SAE Mini Baja: Suspension and Steering

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Concept Generation Selection

Document

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I. Need Statement

The client, Dr. John Tester, has expressed the following need:

The competition vehicle should adhere to all SAE Baja competition safety regulations, and provide an agile and competitive platform for the upcoming SAE UTEP Competition.

Based on this need statement, the goal of the SAE Baja Suspension and Steering design team is to research, design, and produce a competitive and versatile suspension system capable of traversing rough terrain while still staying light and maneuverable. The team will accomplish this goal by researching winning designs, modifying these designs to the team's Baja vehicle, and analysis of each system.

II. Introduction

This report explains and depicts the design concepts chosen for the SAE Baja steering and suspension systems. Included in this report are visual representations of three suspension designs and three steering system designs for a total of six concepts. Each design will be covered in depth, describing the advantages and disadvantages of each conceptual system most important to the team and client. The design process was reinforced through researching previous SAE Baja competition winners, and cost effective designs. The researched designs will be compared to both customer and team needs using decision matrices on a weighted scale.

III. Concept Generation

IIIa1. <u>Suspension Concept 1: Front and Rear Independent Suspension (double wishbone)</u>

The first suspension concept utilizes front and rear independent suspension. The suspension system uses a double a-arm, double wishbone, design which allows for optimized wheel motion and adjustability. Although this design is slightly more complex and requires more parts than other designs, it is a proven system that works in an off road and racing environment. Figure 1 shows a double wishbone design used on racing ATV's.

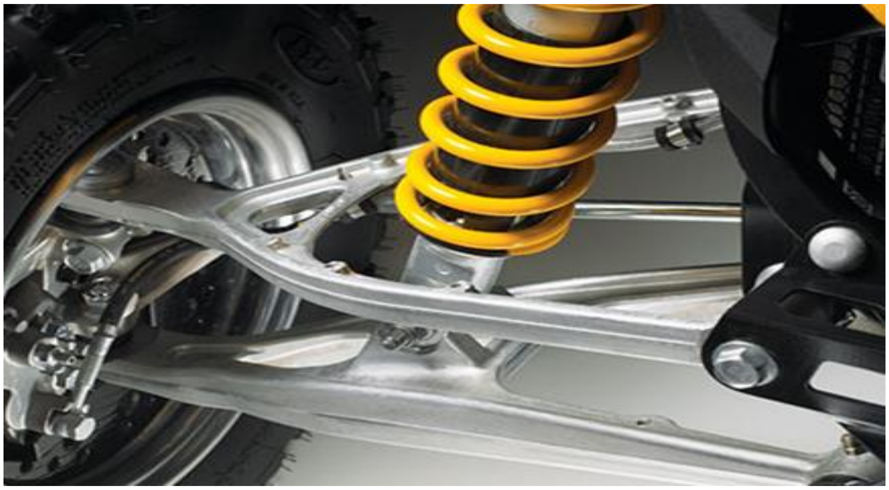

Figure 1: Double Wishbone Suspension Design [1]

The front and rear a-arms move independently of each other throughout the suspension travel range. This design allows each wheel to travel at the same or varying rates when traversing over rough terrain by always having one or more tires making full contact with the ground, essentially creating a much more stable and smooth ride for the occupant.

IIIa2. Suspension Concept 2: Rear Semi-Trailing Arms

This suspension concept utilizes independent lever arms pivoting from one or two points on the frame and continuing at an angle back to the CV axles for drive. The semi-trailing arm design has the advantage of being durable and strong while also being very simple to design in a desired amount of travel and static camber. Unfortunately though, the amount of camber hardly changes throughout the travel of this design, letting it suffer from some stability and traction problems at the extremes of travel. Though, with those disadvantages in mind, a much larger vehicle might experience more dangerous consequences than anything in the SAE Mini Baja competition.

Figure 2: Rear Semi-trailing Arm

IIIa3. <u>Suspension Concept 3: Rear Live Axle (solid axle)</u>

This suspension concept utilizes a front independent suspension with a live rear axle. Live axles get their name from the fact that the whole axle moves whenever either wheel hits a bump. Live axles are simpler, tougher, and more durable than independent suspension systems. They also allow for increased articulation which is beneficial for rock crawling. The trade off is that live axles are heavier, increase the unsprung weight, and do not allow the wheels to independently follow the contours of a rough road.

