SAE Mini Baja 2014-2015

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Team 11

Project Update
Document

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Introduction

Society of Automotive Engineers (SAE) is a world known association for setting standards in the automotive industry around the world. SAE is also interested in collegiate opportunities and participation to help educate and stimulate future engineers. For many years SAE has helped students of all ages to develop their skills and knowledge of mechanical operations and properties. For NAU, the senior capstone mechanical engineering students are participating in competitions held by SAE in the fields of the regular class aero, the micro aero, and the mini Baja.

The mini Baja project is a compilation of design, from the ground up, of suspension, steering, drivetrain, frame, wheels, and overall presentation with respect to cost. The vehicle needs to be built to handle off road conditions and be competitive in different dynamic events against other schools teams. The events at the competition that the Baja vehicle will have to go through are acceleration, hill climb/traction event, maneuverability, endurance, and the sales presentation event. Each event is worth a certain amount of points, adding up to a total of 750 allowable points. Based on how the vehicle does in each event, the team will be ranked accordingly out of 100 positions. The closer you are to being rank 1, the better your vehicle overall is. This 2014-2015 competitions rules and locations have been released by SAE, as every year there are changes made to requirements and locations.

This report provides a complete discussion about the team’s client, goals, constraints, and objectives. It will provide a QFD along with a projected timeline for the spring semester of this project. It will discuss the scenarios and calculations used for analysis on the final frame, along with a bill of materials.

Problem Statement

Here at Northern Arizona University (NAU), Dr. John Tester has assigned the senior design project of the SAE Mini Baja to a set of senior mechanical engineering students. The task is to design and build a SAE mini Baja vehicle for the 2015 SAE competitions that need to outperform Dr. John Tester’s SAE mini Baja vehicle from 2014.

For the capstone project of the mini Baja, the frame team is focusing on the design and building of a single seat mini Baja frame. The frame will be put through a series of dynamic events that will test the structural integrity.

Customer Needs

Dr. Tester's highest concern with the previous Baja vehicle was the weight. Last year's mini Baja vehicle weighed about 650 pounds in total [1]. This caused them to have an acceleration struggle while competing with the other mini Baja vehicles that had better power to weight ratios. Dr. Tester also needs the front of the frame to have a better attack angle for clearing obstacles and climbing hills [2].

Goals

The frame team of the mini Baja vehicle has many goals. One goal is to design and build a light weight frame that will meet strength, safety, and dimension requirements for SAE Baja competition(s) and our customer needs. Another goal is to integrate all additional equipment into the frame with mounting tabs. Last year's mini Baja team did not design the frame with the thought or consideration of how the suspension and other components of the vehicle were going to be installed, and thus had to increase the number of structural members along with the weight of the vehicle. This year, the frame team is going to make sure to consider all other components of the vehicle when designing the frame. A third goal for us is to try and incorporate packaged extras that the vehicle can have installed while not being used in the competitions such as a glove box in the front of the vehicle, a speaker system, a winch, and additional body paneling for cosmetics. These extras will attract a buyer's eye, while not affecting the ability of the Baja while it is being used for the competitions. The driver ergonomic designs is another goal for the frame team because comfortability is important, but not too important. The driver should not get fatigued or cramped while driving the vehicle in competition while being able to drive with ease. While keeping all of these goals in mind, we realize that the frame needs to be as inexpensive as possible to manufacture, but good enough to outperform the previous NAU Mini Baja teams in the competitions with our current constraints.

Constraints

Most of the constraints that we must adhere to are within the SAE Mini Baja rules which can be found on their web page. A few extra constraints that we are being given is that the total width of the vehicle must not be wider than 59 inches and that the total weight must not exceed 450 pounds.

Objectives

The objectives for the frame team are to:

- Design and build a light weight frame of maximum 150 pounds
- Design a frame that can be built within a short amount of time
- High enough strength to withstand a roll over and/or a collision
- Build the frame with considerations to all other components of the vehicle with respect to the overall dimensions so that it may be transported to and from competitions with ease

QFD

The following is the QFD with our engineering requirements and customer's needs along with the House of Quality that shows the positive or negative correlations. This chart also shows the NAU's and ASU's previous mini Baja strengths in correlation with Dr. Tester's requirements.

