Basic Utility Vehicle (BUV): 
Electronics and Braking

A Baccalaureate thesis submitted to the
School of Dynamic Systems
College of Engineering and Applied Science
University of Cincinnati

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requirements for the degree of

Bachelor of Science

in Mechanical Engineering Technology

by

James M. Tierney

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Thesis Advisor:

Professor Janak Dave, Ph.D.
ACKNOWLEDGEMENTS

The 2014 MET Senior Design BUV Team would to thank the following individuals and companies for their contributions, donations, and support to the BUV and to individual team members.

With your dedication and support, we succeeded in designing and fabricating a vehicle for change.

To Mr. and Mrs. Glenn and Gail Burket, for your generous donation to the project.

To Mr. and Mrs. Al and Beth Maupin, for your generous donation to the project.

To ADP, for the company’s sponsorship of the project.

To Mr. Rob Cropper, for your contributions of time and resources to the project.

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To CAST-FAB Technologies, for the company’s contributions to the project.

To J&N Auto Electric, for the company’s contributions to the project.

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# TABLE OF CONTENTS

ACKNOWLEDGEMENTS ................................................................................................................... 2
TABLE OF CONTENTS ...................................................................................................................... 3
LIST OF FIGURES .............................................................................................................................. 5
LIST OF TABLES .............................................................................................................................. 5
ABSTRACT ........................................................................................................................................... 6
INTRODUCTION .................................................................................................................................... 7
PROBLEM STATEMENT: ...................................................................................................................... 7
TEAM MEMBER RESPONSIBILITIES: ................................................................................................. 7
RESEARCH AND BACKGROUND ....................................................................................................... 8
INTERVIEWS ....................................................................................................................................... 8
PREVIOUS BUV DESIGNS .................................................................................................................. 9
SIMILAR PRODUCTS/COMPONENTS ................................................................................................. 10
CUSTOMER REQUIREMENTS .......................................................................................................... 12
PRODUCT OBJECTIVES .................................................................................................................... 14
CONCEPT GENERATION AND SELECTION ................................................................................. 15
CONCEPT 1: MINIMUM COMPONENTS ............................................................................................ 15
CONCEPT 2: MAXIMUM COMPONENTS ............................................................................................ 16
CONCEPT 3: START BUTTON ............................................................................................................. 17
CONCEPT SELECTION ....................................................................................................................... 18
ELECTRICAL COMPONENTS ............................................................................................................. 19
PART SELECTION ............................................................................................................................... 19
BRAKING COMPONENTS .................................................................................................................... 20
PART SELECTION ............................................................................................................................... 20
THROTTLE COMPONENTS ............................................................................................................... 20
PART SELECTION ............................................................................................................................... 20
FABRICATION ..................................................................................................................................... 21
ELECTRICAL SYSTEM ....................................................................................................................... 21
BRAKE SYSTEM ............................................................................................................................... 22
THROTTLE SYSTEM .......................................................................................................................... 23
COMPETITION RESULTS ............................................................................................................... 24
CONCLUSION ...................................................................................................................................... 25
WORKS CITED ................................................................................................................................... 26
APPENDIX A – COMPETITION SPECIFICATIONS ........................................................................... 27
APPENDIX B - RESEARCH .............................................................................................................. 28
APPENDIX C – QUALITY FUNCTION DEPLOYMENT (QFD) ............................................................... 32
LIST OF FIGURES

Figure 1: 2012 Purdue University BUV
Figure 2: 2009 University of Cincinnati BUV
Figure 3: 2013 University of Cincinnati BUV
Figure 4: Wilwood Brake Pedal
Figure 5: Alternator
Figure 6: Concept 1-Minimum Components
Figure 7: Concept 2-Maximum Components
Figure 8: Concept 3-Start Button
Figure 9: Headlights and Brake Lights
Figure 10: Engine Temperature Gauge
Figure 11: Alternator
Figure 12: Horn
Figure 13: Headlights
Figure 14: Brake Lights
Figure 15: Control Panel
Figure 16: Brake Pedal
Figure 17: Original Brake Pedal
Figure 18: Throttle
Figure 19: Competition Course

