# Basic Utility Vehicle (BUV)
# Team

A Baccalaureate thesis submitted to the
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Bachelor of Science

in Mechanical Engineering Technology

by

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# ACKNOWLEDGMENTS

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# ABSTRACT

Third world countries, such as Afghanistan or Ethiopia, possess a high demand for low cost, reliable transportation and for 16 years the Institute of Affordable Transportation has acknowledged those needs. Since 2001, the Institute of Affordable Transportation (IAT) has held an annual Basic Utility Vehicle competition. This competition consists of inspired college students from across the nation who are motivated in improving transportation in under privileged countries (1). The vehicle must be able to transport heavy loads and be fabricated and maintained at low costs (1). For 2017, our selected country is Haiti.

The University of Cincinnati has an option for seniors in the College of Engineering to be a part of this experience. This year's Basic Utility Vehicle (BUV) team consists of 5 seniors; Bethany Nickson, Dickson Opoku, Christopher Steward, Deamann Strefas, and Guanchun Ye. Each team member manages a key component within the BUV. This report covers the Frame and Chassis component of the Basic Utility Vehicle, written by Bethany Nickson.

This in-depth report will cover Project Management, Research, Design Phase, Fabrication, Assembly, Testing, and Product Performance. Project Management will showcase team member responsibilities, scheduling, and budgeting. The research will explain background information, parameters, and IAT BUV competition specifications. In the Design Phase, multiple concepts will be measured, 1 will be selected, and simulation tests will be run to help improve modifications. Fabrication and Assembly will show the teams manufacturing processes. Lastly, Testing and Performance will bring the report to a conclusion and reveal its efficiency and how it performed in the competition.

In the end, the BUV did not finish the competition. Initially, the vehicle had issues starting. After those issues were resolved and fixed, the BUV made it about halfway through the first lap before it got stuck in mud. Soon after, the front wheel popped out. From this point we never recovered and had to end the race early.

# INTRODUCTION

## *PROBLEM STATEMENT*

Every year since 2001 the Institute of Affordable Transportation (IAT) has held a Basic Utility Vehicle (BUV) competition. IAT is a non-profit organization located in Indianapolis, IN that is devoted to developing high-quality, low-cost transportation. The BUV should be developed to provide a durable, low cost vehicle that can be built and maintained in a third world country (1). The vehicle is designed for mobility, to transport people, water, and various other materials. The vehicle should be suitable for farming and operating in areas without roads. The design should be in kit form and should be able to assemble with ease (1). Regulations for competition are given on the spec sheet provided by the Institute of Affordable Transportation. The vehicle is to be ready for competition around April 2017.

We have delegated responsibilities for this project, however, we will be working closely as a team and that includes sharing ideas and supporting roles. I am responsible for the frame and chassis components. We are working closely with Professor David Conrad on every step of this project to ensure that we meet our time and design goals.

## *RESEARCH & BACKGROUND*

Figure 2: Current BUV in Production

Figure 1: First IAT BUV Competition Winner (2001)

Over the past 16 years there have been various designs in the Basic Utility Vehicle Competition hosted by IAT. The more recent submissions have yielded the best performances. In regard to the frame, the chassis has been showcased as a 4-wheel design and later transformed to a 3-wheel design. I received information from previous BUV competition teams and the BUV Club at UC and designs of past competition winners.

In 2012, Purdue University came in 1st place at the IAT BUV Competition. The materials they used were mostly wood and angle iron. This made their BUV lighter in weight which would help to increase their overall speed (2). Since then, many teams have used angle iron for the chassis.

Figure 3: Purdue BUV (2012, 1st Place Winners)

Also, in 2012, UC's BUV team used a small truck frame with a custom front end. We are aware that the weight of the vehicle is crucial to the overall performance and efficiency. My focus is aimed at designing the front-end chassis with angle iron that is low in weight with high in strength. This will in return increase the overall speed, lower costs, and increase efficiency.

Figure 4: UC BUV (2012, 2nd Place Winners)

In 2013, the Senior Project BUV team proved their innovative and creative skill set by coming in 3rd place at the competition. A few of their technical specifications include an angled Iron frame and a

2000-pound payload. The use of wood and angle Iron helped to reduce the cost and weight of the BUV (2). They recommend that future groups continue using the frame, chassis, truss design, and angle Iron for future models (2). Problems they encountered were a broken PVC barrel rotating out of place and front design of the suspension wasn't fit for a 3ft drop (3). They also suggested that future teams secure barrels before working on irrigation system and design the front suspension.

## *CUSTOMER PROFILE*

The 2017 UC BUV team is focusing on improving items such as good gas mileage, hauling capacity/cargo capacity, ability to handle rough terrain, and ease of maintenance. We are designing our BUV to be affordable (less than $6500), durable (automotive parts), and utilizing (power pump, mill, compressor etc.).

## *CUSTOMER FEATURES*

Our main goal of the BUV Team is to develop a durable, low cost vehicle that can be built and maintained in a third world country. We must keep in mind that this vehicle will be used for transporting water and cargo, used in off road conditions, and have at least a 10-year life expectancy. We are developing our BUV to be shipped in the form of a kit and easily maintained over time.

## *COMPETITION GUIDELINES & EVENTS*

The 2017 IAT BUV Competition will be held on Friday & Saturday April 21st and 22nd at 2630 Herold Road in Batavia OH. Teams will be competing to finish an obstacle course where they must transport up to 150 gallons of water. This will be done by pumping pond water into vehicle irrigation system, carrying it for 3 full laps on a 2.2-mile course, and dumping and refilling back at the pond. This cycle will carry on for 7 hours (1).

*See full IAT BUV Specifications in Appendix...*

## PRODUCT OBJECTIVES

In late April, we will test how well our BUV performs in the 2017 BUV Competition. During the 7-hour contest, the BUVs will run through an obstacle course in off-road conditions transporting water. Throughout our design, we will implement a variety of ways to improve past designs and effectively implement safety, easy maneuverability, comfort, quick and easy maintenance, and reliability.

Table 1: Customer Features & Importance Ratings

| | **Customer Feature** | **Customer Importance Rating** |
|---|---|---|
| **1** | Reliability | 0.25 |
| **2** | Price | 0.15 |
| **3** | Cargo Space | 0.15 |
| **4** | Easy Maintenance | 0.15 |
| **5** | Easy Assembly | 0.10 |
| **6** | Safety | 0.08 |
| **7** | Maneuverability | 0.07 |
| **8** | Other Capabilities (towing, etc.) | 0.05 |

## PROJECT MANAGEMENT

### *TEAM RESPONSIBILITIES:*

Deamann Strefas: Irrigation System

Christopher Steward: Powertrain / Drive Train

Bethany Nickson: Frame / Chassis

Dickson Opoku: Suspension

Guanchun Ye: Brakes System

## *SCHEDULE:*

Table 2: Schedule

| **Task** | **Project Date** | **Actual Date** |
|---|---|---|
| Design Agreement | 10/5/2016 | 10/5/2016 |
| Separation of Duties | 11/9/2016 | 11/9/2016 |
| Bill of Materials (BOM) | 11/18/2016 | 12/18/2016 |
| Design Phase | 12/14/2016 – 2/12/2017 | 12/14/2016 – 2/24/2017 |
| Oral Presentation | 2/13/2017 | 2/13/2017 |
| Design Modification | 2/13/2017 - 2/20/2017 | 2/13/2017 - 2/27/2017 |
| Fabrication | 2/13/2017 – 3/20/2017 | 2/27/2017 – 4/20/2017 |
| Testing | 3/13/2017 – 3/27/2017 | 4/3/2017 – 4/21/2017 |
| Modifications | 3/27/2017 – 4/3/2017 | 4/4/2017 – 4/20/2017 |
| Final Testing | 4/1/2017 - 4/6/2017 | 4/21/2017 |
| Tech. Expo | 4/7/2017 | 4/6/2017 |
| Final Presentation | 4/14/2017 | 4/14/2017 |
| BUV Competition | 4/22/2017 | 4/22/2017 |

## *BUDGET:*

Table 3: Budget

| | Estimated Cost | Actual Cost |
|---|---|---|
| Frame / Chassis | $220.00 | $454.54 |
| Braking | $200.00 | $164.40 |
| Suspension | $160.54 | $392.82 |
| Drivetrain | $350.00 | $314.17 |
| Irrigation | $161.01 | $22.92 |
| Assembly Tooling | Free | N/A |
| Others / Miscellaneous | $100.00 | $206.55 |
| | Total = $1,091.55 | $1,555.40 |

## DESIGN MANAGEMENT

Before designing concepts for the chassis, it is important to recollect important factors in its final production and performance and consider the recommendations of previous teams. During this phase, I considered the cost to build, ease of fabrication, durability, and ground clearance. As noted before, past teams have come to use angle iron steel with A36 grade steel. It is also important to consider how the chassis is assembled to the frame. We have decided to use a 1994 Chevrolet s10 truck from U-Pull & Pay (4). The s10 frame is versatile and can work with many chassis designs. However, for these concepts, I kept the back end simple and consistent.

### *CONCEPT 1: UC BUV 2013 DESIGN*

Concept 1 has a similar style to the UC BUV chassis of 2013. It is made from 2x2x1/8-inch angle iron steel, which differs from the 1x1x1/8-inch angle iron used in 2013, to obtain durability. My design also differs in height to create more ground clearance and offers more vertical strength.

**Pros:**

- Lightweight
- Standard Manufacturing
- Less Material
- Good Ground Clearance

**Cons:**

- Lots of Welding
- Low Strength & Durability

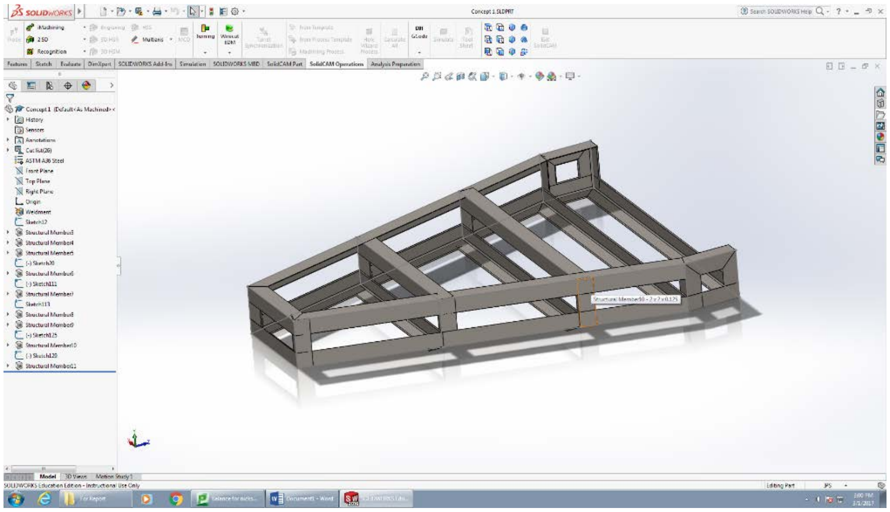


Figure 5: Concept 1 – UC BUV 2013 Design

## CONCEPT 2: WARREN TRUSS DESIGN

A recommendation from the Institute of Affordable Transportation was to incorporate truss design on to the chassis. For concept 2 I attempted to replicate the warren truss design. The side beams are equilateral triangles which would make material simple to cut for fabrication and give the chassis a great deal of vertical strength (5). It is made from 2x2x1/8-inch angle iron steel to obtain durability and has a sleek sloping front design.

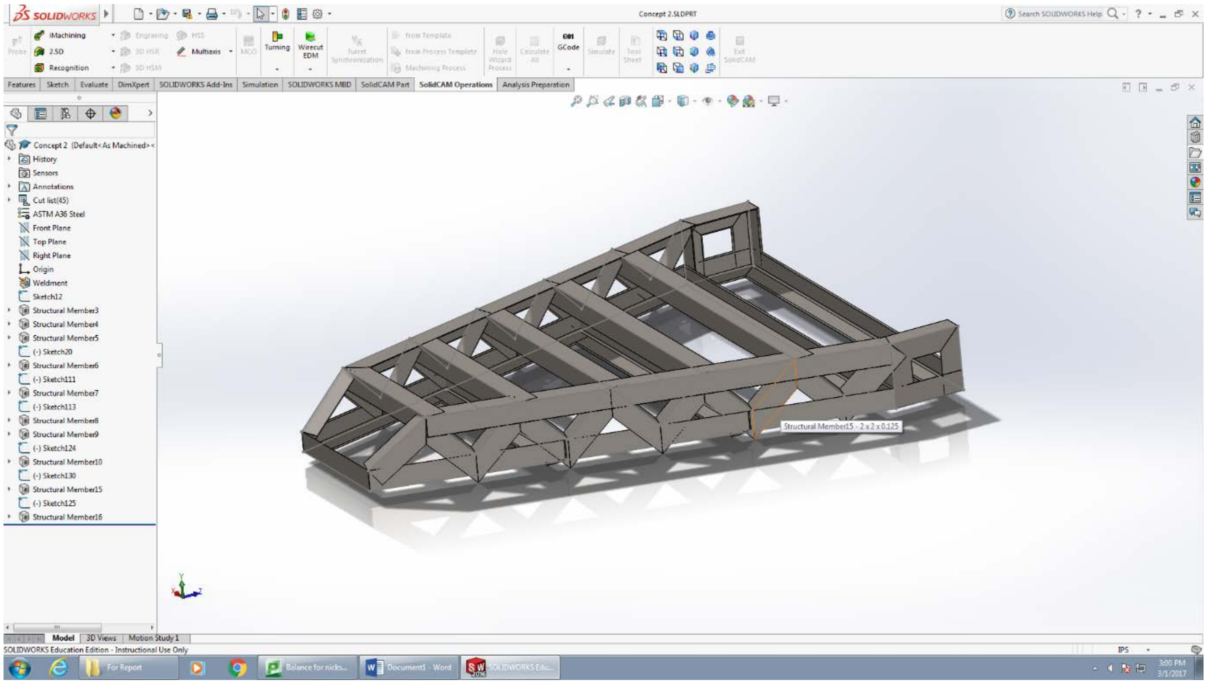


Figure 6: Concept 2 – Warren Truss Design

**Pros:**

- Lightweight
- Standard Manufacturing
- Strength & Durability
- Good Ground Clearance

**Cons:**

- Lots of Welding
- Lots of Material

## CONCEPT 3: HOWE TRUSS DESIGN

Along with the warren truss, many other truss designs were taken into consideration. For concept 2 I attempted to replicate the Howe truss design. The side beams are triangles which gravitate inward toward the center of the chassis (5). This pattern would give the chassis high levels of vertical strength, but would be very hard to work with during the fabrication stage. It is also made from 2x2x1/8-inch angle iron steel to obtain durability and has a sleek sloping front design.

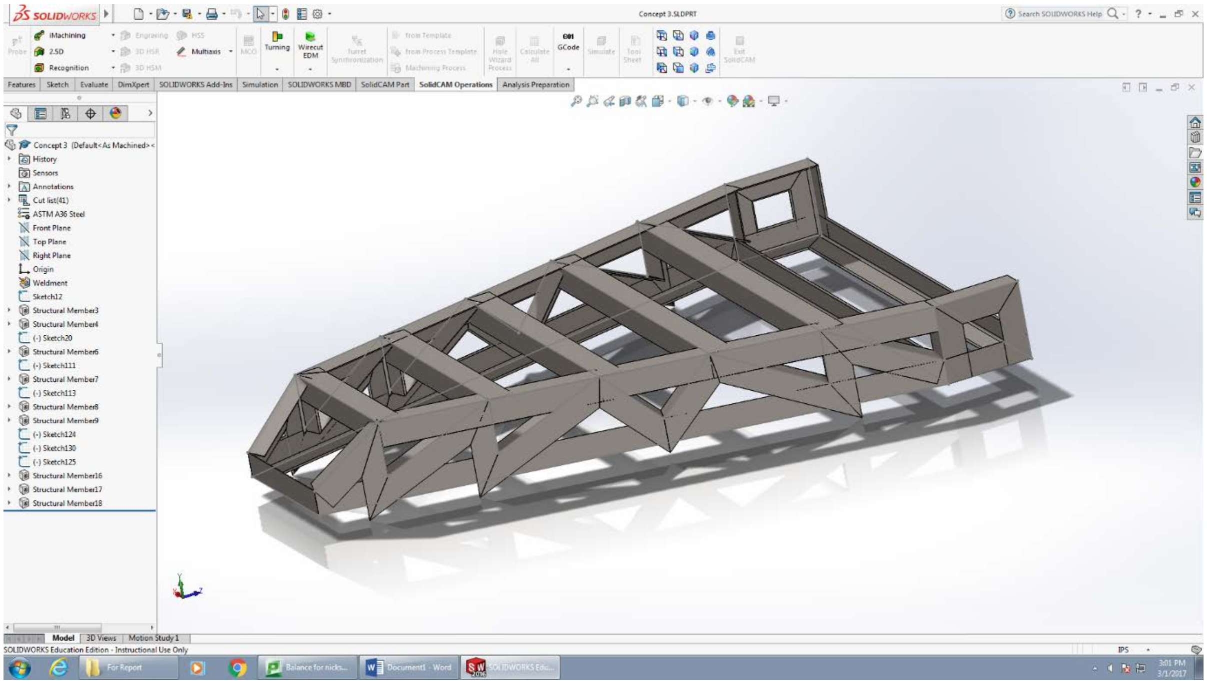


Figure 7: Concept 3 – Howe Truss Design

**Pros:**

- Lightweight
- Strength & Durability
- Good Ground Clearance

**Cons:**

- Lots of Welding
- Lots of Material
- Multiple Size Members, Complex Manufacturing

## *CONCEPT SELECTION:*

To come to a final decision for the front chassis, we used the weighted decision matrix. In the first column, there are criteria associated to vehicle performance and were mentioned as pros and cons throughout the conceptual phase. The 2 second column gives a weighted rating percentage to each criterion. The 3rd, 5th, and 7th columns give a rating of 0-4 on how well they met the criterion. The weights in the 4th, 6th, and 8th columns were then calculated to find the best alternative for the chassis design.

Table 4: Weighted Decision Matrix

| **Criteria** | **Weight %** | **Standard Design** | **Weight %** | **Warren Truss Design** | **Weight %** | **Howe Truss Design** | **Weight %** |
|---|---|---|---|---|---|---|---|
| **Ground Clearance** | 5 | 4 | 0.2 | 4 | 0.2 | 4 | 0.2 |
| **Easy Manufacturing** | 10 | 4 | 0.4 | 3 | 0.3 | 1 | 0.1 |
| **Durable / Strong** | 35 | 2 | 0.7 | 4 | 1.4 | 4 | 0.7 |
| **Amount of Material Needed** | 20 | 4 | 0.8 | 3 | 0.6 | 2 | 0.4 |
| **Low Weight** | 30 | 4 | 1.2 | 4 | 1.2 | 3 | 0.9 |
| | = 100 | | =3.3 | | **=3.7** | | =2.3 |

In the end, we calculated the Warren Truss concept design to have the highest rating and concluded that it was the most suitable chassis design. The lead factors that lead to its success was its high durability and low weight.