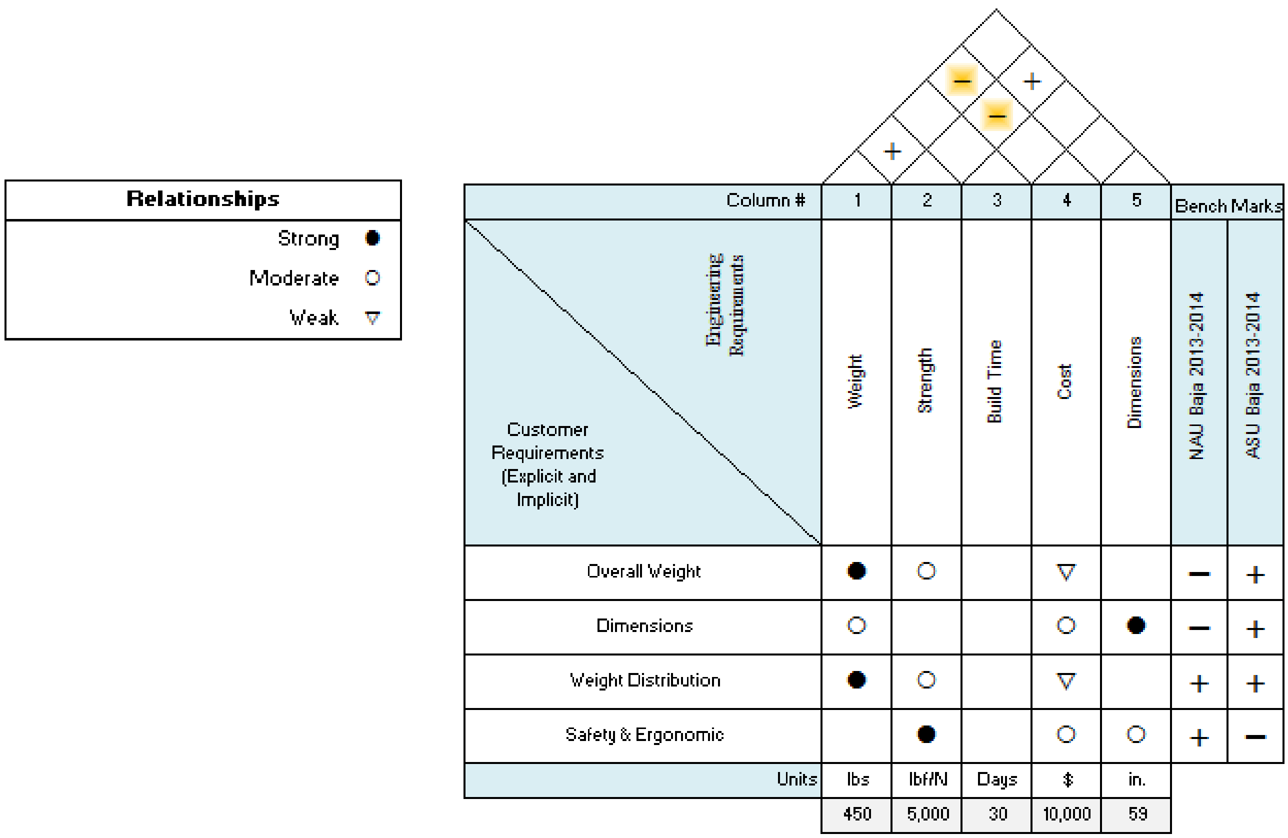
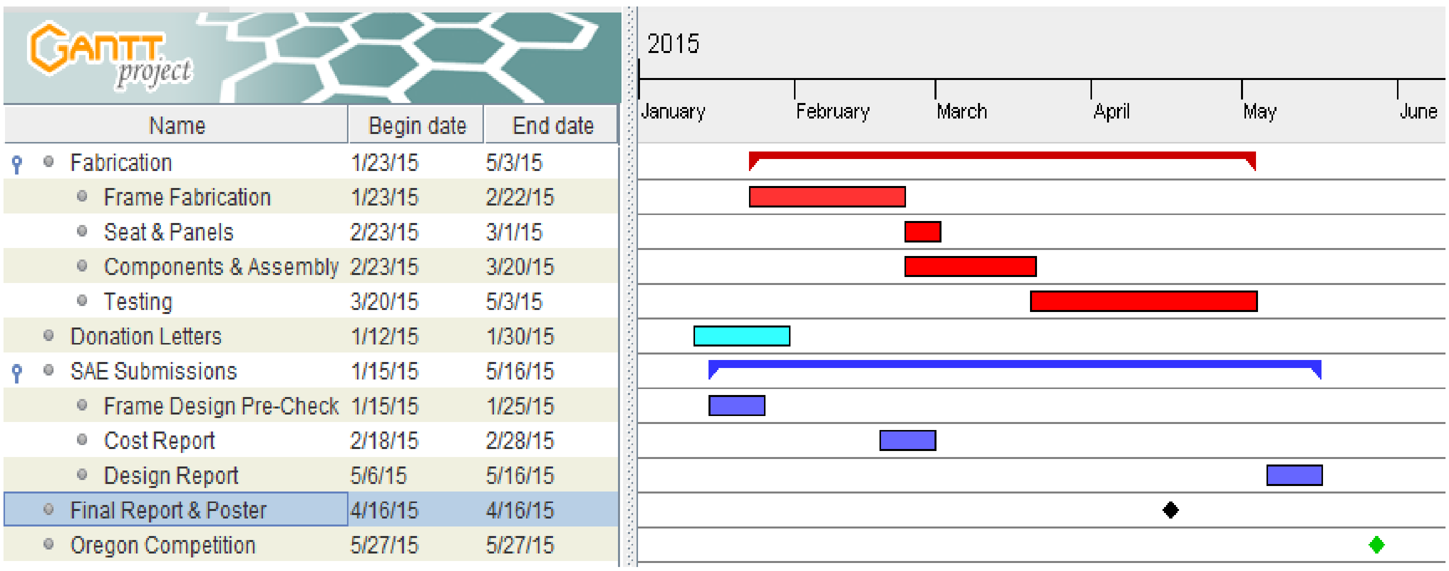


Figure 1 - QFD with HOQ: The above figure shows the relationships between customer requirements and the engineering requirements.

Fabrication Schedule

Gantt Project was used to develop a timeline for the spring semester. Based off the Gantt chart below, the frame team's main goal is to have the frame built by February 22nd per Dr. John Tester. Once the frame has been built, the team can then focus on other parts of vehicle such as installing paneling, and the seat as well as helping the other teams fabricate and install their designs.



Name	Begin date	End date
Fabrication	1/23/15	5/3/15
Frame Fabrication	1/23/15	2/22/15
Seat & Panels	2/23/15	3/1/15
Components & Assembly	2/23/15	3/20/15
Testing	3/20/15	5/3/15
Donation Letters	1/12/15	1/30/15
SAE Submissions	1/15/15	5/16/15
Frame Design Pre-Check	1/15/15	1/25/15
Cost Report	2/18/15	2/28/15
Design Report	5/6/15	5/16/15
Final Report & Poster	4/16/15	4/16/15
Oregon Competition	5/27/15	5/27/15

Figure 2 – Gantt chart: The following chart above shows a visual description what the frame team will be working on for the spring semester.

