Basic Utility Vehicle (BUV)
Electrics and Braking System

A Baccalaureate thesis submitted to the
Department of Mechanical and Materials Engineering
College of Engineering and Applied Science
University of Cincinnati

in partial fulfillment of the
requirements for the degree of

Bachelor of Science
in Mechanical Engineering Technology

by

Guanchun Ye

April 2017

Thesis Advisor: Moise Cummings
ACKNOWLEDGEMENTS

The 2017 MET Senior Design BUV team would like to thank all peoples and companies generous donation and support to BUV project.

Without your support, we are impossible to design and fabricated 2017 BUV

To Professor Cheryll A. Dunn, for your generous donation to the project.

To Professor Moise Cummings, for your outstanding advisement to our senior design.

To Professor David W. Conrad, for your excellent advisement for machining and hosting the BUV competition.

To all team members, for your great contribution to our project.
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ABSTRACT

BUV (Basic Utility Vehicle) is design and developing for third world country to provide a low cost, easy to maintain transportation. BUV must be able to handle all terrain and easy to fix problem by simple tools. The BUV competition is host by The Institute of Affordable Transportation (IAT) every year. IAT provide a bridge from students to those third world country customers, so students can get customer requirement and also feedback about our design. Our target of this project is to design and build a BUV with low cost, easy to build and maintain and good handling on non-pavement road. Our team has five members, and whole project was separate into five parts, each of us has to design one of them, and build whole vehicle together. Bethany Nickson designed front chassis and frame, Christopher Steward designed power system, Dickson Opoku designed front suspension and turning system. Deamann Strefas designed irrigation system and Guanchun Ye designed Brake system. Once whole design finished and approved by adviser Professor Moise Cummings, Whole team work together for fabrication and installation.
INTRODUCTION

**PROBLEM STATEMENT:**

For people living in third world countries and lack of affordable translation methods, basic Utility Vehicle is one the best choice to improve quality of life. Institute for Affordable Transportation is a group wants to solve this problem, so they collect vehicle requirements from those third world countries and host a BUV competition to encourage Engineers from US collages and social to provide better design.

BUV is very simple and reliable daily drive vehicle; it must able to carry object from small daily using items to heavy material like cement and sand. Besides, BUV must easy to drive and maintain, driver doesn’t need to be trained before driving and also able to fix issues with simply tools.

**TEAM MEMBER RESPONSIBILITIES**

Bethany Nickson - Chassis & Frame
Christopher Steward - Drive Train
Dickson Opoku - Front Suspension
Deamann Strefas - Irrigation System (Team Leader)
Guanchun - Brake system
RESEARCH AND BACKGROUND

CUSTOMER REQUIREMENTS

Below is the requirement for brake system from ITA organization.

1. Dual or more brake system to prevent one brake unit failure.
2. Brake must locate at wheel, not at drive line.
3. Front wheel brake is not required on three wheels vehicles.
4. Parking Brake is not considered as redundancy.
5. Hydraulic Drives may use reverse for brakes.

INTERVIEWS

To better understand brake system of BUV, we made an informal interview with UC BUV club team and Professor David Conrad.

Information gathered:

1. Using Dual Wilwood High Volume Master Cylinder, because many teams use it, and work perfectly.
2. Must use brake hose to connect brake end with chassis end, because hard pipe might broke when rear suspension been compressed.
3. Make sure brake line use same type of connector, inverted flare or bubble flare, pipe and hose must connect with same type connector, different type connector will cause fluid leakage.
4. Use flex joint to connect brake pedal with master cylinder.
PREVIOUS BUV DESIGN
It’s necessary to look at previous design to help build up a brief understanding of BUV.

In 2012, Purdue University BUV team won first place of BUV competition. They use dual brake unit with two individual brake pedal to control each rear wheel, this design will meet requirement 1 on requirement sheet, also might help turning (See Figure 1).

Good thing about this unit is two brake unit will not affect each other when one unit failure. And also able to use torque turning to help BUV get out of mud.

In 2014, UC BUV team use one brake pedal to push two master cylinders (See Figure 2), and they got fourth place in the BUV competition.
Figure 2. 2014 UC BUV (2)

Benefit of this design is cheap to build, but when 2014 BUV test this system, one master cylinder broken, so they have to replace new unit. So the disadvantage of this design is when one unit broken or jammed, whole brake system might fail.

In 2016 & 2017, UC BUV club team use two brake unit system with different design (See Figure 3 & 4)
It’s clear that, dual brake unit with feet pedal become more popular after many years competition, it is a success design.
**IDEA TO SOLVE PROBLEM:**

To design this dual brake system, the final target is to lock rear tires, because BUV normally don’t have an Anti-Lock Braking System onboard, so when rear wheels locked, BUV will finally stop.

To lock rear wheels, it’s necessary to have friction factor between tire and ground, friction factor of brake. Calculate needed brake force first, and then calculate hydraulic pressure in hydraulic system.

Finally calculate needed force apply on master cylinder. Brake pedal system use lever principle to increase output force. Input force and output force of pedal system is necessary for design a brake pedal system.

![Brake System Flow Chart](image)

Figure 5. Flow chart of brake system

Data needed:

1. Estimate length, width and total weight of BUV.

2. Average pedal force of human.

3. Friction factor of brake, friction factor between ground and tires.
According to a report from National Highway Safety Bureau U.S. Department of Transportation Washington. 
Average pedal force of male is around 250 lbs (See Figure 6) 

![Cumulative percent pedal force for 323 males.](image)

Figure 2.5. Cumulative percent pedal force for 323 males.

Figure 6. Average pedal force of male (3)

Average Pedal force of female is around 150 lbs (See Figure 7)
This BUV is designed for both male and female drivers, so 150 lbs is selected as the average pedal force.