# MODELS

## *ASSEMBLY MODELS*

The front chassis will be attached to the front of the s10 frame and the front wheel suspension. It needs to be able to carry at least 2 passengers and support the drive train. To incorporate more vertical strength, I changed the material 2x2x1/8-inch to 3x2x3/8-inch angle iron steel. The back will be welded into the s10 frame and the front to the front wheel suspension system. Plywood will also be bolted down to the top of the chassis to build seating and footing for the passengers. For the IAT BUV Competition, it is specified that we must be able to hold at least 2 55-gallon steel drums to carry water in the BUV’s cargo bed. If drums are not secure and begin to roll, the center of gravity will shift and cause the chassis to fail. Recommendations from the 2013 BUV team state that we use a wedge to keep drums from rolling while the vehicle is in motion (3).

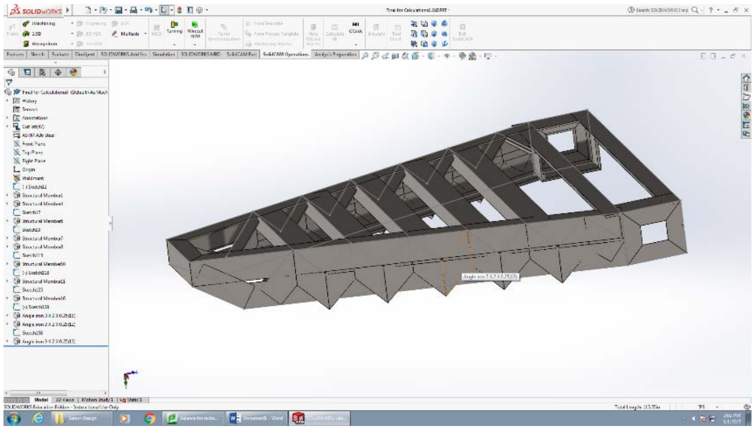


Figure 8: Chassis Design Model

Figure 9: Assembly Model

# DESIGN ANALYSIS

To calculate the possible total forces acting on the chassis and assumed stresses, I performed a design analysis to showcase Von Mises Stresses, Displacement, and Factor of Safety. The design analysis was performed in SolidWorks Simulation and measured in English units.

## *FINITE ELEMENT ANALYSIS*

### Von Mises Stress w/ Diagram

The back end of the chassis is welded to the Chevrolet S10 truck frame. In the model these four corners are noted as fixed geometry. The front end is attached and supports the front suspension. After adding up the suspension and passengers max load, the total force was slightly under 1500 pounds. I then applied an upward force to the front of the chassis of 1500 pounds. With these parameters, the chassis passed and all areas remained under 36,000 psi of stress.

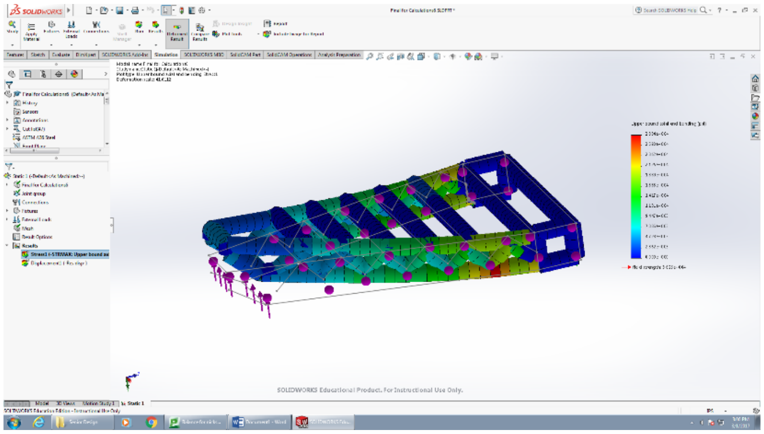


Figure 10: Von Mises Stress Diagram

## Displacement Diagram

The Finite Element tool in SolidWorks calculates the deflection and displacement of the chassis. For this test, the fixed positions and force added remained the same. After the test was run, it was concluded that it passed with a maximum deflection of only 0.1291 inches.

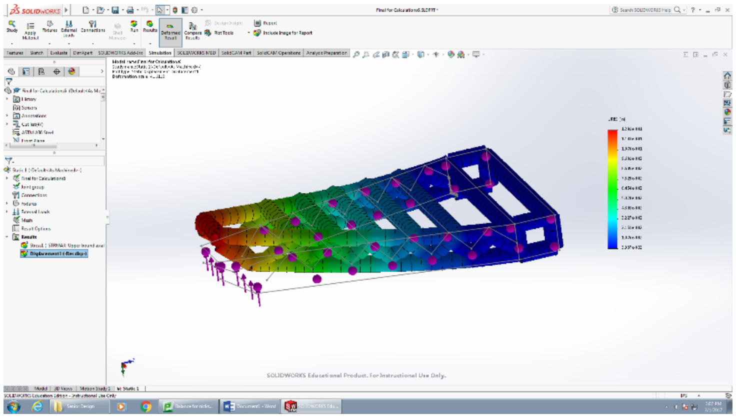


Figure 11: Displacement Diagram

## Factor of Safety Diagram

The Finite Element tool in SolidWorks also calculates the factor of safety of the chassis. For this test, the fixed positions and force added again remained the same. Unfortunately, after the test was run, it was concluded that the chassis did not pass. Other than the 2 fixed beams, all other beams failed and are shown in Figure 12 in the color red.

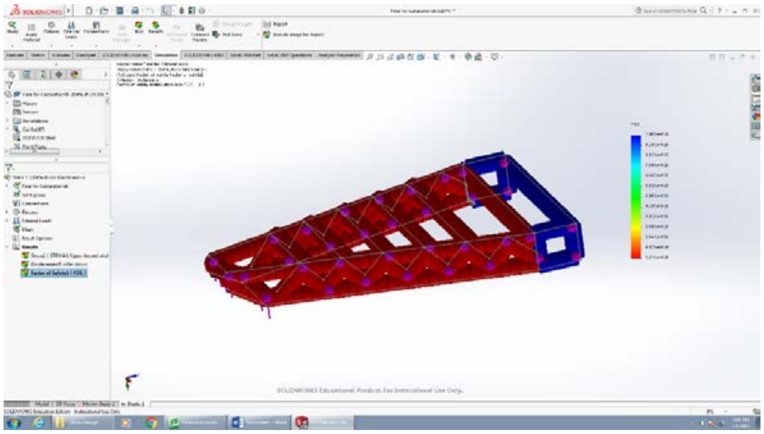


Figure 12: Factor of Safety Diagram

## DESIGN MODIFICATIONS – NEW MODELS

### *ASSEMBLY MODELS*

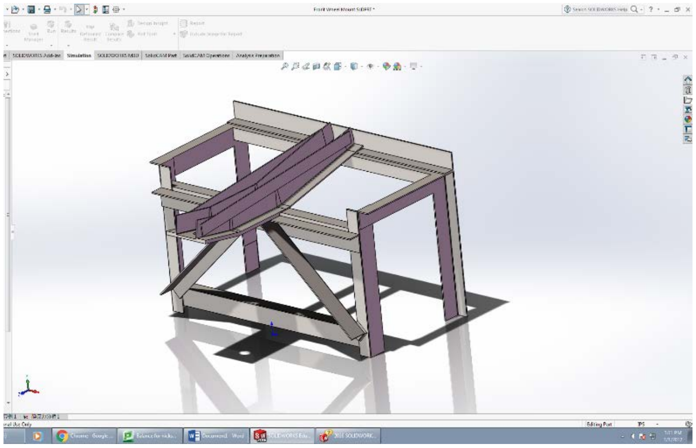


Figure 13: New Chassis Model

Nearing the Fabrication stage of our project, we concluded that the previous chassis model would not be a sufficient component for our assembly. A new model was needed and it must be capable of supporting the engine and transmission at the front end. Also, the last model was too complex to build during the limited amount of time left. Figure 13 and Figure 14 display the new chassis model and the full assembly. The new chassis will be built with A36 3x2x3/8-inch angle iron steel and welded. More of the S10 frame will be used to support passenger load. This new model will only weigh 141 pounds. The low weight should be helpful in the speed of the vehicle during the competition.

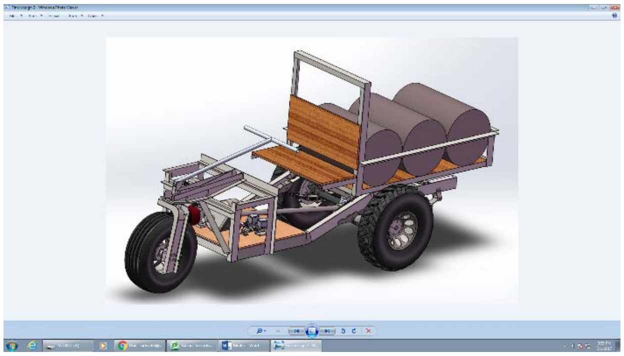


Figure 14: New Assembly Model

## DESIGN MODIFICATIONS – DESIGN ANALYSIS

This design analysis was also performed in SolidWorks Simulation and measured in English units. Similar tests were performed to showcase Von Mises Stresses, Displacement, Strain, and Factor of Safety. The corrected calculated design load is 2840 pounds. This was found by measuring the load placed on the front wheel. Based off the center of gravity, most of the weight was held in the back end and the front suspension held about 315 pounds. The 315lbs is the force exhibited on the front chassis. Our designed safety factor for a continuous load is 18. Therefore, the max load on the front chassis should be 5680 pounds. The safety factor for impact loading is about 2.00 when the design load is about 2840lb. This fits into our requirements of a 1200lb payload since the BUV weight is approx. 1500lbs. The calculations are shown below along with Simulation figures.

BUV Weight ~ 1500lbs

315lbs in the front suspension

1185lbs in the rear suspension

SF continuous load:18

$$Max\ Load = 315.56 * 18 = 5680lbs$$

SF impact load: 2

$$Design\ Load = \frac{5680}{2.00} = 2640lbs$$

$$Check\ Requirement: 1200 + 1500 = 2700 < 2840 \quad \checkmark$$

## *FINITE ELEMENT ANALYSIS*

### Von Mises Stresses

The back end of the chassis is welded to the front end of the Chevrolet S10 truck frame. More of the frame is being used so the chassis does not have much length. In the model these four corners are labeled fixed geometry. The top, front arm is attached and supports the front suspension and the transmission and engine are supported and held underneath the chassis. After completing calculations, the max load placed on the arm from the front suspension is approximately 2840lbs. With these parameters, the chassis passed stress tests and all areas remained under 36,000 psi of stress. The highest point of stress was 20,380 psi.

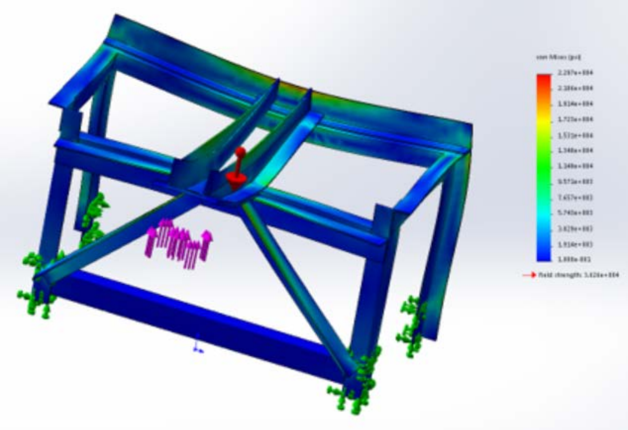


Figure 15: New Model - Von Mises Stress Diagram

### Displacement Diagram

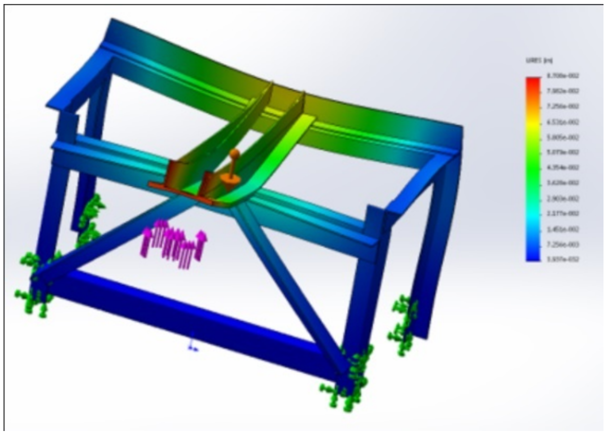


Figure 16: New Model - Displacement Diagram

The next test calculates the deflection in the chassis to make sure it does not surpass the materials modulus of elasticity. For this test, the fixed positions and force added remained the same. After the test was run, it was concluded that it passed with a maximum deflection of only 0.0871 inches. The most displacement was in front arm which is attached to the front suspension.

**Factor of Safety Diagram**

The last test calculates the factor of safety of the chassis to show its safety. For this test, the fixed positions and force added again remained the same. After the test was run, it was concluded that the chassis passed. Red would indicate (as shown in the previous model) that the chassis was an unsafe component. The lowest factor of safety based off the lowest point of stress (20,380 psi) comes to 1.77. The new model shows all blue beams which indicate safety when the chassis is supporting its design load of 2840lbs.

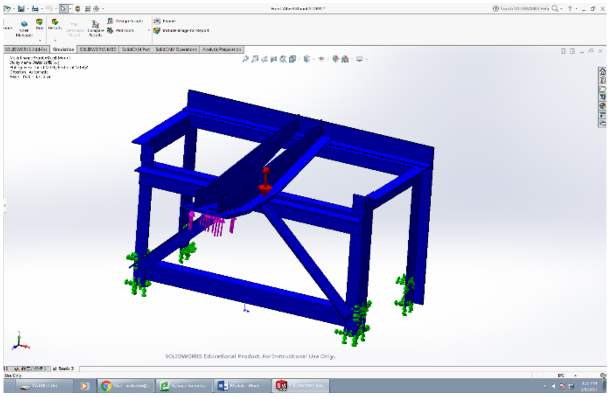


Figure 17: New Model - Factor of Safety

## FABRICATION AND ASSEMBLY

### *FRONT CHASSIS TO CHEVROLET S10 FRAME*

The truck frame we used was a 1994 Chevrolet S10. Figure 18 shows the part of the frame that the front chassis will be welded to. The chassis is made from 3x2x3/8” A36 angle iron steel. The angle iron was cut down to size and the welding process began. We performed MIG welding with 0.035-inch wire diameter (6). Figure 19 shows the chassis about half way completed. Figure 20 shows the completed chassis with plywood placed underneath where the drive train fits.


Figure 18: Fabrication - S10 Frame

Figure 20: Fabrication - Chassis in Progress

Figure 19: Fabrication - Completed Chassis

### CARGO BED TO FRAME

Figure 21: Fabrication - Cargo Bed in Progress

The cargo bed must hold at least two 55 gallon barrels. Our bed will hold 3 barrels and have an area of approximately 20 feet squared. The cargo bed was made out of 2x2x3/8” A36 angle iron steel. The base rail was welding and the top rail was bolted into place. The top rail was bolted so that the cargo bed can be more versatile. This would allow barrels to be removed and other materials to be loaded in. Figure 21 shows the angle iron lining the frame before it is welded. Figure 22 shows the back end and our BUV with a fully loaded cargo bed.

Figure 22: Fabrication - Completed Cargo Bed

### CHASSIS TO FRONT SUSPENSION

The front chassis is attached to the front suspension by an arm/plate design. There is a plate at the end of the arm that is welded to the front suspension design. Specialized bolts were added to ensure a steady hold in case the welds fail. Figure 23 depicts the front wheel suspension connected the chassis. There are 4 bolts in place.

Figure 23: Fabrication – Chassis to Front Suspension

### FINAL ASSEMBLY W/ PLYWOOD GUARDING

To complete the frame of our BUV we used ¼, ½, and ¾ inch plywood for seating. To ensure driver/passenger and machine safety, we added guarding around the seats and around the front chassis to protect the drive train from the environment. Figure 24 shows the process of adding seating and laying down the floor boards. All of our plywood was bolted into the S10 Frame or angle iron with ½ inch screws and nuts. Figure 25 shows the final build of the frame, chassis, and guarding with team member, Chris Steward, testing out our steering.

Figure 24: Fabrication – Guarding Placement

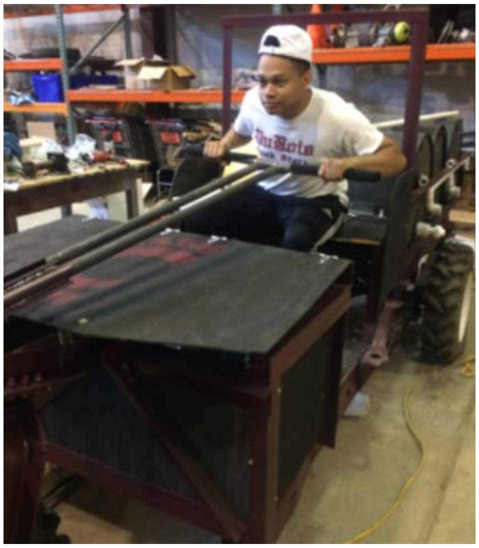


Figure 25: Fabrication – Final Frame & Chassis

## PROOF OF DESIGN TESTING

After all the components were completed and fabrication was done, we performed testing on the basic utility vehicle. Testing was done April 21st and 22nd before the competition. Initially, all test passed. However, the front suspension failed during the competition. As for the frame and chassis, I designed them to support the drivetrain and have a payload of approximately 1200 pounds. The engineering characteristics related to the frame and chassis were: a payload of 1200lbs, plywood safe guarding, at least a 10-inch ground clearance, angle iron material selection, and at least 18 feet squared of area in the cargo bed. The vehicle was built of 3x2x3/8-inch and 2x2x3/8-inch A36 angle iron steel. This material allows the vehicle to be light weight and inexpensive. The plywood installed allowed a barrier in between passengers and moving and working machines. We tested the BUV on the competition field where it could carry about 1300 pounds up a 20-degree inclined hill. This exceeds the 1200 payload for the competition requirements. The final size of the cargo bed was 20 feet squared. The extra space will allow more equipment and materials to be loaded and transported. The final ground clearance was 10 inches. This could have been better for competition purposes. With the relatively small clearance, the BUV constantly got stuck in the mud.

