



SEMI-TRAILER BUMPER DESIGN

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Executive Summary

When a car hits a bumper off-center, it has the potential to damage the bumper enough to allow the car to travel underneath the trailer. This is a very dangerous situation for the passengers as they will likely suffer injuries from impact with the trailer. The Insurance Institute for Highway Safety (IIHS) impact tested the top 8 best-selling trailers bumpers at 100, 50, and 30 percent overlap. All trailer bumpers passed the 100 percent overlap test, all but 1 passed the 50 percent overlap test and all but 1 failed the 30 percent overlap test.

Our team's goal is to work together to effectively design, develop, and build the next generation Interstate Commerce Commission (ICC) rear underride guard that meets the National Highway Traffic Safety Administration (NHTSA) standards and pass all IIHS overlap test. The main purpose behind this project is to design a bumper that will prevent a car from under-riding a tractor trailer bumper upon impact. The main motivation behind this project is to prevent fatalities when impacting the rear of a tractor trailer underride guard. Our bumper design will prevent under-riding for 100, 50 and 30 percent offset impacts and absorb impact loads.

Testing of the system will be accomplished in an outdoor environment using sensing and data acquisition systems that can quantify performance from human input to the static and dynamic responses that affect performance of the rear underride guard. The bumper will also be tested through finite element analysis (FEA) to achieve a prediction of real world tests. Team members will apply skills and knowledge they have gained through coursework and experience to solve complex structural and durability challenges of designing a tractor trailer rear underride bumper.

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Introduction

Every year, underride accidents account for fatalities in traffic accidents. Rear underride accidents occur when a passenger vehicle runs under the rear of a straight truck or semi-trailer. This brings an alarming issue that the current standards for underride guards are not sufficient enough to prevent these accidents. Shown in Figure 1 is how a car looks after a rear-end crash with a weak underride guard. This type of crash can result in serious injuries in the head and chest, or even death due to decapitation to the passengers of the vehicle.



Figure 1. A case of underride from a weak underride guard.

National Highway Traffic Safety Administration (NHTSA) has worked with Trucks Involved in Fatal Crashes (TIFA) to determine the severity of these crashes. For the 539 vehicles that struck the rear of the trucks, 532 were fatal. Of those fatalities, 312 of them were due to underride. The death toll on this type of accident is fairly significant. Associations such as Truck Safety Coalition and AnnaLeah and Mary for Truck Safety are bringing awareness to this case [1].

New crash tests and analysis by the Insurance Institute for Highway Safety (IIHS) demonstrates that underride guards on semi-trailers can fail in relatively low speed crashes. They have conducted tests with eight semitrailers including Great Dane, Hyundai, Manac, Stoughton, Strick, Utility, Vanguard and Wabash. Each of these were tested in various percent overlap cases. Overlap is the amount of the front bumper that is in contact with the object. Shown in Figure 2 is an example of a crash test with a 50% overlap. This means that half of the vehicle bumper is in

contact with the underride guard of the trailer. From the tests, all eight semi-trailers passed the 100% full width test. Seven of them passed the 50% overlap test and only one passed the 30% overlap test [2].

Table 1: Summary of the IIHS Semitrailer bumper tests results.

Crash test results for 8 top-selling trailers

	Full-width	50% overlap	30% overlap
Great Dane	pass	pass	fail
Hyundai	pass	pass	fail
Manac	pass	pass	pass
Stoughton	pass	pass	fail
Strick	pass	pass	fail
Utility	pass	pass	fail
Vanguard	pass	fail	n/a
Wabash	pass	pass	fail



Figure 2. A 50% overlap test using a 2010 Chevrolet Malibu.

Virginia Tech Transportation Institute took interest in this case to work towards real life solutions to this problem. The objective of this project is to develop and design a semi-trailer bumper that will prevent underride cases during rear end accidents. Based on the crash tests done by IIHS, this project would like to develop and design a semi-trailer bumper that will stand against 30, 50, and 100% overlap. The design team would like to focus on addressing the cases for 30 and 50% overlap since most of the fatalities occur in those scenarios. The design team will come up with several concepts, down select the concepts addressed, and aim to narrow down to one or two concepts for testing. The goal by the end of April 2016 is to have a concept fabricated and tested for analysis. Then, these findings will be presented to Mr. Jared Bryson.

Target Specifications and Requirements

Before arriving at our target specifications, our team needed to discuss the customer's needs with our sponsor, Jared Bryson, as seen in Table 2. The sole purpose of this design project is vehicle passenger safety. Therefore, safety concerns were one of the most significant customer needs discussed. The topic of safety was broken down into two basic needs: the prevention of under-ride in the event of a rear end collision, and the creation of a deceleration zone to ensure the passengers in the car did not experience severe G-loads. Prevention of underride was a mandatory requirement for this design that could not be overlooked and was the founding need for this design project. The creation of a deceleration zone ensured passenger safety beyond simply the prevention of underride. The added safety value of a deceleration zone would aid in the acceptance of the final design in the trucking industry.

The other general customer need that was stressed by Mr. Bryson was maintaining trailer functionality. The new design could not impede the day to day performance requirements of tractor trailers. Our team broke this general customer need down into three basic needs. The first was trailer axle mobility. Trailer axles can be moved in order to accommodate different loads in the trailer, and this range of mobility could not be affected to an extreme. The second basic need focused on the function of loading and unloading trailers. The customer's request was that the final design did not cause a severe gap between the trailer and trailer loading docks. This would cause extra steps the driver would need to take to unload and load his cargo, therefore creating cause for the industry to ignore the design all together. The final general customer need derived from maintaining trailer functionality was durability. If the bumper design were not durable, it

would require constant maintenance and extra time for care and attention that modern bumpers simply do not. Maintenance of basic trailer functionality would help ensure our design was not cast off as being too complex for implementation in the modern trucking industry.

Table 2: Refined customer needs according to our sponsor's design.

