SAE Mini Baja: Suspension and Steering

By

Benjamin Bastidos, Victor Cabilan, Jeramie Goodwin, William Mitchell, Eli Wexler

Team 19

Final Project Proposal

Document

Submitted towards partial fulfillment of the requirements for

Mechanical Engineering Design II – Spring 2014

Department of Mechanical Engineering

Northern Arizona University

Flagstaff, AZ 86011

Memorandum

To: Dr. John Tester

From: Team 19; SAE Mini Baja Suspension Design Team; Benjamin Bastidos, Victor Cabilan, Jeramie Goodwin, William Mitchell, Eli Wexler

Date: 5/2/2014

Subject: Final Suspension & Steering Design and Testing

The SAE Mini Baja design challenge tests teams to design every component for a competitive vehicle in a rough, off road environment. The originally very large team split into three smaller teams, each in charge of designing the frame, suspension/steering or drivetrain for the vehicle. This memo is regarding the suspension and steering design aspect of the vehicle as well as the expected cost of the suspension components.

Final Design

The final concepts that have been selected for the suspension design follow the main objectives of being light, durable while also remaining as cheap as possible. The front suspension follows a simple double a-arm design while the rear suspension is a 3-link, semi-trailing arm with links. Material choice is planned to be made from AISI 4130 Steel following the frame team and their choice to use the same material with an increased thickness of 0.095”. The final concept for the steering is an off the shelf rack and pinion, with tie rods made of solid 1” AISI 4130 rod with threaded heim joints.

Prototype & Testing

The prototype, shown throughout the following report, performed well throughout competition. All suspension members and steering components performed as expected and did not fail despite the very rugged course laid out by the SAE Mini Baja colligate competition. The only problems that arose during testing is that the outside wheel does push and create understeer when the steering is at full lock. Other than some slight understeer though, the suspension and steering systems both performed flawlessly.

Sincerely, Team 19

Abstract

SAE Baja Collegiate Design competition is a nationwide competition in which students teams from many universities compete in a series of events designed to test the Baja vehicle to its limits. Student teams must engineer and build a single seat off-road vehicle. It must be able to traverse rugged terrain like rough roads or steep hills while offering the upmost level of safety for the occupant. A group of 15 students from NAU is participating in this competition at University of Texas, El Paso in late April. Three five person teams have designed the frame, drivetrain, and suspension. Our team is responsible for the vehicle's suspension and steering design and analysis. The suspension and steering systems allow the vehicle to be able to maneuver over and around obstacles while reducing shock and fatigue on the driver and essential components of the vehicle.

This report will also present the teams final designs and fabricated suspension and steering components. The SAE Mini Baja Collegiate Design Competition was used as the main testing ground where the vehicle was pushed to its limits, the results from this competition will also be presented in this report.

Table of Contents

Chapter 1: Introduction 4
1.1 Project Overview 4
Chapter 2: Problem Formulation 4
2.1 Project Need Statement 4
2.2 Project Goals 5
2.3 Operating Environment and QFD 5
Table 1.1 - Steering Quality Function Deployment 5
Table 1.2 - Suspension Quality Function Deployment 6
Chapter 3: Proposed Design 6
3.1 - Front Suspension 6
Figure 3.1 - New bottom control arm 7
Figure 3.2 - New upper control arm 7
3.2 - Rear Suspension 7
Figure 3.3 - Rectangular tubing trailing arm 8
Figure 3.4 - Trailing arm V3 8
Figure 3.5 – Trailing arm V3 (top view) 9
Figure 3.6 – Trailing arm V4 (top view) 9

Figure 3.7 – Trailing arm V4 9
Figure 3.8 - Trailing arm V5 10
Figure 3.9 - Suspension plate 10
3.3 Steering 10
Figure 3.10 - Schematic of steering system 11
Figure 3.11 - Rack and pinion mounting 12
Chapter 4: Prototype Fabrication 12
4.1 Rear Suspension 12
Figure 4.1 - Trailing arm members 13
Figure 4.2- CNC cutout of the rear suspension plate 13
Figure 4.3 - Trailing arm assemblies 14
Figure 4.4 - Final rear end assembly 14
4.2 Front Suspension 15
Figure 4.5 - Front suspension/frame assembly 15
4.3 Steering Fabrication 15
Figure 4.6 - Steering rack and plate assembly 16
Chapter 5: Testing and Results 16
Figure 5.1 -Aluminum box tubing tie rod support 16
Chapter 6: Cost Analysis 17
Table 6.1 - Steering cost report 17
Table 6.2 - Suspension cost report 18
Figure 6.1 - Total production vehicle cost estimate 19
Chapter 7: Conclusion 19
References 20
Appendix A: Engineering Drawings 20
Appendix Figure 1A - Front suspension uniball design 21
Appendix Figure 2A - Front suspension frame mounting bracket 22
Appendix Figure 3A - Front suspension Mini Baja knuckle 23
Appendix Figure 4A - Upper a-arm member 24
Appendix Figure 5A - Lower a-arm member 25
Appendix Figure 6A - Front a-arm assembly 26

Appendix Figure 7A - Trailing arm members 27
Appendix Figure 8A - Rear upright, hub plate 28
Appendix B: Finished Vehicle, Competition, Failure 28
Figure 1B - Complete (and clean) Mini Baja 29
Figure 2B - Endurance race starting lineup front 29
Figure 4C - Completed car post-competition 30
Figure 5C - Broken engine mount 31
Figure 6C - Old CVT belt (what's left of it) vs. new CVT belt right side 31

Chapter 1: Introduction

1.1 Project Overview

The Society of Automotive Engineers International (SAE) has contracted the Northern Arizona University (NAU) chapter to design and build a Mini Baja vehicle for competition use. The stakeholders for the project are Dr. John Tester and SAE NAU. SAE is a United States based organization that sets international standards for the automotive, aerospace, and commercial vehicle industries. The Mini Baja competition is one of many collegiate competitions sponsored by SAE, it is designed to challenge each team in the design, planning, and manufacturing process involved in the production of small, consumer based off-road vehicles. The competition itself consists of several different disciplines to test speed and maneuverability as well as endurance racing. The suspension and steering team has been assigned to design effective and efficient systems to support and maneuver the vehicle during competition.

The team performed extensive research in the personal off-road vehicle market looking for market trends in suspension and steering design. The team not only used larger companies such as Polaris, Arctic Cat, and others, but also previous years competitors to get inspiration for which design path to take. Ultimately the team decided to go with a simple, and very common suspension designs as well as steering.

Chapter 2: Problem Formulation

2.1 Project Need Statement

The Northern Arizona University chapter has not won an event at the SAE Mini Baja competition in years. The competition consists of several events that the vehicle must be able to handle each one effectively. These events include the Presentation, Hill Climb, Endurance, and Acceleration tests. The team must make a sales presentation to a panel of judges on the marketability of the vehicle and therefore must be aesthetically pleasing.

2.2 Project Goals

The goal of the suspension and steering team is to design efficient, strong, and easily manufactured systems of each system. Having a vehicle that is both maneuverable and capable of handling rough terrain is key for victory at the 2014 SAE Mini Baja competition. To achieve this goal the team will design suspension members with the strongest materials that are easily machineable while still maintaining relative low weight and adhering to all safety regulations. The steering system will be designed with an adequate turning radius to stay competitive in the maneuverability event. Once the frame is completed, construction on the front suspension, rear suspension, and steering systems will be built and installed.

2.3 Operating Environment and QFD

Multiple suspension components were analyzed to produce an improved front and rear system. The front suspension will consist of an independent front a-arms and the rear will consist of a 3-link trailing arm design. The decision was conducted on the fact that a-arm suspension is generally used for the front because the geometry keeps the camber on the wheels static and this is an adequate suspension to have for handling rugged terrain. The steering is kept simple by using a rack and pinion design with 180 degrees of freedom on the steering wheel for quick response from the driver. The operating environment of the competition is in El Paso Texas where there will be four tests for the vehicle to traverse. The tests will consist of a brake test, acceleration test, a hill climb, maneuverability test, suspension and traction test, and finally a four hour endurance race which will push the vehicle to its limits. The suspension design is very crucial for all absorbing large and small impacts and reducing the amount of shock transferred to the driver and crucial components. *Tables 1.1* and *1.2* show the teams QFD charts for choosing the final suspensions and steering designs.

