. The frame will need to run FEA analysis in order to ensure that the structural integrity of the material makeup will not fail when exposed to potential external forces. The drive train will desire to efficiently provide power to the four wheels of the vehicle with a gear box and four-wheel drive system. The front-end sub system will focus on the steering and suspension that will provide the necessary turning radius for the pathways of the competition. Furthermore, the rear end suspension will provide much of the support to the drive system and will need to ensure the least amount of shock to the rear internal drive train components.

2.3.1 Black Box Models

The Black Box Models created by each sub team will help simplify their tasks into the basic elements that make up the overall design. These Black Box models simplify the different inputs and outputs that make up each sub team goals. At the center of the Box is the function that each sub team is looking to maximize when creating their design. Understanding the purpose of each sub section allows the engineers working on this project to narrow their focus on what they need to improve on when creating their specific designs.

Rear End

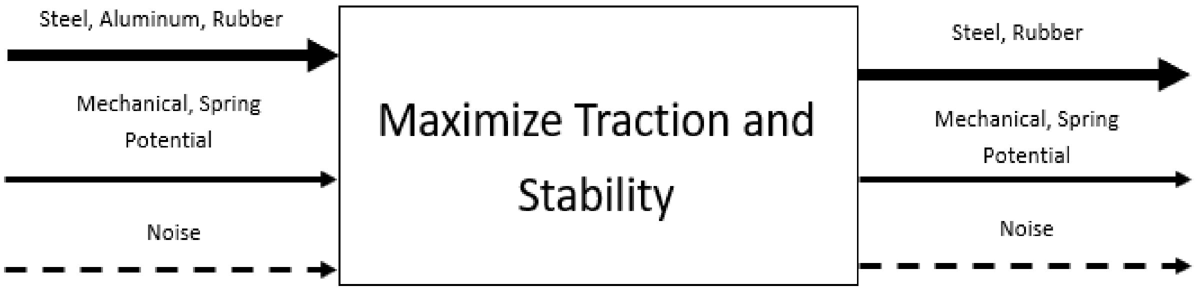


Figure 2: Rear End Black Box Model

Front End

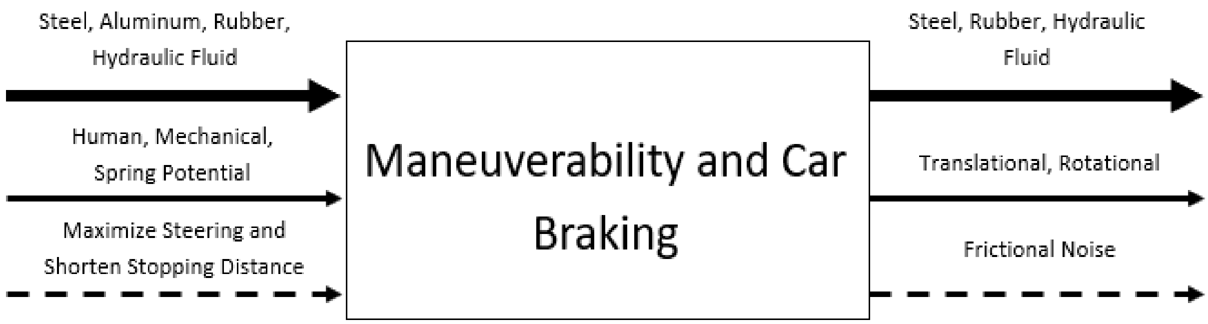


Figure 3: Front End Black Box Model

Drivetrain

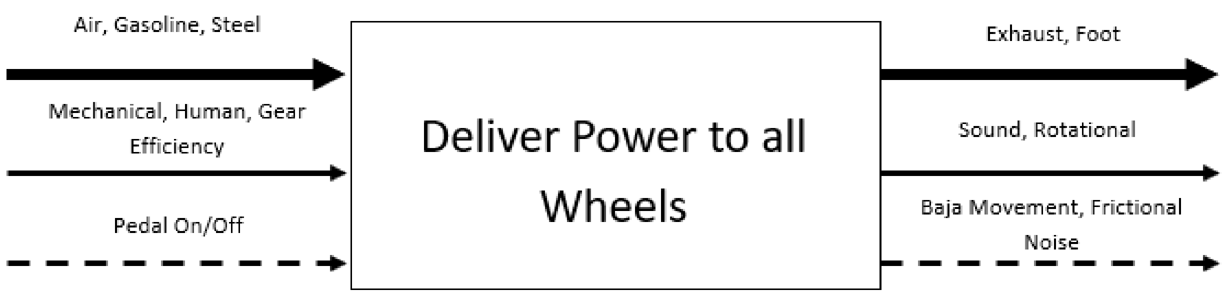


Figure 4: Drivetrain Black Box Model

Frame

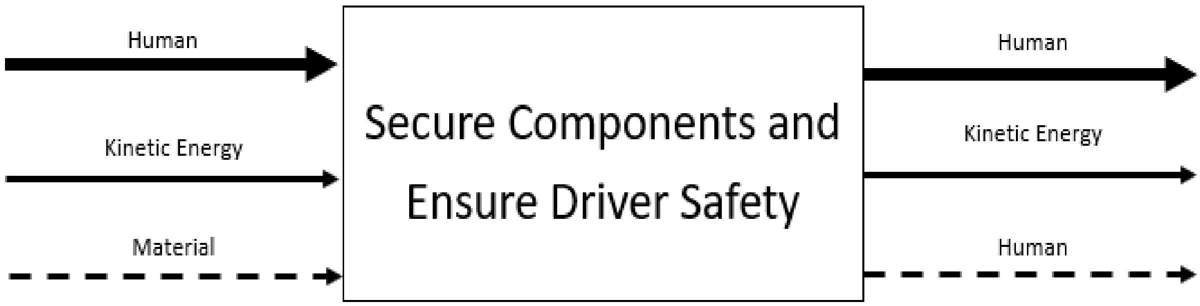


Figure 5: Frame Black Box Model

2.4 House of Quality (HoQ)

Furthering the design prosses, a house of quality is created and used to better understand which aspects of the overall Baja design important and what design aspects need to be greatly improved from previous years. The customer requirements where based off what a Baja vehicle needs to have to score well in the competition as well as to just pass the inspection for the competition. Then based off the customer requirements, the quantifiable engineering requirements where created. From the completed house of quality seen in Appendix A, the most important requirements the car needs to fulfill are as follows. Weight, meaning the car needs to be as light as possible. This is due to the power from the engine is limited to 10 horsepower across the competition and to perform well in the competition the power to weight ratio needs to be as high as possible. The next requirement is durability, this is so that throughout the competition the car will remain fully operational. The Baja car should also be easily manufacturable. This is because we will be manufacturing the car. The house of quality was also used to evaluate and benchmark previous Baja car designs at NAU. The past two cars that competed in competition where used, NAU car #44 and NAU car #52. Concluding the benchmarking section, it was determined that the worse overall performance from previous designs is maneuverability and comfort. These improvements and important engineering requirements will be utilized to create the best overall design possible.

2.5 Standards, Codes, and Regulations

The first engineering standard referenced for the Baja design project was ASTM A1103 which specifies the heat treatment of steel tubing after bending or welding operations. This will inform the team on how to preserve the mechanical properties of the steel tubing used in the construction of the frame. Because the frame team will need to bend and weld more than 20 joints, the frame might possibly need to be heat treated to maintain the strength of steel tubing. The ASTM standard specifically refers to automotive racing applications, which is applicable to the Baja team's loading cases.