No.	Original Customer Need	Refined Customer Need	Engineering Characteristic	Importance (1-5 Important)
1	Does Not Affect Payload	Weight Conscious Design	Weight, kg	3
2	Aerodynamic	Does not Affect Current MPG Values	Change in MPG	3
3	Low Production Cost	Cost Conscious Design Process and Final Product	Production Cost, US Dollars	2
4	Durable	Does not Fail in Rear End Collision Scenarios	Adequate Factor of Safety	5
5	Weather Resistant	Rust and Corrosion resistant	Reactive Resistant Coating / Steel	1
6	Detachable	Easily Replaceable	Low Assembly Time	1
7	Repairable	Can be weld-repaired	Modularity	2
8	Fits Current Trailers	Bolts in/Welds on the Same Way Current Designs Do	Modularity	2
9	Meet/Exceed Current Performance Standards	Design for Rear End Collisions	Adequate Factor of Safety	5
10	Axle Mobility	Application does not limit adjustability/mobility of axles	% Mobility Lost	4
11	Allows for Common Trailer Use	Does not Interfere with Loading and Unloading	Gap Between Trailer and Loading Dock, cm	4
12	Disperses Load More Efficiently	Crumple Zone	Damping / Deceleration Zone	4

In Table 2, our team generated a set of engineering characteristics based on the customer needs presented by our client, Mr. Bryson. In Table 3, our team created target specifications based on these engineering characteristics. The first column of Table 3, Needs, displays which customer needs each engineering characteristic affects. The Importance column was discussed with our sponsor and he determined the final importance values for each characteristic. The Units column displays the units associated with each characteristic; for example, the units of the first characteristic, weight, will be kilograms in our measurements. The final two columns, Threshold Value and Target Value, are determined from both research and estimation. We researched approximate values based on current products and estimated values based on engineering experience and basic calculation. The Target Value column presents the final values we are trying to achieve. For example, in the first row, in an ideal design, our team would create a bumper with a weight near 40 kilograms. The threshold value is essentially the pass/fail mark for the design. From the first row, if the weight of the trailer bumper is above 100 kilograms, the design is

considered a failure and our team must redesign the bumper. Each value discussed above can be seen in Table 3.

Table 3: Target Specifications table derived from the Customer Needs and Engineering Characteristics.

Need(s)	Engineering Characteristic	Importance	Units	Threshold Value (Needed to Pass)	Target Value (What we're shooting for)
1, 2, 3, 6	Weight	3	kg	100 kg	40 kg
1, 2	% Change in MPG	3	%	≤ 5	≤ 0
3, 7	Production Cost	2	\$(US)	1000	500
4, 9	Factor of Safety	5	Ratio	3	4
4, 5	Non-Reactive	1	List	Low Grade Steel	Non-Reactive Coating & Low Grade Steel
1, 6, 7, 8	Assembly Time	1	Minutes	45	15
8, 10, 11	Modularity	2	# of Trailers Design Fits	1	4
10	% Mobility Lost	4	%	≤ 10	0
11	Gap Between Trailer and Loading Dock	4	cm	5	0
4, 9, 12	Damping/Deceleration Zone	4	cm	5	100

From the table above, it is clear that the general customer needs of vehicle passenger safety and trailer functionality remained the issues of highest importance. With our sponsor in mind, our team therefore set the target values to achieve high standards of performance with the threshold values still surpassing modern designs' standards.

The target specifications were useful in generating numerical goals for our design to meet while also providing a stepping stone in the creation of the project requirements, as seen in Table 4.

Table 4: The requirements based off of the specifications of Table 3.

Requirement	Category	Specification	Threshold Value (Needed to Pass)	Target Value (What we're shooting for)
Payload shall not be affected	Design	Weight	100 kg	40 kg
Gas mileage shall not be affected	Functionality	% Change in MPG	≤ 5	≤ 0
Part shall meet current budget for trucking industry	Manufacturing	Production Cost	\$1000 US	\$500 US
Part shall meet and exceed the maximum allowable load based on material properties	Design	Factor of Safety	3	4
Part shall not corrode or react to road salt/sea air	Design	Non-Reactive	Low Grade Steel	Non-Reactive Coating & Low Grade Steel
Part shall not cause a waiting period for production	Manufacturing	Assembly Time	45 mins	15 mins
Part shall be compatible with common trailers	Functionality	Modularity	Fits 1 Trailer	Fits 4 Trailers
Part shall not interfere with trailer axle functionality	Functionality	% Mobility Lost	≤ 10	0
Loading ability shall not be impeded	Functionality	Gap Between Trailer and Loading Dock	5 cm	0
Part shall absorb at least 20 kJ within the first 125 mm of deflection	Functionality	Damping/Deceleration Zone	5 cm	100 cm

Table 4 displays the relationship between each specification and the requirement associated with that specification. Essentially, a requirement is an explanation of each specification in the form of a command. For example, in row one, the specification is weight; the accompanying requirement for weight is that the payload shall not be affected by the weight of the bumper. This long winded explanation of the specification is written as a goal that must be achieved.

One characteristic of the requirements from Table 4 that is worth noting is that each requirement is written to achieve the target value as opposed to the threshold value. For example, in row two, the requirement states that gas mileage shall not be affected. Our team's target value for percent change in miles per gallon is 0% change. If gas mileage is not affected by the installation of the new bumper, then the percent change in miles per gallon of fuel must be 0%. However, for this design specification, our team has allotted a threshold value of 5% change in fuel efficiency for potential aerodynamic effects. The reason each requirement is written to achieve the target value is that our team must strive to achieve the perfect design with respect to each specification, ensuring the absolute best final product.

Before we could complete the requirements table, though, our team needed to make one final adjustment. The category column is usually determined by the mechanical sub-category each requirement addresses. For example, in an airplane, if the requirement stated that the plane shall produce a certain amount of thrust, the category for that requirement would be the engine, a mechanical sub-category of the airplane. For this project, however, the mechanical sub-category of each requirement was simply the tractor trailer bumper and further simplification could not be conducted. As a team, we decided to sort each requirement into one of three categories: Functionality, Manufacturing, or Design. Although this is not how the category column was originally designed to function, our team and our client both agree that this is the best way to address the issue.

Analysis, Prototyping, Concept generation, and Concept selection

Analysis. In an effort to complete the challenge of developing a rear underride guard that will successfully prevent a deadly collision, the team has considered many different design ideas. One of the more promising ideas is to produce a damping that will create a longer collision time, resulting to a longer stopping distance. This leads to a lesser average force being exerted on the vehicle. In an effort to quantify the impact of damping on force during a collision an equation that relates force to stopping distance can be created. This is done using kinetic energy, shown in equation (1), and work, shown in equation (2) together.

$$KE = \frac{1}{2}mv^2 \quad (1)$$

$$W = Fd \quad (2)$$

Combining equations (1) and (2) and solving for Force (F) gives:

$$F = \frac{(mv^2)}{2d} \quad (3)$$

Where m is mass of the vehicle, v is the initial velocity of the vehicle, and d is the stopping distance of the vehicle.

Once the relationship from equation (3) is established, a vector of stopping distances may be generated and the corresponding forces may be calculated by assuming the weight of a common car (Chevy Malibu) and an initial velocity of 30mph. This relationship can be found in Figure 3.