LIST OF TABLES

Table 1: Interview Information
Table 2: Concept Selection
ABSTRACT

The Basic Utility Vehicle (BUV) Farm Tanker and Transporter competition is an annual event started by the Institute of Affordable Transportation (IAT). The purpose of the event is to design and fabricate a vehicle that can be used by people in third-world countries. Colleges from all over the United States participate in the competition. The BUV is designed to be very simple, so that anyone can assemble and operate it regardless of their technical knowledge. It also must cost less than $2500 and not exceed 20 mph. This year’s event requires a BUV that can transport water over rough terrain. The course that the BUV must be driven on resembles many remote regions in the world that don’t have paved roads. Once the eight hour competition is over, judges from the IAT make a list of the most effective features from each BUV. The design work for this project was divided among five seniors from the University of Cincinnati College of Engineering and Applied Science. James Tierney designed the electrical and brake systems, Anthony Price designed the drive-train, Nick Isaac designed the frame, Chris Burket designed the irrigation system, and Kabimbi Kalubi designed the suspension and steering systems.
INTRODUCTION

PROBLEM STATEMENT:

For people who live and work in developing countries around the world, there is an overall lack of affordable utility vehicles to help them make a better living for themselves and their families. The Institute for Affordable Transportation (IAT) realized this and set out to find a way to help these people, eventually creating the Basic Utility Vehicle Design Competition. The purpose of the competition is to not only give engineering students valuable experience but to also find new and innovative ideas to help people in these countries (1).

The basis of a BUV is that it allows the people in developing countries to perform their day to day undertakings much more efficiently by being a reliable, affordable, and simple solution to their transportation requirements. The BUV will increase the possibilities of what the end user is able to accomplish in their day to day capacity.

TEAM MEMBER RESPONSIBILITIES:

- James Tierney
  - Electrical System
  - Throttle
  - Brakes
- Nick Isaac
  - Frame
  - Chassis
- Chris Burket
  - Irrigation System
- Anthony Price
  - Drivetrain
  - Engine
  - Transmission
- Kabimbi Kalubi
  - Suspension
  - Steering
RESEARCH AND BACKGROUND

INTERVIEWS

Research was conducted in order to gain a better understanding of previous BUV concepts and whether those concepts were successful or not. Members from previous BUV teams were interviewed in order to gain a better understanding of what features on the vehicle should be focused on. The first interview was with James Voet (2), a member of the 2013 University of Cincinnati BUV team. This interview, which took place on 4/25/13, provided insight into what electrical components gave him the most trouble during the competition; he also described what research should be conducted prior to designing the vehicle. Another interview, with Steve Guidi (3), an electrical engineer at Systecon, was conducted on 6/26/13. This interview provided insight into what electrical components should be used that are cheap but still reliable.

<table>
<thead>
<tr>
<th>Person Interviewed</th>
<th>Information Gathered</th>
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<tr>
<td><strong>James Voet</strong>&lt;br&gt;(2013 University of Cincinnati BUV Team Member)</td>
<td>• Make sure all wiring is weather-proof&lt;br&gt;• Make sure brake pedal is comfortable distance away from driver</td>
</tr>
<tr>
<td><strong>Steve Guidi</strong>&lt;br&gt;(Electrical Engineer at Systecon)</td>
<td>• Make sure wiring can’t get wet&lt;br&gt;• Keep electrical system as simple as possible</td>
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Table 1: Interview Information
PREVIOUS BUV DESIGNS

Research on previous BUV’s provided background information on what made the vehicles successful and unsuccessful. The 2012 Purdue University BUV, seen below in Figure 1, came in second place at the Farm Tanker and Transporter competition. This vehicle utilized two brake pedals as opposed to only one, which increased the cost and complexity with no added benefit. It was also equipped with two headlights which increased the safety, especially when operating the vehicle at night.