According to the report *Influence of soil and tire parameters on traction*, ground coefficient of agriculture tires is 0.5 at clay and moisture condition of ploughed land. (4)

According to the report *Comparative Frictional Analysis of Automobile Drum and Disc Brakes*, friction factor of drum brake is about 0.4 to 0.6. In this calculation, 0.4 is selected as the brake coefficient. (5)

Assume total length of wheel base is 100 In. Height of COG (center of gravity) = 30 In.
Total weight of BUV (Fully loaded) = 2841 lbs (See Figure 8)

<table>
<thead>
<tr>
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<tr>
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<td>BUV</td>
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<td>Total Weight</td>
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Figure 8. Total Weight of BUV

**BRAKE CONCEPT SELECTION:**

There are three most common brake systems; hydraulic disc brake, hydraulic drum brake and wire drum brake. The criterion of this selection is higher brake efficiency, high reliability, low maintenance, low cost, light weight and weather resistance. By using weighted rating method, best choice is use Hydraulic drum brake system.

Hydraulic Disc Brake is one of the most common brake systems on market, it able to provide great brake force, better cooling than drum brake, high resistance to water. But in basic utility vehicle, cost of brake unit is major concert, disk brake is much expensive than drum brake.

Hydraulic Drum Brake is normally use for truck and low price vehicle, it’s able to provide good brake force, good water resistance and cheaper than disk brake. But drum brake also get lower cooling ability and heavier than disk brake.

Wire Drum Brake is the cheapest brake unit, but might not able to stop such a heavy vehicle.
## Brake Selection

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Importance Weight (%)</th>
<th>Rating</th>
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<th>Concept Alternatives</th>
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<td>Adequate</td>
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<tr>
<td>Good</td>
<td>3</td>
</tr>
<tr>
<td>Very Good</td>
<td>4</td>
</tr>
</tbody>
</table>

Conclusion: Hydraulic Drum brake is better than disc brake under the requirement of competition.

Table 1. Brake Concept Selection
CALCULATION

CENTER OF GRAVITY
Set maximum climbing angle is 30° (See Figure 9)

Figure 9. Center of Gravity

Let

Total Weight = W
wheel base = L
Distance from front axle to center of gravity = a
Distance from rear axle to center of gravity = L-a
Distance from wheel base to center of gravity = b
Ground force support front wheel = f1
Ground force support rear wheel = f2
Brake force = B
Slope Angle = \( \theta \)

Then: \( f_1 \cdot a + B \cdot b = (L - a) \cdot f_2 \) \hspace{1cm} (1)

\( f_1 + f_2 = W \cdot \cos(\theta) \) \hspace{1cm} (2)

\( B = W \cdot \sin(\theta) \) \hspace{1cm} (3)

When center of gravity fixed, higher brake force will lower \( f_1 \), make BUV easier roll over.

To calculate center of gravity under worst condition, we assume BUV stop at slope, then rear wheel provide static friction, so \( B=W \cdot \sin(\theta) \).

Combine equation 1, 2 & 3

\[
f_1 = \frac{LW \cdot \cos(\theta) - aW \cdot \cos(\theta) - W \cdot \sin(\theta) \cdot b}{L}
\] \hspace{1cm} (4)

When \( f_1 = 0 \), which mean BUV about to roll over if center of gravity move backward.

Assume: \( L = 100 \) In.

\( W = 2841 \) lbs

\( \theta = 30^\circ \)

\( B = 30 \) In

Solve equation 5. \( a = 82.679 \) In.

Then the center of gravity should located around 80 In. from front wheel axle.
**BRAKE PEDAL LEVEL RATIO**

![Diagram of BUV braking system]

Figure 10. BUV Stop at 30° slope

Safety Factor for Single Brake Unit = 1.5

Safety Factor for Brake System = 3

Force Applied on pedal = 150 lbs.

Force vertical to ground = Total Weight * cos 30° = 2841Lbs * cos(30) = 2460.378 Lbs.

Maximum brake force to lock wheel = \( \frac{\text{Ground force}}{2} \) * Ground Coefficient = \( \frac{2460.378Lbs}{2} \)

0.5 = 615.0945 Lbs

Torque provided by drum brake = Lock wheel force * Tire Loaded Radius =

615.0945Lbs * 13In. = 7996.2285In.Lb

Force provided by brake cylinder = \( \frac{\text{Torque provide by brake}}{\text{Brake hose radius}^2} \) = \( \frac{7996.2285Lbs}{0.5In^2} \) = 841.708 Lbs

Hydraulic pressure provided by brake cylinder = \( \frac{\text{Force}}{\text{Bore Area}} \) * safety factor = \( \frac{841.708Lbs}{\pi * 0.75^2} \)

1.5 = 2857.855psi
Assume there is no Hydraulic Pressure Loss, So Hydraulic inside brake line is equal, then

Hydraulic pressure provided by master cylinder = Hydraulic pressure of brake cylinder = 2857.855 psi

Force applied on master cylinder = \( \text{Hydraulic Pressure} \times \text{Bore Area} = 2857.855 \times \frac{\pi \times 0.75^2}{4} = 1262.562Lbs \)

Lever Ratio = \( \frac{\text{Output Force}}{\text{Input Force}} = \frac{1262.562Lbs}{150} = 8.42 \)

**DESIGN**

**PEDAL CONCEPTS SELECTION:**

Below is three brake pedal concepts, one will be selected by using weighted rating method. The criterions of pedal design the size of brake unit, low cost, high reliability, easy to maintain and use. Save room are most important criterions of this selection, because size of engine house is very compact, most room must left for power unit. First design is come from 2016 UC BUV club team, it is the most classical pedal design, but this design is too high. Second concept is from 2015 UC BUV club team, by look at the total length of pedal, it’s too long. Third design is very compact, design to fit small engine house. After fill out weight value of each concept, design 3 get highest score.
### Brake Selection