Figure 26: BUV Competition

# CONCLUSION

## *IAT BUV Competition Results*

The competition started at 9 am, April 22nd in Batavia, OH. At the beginning, we were struggling to get our engine started, limit excessive rattling, and replace a missing bolt in our transmission. By about 11:00am, we finally had our vehicle on the track. We road about 1/2 lap before getting stuck in a patch of mud. In the process of pulling the BUV out of the mud, the front wheel snapped off. It took us another hour to get it back on and within 30 minutes it popped off again. In conclusion, our fail was issues in the front suspension system and getting stuck because of the low ground clearance.

Figure 27: BUV Competition Failure

## *Recommendations*

I would recommend future BUV teams continue to use A36 angle iron material, a rectangular prism shaped chassis, and a larger cargo bed to hold more materials. Although the frame and chassis held up in the competition, they did not lack issues throughout the course. The ground clearance got us stuck in the mud more often than not and caused a high level of stress to the front wheel. I recommend using larger tires and better design for the front suspension to aid the vehicle in achieving at least 12-inches in clearance.

## WORKS CITED

1. **IAT Administrator.** Basic Utility Vehicles for Rural Transportation. *Home.* [Online] Institute of Affordable Transportation, 1 30, 2010. [Cited: 9 13, 2016.] http://www.drivebuv.org/about-iat. ..
2. **Wells, Sara.** *Basic Utility Vechicle (BUV).* 2013.
3. **Stoll, Mark.** *Basic Utility Vehicle(BUV) Suspension and Irrigation System.* 2013.
4. **Used Auto Parts Cincinnati.** ***U-Pull-&-Pay.*** **[Online] [Cited: 11 20, 2016.] https://upullandpay.com/cincinnati/home/.**
**5. Boon, Garrett. Truss Design.** ***Garrett's Bridges.*** **[Online] 8 16, 2005. [Cited: 9 28, 2016.] https://www.garrettsbridges.com/design/trussdesign/.**
**6. Rice, Marty. MIG welding—The basics and then some.** ***The Fabricator - A publication of the Fabricators and Manufacturers Association, Intl.*** **[Online] The Fabricator, 7 13, 2014. [Cited: 12 12, 2016.] http://www.thefabricator.com/article/arcwelding/mig-welding-the-basics-and-then-some. ..**
**7. Replogle, Michael A. Sustainable transportation strategies for third-world development.** ***Transportation Research Record 1294.*** **[Online] Academia.edu, 3 7, 2013. [Cited: 11 2, 2016.] http://www.academia.edu/719382/Sustainable_transportation_strategies_for_third-world_development. 719382.**
**8. Helmkamp, Jim. NIOSH Science Blog.** ***Centers for Disease Control and Prevention.*** **[Online] NIOSH, 12 7, 2016. [Cited: 10 13, 2016.] https://blogs.cdc.gov/niosh-science-blog/2012/10/24/atv/. ..**
**9. Ascione, Adam. Steel Angle Basics - How to Buy Steel Angle.** ***metalspecialist.continentalsteel.com.*** **[Online] Continental Steel and Tube Company, 7 24, 2014. [Cited: 10 27, 2016.] https://metalspecialist.continentalsteel.com/blog/bid/76250/Steel-Angle-Basics-How-to-Buy-Steel-Angle. ..**
**10. Unknown. What is Ground Clearance of a vehicle?** ***CrankIT.*** **[Online] 7 18, 2016. [Cited: 12 19, 2016.] https://crankit.in/ground-clearance/. ..**
**11. Staff, Wood Magazine. What You Need To Know About Plywood.** ***WOOD Magazine.*** **[Online] 5 16, 2016. [Cited: 1 14, 17.] http://www.woodmagazine.com/materials-guide/lumber/what-you-need-to-know-about-plywood. ..**
**12. Quinnell, Cole. Modern Subframe Onto An Outdated Frame, Part I - How To - Hot Rod Magazine.** ***Hot Rod Network.*** **[Online] 6 15, 2016. [Cited: 3 2, 2017.] http://www.hotrod.com/articles/42838-modern-subframe-installation/.**
**13. Conrad, David.** ***Past BUVs and Recommendations.*** **UC Victory Parkway Campus; Cincinnati, OH, 9 5, 2016.**

# APPENDIX A - RESEARCH

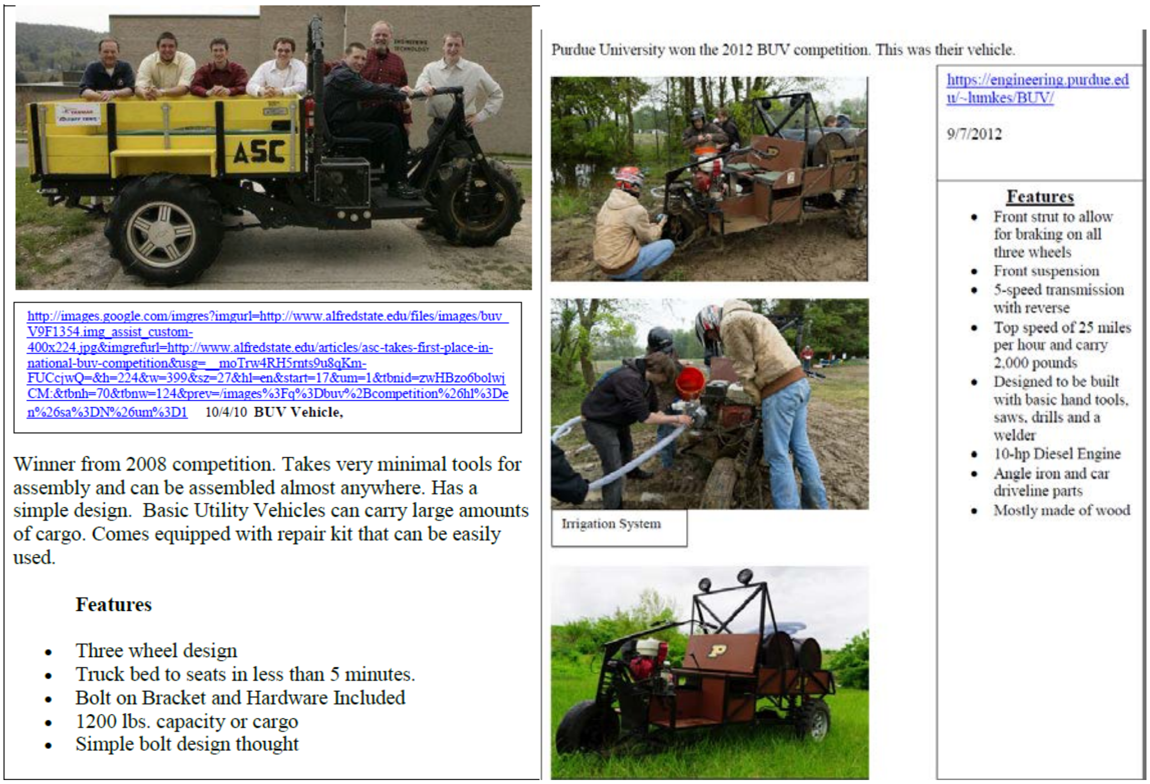
Initial Discussion with Professor Conrad and UC BUV team members

- Using an old truck frame (Chevrolet S10)
- Recommended going to U-Pull-&-Pay
- Using either angle iron or steel piping (lightweight material)
- Ground Clearance of at least 10 inches, preferably 13 inches

Discussion with Professor Conrad for Design Modifications

- Using 3x2x3/8 inch instead of 2x2x3/8 inch A36 angle iron steel
- Should support the drivetrain and brakes underneath
- Design for less material and easier welds in fabrication

Past BUV Winners:



http://images.google.com/imgres?imgurl=http://www.alfredstate.edu/files/images/buv_V9F1354.img_assist_custom-400x224.jpg&imgrefurl=http://www.alfredstate.edu/articles/asc-takes-first-place-in-national-buv-competition&usg=__moTrw4RH5rnts9u8qKm-FUCcjwQ=&h=224&w=399&sz=27&hl=en&start=17&um=1&tbnid=zwHBzo6bolwjCM:&tbnh=70&tbnw=124&prev=/images%3Fq%3Dbuv%2Bcompetition%26hl%3Den%26sa%3DN%26um%3D1 10/4/10 **BUV Vehicle,**

Winner from 2008 competition. Takes very minimal tools for assembly and can be assembled almost anywhere. Has a simple design. Basic Utility Vehicles can carry large amounts of cargo. Comes equipped with repair kit that can be easily used.

**Features**

- Three wheel design
- Truck bed to seats in less than 5 minutes.
- Bolt on Bracket and Hardware Included
- 1200 lbs. capacity or cargo
- Simple bolt design thought

Purdue University won the 2012 BUV competition. This was their vehicle.

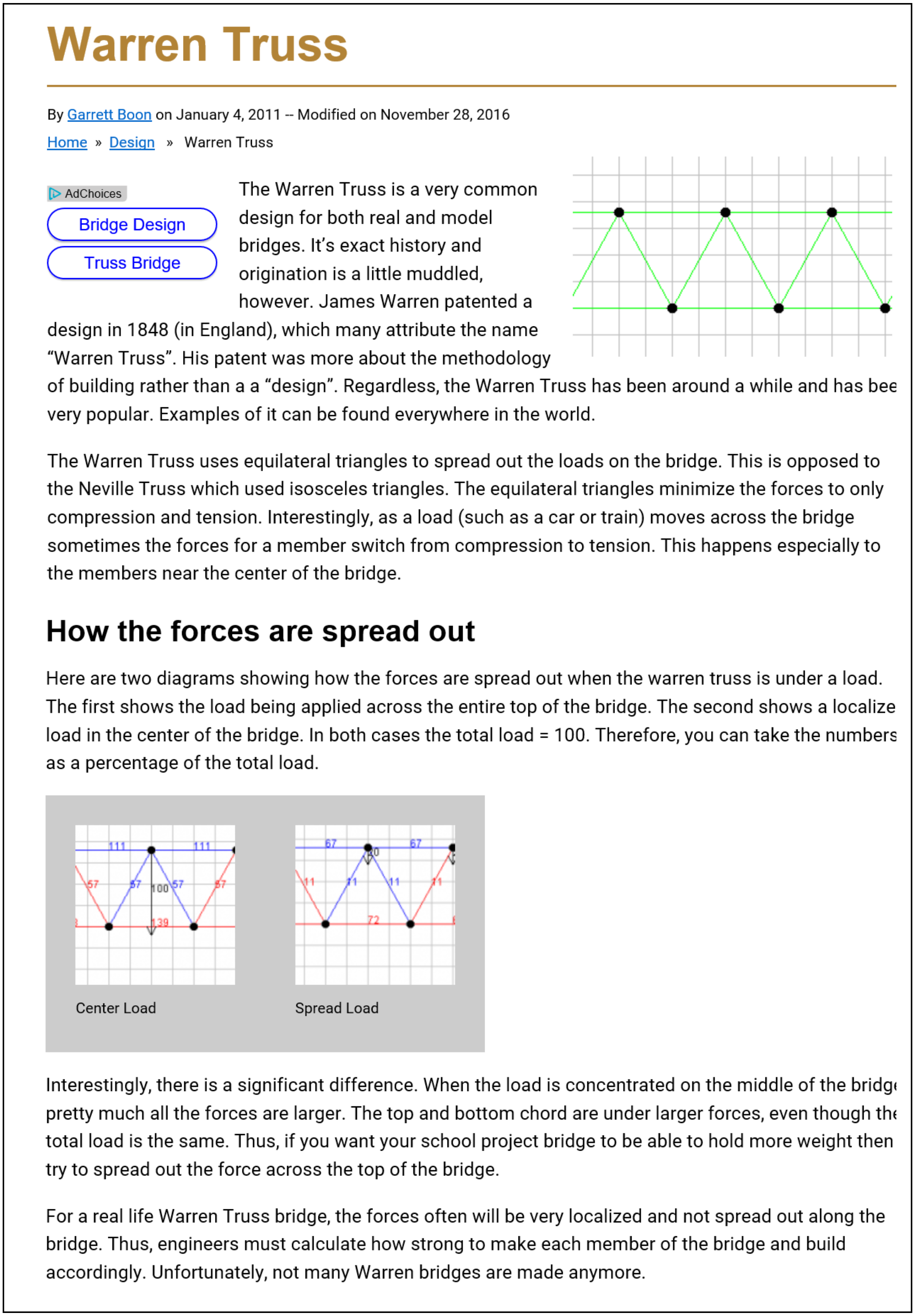
Irrigation System

https://engineering.purdue.edu/~lumkes/BUV/

9/7/2012

**Features**

- Front strut to allow for braking on all three wheels
- Front suspension
- 5-speed transmission with reverse
- Top speed of 25 miles per hour and carry 2,000 pounds
- Designed to be built with basic hand tools, saws, drills and a welder
- 10-hp Diesel Engine
- Angle iron and car driveline parts
- Mostly made of wood



# Warren Truss

By Garrett Boon on January 4, 2011 -- Modified on November 28, 2016

Home » Design » Warren Truss

The Warren Truss is a very common design for both real and model bridges. It's exact history and origination is a little muddled, however. James Warren patented a design in 1848 (in England), which many attribute the name "Warren Truss". His patent was more about the methodology of building rather than a a "design". Regardless, the Warren Truss has been around a while and has bee very popular. Examples of it can be found everywhere in the world.

The Warren Truss uses equilateral triangles to spread out the loads on the bridge. This is opposed to the Neville Truss which used isosceles triangles. The equilateral triangles minimize the forces to only compression and tension. Interestingly, as a load (such as a car or train) moves across the bridge sometimes the forces for a member switch from compression to tension. This happens especially to the members near the center of the bridge.

## How the forces are spread out

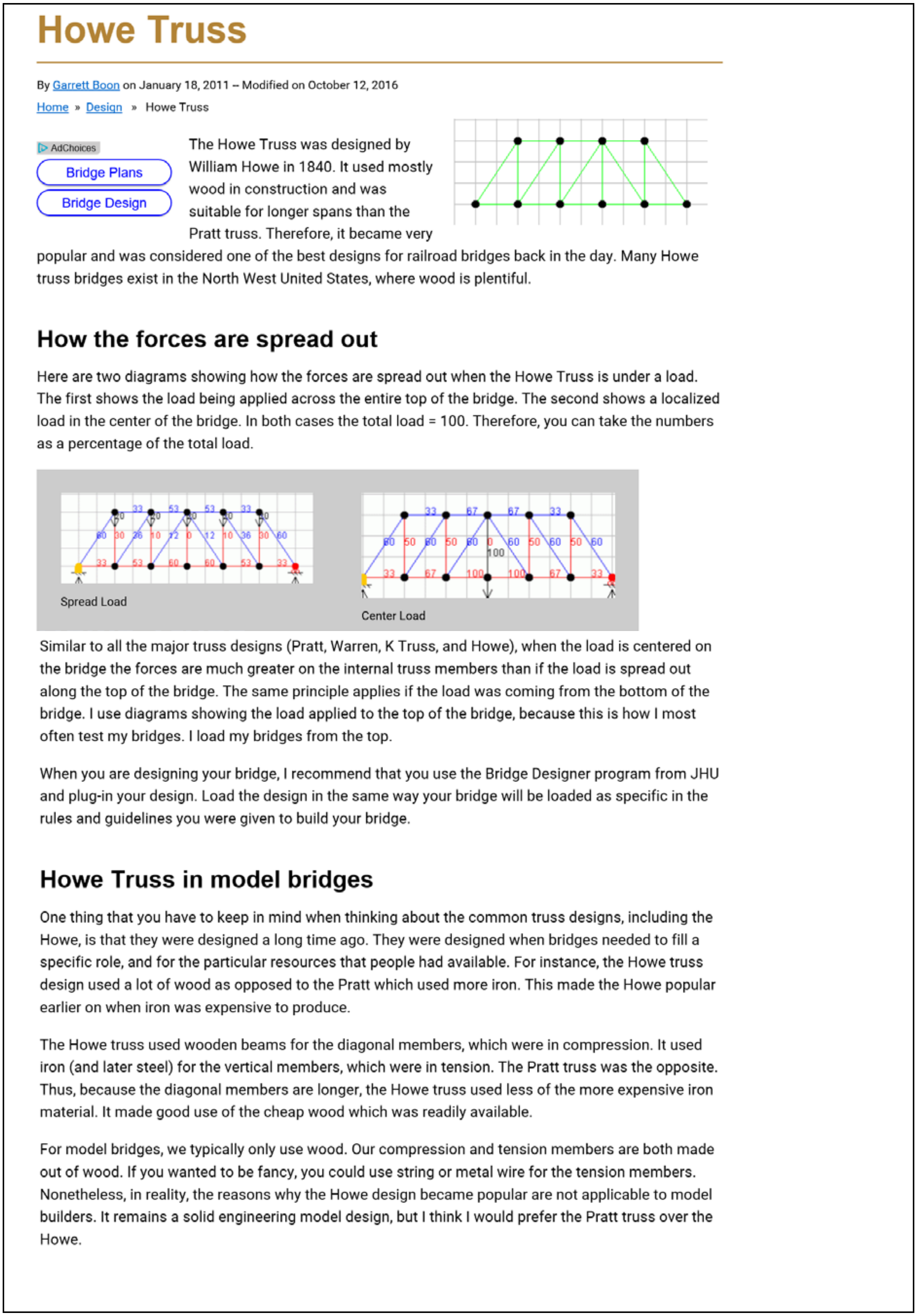
Here are two diagrams showing how the forces are spread out when the warren truss is under a load. The first shows the load being applied across the entire top of the bridge. The second shows a localize load in the center of the bridge. In both cases the total load = 100. Therefore, you can take the number as a percentage of the total load.

Center Load

Spread Load

Interestingly, there is a significant difference. When the load is concentrated on the middle of the bridg pretty much all the forces are larger. The top and bottom chord are under larger forces, even though th total load is the same. Thus, if you want your school project bridge to be able to hold more weight then try to spread out the force across the top of the bridge.

For a real life Warren Truss bridge, the forces often will be very localized and not spread out along the bridge. Thus, engineers must calculate how strong to make each member of the bridge and build accordingly. Unfortunately, not many Warren bridges are made anymore.



# Howe Truss

By Garrett Boon on January 18, 2011 – Modified on October 12, 2016

Home » Design » Howe Truss

The Howe Truss was designed by William Howe in 1840. It used mostly wood in construction and was suitable for longer spans than the Pratt truss. Therefore, it became very popular and was considered one of the best designs for railroad bridges back in the day. Many Howe truss bridges exist in the North West United States, where wood is plentiful.

## How the forces are spread out

Here are two diagrams showing how the forces are spread out when the Howe Truss is under a load. The first shows the load being applied across the entire top of the bridge. The second shows a localized load in the center of the bridge. In both cases the total load = 100. Therefore, you can take the numbers as a percentage of the total load.

Spread Load

Center Load

Similar to all the major truss designs (Pratt, Warren, K Truss, and Howe), when the load is centered on the bridge the forces are much greater on the internal truss members than if the load is spread out along the top of the bridge. The same principle applies if the load was coming from the bottom of the bridge. I use diagrams showing the load applied to the top of the bridge, because this is how I most often test my bridges. I load my bridges from the top.