Manufacturing Process

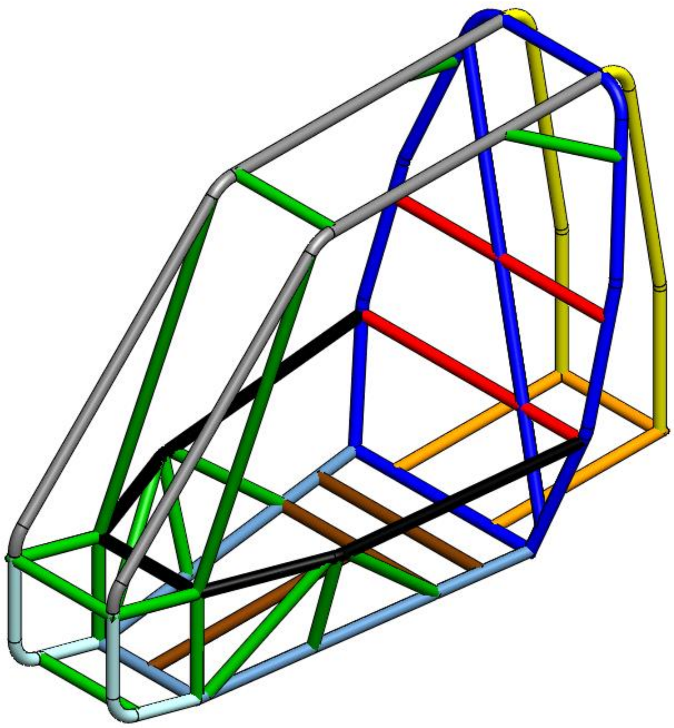


Figure 3: Color Coded Isometric View

The process to build the frame is going to be done in segments. The first segment will be the fire wall as shown in *Figure 3* above in the dark blue. The second segment the frame team will proceed to build is the light blue and black segments for the sides of the roll cage. The gray members for the roll hoop will be fabricated connected to the teal members below in the front. The next segments to be installed will be the dark green and light green support members. The orange and yellow segments for the rear engine bay will be constructed towards the end, and will be followed by the brown and red support members. The estimated time to fabricate the frame is one month. It is expected to be finished by February 22, 2015.

Testing and Calculations

SolidWorks Simulation was used to test the stresses, the displacement, and the overall factor of safety for the design upon impact. This analysis allows us to make any necessary changes before building the actual frame while ensuring the maximum safety for the driver along with the frame being light in weight. Therefore, the frame analysis was based on applying four different simulation studies on the frame, and each simulation study describes a different scenario of collision. The scenarios tested were; drop test, front impact, rear impact, and side impact. The figure below shows the drop test scenario.

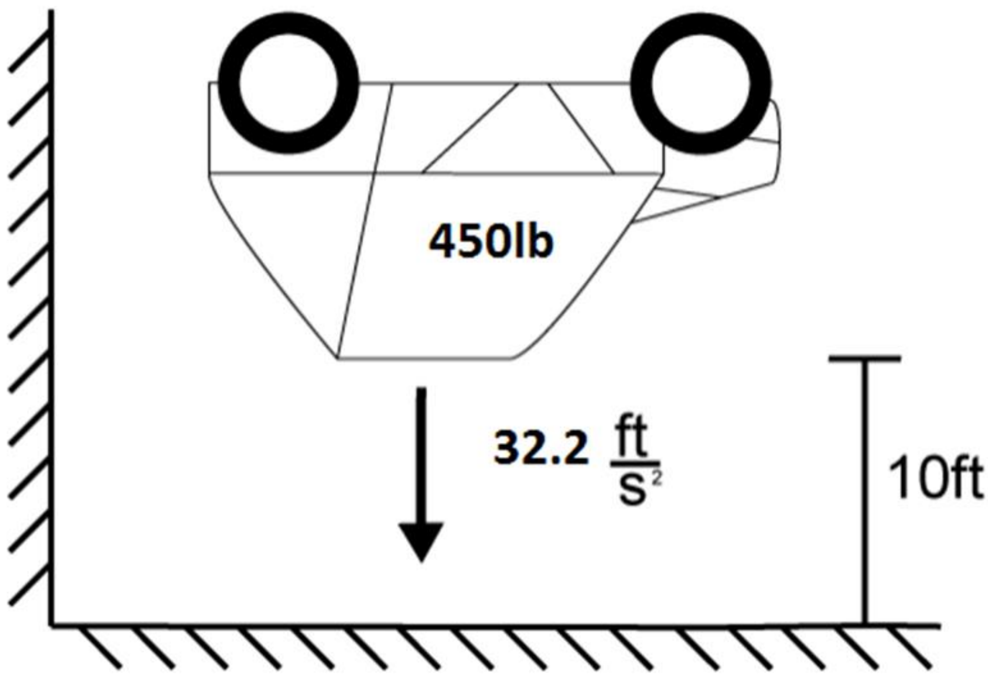


Figure 4: Drop Test Scenario

For the frame drop test (*Figure 4*), it was assumed that the vehicle rolled over and landed upside down from a height of 10 feet. In addition, the assumed weight of the baja is 450lbs and the impact time is 0.1 seconds. In order to analyze the frame in a rollover scenario, the following equation needed to be used to determine the force of impact.