Table 1.1 - Steering Quality Function Deployment

Engineering Requirements for given design								
Customer Needs	**Weight**	**Y.S.**	**Caster Angle**	**Ackerman Angle**	**Turning Radius**	**Cost**	**Bolt Shear**	**Width**
1. Lightweight	10					3	1	
2. Maneuverability	10		9	9	9			9
3. Relatively inexpensive	6	9				9	3	
4. Stable/safe	9		9	9	3			9
5. Must be durable	8	9				9	3	

6. Transportable	8				3			3
	Raw score	126	171	171	141	156	52	195
	Relative Weight	12%	17%	17%	14%	15%	5%	19%
	Unit of Measure	psi	degrees	degrees	ft	$	psi	lb

Table 1.2 - Suspension Quality Function Deployment

Engineering Requirements for given design								
Customer Needs	**Weight**	**Ground Clearance**	**Suspension Travel**	**Y.S.**	**Stiffness**	**Spring Rate**	**Cost**	**Weight**
1. Lightweight	10					3	3	9
2. Maneuverability	10	9	9		3	9	3	9
3.Relatively inexpensive	6		1				9	
4. Must be safe	7	3	1	9	3		1	
5. Must be durable	8			9	9		3	
6. Transportable	8	3	3					3
	Raw score	135	127	135	123	120	145	204
	Rel. Weight	14%	13%	14%	12%	12%	15%	21%
	Units	in	in	in	lb	lb/in	$	ft

Chapter 3: Proposed Design

3.1 - Front Suspension

The front a-arms were modified in several ways. The old design used a uniball system that is more appropriate for heavier applications like trucks. In addition to being heavier it would also have been much more difficult to fabricate.

The new design is lighter and easier to fabricate. It will use male Heim joints with studs to attach the a-arms to the hub. The new design also angles the end of the A-arms up to match the angle of the mounting points of the hub. This will increase ground clearance and provide smoother articulation.

The mounts from the frame to the A-arms have also been redesigned. Instead of facing outwards they are now aligned vertically with the frame. This allows us the same amount of travel but narrows the track width by a few inches.

Our final design change was to switch the mounting of the shock from the lower A-arm to the upper a-arm. This change was done to provide clearance to the tie rod for the steering.

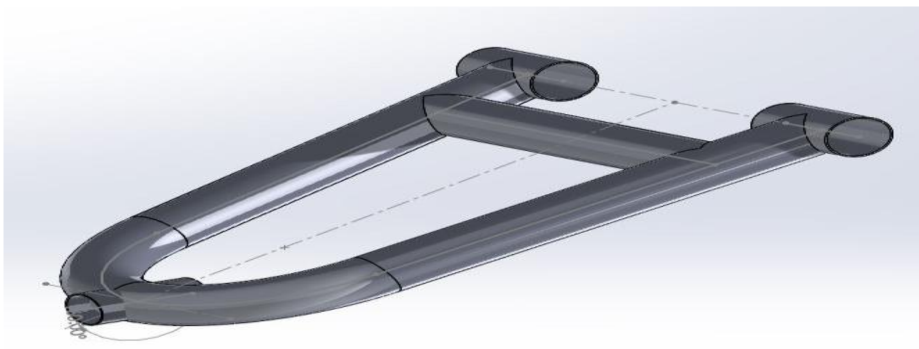


Figure 3.1 - New bottom control arm

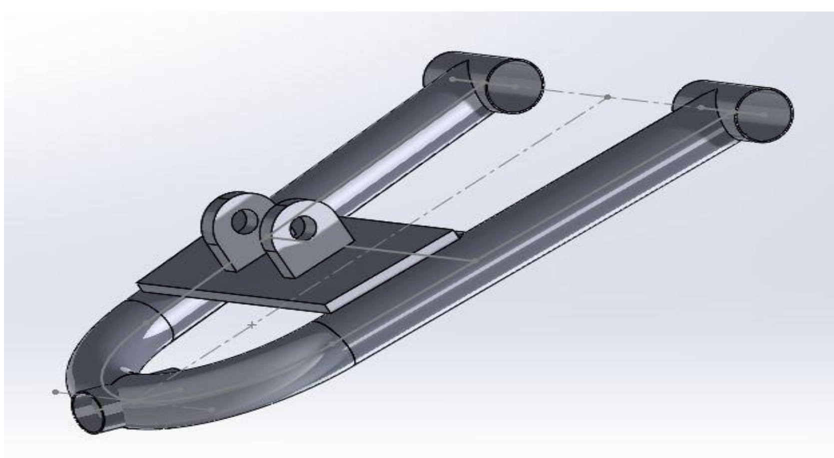


Figure 3.2 - New upper control arm

3.2 - Rear Suspension

The rear suspension design for the Mini Baja vehicle was one of the main concerns for the team. The rear suspension system has gone through many iterations with varying materials, geometry, and tubing selection. The Baja team received advice from 316 Motorworks, a local Rally America race team and fabrication shop located in Flagstaff, Arizona, which inevitably lead to the final design for the rear suspension system.

The first major design change was to switch to a rectangular or square tubing selection for the body of the rear trailing arm, shown in *Figure 3.3.*

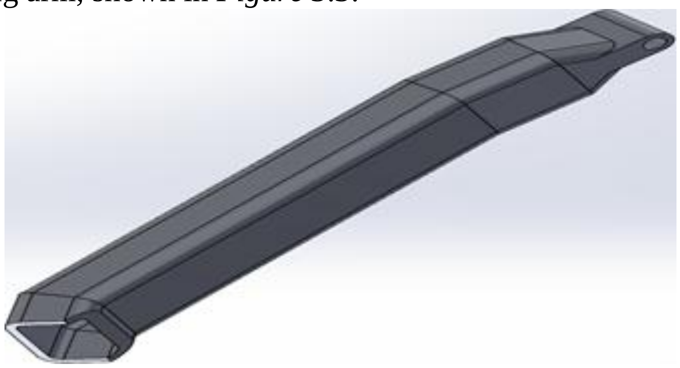


Figure 3.3 - Rectangular tubing trailing arm

This design proved difficult to not only machine, but fit to the frame without interference. Without the capability of bending rectangular tubing, the trailing arm would need to be cut, folded, and gusseted to achieve the desired length, angle, and strength needed for this application. This method did not seem beneficial to the team's goal for a light, strong, and simple rear suspension design.

The updated rear trailing arm design uses 4130 1.25in OD with a .0625in wall thickness round tubing. *Figure 3.4* shows the updated trailing arm assembly without the rod end frame mount. *Figure 3.5* shows the top view of the trailing arm.

Figure 3.4 - Trailing arm V3

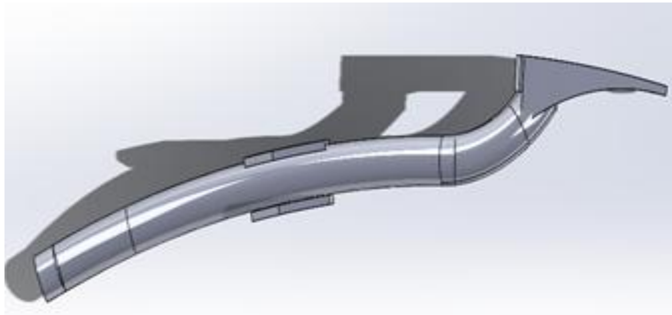


Figure 3.5 – Trailing arm V3 (top view)

The redesigned trailing arm is one of three possible final designs chosen by the Mini Baja Team. Because of the limitations the available tools at the Northern Arizona University machine shop, the radical bends in the vertical and horizontal directions this design seemed improbable to build even with the guidance and tools available at 316 Motorworks.
The following designs are based off of the same platform designed by the SAE Mini Baja team captain Chris Bennett. Both the fourth and fifth trailing arm design uses 1.25in OD 4130 tubing with a wall thickness of 0.0625in. The tools available at the Northern Arizona machine shop limit each bend to about 4.5in minimum.

The fourth iteration of the trailing arm would be connected to the frame by nuts, bolts, and bushings through the end piece shown on the left end of the member.
The steel plate shown in *Figure 3.6* is a SolidWorks mock-up and will not be used in the final design due to its complexity.