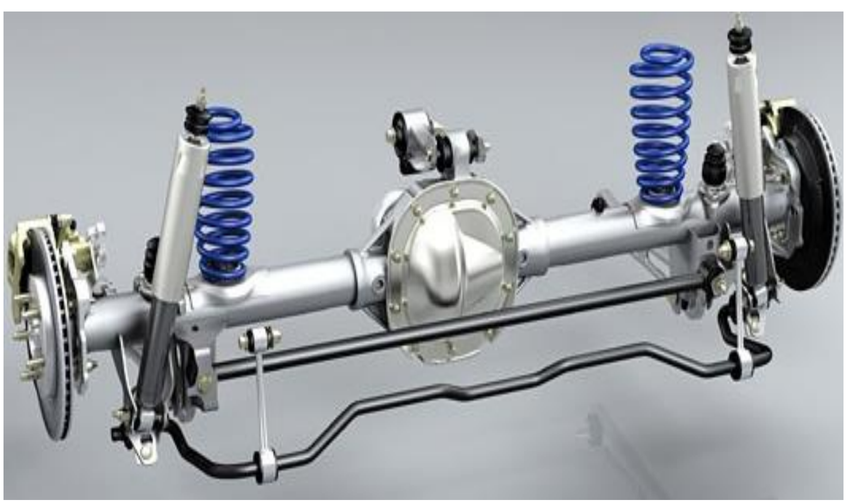

Figure 3: Solid Rear Axle Design

IIIa4. <u>Suspension Concept 4: Front Equal I Beams</u>

This suspension design concept revolves around dual swing arms that pivot on the opposite side of wheel it is controlling. This design has the advantage of being very simple, with lots of travel as well as being very strong. Though this design being simple is an advantage, it also serves as a disadvantage, camber and caster change can be radical and hard to control as all alignment values are dialed in and are difficult to change once the beams are built. While it is possible to add in radius arms to control caster change, it would add to the already substantial weight of which this design also suffers.

Figure 4: Equal I Beam Suspension Design

IIIa5. <u>Suspension Concept 5: Front twin trailing arm</u>

This suspension design is a version of a trailing arm suspension, commonly used in early Volkswagens, using upper and lower arms tied to a torsion beam between the left and right arm and often accompanied by a shock for further dampening. These systems have the advantage of moving away from obstacles when struck, moving in a backward arc toward the rear of the vehicle. This design also suffers from the same disadvantages as a trailing arm type, which involves no camber change throughout its travel which is more important for the front seeing as it does the turning. This design is also extremely bulky and heavy, making it impractical to use for this Baja vehicle.

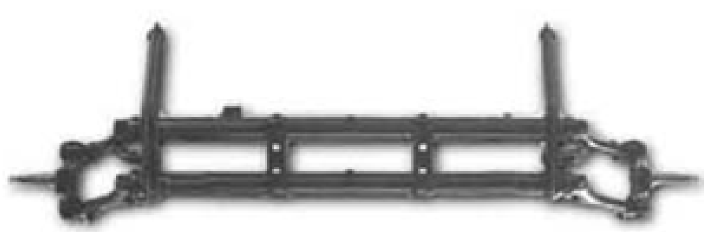

Figure 5: Front twin trailing arm Suspension Design

IIIb1. **Steering Concept 1: Rack and Pinion Steering**

The rack and pinion steering will consist of a gear that is driven by the steering column and a gear rack that will mesh with the steering column gear. The rack is then connected to the tie rods that are connected to the hubs in a way where if they are pulled or pushed by the tie rods, the wheels will turn in the direction driven by the steering wheel.

The types of rack and pinion steering that are available are the spur gear type and the helical gear type. The difference between the two is the angle that the teeth of the gear make with the face of the gear, where the teeth on the spur gear are always 90 degrees with the face of the gear and the helical have an angle less than 90 degrees to the face of the gear. The difference in performance with the two are that the helical type has a smoother gear mesh while the spur type has a rough gear engagement. Although the drawback of a smoother mesh is a thrust load to the steering column that is created by the helix angle on the helical rack and pinion type.

If there is a problem in design where the gear ratio and type cause a problem with meshing then the right design that will be used will be the helical rack and pinion type. As for rack and pinion being compared to other types of steering, the response that rack and pinion produces is great but the amount of stress put on the driver can be taken into account according to the gear ratio that is used for the system. This factor will also count on whether the system is mechanically or hydraulically driven.