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Importance Weight (%)</th>
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<th>Design 3</th>
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<tr>
<td>High reliability</td>
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<td>3</td>
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<tr>
<td>Low cost</td>
<td>15</td>
<td>3</td>
<td>45</td>
<td>3</td>
</tr>
<tr>
<td>Easy to maintain</td>
<td>20</td>
<td>3</td>
<td>60</td>
<td>2</td>
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<td>Easy to use</td>
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<td>Good</td>
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</tr>
<tr>
<td>Very Good</td>
<td>4</td>
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Design 3 is the best choice under this condition

### Concept Alternatives

<table>
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<th>Brake arm length (in)</th>
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<th>Design 3</th>
<th>Brake arm length (in)</th>
<th>Total length (in)</th>
<th>Total Height (in)</th>
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<td>8.42</td>
<td>9.15</td>
<td>6</td>
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</table>

Table 2. Pedal Concepts Selection
**DESIGN MODIFICATION:**

When whole BUV design finished, it’s clear that there no ground room to install dual brake system, master cylinder must move to top of engine house, brake pedal must move out from engine house. (See Figure 11)

![Master Cylinder and Brake Pedals](image)

Figure 11. New Pedal Design

Benefit of this design:

1. Save ground room, left more room for power system.
2. Easy to maintain, master cylinder is hanged under hood, same position as most vehicle.
3. No special design part, all components can be made from steel strip, angle iron, square head tube and steel plate.
FABRICATION

Whole brake system fabrication will separate into three parts: Drum brake unit, Brake line and Brake pedal assembly.

DRUM BRAKE UNIT ASSEMBLY

Chassis of BUV is 1999 Chevrolet S10 Pickup truck; chassis came with two drum brake units. (See Figure 12)

Figure 12. Chevy S10 Drum Brakes

It’s not too bad inside, but for safety reason, spring kits, master cylinder and brake shoes must be replaced. It’s easy to find those parts at local auto part store. Below is the list of replaced parts:
1. Two brake cylinder.
2. Two brake shoes set
3. All in one spring kits
4. Two self-adjusting Kits

After several hours assembly, brake unit ready for brake line connection. (See Figure 13)
Figure 13. Finished Drum Brake unit

**BRAKE LINE ASSEMBLY**

Since brake unit from Chevy S10, it’s easy to find all brake line at local auto parts store. Below is the list of part:

1. Two Wilwood master cylinder
2. Two 1/8 – 27 NPT to 1/4 pipe fitting (Connect master cylinder to brake pipe)
3. Two 1/4 In. Brake line with about 120 In. long
4. Two brake hose (female 3/8-24 to junction 3/8-24) x 11 In.
5. Two 3/8 -24 Hydraulic Plug (Junction of brake hose get two outlet port, only use one port, seal another port)
6. 3/8-24 to 3/8-20 brake line x 40 In.
7. 3/8-24 to 3/8-20 brake line x 20 In.

Brake line connection as Figure 14 shows
Something must clear is, there are two type of pipe fitting, inverted flare and bubbly flare. Inverted flare must connect with inverted flare, bubbly must connect with bubbly flare, is two different type fitting connected, hydraulic fluid will leak out from connect area.
Two master cylinders is bolted on steel strip with grade 8 bolts and self-lock nuts, so master cylinder will not come out when driving on Un-pavement road.
**PEDAL ASSEMBLY**

Each brake pedal has two angle iron welded at top horizontal bar (See Figure 17), that is the only un-moveable part of pedal system. Use one grade 8 bolts and self-lock nuts to prevent pedal rod come out from angle iron supporter. Flex joint is connect with master cylinder.

Pedal is welded on pedal rod.

Figure 17. Finished Pedal
**FILL BRAKE FLUID IN:**

Fill brake fluid is the last step of brake system assembly. According to instrument from Wilwood, brake fluid must be DOT3, DOT4 and DOT5.1, DOT 5 is not suitable for this master cylinder.

Bleeding brake fluid is the first step. Disconnect pipe fitting from master cylinder, push pedal all the way in, hold pedal and put finger on outlet of master cylinder then Release pedal. Repeat those steps until no air bubby come out from inlet of master cylinder.

Reconnect pipe fitting and make sure all pipe connected tight. Loose brake cylinder release bolts little bit, allow air come out and prevent bolt fall down. Full master cylinder with brake fluid, then push pedal and release many times until no air come out from brake cylinder release hole.

When pressure build up inside pipe, brake pedal should be hard to push down.

**TEST**

Apply same test method with IAT.

Push pedal down and hold it about 15 second, good brake should feel no pressure loss in 15 second. Then, check is any leakages appear at any section of brake line.

Push BUV forward, then drive should push brake down, BUV should stop immediately.

Result of brake test is BUV stop immediately when push pedal down and no pressure release..
COMPETITION RESULTS

The BUV competition of this year was host at Batavia Ohio on April 22th, it was heavy raining before competition, so ground become very muddy. Our BUV got problem with transmission at first, so we take long time to fix transmission problem. When our BUV start first lap, we get problem with lack of ground clearance. BUV trapped on the road. Finally BUV get out muddy, but the biggest problem came out: Front wheel hub disassembled during competition. (See Figure 18)

Figure 18. Result of 2017 MET BUV
PROOF OF DESIGN

For this competition, ITA list several requirements for BUV braking system:

1. Dual or more brake system to prevent one brake unit failure.
2. Brake must locate at wheel, not at drive line
3. Front wheel brake is not required on three wheels vehicles.
4. Parking Brake is not considered as redundancy.
5. Hydraulic Drives may use reverse for brakes.

For first requirement, our BUV equipped with dual Brake unit, and it’s working well.

For second requirement, we use dual drum brake located at wheel.

We don’t have a parking brake, the way to park BUV is turn steering 90 from front, then BUV will not able to move.