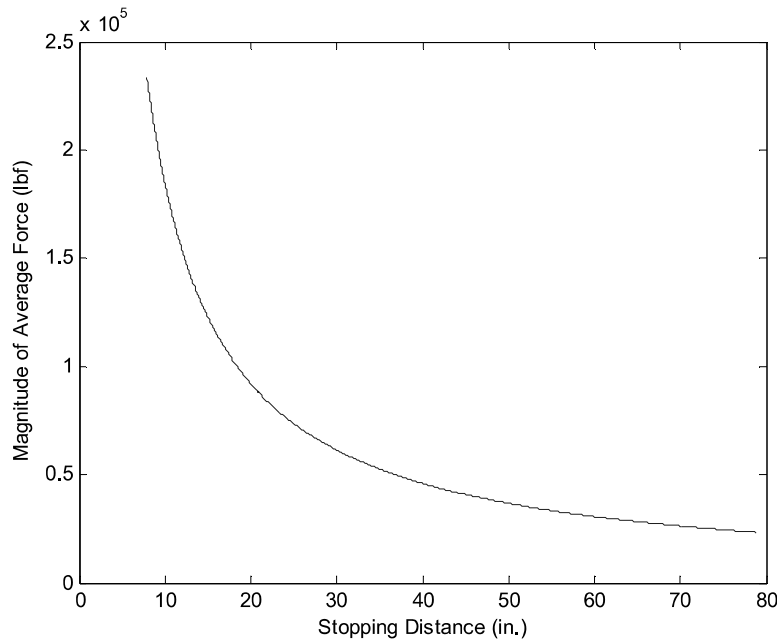


Figure 3. The effect of an increased stopping distance on the force exerted on a vehicle during a collision.

As shown in Figure 3, there is a tremendous impact upon the force as the stopping distance is increased especially if the stopping distance becomes greater than 20 inches. If the stopping distance is increased from 10 to 20 inches, the average force is cut in half. This means that damping is an important design consideration as the concept generation procedure begins.

Another consideration for the design that should be quantified prior to concept generation is the size of the vehicle that will be impacting the rear underride guard. This is critical for the success of this project. An example of this is if the underride guard is designed for a vehicle that has an extremely high curb height, then in the case of a collision with a short curb height the design will most likely fail catastrophically. The team decided to base the design on the most common cars found on American highways. This was found by a report [3] of the top 20 most commonly bought cars in America done by MotorTrend. In addition, a vehicle database [4] was then used to determine the curb height and hood length of each of the cars on the list.

This gave appropriate data for hood length, but left us with results that still must be verified. This will be done by directly measuring several vehicles in an empty lot as soon as the group is able. From this data a probability density function was created for each of the two parameters.

These graphs are shown in Figures 4 and 5, and a table of selected percentages for each graph is available in Appendix A.

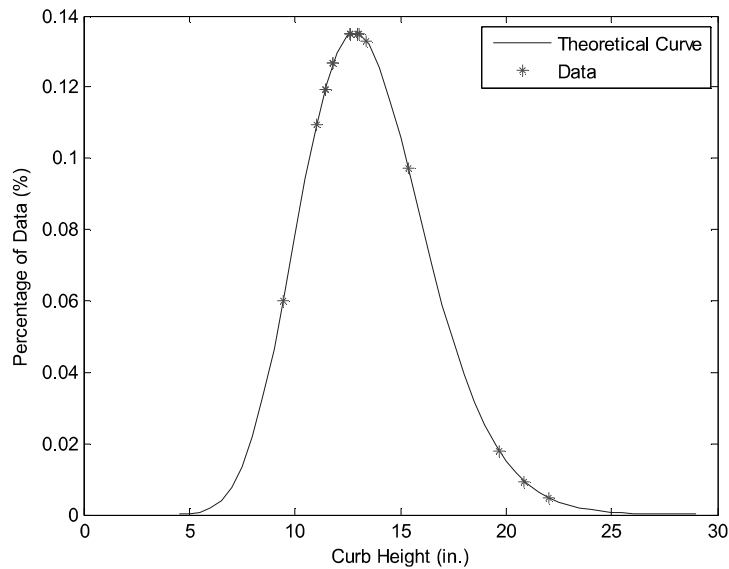


Figure 4. Gamma probability density function of curb height based on the top 20 most commonly bought cars in America. The middle 50% of the data is found between 11.5” and 15.5”. This data is subject to verification.

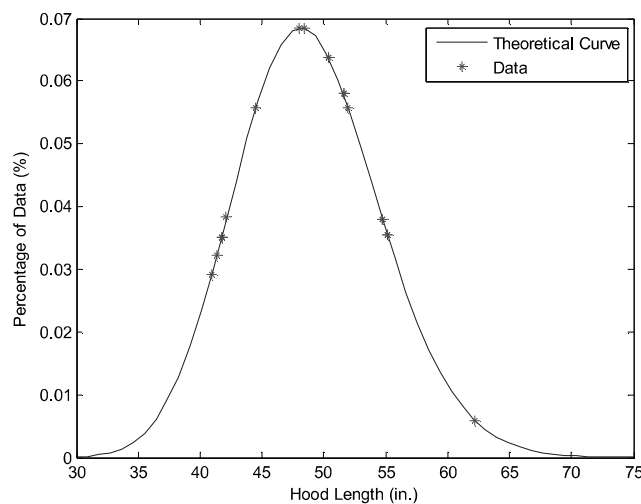


Figure 5. Gamma probability density function of hood length based on the top 20 most commonly bought cars in America. The middle 50% of the data is found between 44.7” and 53”.

Prototyping In an effort to establish a testing method that can be validated the team sought to create 3D renderings of current models. In order to do this the team took a field trip to the Virginia Tech Transportation Institute and measured two guards, the 2016 Wabash and the 2007 Utility. These measurement were then used to create two 3D models using Abaqus 6.14 and the results for the Wabash and Utility trailers are shown in Figure 6 and Figure 7 respectively.

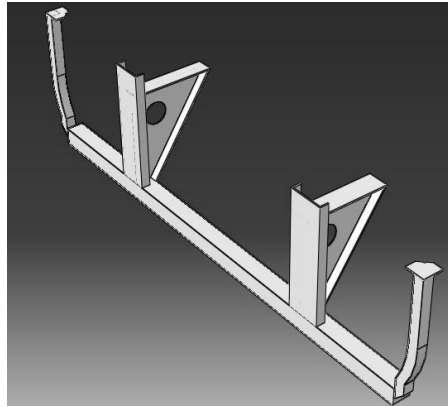


Figure 6. CAD rendering of a 2016 Wabash created using Abaqus. This was rendered from calculations obtained in person on a trailer located at the Virginia Tech Transportation Institute(VTTI).