Figure 1: Purdue BUV

- Two brake pedals
- Headlights
The 2009 University of Cincinnati BUV can be seen below in Figure 2. This BUV, per competition requirements that year, utilized hand brakes as opposed to foot brakes. It also was equipped with a kill switch, head lights, and brake lights, all of which are required for this year’s competition.
The 2013 University of Cincinnati BUV can be seen below in Figure 3. I attended the 2013 BUV Competition in order to observe which features of the vehicles worked best and which ones did not work. Some observations I made from the competition:

- All wiring must be weather-proof. Several vehicles ran into problems when their wiring got wet.
- The throttle should be installed in a comfortable position. Coordination with the handlebar designer will ensure that this is achieved.
**SIMILAR PRODUCTS/COMPONENTS**

Seen below, in Figure 4, is a Wilwood brake pedal. This pedal can be swing mounted or floor mounted, depending on how much room is available on the BUV. This specific model has a pedal ratio of 6:1, which multiplies the input force from the driver by 6. It also has a dual master cylinder setup. This type of setup allows the pedal to control both the front and rear brakes.

Figure 4: Wilwood Brake Pedal
An automotive alternator, as seen below in Figure 5, is required for the BUV. The purpose of an alternator is to charge the battery and provide power to the electrical system while the engine is running. The alternator below fits around the driveshaft and is bolted directly to the engine. This setup reduces the amount of moving parts as well as the parasitic loss on the drivetrain compared to an exterior automotive alternator.

Figure 5: Alternator
CUSTOMER REQUIREMENTS

PRODUCT OBJECTIVES

Based on the competition specifications provided by IAT, the product objectives are the list of features that are taken into consideration. The following is a list of product objectives and how they will be obtained or measured to ensure that the goal of the project was met.

1. Sufficient capacity (21%)
   a. Redundant brake system will be installed to prevent total brake failure
   b. Under full payload, vehicle will be capable of coming to a complete stop in 75 feet

2. Durability (19%)
   a. Materials and components will be selected to withstand the mechanical stresses during operation

3. Ease of operation (17%)
   a. Turn-key or pull-starter will be installed
   b. Both brakes will be located on rear wheels (no front brake)
   c. Designed to be operated by one person
   d. No additional skills needed to operate

4. Safety (15%)
   a. Vehicle will have a maximum speed of 20 mph
   b. Vehicle will be equipped with an engine kill switch easily accessible by the operator
   c. Vehicle will be equipped with a fire extinguisher
   d. A horn will be installed on this vehicle
   e. A roll bar will be installed per the competition’s specifications
   f. A high visibility safety flag will be installed on this vehicle
   g. All sharp or dangerous edges will be equipped with proper padding

5. Ease of maintenance (14%)
   a. Access to each component in the vehicle
   b. Vehicle will be maintained with standard tools

6. Affordability (14%)
   a. Vehicle will cost less than $5500 to manufacture
CONCEPT 1: MINIMUM COMPONENTS

The first concept, shown above in Figure 6, has the minimum amount of components required for the competition. The components included in this concept are a battery, alternator, engine temperature gauge, kill switch, horn, head lights, and brake lights. The minimum amount of components in this concept makes it affordable and easy to repair.
CONCEPT 2: MAXIMUM COMPONENTS

The second concept, shown above in Figure 7, has more components than are required for the competition. The components included in this concept are a battery, alternator, start button, engine temperature gauge, odometer, hour meter, horn, head lights, and brake lights. Fuses are also included in this concept. All of these components make it a very expensive concept and difficult to repair.
The third concept, shown above in Figure 8, consists of the minimum required components, similar to the first concept. This concept also utilizes a start button, which increases the cost and complexity with no added benefit.
CONCEPT SELECTION

The above concepts were analyzed using the weighted rating method. The criteria used were low cost, safety, ease of maintenance, reliability, and ease of operation. The score scale was 0-4, with 0 being unsatisfactory and 4 being excellent. After assigning a score for each category and concept and applying the weight values, Concept 1 had the highest score and thus was chosen.