A second engineering standard considered for use in the Baja capstone project is ASTM E556. The standard documents the calibration method for a torque transducer. The team will use this method to experimentally measure the wheel torque produced by the motor and gear reduction and compare it to the theoretical output. By implementing the standard, the team will be able to gather accurate data. Another useful standard is SAE J2525_200003 which documents the proper setup of a continuously variable transmission. This will be critical to setting up the Baja Gaged CVT for the vehicle. The team also plans to gather experimental data to find the optimum CVT parameters that will lead to highest acceleration. The standard will then be useful to compare to the experimental data to double check the data analysis.

The engineering standard ASTM A519 will be used when choosing the material for the frame. The ASTM standard gives specifications for chromoly tubing, which the frame team plans on using for tubing material. The material used will need to have the associated certifications in order to comply with the SAE rulebook, so it will be vital to purchase the correct tubing material for not only the frame but also the control arms.

Table 2: Standards of Practice as Applied to this Project

Standard Number or Code	Title of Standard	How it applies to Project
ASTM A1103 [1]	Standard Specification for Seamless Cold-Finished Carbon Steel Structural Frame Tubing for Automotive Racing Applications	The ASTM standard documents the proper heat treatment of carbon steel tube either bent or welded in automotive racing applications.
ASTM E556 [2]	Standard Test Method for Calibrating a Wheel Force or Torque Transducer Using a Calibration Platform (User Level)	A torque transducer can be used to experimentally measure the wheel torque output and compare it to the theoretical value. This will provide experimental data on power train losses.
SAE J2525_200003 [3]	SAE Design Guideline: Metal Belt Drive Continuously Variable Ratio (CVT) Automatic Transmissions	This standard will inform the team's design of the CVT system and help with CVT tuning parameters.
ASTM A519 [4]	Standard Specification for Seamless Carbon and Alloy Steel Mechanical Tubing	The chromoly tubing purchased must be of a standard quality to guarantee proper and dependable performance in the Baja frame application.

3 TESTING PROCEDURES (TPs)

3.1 Testing Procedure 1: Drop Test

3.1.1 Testing Procedure 2: Objective

This test applies maximum torsional strain on the drive train system. To execute this test the car will be lifted off the ground and the tires will be brought to full speed. While the wheels are being powered and tires have met full speed, the car is dropped to shock the system. This sudden change applies a worst-case scenario load on the axles, u-joints, shafts and gears.

3.1.2 Testing Procedure 1: Resources Required

The resources required for this test are the complete car and a mechanism to lift the car. Since the results of this test will be evaluated by visual inspection, instrumentation will not be needed.

3.1.3 Testing Procedure 1: Schedule

This test will be performed concluding the completion of the car. The completion of the car is planned to happen by March 1st.

3.2 Testing Procedure 2: Prototype Rear Half-Shaft

3.2.1 Testing Procedure 2: Objective

The rear end design features a new innovative upper link lower drive shaft design (ULDS) that utilizes the rear half shafts as a suspension component. This means the drive shaft will need to support the forces that a normal suspension arm will need to support all while still functioning as a drive shaft. To test the validity of this design we created a prototype half shaft that can be retro fitted to a previously built SAE Baja car, car #52.

3.2.2 Testing Procedure 2: Resources Required

As seen in Figure 6 is the manufactured prototype for the half-shaft design that was retrofitted to car #52. The car was then driven through normal operation. And visually inspected to see if the half shaft yielded in any way. The shaft was also inspected when the wheels where off the ground during operation to check for vibration.