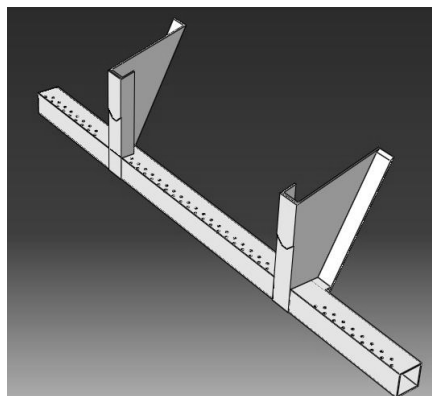


Figure 7. CAD rendering of a 2007 Utility created using Abaqus. This was rendered from calculations obtained in person on a trailer located at the Virginia Tech Transportation Institute (VTTI).

There are a couple of tests that the team would like to perform moving forward onto the next part of this project. First, both models will be statically-loaded with loads corresponding to FMVSS standards 223 and 224. This should help in finding the correct way to constrain the models

for a more accurate testing process. After satisfactory results are found using static methods, the team will try to move onto some dynamic loading. This will be done by replicating tests performed by IIHS for the 30, 50 and 100 percent overlap scenarios. If the team is successful in matching the data from IIHS there is enough evidence to prove that our testing method is one that can be used moving forward.

Concept Generation The concept development process performed by this group was extensive. We accounted for all possibilities and design alterations that could affect the final design using the target specifications created previously from the customer needs and engineering requirements. A series of structured methods were performed to generate ideas towards our final concept.

Initially, a series of brainstorming activities were performed. A 6-3-5 brainstorming method was used to generate the initial ideas. This allowed for all members to have an equal opportunity in the process. This structured brainstorming method led into a more free-for-all brainstorming session where each team member contributed ideas to the group discussion. Once an idea was proposed, team members would build upon it, or discuss it to create more ideas that might branch off of that single idea.

The next brainstorming activity performed was a morphological analysis. The design team considered the overarching functions of the underride guard as well as the target specifications. These functions and specifications were then used to generate sub functions to define the purpose of the design. These sub functions helped in creating concepts specific to each aspect of our design and covering specific functions rather than an overarching goal.

Concept Selection From these concept generation methods, a total of 32 concepts were determined. To down select these concepts into a final concept, a series of selection methods were used. First, a concept screening matrix was used to narrow down the possibilities. Each concept was compared with the determined engineering characteristics. A datum was chosen as the base. Then each concept was compared to that datum in the respective engineering characteristic. If the concepts performed better in that category, the concept was given a 1. If it was similar, it was given a 0. If it was inferior in that engineering characteristic, it was given a -1. These totals were added up and each concept was given a rank. This process was repeated for a different datum to continue to down select. After these iterations, 11 concepts were determined from the original

set. These 11 concepts can be seen in Table 5. These final concepts are the highest ranking concepts involved.

Table 5: Concept screening matrix

	Concepts										
	"+1" support beam	Dampener Support Bumper	Leaf Springs Bumper	Sine/Triangular Support Beam Bumper	Night Rider	Curved Bumper w/ Honeycomb	Retractable Bumper with Shear Webbing	Airbags	Wrap Around Bumper	"+2" Support Beam	Soft/Hard Wall Bumper
Cost	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
% Change MPG	0	0	0	0	0	0	0	0	0	0	0
Weight	0	-1	-1	0	-1	0	-1	0	-1	-1	-1
Factor of Safety	0	1	1	1	1	1	1	-1	1	1	1
Non-Reactive	0	-1	0	0	-1	-1	-1	0	0	0	0
Assembly Time	0	0	-1	0	-1	0	-1	-1	-1	0	-1
Modularity	0	-1	-1	0	0	1	-1	0	-1	0	-1
% Axle Mobility Loss	0	0	0	0	0	0	-1	0	0	0	-1
Gap Between Trailer and Loading Dock	0	0	0	0	0	0	0	0	0	0	0
Deceleration Zone / Damping	0	1	1	1	1	1	1	1	0	0	1
TOTAL	0	-2	-2	1	-2	1	-4	-2	-3	-1	-3

After the concept selection, these 11 concept designs were considered. 2 of the designs were default designs that already exist as shown in Figure 8 and Figure 9. Figure 8 shows the basic 3 support beam guard. It is a common existing design and serves as our basic design. Figure 9 also serves as a fallback design but has 4 support beams. This design also is an existing design in industry. Shown in Table 6, a further down selection was made until 6 concepts remained.

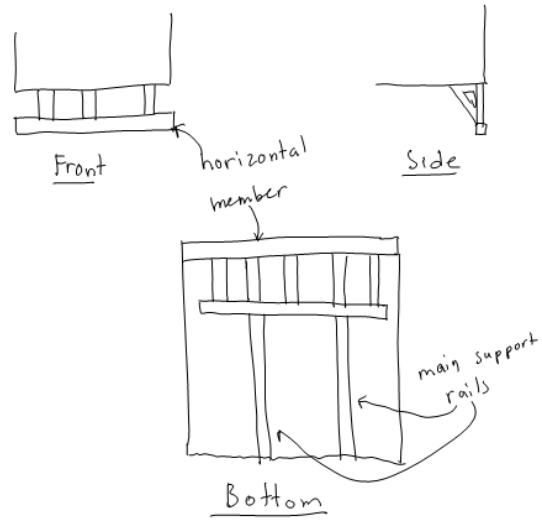


Figure 8. Image showing the design of the 3 support beam bumper

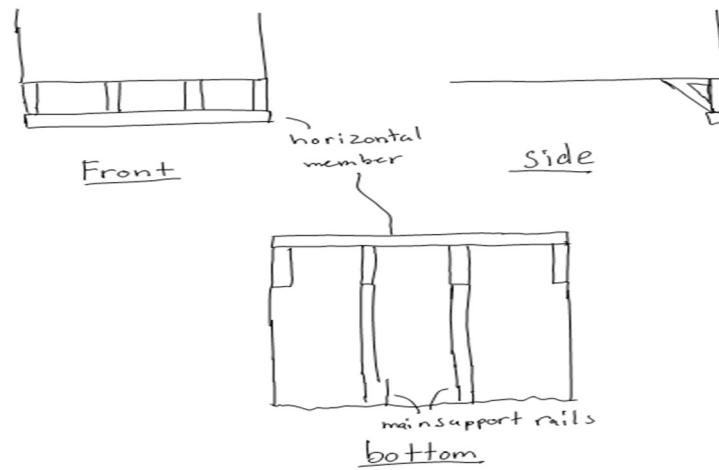


Figure 9. Image showing the design of the underride guard with 2 additional support beams.