$$F = m \cdot \frac{\sqrt{2gh}}{t} \tag{1}$$

$F = total\ force\ (lbf)$

$m = object\ mass\ (lbm)$

$g = acceleration\ of\ gravity\ ({}^{ft}/{}_{s^2})$

$h = drop\ height\ (ft)$

$t = impulse\ drop\ test\ time\ (s)$

In order to run the drop test simulation study and receive better test results, the team had to define the applied force on the chosen beams. This force is the total force Equation (1) divided by the total length of members force is applied to. Thus, this force can be illustrated as,

$$F_a = \frac{F}{l} \qquad (2)$$

$F_a = applied\ force\ \left(\frac{lbf}{in}\right)$

$F = total\ force\ (lbf)$

$l = total\ length\ of\ members\ force\ is\ applied\ to(in)$

For the remaining impact test scenarios to be conducted on the frame in the SolidWorks simulation studies, a different method to calculate the total force is needed. This method was applied to the remaining three simulation studies. Our front, rear, and side impact simulation studies were tested based on assuming a vehicle weight of 450lbs, an initial impact velocity of 25mph, and an impulse impact test time of 0.2 seconds. In order to analyze the frame experiencing front, rear, and side impacts, a mathematical calculation is needed to calculate the total force. From the total force the team can then determine the applied force to be used for testing the various impact scenarios. As a result, the following equation is obtained.

$$F = m \cdot \frac{V_0}{t} \qquad (3)$$

$F = total\ force\ (lbf)$

$m = object\ mass\ (lbm)$

$V_0 = initial\ impact\ velocity\ \left({}^{ft}/_{s}\right)$

$t = impulse\ impact\ test\ time\ (s).$

In order to run the different impact test simulation studies and receive accurate test results, the team has to define the applied force on the chosen beams. This force is basically the total force Equation (3) divided by the total length of members the force is applied to. Thus, this force can be illustrated as,

$$F_a = \frac{F}{l} \tag{4}$$

$F_a = applied\ force\ \left(\frac{lbf}{in}\right)$,

$F = total\ force\ (lbf)$,

$l = total\ length\ of\ members\ force\ is\ applied\ to (in)$.

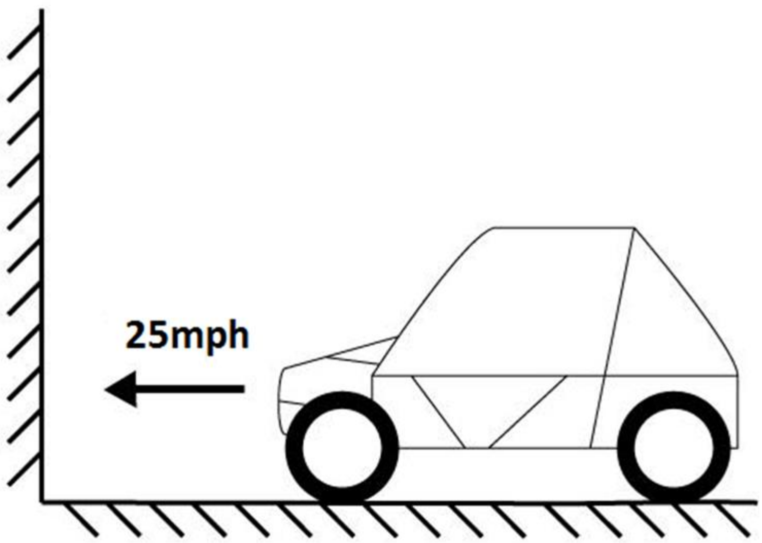


Figure 5: Front Impact Scenario

In *Figure 5*, the front impact scenario is shown as if the 450lb baja vehicle would collide at an impact velocity of 25mph into a wall. The applied force distribution is applied at the front members of the vehicle, while the rear-end members of the vehicle are chosen to be fixed.

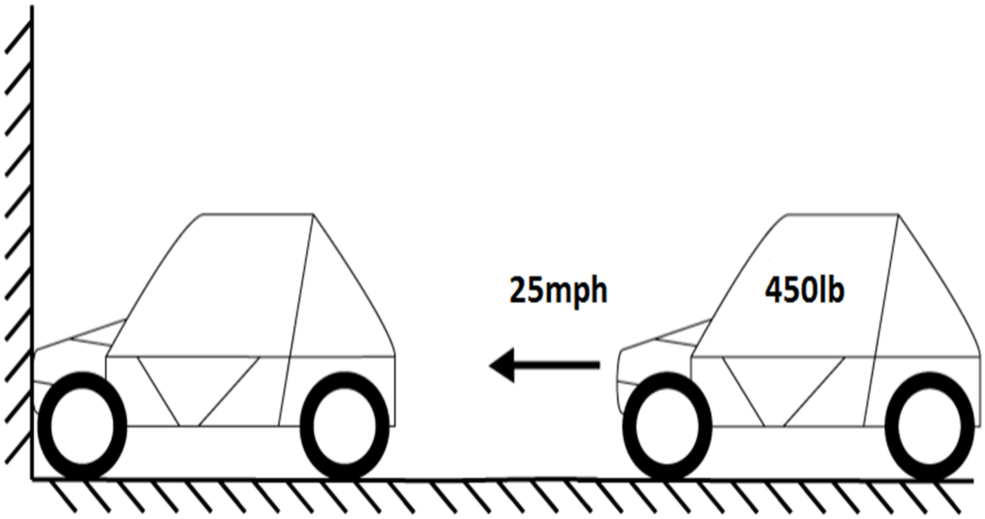


Figure 6: Rear Impact Scenario

Figure 6 illustrates the impact scenario of the baja vehicle being hit by 450lb baja vehicle from the rear end. This scenario can be described as if an approaching vehicle collides with the baja vehicle from the rear at an initial impact velocity of 25mph. The applied force distribution is applied at the rear end members of the vehicle, while the front of the baja vehicle is chosen to be fixed.