Figure 6: Half Shaft Prototype

3.2.3 Testing Procedure 2: Schedule

This test was already performed, yet further testing will be done to other half shaft designs to validate FEA analysis.

4 DESIGN SELECTED – First Semester

Since the preliminary report, each of the sub-teams have made significant improvements to their originally proposed designs. To improve each sub-design, teams began to redesign parts in order to reduced weight without affecting the structural integrity. In these subsections, teams will introduce the changes they made to their design with supporting calculations and/or reference material. They will also explain the benefits of these changes and how they will make a substantial improvement to the previous design. With these subsections, each team will justify the improvements to the design and how it will improve our performance in the mini-Baja competition.

4.1 Design Description

4.1.1 Subsystem: Frame

The frame had been adjusted to accommodate for the designs provided from the other sub-teams, along with prioritizing the overall weight. Members have been added to allow for drivetrain to mount sprockets to for the chain drive on both the front and rear end of the vehicle. Collaborating with the rear end sub-team had provided a redesign of the rear cage. To align the shock mount member parallel with the ground, there was a needed side impact member (SIM) change to make the named point higher up along the roll hoop. Not only that, the rear cage width needed to increase in order for the rear shocks to be closer to perpendicular with the ground. There is an added gusset member that supports the shock mount point for the rear cage.

The structural integrity of the final frame design increased due to optimization of specific member locations. The FEA completed with the final frame shows that the maximum impulse forces due to a front collision, t-bone collision, and a drop test, succeed the integrity shown in Figures 7 and 8.

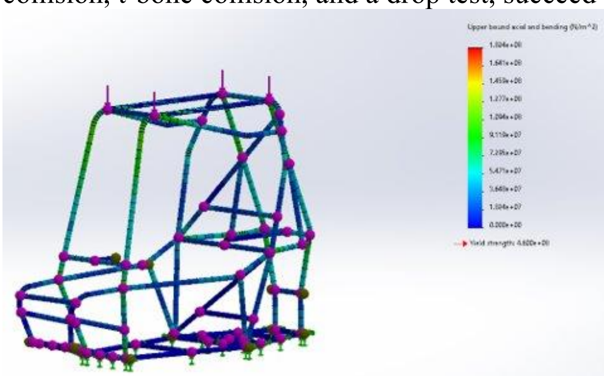


Figure 7: Drop Test

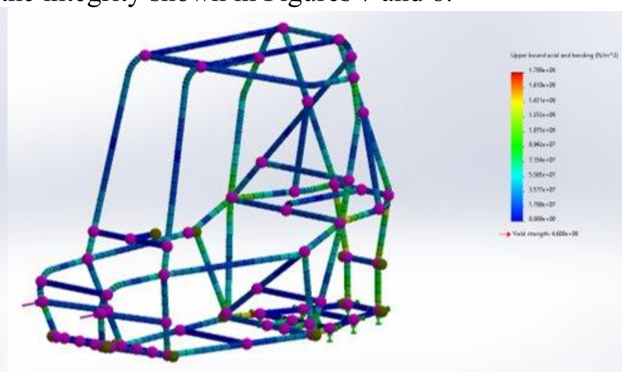


Figure 8: Front Collision

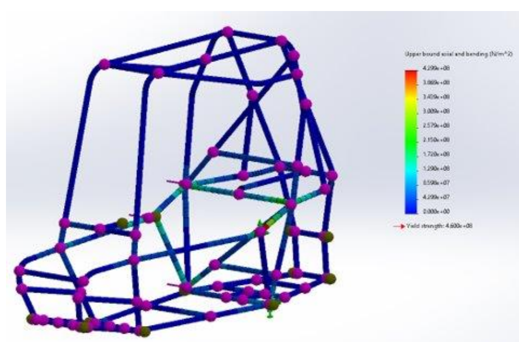


Figure 9: T-Bone Collision

Regarding the overall ergonomics of the final frame design still meet all of the requirements necessary to compete at competition. These requirements being that the Baja can comfortably seat both a male in the 95th percentile and a female in the 5th percentile. What this requirement causes us to account for is to make the Baja capable for most Americans. Other ergonomic requirements are making sure the members are at 6in away from the driver's head. This was difficult to determine in SolidWorks. However as of now we are still meeting this requirement and the ergonomics of the frame are good to go.

The pedals and seat were additional components that were designed on SolidWorks after the final redesign of the frame. The pedal was designed to connect directly to the brake system without additional mounting plates, but will most likely be redesigned to better fit within its space in the vehicle and to make it easier to manufacture. The seat mount was redesigned to accommodate for the chain drive system under the seat and to meet the under-seat member requirements in the 2021 Baja rulebook [10]. The seat itself was designed to fit on the seat mount and align with the firewall. The team also took comfort into account while creating the seat. The seat has a 78 degree back seat angle, where the angle is in reference to the back of the seat and the horizontal plane. The seat design is shown below in Figure 10.

Figure 10: Seat Design

The body panels had been designed using SolidWorks as to protect the driver from debris, following the requirements defined in the 2021 rulebook [10] by using carbon fiber. A skid plate had also been designed, also utilizing carbon fiber, covering the entire bottom of the cockpit, as to prevent debris from hitting the driver. This skid plate had also been carried out to block the drivetrain sub system, to prevent debris from damaging it. These carbon fiber components were designed to meet the same thickness as previous project years at NAU, which had provided a thickness of 0.04 inches. The body panels are shown within Figure 11, and the skid plate is shown in Figure 12 below.