Table 6: Refined concept screening matrix

	Concepts					
	Curved Bumper with Honeycomb	Dampener Support Bumper	Sine/Triangular Support Beam Bumper	Night Rider	Wrap Around Bumper	"=2" Support Beam
Cost	0	-1	-1	-1	-1	-1
% Change MPG	0	0	0	0	0	0
Weight	0	-1	0	-1	-1	-1
Factor of Safety	0	1	1	1	1	1
Non-Reactive	0	-1	0	-1	0	0
Assembly Time	0	0	0	-1	-1	0
Modularity	0	-1	0	0	-1	0
% Axle Mobility Loss	0	0	0	0	0	0
Gap Between Trailer and Loading Dock	0	0	0	0	0	0
Deceleration Zone / Damping	0	1	1	1	0	0
TOTAL	0	-2	1	-2	-3	-1

With these final 6 concepts decided, we organized them into 2 categories. The first category represented the concepts that served as a better brick wall. They are simply designed to stop the car, without absorbing impact or trying to reduce the forces upon the car. The second category was the energy absorbing category. This category focused on increasing the stopping distance of the car to reduce the load felt by the driver and car.

In Figure 10, the damper support concept is shown. This design uses a series of dampers to absorb the impact of the car and attempt to stop the car before a complete stop is reached further back on the trailer. The size of the dampers would be rather large and expensive but the possibility of this design and its features are still considered. This concept uses its extent of energy absorption as the primary means of satisfying the engineering requirements.

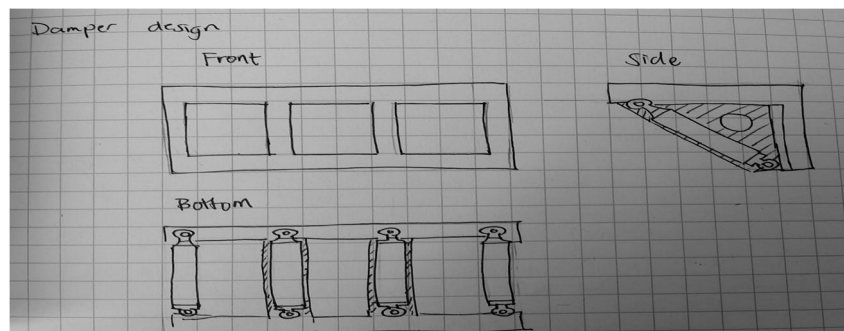


Figure 10. This image shows an orthographic view of the basic design of the damper concept

The next design in the energy absorbing concepts is the honey comb bumper concept. As shown in Figure 11, this design absorbs the energy resulting from the impact of the car by including an energy absorbing material on the outside face of the bumper. This would increase the stopping distance of the car, thus creating less force on the car and bumper.

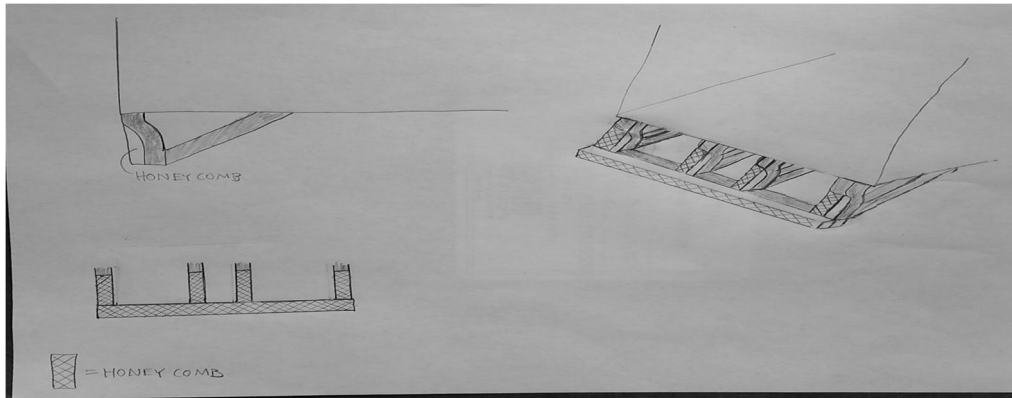


Figure 11. This image is a depiction of both an orthographic and isometric view of the design of the honeycomb absorption bumper.

Shown in Figure 12 is the next energy absorbing concept, the sine beam design. This concept uses either sine beams or triangular prism shaped beams to increase the absorption of the bumper. These shapes of beams allow the compression and deformation of the bumper to be uniform and predictable in every case across all trailers. This allows the design of the bumper to allow maximum absorption of forces without the need to overdesign.

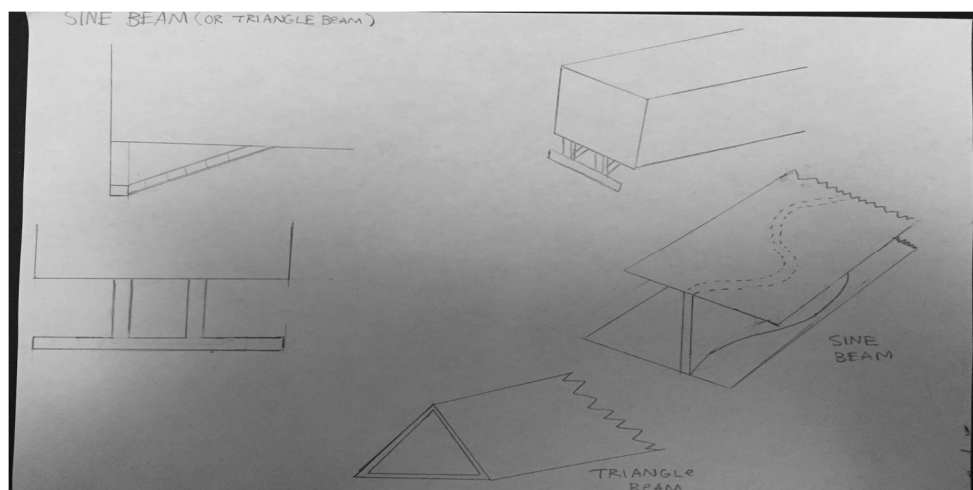


Figure 12. This is an image of the sine beam or triangular beam design showing both orthographic and isometric views.

Figure 13 shows the final concept included in the energy absorption category which is the night rider design. This concept consists of a bottom plate that is mounted underneath the trailer. This serves as a functional catcher's mitt that wedges the car into place. The plate is pulled upward in the vertical direction by a series of chains or cables attached to both the plate and the bottom of the trailer. When the car pushes against these cables, the plate is pulled upward, resulting in the wedging of the car between the plate and the bottom of the trailer.