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<th>Criteria</th>
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<th>MAXIMUM COMPONENTS</th>
<th>START BUTTON</th>
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Table 2: Concept Selection
ELECTRICAL COMPONENTS

PART SELECTION

The head lights and brake lights selected for the BUV can be seen in Figure 9. They were donated from J&N Electric. Both sets of lights will be wired into a switch so that they are always on or always off. Although it is common for brake lights to be wired to a pressure switch located on the brake pedal, this will be intentionally avoided to keep the cost and complexity down.

Figure 9: Headlights and Brake Lights

Figure 10 shows the engine temperature gauge that was chosen for the BUV. This component was also donated from J&N Electric. It has a temperature range from 100F to 280F.

Figure 10: Engine Temperature Gauge

The alternator selected for the BUV can be seen in Figure 11. It is an internal alternator that can be bolted directly to the engine. This type of alternator reduces the amount of moving parts as well as the power loss on the drive train. It is also more affordable than an exterior automotive alternator.

Figure 11: Alternator
Figure 12 shows the horn that was chosen for the BUV. It will be wired to a push button so that it only works when the button is pushed. This component was donated from J&N Electric.

![Figure 12: Horn](image)

**BRAKING COMPONENTS**

*PART SELECTION*

The rear clip of a 1995 Chevrolet S10 pickup truck was selected as the rear of the BUV. Therefore the drum brakes that came with it were utilized. The drum brakes have a rated payload of 1500 lbs and a curb weight of 3000 lbs. The most important factors when selecting brakes are how much weight they are capable of stopping and how long it takes to bring the vehicle to a complete stop. Calculations for the brakes can be seen in Appendix B.

**THROTTLE COMPONENTS**

*PART SELECTION*

According to the 2014 BUV specifications, a spring-return throttle is required for the vehicle. Due to the rough terrain, a spring-return throttle makes the vehicle safer to operate. A bicycle hand brake and brake cable will be converted into the throttle for the BUV.
FABRICATION

ELECTRICAL SYSTEM

Two headlights, which can be seen in Figure 13, were installed on the front of the BUV frame. Two brackets that the headlights could be attached to were fabricated and welded to the frame. The headlights were wired to a rocker switch on the control panel so that they could be turned on and off by the driver.

The specifications for the 2014 BUV Competition also required two brake lights on the vehicle. The brake lights, which can be seen in Figure 14, were installed similarly to how the headlights were installed. Two brackets were fabricated and welded to the frame. The brake lights were then attached to the bracket and wired to the same rocker switch as the headlights. This made the vehicle safer since the brake lights would be on all the time and it made the wiring less complex. A pressure switch could have been installed on the brake line so that the brake lights only lit up when the brake pedal was in use, but this would have increased the complexity of the wiring. Therefore it was decided to keep the brake lights on at all times.

An engine temperature gauge, as required by the specifications, was also installed on the BUV. The gauge, along with the kill switch, light switch, and horn button, can be seen in Figure 15. A sensor was installed on the engine and replaced one of the oil drain plugs. A sending wire from the sensor was connected to the gauge, which was in view of the driver.
**BRAKE SYSTEM**

A redundant brake system was required for the BUV. This type of system helps to prevent total brake failure since all brakes are independent of each other. Figure 16 shows the brake pedal that was used on the BUV. This is not the original brake pedal that was installed; during testing it was discovered that one of the master cylinders on the original pedal was broken. Because of this, a replacement pedal was fabricated and installed. Two separate brake lines were connected from the reservoir to the rear brakes, making this a redundant brake system. The original brake pedal can be seen in Figure 17.