Figure 6: Simple Rack and Pinion with Spur Gear

IIIb2. Steering Concept 2: Pitman Arm

A pitman arm steering system consists of a box that converts the steering wheel input into a lever arm output. This Pitman Arm lever controls a track rod. Depending on the variation of this design the track rod is in some way connected to the tie rods that directly control the wheels to steer. The advantage of the Pitman arm system is that it is simple robust, and provides a mechanical advantage to the driver. For these reasons Pitman Arms are common on jeeps and other off road vehicles. The disadvantages of the Pitman Arm system are that they have a "dead spot" allowing the steering wheel to turn before the wheels. With the advent of modern power steering systems that give the same mechanical advantage without the dead spot the Pitman Arms are falling out of favor.

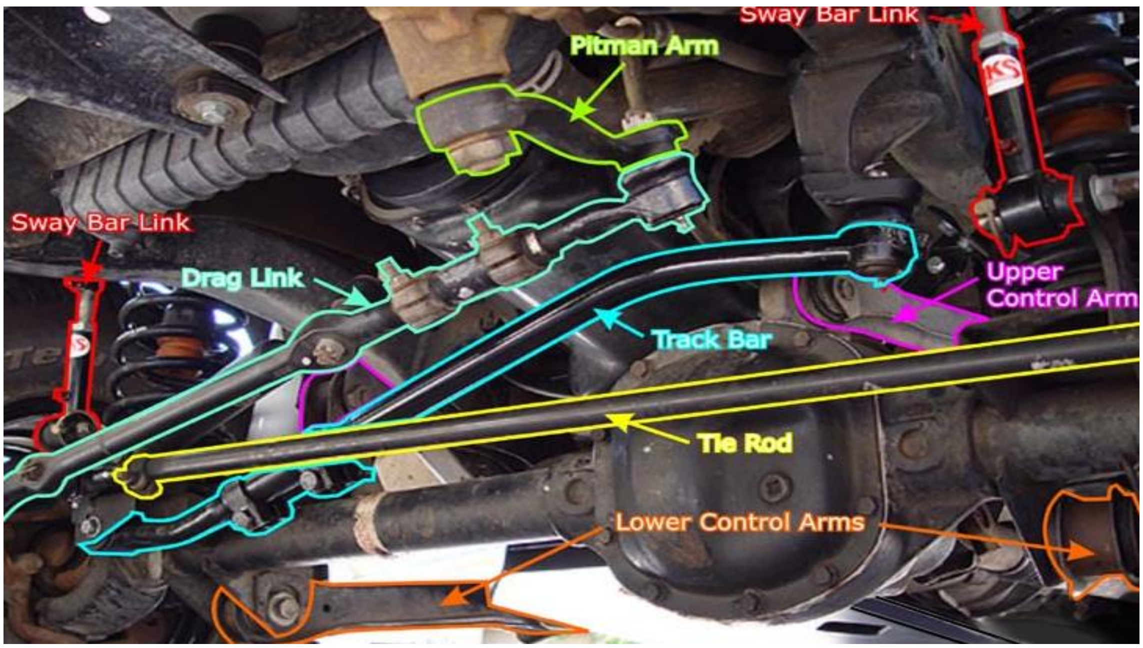

Figure 7: Pitman Arm Steering Assembly

IIIb3. Steering Concept 3: Steer by wire

Steer by wire systems are becoming more common as the price of computing power falls. In theory they can be simpler that traditional steering systems. They can save weight by using electrical controls instead of mechanical linkages. They allow for more advanced forms of Electronic Traction and Stability control. However because of the importance of steering the electrical connections need to be very secure along with the programs to control them. Also in the event of anything breaking they need to be very well grounded to allow for welding repairs in the field.

Steer by wire can be any type of steering system type with the intermediate step between the driver and the wheels being an electronic response device. The interaction with the steering wheel by the driver, later drives an electric motor that will drive the rack and pinion. With this type of steering system the advantages are corrections that can be made to the steering and the ease on the driver since an electrical motor will be driving the wheels instead of a person.