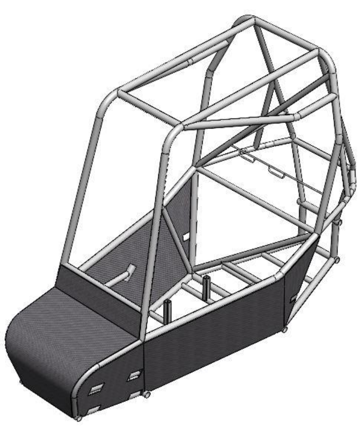


Figure 11: Body Panels

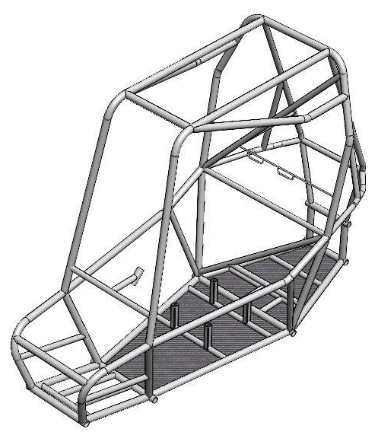


Figure 12: Skid Plate

The firewall had also been designed in SolidWorks, also following the rules that had been defined in the 2021 rulebook [10]. This had been designed to meet the minimum thickness requirement of 0.02 inches, made of 6061 aluminum. The minimum thickness had been used to minimize the weight of the vehicle. This includes an opening for the chain drive to run through, and two openings for the seat belt to be mounted to. The design for the fire wall is shown in figure *13.*

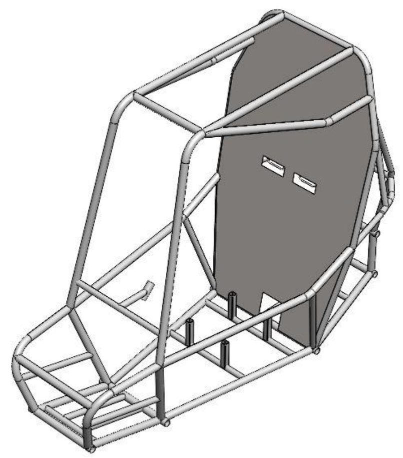


Figure 13: Firewall Design

4.1.2 Subsystem: Drive Train

4.1.2.1 Half Shafts

The original design for the u joint half shafts seen in the preliminary report were machined to be fitted to a previous year's car. This was purely for testing purposes allowing the team to examine if the design would be effective at transmitting power and acting as a suspension member. The prototype design was ineffective for these purposes, as the design would vibrate in rotation and was not stable enough to be used as a rear suspension member. This is because the dimensions of the u joint housings were not exact, allowing the u joint to slide within its housing. Upon further inspection it was clear that the u joint housings were bent, most likely from press fitting the u joints into the housings. To solve these issues the u joint housings were redesigned ensuring exact dimensions and utilizing a squared design to prevent bending, seen below in Figure 10.

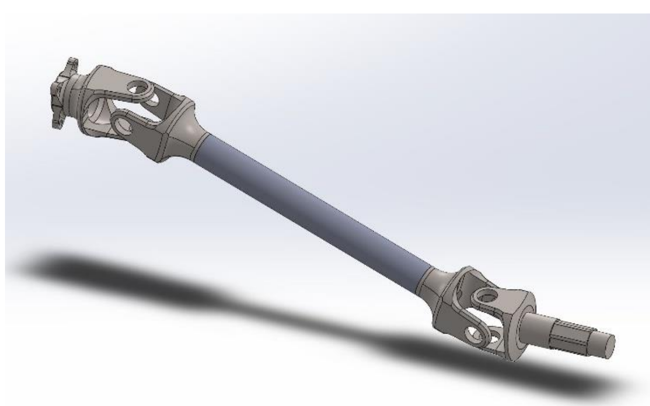


Figure 13: Half Shaft Design

The next element of the drive train's design is the chain drive system. The sprocket shafts will be mounted to the frame using pillow block bearing clamps that will be manufactured in-house

4.1.2.2 Chain Drive System

The final four-wheel drive systems that our team will implement is the chain drive system. As shown in the figure below, there will be a small sprocket on the rear output shaft, a large and small sprocket on the intermediate shaft, and a small sprocket on the front end shaft.