Figure 16: Brake Pedal

Figure 17: Original Brake Pedal
THROTTLE SYSTEM

The throttle used on the BUV can be seen in Figure 18. The system consists of a hand brake and brake line that were sourced from a bicycle. The brake line was run from the hand brake to the throttle on the engine. To help prevent the throttle system from breaking or becoming tangled with other parts of the BUV, it was attached to the frame using zip ties.

Figure 18: Throttle
COMPETITION RESULTS

The day before the competition, we brought the BUV to the competition site in order to test the BUV and learn the route. The front suspension failed almost immediately. Because of this we decided to use the front suspension from the 2013 BUV. This suspension held up throughout the entire competition. Figure 19 shows a section of the course.

The BUV performed very well throughout the six hour competition. All seven laps that we were able to complete were with two full drums of water. The BUV only got stuck once; this was due to driver error when one of our partners did not follow the course and ended up on very soft ground that buried the BUV up to the axels.

We came in fourth place in the competition.

Figure 19: Competition Course
CONCLUSION

The vehicle performed adequately throughout the entire competition, resulting in a fourth place finish overall. The electronic, brake, and throttle systems fulfilled all of the design criteria that were able to be tested per the proof of design. All of the electrical components worked throughout the competition without issue. The throttle system also worked without any issues. The brake system, however, did have an issue; the fabricated brake pedal did not work very well. It did not slow down the vehicle as quickly as desired. Because it was discovered that the original brake pedal was broken so late in the fabrication process, there was not a lot of time to test and adjust the replacement brake pedal.
WORKS CITED

http://www.drivebuv.org/about-iat.
APPENDIX A – COMPETITION SPECIFICATIONS

BUV Farm Tanker & Transporter
2014 Design Specifications:

Engine  Use up to 11 horsepower unmodified engine. Use stock fuel tank. No extra tanks allowed.
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 no enhancements added.
Transmission  It is builder’s choice, to meet event conditions, but must have reverse and should have two forward speeds
Electrical  A 12 volt 35 amp or larger automotive alternator and automotive battery are required.
Cargo Bed  The bed must hold two, but may hold three 55 gallon 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.
Roll Bar  A minimum height of 36 inches above the surface the driver is seated upon. It must be completely padded above the seat height. It must have a cross member that covers the ends of the vertical structures, and 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 items:
1. An engine shutoff device marked with a nine-inch red streamer located within reach of the driver.
2. A spring return throttle with the spring located directly on the throttling device and not on the control linkage.
3. Guarding from all moving parts.
4. Padding of all sharp or dangerous areas.
5. Automotive horn.
6. A fire extinguisher.
7. A high visibility bicycle style safety flag above the vehicle.

Brake System  A redundant brake system that will prevent total brake failure. The brakes must be located on all the wheels and not on the driveline. A front wheel brake is not required on three wheeled vehicles. The parking brake is not considered the redundancy that is required.
Parking Brake  A parking brake capable of overcoming the engine power. It may be on the driveline.
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 25 foot looped-end tow strap. There must be an attachment point at the front of the vehicle for towing. The trailer ball will be 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 20 MPH.
Load  Maximum of 165 gallons of water, weighting roughly 1376 pounds.
Water Pump  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.
Cost Target  Between $1500 and $2500 to build. See the event rules for details.
Name Plate  The school name and team number displayed in 4-inch font on all sides of the vehicle.
## APPENDIX B - RESEARCH

**Interview – James Voet, University of Cincinnati 2013 BUV Team Member**

- Picture of 2013 BUV during competition, which the 2014 team attended
- Advice for control and braking systems:
  - Brake pedal should be comfortable distance from driver-placement of their brake pedal was uncomfortable
  - Make sure all wiring is safe from the elements—they had several instances when wiring became wet
- Advice for other BUV systems:
  - Ground clearance is crucial since course is very bumpy
  - Handlebars should be at comfortable position
  - Diesel engine would be better than gas engine since it would deliver more torque
  - Design for two barrels is a good strategy since it would reduce wear and tear on BUV and a few teams could not finish competition due to higher payload
Drum Brake from 1994 Chevrolet S10