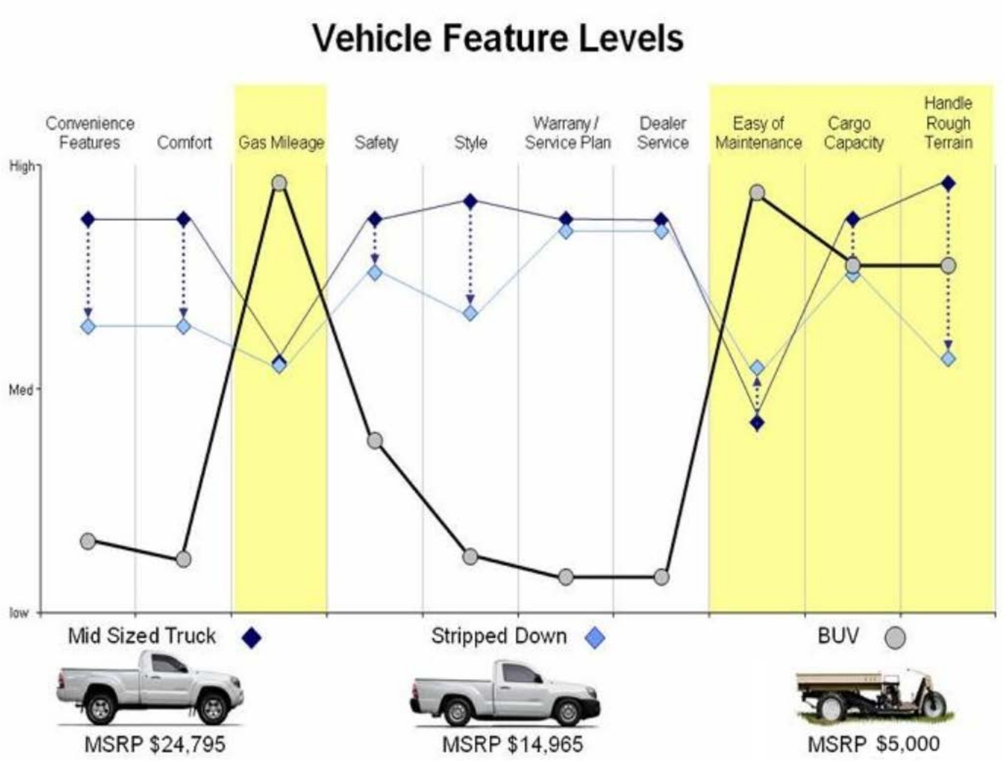
When you are designing your bridge, I recommend that you use the Bridge Designer program from JHU and plug-in your design. Load the design in the same way your bridge will be loaded as specific in the rules and guidelines you were given to build your bridge.

## Howe Truss in model bridges

One thing that you have to keep in mind when thinking about the common truss designs, including the Howe, is that they were designed a long time ago. They were designed when bridges needed to fill a specific role, and for the particular resources that people had available. For instance, the Howe truss design used a lot of wood as opposed to the Pratt which used more iron. This made the Howe popular earlier on when iron was expensive to produce.

The Howe truss used wooden beams for the diagonal members, which were in compression. It used iron (and later steel) for the vertical members, which were in tension. The Pratt truss was the opposite. Thus, because the diagonal members are longer, the Howe truss used less of the more expensive iron material. It made good use of the cheap wood which was readily available.

For model bridges, we typically only use wood. Our compression and tension members are both made out of wood. If you wanted to be fancy, you could use string or metal wire for the tension members. Nonetheless, in reality, the reasons why the Howe design became popular are not applicable to model builders. It remains a solid engineering model design, but I think I would prefer the Pratt truss over the Howe.

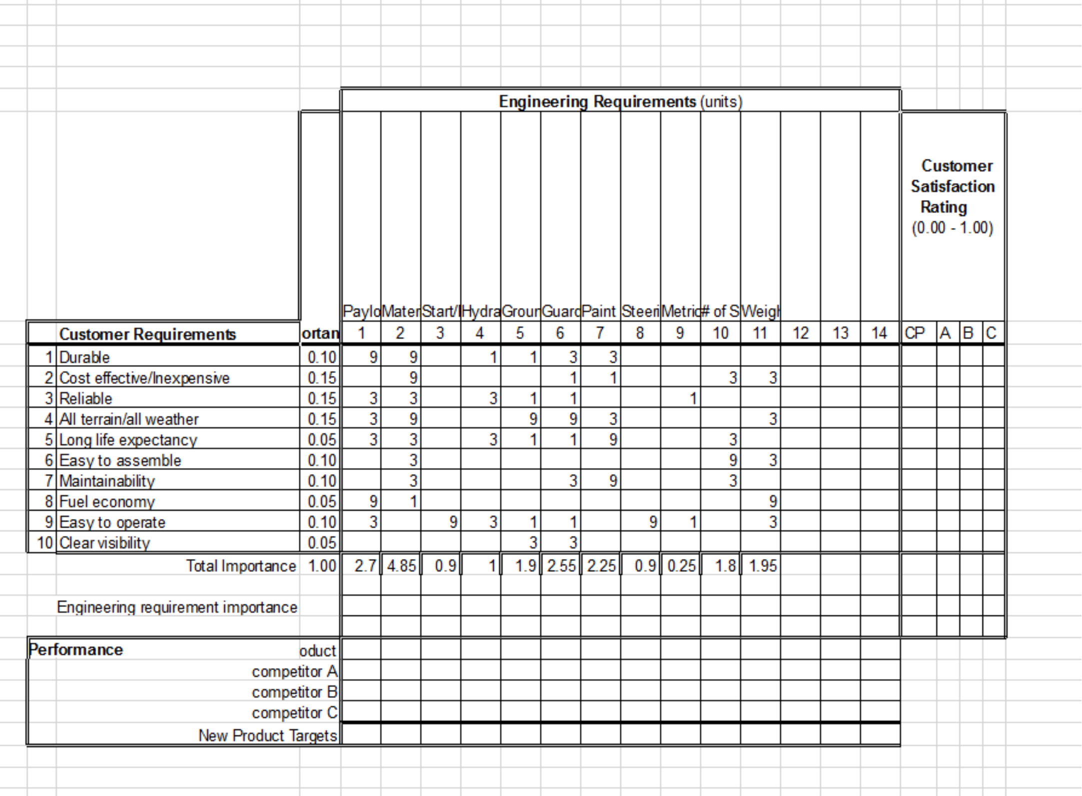


### 1994 Chevrolet S10 Truck Frame

S10 Truck Frame

- Used by 2013 UC BUV Team
- Used by 2014 UC BUV Team
- Back end was used and welded to the designed front chassis

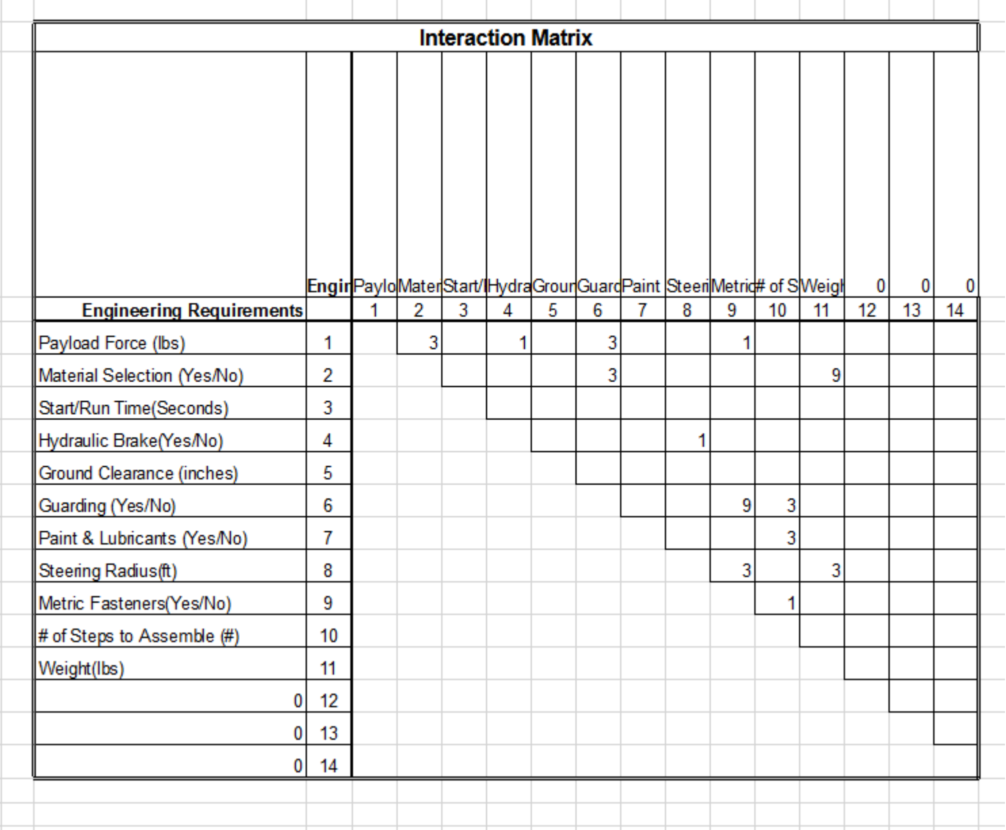
# APPENDIX B – HOUSE OF QUALITY



**Engineering Requirements** (units)

**Customer Satisfaction Rating** (0.00 - 1.00)

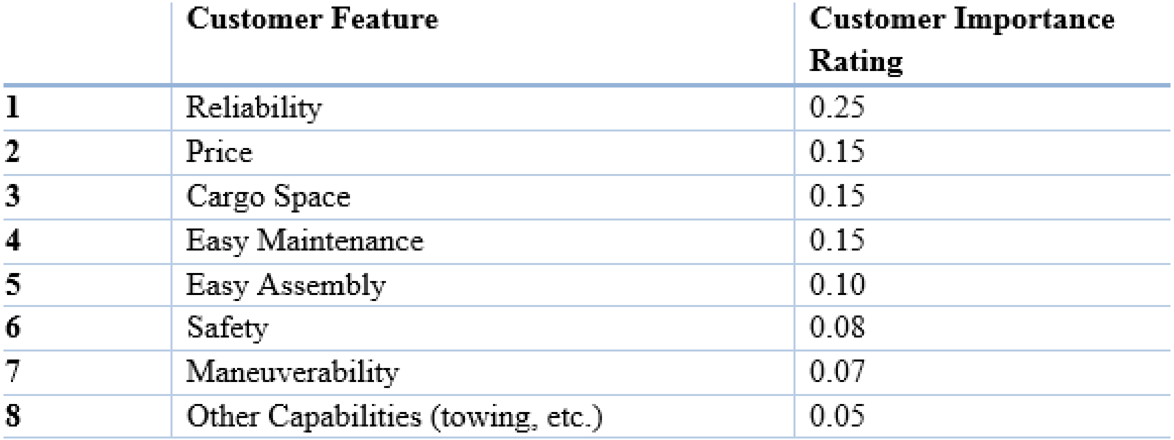
| | | | Paylo | Mater | Start/I | Hydra | Groun | Guard | Paint | Steeri | Metric | # of S | Weigh | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Customer Requirements** | ortan | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | CP | A | B | C |
| 1 | Durable | 0.10 | 9 | 9 | | 1 | 1 | 3 | 3 | | | | | | | | | | | |
| 2 | Cost effective/Inexpensive | 0.15 | | 9 | | | | 1 | 1 | | | 3 | 3 | | | | | | | |
| 3 | Reliable | 0.15 | 3 | 3 | | 3 | 1 | 1 | | | 1 | | | | | | | | | |
| 4 | All terrain/all weather | 0.15 | 3 | 9 | | | 9 | 9 | 3 | | | | 3 | | | | | | | |
| 5 | Long life expectancy | 0.05 | 3 | 3 | | 3 | 1 | 1 | 9 | | | 3 | | | | | | | | |
| 6 | Easy to assemble | 0.10 | | 3 | | | | | | | | 9 | 3 | | | | | | | |
| 7 | Maintainability | 0.10 | | 3 | | | | 3 | 9 | | | 3 | | | | | | | | |
| 8 | Fuel economy | 0.05 | 9 | 1 | | | | | | | | | 9 | | | | | | | |
| 9 | Easy to operate | 0.10 | 3 | | 9 | 3 | 1 | 1 | | 9 | 1 | | 3 | | | | | | | |
| 10 | Clear visibility | 0.05 | | | | | 3 | 3 | | | | | | | | | | | | |
| | Total Importance | 1.00 | 2.7 | 4.85 | 0.9 | 1 | 1.9 | 2.55 | 2.25 | 0.9 | 0.25 | 1.8 | 1.95 | | | | | | | |
| | Engineering requirement importance | | | | | | | | | | | | | | | | | | | |
| **Performance** | | oduct | | | | | | | | | | | | | | | | | | |
| | | competitor A | | | | | | | | | | | | | | | | | | |
| | | competitor B | | | | | | | | | | | | | | | | | | |
| | | competitor C | | | | | | | | | | | | | | | | | | |
| | | New Product Targets | | | | | | | | | | | | | | | | | | |



**Interaction Matrix**

| | Engir | Paylo | Mater | Start/I | Hydra | Groun | Guard | Paint | Steeri | Metric | # of S | Weigh | 0 | 0 | 0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Engineering Requirements** | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| Payload Force (lbs) | 1 | | 3 | | 1 | | 3 | | | 1 | | | | | |
| Material Selection (Yes/No) | 2 | | | | | | 3 | | | | | 9 | | | |
| Start/Run Time(Seconds) | 3 | | | | | | | | | | | | | | |
| Hydraulic Brake(Yes/No) | 4 | | | | | | | | 1 | | | | | | |
| Ground Clearance (inches) | 5 | | | | | | | | | | | | | | |
| Guarding (Yes/No) | 6 | | | | | | | | | 9 | 3 | | | | |
| Paint & Lubricants (Yes/No) | 7 | | | | | | | | | | 3 | | | | |
| Steering Radius(ft) | 8 | | | | | | | | | 3 | | 3 | | | |
| Metric Fasteners(Yes/No) | 9 | | | | | | | | | | 1 | | | | |
| # of Steps to Assemble (#) | 10 | | | | | | | | | | | | | | |
| Weight(lbs) | 11 | | | | | | | | | | | | | | |
| 0 | 12 | | | | | | | | | | | | | | |
| 0 | 13 | | | | | | | | | | | | | | |
| 0 | 14 | | | | | | | | | | | | | | |

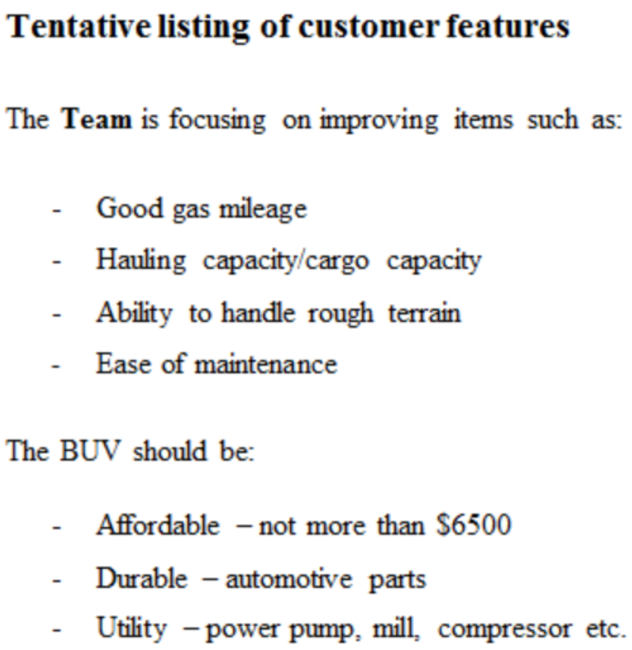
# APPENDIX C – PRODUCT OBJECTIVES



| | Customer Feature | Customer Importance Rating |
|---|---|---|
| **1** | Reliability | 0.25 |
| **2** | Price | 0.15 |
| **3** | Cargo Space | 0.15 |
| **4** | Easy Maintenance | 0.15 |
| **5** | Easy Assembly | 0.10 |
| **6** | Safety | 0.08 |
| **7** | Maneuverability | 0.07 |
| **8** | Other Capabilities (towing, etc.) | 0.05 |

1) Reliability (25%)
    - Use of angle iron material with a high yield strength
    - Calculations will be performed to prove ability to hold a payload of at least 1200 pounds.
    - At least a 10-inch clearance
2) Price (15%)
    - Use of inexpensive materials
    - Cost less than $5000 (20% of the cost of a small truck)
3) Cargo Space (15%)
    - Must be able to hold 3 55 gallon barrels
    - Area of at least 18 ft^2
4) Easy Maintenance (15%)
    - Easy transformation of cargo bed to hold various materials
    - Easy access to drive train, gas tank, and irrigation

5) Easy Assembly (10%)
    - Simple Welds (90 degree angles)
    - Bolts to secure removable parts (floor boards & guarding)
6) Safety (8%)
    - Add guarding against moving and heated components
    - Add guarding to protect passengers from falling out
7) Maneuverability (7%)
    - Sharp Front Wheel Pivot point
    - Small turning radius
    - Lightweight
8) Other Capabilities (5%)
    - Ability to tow
    - Ability to hold other cargo than water barrels