IV. Concept Selection

Based on the customer and team needs, several criteria were identified as the most important focuses of the design. These criteria are shown in Table 1:

Table 1: Criteria Definitions and Weight

Criteria	Definition	Weight
Simplicity of build	The build must be easy to build with the equipment and materials available to the team	0.20
Reliability	The design must be reliable in a racing environment	0.30
Weight	The design must relatively light i.e. low unsprung weight	0.30
Cost	The cost of the design and build must be affordable and cost effective	0.20

These criteria were identified from the project need statement as well as the customer's requests. It is important that the designs be simple to build with the limited equipment available to the team. The designs must also be reliable, the vehicle will be used in an off road race environment so the parts must be able to handle varying terrain and events. Thirdly the weight of each design must be relatively low. A higher weight in the suspension and steering systems could affect the vehicle's performance during competition by increasing the power to weight ratio as well as increase costs. Finally the designs must be relatively cheap to purchase from off the shelves if necessary.

Using these criteria, decision matrices were formed for the front and rear suspension systems as well as the steering system. The decision matrices were used to help the team in deciding which design would be most beneficial. The weights were assigned to each of the aspects the team felt were most important, the higher the weight the more important the requirement. After the criteria were weighted, the designs were rated 1-5 (1 being the worst and 5 being the best) for each criteria and then the weighted amounts were summed. The decision matrices are shown in Tables 2-4:

Table 2: Suspension Decision Matrix (Front)

Criteria	A-arm	Equal I Beam	Solid Axle
Simplicity (0.20)	4	4	5
Reliability (0.30)	4	4	5
Weight (0.30)	3	3	1
Cost (0.20)	4	2	2
Totals	3.7	3.2	3.2

Table 3: Suspension Decision Matrix (Rear)

Criteria	A-arm	Solid Axle	Trailing Arms
Simplicity (0.20)	3	4	4
Reliability (0.30)	3	5	3
Weight (0.30)	4	1	4
Cost (0.20)	4	2	4
Totals	3.5	3.0	3.7

Table 4: Steering Decision Matrix

Criteria	Rack & Pinion	Pitman Arm	Steer by Wire
Simplicity (0.20)	5	4	2
Reliability (0.30)	4	5	2
Weight (0.30)	4	3	3
Cost (0.20)	4	3	1
Totals	4.2	3.8	2.1

These designs scored the highest in their respective decision matrices, and fulfill the design criteria created by the customer and team. Based on the team's design criteria the decision matrices confirm that the most beneficial designs are:

- Front Suspension: independent, double a-arms
- Rear Suspension: trailing arms
- Steering system: rack and pinion

V. Project Plan

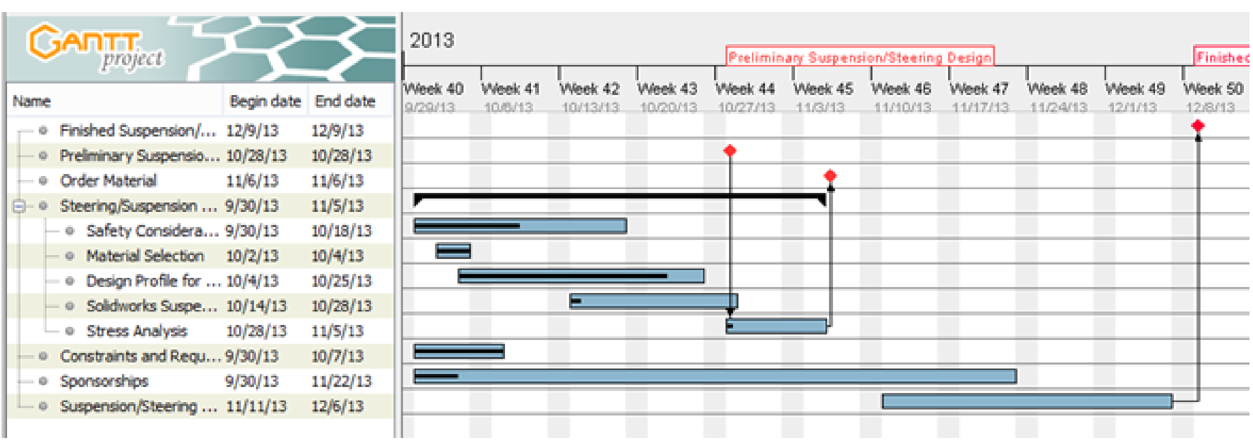

Figure 8: Gantt Chart

Figure 8 shows the team's progress to-date based on the progress of the frame and drivetrain teams. From this point on collaboration between the sub-teams is critical to produce the best design that will work for the Baja vehicle. By following this timetable and strict design collaboration, the team hopes to minimize any possible design mistakes during the build. Once the frame is finished being built, the suspension system will be next.