Features:
- Drum brake from 1994 Chevrolet S10
- Used in 2013 BUV
- Donated to 2014 BUV Team
Drum Brakes
- Inexpensive
- Light weight
- Wear down faster

Disc Brakes
- Low operating temperature
- Longer life
- High stopping power
- Expensive
- Battery powered
- Batteries weigh about 200 pounds
- Power output of 8.5 hp
- Towing capacity of 4000 pound
## APPENDIX C – QUALITY FUNCTION DEPLOYMENT (QFD)

**Basic Utility Vehicle**  
**Senior Design Team**  
9 = Strong  
3 = Moderate  
1 = Weak

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<td>Carries two 55 gallon drums</td>
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<td>Final product cost is &lt; $6000</td>
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Relative weight %: 16%
## APPENDIX D – SCHEDULE

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APPENDIX D - CALCULATIONS

BRAKE CALCULATIONS
- Braking figured for grassy surface
- Stopping distance of 60 feet
- Worst case assumption is that the vehicle will be fully loaded at 2500 lbs going down a 20° slope

**Total energy needed to dissipate**

Total energy = Kinetic energy + Potential energy

Total energy = \( \frac{1}{2} \left( \frac{2500 \text{ lbs}}{32.2 \text{ ft/s}} \right) \left( \frac{29.3 \text{ ft}}{s} \right)^2 + (2500 \text{ lbs})(60 \text{ ft})(\sin(20)) \)

Total energy = 33,326 ft lbs + 51303 ft lbs = 84,629 ft lbs

**Force required to stop in 60 ft**

\[
F_{\text{brake}} = \frac{\text{Total energy}}{\text{Stopping distance}}
\]

\[
F_{\text{brake}} = \frac{84,629 \text{ ft lbs}}{60 \text{ ft}}
\]

\[
F_{\text{brake}} = 1410 \text{ lbf}
\]

**Deceleration**

\[
\text{Deceleration} = \frac{\text{Force}}{\text{Mass}}
\]

\[
\text{Deceleration} = \frac{1410 \text{ lbf}}{78 \text{ slugs}}
\]

\[
\text{Deceleration} = 18 \frac{\text{ft}}{s^2}
\]
## APPENDIX E – BILL OF MATERIALS

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<th>Item</th>
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<td>Cable Clamp</td>
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<td>Return Spring</td>
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<tr>
<td>1/4&quot; Lock Washer</td>
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</tr>
<tr>
<td>1/4&quot; x 20 Nut</td>
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<td>1/4&quot; x 20 Bolt</td>
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<td>Banjo Bolt with Sensor (For Brake Lights)</td>
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### APPENDIX F – BUDGET

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Electronics, Throttle, and Braking

James Tierney
Brakes Research

• Most Common Brakes used by Similar Vehicles:
  – Disc Brakes
    • More Efficient
    • Higher Stopping Power
    • Difficult to Install
  – Drum Brakes
    • Simple to Install
    • Inexpensive
    • Ineffective at Higher Temperatures
Electronics Research

• Attended 2013 BUV Competition:
  – 2013 BUV Team had problems with wiring
  – Make sure all wiring is safely tucked away
  – Make sure all wiring is weather-proof
Competition Requirements

• BUV must have:
  – Engine temperature gauge in view of driver
  – 12 volt 35 amp or larger alternator and battery
  – Emergency shutoff device in reach of driver
  – Horn
  – Spring return throttle
  – Redundant brake system
Customer Requirements

1. Sufficient capacity (21%)
   a. Redundant brake system will be installed to prevent total brake failure
   b. Under full payload, vehicle will be capable of coming to a complete stop in 75 feet

2. Durability (19%)
   a. Materials and components will be selected to withstand the mechanical stresses during operation