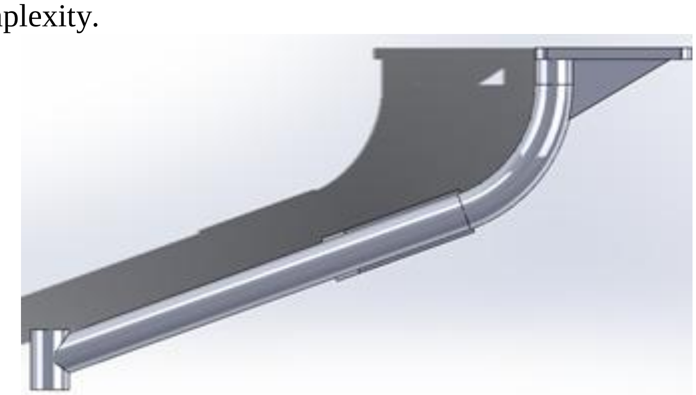


Figure 3.6 – Trailing arm V4 (top view)

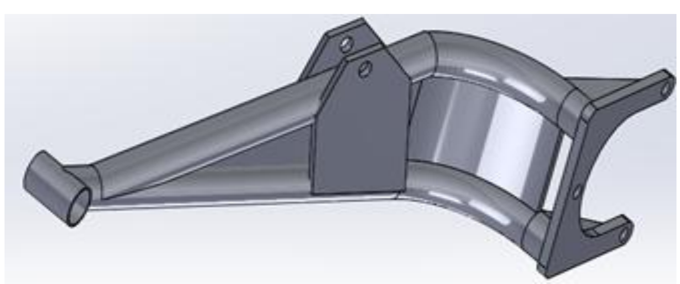


Figure 3.7 – Trailing arm V4

The final design consideration, shown in *Figure 3.8*, follows the same template as the previous design with a few modifications. The first modification can be seen in the top tube of the trailing arm. The straight tube was replaced with a gradually curving member for added structural strength. This design modification was suggested by the fabricators at 316 Motorworks.
The second design modification can be seen at the far left end of the trailing arm member. The laterally fixed end shown in the previous model changed to a rod end mounting system. The rod end allowed for better articulation and added flexibility to the system. *Figure 3.9* shows the final suspension plate design.

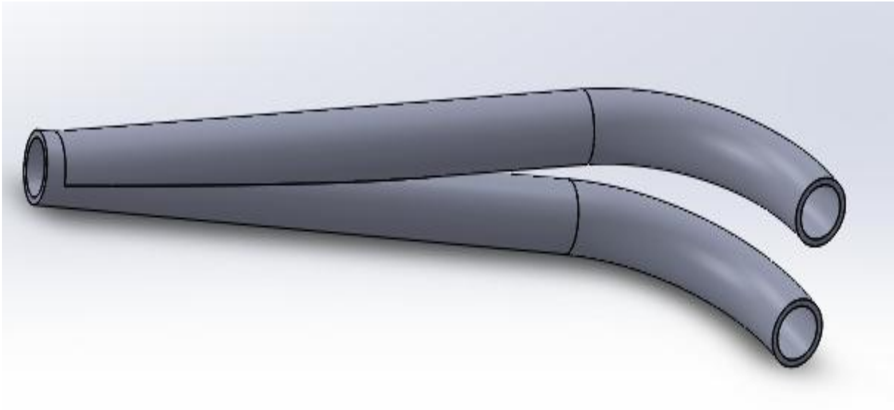


Figure 3.8 - Trailing arm V5

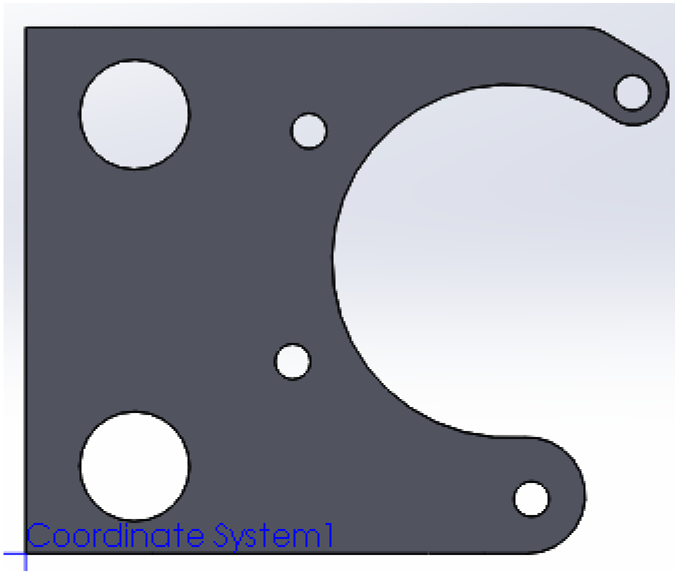


Figure 3.9 - Suspension plate

3.3 Steering

Selection for steering components are not so much toward the parts that are selected for use in the Baja vehicle but towards the placement of each of the components to complete the visual and mathematical geometry for the steering system for the calculation of the steering radius. The rack mount point went through various modifications for an optimal design.

The first design started with one additional bar added to the top with a plate hanging off 90 degrees to the vertical ground, however a bar with a plate would not be strong enough to take the push and pull of the tie rods, so more support would be needed. One modification made to this design was the addition of two additional bars; one that connects the left and right upper A-Arm mount beam and one that connects the left and right lower a-arm mount beams. Both additional beams will be horizontal to each other with respect to the natural 10 degree rake that the front of the frame has. This design caused a weight issue considering that adding two more support bars in the front would add more weight, than if the team were to use angle iron or used a design that could utilize only one more support bar. Another disadvantage of this design was that the rack would point the pinion vertically into the driver's quarters resulting in an extreme angle at the universal joint

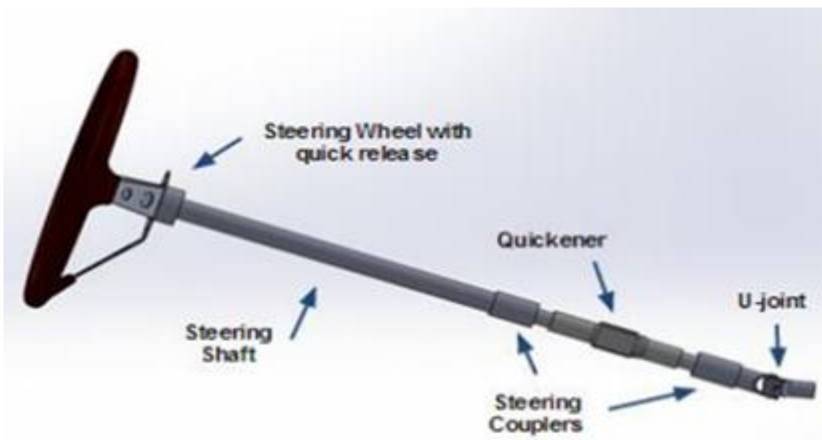


Figure 3.10 - Schematic of steering system

The second design consisted of one bar connecting the two top a-arms with a plate that connects the additional bar to an additional bar that would be located in the lower corner of the driver's quarters. This can be seen in *Figure 3.11*. This design utilizes the structural members that already exist and will lower the amount of weight added to the vehicle. The original design had the rack mounted to the front of the plate shown in *Figure 3.11***.** An additional hole would have to be machined so that the pinion would point outward from the mounting plate towards the driver's quarters.

Figure 3.11 - Rack and pinion mounting

This mounting orientation, with the additional steering column hole, would have caused a problem with the strength and the adjustability of the rack mount. An additional change was made so that the rack mounted on the top of the plate to eliminate the need for the additional hole in the mount plate. The rack would also be adjustable to the left or the right of the mount for steering alignment.

After mounting the rack in the previously stated orientation, the team was able to see that very little room was left for the braking components. In addition, because of the angle of the mounting plate, when the u-joint was connected to the rack it experienced an extreme angle which prevented it from rotation and preventing the u-joint from functioning properly. This was fixed by using a bit thicker mounting plate and mounting the rack on the back side of the mounting plate. This way, even though a hole needed to be cut out for the steering column, a thicker mounting plate would keep the mounting plate structurally sound. In addition by mounting the rack on the back side of the mounting plate, the team was able to reduce the angle experienced by the u-joint.

Chapter 4: Prototype Fabrication

4.1 Rear Suspension

The fabrication process for the suspension and steering sections of the vehicle started early during Spring Break and was slow from the start. The a-arms and trailing arm members used the same 4130 steel as the frame with a 1.25" outer diameter and 0.065" wall thickness. As previously stated the tubing wall thickness was changed to 0.095" for add strength and durability. After the tubing choice was made construction on the final suspension components began.

The rear trailing arms were made of two 21" long pieces of 4130 chromolly steel bent at a 4.5" radius approximately 85 degrees form the horizontal body. *Figure 4.1* shows the two bent pieces of steel.