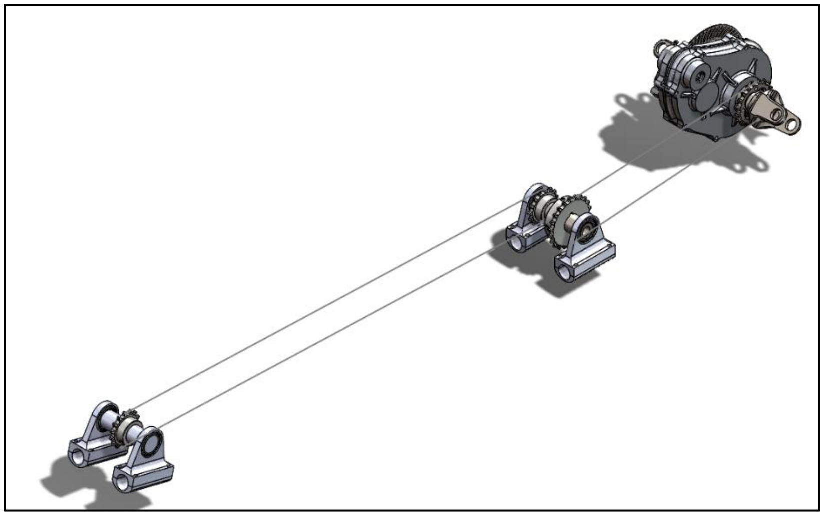


Figure 14: Chain Drive System

The sprockets will be mounted to the shafts using hubs, and the shafts will be mounted to the frame using pillow block bearings. These pillow block bearings will be clamped to the frame at adjustable locations which will allow the team to control the amount of tension within the chain. There will be one set of 420nZ3 chain going from the small, rear output shaft sprocket to the large, intermediate shaft sprocket. Then there will also be another 420nZ3 chain going from the small intermediate shaft sprocket to the front shaft sprocket. There are 19 teeth on the small output shaft sprockets, 24 teeth on the singular large sprocket, and 15 teeth on the front end system sprockets. This will provide a power ratio of 1.2:1. The chain from the intermediate shaft leading to the front shaft will be running underneath the seat of the driver up the centerline of the Baja vehicle. There will be a chain tensioner applied to the length of the chain between the intermediate shaft and the front end shaft in order to maintain tension in the chain. This will prevent too much slack from occurring within the chain drive system. The chain will be protected by a cylindrical tubing running through the center of the vehicle. This chain drive system will be primarily made of aluminum material in order to remain as light weight as possible while still maintaining the necessary strength to support the system. As a result, our vehicle will be able to meet the new four-wheel drive competition requirement in the 2021 SAE Baja competition.

4.1.2.3 Gear Reduction System

The gear reduction system can be seen in the figure below. The gears sizes and ratios were developed from the modal speed during the endurance competition. The strength of the gears was first developed using AGMA methods with the given 10HP motor by Briggs and Stratton. The gears were further evaluated using finite element analysis with the expected tangential loads. The material specified was 9310 a steel alloy commonly used in aerospace which is known to have good surface hardness (~60

Rockwell C) after treatment yet still have ductility to handle fatigue. The material is also relatively easy to machine at its pre-hardened state. The shafts were evaluated using techniques from machine design courses. A shaft was modeled and loaded using normal point forces and expected torque. To reduce inertial resistance shafts were bored to hollow their cross section. The material used for the shafts were 4340M which is an alloy steel that has properties to support the best strength to weight ratio.

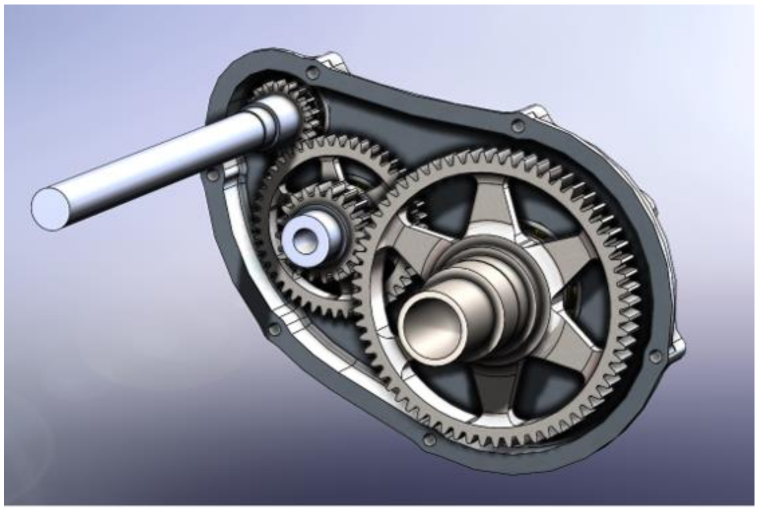


Figure 15: CAD Model of Gear Box with Cover Removed

4.1.3 Subsystem: Front End

4.1.3.1 Design Improvements: Steering Knuckle

Since the previous preliminary report, many improvements have been made to the steering knuckle to reduce its weight and increase its overall strength. After finding our ideal mounting locations from Shark, the Lotus suspension geometry software, the ball joint, and tie rod locations on the knuckle were moved to meet travel requirements. Next, the design of the tie rod mount on the knuckle was put in double shear and was shelled out to an 1/8 of an inch thick. By triangulating and shelling the tie rod mount we can increase the strength of the mount, which has been an issue in previous years, and limit the weight by having a thin part. This new mount style will be easier to manufacture in house and will be a basis for other improvements on the design. This concept will likely be incorporated on the upper ball joint mount to reduce the overall weight and to also center our ball joints over the major bore. By centering the ball joints over the bore, we will only have axial loads going through our design and not have a moment when cycling the loading. Lastly, we placed a waffle design between the mounting locations of the lower ball joints instead of the triangular cut outs. This design idea is much stronger, easier to manufacture and overall lighter than the previous cut outs.