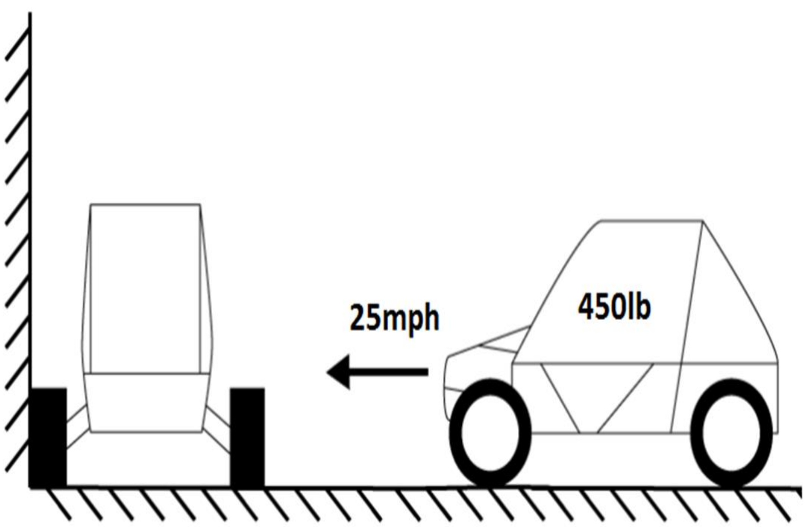


Figure 7: Side Impact Scenario

Figure 7 illustrates the impact scenario of the baja vehicle being hit by 450lb baja vehicle from the side. This scenario can be described as if a vehicle collides with the baja from the side at an initial impact velocity of 25mph. The side impact test using SolidWorks is performed by placing an applied force distribution to the members on one side of the vehicle in a plane, while the members on the other side of the vehicle are set to be fixed.

Updated Frame Design

Modifications made to the frame were to have the correct spacing in the front for the suspension arms. Members have been added near the driver and in the rear for more stability as requested by Dr. Tester. The cross-sectional area of the fire wall has been decreased and the modified frame has a decrease in weight of 10 pounds. Another change is that based on designs for a seat, the team has chosen to use the previous baja's plastic seat due to the weight being almost the same to a ion house designed seat. Lastly, main members will be AISI 4130 steel tubing with a diameter of 1.25 (in) and wall thickness of 0.065 (in), while secondary members have changed to be 1 (in) diameter and wall thickness of 0.035 (in). The Finalized frame is shown below in *Figure 8.*

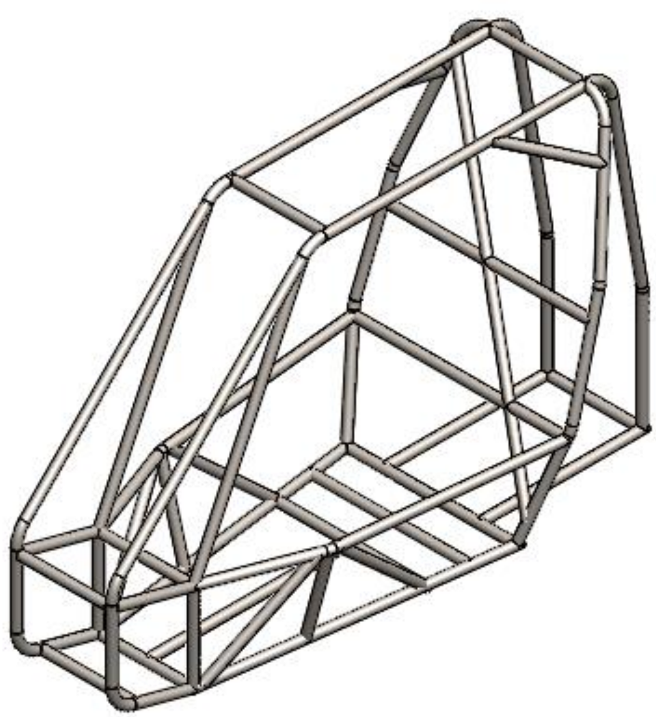


Figure 8: Isometric View of the Final Frame Design.

Simulation Results

The results generated for the final updated frame is discussed below, the images generated in SolidWorks are shown in the Appendix. The factor of safety of the frame has to do with the material being used and the configuration the members are in when a load is applied. The material being used is 4130 chromoly steel with a yield strength of 66ksi.

Table 1: Updated Frame Simulation Results

Tests	Max. Stress (ksi)	Max Deformation (in)	F.O.S
Drop Test	30.3	0.452	2.2
Front Impact	17.1	0.375	3.9
Rear Impact	25.7	0.243	2.6
Side Impact	18.0	0.120	3.7

Bill of Materials

In order to determine the budget for building the baja vehicle, the baja frame team created a list of materials that has beens broken up into two categories; raw materials and commercial materials. Each list contains the material, the quantity, and cost of the materials. The following table shows the list of materials for the raw materials need for building the frame.

Table 2: List of Raw Materials for building the frame.

Raw Materials		
Material	Quantity	Cost
AISI 4130 Steel Tubing $(d = 1.25'', t = 0.065'')$	120 ft.	Donated
AISI 4130 Steel Tubing $(d = 1'', t = 0.035'')$	30 ft.	Donated
$0.375'' \times 6''$ AISI 1018 Steel Plate	2 ft.	Donated
Sheet Metal	3 x 3 ft.	$25
Plastic Sheeting	2 x 3 ft.	$20
PVC	120 ft.	$30
	Total	$75

AISI 4130 steel tubing with a diameter of 1.25 inches and wall thickness of 0.065 inches is used to construct the main members of the frame. The AISI 4130 steel tubing with a diameter of 1 inch and wall thickness of 0.035 inches will be used to construct the secondary members of the frame. In addition, 0.375x6 (in) AISI 1018 steel plating is used for making the tabs for panels and attaching the other team's parts. Sheet metal is going to be used to build the required fire wall on the frame. Plastic sheeting is needed to be purchased, so the frame team can make body panels for the vehicle. Thus, in order to make the mentioned parts, the frame team is going to purchase a 2x3 ft. plastic sheeting. The PVC piping was used to build a dimensional prototype of the frame to give a realistic fabrication process to the design. This allowed the team to check dimensions and/or change dimensions based on the size of the drivers. All of these mentioned materials are the required raw materials for our frame design. The total cost of the needed raw materials to be purchased to build the baja frame is $75. The following table shows the commercial parts that will be purchased for the safety of the driver.