CONCLUSION

Overall, this BUV meet most requirements. We didn’t finish BUV competition because lack of testing. I would suggest later team use a bolt though center hole of wheel hub to tight front wheel hub, this should able to prevent wheel hub disassembly.

Brake system performing well under very tight budget, I would recommend use original brake system if you build BUV based on truck chassis. So it’s easy to find component from local auto parts store. Brake pedal design should depend on front chassis design; our pedal design is only suitable for front chassis with high horizontal bar.

Angle iron is good material to BUV, it’s light and strong, easy to melding and machining.

And try to start fabrication as soon as possible; time will be very tight during last semester.
WORKS CITED
APPENDIX A. 2017 BUV SPECIFICATION

BUV Farm Tanker & Transporter:
2017 Design Specifications:

Engine: Use up to 11 horsepower unmodified engine. An auxiliary fuel tank may be added.

Exhaust: Stock muffler, which may be relocated, with additional heat shields as needed.

Gauges: An engine temperature indicator located in view of the driver.

Fuel: Retail pump fuel and oil with provisions to prevent spilling fuel on a hot engine.

Transmission: It is builder's choice, to meet event conditions, but should have reverse and should have at least two forward speeds not counting any variable drive features.

Power Takeoff: The ability to power auxiliary equipment at approximately 1000 rpm. A V-belt drive is anticipated for auxiliary equipment.

Electrical: A 12 volt 35 amp or larger automotive alternator and an automotive battery are required.

Cargo Bed: The bed must hold two, but may hold three or more standard steel drums. The drums must be located on their sides with the small hole at the top. The drums must be located as low as possible in the bed. The drums must not be stacked in any manner. The front of the cargo bed must have a 16 inch minimum high bulkhead between the driver and the cargo. The other sides of the bed must be a minimum of 8 inches high. Drums should be easily removable for cargo.

Roll Bar: A minimum height of 36 inches above the surface the driver is seated upon. The roll bar must be completely padded above the seat height. It must have a cross member that covers the ends of the vertical structures, and adequate bracing to prevent the vehicle from rolling over.

Driver Safety: A helmet is required for each person aboard the vehicle. Seat belts are at the option of the team and the team advisor.

Safety Items: To participate in the event, you must have the following safety items:

1. An engine shutoff device marked with a nine-inch red streamer located within reach of the driver.
2. A dead man throttle with the spring located directly on the engine throttle linkage and not on the throttle control devices of vehicle.
3. Guarding from all moving parts and padding of all sharp or dangerous areas.
4. An automotive horn, a fire extinguisher, and a high visibility safety flag above the vehicle.

Brake System: A redundant brake system that will prevent total brake failure if a brake line is severed anywhere on the vehicle. The brakes must be located at the wheels and not on the drive-line. A front wheel brake is not required on three-wheeled vehicles. The parking brake is not considered the redundancy that is required. Hydraulic drives may use reverse for brakes.

Parking Brake: A parking brake capable of overcoming the engine power. It may be on the drive-line.

Tires: Agricultural tread, or aggressive tire chains are required. Chains must be carried by the vehicle if removed from the tires.

Towing: Each vehicle must have a 20 foot looped-end tow strap. There must be an attachment point at the front of the vehicle for towing. The trailer ball will be the rear attachment point for towing.

Trailer Hitch: A 1-7/8 inch trailer ball must be mounted 15 inches above the ground when the vehicle is unloaded.

Weatherproof: The vehicle should have protection from the weather elements to provide better reliability and greater durability.

Speed: Maximum of 120 MPH.

Load: Maximum of 165 gallons of water, weighting roughly 1376 pounds.

Water Pump: The ability to fill 55-gallon drums from within 15 feet of a pond. All pumping equipment and hoses must be carried on the vehicle during the event. Pump driven form PTO device only.

Name Plate: The school name and team number displayed in 4 inch font on all sides of the vehicle.

** See Tech Inspection Sheet for deductions if this feature is missing.

August 11, 2016.
APPENDIX B. HOUSE OF QUALITY

<table>
<thead>
<tr>
<th>Engineering Requirements (units)</th>
<th>CP</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Importance wt.</td>
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<tr>
<td>Payload Force (lbs)</td>
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<td>2</td>
<td>3</td>
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<tr>
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<tr>
<td>Start/Run Time(Seconds)</td>
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<tr>
<td>Hydraulic Brake(Yes/No)</td>
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<tr>
<td>Ground Clearance (inches)</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>Guarding (Yes/No)</td>
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<tr>
<td>Paint &amp; Lubricants (Yes/No)</td>
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<tr>
<td>Metric Fasteners(Yes/No)</td>
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<td></td>
<td></td>
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<tr>
<td># of Steps to Assemble (#)</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight(lbs)</td>
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<td>6</td>
<td>7</td>
<td>8</td>
</tr>
</tbody>
</table>

Customer Satisfaction Rating (0.00 - 1.00)

Customer Requirements Importances

| Importance wt. | 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 | 9 | 3 |   |    |    |    |    |    |    |    |    |    |    |
| 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 | 3 | 3 | 1 | 1 | 9 | 3 |   |    |    |    |    |    |    |    |    |    |
| 7 Maintainability | 0.10 | 3 |   | 3 | 9 |   | 3 |   |    |    |    |    |    |    |    |    |    |    |
| 8 Fuel economy  | 0.05 | 9 | 1 | 1 | 9 | 3 |   | 3 |   |    |    |    |    |    |    |    |    |
| 9 Easy to operate | 0.10 | 3 | 3 | 3 | 1 | 1 | 9 | 1 | 3 |    |    |    |    |    |    |    |
| 10 Clear visibility | 0.05 | 3 | 3 |   |   |   |   |    |    |    |    |    |    |    |    |    |