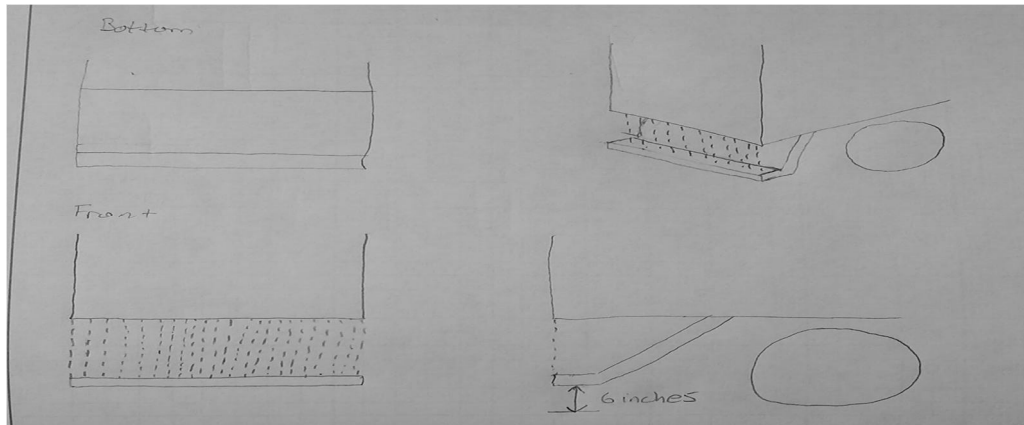


Figure 13. This is an image of the night rider concept showing both orthographic and isometric views

The next series of concepts are part of the category of better brick walls. These concepts completely stop the car without providing damping. These designs prevent underride, but do not attempt to decrease the force seen on the car. The first design is seen in Figure 9. The standard support beam provides a brick wall and is supported by an additional 2 supports to increase strength.

The second design in this category is the wrap around bumper as shown in Figure 14. This design has a full bumper that wraps around to the sides of the trailer. This serves as an underride guard in the instance of a side collision. These side panels also provide support for rear collisions happening with less than 100% overlap.

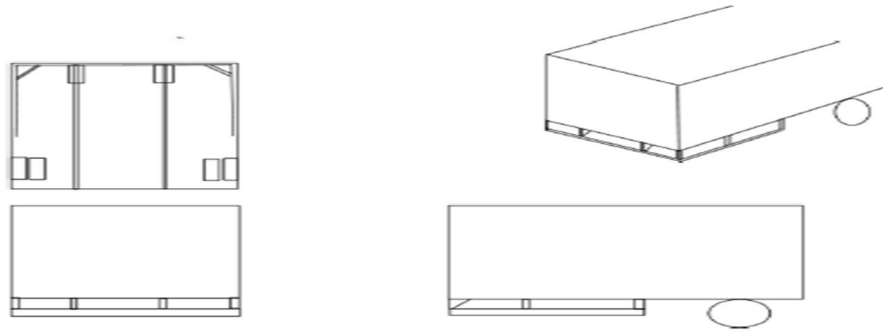


Figure 14. This image is a depiction of both the isometric and orthographic views of the wrap around bumper.

Project Team and Resource Allocation

The structure of our team is broken down into 3 subgroups: CAD, Testing & Analysis, and Manufacturing. The CAD team is responsible for the creation of drawings, determining constraints and CAD models. The Testing & Analysis team is responsible for any finite element analysis, data processing, hand calculations, and does any research that the team may need. The Testing & Analysis group will also be responsible for test preparation, test support, and test execution for any tests the team may execute. The Manufacturing group is responsible for the assembly and fabrication of the tractor-trailer bumper. The Manufacturing group is also in charge of the following: getting quotes from suppliers, obtaining metal or part materials, creating prototypes, requesting funds or sponsorships, project scheduling and finance. The team will also have a Team Facilitator whose main responsibilities are the following: keep all the sub-teams on schedule, directly communicate with the project sponsor and advisor, submit any team assignments, create a supportive environment for all meetings and group interactions, will ensure all team members are held accountable for their task, evenly distribute work, and attend weekly facilitator meetings. The Team Facilitator will have access to all ME 4006 professors, the project sponsor, and the project advisor. The Team Facilitator for this team is Wayne Carter.

The CAD team has access to the following resources: CAD room in Randolph, Abaqus and Autodesk Inventor. The team will use Autodesk Inventor to create all drawings and formal sketches. The team will use Autodesk Inventor & Abaqus to create all 3D CAD models. The following team members will make up the CAD team: Kristine Adriano, Andrew Pitt, and Sean

Gardner. All drawings and CAD models will follow the standard GD&T practices learned in ME 4006.

The Testing and Analysis team will have access to the following resources: Abaqus, MATLAB, LabVIEW, Microsoft Excel, Microsoft PowerPoint, Virginia Tech Transportation Institute (VTTI), Virginia Tech Mechanical Engineering Staff (VTME) and Jared Bryson (our sponsor). The team will use Abacus to create finite element models, execute analysis, and post process the results. The team will use MATLAB, LabVIEW, Microsoft Excel, Microsoft PowerPoint to post process data and present results. The team will utilize VTTI, VTME, and Mr. Jared Bryson for advice and suggestions for analysis set up and execution. The following team members will make up the Testing and Analysis team: Daniel Carrasco, Wayne Carter, Andrew Pitt and Brian Smith.

The Manufacturing team will have access to the following resources: Ware Lab, Applied Lab, Suppliers, on-campus welders, VTTI, Microsoft Project and Microsoft PowerPoint. The team will use the Ware Lab, Applied Lab, On-campus welders and Suppliers to fabricate the tractor trailer bumper. The team can do mocks up and assemble the tractor-trailer bumper at VTTI or at the Applied Lab. The team will use Microsoft Project and Microsoft PowerPoint to convey Project schedule and progress to our project sponsor and advisor. The following team members will make up the Manufacturing team: Kristine Adriano, Daniel Carrasco, Brian Smith and Sean Gardner.

All team members will have access to their personal computer and to other sub-team resources. Each team member can obtain additional roles and responsibilities in other teams if their workload has decreased. Members in other sub-teams can provide assistance to other sub-team members if the help is needed. The distribution of team members within each sub-team may change based upon project schedule, project demand, and team member interests.

The team will have the following test plan and strategy for this project. The CAD team will develop CAD models and drawings of our final concepts. The Testing and Analysis group will take those CAD models and convert them to finite element models. The Testing and Analysis group will then apply appropriate boundary conditions and execute the analysis. After the Testing and Analysis group determines a feasible solution to our problem, the Manufacturing team will create prototypes of our design. Then from the prototypes the team will create final product designs. The goal of our team is to use our final design in an IIHS test facility. The finite element

analysis and the real world testing will determine if our product meets all of our target specifications and requirements.

Schedule

The Senior Design project encompasses a full year. In order to easily visualize what is due throughout the year, a Gantt Chart was developed as shown in Figure 15. The Gantt Chart shows the start date of a task and the end date. It also allows us to schedule tasks in parallel to complete objectives on time. In Appendix B is the entire yearlong schedule represented on the Gantt Chart. It has been broken into several pages due to the size and in depth details of the yearlong project.