## Tentative listing of customer features

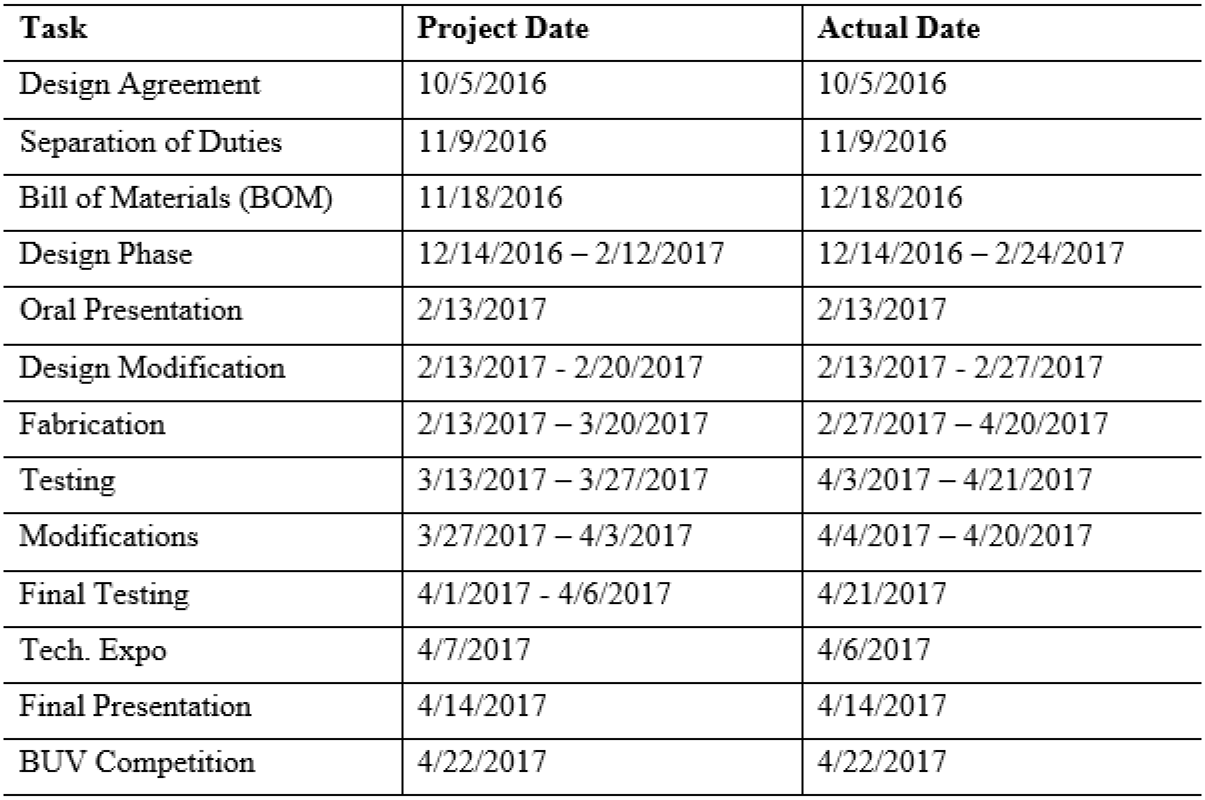
The **Team** is focusing on improving items such as:

- Good gas mileage
- Hauling capacity/cargo capacity
- Ability to handle rough terrain
- Ease of maintenance

The BUV should be:

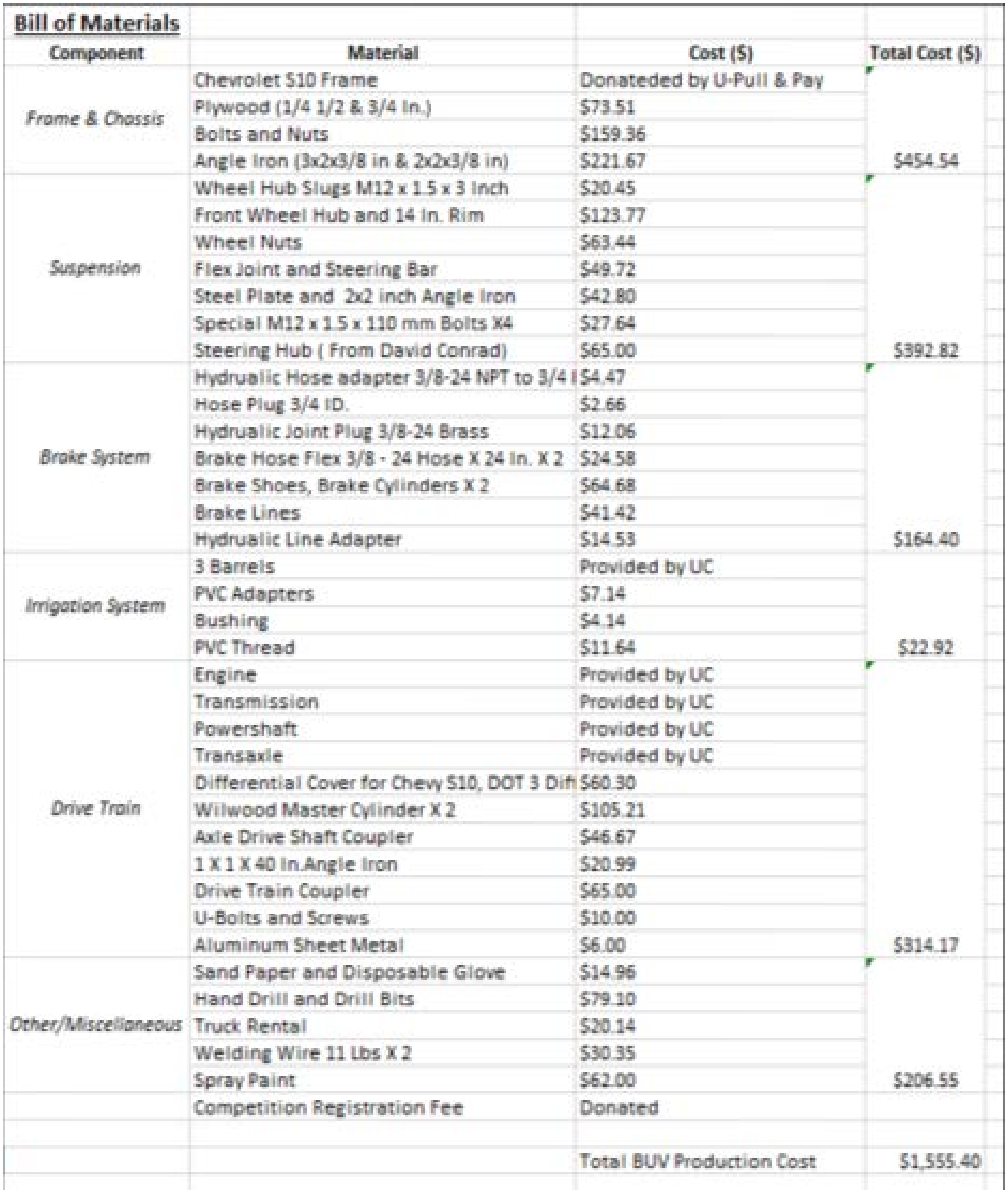
- Affordable – not more than $6500
- Durable – automotive parts
- Utility – power pump, mill, compressor etc.

## APPENDIX D – SCHEDULE



| Task | Project Date | Actual Date |
|---|---|---|
| Design Agreement | 10/5/2016 | 10/5/2016 |
| Separation of Duties | 11/9/2016 | 11/9/2016 |
| Bill of Materials (BOM) | 11/18/2016 | 12/18/2016 |
| Design Phase | 12/14/2016 – 2/12/2017 | 12/14/2016 – 2/24/2017 |
| Oral Presentation | 2/13/2017 | 2/13/2017 |
| Design Modification | 2/13/2017 - 2/20/2017 | 2/13/2017 - 2/27/2017 |
| Fabrication | 2/13/2017 – 3/20/2017 | 2/27/2017 – 4/20/2017 |
| Testing | 3/13/2017 – 3/27/2017 | 4/3/2017 – 4/21/2017 |
| Modifications | 3/27/2017 – 4/3/2017 | 4/4/2017 – 4/20/2017 |
| Final Testing | 4/1/2017 - 4/6/2017 | 4/21/2017 |
| Tech. Expo | 4/7/2017 | 4/6/2017 |
| Final Presentation | 4/14/2017 | 4/14/2017 |
| BUV Competition | 4/22/2017 | 4/22/2017 |

# APPENDIX E – BUDGET



| **Bill of Materials** | | | |
|---|---|---|---|
| **Component** | **Material** | **Cost ($)** | **Total Cost ($)** |
| *Frame & Chassis* | Chevrolet S10 Frame | Donateded by U-Pull & Pay | |
| | Plywood (1/4 1/2 & 3/4 In.) | $73.51 | |
| | Bolts and Nuts | $159.36 | |
| | Angle Iron (3x2x3/8 in & 2x2x3/8 in) | $221.67 | $454.54 |
| *Suspension* | Wheel Hub Slugs M12 x 1.5 x 3 Inch | $20.45 | |
| | Front Wheel Hub and 14 In. Rim | $123.77 | |
| | Wheel Nuts | $63.44 | |
| | Flex Joint and Steering Bar | $49.72 | |
| | Steel Plate and 2x2 inch Angle Iron | $42.80 | |
| | Special M12 x 1.5 x 110 mm Bolts X4 | $27.64 | |
| | Steering Hub ( From David Conrad) | $65.00 | $392.82 |
| *Brake System* | Hydrualic Hose adapter 3/8-24 NPT to 3/4 I | $4.47 | |
| | Hose Plug 3/4 ID. | $2.66 | |
| | Hydrualic Joint Plug 3/8-24 Brass | $12.06 | |
| | Brake Hose Flex 3/8 - 24 Hose X 24 In. X 2 | $24.58 | |
| | Brake Shoes, Brake Cylinders X 2 | $64.68 | |
| | Brake Lines | $41.42 | |
| | Hydrualic Line Adapter | $14.53 | $164.40 |
| *Irrigation System* | 3 Barrels | Provided by UC | |
| | PVC Adapters | $7.14 | |
| | Bushing | $4.14 | |
| | PVC Thread | $11.64 | $22.92 |
| *Drive Train* | Engine | Provided by UC | |
| | Transmission | Provided by UC | |
| | Powershaft | Provided by UC | |
| | Transaxle | Provided by UC | |
| | Differential Cover for Chevy S10, DOT 3 Diff | $60.30 | |
| | Wilwood Master Cylinder X 2 | $105.21 | |
| | Axle Drive Shaft Coupler | $46.67 | |
| | 1 X 1 X 40 In.Angle Iron | $20.99 | |
| | Drive Train Coupler | $65.00 | |
| | U-Bolts and Screws | $10.00 | |
| | Aluminum Sheet Metal | $6.00 | $314.17 |
| *Other/Miscellaneous* | Sand Paper and Disposable Glove | $14.96 | |
| | Hand Drill and Drill Bits | $79.10 | |
| | Truck Rental | $20.14 | |
| | Welding Wire 11 Lbs X 2 | $30.35 | |
| | Spray Paint | $62.00 | $206.55 |
| | Competition Registration Fee | Donated | |
| | | | |
| | | Total BUV Production Cost | $1,555.40 |

# APPENDIX F – COMPETITION SPECIFICATIONS

## BUV DATA SHEET

The Basic Utility Vehicle is a vehicle for change. It is a simple, rugged, low cost, low weight vehicle that is easy to operate, maintain and repair. Designed for rural off-road areas and heavy payloads, the BUV has high torque and does not require shifting or a clutch. The rural parts of **Africa need a vehicle that is "appropriate"** for their geography. They have low population density, and vast distances with terrible road conditions. Our primary mission has been to provide vehicle that is safe and manageable for people in these areas.

*Simple, Rugged, Low-Cost Transportation*

**Features**
- Affordable – 20% of the cost of a small truck
- Flexible – easy to modify cargo area
- Comfortable – automotive suspension
- Durable – automotive parts

**Performance**
- 20 mph
- 1200 lb payload (and low ground pressure)
- 50+ mpg diesel
- power other devices (water pump, mill, etc.)

**Specifications**
- 10 hp engine (diesel or gas )
- 1000 lb vehicle weight (low ground pressure)
- 12' L x 5' W; cargo bed 6.5' L

**Service / Maintenance**
- common "off-the-shelf" parts
- easy access to engine and drivetrain
- 95% less parts than a typical car

**Packaging & Shipping**
- 8 assembled units per ocean container
- crate size 2'H x 2'H x 4'L for power kit
- farm classification (lower duty rates)

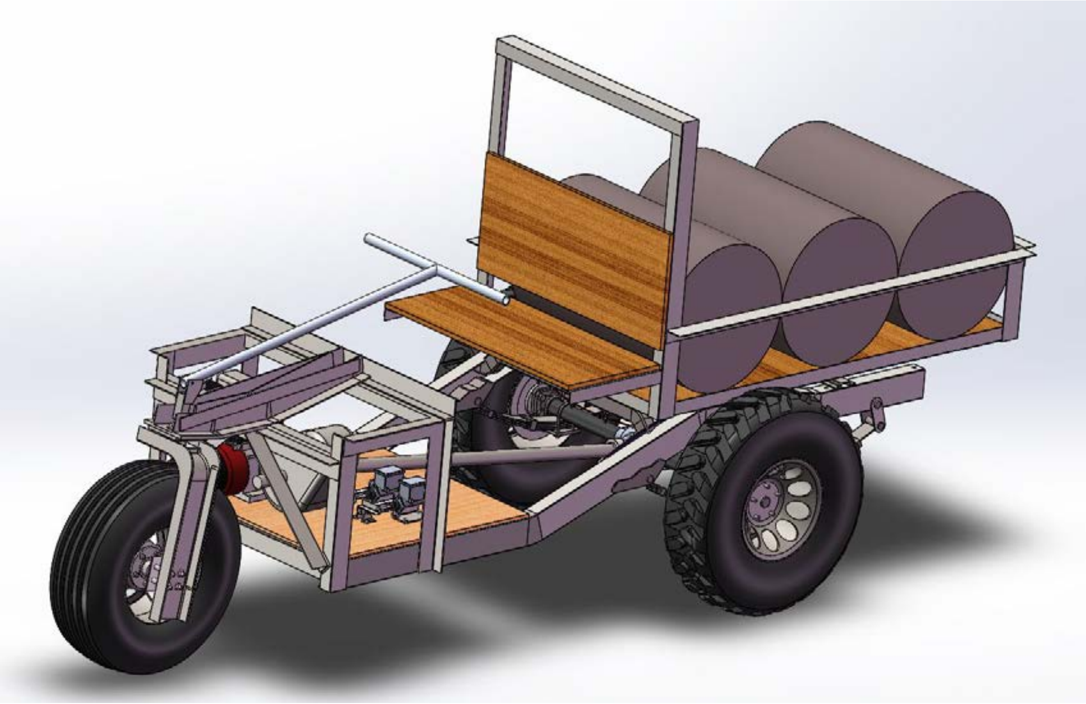
**Automotive Grade Components**
- suspension / axle / rear frame
- brakes / tires / wheels / hubs
- expected life: 20+ years for auto parts

**Safety**
- high driver visibility
- speed limited to 20 mph
- low center of gravity

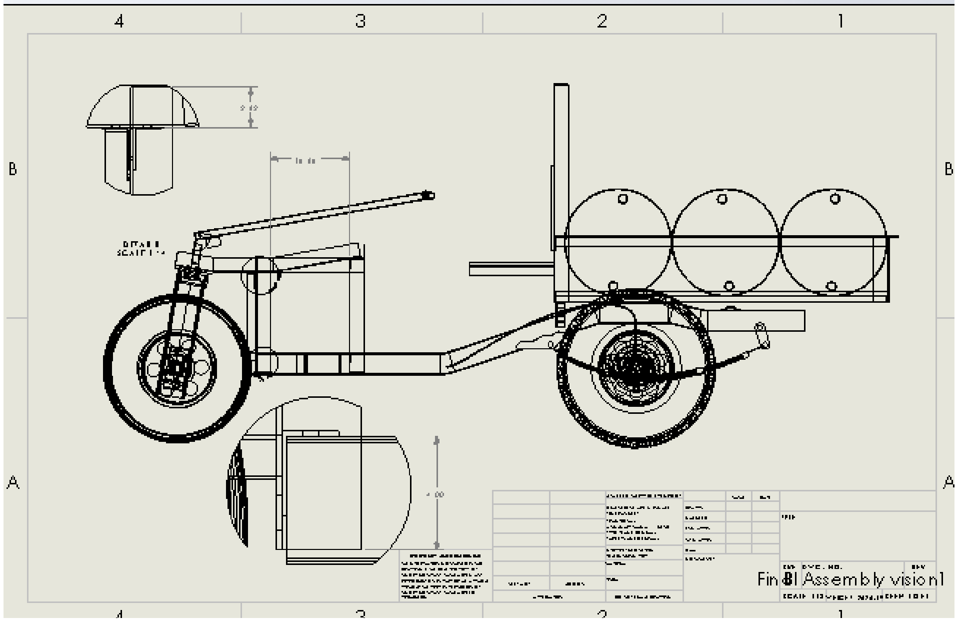
**Cultural Factors**
- middle steering, gender friendly
- car-like operation; no shifting, no clutch
- easy to rescue
- customize as necessary (canopy, lights, etc.)