Table 3: List of Commercial Parts need to compete.

Commercial Parts		
Part	Quantity	Cost
Safety Harness	1	$75
Kill Switch	2	$40
Fire Extinguisher and Mount	2	$120
Brake Light	1	$20
Neck Brace	1	$25
Helmet	1	$80
Goggles with Tear-aways	1	$25
	Total	$385

All of the materials listed above are required for participating in the SAE competition. If the team is missing any of the items the team will not be able to compete, which makes this a non-negotiable budget of $385.

Table 4: Total Budget of the frame.

Item	Cost
Raw Materials	$75
Commercial Parts	$385
Total Bill	$460

Table 4 shows the entire cost of the need materials for the frame is $460. Since there was no exact limitation on the cost to build the frame, this cost is deemed acceptable.

Conclusion

The frame team's task was to design and build a Mini Baja frame that would outperform the last year's baja vehicle. After examining the previous vehicle, and communicating with the client, the team started designing various concepts that would be light in weight but still have a large amount of strength. After the team's time over break, the frame design was reexamined and modified. The modified frame was 10 lbs lighter than the previous design. This new frame was then put through the same testing scenarios and produced similar results, well within safety parameters. The budget for the frame as decreased significantly as well. Industrial Metal Supply donated the tubing which brought the total budge to $460. Next on the team’s time line is to finish fabricating the frame by February 22, 2015.

References

[1] Dr. John Tester

[2] K. Nam-Ho, "Introduction to Finite Element Analysis and Design" 2008, Wiley.

[3] SAE International, "2015 Collegiate Design Series Baja SAE Rules" 2014, 2014.

[4] A. T. Owens, "Structural considerations of a Baja SAE frame," 2006-12-05, 2006.

[5] NAU SAE Baja 2013-2014

[6] http://www.youtube.com/watch?v=gAwVya8AfyM

[7] SAE Design and Analysis Project with SolidWorks Software

[8] SAE Mini Baja Frame Analysis 2013

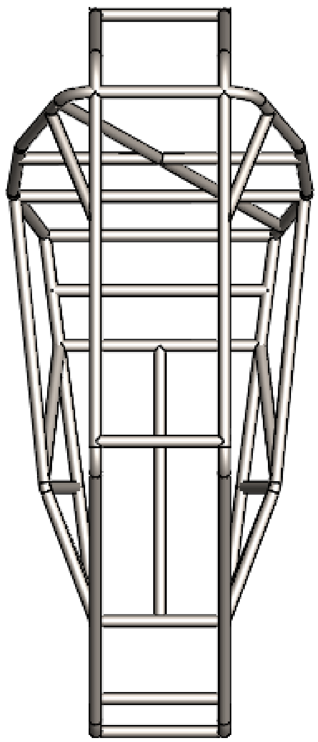
[9]. http://www.superatv.com/Polaris-Ranger-XP-900-6-Lift-Kit-P8182.aspx, access 2014.

[10]. http://socalbajas.com/, access 2014.

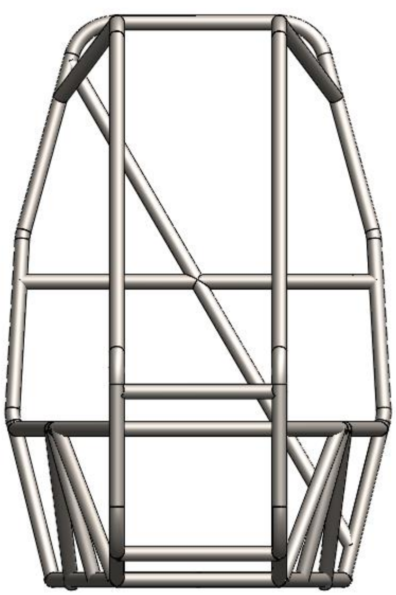
[11]. 2015 Collegiate Design Series Baja SAE Rules