Total Importance 1.00

Engineering requirement importance

Performance
- Current Product
- Competitor A
- Competitor B
- Competitor C

New Product Targets

Interaction Matrix

<table>
<thead>
<tr>
<th>Engineering Requirements</th>
<th>Payload Force (lbs)</th>
<th>Material Selection (Yes/No)</th>
<th>Start/Run Time(Seconds)</th>
<th>Hydraulic Brake(Yes/No)</th>
<th>Ground Clearance (inches)</th>
<th>Guarding (Yes/No)</th>
<th>Paint &amp; Lubricants (Yes/No)</th>
<th>Metric Fasteners(Yes/No)</th>
<th># of Steps to Assemble (#)</th>
<th>Weight(lbs)</th>
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<tr>
<td>Payload Force (lbs)</td>
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# APPENDIX C. BUDGET OF BRAKE SYSTEM

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<thead>
<tr>
<th>Items</th>
<th>Amount</th>
<th>Price ($)</th>
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<tbody>
<tr>
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<td>4.47</td>
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<tr>
<td>Wilwood Master Cylinder X 2</td>
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<td>Bolts 3/8 - 18 Bolts X 4</td>
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<td>Hose Plug 3/8-24 ID.</td>
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<td>Brake Hose 3/8 - 24 Hose X 11 In. X 2</td>
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<td>24.58</td>
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<td>Hydraulic Line 3/8-24 to 3/8 - 24 X 51 In</td>
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<td>20.3</td>
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<tr>
<td>Hydraulic Line 3/8-24 to 3/8 - 24 X 20 In</td>
<td>1</td>
<td>15.25</td>
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<tr>
<td>Hydraulic Line 1/4 X 20 In</td>
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<td>14.96</td>
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<tr>
<td>Hydraulic Line 1/4 X 50 In</td>
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<tr>
<td>1/8-27 NPT to 1/4 Pipe Fitting</td>
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<td>3.96</td>
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<tr>
<td>2 x 2 In. x 42 Angle iron</td>
<td>1</td>
<td>16</td>
</tr>
<tr>
<td>1 1/2 x 1 1/2 Square head pipe x 42 In.</td>
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<td>20.6</td>
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<tr>
<td>3/8 In. self-lock Nuts</td>
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<tr>
<td>DOT3 Brake Fluid</td>
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<td><strong>Total</strong></td>
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<td><strong>371.91</strong></td>
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## APPENDIX D . SCHEDULE

<table>
<thead>
<tr>
<th>BUY TEAM</th>
<th>Actions</th>
</tr>
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<tbody>
<tr>
<td>Bethan</td>
<td>AUG 22 ~ AUG 26</td>
</tr>
<tr>
<td>Dickson</td>
<td>AUG 29 ~ SEP 2</td>
</tr>
<tr>
<td>Drahann</td>
<td>SEP 5 ~ SEP 9</td>
</tr>
<tr>
<td>Guanchun</td>
<td>SEP 12 ~ SEP 16</td>
</tr>
<tr>
<td>Christopher</td>
<td>SEP 19 ~ SEP 23</td>
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<tr>
<td></td>
<td>SEP 26 ~ SEP 30</td>
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<tr>
<td></td>
<td>OCT 3 ~ OCT 7</td>
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<tr>
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<td>OCT 10 ~ OCT 14</td>
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<td>OCT 17 ~ OCT 21</td>
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<td>OCT 24 ~ OCT 28</td>
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<tr>
<td></td>
<td>OCT 31 ~ NOV 4</td>
</tr>
<tr>
<td></td>
<td>NOV 7 ~ NOV 11</td>
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<tr>
<td></td>
<td>NOV 14 ~ NOV 18</td>
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<tr>
<td></td>
<td>NOV 21 ~ NOV 25</td>
</tr>
<tr>
<td></td>
<td>NOV 28 ~ DEC 2</td>
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</tbody>
</table>

**BUV TEAM Members (with Professor Moise Cummings)**

- Initial Design specification & review with the design concept
- Calculate parameters of initial design
- Modeling draft design
- 3D modeling to create design
- Assembly of models
- Project Design Agreement
- Concept Developing
- Concept selection
- Group Meeting
- Final Design Confirm
- Order Parts
- Cut Material
- Weld front chassis
- Weld cargo bed chassis
- Differential Oil change
- Brake unit assembly
- Front suspension assembly
- Install front and rear tires
- Cargo bed assembly
- Brake line assembly
- Brake pedal assembly
- Assembly driver and passenger seats
- Install clutch
- Mount engine and transmission on base
- Install shaft support
- Install shaft
- Install engine mount
- Install lubrication systems
- Install selection of engine battery
- Install cover and headlight
- Test
- Competition
<table>
<thead>
<tr>
<th>Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>BUY TEAM</td>
</tr>
<tr>
<td>Bethany Dickson Deaman Guanchun Christopher</td>
</tr>
<tr>
<td>Group Meeting (With Professor Moise Cummings)</td>
</tr>
<tr>
<td>Read Design Specification &amp; come out first design concept</td>
</tr>
<tr>
<td>Calculate parameters of the design</td>
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<tr>
<td>Weld steering axis</td>
</tr>
<tr>
<td>Weld body chassis</td>
</tr>
<tr>
<td>Weld cargo bed chassis</td>
</tr>
<tr>
<td>Differential Oil change</td>
</tr>
<tr>
<td>Weld front wheels</td>
</tr>
<tr>
<td>Final front suspension assembly</td>
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<tr>
<td>Camp bed assembly</td>
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<tr>
<td>Weld rear suspension</td>
</tr>
<tr>
<td>Weld rear suspension assembly</td>
</tr>
<tr>
<td>Assembly driver and passenger seats</td>
</tr>
<tr>
<td>Install clutch</td>
</tr>
<tr>
<td>Mount engine and transmission on base</td>
</tr>
<tr>
<td>Install fuel tank</td>
</tr>
<tr>
<td>Install engine and transmission</td>
</tr>
<tr>
<td>Install frame and suspension system</td>
</tr>
<tr>
<td>Final assembly and testing</td>
</tr>
<tr>
<td>Test</td>
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<tr>
<td>Competition</td>
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</tbody>
</table>
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
- Bethany – Chassis & Frame
- Dickson – Suspension
- Guan – Brake System
- Deamann – Irrigation System
- Christopher – Drive Train
- Proof of Design
- Up-to-Date Schedule
- Up-to-Date Budget
- Current Build
- 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 have 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
- 95% less parts than a typical car

Packaging & Shipping
- 8 assembled units per ocean container
- crate size 2’H x 2’W 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.)