## APPENDIX G – ASSEMBLY DRAWINGS

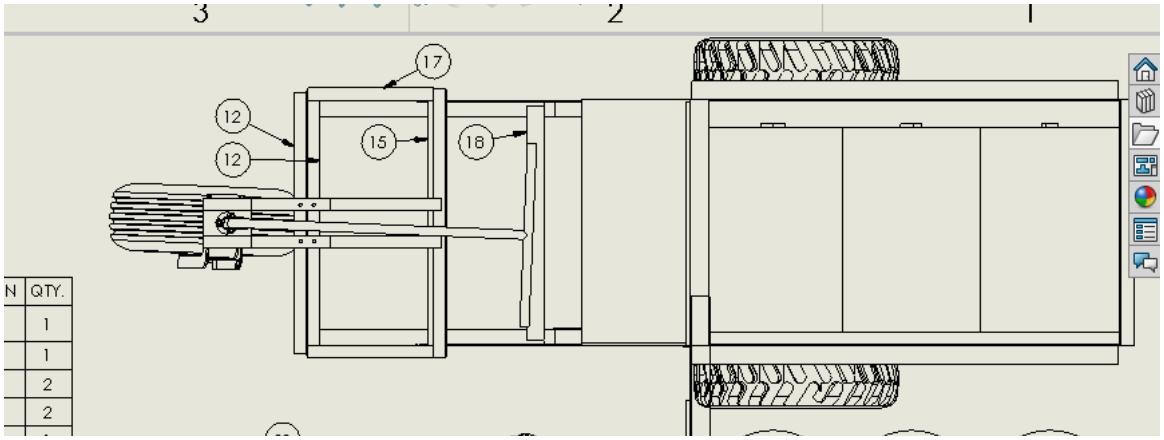
### *ISOMETRIC VIEW*

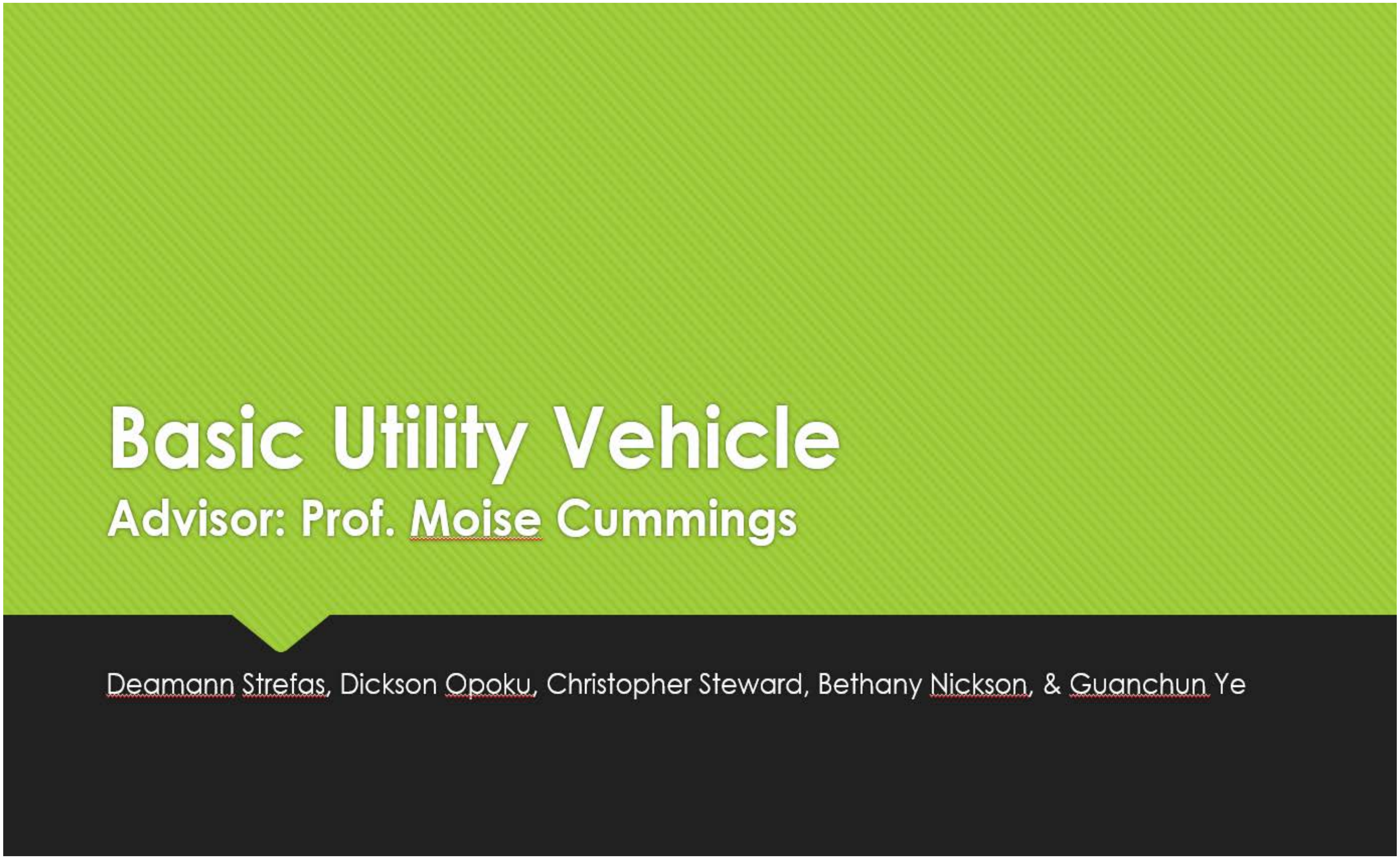


## *SIDE VIEW*



## *TOP VIEW*





# Basic Utility Vehicle

## Advisor: Prof. Moise Cummings

Deamann Strefas, Dickson Opoku, Christopher Steward, Bethany Nickson, & Guanchun Ye

# Objectives

- Problem Statement
- Background & State-of-the-Art
- Competition Guidelines
- QFD & House of Quality
- Chassis & Frame
- Proof of Design
- Final Schedule
- Final Budget
- Final Build
- Competition Results
- Recommendations
- Overview
- Questions

# Problem Statement

IAT is a non-profit organization located in Indianapolis, IN that is devoted to developing high-quality, low-cost transportation to provide mobility, freedom and economic hope to people in rural areas of developing countries. The vehicle is designed to transport people, water , and various other materials. To develop a durable, low cost vehicle that can be built and maintained in a third world country. The vehicle should be suitable for farming and operating in areas without roads. The design should be in kit form and should be able to assemble with ease. Regulations for competition are given on the spec sheet provided by the Institute of Affordable Transportation. The vehicle is to be ready for competition on April 22nd 2018.

# Background & State-of-the-Art

IAT has held this competition every year since 2001

More recent submissions has shown the best results

Purdue, 1st Place Winners (2012)

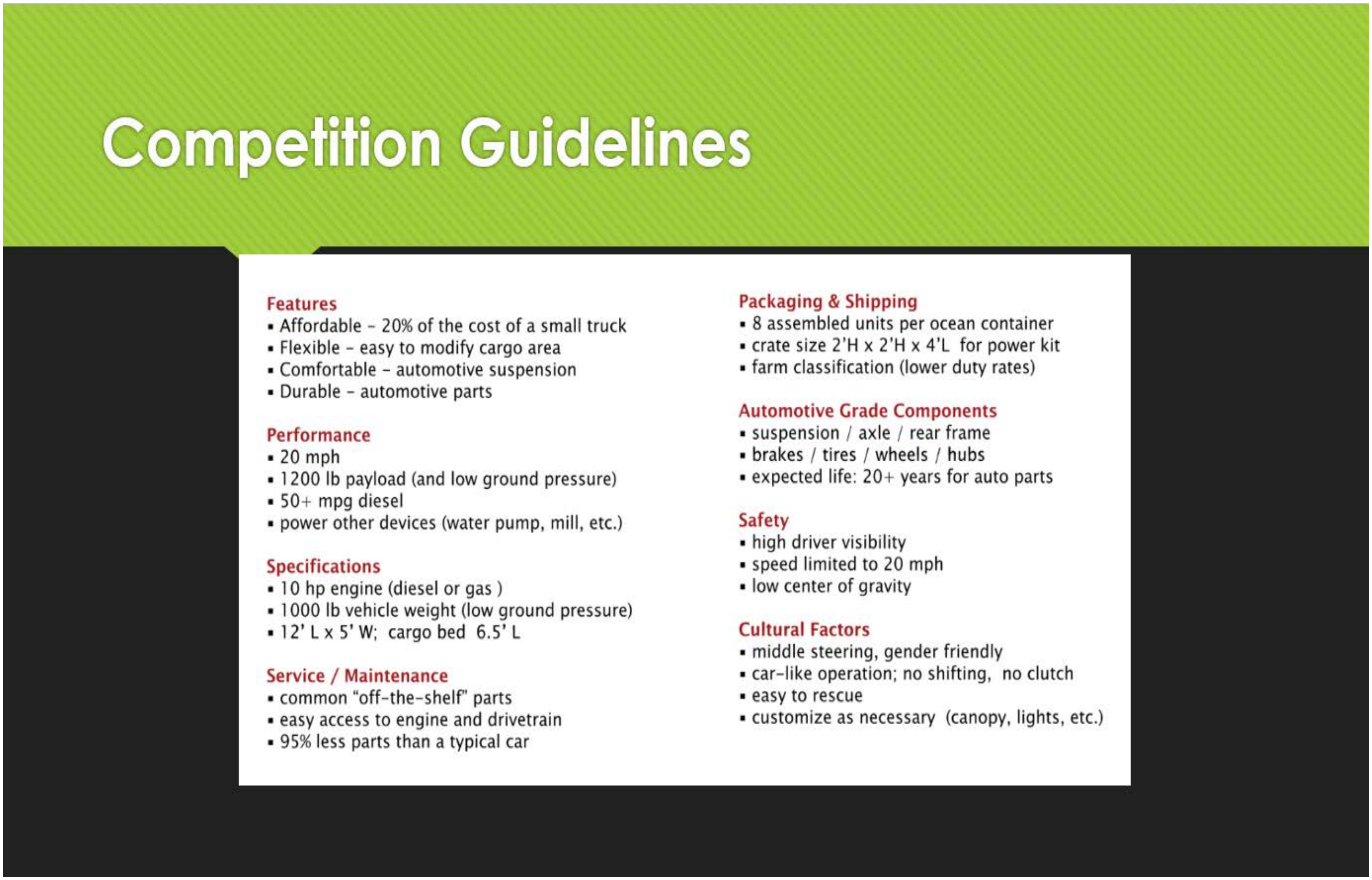
- Wood & Angle Iron Material
- Decrease overall Weight, increase speed

UC, 3rd Place Winners (2013)

- Recommend using angle iron and plywood for material; using truss design for chassis
- Weighted pressure was on the intermediate shaft which causes Drive train to have error

Current BUV in Production (2016)

- Cost about $5000 to produce



# Competition Guidelines

**Features**
- Affordable - 20% of the cost of a small truck
- Flexible - easy to modify cargo area
- Comfortable - automotive suspension
- Durable - automotive parts

**Performance**
- 20 mph
- 1200 lb payload (and low ground pressure)
- 50+ mpg diesel
- power other devices (water pump, mill, etc.)

**Specifications**
- 10 hp engine (diesel or gas )
- 1000 lb vehicle weight (low ground pressure)
- 12' L x 5' W; cargo bed 6.5' L

**Service / Maintenance**
- common "off-the-shelf" parts
- easy access to engine and drivetrain
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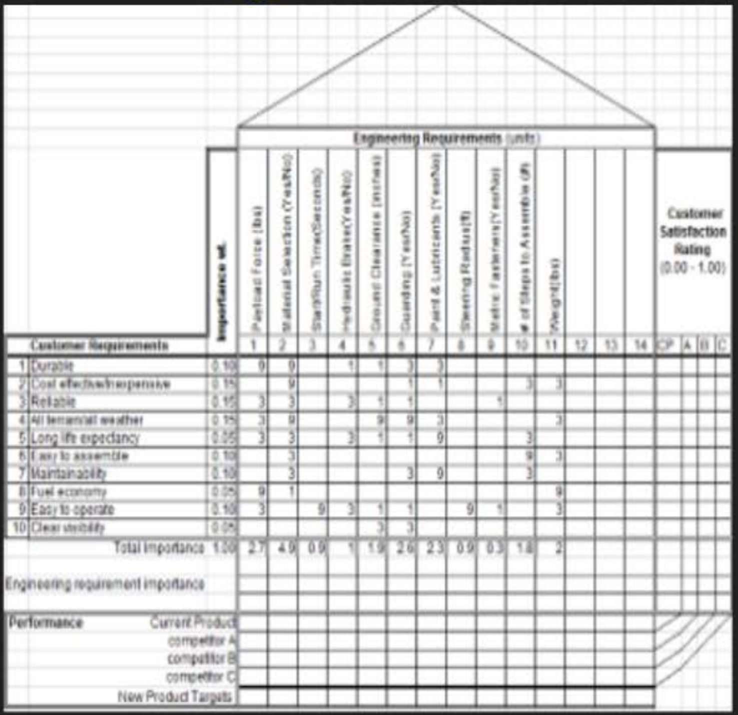
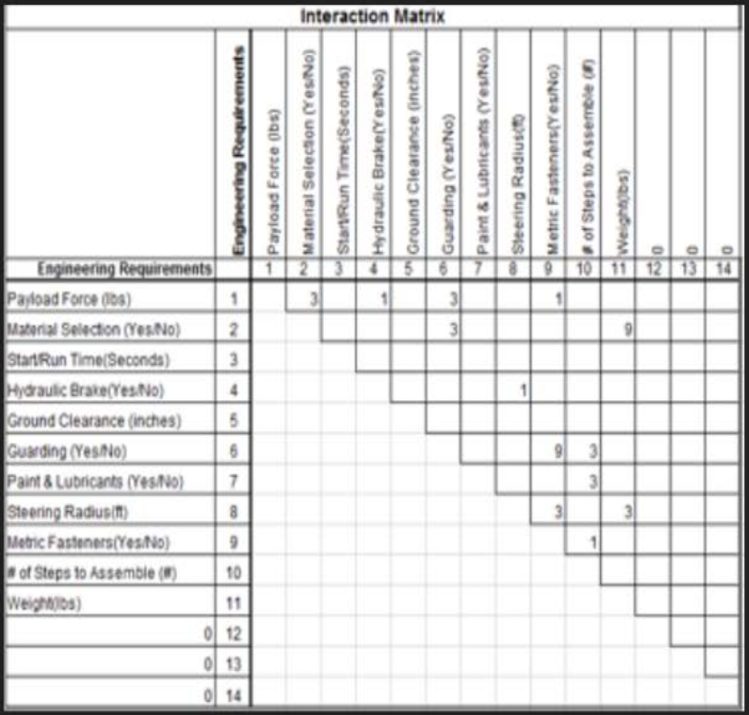
# QFD & House of Quality

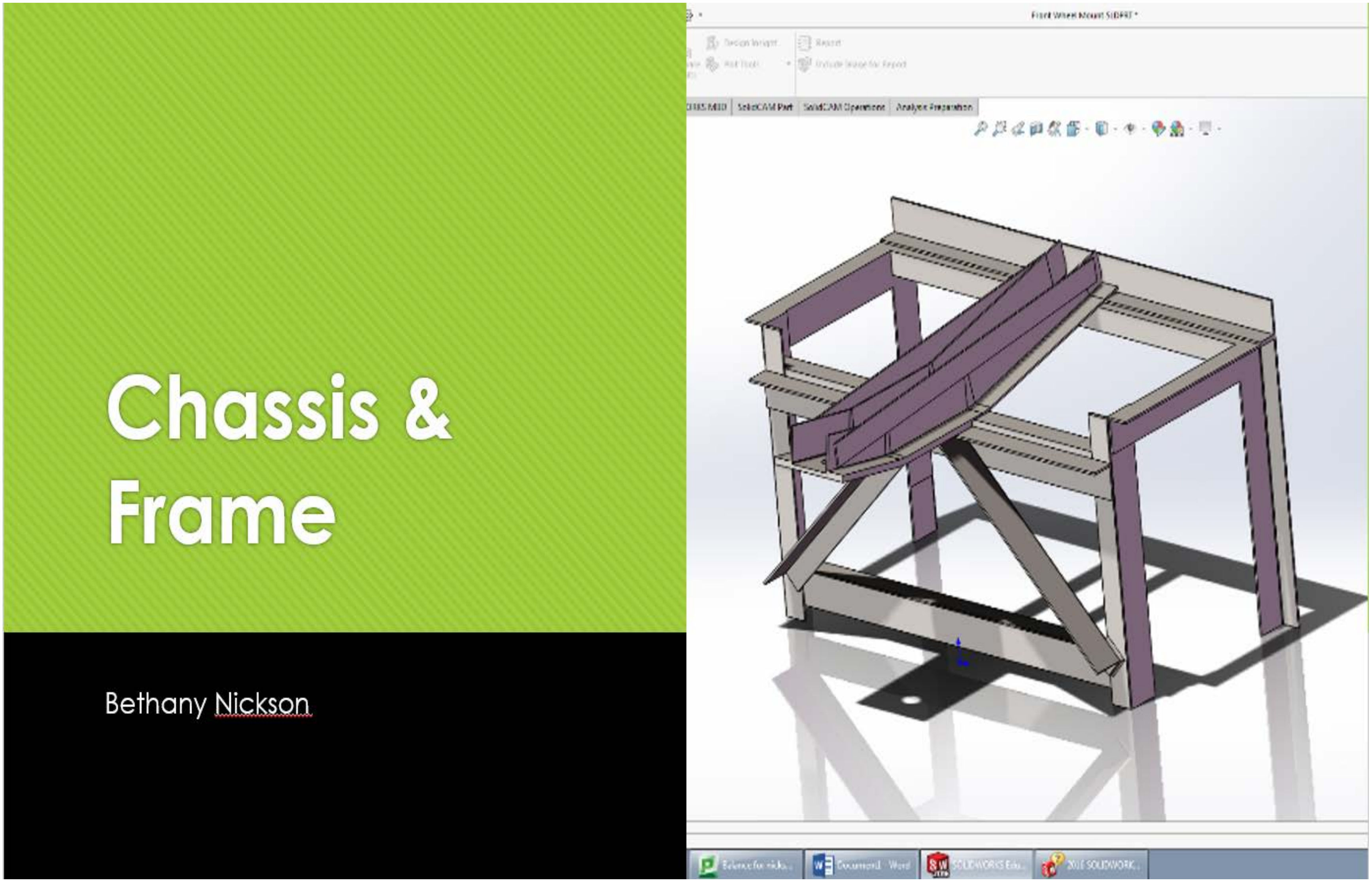


| | | | Engineering Requirements (units) | | | | | | | | | | | | | | Customer Satisfaction Rating (0.00 - 1.00) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Importance wt. | Payload Force (lbs) | Material Selection (Yes/No) | Start/Run Time(Seconds) | Hydraulic Brake(Yes/No) | Ground Clearance (inches) | Guarding (Yes/No) | Paint & Lubricants (Yes/No) | Steering Radius(ft) | Metric Fasteners(Yes/No) | # of Steps to Assemble (#) | Weight(lbs) | | | | | | | |
| | Customer Requirements | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | CP | A | B | C |
| 1 | Durable | 0.10 | 9 | 9 | | 1 | 1 | 3 | 3 | | | | | | | | | | | |
| 2 | Cost effective/inexpensive | 0.15 | | 9 | | | | 1 | 1 | | | 3 | 3 | | | | | | | |
| 3 | Reliable | 0.15 | 3 | 3 | | 3 | 1 | 1 | | | 1 | | | | | | | | | |
| 4 | All terrain/all weather | 0.15 | 3 | 9 | | | 9 | 9 | 3 | | | | 3 | | | | | | | |
| 5 | Long life expectancy | 0.05 | 3 | 3 | | 3 | 1 | 1 | 9 | | | 3 | | | | | | | | |
| 6 | Easy to assemble | 0.10 | | 3 | | | | | | | | 9 | 3 | | | | | | | |
| 7 | Maintainability | 0.10 | | 3 | | | | 3 | 9 | | | 3 | | | | | | | | |
| 8 | Fuel economy | 0.05 | 9 | 1 | | | | | | | | | 9 | | | | | | | |
| 9 | Easy to operate | 0.10 | 3 | | 9 | 3 | 1 | 1 | | 9 | 1 | | 3 | | | | | | | |
| 10 | Clear visibility | 0.05 | | | | | 3 | 3 | | | | | | | | | | | | |
| | Total importance | 1.00 | 2.7 | 4.9 | 0.9 | 1 | 1.9 | 2.6 | 2.3 | 0.9 | 0.3 | 1.8 | 2 | | | | | | | |
| | Engineering requirement importance | | | | | | | | | | | | | | | | | | | |
| Performance | Current Product | | | | | | | | | | | | | | | | | | | |
| | competitor A | | | | | | | | | | | | | | | | | | | |
| | competitor B | | | | | | | | | | | | | | | | | | | |
| | competitor C | | | | | | | | | | | | | | | | | | | |
| | New Product Targets | | | | | | | | | | | | | | | | | | | |