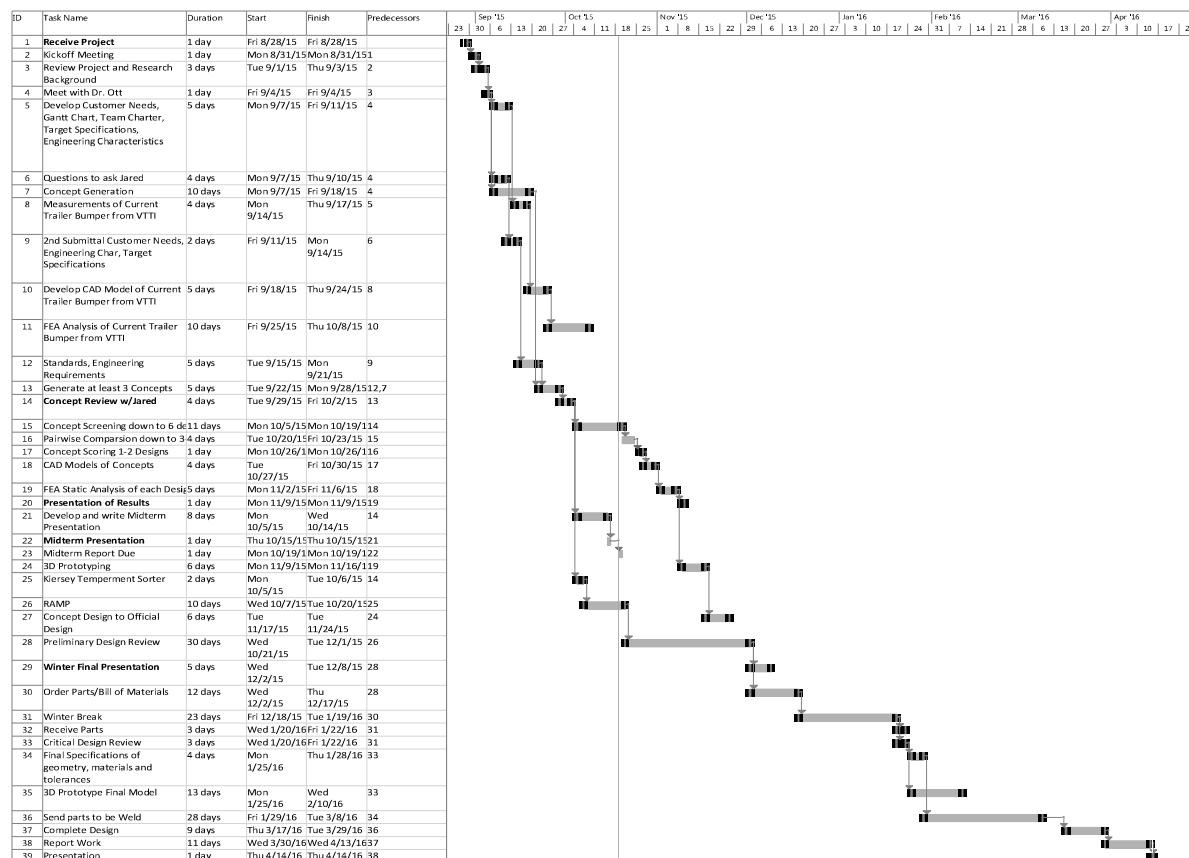


Figure 15. Represents full Gantt chart with graphics to see how one task flows into the next.

The team was assigned the project on August 28, 2015. We have until April 14, 2016 to fully complete the task. Along the way, there will be three checkpoints in terms of midterm presentations and a winter report. Before each midterm, we are scheduled to turn in necessary

details to keep our project running smoothly. The main tasks of each subsection before a midterm are as follows: concept generation before October 19, 2015, concept selection before Winter Break, and then built design before mid-spring semester.

In the month of September we researched our project in depth. We visited the Virginia Tech Transportation Institute to help us further understand the scope of our project and to give us current measurements of bumpers in use today. From the data we collected we began concept generation for a more improved design. While brainstorming concepts, our CAD sub team worked on making a CAD model of the current design used in industry.

In the month of November and December the team will begin to further down select our current concepts to 1-2 official designs. We will also begin Finite Element Analysis of the current trailer bumpers used in industry. Once we have our official designs we will model them in CAD and begin FEA analysis to determine the best concept.

Towards the end of December, we hope to 3D print our two concepts. This 3D print will allow us to show and explain our design easily. We will also need to determine what materials we should order. Lastly, the winter presentation is also presented at this time.

For the spring semester, the team needs to finalize the specifications and tolerances of the design. We will need to develop a plan on how to build the concept as well. Then, the parts and instructions will be sent to a professional welder for manufacture. While we wait on the design to be built, we will begin gathering all the information from the project and compiling it into a report. Once our design is built, we hope to contact the National Highway Transportation Safety Administration and inform them of our progress with the hopes of the Administration sponsoring a full test of our design.

Budget

The following table shows the estimated budget for the school year. As the project is to build a bumper to withstand the impact of a car the cost to do so is large. The purchase of steel will become a habit.

Table 7: Semitrailer Bumper Budget for 2015-2016 Year

Starting Funds	
Mechanical Engineering Senior Design Start Money	\$0
Income	
Grant Request	\$3000
Company Sponsorship	TBD
Expenses	
Direct Labor	\$950
Equipment & Materials	\$2000
Miscellaneous	\$50
Subtotal -	\$3000
Total	\$0

Table 7 shows that we currently have \$0 at our disposal for this project. The main source of income for this year will be banked on getting the full amount from the Grant Proposal Request. The team will also try contacting main truck manufacturing companies and explaining the goal of our project to them. We hope that they will see that our project will be of great benefit to the community and that they would like their name involved for good press. We will also try to contact charities and organizations that support highway safety efforts. As they are already looking for ways to increase safety on the highway with semitrailers, discussing our project description with them they may feel compelled to donate money to our team.

The expenses for the project mostly fall under the equipment and material that will be needed to assemble our design. As the bumper needs to withstand a car impact we need material that will be able to compete with the force a car delivers. Some variation of steel will be used heavily for our project. The unique concept of our designs call for special modifications to the standard design which will also give a larger increase in cost. The next highest cost will be the direct labor. To assemble our design we need to weld the steel together. The team does not have a certified welder, so we will have to outsource to local welders. We believe that this may cost anywhere from \$50-100/hour. Lastly the cost of miscellaneous items will be gloves, safety glasses, and tools needed for use in the Applied Lab as we work on making a small prototype of

our design. Grant proposal information has yet to be released so we do not know how much money we have to work with. However we look to start buying materials toward the end of the semester so we should have plenty of time to decide on expenses till then.