QFD & House of Quality

[Diagram of QFD & House of Quality matrix]
Chassis & Frame

Bethany Nickson

Design Selection

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

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Weight %</th>
<th>Standard Design</th>
<th>Weight%</th>
<th>Warren Truss</th>
<th>Weight%</th>
<th>Howe Truss</th>
<th>Weight %</th>
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<tbody>
<tr>
<td>Ground Clearance</td>
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</table>

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

Concept 1: 2013 Design
- Pros: Good Ground Clearance, Standard Manufacturing, Lightweight
- 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 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: 2.07

- **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
Front Suspension & Steering

Concept Designs

Concept 1: Earle’s Fork suspension
- Advantages: Good damping, Precise steering, Dynamic compensation
- Disadvantages: Expensive, Complex, High maintenance

Concept 2: Unit-Strut spring and shock
- Advantages: Durable, High Agility, No skills required
- Disadvantages: Poor damping on tarred road, Poor aesthetic

Concept 3: Unit-Strut- Chosen Design
- Advantages: Simple to manufacture, Low Maintenance cost
- Disadvantages: Complex, High maintenance, Expensive
### Finite Element Analysis/Simulations (Test)

**Selected Material**

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<tr>
<th>Parameters/Properties</th>
<th>Value</th>
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<tbody>
<tr>
<td>ASTM A36 Structural Steel C-Channel</td>
<td></td>
</tr>
<tr>
<td>Density</td>
<td>0.284 lb/in³</td>
</tr>
<tr>
<td>Tensile Strength, Ultimate</td>
<td>58,000-80,000 psi</td>
</tr>
<tr>
<td>Tensile Strength, Yield</td>
<td>36,300 psi</td>
</tr>
<tr>
<td>Modulus of Elasticity</td>
<td>29,000 ksi</td>
</tr>
<tr>
<td>Compression Yield Strength</td>
<td>22,000 psi</td>
</tr>
<tr>
<td>Shear modulus</td>
<td>11,500 ksi</td>
</tr>
<tr>
<td>Weight of BUV</td>
<td>1,200 lbs</td>
</tr>
<tr>
<td>Applied force</td>
<td>5,680 lbs</td>
</tr>
<tr>
<td>Factor of safety</td>
<td>2</td>
</tr>
</tbody>
</table>

**Result:** 68,880 psi > 36,300 psi
**Modifications**

- Increase thickness of hub mount plate (1/2 in plate) to reinforce flange
- Reinforce web & steering column (4 in x 1 in steel plate)
- Final Result: 28,520 psi < 36,300 psi

**Fabrication & Proof of Design**

- Finish touches
- Front tire mounted onto suspension
Final Assembly of Front suspension and Steering (two 3/2in seamless steel pipe)

Brake System

Guanchun Ye
**Solution**

- Research
  - Find Input Force
  - Find output Force
- Calculate
  - Required Hydraulic Pressure
  - Enlargement Factor
- Design
  - Brake Pedal Design
  - Mount Base Design

---

**Research**

Set the Input Force equal to 150 Lbs

Excerpt: National Highway Safety Bureau U.S. Department of Transportation Washington

---

**Figure 2.4.** Cumulative percent pedal force for 276 females.

**Figure 2.5.** Cumulative percent pedal force for 323 males.
Research

Target: Find out Maximum Brake Force

Safety Factor = 1.5 (Single Unit) 3 (Dual Unit)

Here we using Single Brake

Desired Result: Stop braked wheel rotation

Total Weight of BUV is around 2840 lbs

Final Result is that: Needed brake force to the ground is about 319 lbf

Detailed Calculations will be showed on Final Report

Table 2. Examples for 4 different soil conditions (used tire: 340/85R30)

<table>
<thead>
<tr>
<th>Tire and soil parameters</th>
<th>Stable field</th>
<th>Grass land</th>
<th>Ploughed</th>
<th>Cultivated</th>
</tr>
</thead>
<tbody>
<tr>
<td>$k_{stab}$</td>
<td>0.5</td>
<td>0.9</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>$k_{grass}$</td>
<td>0.6</td>
<td>0.7</td>
<td>0.0</td>
<td>0.25</td>
</tr>
<tr>
<td>$k_{plough}$</td>
<td>0.8</td>
<td>0.8</td>
<td>0.1</td>
<td>0.6</td>
</tr>
<tr>
<td>$k_{cult}$</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>$k_{max}$</td>
<td>0.5</td>
<td>0.6</td>
<td>0.6</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Excerpt: Influence of soil and tire parameters on traction

Center of Gravity is located at 70%

Calculation

Torque provided by brake cylinder = 4504.95 lbf

Hydraulic Pressure of brake cylinder and master cylinder = 2683.453 psi

Force applied on master cylinder = 1185.513 lbf

Input Force = 150 lbf & Output force is 1185 lbf, So the enlargement ratio = 7.9
# Brake Selection