Figure 4.1 - Trailing arm members

Once the main body of the training arms were cut to the appropriate 17" length the other components were fabricated by the team. The second component for the rear suspension was the suspension plate which would ultimately bolt of to the Polaris RZR XP 900 bearing carrier during finale assembly. This specific part was one of the most difficult to machine on the smaller in shop Tormach CNC machines because of its mild steel composition, small arcing turns, and 0.25" thickness. Milling bits were consumed at a high rate during the machining process, but the suspension plate shown in *Figure 4.2* was completed for the left and right trailing arms. The initial design had the ends of the 85 degree pipe sections welded to the back side of the plate. This was created a weaker bond do to the smaller welding area, the team decided to add two 1.25" holes on the left side of the plate. These added holes increased the welding surface area and therefore increased strength in the final product.

Figure 4.2- CNC cutout of the rear suspension plate

The next step was to weld the plate to the trailing arm members shown in the left image *Figure 4.3*. All of the welding on the rear suspension used TIG welding for deeper penetration and stronger welds. The right side of *Figure 4.3* is the fully assembled trailing arm. The team welded solid slugs with threads into the far left end for rigidity and a mounting point for the rod ends. The RZR XP 900 bearing carrier is bolted to the plate as shown on the far right of the trailing arm.

Figure 4.3 - Trailing arm assemblies

With the trailing arms assembled, the next step was to bolt it on the frame with the massive 3/4" bolts. The team ran into some articulation problems with the radius rods and shortened half shafts. The trailing arm was not getting full travel due to the radius rods being too long. This issue was solved by shortening the radius rods and adding 3/8" rod ends for better articulation and adjustability. Secondly the radius rods and shortened half shafts were adjusted to be parallel at ride height, full extension, and full compression. The final rear end assembly is shown in *Figure 4.4*.

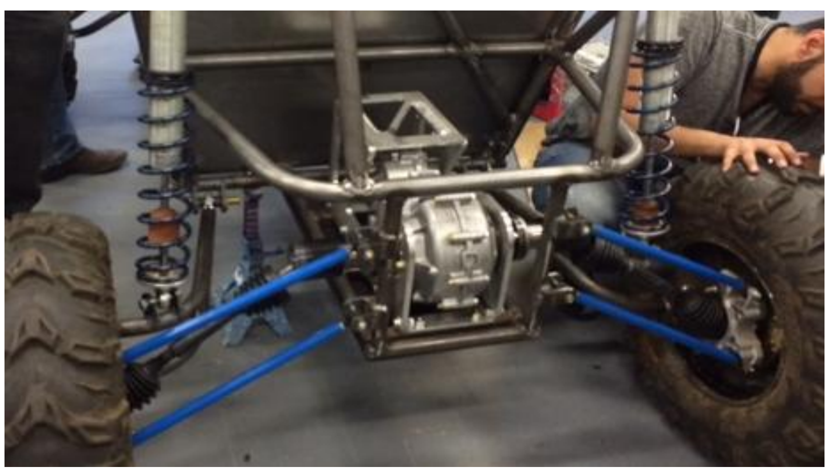


Figure 4.4 - Final rear end assembly

4.2 Front Suspension

Fabricating the front a-arms required several small, but very important details, first there is a small angle on the knuckles we used, meaning we needed to have a 20 degree upward rake where the a-arms attach to the knuckles. The upward rake on the a-arms adds significant complexity to the fabrication process, notching the tubing to accept the upward rake is a time consuming process that required a lot of precision in order to get the exact same angle on all four control arms. The design also called for a large amount of adjustability, and in order to do this the rod ends used to attach to the frame and steering knuckle needed to be threaded into the control arms. In order to thread the control arms, several slugs were made up and tapped in the lathe in the NAU machine shop and then later welded into each opening in the control arms. The only major redesign needed in the fabrication process was the choice to move away from the frame tubing into a much thicker wall thickness while keeping the same diameter tubing, the frame used a 0.065” wall thickness and all suspension members use a 0.095” wall thickness which substantially strengthened all components at the cost of weight. The final front suspension/frame assembly is shown in.

Figure 4.5 - Front suspension/frame assembly

4.3 Steering Fabrication

The fabrication process of steering system for the mini Baja was completed using many off the shelf parts. The 14" rack and pinion purchased from Desert Karts was too short for to meet the teams needs. To answer this problem, threaded steel extensions were made to meet the desired steering geometry; the final length of the rack and pinion with the extensions was 20" long. The rack was then bolted to a 0.25" mild steel plate which would later be welded onto the frame. This thick steel plate added much needed rigidity and strength to the steering system. The steering rack with extensions and plate are shown in *Figure 4.5*.

Figure 4.6 - Steering rack and plate assembly

The steering system did not run into any more problems during fabrication other than waiting for essential parts to be shipped by the team's supplier. Problems arose when initial testing began; the problems faced and solution to the problem will be explained in Chapter 5.

Chapter 5: Testing and Results

The vehicle was tested both in the desert of Phoenix, AZ and in the forest located behind Northern Arizona University in Flagstaff, AZ. It was during the testing session in Phoenix, AZ that the tie rod extension broke and a new design was quickly adapted after consulting with a local off road shop, Geiser Bros. Design & Development.

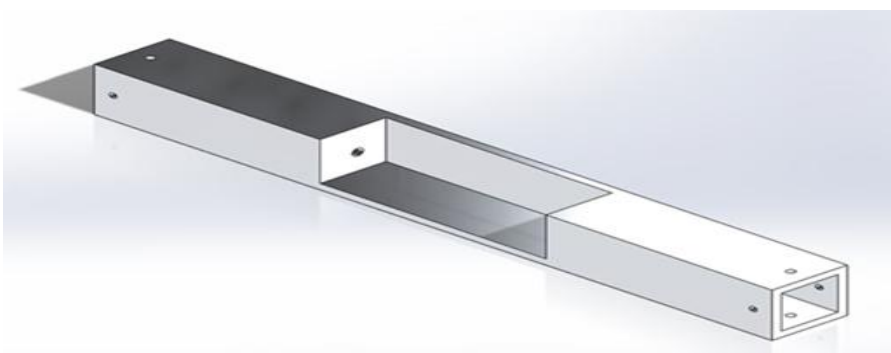


Figure 5.1 -Aluminum box tubing tie rod support

After the new tie rod extension and bracing was implemented, no other issues arose during the testing in Flagstaff, AZ. Although steering components broke during testing, the suspension system performed without issue throughout testing and even weathered the grueling tests thrown at the vehicle in El Paso, TX. The alterations made to the steering system make it satisfy all objectives, including the substantially decreased turning radius from the last mini Baja vehicle that NAU produced. The suspension system did perform very well in both competition and testing, and required no modifications to satisfy all objectives for the project.

Chapter 6: Cost Analysis

The total cost of the front and rear suspension and steering has been calculated based on assembled parts list of the respective systems. Table 6.1 shows the total cost of the steering components purchased from Polaris and Desert Karts. Table 6.2 shows the total amount of team money spent on suspensions components alone.

One of the teams goals for this project was to design and build a vehicle that could not only compete in the SAE competition, but also a possible production off-road vehicle. Research on materials, labor, and manufacturing cost was done to get an estimate for what a vehicle like this would cost. Figure 6.1 shows a summary of these costs and gives a general production cost of $13,018.30.