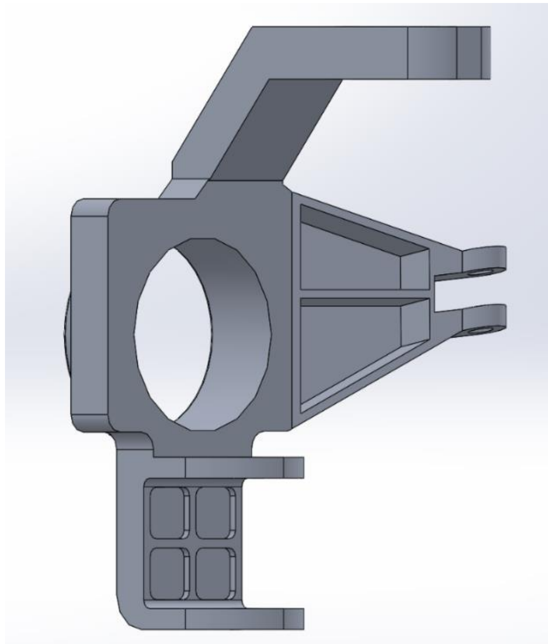


Figure 16: Front Knuckle Improvements

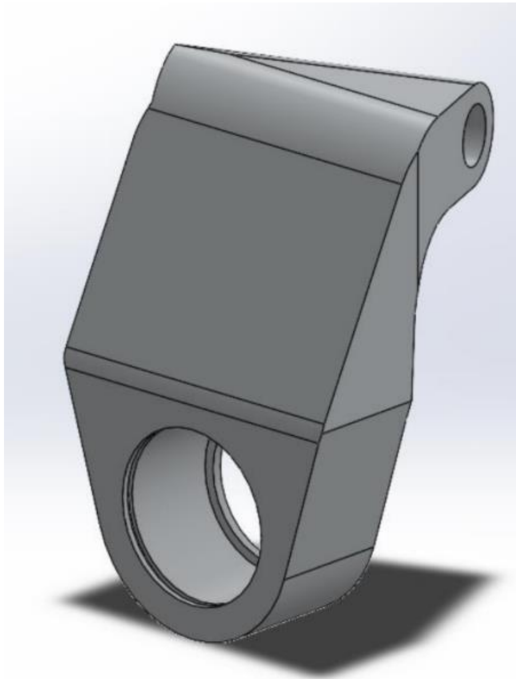
A large factor for the front-end team when making design changes was using LOTUS software to ensure selected components properly satisfied the suspension geometry. Some of the most challenging design criteria has been due to the placement of the steering rack as well as the tie rod because LOTUS would show a large increase in toe angle when the vehicle would experience a bump cycle. After many attempts working with the software and CAD models to ensure proper placement a desired location was found that would both optimize the suspension geometry throughout its travel as well as the vehicle body roll.

4.1.4 Subsystem: Rear End

4.1.4.1 Design Improvements: Rear Knuckle

Because of its integral role in the rear suspension system, the team has made several improvements to the rear knuckle design. These improvements involve the geometry, weight, and safety of the knuckle. The original knuckle design, shown in Figure 14 met the team's requirements, and properly held the geometry for the rear suspension. The design, however, weighed 2.56lbs. The team decided to reduce the part's weight while retaining a moderate factor of safety.

Using SolidWorks' FEA tools, the rear end team was able to iteratively remove material in strategic locations on the knuckle to reduce its overall weight without significantly affecting the part's factors of safety under critical load conditions. The final knuckle design weighs 1.15lbs; the team achieved a weight savings of 1.41bs, reducing the knuckle's weight by 55%. The final knuckle design is shown in Figure 15.



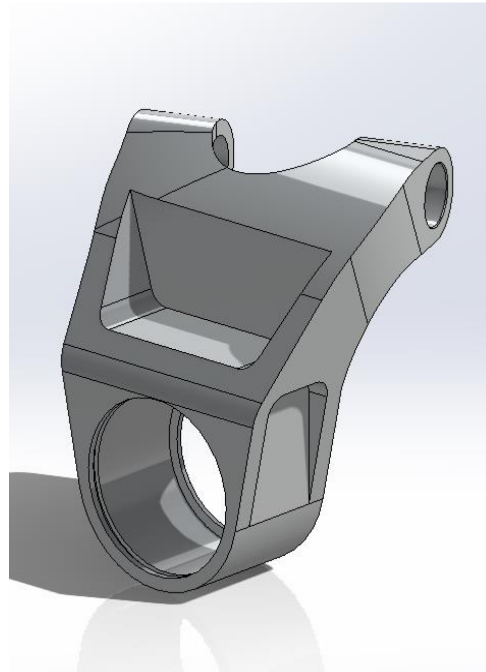


Figure 17: Preliminary Rear Knuckle Design *Figure 18: Final Rear Knuckle Design*

By reducing the weight of the knuckle, the team was able to reduce the rear suspension's un-sprung weight. Reducing un-sprung weight is important for reducing the suspension's inertia, which improves how quickly the suspension can react to changing terrain and traction conditions [30]. By greatly reducing the weight of the rear knuckles, the team has improved the main function of the rear suspension to maximize traction and effectively deliver power from the rear wheels to the ground.

5 IMPLEMENTATION PLAN

As a result of finalizing our drive train, frame, front end, and rear end systems, our team can begin implementing our Baja vehicle design. The components will be manufactured in house at building 98C this was a consideration in all our designs. The tools and equipment used will be a CNC 4-axis mill, manual lathes, manual mills, tubing bender, TIG welder, and tube notching tool. The only outsourced components will be 2D parts. The parts will be CNC laser cut at a company down in Tucson. This service will be donated in support of our limited budget.

5.1 Implementation Plan: Bill of Materials

The Bill of Materials shown below highlights the items needed for purchase, as well as their corresponding costs. The Gore Fund Budget provided to our team is $9,000, and the competition cost is $1,350. Based off of the Bill of Materials, the estimated cost of materials is approximately $5,400. There will be additional costs that need to be considered. These costs include travel, spare parts, and safety equipment. As a result of breaking down the frame, drive train, front end, and rear end assembly costs, the team can plan and anticipate the expenses that will occur when manufacturing begins.