## Concept Alternatives

- **Hydraulic Disc Brake**
- **Hydraulic Drum Brake**
- **Wire Drum Brake**

### Criteria

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Importance</th>
<th>Weight (%)</th>
<th>Rating</th>
<th>Weighted Rating</th>
<th>Rating</th>
<th>Weighted Rating</th>
<th>Rating</th>
<th>Weighted Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>High brake efficiency</td>
<td>15</td>
<td>4</td>
<td>0.6</td>
<td>3</td>
<td>0.45</td>
<td>2</td>
<td>0.3</td>
<td></td>
</tr>
<tr>
<td>Reliability</td>
<td>20</td>
<td>3</td>
<td>0.6</td>
<td>4</td>
<td>0.8</td>
<td>2</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>Low maintenance</td>
<td>10</td>
<td>3</td>
<td>0.3</td>
<td>4</td>
<td>0.4</td>
<td>4</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>Low cost</td>
<td>30</td>
<td>2</td>
<td>0.6</td>
<td>3</td>
<td>0.9</td>
<td>3</td>
<td>0.9</td>
<td></td>
</tr>
<tr>
<td>Light weight</td>
<td>10</td>
<td>2</td>
<td>0.2</td>
<td>3</td>
<td>0.3</td>
<td>3</td>
<td>0.3</td>
<td></td>
</tr>
<tr>
<td>Weather resistance</td>
<td>5</td>
<td>4</td>
<td>0.2</td>
<td>2</td>
<td>0.1</td>
<td>2</td>
<td>0.1</td>
<td></td>
</tr>
</tbody>
</table>

**Total**

<p>| | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100</td>
<td>NA</td>
<td>2.5</td>
<td>NA</td>
<td>2.95</td>
<td>NA</td>
<td>2.4</td>
</tr>
</tbody>
</table>

### Conclusion

Hydraulic Drum brake is better than disc brake under the requirement of competition.

---

# Brake Pedal Design

## Enlargement Ratio = 7.9

### Brake Selection

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Importance</th>
<th>Weight (%)</th>
<th>Rating</th>
<th>Weighted Rating</th>
<th>Rating</th>
<th>Weighted Rating</th>
<th>Rating</th>
<th>Weighted Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size of brake unit</td>
<td>20</td>
<td>2</td>
<td>40</td>
<td>2</td>
<td>40</td>
<td>80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High reliability</td>
<td>20</td>
<td>4</td>
<td>80</td>
<td>4</td>
<td>80</td>
<td>3</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Low cost</td>
<td>15</td>
<td>3</td>
<td>45</td>
<td>3</td>
<td>45</td>
<td>3</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>Easy to maintain</td>
<td>20</td>
<td>3</td>
<td>60</td>
<td>2</td>
<td>40</td>
<td>2</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>2</td>
<td>50</td>
<td>3</td>
<td>75</td>
<td>3</td>
<td>75</td>
<td></td>
</tr>
</tbody>
</table>

**Total**

<p>| | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100</td>
<td>NA</td>
<td>275</td>
<td>NA</td>
<td>280</td>
<td>NA</td>
<td>300</td>
</tr>
</tbody>
</table>

### Conclusion

Select Design 3
Final Design
Problem: No enough ground space for brake units
Enlargement Ratio = 7.9
2 x 7.9 = 14.8 In. < 16.6 In.

Irrigation System

Deamann Strefas
### 2014 Irrigation Design

Similar to 2013, water is pumped in through the top of the barrels but is also pumped out through the same holes.

**Pros:**
- Faster than 2013 design
- Minimal material use

**Cons:**
- Easily Damaged

### Modifications

Relocated water pump under the seat.

Designed quick connect system.

**Pros:**
- Minimal material usage
- Eliminates risk of damage during transit

**Cons:**
- To be determined
Modifications

Designed quick connect pumping system.
Easy to use, durable and time efficient.
Eliminates break factor while in transit.

Water Pump Selection

Pump one was picked based on the results of the Weighted Rating Method.
This pump is easy to use and affordable.
By choosing this pump, the complexity of the irrigation system is significantly reduced.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Importance Weight %</th>
<th>Rating</th>
<th>Weighted Rating</th>
<th>Rating</th>
<th>Weighted Rating</th>
<th>Rating</th>
<th>Weighted Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Affordable</td>
<td>25</td>
<td>3</td>
<td>75</td>
<td>2</td>
<td>50</td>
<td>4</td>
<td>100</td>
</tr>
<tr>
<td>Easy to Use</td>
<td>15</td>
<td>4</td>
<td>60</td>
<td>2</td>
<td>30</td>
<td>3</td>
<td>45</td>
</tr>
<tr>
<td>Reliability</td>
<td>40</td>
<td>3</td>
<td>120</td>
<td>2</td>
<td>80</td>
<td>2</td>
<td>80</td>
</tr>
<tr>
<td>Pumping Rate</td>
<td>20</td>
<td>2</td>
<td>40</td>
<td>4</td>
<td>80</td>
<td>1</td>
<td>20</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>N/A</td>
<td>285</td>
<td>N/A</td>
<td>240</td>
<td>N/A</td>
<td>245</td>
</tr>
</tbody>
</table>

Pump 1

Pump 2

Pump 3

Ratings

- Satisfactory: 0
- Just Tolerable: 1
- Adequate: 2
- Good: 3
- Very Good: 4
Pump Specifications

- Pacific Hydrostar 1" Clear Water Pump

<table>
<thead>
<tr>
<th>Horsepower (hp)</th>
<th>1.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impeller Material</td>
<td>Aluminum Alloy</td>
</tr>
<tr>
<td>Maximum Discharge Flow (gph)</td>
<td>2220</td>
</tr>
<tr>
<td>Maximum discharge flow (gpm)</td>
<td>37</td>
</tr>
<tr>
<td>Maximum Discharge Pressure (psi)</td>
<td>45.5</td>
</tr>
<tr>
<td>Self priming</td>
<td>Yes</td>
</tr>
<tr>
<td>Submersible</td>
<td>No</td>
</tr>
</tbody>
</table>

Calculations

Times based on 2014 BUV Design. New system has not been tested but is anticipated to ADD 20-30 seconds.