VI. Conclusion

In conclusion, the rack and pinion steering system was the most viable concept based on the design criteria chosen by both the Suspension and Steering Team and the Baja Team as a whole. For the front suspension the team chose the independent, double wishbone design and trailing arms for the rear. Going into the design process, the team had a general idea of which steering and suspension system would work best based off of researching winning vehicles, ease of build, reliability, and cost. Using these criteria, and a few others, decision matrices were formed to help aid the team in making the correct design choices that best fit the customer's requirements as well as the demands of a competitive racing environment. Finally the decision matrices confirmed these designs would meet all of the design criteria and customer needs. From this point forward, all analysis calculations and design will be for rack and pinion steering, independent/double a-arm front suspension, and training arm rear suspension.

VII. References:

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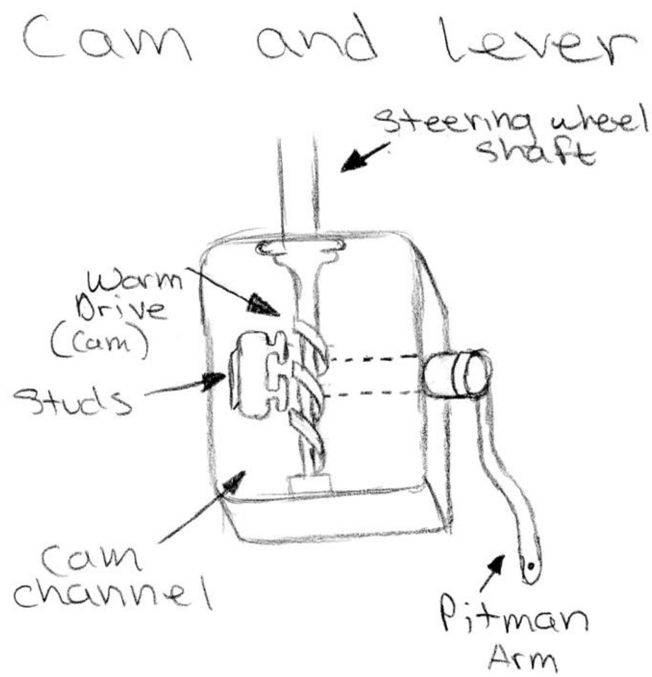
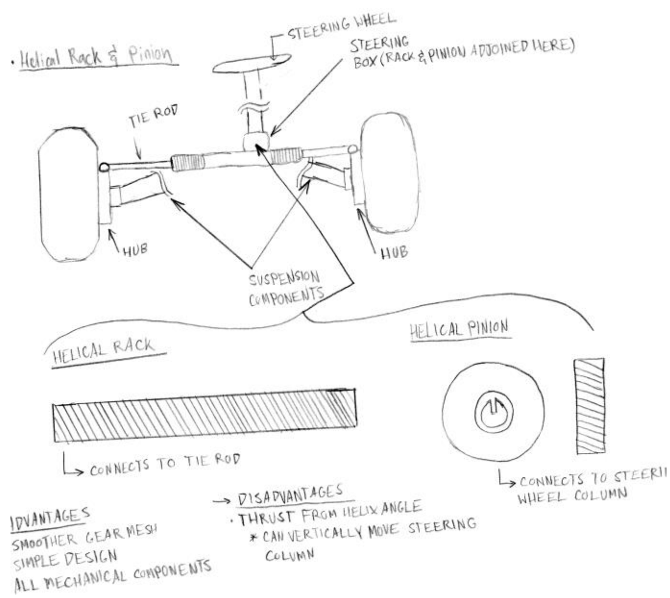
VIII. Appendices:

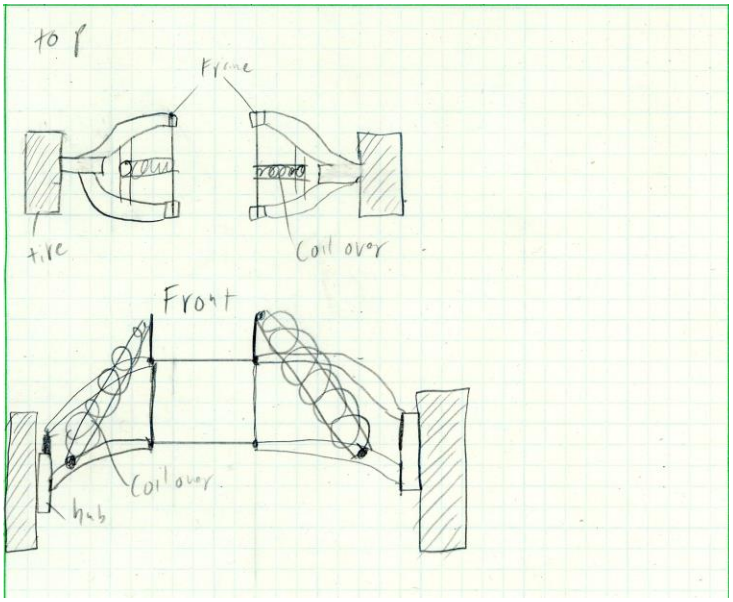
Appendix A
Hand drawn Design Sketches



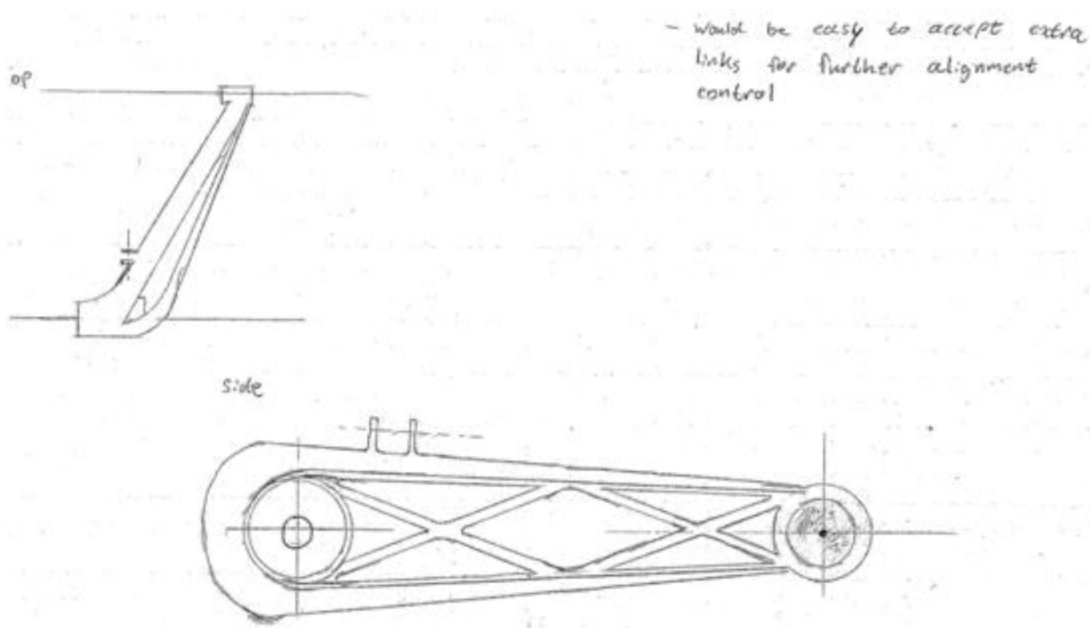
Appendix Figure 1: Pitman Arm



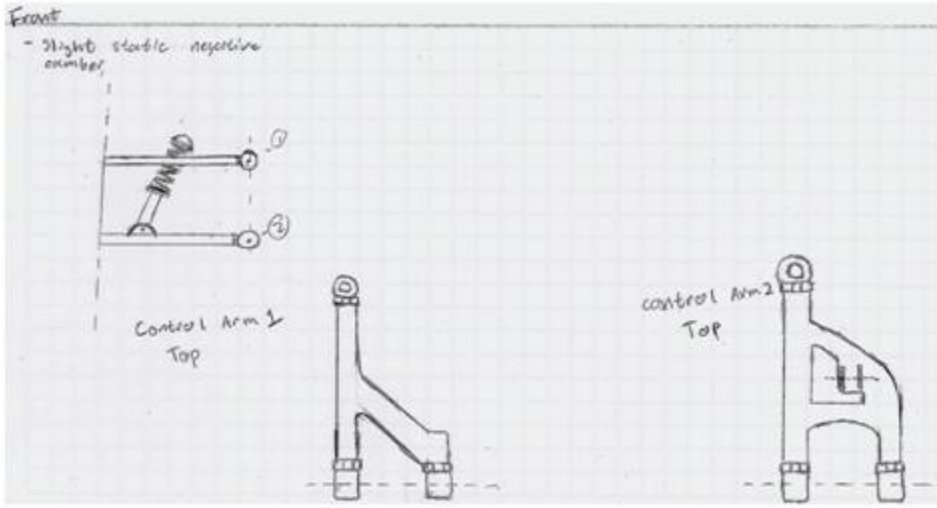
Appendix Figure 2: Rack & Pinion (Helical)