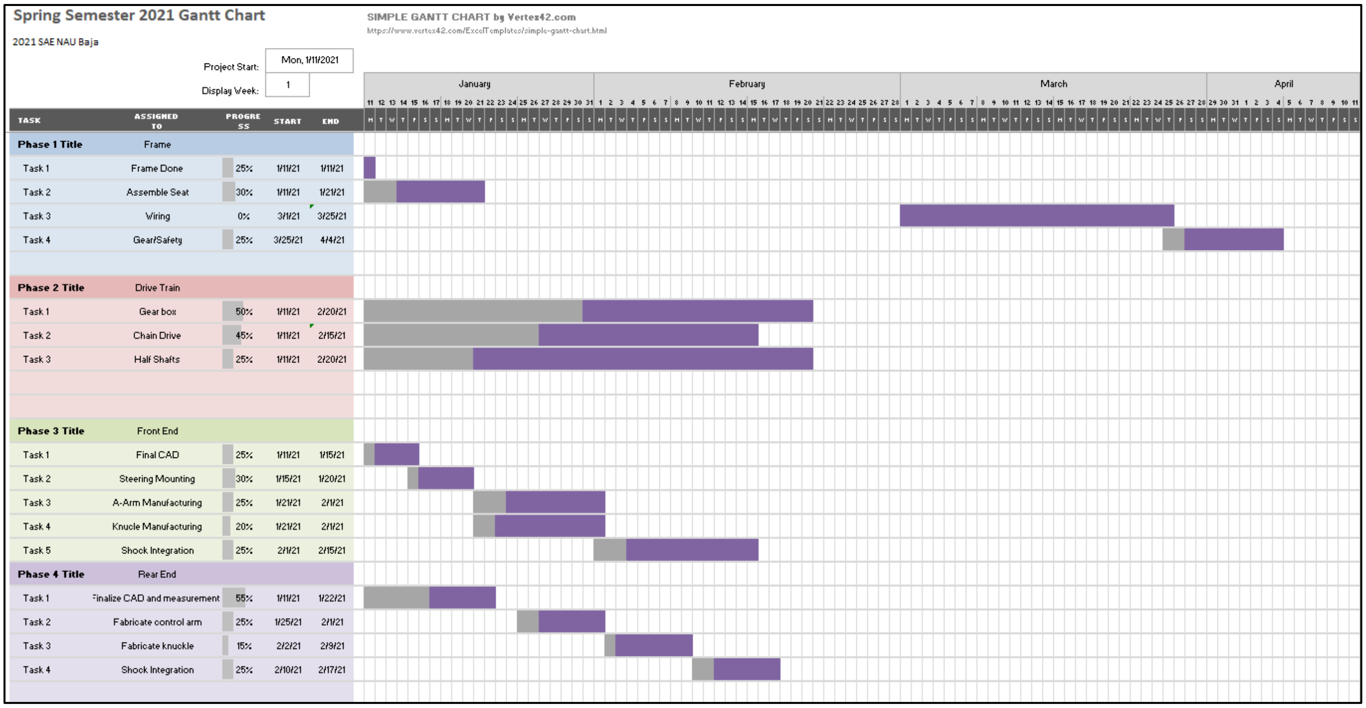
Table 3: Bill of Materials

Sub-Team	Item	Link(s) to item (if available)	Expected cost	Other details
	Round 1.25" OD x 0.065" Wall Tubing		Donated	4130 Steel
Frame	Firewall		$60.00	
	Fuel Tank (has to be one from link)	https://pyrotectstore.com/product/baja-sae	$265.00	
	Gear Material		$277.61	
	Front Half Shafts		$250.00	
	Gear Manufacturing		Donated	
	Gear Box material		Already have	
	Sprocket Material		Already have	
	Shaft Material		$400.00	
	Sprag Clutches		$1,200.00	
	Protective Gaurds		Donated	
	Material for chain tensioner		$100.00	
	Bearings		Donated	
Drivetrain	Chain		$120.00	
	Spherical Ball Joint	fkrodends.com	$15.00	
	Ball Joint Cup	fkrodends.com	$20.99	
	Oil Embedded Bronze Bushing		$1.65	
	4130 Chromoly Tubing (1" x 0.0625" x 10')		$50.00	
	JOES Jr Sprint/Jr Drag Steering Rack		$350.00	
	SKF 3306 A-2RS1TN9/MT33		$130.00	
	Wheels	rockymountainatv.com	$160.00	
	Tires	rockymountainatv.com	$80.00	
	Bushing Shoulder Bolt		Already have	
	Spherical Shoulder Bolt		$2.35	
	Spherical High Misalignment Spacers	fkrodends.com	$15.99	
	Nylon Nuts		$0.79	
	Tie Rod		$25.00	
	Steering Heim	fkrodends.com	$13.25	
	Lug Nuts		$1.05	
	Wheel Studs		$2.30	
	Shock Mount Hardware		$19.85	
	Shocks		$500.00	
	Hubs		$50.00	6061 Alum.
Front End	Steering Knuckle		$75.00	6061 Alum.
	Hoop arm		$100.00	1045 Steel
	Knuckle		$200.00	6061 Alum.
	Wheel Bearings		$60.00	
	Wheels	rockymountainatv.com	$160.00	
	Tires	rockymountainatv.com	$80.00	
	Wheel Bearing Clips		$6.00	
	Bushings Knuckle side		$40.00	
	Polyurethene Bushings Frame side		$40.00	
	Knuckle Bolts		$8.00	
	Frame side Bolts		$8.00	
	Avacado steel plates		$5.00	
	Shock Mounts		$5.00	
Rear End	Air shocks		$500.00	6061/7075 Alum
		Total:	$5,397.83	

5.2 Implementation Plan: Schedule

During the fall semester of 2020, the Baja team has maintained their design schedule. All sub systems have finalized their designs, and different parts have already begun the process of being ordered from the Bill of Materials. As a result, the team is prepared to follow the schedule provided in the Gantt chart below.