3. Ease of operation (17%)
   a. Turn-key or pull-starter will be installed
   b. Both brakes will be located on rear wheels (no front brake)
   c. Designed to be operated by one person
   d. No additional skills needed to operate

4. Safety (15%)
   a. Vehicle will have a maximum speed of 20 mph
   b. Vehicle will be equipped with an engine kill switch easily accessible by the operator
   c. Vehicle will be equipped with a fire extinguisher
   d. A horn will be installed on this vehicle
   e. A roll bar will be installed per the competition’s specifications
   f. A high visibility safety flag will be installed on this vehicle
   g. All sharp or dangerous edges will be equipped with proper padding

5. Ease of maintenance (14%)
   a. Access to each component in the vehicle
   b. Vehicle will be maintained with standard tools

6. Affordability (14%)
   a. Vehicle will cost less than $5500 to manufacture
Design Concepts

Minimum Components

Positives:
- Affordable
- Easy to operate
- Easy to repair

Negatives:
- Less diagnostic information
- No fuses
Design Concepts

Maximum Components

Positives:
- Safety
- Reliability

Negatives:
- Expensive
- Complex wiring
- Difficult to repair
Design Concepts

Start Button

Positives:
• Affordable compared to maximum components concept

Negatives:
• Start button increases cost and complexity with no real benefit
• Could just use pull-starter that is standard on engine
Design Selection

The above concepts were analyzed using the weighted rating method. The criteria used were low cost, safety, ease of maintenance, reliability, and ease of operation. The score scale was 0-4, with 0 being unsatisfactory and 4 being excellent. After assigning a score for each category and concept and applying the weight values, Concept 1 had the highest score and thus was chosen.

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Braking Force Calculations

BRAKE CALCULATIONS
- Braking figured for grassy surface
- Stopping distance of 60 feet
- Worst case assumption is that the vehicle will be fully loaded at 2500 lbs going down a 20° slope

Total energy needed to dissipate
Total energy = Kinetic energy + Potential energy

Total energy = \( \frac{1}{2} \left( \frac{2500 \text{ lbs}}{32.2 \text{ ft/s}} \right) \left( \frac{29.3 \text{ ft}}{8} \right)^2 + (2500 \text{ lbs})(60 \text{ ft})(\sin(20)) \)

Total energy = 33,326 ft lbs + 51303 ft lbs = 84,629 ft lbs

Force required to stop in 60 ft
\( F_{\text{brake}} = \frac{\text{Total energy}}{\text{Stopping distance}} \)
\( F_{\text{brake}} = \frac{84,629 \text{ ft lbs}}{60 \text{ ft}} \)
\( F_{\text{brake}} = 1410 \text{ lbf} \)

Deceleration
\( \text{Deceleration} = \frac{\text{Force}}{\text{Mass}} \)
\( \text{Deceleration} = \frac{1410 \text{ lbf}}{78 \text{ slugs}} \)
\( \text{Deceleration} = 18 \frac{\text{ft}}{\text{s}^2} \)
Brake Components Selection and Fabrication

- Master Cylinder: Wilwood aluminum universal fit, 0.750 in. bore
- Brake Pedal: Wilwood aluminum forwardmount

Drum brake on 1995 Chevrolet S10 pickup truck
Electrical Components Selection

- Head lights and brake lights
- Automotive horn
- Engine temperature gauge
Electrical Components Selection

12V battery

Alternator
Throttle Components Selection

- Sourced from a bicycle
  - Hand brake
- Mounted on right side of handle bars
Electrical Components Fabrication

- Control Panel
- Head lights
- Brake lights
Brake Pedal Fabrication

- Wilwood brake pedal mounted on BUV
- Brake lines running to rear brakes
Testing

• Electrical components:
  – Head lights and brake lights switch
  – Horn button
  – Engine temperature gauge
  – Kill switch

• Throttle
  – Spring return throttle
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## Budget

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<th>PRICE</th>
<th>TOTAL (PROPOSED)</th>
<th>TOTAL (ACTUAL)</th>
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