APPENDACIES

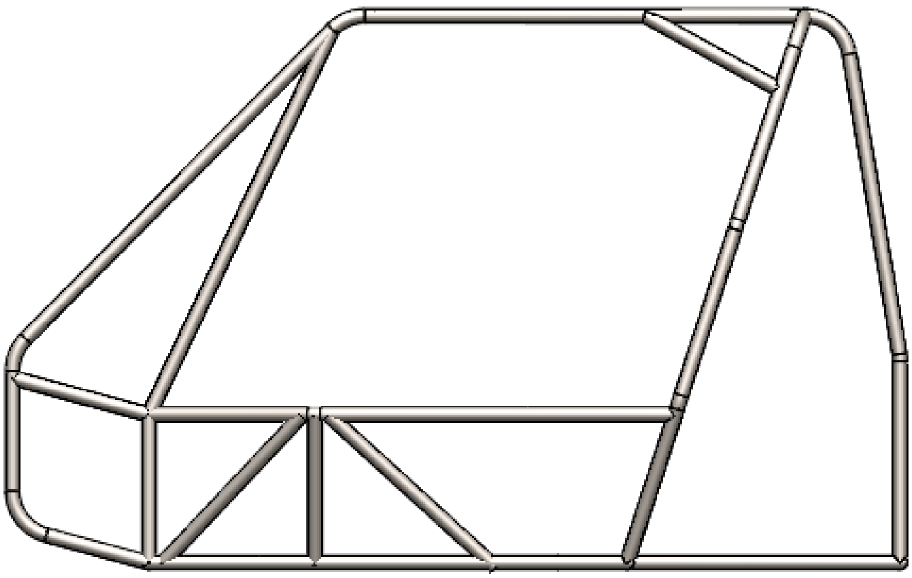
Appendix A: Top View



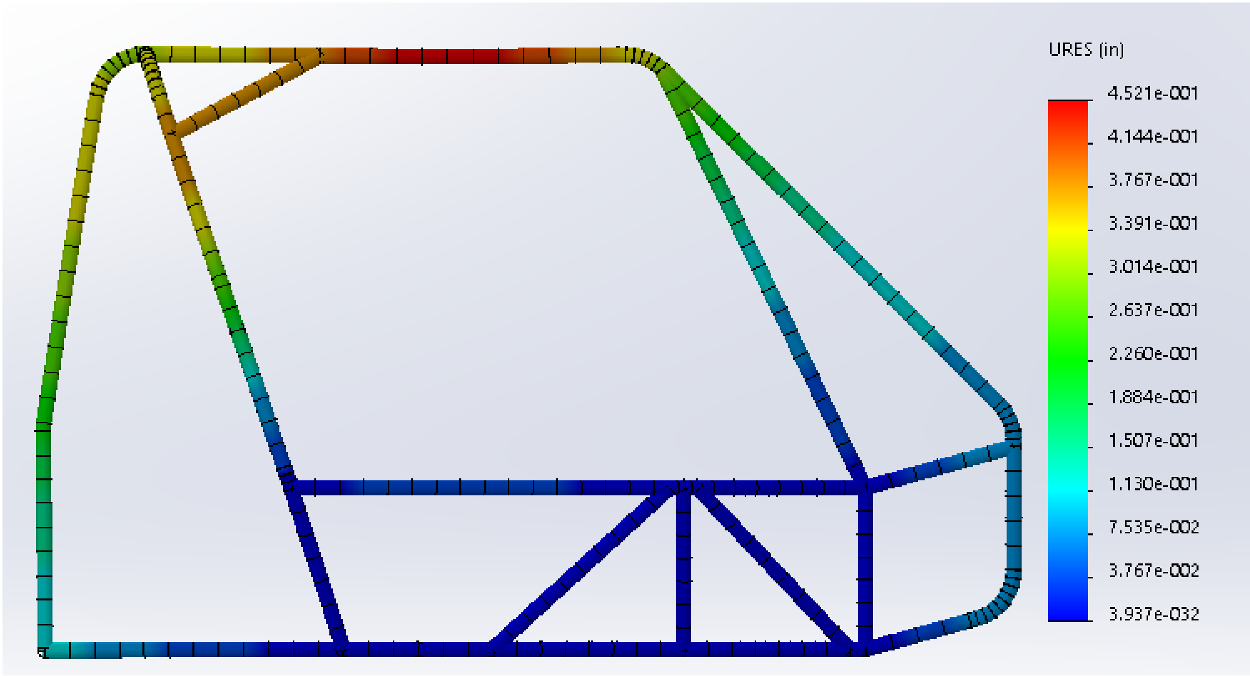
Appendix B: Front View



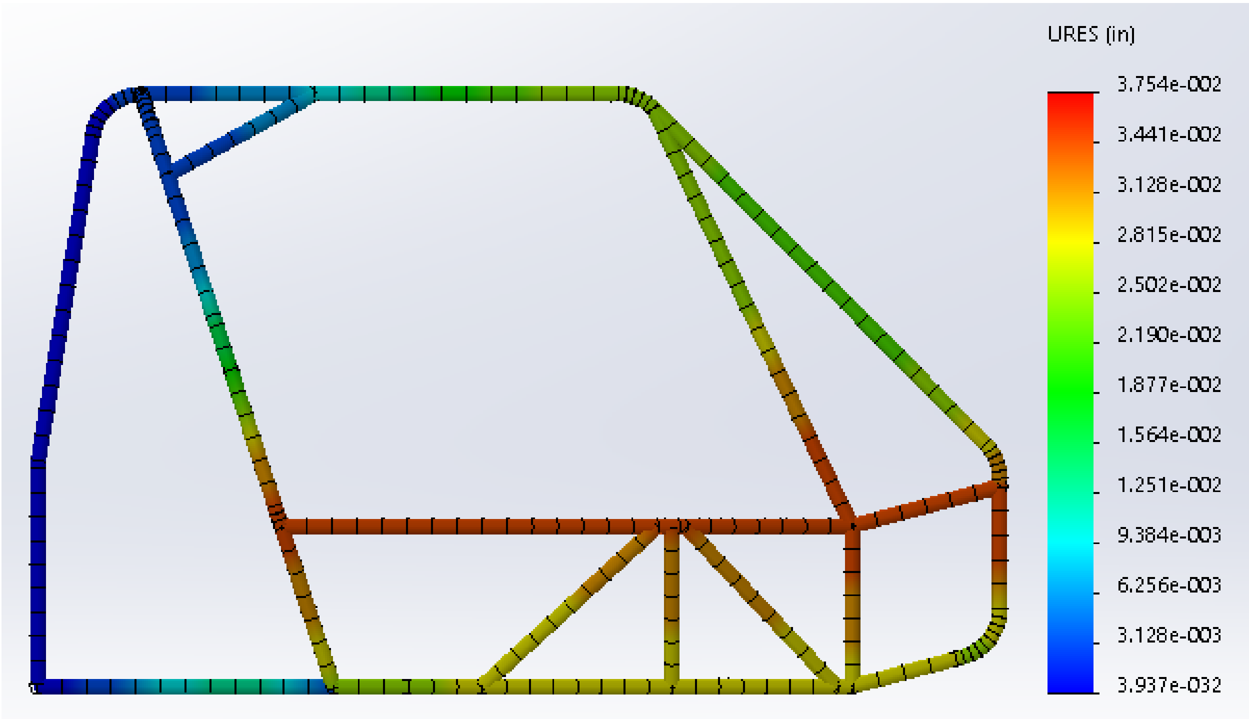
Appendix C: Side View