This equations proves that a pump will provide the necessary pumping power needed that gravity cannot provide.
**Fabrication**

**Up Until Now**
- x3 – 55gallon barrels from previous senior design BUV team.
- Replaced fittings with new and improved fixtures/adaptors.

**In Progress**
- Weld pump fixture under seat.
- Install pipes and hanging fixture.
- Install pump.
- Test system.

---

**Drive Train**

Christopher Steward
Design Concepts

- **Clutch to Chain Drive**
  - Design is fairly straightforward
  - Minimizes the number of custom components required
  - Primary advantage is that they tend to be relatively durable with proper maintenance

- **CVT to Driveshaft**
  - Transmission would have two top speeds
  - Driveshaft has to be customized
  - Setup is very expensive
  - Decreases danger of contaminants hindering overall performance

- **Clutch to Chain Drive**
  - Once installed, no need for preventative maintenance
  - Downside is the high amount of tension that must be constantly maintained between the drive and driven sheaves

Design Comparison's

- Concept 1 was the best choice at the time based off of cost, time and safety.

<table>
<thead>
<tr>
<th>Decision Criteria</th>
<th>Weight Factor</th>
<th>Concept 1</th>
<th>Concept 2</th>
<th>Concept 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Score</td>
<td>Rating</td>
<td>Score</td>
<td>Rating</td>
</tr>
<tr>
<td>Fabrication Time</td>
<td>0.2</td>
<td>4</td>
<td>0.6</td>
<td>3</td>
</tr>
<tr>
<td># Extra Components</td>
<td>0.2</td>
<td>3</td>
<td>0.6</td>
<td>3</td>
</tr>
<tr>
<td># of Parts</td>
<td>0.2</td>
<td>4</td>
<td>0.6</td>
<td>3</td>
</tr>
<tr>
<td>Manufacturing Cost</td>
<td>0.15</td>
<td>4</td>
<td>0.6</td>
<td>3</td>
</tr>
<tr>
<td>Appeal</td>
<td>0.1</td>
<td>3</td>
<td>0.4</td>
<td>2</td>
</tr>
<tr>
<td>Safety</td>
<td>0.15</td>
<td>4</td>
<td>0.6</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>3.4</td>
<td></td>
<td>2.7</td>
<td></td>
</tr>
</tbody>
</table>
Drive Train Equipment

Transmission: Tuff Torq KT35
- Max Speed of 20mph
- Forward, neutral, and reverse
- Reduction rate of 15:1 forward and 15:3.1 backward

Engine: 10 HP INTEK I/C
- Electric ignition for quick start
- Bore: 3.12 in.
- Stroke: 2.43 in.
- Oil Capacity: 28 fl. oz.

Comet 770 Series Centrifugal Clutch
- The pulley ratios on the clutch are:
  - Low: 3.95:1
  - High: 0.76:1

Intermediate shaft and mount
- Custom Made
- Donated from Dave Conrad
- Connects Chevy S-10 transaxle to 4x2 John Deere gator transmission

Actual drawing
Solidworks drawing
Actual drawing
Solidworks drawing
Actual image
Solidworks drawing
Actual image
Solidworks drawing
Actual image
Solidworks drawing
Fabrication & Modifications

Initially I did not have a stand for the transmission to sit on.
- After seeing that the transmission would not stand without some support, I designed a stand to house it and the engine.
- Used angle iron and aluminum sheet metal to create the frame
- Used UC’s machine shop to cut, drill, sheer and weld the metal

- SF: 3
- hold 65lb
  Transmission up off the ground

Current Progress

- As Thursday April 13, 2017 at 3:36pm, the engine and transmission have been mounted in the vehicle
- The next steps are the following:
  - Mount the intermediate shaft
  - Cutting power shaft from 1994 Chevrolet S-10 and welding it to the intermediate shaft
  - Under go final speed and load testing’s
  - Compete in final competition on April 22nd
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)

Up-to-Date Schedule

<table>
<thead>
<tr>
<th>Task</th>
<th>Project Date</th>
<th>Actual Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bill of Materials (BOM)</td>
<td>11/18/2016</td>
<td>12/18/2016</td>
</tr>
<tr>
<td>Design Phase</td>
<td>12/14/2016 - 2/12/2017</td>
<td>12/14/2016 - 2/24/2017</td>
</tr>
<tr>
<td>Oral Presentation</td>
<td>2/13/2017</td>
<td>2/13/2017</td>
</tr>
<tr>
<td>Design Modification</td>
<td>2/13/2017 - 2/20/2017</td>
<td>2/13/2017 - 2/27/2017</td>
</tr>
<tr>
<td>Fabrication</td>
<td>2/13/2017 - 3/20/2017</td>
<td>2/27/2017 - ongoing</td>
</tr>
<tr>
<td>Final Testing</td>
<td>4/1/2017 - 4/6/2017</td>
<td>N.A</td>
</tr>
<tr>
<td>Tech. Expo</td>
<td>4/7/2017</td>
<td>4/6/2017</td>
</tr>
<tr>
<td>Final Presentation</td>
<td>4/14/2017</td>
<td>4/14/2017</td>
</tr>
<tr>
<td>BUV Competition</td>
<td>4/22/2017</td>
<td>4/22/2017</td>
</tr>
</tbody>
</table>
Up-to-Date Budget

Total Cost of Production = $1,555.40

Current Build

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

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

Overview

- Problem Statement
- Background & State-of-the-Art
- Competition Specifications
- QFD & House of Quality
- Bethany – Chassis & Frame
- Dickson – Suspension
- Guan – Brake System
- Deamann – Irrigation System
- Christopher – Drive Train
- Proof of Design
- Up-to-Date Schedule
- Up-to-Date Budget
- Current Build
- Recommendations