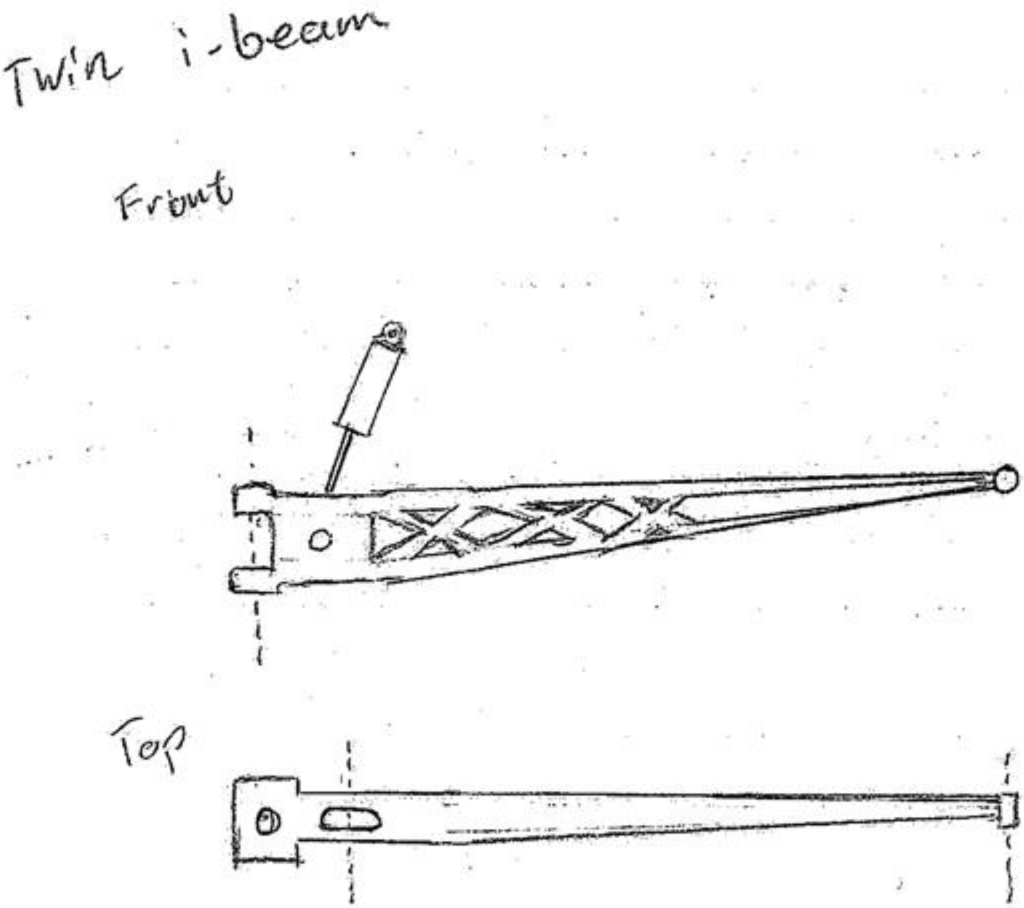
Appendix Figure 3: Double A-arm



Appendix Figure 4: Semi-Trailing Arm

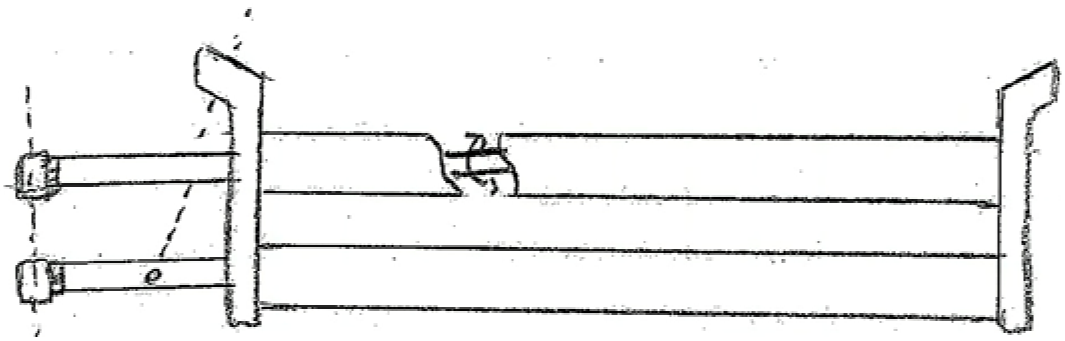


Appendix Figure 5: Double A-arm (alternate)