**Interaction Matrix**

| | Engineering Requirements | Payload Force (lbs) | Material Selection (Yes/No) | Start/Run Time(Seconds) | Hydraulic Brake(Yes/No) | Ground Clearance (inches) | Guarding (Yes/No) | Paint & Lubricants (Yes/No) | Steering Radius(ft) | Metric Fasteners(Yes/No) | # of Steps to Assemble (#) | Weight(lbs) | 0 | 0 | 0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Engineering Requirements | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| Payload Force (lbs) | 1 | | 3 | | 1 | | 3 | | | 1 | | | | | |
| Material Selection (Yes/No) | 2 | | | | | | 3 | | | | | 9 | | | |
| Start/Run Time(Seconds) | 3 | | | | | | | | | | | | | | |
| Hydraulic Brake(Yes/No) | 4 | | | | | | | | 1 | | | | | | |
| Ground Clearance (inches) | 5 | | | | | | | | | | | | | | |
| Guarding (Yes/No) | 6 | | | | | | | | | 9 | 3 | | | | |
| Paint & Lubricants (Yes/No) | 7 | | | | | | | | | | 3 | | | | |
| Steering Radius(ft) | 8 | | | | | | | | | 3 | | 3 | | | |
| Metric Fasteners(Yes/No) | 9 | | | | | | | | | | 1 | | | | |
| # of Steps to Assemble (#) | 10 | | | | | | | | | | | | | | |
| Weight(lbs) | 11 | | | | | | | | | | | | | | |
| 0 | 12 | | | | | | | | | | | | | | |
| 0 | 13 | | | | | | | | | | | | | | |
| 0 | 14 | | | | | | | | | | | | | | |

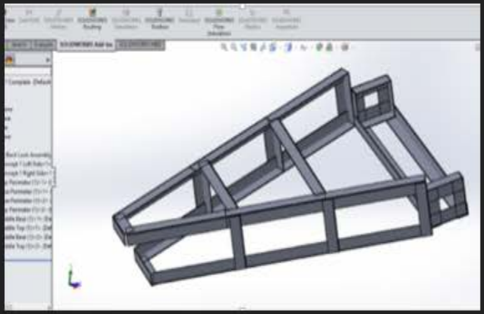


# Chassis & Frame

Bethany Nickson

# Concept Designs

## Concept 1: 2013 Design



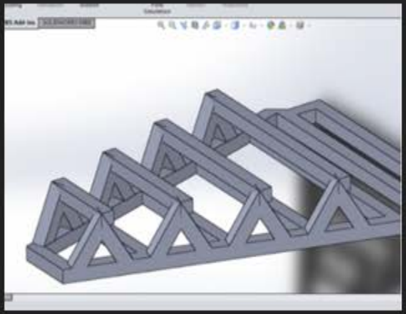
Pros:

- Good Ground Clearance
- Standard Manufacturing
- Lightweight
- Less Material

Cons:

- Lots of Welding
- Strength & Durability

## Concept 2: Warren Truss Design



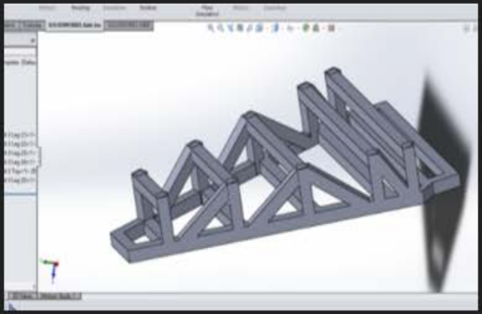
Pros:

- Good Ground Clearance
- Standard Manufacturing
- Durable / Strong
- Lightweight

Cons:

- Lots of Welding
- Lots of Material

## Concept 3: Howe Truss Design



Pros:

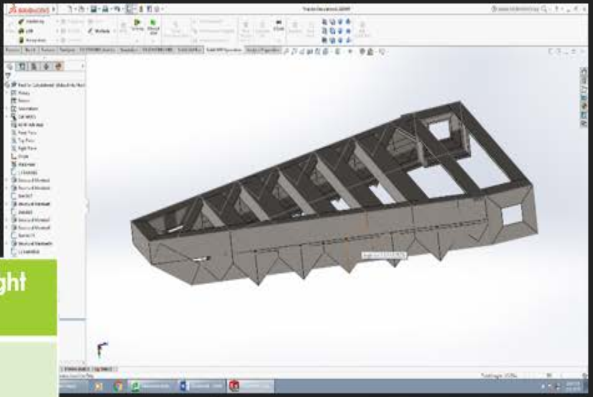
- Good Ground Clearance
- Durable / Strong

Cons:

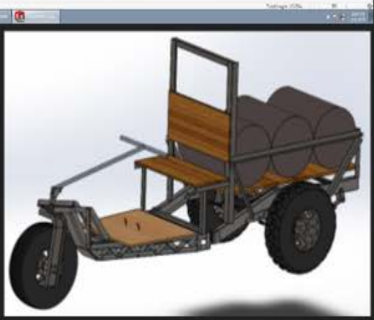
- Lots of Material
- Lots of Welding
- Multiple Size Members; Difficult Manufacturing

# Design Selection

Concept 2 (Warren Truss Design) was Selected
Material A36 2x2x3/8 inch angle iron steel

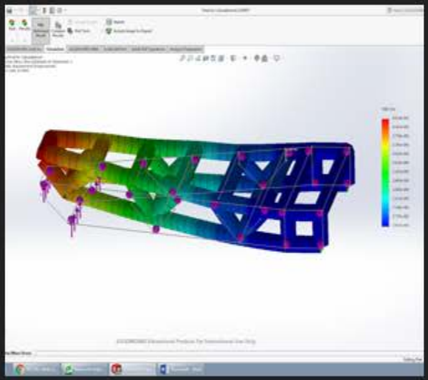


| Criteria | Weight % | Standard Design | Weight% | Warren Truss | Weight% | Howe Truss | Weight % |
|---|---|---|---|---|---|---|---|
| Ground Clearance | 5 | 4 | 0.2 | 4 | 0.2 | 4 | 0.2 |
| Easy Manufacturing | 10 | 4 | 0.4 | 3 | 0.3 | 1 | 0.1 |
| Durable & Strong | 35 | 2 | 0.7 | 4 | 1.4 | 4 | 0.7 |
| Amount of Material | 20 | 4 | 0.8 | 3 | 0.6 | 2 | 0.4 |
| Weight | 30 | 4 | 1.2 | 4 | 1.2 | 3 | 0.9 |
|  | =100 |  | =3.3 |  | **=3.7** |  | =2.3 |



# Design Selection Calculations

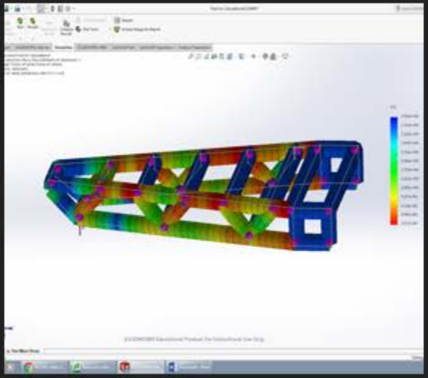
### Von Mises Stress



When applying 1500lbs of continuous force:

- Max: 36,000 psi
- Did not Pass

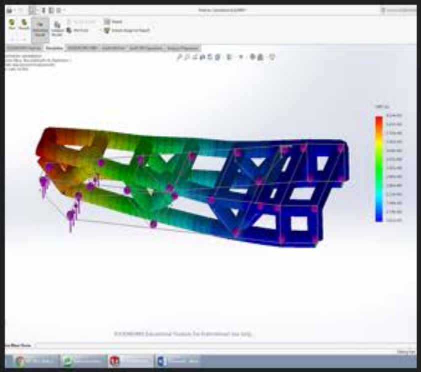
### Factor of Safety



When applying 1500lbs of continuous force:

- Highest FS = 2.45

### Displacement



When applying 1500lbs of continuous force:

- Max: 4.52 in
- Faulty

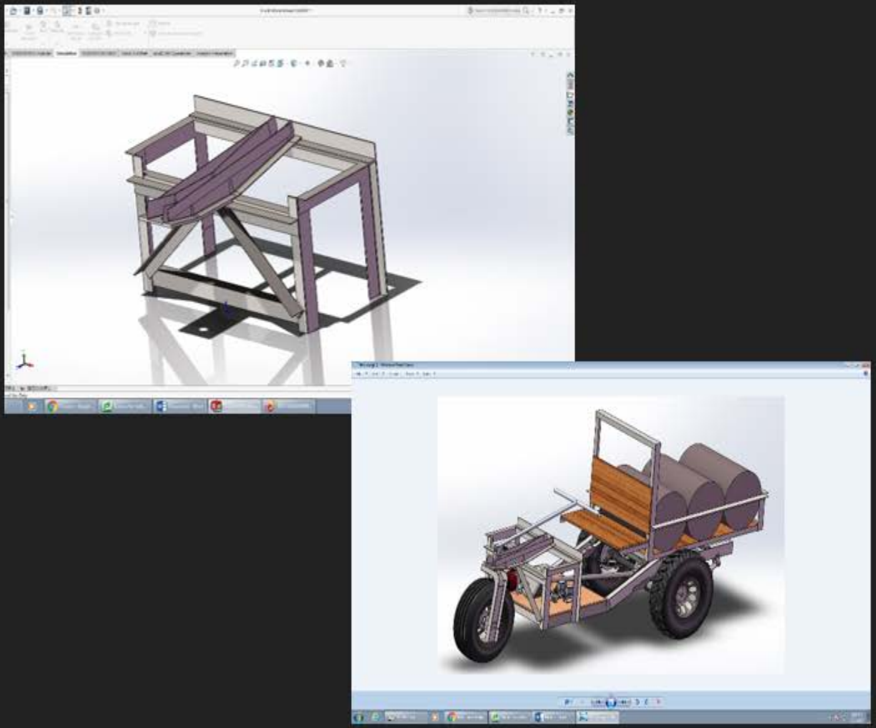
# Design Modifications

Thoughts:

- Needs to have a higher payload
- Support the drivetrain, brake system, and front suspension with the front chassis
- Less Material
- Easier to Fabricate (Less Welding)

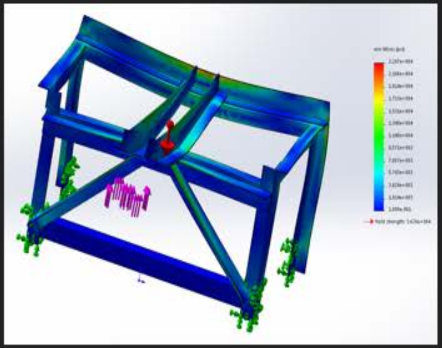
Conclusion:

- Use more of the truck frame
- Material: A36 3x2x3/8 angle iron steel
- Build up, not out
- Payload = 2840 pounds



# Final Design Calculations

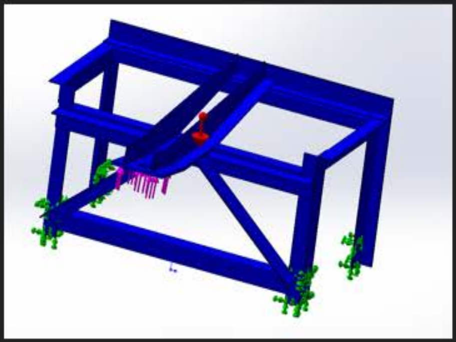
## Von Mises Stress



When applying design load of 2840 pounds:

- Max: 36,000 psi
- Highest: 20,380 psi

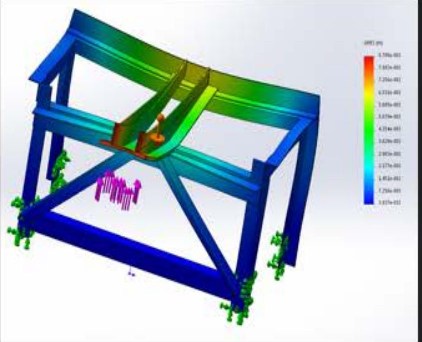
## Factor of Safety



With a 2840 pound design load:

- Min: 1.77

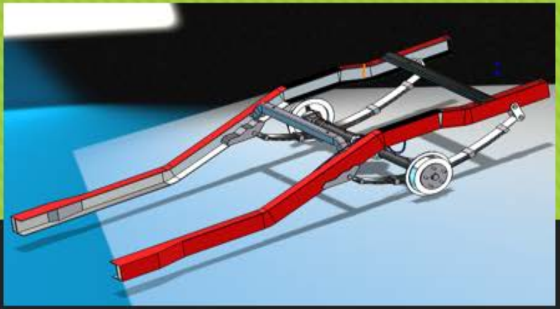
## Displacement



When applying 2840 pounds of force:

- Max: 0.0871 inches

# Fabrication & Modifications



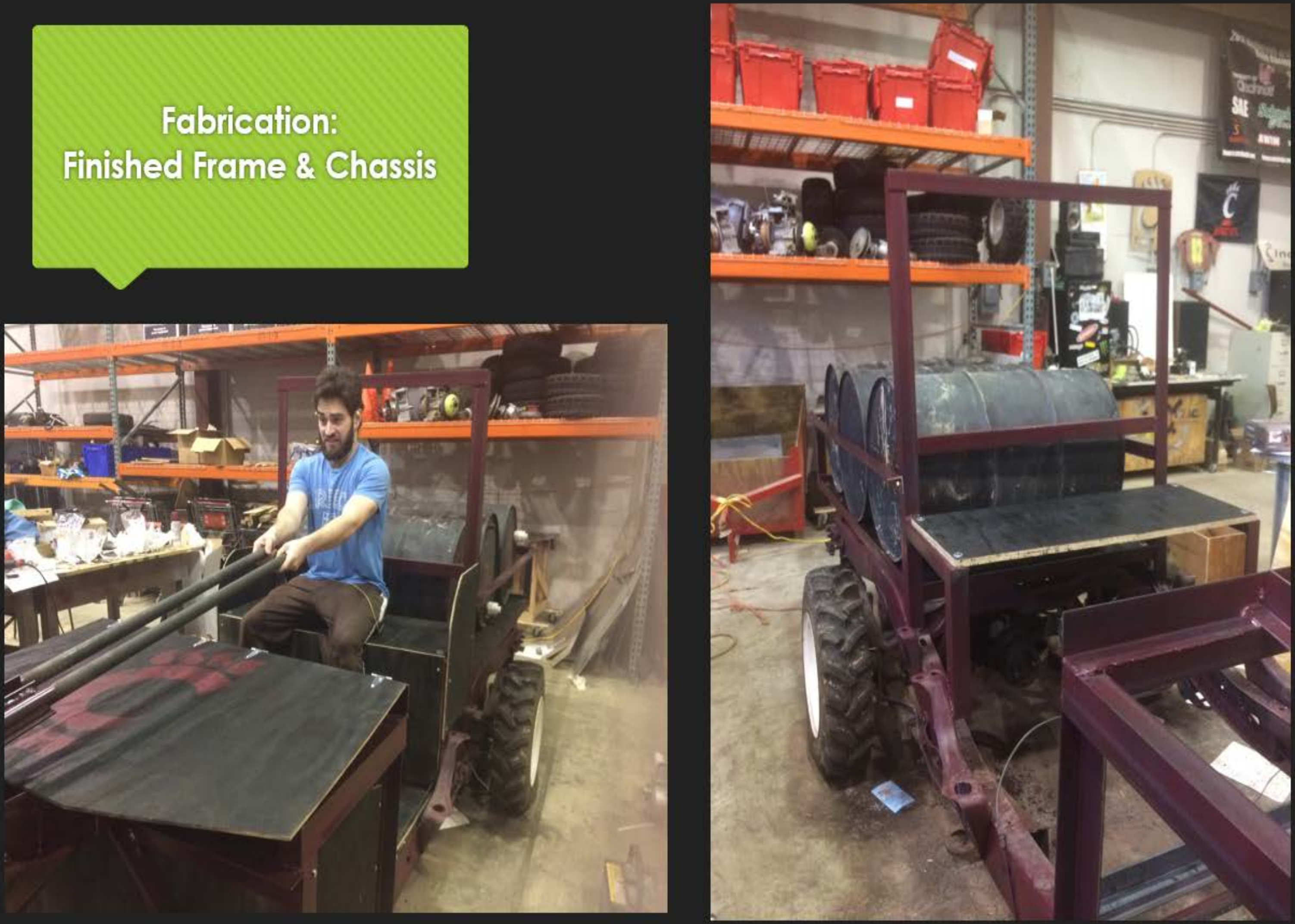
Fabrication Process

- 1994 Chevrolet S10 Frame from U-Pull & Pay
- MIG Welding – of Front Chassis, S10 Frame, & Lower Cargo Bed Rail
- Bolt – upper Cargo Bed Rail (allow removal of barrels)

Modifications

- Used 2x2 angle iron for cargo bed

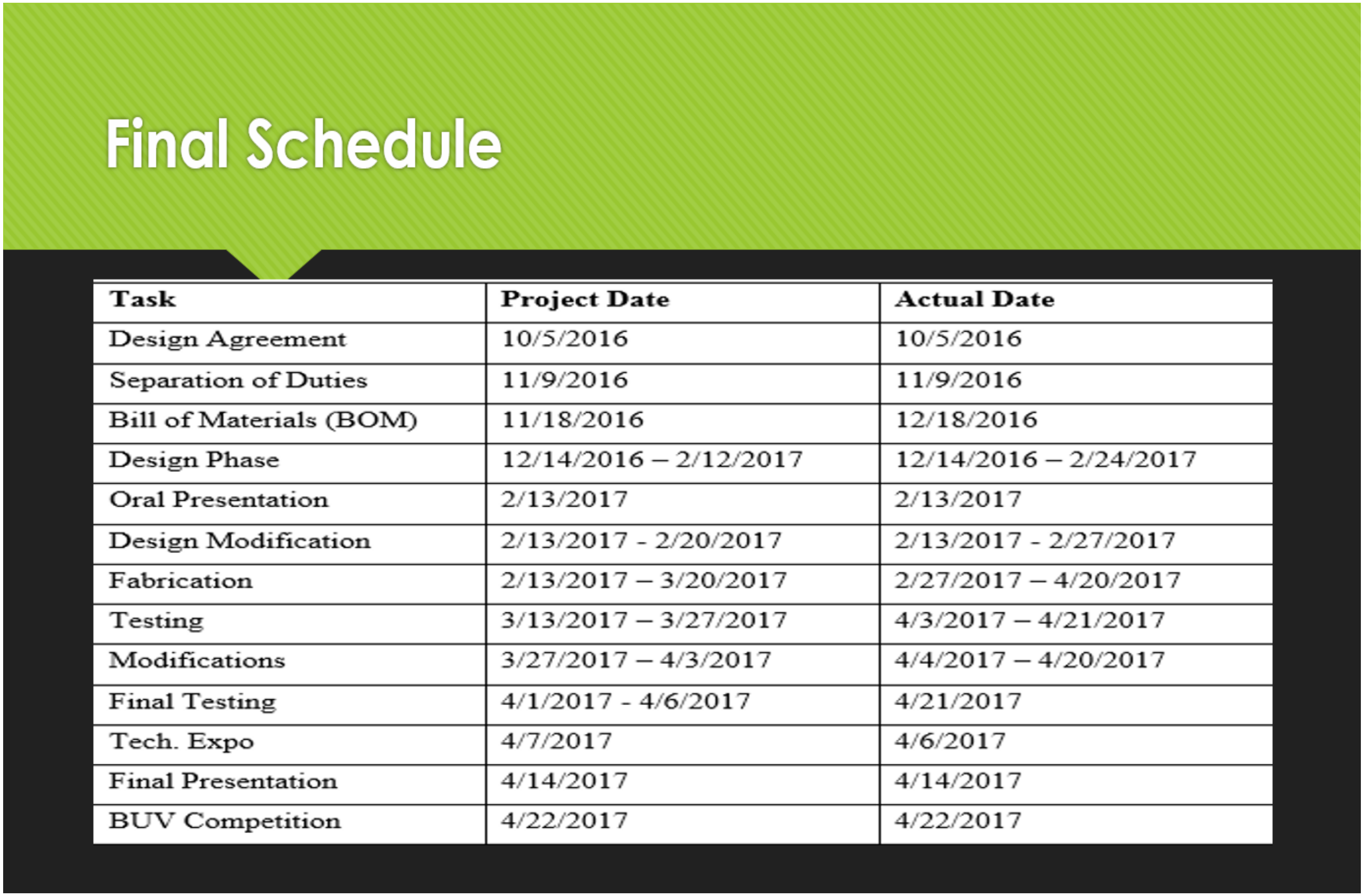
## Fabrication:
## Finished Frame & Chassis