Table 4: Spring Semester 2021 Gantt Chart



The Gantt Chart highlights the individual deadlines for each sub-team. The frame team will be done with the body of the Baja vehicle by early January so that the team can begin testing the performance of the vehicle. The final touches of the frame will be done before the competition in March when finalizing wiring and safety equipment. The drive train team plans on completing the manufacturing and assembly of the gear box, chain drive, and half shafts by the end of February. The front end team anticipates completing the manufacturing and assembly of the steering mounting, A-Arm, knuckle, and shock integration by the end of February as well. The rear end team will also plan on completing their assembly for the control arm and knuckles at this time as well. As a result, the entire Baja and all the sub-components of the vehicle will be built and finished at the same time. Our team anticipates doing drive tests throughout the month of March leading up to the competition at the end of April.

6 CONCLUSIONS

At the conclusion of this semester, the team has developed a complete car in CAD including all subsystem components. The team looked at many other design concepts and used a combination of successful designs to build the final CAD design. The CAD models were analyzed using several engineering tools to ensure components would not fail due to the rigors of the competition. The design is challenging because all components must be optimized for best strength to weight ratio. This will allow the design to take full advantage of the 10hp that the engine outputs. The car must be light to compete with the successful universities. With all optimized designs completed in CAD, the manufacturing of these designs will begin next semester.

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OBJ

8 APPENDICES

8.1 Appendix A: House of Quality

System QFD

2020-2021 Baja
October 18, 2020

	Material Density ↓	Fatigue Life Cycles ↑	Overall Weight ↓	Frictional Coefficent ↑	Turning Radius ↓	Yield Strength ↑	Projected Cost to Manufacture ↓	Number of Standardized Parts ↑	Interior Volume ↑	Safety ↑	Number of Adjustable parts ↑
Material Density ↓											
Fatigue Life Cycles ↑	-										
Overall Weight ↓	+										
Frictional Coefficent ↑			-								
Turning Radius ↓			+	+							
Yield Strength ↑	-		-								
Projected Cost to Manufacture ↓			+			-					
Number of Standardized Parts ↑							+				
Interior Volume ↑			-								
Safety ↑		+		+	+	+			+		
Number of Adjustable parts ↑			-				+	+			

Legend	
A	Previous NAU Baja Car #52
B	Previous NAU Baja Car #44

Scale
3,6,9

Customer Needs	Customer Weights	Material Density ↓	Fatigue Life Cycles ↑	Overall Weight ↓	Frictional Coefficent ↑	Turning Radius ↓	Yield Strength ↑	Projected Cost to Manufacture ↓	Number of Standardized Parts ↑	Interior Volume ↑	Safety ↑	Number of Adjustable parts ↑	*1 Poor*	*2*	*3 Acceptable*	*4*	*5 Excellent*
		Technical Requirements											**Benchmarking**				
Cost Efficientcy	8%	9	6	6	3	6	6	9	9	3	6	6			AB		
Reliability	10%	9	9	6	3	6	9	6	9	3	9	3			B	A	
Lightweight	15%	9	6	9	3	3	3	0	3	6	3	3		B		A	
High Traction	5%	0	0	6	9	3	0	0	0	0	0	3				AB	
Maneuverability	10%	0	0	6	6	9	0	0	0	0	0	3			B	A	
Durability	15%	6	9	3	0	0	9	0	3	0	6	3			B		A
Manufacturablility	12%	0	0	6	0	0	3	9	9	0	0	3		A		B	
Easy to repair/adjust	10%	0	3	3	0	0	0	6	9	0	0	6			B	A	
Comfortable	3%	0	0	3	0	0	0	0	0	9	3	0		A	B		
Safe	10%	0	9	0	6	3	6	0	0	6	9	0			B	A	
Adjustibility	2%	0	0	6	3	6	3	6	9	3	0	9				AB	

	Material Density ↓	Fatigue Life Cycles ↑	Overall Weight ↓	Frictional Coefficent ↑	Turning Radius ↓	Yield Strength ↑	Projected Cost to Manufacture ↓	Number of Standardized Parts ↑	Interior Volume ↑	Safety ↑	Number of Adjustable parts ↑
Technical Requirement Units	kg/M^3	Cycles	Pounds	Coefficent of Firction	feet	Psi	Dollars	# of Parts	Square Feet	Lifetime(hours)	# of Parts
Technical Requirement Targets	2.810-7.87	> 4 hours of continuous use	<400	>2	<8	4-6	<9000	40	25	4+	20
Absolute Technical Importance	3.87	4.83	5.01	2.7	3	4.2	3.12	4.68	2.37	3.72	3.27
Relative Technical Importance	9%	12%	12%	7%	7%	10%	8%	11%	6%	9%	8%