Table 6.1 - Steering cost report

Part	Manufacturer	Quantity	Price
14" Steering Rack	Desert Kart	1	$98.00
Steering Quickerner	Desert Kart	1	$85.00
Splined Coupler	Desert Kart	2	$13.00
Shipping and Taxes for Desert Kart	Desert Kart	1	$28.88
3/4" Rod Ends	McMasterCarr	3	$12.34
5/8" Rod Ends	McMasterCarr	6	$14.40
Shipping and Taxes for McMAster	McMasterCarr	1	$7.06
1.25"x.095" 4130 Tubing For A-arms and Trailing Arms	IMS	5	$38.12
1/4"x2" Flat for Tabs	IMS	1	$10.80
1/4"x1.5" Flat for Tabs	IMS	1	$9.50

1/4"x4" Flat for Steering	IMS	1	$12.92
5/16"x1.5" for Tabs	IMS	1	$12.74
1.25" Solid Round Slugs for Rod Ends	IMS	1	$28.52
3/4"x2" for Tabs	IMS	1	$14.06
Tax for Material from IMS	IMS	1	$23.18
3/8" Rod Ends	McMasterCarr	4	$9.92
Shipping for Rod Ends	McMasterCarr	1	$5.61
4130 Tie Rod Material	Amazon	1	$35.96

Table 6.2 - Suspension cost report

Part	Manufacturer	Quantity	Cost/EA	Total Cost
Steering Knuckle LH	Polaris	1	$99.00	$99.00
Steering Knuckle RH	Polaris	1	$99.00	$99.00
Outlaw Front Hub	Polaris	2	$29.00	$58.00
Rear Hub	Polaris	2	$28.00	$56.00
RZR S 800 Front Fox Shock	Polaris	2	$278.00	$556.00
RZR XP 900 Rear Shocks	Polaris	2	$340.00	$680.00
LH Rod End	Polaris	3	$20.00	$60.00
RH Rod End	Polaris	3	$20.00	$60.00
Stud for Front Wheel	Polaris	10	$1.00	$10.00
Stud for Wheel	Polaris	10	$1.00	$10.00
Radius Rod Blue Upper	Polaris	3	$59.00	$177.00
Radius Rod Blue Lower	Polaris	3	$59.00	$177.00
RZR 900 Rear Blue Spring for Shock	Polaris	2	$36.00	$72.00

Upper Spring For RZR 900 Rear	Polaris	2	$15.00	$30.00
Spacer RZR 900 Rear spring	Polaris	2	$2.00	$4.00
Retainer RZR 900 spring	Polaris	2	$15.00	$30.00
Main Spring RZR 800 S Front	Polaris	2	$26.00	$52.00
Tender Spring RZR 800S Front	Polaris	2	$16.00	$32.00
Spring Spacer RZR 800 S Front	Polaris	2	$1.00	$2.00
Spring Retaining RZR 800 S Front	Polaris	2	$8.00	$16.00
Sleeve for Shock RZR 800 S Front	Polaris	4	$2.00	$8.00

2014 Baja SAE Official Costing Sheet **NAU Lumber Jack Racing**

	ILL	TEX	KAN
Car Number		*106*	
Total Cost		*$ 13,018.30*	

Sect #	Item	Description	Subassembly Costs		Vehicle Assembly Labor		Subtotal	
			Material	Labor	Time(min)	Cost	Material	Labor
1	Engine		$1,139.93	$17.50		$0.00	$1,139.93	$17.50
2	Transmission		$1,917.60	$17.50		$0.00	$1,917.60	$17.50
3	Drive Train		$1,351.22	$70.00		$0.00	$1,351.22	$70.00
4	Steering		$1,128.01	$26.25		$0.00	$1,128.01	$26.25
5	Suspension		$3,441.65	$105.00		$0.00	$3,441.65	$105.00
6	Frame		$543.94	$353.60			$543.94	$353.60
7	Body		$261.50	$11.67		$0.00	$261.50	$11.67
8	Brakes		$1,428.36	$35.00		$0.00	$1,428.36	$35.00
9	Safety Equipment		$259.15	$17.50		$0.00	$259.15	$17.50
10	Electrical Equipment		$278.00	$35.00		$0.00	$278.00	$35.00
11	Fasteners		$0.00			$0.00	$0.00	$0.00
12	Miscellaneous		$0.00	$0.00		$0.00	$0.00	$0.00
13	ILL Event		$0.00	$0.00		$0.00	$0.00	$0.00
14	TEX Event		$579.92	$0.00		$0.00	$579.92	$0.00
15	KAN Event		$0.00	$0.00		$0.00	$0.00	$0.00
		ILL Total:	$11,749.36	$ 689.02		$ -	$ 11,749.36	$ 689.02
		TEX Total:	$12,329.28	$ 689.02	0	$ -	$ 12,329.28	$ 689.02
		KAN Total:	$11,749.36	$ 689.02		$ -	$ 11,749.36	$ 689.02

Figure 6.1 - Total production vehicle cost estimate

Chapter 7: Conclusion

A large project such as the mini Baja consists of many sections and subsections. From the series of iterations on each subsection to the final design changes to make them all fit together. Almost every part of the suspension and steering had to be redesigned in order to fit with other parts. This project shows the need for good team cooperation and communication at all levels of design to ensure that all parts fit together without needing last minute redesigns. In the end the suspension and steering was overbuilt and heavy but it was reliable.

References

[1] SAE International, "SAE Collegiate Design Series: 2014 Baja SAE Series Rules," 2014

[2] BajaSAE.net "Trailing Arm Suspension," http://forums.bajasae.net/forum/trailing-arm-suspension_topic753.html

[3] The Steering Bible, "Steering System Designs, Suspension System Designs," http://www.carbibles.com/steering_bible.html, 2013

[4] Quadratec Knowledge Center, "Bump Steer Explained," http://www.quadratec.com/jeep_knowledgebase/article-68.htm, 2013

[5] Racing Aspirations, "My Suspension Geometry Applet," http://www.racingaspirations.com/mods/kknkv6sd**,** 2013

[6] Polaris RZ XP 900, "Suspension Design," http://www.utvguide.net/polaris_rzr_900_xp.htm, 2010

[7] Kenedi, Pacheco, Vieira, Jorge, Danninger, "Analysis of the Transmissibility of the Rear Suspension of a Mini-Baja Vehicle," Warrendale, Pennsylvania, ISBN 0-7680-1109-4

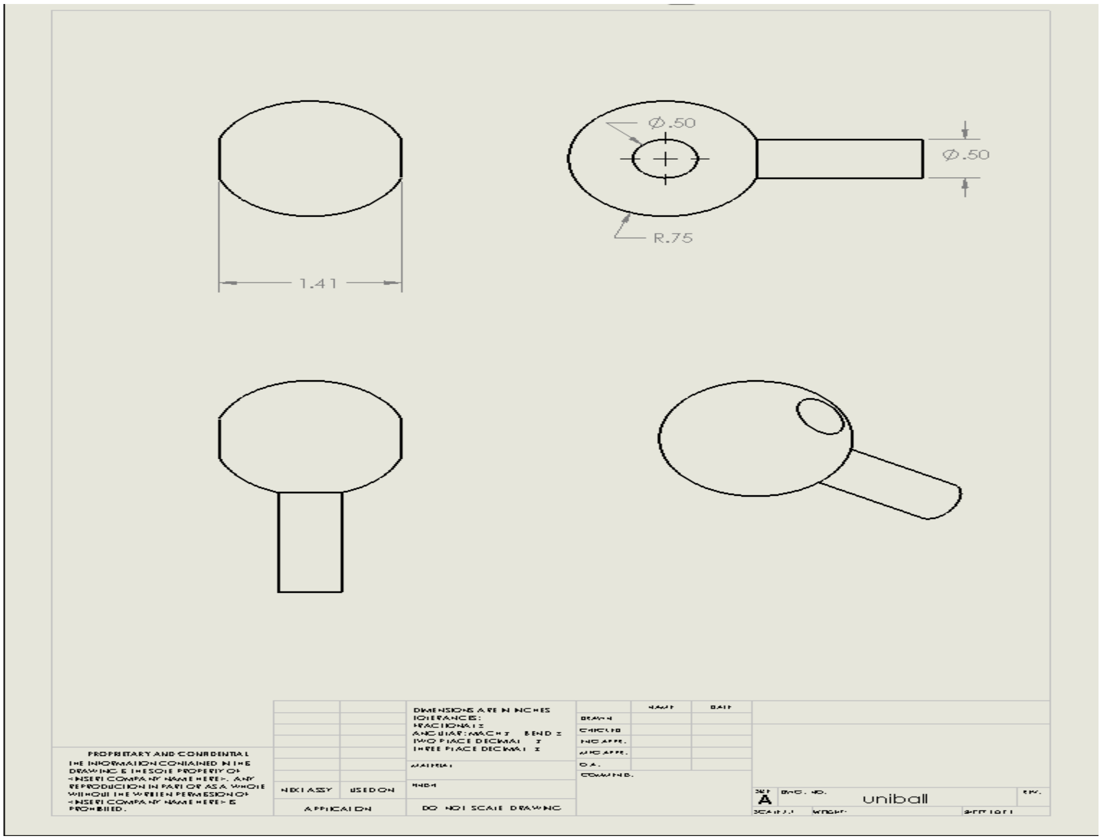
844085-9:101-110, 2002.

[8] Gillespie, T., <u>The Fundamentals of Vehicle Dynamics,</u> Society of Automotive Engineers, Warrendale, PA, 1992.