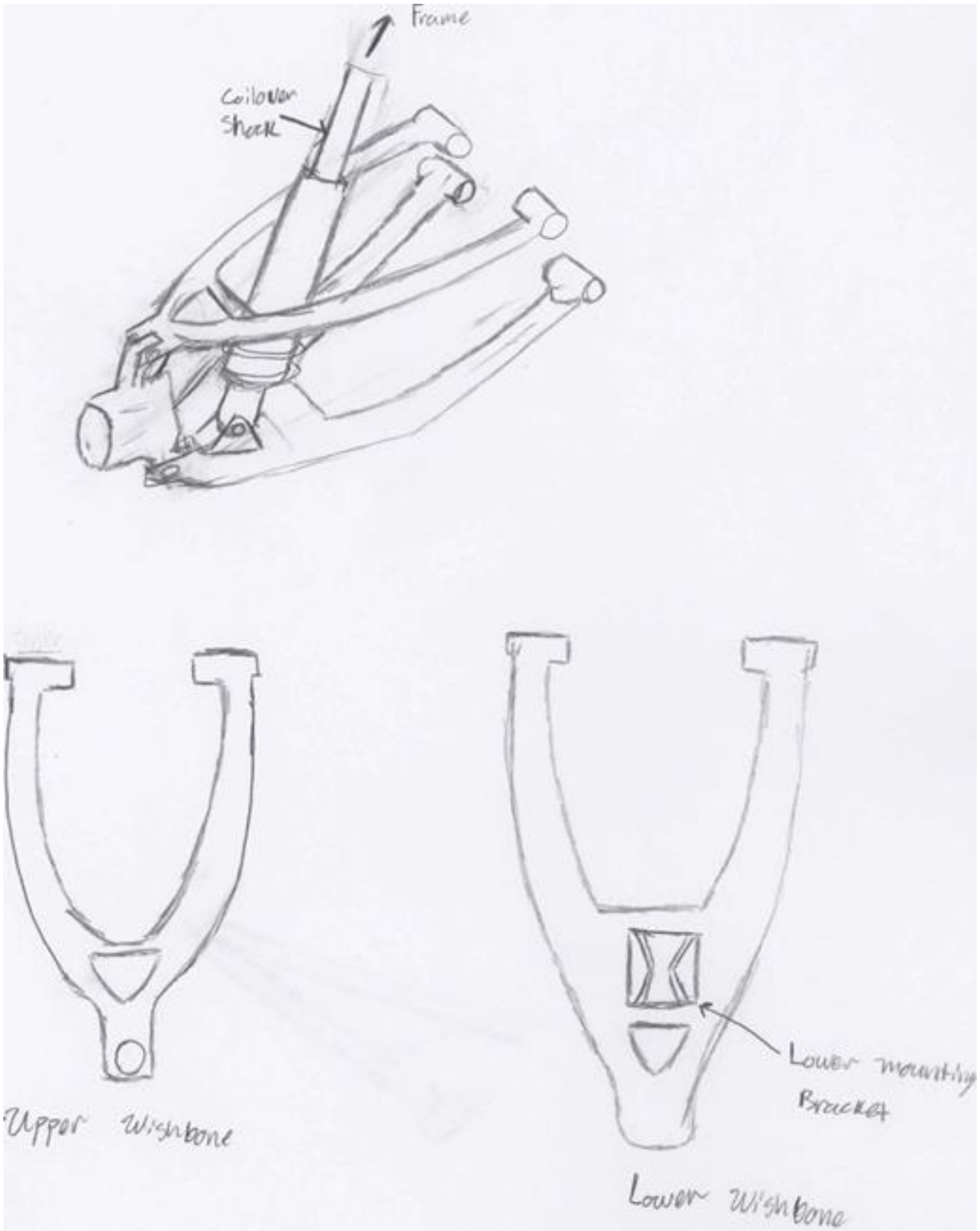


Appendix Figure 6: I-Beam

Twin torsion beam (VW bug style)



Appendix Figure 7: Twin Torsion Beam



Appendix Figure 8: Double Wishbone/A-arm