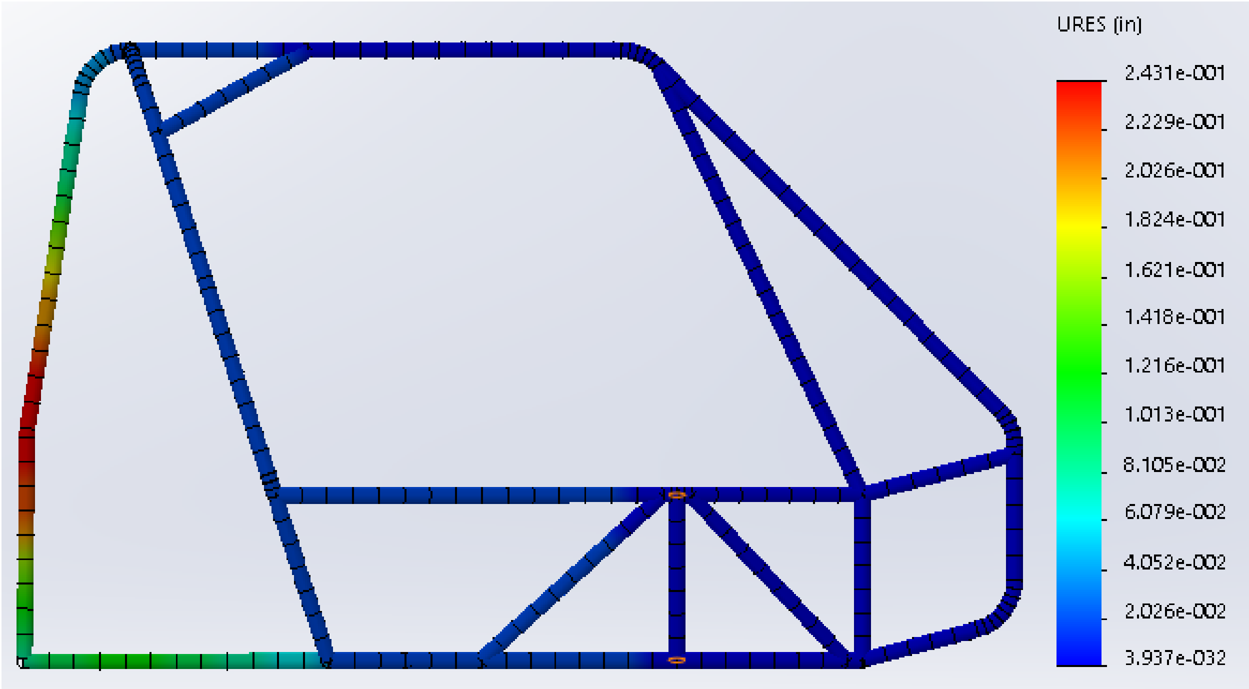
Appendix D: Drop Test Deflection



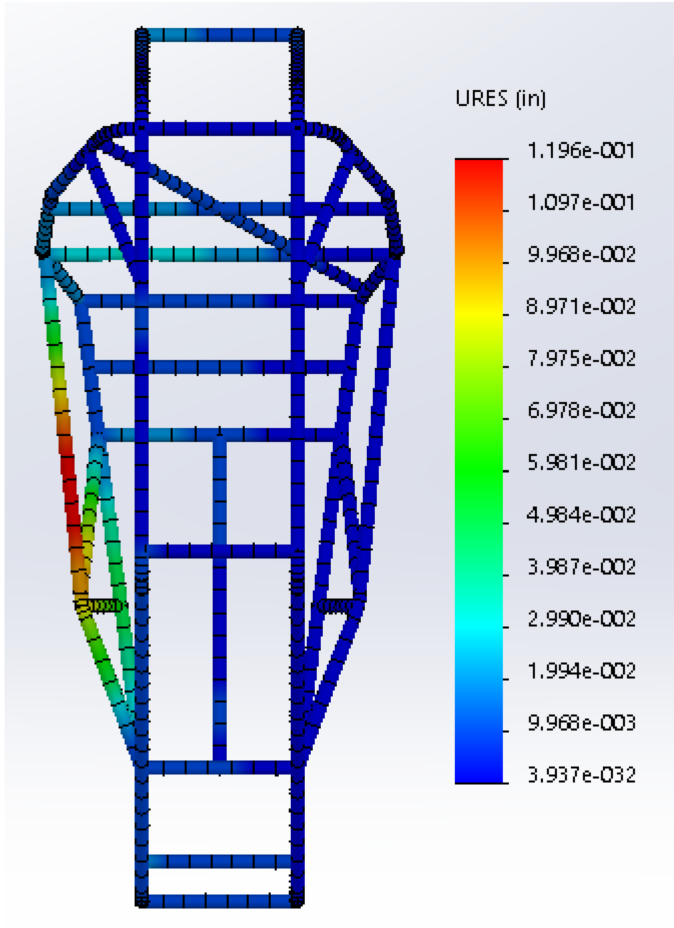
Appendix E: Front Impact Test



Appendix F: Rear Impact Test



Appendix G: Side Impact Test



Side impact ^^^^^