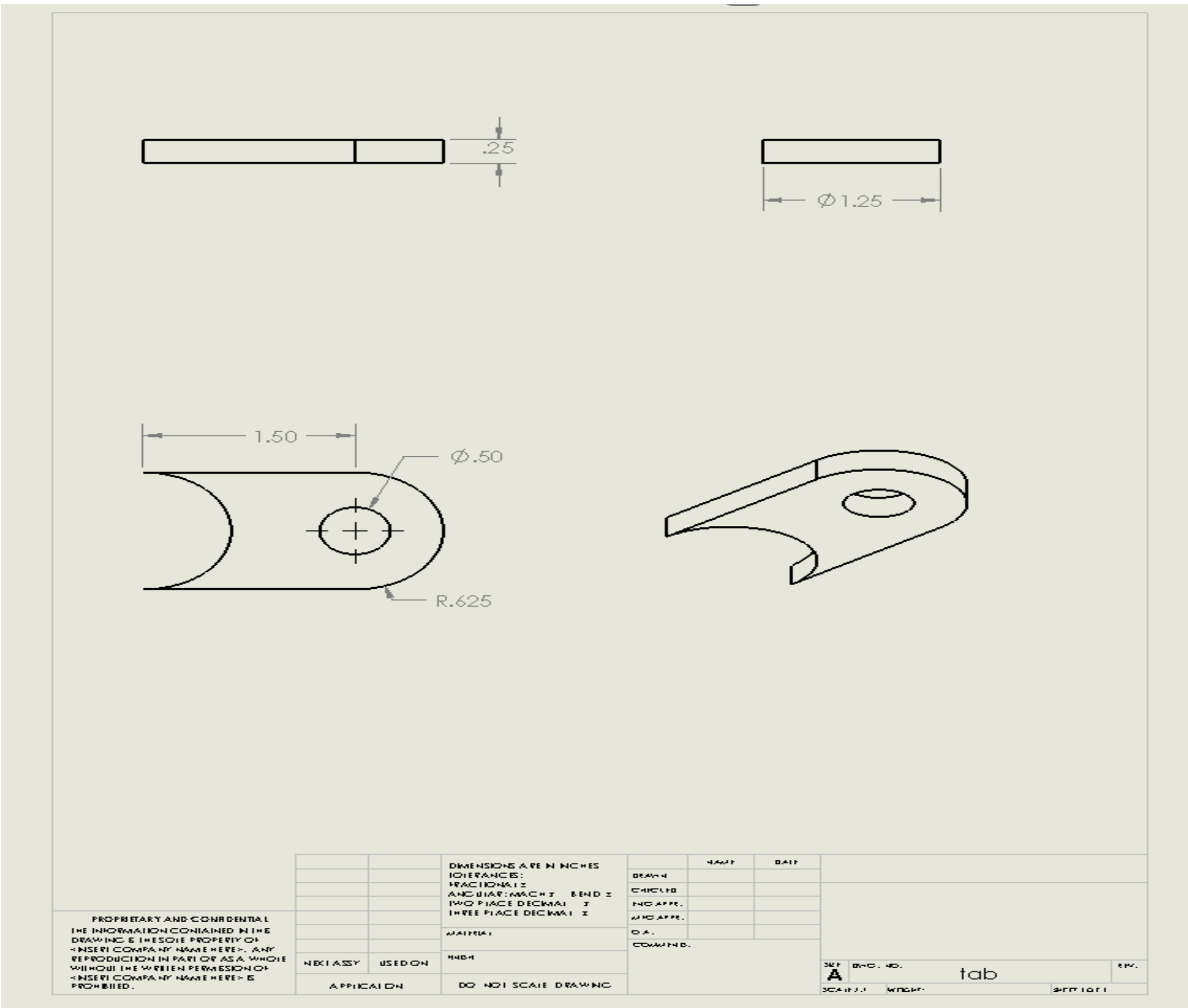
[9] Milliken, W.F. and Milliken, D.L., <u>Chassis Design Principles and Analysis,</u> Society of Automotive Engineers, Warrendale, PA, 2002.

[10] Hunt, D., <u>farm Power and Machinery Management,</u> Iowa State University Press, Ames, IA, 2001.