# Proof of Design

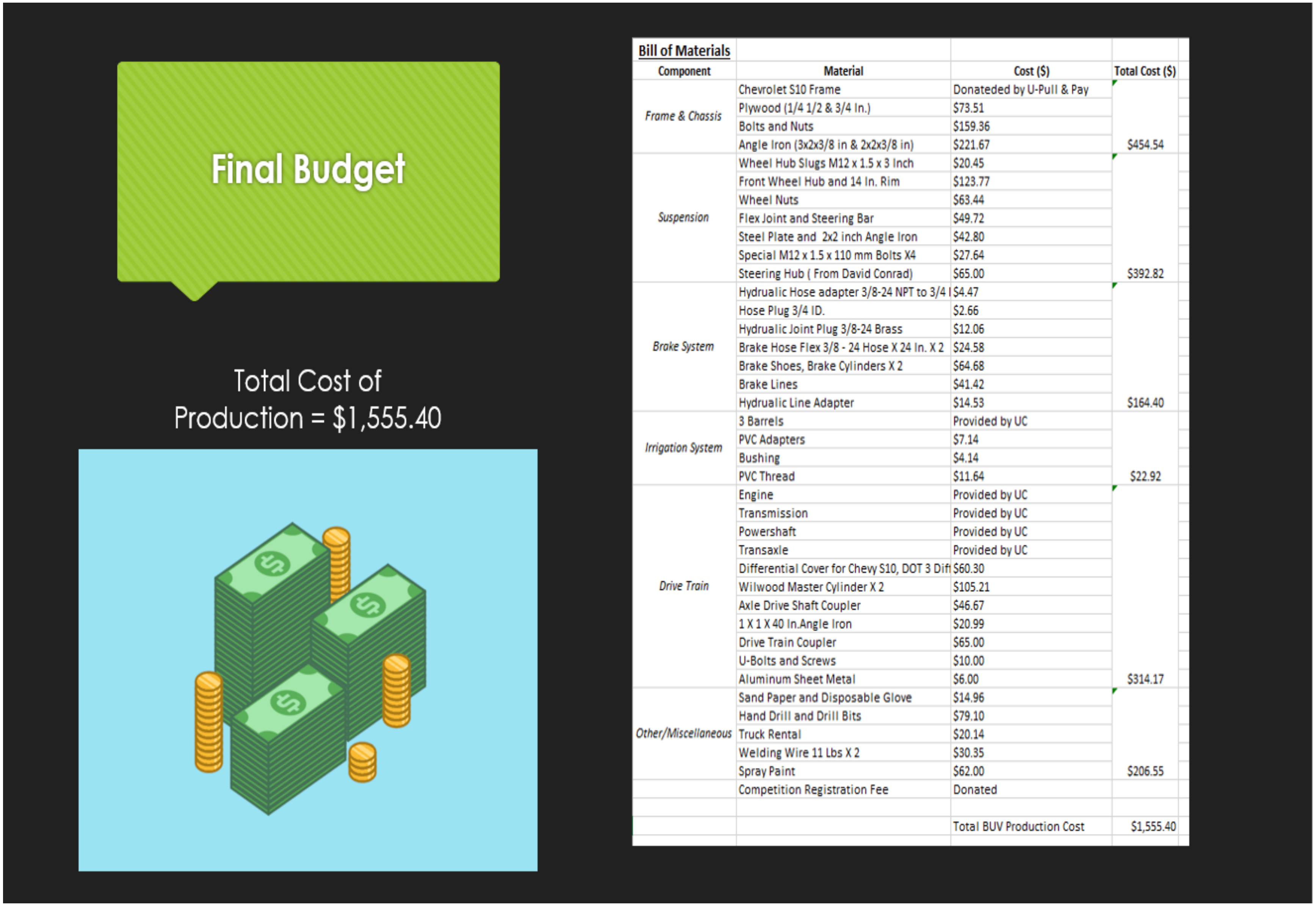
- Light Weight angle iron Material
- 10 inch ground clearance
- 2840lbs Payload, w/ 20 degree incline
- Cargo Bed area is approx. 20 ft^2
- Production Cost is relatively low; under $2000
- 10 hp engine: Product Specification Sheet (Drive train)
- Will have a reverse mode Physical Shift to Reverse: Visual Verification (Drive Train)

Reverse mode; Physical Shift to reverse



# Final Schedule

| Task | Project Date | Actual Date |
|---|---|---|
| Design Agreement | 10/5/2016 | 10/5/2016 |
| Separation of Duties | 11/9/2016 | 11/9/2016 |
| Bill of Materials (BOM) | 11/18/2016 | 12/18/2016 |
| Design Phase | 12/14/2016 – 2/12/2017 | 12/14/2016 – 2/24/2017 |
| Oral Presentation | 2/13/2017 | 2/13/2017 |
| Design Modification | 2/13/2017 - 2/20/2017 | 2/13/2017 - 2/27/2017 |
| Fabrication | 2/13/2017 – 3/20/2017 | 2/27/2017 – 4/20/2017 |
| Testing | 3/13/2017 – 3/27/2017 | 4/3/2017 – 4/21/2017 |
| Modifications | 3/27/2017 – 4/3/2017 | 4/4/2017 – 4/20/2017 |
| Final Testing | 4/1/2017 - 4/6/2017 | 4/21/2017 |
| Tech. Expo | 4/7/2017 | 4/6/2017 |
| Final Presentation | 4/14/2017 | 4/14/2017 |
| BUV Competition | 4/22/2017 | 4/22/2017 |



## Final Budget

Total Cost of
Production = $1,555.40

**Bill of Materials**

| Component | Material | Cost ($) | Total Cost ($) |
|---|---|---|---|
| *Frame & Chassis* | Chevrolet S10 Frame | Donateded by U-Pull & Pay | |
| | Plywood (1/4 1/2 & 3/4 In.) | $73.51 | |
| | Bolts and Nuts | $159.36 | |
| | Angle Iron (3x2x3/8 in & 2x2x3/8 in) | $221.67 | $454.54 |
| *Suspension* | Wheel Hub Slugs M12 x 1.5 x 3 Inch | $20.45 | |
| | Front Wheel Hub and 14 In. Rim | $123.77 | |
| | Wheel Nuts | $63.44 | |
| | Flex Joint and Steering Bar | $49.72 | |
| | Steel Plate and 2x2 inch Angle Iron | $42.80 | |
| | Special M12 x 1.5 x 110 mm Bolts X4 | $27.64 | |
| | Steering Hub ( From David Conrad) | $65.00 | $392.82 |
| *Brake System* | Hydrualic Hose adapter 3/8-24 NPT to 3/4 I | $4.47 | |
| | Hose Plug 3/4 ID. | $2.66 | |
| | Hydrualic Joint Plug 3/8-24 Brass | $12.06 | |
| | Brake Hose Flex 3/8 - 24 Hose X 24 In. X 2 | $24.58 | |
| | Brake Shoes, Brake Cylinders X 2 | $64.68 | |
| | Brake Lines | $41.42 | |
| | Hydrualic Line Adapter | $14.53 | $164.40 |
| *Irrigation System* | 3 Barrels | Provided by UC | |
| | PVC Adapters | $7.14 | |
| | Bushing | $4.14 | |
| | PVC Thread | $11.64 | $22.92 |
| *Drive Train* | Engine | Provided by UC | |
| | Transmission | Provided by UC | |
| | Powershaft | Provided by UC | |
| | Transaxle | Provided by UC | |
| | Differential Cover for Chevy S10, DOT 3 Dif | $60.30 | |
| | Wilwood Master Cylinder X 2 | $105.21 | |
| | Axle Drive Shaft Coupler | $46.67 | |
| | 1 X 1 X 40 In.Angle Iron | $20.99 | |
| | Drive Train Coupler | $65.00 | |
| | U-Bolts and Screws | $10.00 | |
| | Aluminum Sheet Metal | $6.00 | $314.17 |
| *Other/Miscellaneous* | Sand Paper and Disposable Glove | $14.96 | |
| | Hand Drill and Drill Bits | $79.10 | |
| | Truck Rental | $20.14 | |
| | Welding Wire 11 Lbs X 2 | $30.35 | |
| | Spray Paint | $62.00 | $206.55 |
| | Competition Registration Fee | Donated | |
| | | | |
| | | Total BUV Production Cost | $1,555.40 |

# Final Build

- Completed Frame & Chassis
- Completed Cargo Bed
- Completed Suspension System
- Completed Brake System
- Completed Irrigation System
- Completed Drive Train

Competition Expectations

- To Complete the 8 hour course
- Problems w/ 10 inch Ground Clearance
- Front Suspension; pivot point
- Initial pump; starter issues

# Competition Results

Initial Starter Issues

- It took about an hour to start the engine and get it going
- The straps that held the engine down began to melt off and we decided to use a metal chain

Problems w/ Ground Clearance

- We got stuck in the mud a lot!

Front Suspension

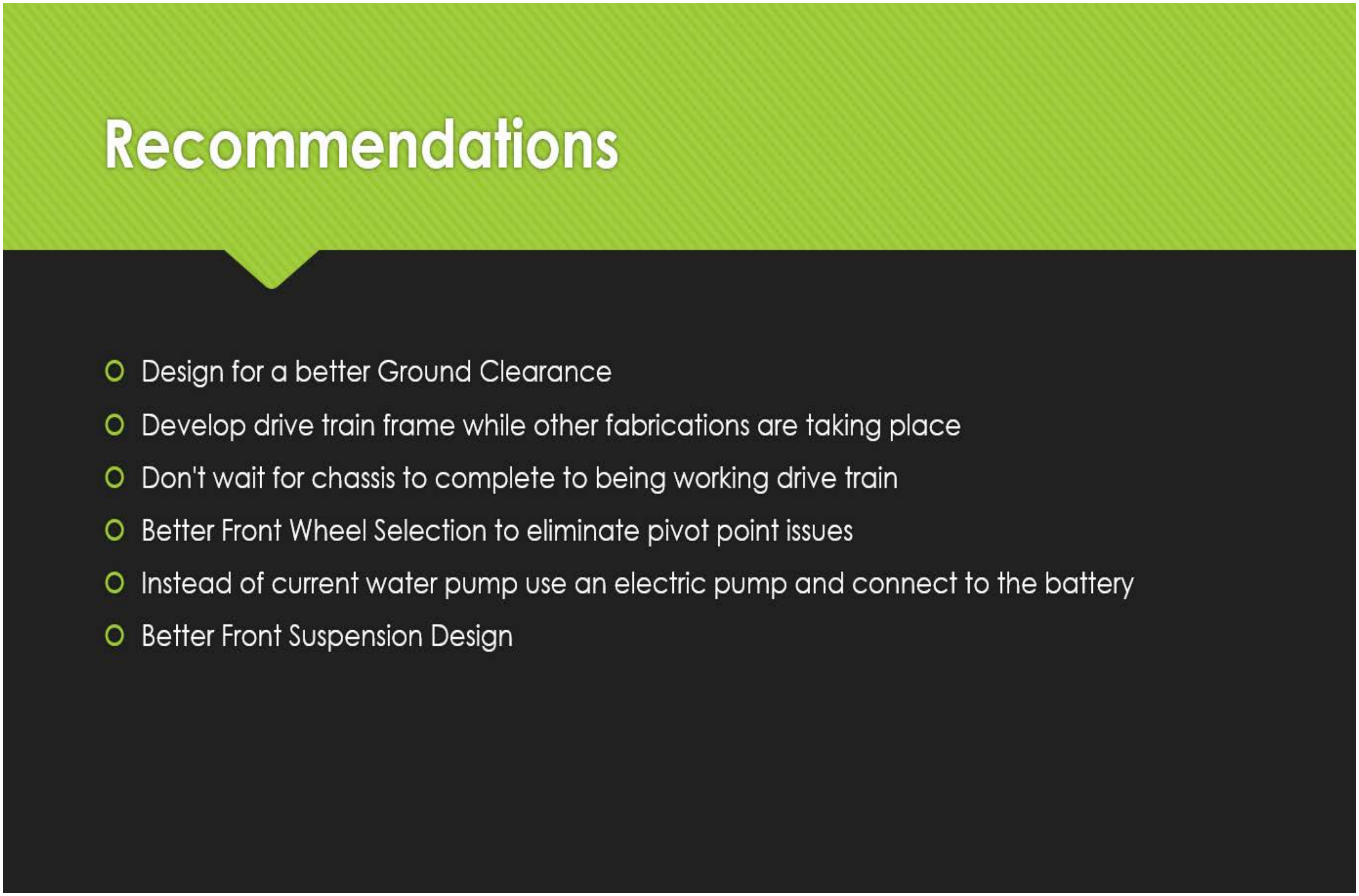
- Large turning radius made it hard to maneuver the BUV; needed at least 2 people

Failure

- Front Wheel popped out when we were getting pulled out of the mud
- Popped out again about 40 minutes later

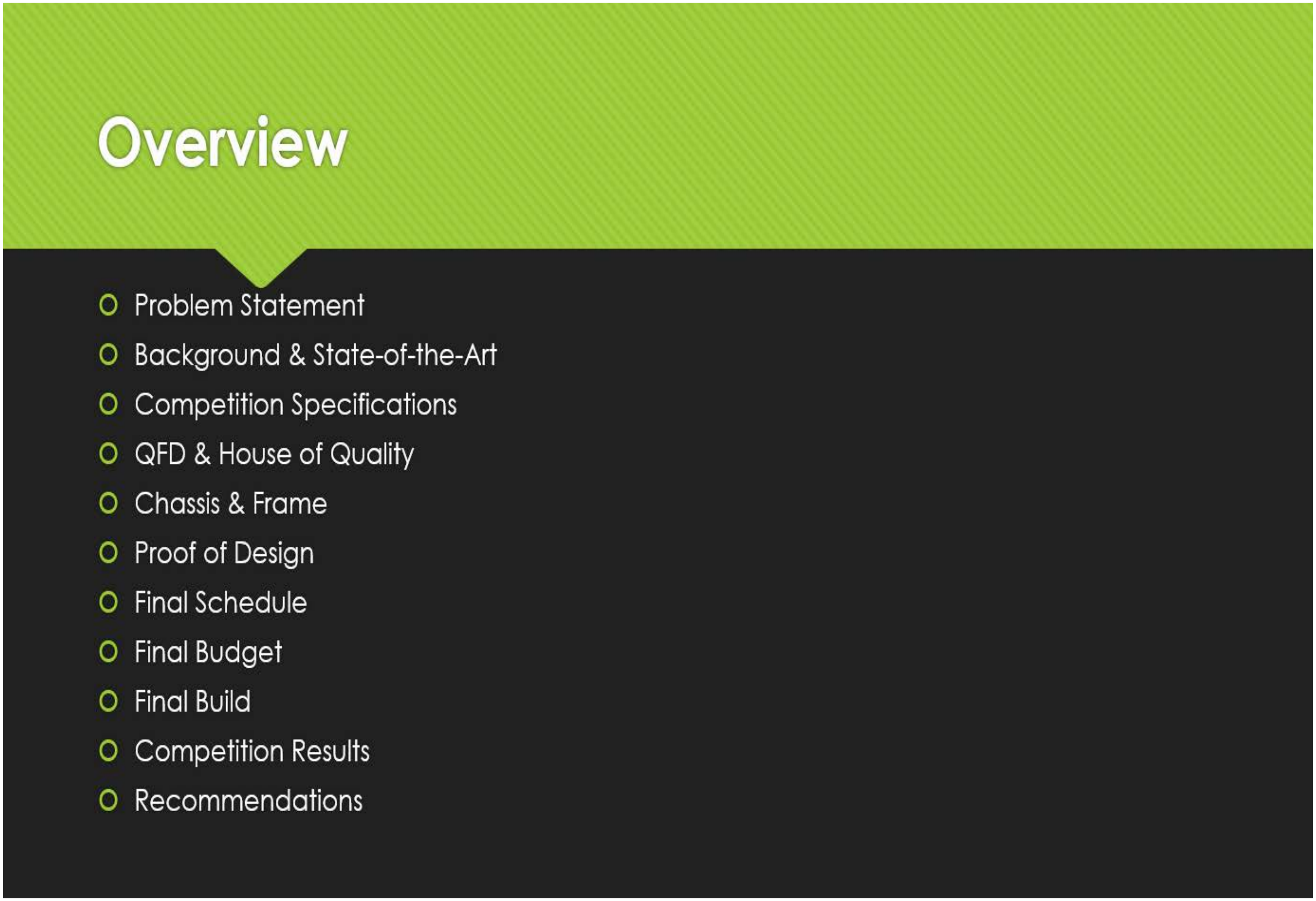
Progress

- Vehicle ran from 11am to 2 pm
- Did not place in the Competition



# Recommendations

- Design for a better Ground Clearance
- Develop drive train frame while other fabrications are taking place
- Don't wait for chassis to complete to being working drive train
- Better Front Wheel Selection to eliminate pivot point issues
- Instead of current water pump use an electric pump and connect to the battery
- Better Front Suspension Design



# Overview

- Problem Statement
- Background & State-of-the-Art
- Competition Specifications
- QFD & House of Quality
- Chassis & Frame
- Proof of Design
- Final Schedule
- Final Budget
- Final Build
- Competition Results
- Recommendations

# Questions