References

- [1] "Heavy-Vehicle Crash Data Collection and Analysis to Characterize Rear and Side Underride and Front Override in Fatal Truck Crashes." DOT HS 811 725, March 2013.
<http://www.nhtsa.gov/DOT/NHTSA/NVS/Crashworthiness/Truck%20Underride/811725.pdf>
- [2] "Not good enough: Underride guards on big rigs can be lifesavers, but most leave passenger vehicle occupants at risk in certain crashes." IIHS Status Report, Vol. 48, No. 2.
Insurance Institute for Highway Safety.
- [3] Stewart, M., 2014, "Top 20 Most Popular Cars in the US.", from
<http://beta.motortrend.com/auto-news/>
- [4] "Vehicle Specs Database." Vehicle Specs Database. Aras360, FARO Technologies, 2014
2015 Published. Web. October 12, 2015 Accessed.

APPENDIX

Appendix A: Table of Percentages for Vehicle Characteristics

Curb Height	Percentage of Data	Hood Length	Percentage of Data
4.5	0	30	0.01
5	0.01	30.9	0.02
5.5	0.03	31.8	0.05
6	0.09	32.8	0.1
6.5	0.22	33.7	0.2
7	0.5	34.6	0.37
7.5	1.01	35.5	0.66
8	1.88	36.4	1.11
8.5	3.23	37.3	1.79
9	5.2	38.3	2.79
9.5	7.9	39.2	4.18
10	11.4	40.1	6.06
10.5	15.73	41	8.5
11	20.82	41.9	11.56
11.5	26.59	42.9	15.27
12	32.88	43.8	19.62
12.5	39.49	44.7	24.58
13	46.24	45.6	30.06
13.5	52.93	46.5	35.94
14	59.37	47.4	42.11
14.5	65.43	48.4	48.38
15	71	49.3	54.62
15.5	76	50.2	60.68
16	80.39	51.1	66.41
16.5	84.19	52	71.73
17	87.41	53	76.55
17.5	90.1	53.9	80.83
18	92.3	54.8	84.56
18.5	94.08	55.7	87.74
19	95.49	56.6	90.4
19.5	96.61	57.6	92.59
20	97.47	58.5	94.36
20.5	98.13	59.4	95.77
21	98.64	60.3	96.86

21.5	99.01	61.2	97.71
22	99.29	62.1	98.35
22.5	99.49	63.1	98.82
23	99.64	64	99.17
23.5	99.75	64.9	99.42
24	99.83	65.8	99.6
24.5	99.88	66.7	99.73
25	99.92	67.7	99.82
25.5	99.94	68.6	99.88
26	99.96	69.5	99.92
26.5	99.97	70.4	99.95
27	99.98	71.3	99.97
27.5	99.99	72.2	99.98
28	99.99	73.2	99.99
28.5	99.99	74.1	99.99
29	100	75	99.99

Appendix B: The table represents the tasks that are listed on the Gantt Chart. The expected duration of each event is listed. The predecessor column means that to start the listed task the previous task has to be completed.

Task Name	Duration	Start	Finish	Predecessors
Receive Project	1 day	Fri 8/28/15	Fri 8/28/15	
Kickoff Meeting	1 day	Mon 8/31/15	Mon 8/31/15	1
Review Project and Research Background	3 days	Tue 9/1/15	Thu 9/3/15	2
Meet with Dr. Ott	1 day	Fri 9/4/15	Fri 9/4/15	3
Develop Customer Needs, Gantt Chart, Team Charter, Target Specifications, Engineering Characteristics	5 days	Mon 9/7/15	Fri 9/11/15	4
Questions to ask Jared	4 days	Mon 9/7/15	Thu 9/10/15	4
Concept Generation	10 days	Mon 9/7/15	Fri 9/18/15	4
Measurements of Current Trailer Bumper from VTTI	4 days	Mon 9/14/15	Thu 9/17/15	5
2nd Submittal Customer Needs, Engineering Char, Target Specifications	2 days	Fri 9/11/15	Mon 9/14/15	6
Develop CAD Model of Current Trailer Bumper from VTTI	5 days	Fri 9/18/15	Thu 9/24/15	8
FEA Analysis of Current Trailer Bumper from VTTI	10 days	Fri 9/25/15	Thu 10/8/15	10
Standards, Engineering Requirements	5 days	Tue 9/15/15	Mon 9/21/15	9
Generate at least 3 Concepts	5 days	Tue 9/22/15	Mon 9/28/15	12,7
Concept Review w/Jared	4 days	Tue 9/29/15	Fri 10/2/15	13

Concept Screening down to 6 designs	11 days	Mon 10/5/15	Mon 10/19/15	14
Pairwise Comparison down to 3-4 Designs	4 days	Tue 10/20/15	Fri 10/23/15	15
Concept Scoring 1-2 Designs	1 day	Mon 10/26/15	Mon 10/26/15	16
CAD Models of Concepts	4 days	Tue 10/27/15	Fri 10/30/15	17
FEA Static Analysis of each Design	5 days	Mon 11/2/15	Fri 11/6/15	18
Presentation of Results	1 day	Mon 11/9/15	Mon 11/9/15	19
Develop and write Midterm Presentation	8 days	Mon 10/5/15	Wed 10/14/15	14
Midterm Presentation	1 day	Thu 10/15/15	Thu 10/15/15	21
Midterm Report Due	1 day	Mon 10/19/15	Mon 10/19/15	22
3D Prototyping	6 days	Mon 11/9/15	Mon 11/16/15	19
Kiersey Temperament Sorter	2 days	Mon 10/5/15	Tue 10/6/15	14
RAMP	10 days	Wed 10/7/15	Tue 10/20/15	25
Concept Design to Official Design	6 days	Tue 11/17/15	Tue 11/24/15	24
Preliminary Design Review	30 days	Wed 10/21/15	Tue 12/1/15	26
Winter Final Presentation	5 days	Wed 12/2/15	Tue 12/8/15	28
Order Parts/Bill of Materials	12 days	Wed 12/2/15	Thu 12/17/15	28

Winter Break	23 days	Fri 12/18/15	Tue 1/19/16	30
Receive Parts	3 days	Wed 1/20/16	Fri 1/22/16	31
Critical Design Review	3 days	Wed 1/20/16	Fri 1/22/16	31
Final Specifications of geometry, materials and tolerances	4 days	Mon 1/25/16	Thu 1/28/16	33
3D Prototype Final Model	13 days	Mon 1/25/16	Wed 2/10/16	33
Send parts to be Weld	28 days	Fri 1/29/16	Tue 3/8/16	34
Complete Design	9 days	Thu 3/17/16	Tue 3/29/16	36
Report Work	11 days	Wed 3/30/16	Wed 4/13/16	37
Presentation	1 day	Thu 4/14/16	Thu 4/14/16	38