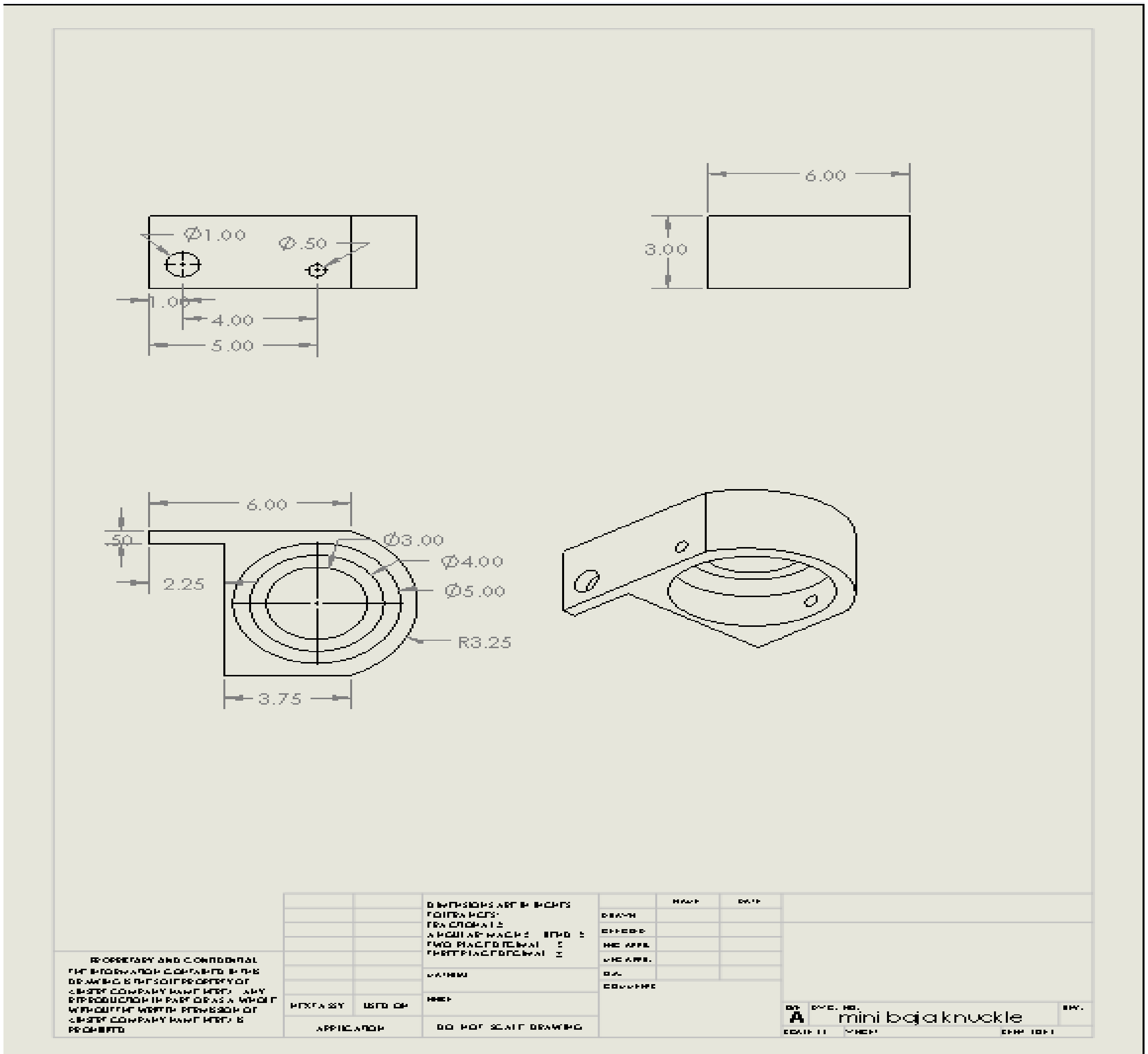
Appendix A: Engineering Drawings



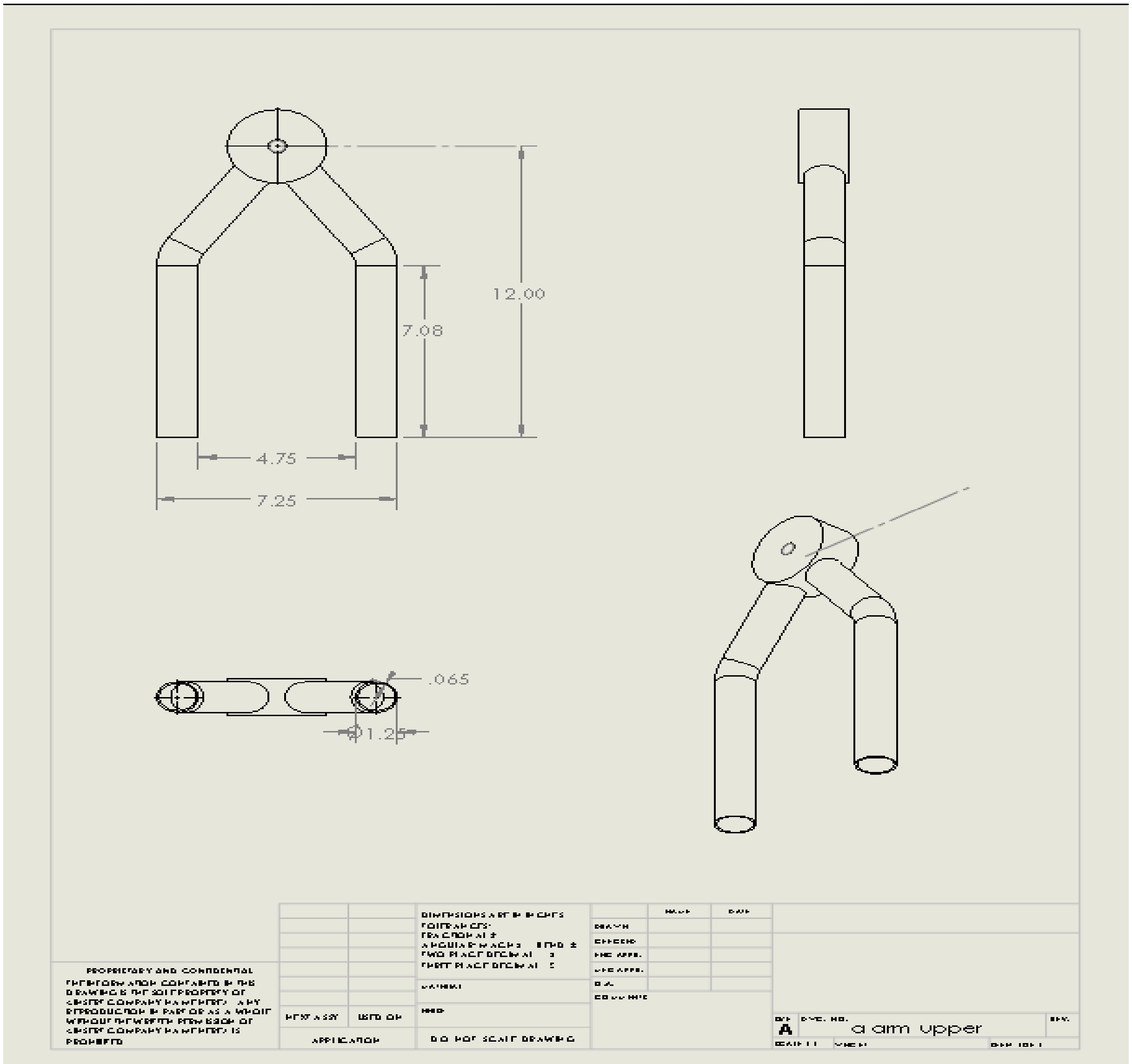
Appendix Figure 1A - Front suspension uniball design



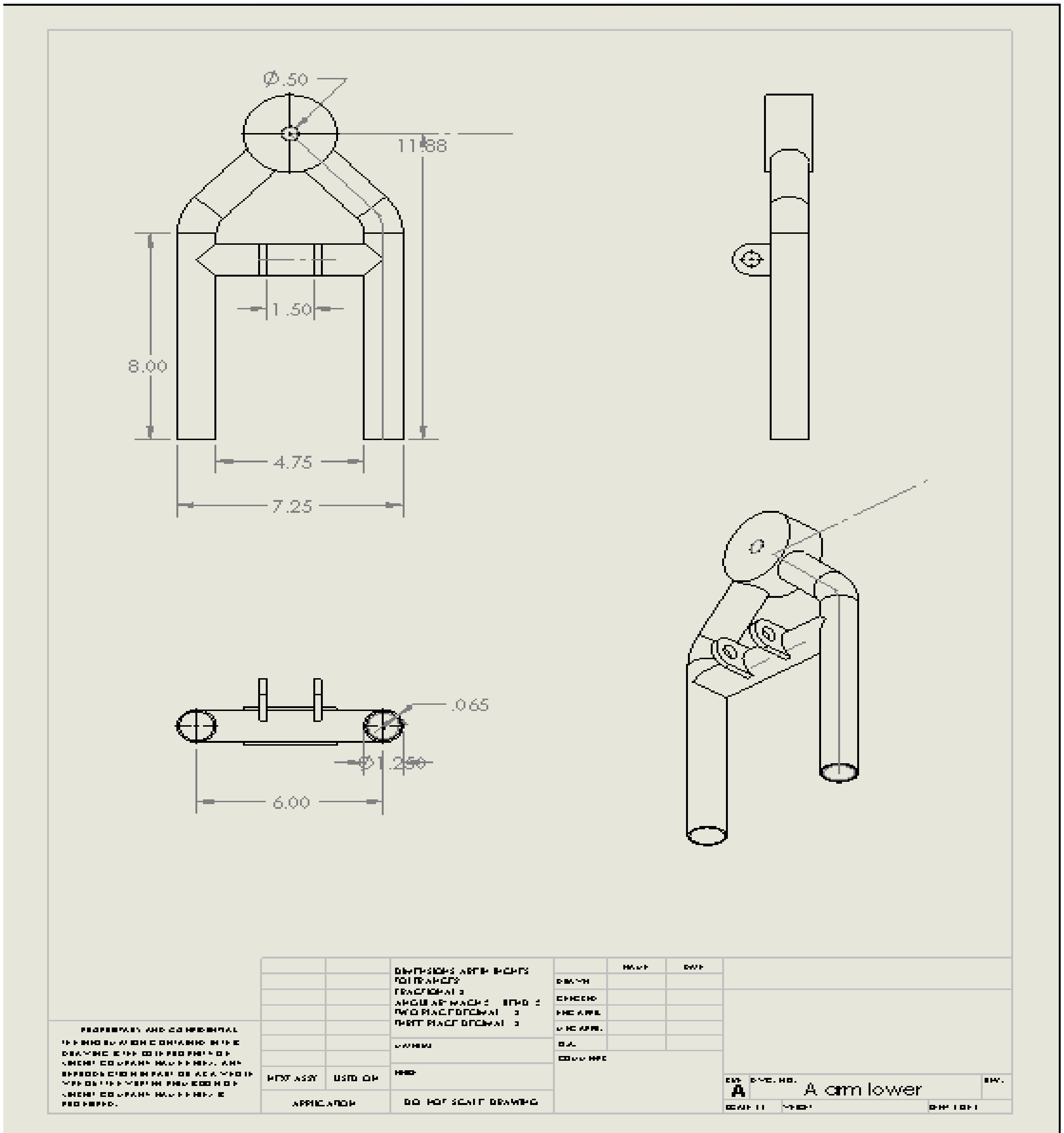
Appendix Figure 2A - Front suspension frame mounting bracket



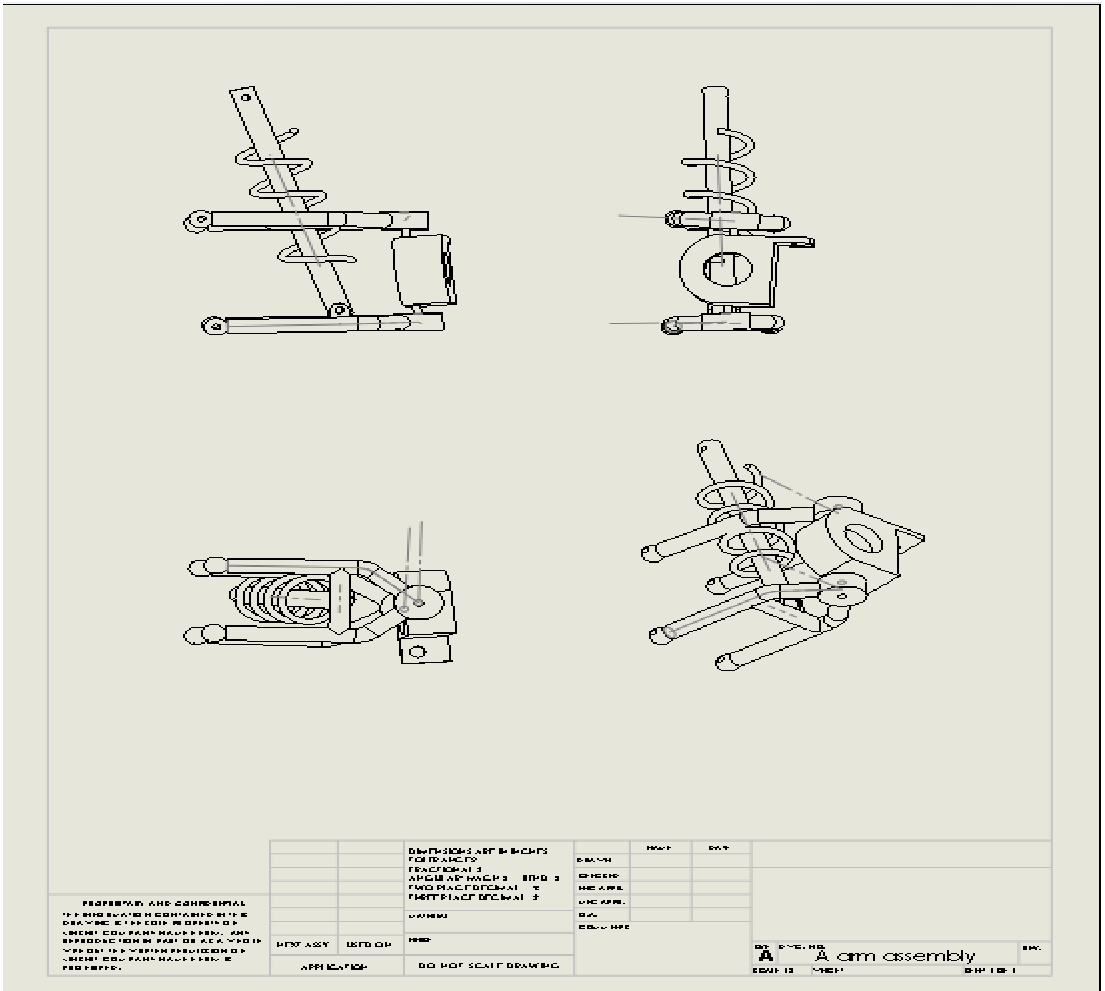
Appendix Figure 3A - Front suspension Mini Baja knuckle



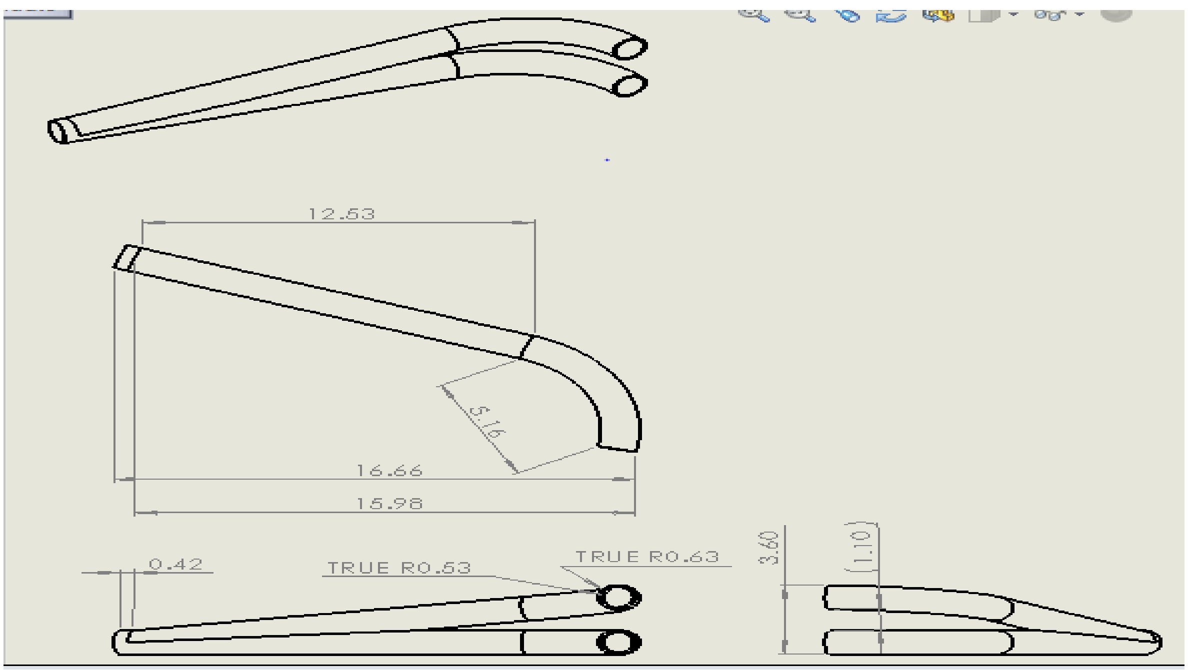
Appendix Figure 4A - Upper a-arm member



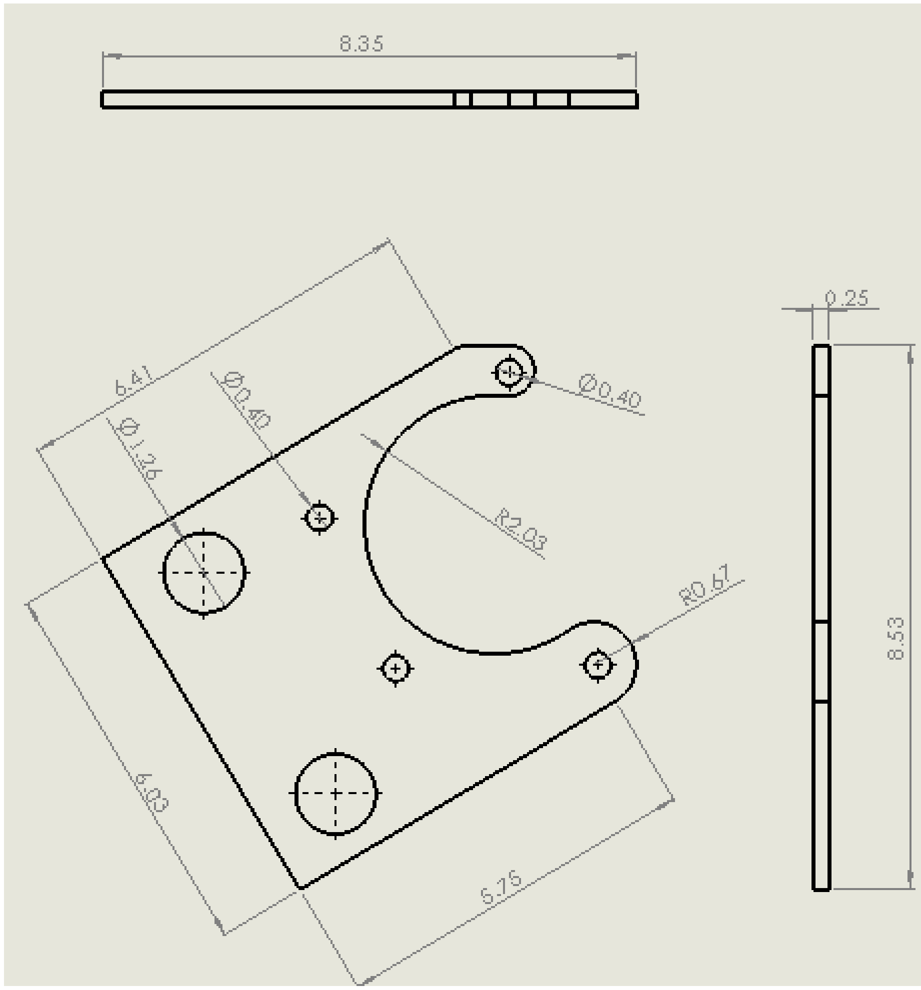
Appendix Figure 5A - Lower a-arm member



Appendix Figure 6A - Front a-arm assembly



Appendix Figure 7A - Trailing arm members



Appendix Figure 8A - Rear upright, hub plate

Appendix B: Finished Vehicle, Competition, Failure

Figure 1B - Complete (and clean) Mini Baja

Figure 2B - Endurance race starting lineup front

Figure 3B - Endurance race starting lineup front

Figure 4C - Completed car post-competition

Figure 5C - Broken engine mount

Figure 6C - Old CVT belt (what's left of it) vs. new CVT belt right side