Basic Utility Vehicle (BUV)

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requirements for the degree of

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by

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ACKNOWLEDGEMENTS

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ABSTRACT

For many years seniors have had to design a Basic Utility Vehicle (BUV) as their senior design project. The BUV competition was created by the Institute of Affordable Transportation (IAT). IAT helps third world countries by supplying Basic Utility Vehicles capable of performing necessary tasks, at a feasible cost. For this project, the vehicle is broken down into parts for each team member to design. The 2013 Senior Design BUV was broken down into four parts: frame and chassis, drive train, front suspension and irrigation, and brakes and controls.

The 2013 Senior Design BUV team consist of Sara Wells (Frame and Chassis), Nathaniel Gertz (Drive Train), Mark Stoll (Suspension and Irrigation), and James Voet (Brakes and Controls). A master schedule was put together to keep the 2013 BUV project on track. This schedule highlighted key dates such as design freeze, oral presentations, beginning fabrication, and completion dates. This is a detailed report of the frame and chassis portion of the BUV. Research was performed by reviewing information on ATVs and past competition BUVs. Key important design features were developed from the research and the IAT competition specifications.

Three design concepts were developed for each part of the BUV project. The weighted customer features were used to select the best concept for the final design. Once the final design was selected a design analysis was performed in order to select the proper material and verify the design would not fail under maximum loading conditions. Maximum loading conditions for the vehicle were assumed to be 2000lbs while traveling up a 20°incline. Material was selected after the design analysis was completed.

The next phase of the project was to purchase and begin fabrication of the 2013 vehicle. Material was purchased mostly at the beginning the fabrication process. Once each portion of the project was completed then the BUV was assembled. Due to delays in the fabrication process there was limited time for testing and modifications before the competition. The vehicle was then taken to the IAT competition.

It competed in the competition and placed third out of six schools. Based on the performance by the 2013 BUV, it was clearly determined that the frame was a successful design.
INTRODUCTION

PROBLEM STATEMENT

Each year the Basic Utility Vehicle (BUV) competition is held by The Institute of Affordable Transportation (IAT). IAT is a not-for-profit organization dedicated to improving the lives of the world’s poor by providing simple, low-cost vehicles in order to make community transportation possible (1). These vehicles help aid in transporting larger loads of crops, supplies, water and other needed materials at a much faster rate. They can also act as school buses and transport children to school or ambulances and transport the sick or wounded to the hospital.

IAT has been hosting the student BUV competition since the organization was founded in 2000. This competition gives students the opportunity to improve the basic utility vehicle concept, by making it more efficient, more reliable, and less costly. Each year the competition has a different “theme”, this year the theme is BUV Farm Tanker and Transporter. The challenge is to design and develop a vehicle to tanker irrigation water and carry produce from the farm to the market. Some additional criteria for the vehicle would be it must be able to handle rough terrain and must be able to carry a payload of approximately 1320lbs plus the driver and one passenger.

RESEARCH AND BACKGROUND INFORMATION

The basic utility vehicles used by IAT have a unique three wheel design. This allows for low cost manufacturing, ease of maintenance, and ease of assembly. During preliminary research it was found that there are many different variations of basic utility vehicles.

Information was gathered from past BUV teams by interviewing those teams’ members and by reviewing information from previous senior design reports (3) (4). Information was also gathered from different all-terrain vehicles (ATV) produced in the USA (5) (6) (2) (7) (8) (9) (10) (11). Most of the ATVs researched do not meet IAT competition specifications; however the team was able to apply some ideas from the ATVs to the design ideas for the BUV. Information was also gathered from the winning team of the 2012 BUV competition Purdue University. Their vehicle was mostly made of wood and angle iron, making the vehicle light weight and able to achieve a top speed of 25 miles per hour.
Most of the researched ATVs are able to perform the tasks that IAT requires; however, they are not a practical option for developing, low income countries. The target cost for IAT’s basic utility vehicles is $2,500 not including the cost of the engine. This is a difficult challenge to all competition participants. In previous competitions, many BUV teams were not able to achieve this cost, and instead the typical price range for previous teams was $3,500 - $5,000 for the fully assembled vehicle. Currently the IAT production vehicle is being sold for roughly $2000, which is a reasonable price for the targeted users.

The 2012 UC BUV team used a small truck frame with a custom front end. The vehicle weight plays a significant role in having a well performing BUV (4). Since, the rear end of the vehicle is already established by the IAT specifications, the goal is to develop a front end that is low weight using high strength materials. A lower weight vehicle will reduce the cost of materials and also reduce the amount of stress on the BUV.

Based on all the research gathered, the team was able to develop a list of key features for the vehicle. Many of the features have been seen in current ATVs throughout the industry. Below is a list of the features that were gathered (4).

- Agricultural Tires
- Foot Pedal for Throttle
- Low Center of Gravity
- Rear Suspension was Leaf Springs
- Shielding on Drive Train

**TEAM MEMBER RESPONSIBILITIES**

Sara Wells – Frame/Chassis Design

Nathaniel Gertz – Drive Train

Mark Stoll – Suspension and Irrigation System

James Voet – Electrical and Controls
COMPETITION GUIDELINES AND EVENTS

Competition Events

The 2013 BUV Competition was held in Batavia, Ohio on April 20th. Each vehicle competed in one long endurance event. At the competition each team was also required to create and overall cost analysis for their vehicle

Competition Specifications

Every competition has certain specifications that the teams must follow, and the teams are judged based on how well they followed the criteria. The following is a list of some of the major design specifications required for this competition (12):

- Cost Target of $1500 for the assembled BUV
- Up to 11hp unmodified engine
- Maximum payload of 1320 lbs. plus the driver and one passenger
- Maximum speed of 20mph
- Onboard irrigation system
- Bonus points of the vehicle is made out of angle iron and rebar
  - These materials are readily available to the end user

See full specification list in Appendix F.
PRODUCT OBJECTIVES

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. The product objectives will focus on a basic utility vehicle for developing communities in impoverished areas. The vehicle will be designed and built to meet competition guidelines. The percentages next to each objective were determined by the team, based on how important each objective was to the entire project.

1) Has sufficient capacity (12%)
   a) Maximum payload will be 2000 lbs. including the driver.

2) Durable (11%)
   a) Materials and parts will be selected from mathematical analysis to withstand the stresses the vehicle will face on the course.
   b) COSMOS will be used to find the maximum stresses existing on the frame.

3) Handle rough terrain (10%)
   a) Vehicle will be equipped with off-road tires.
   b) Vehicle will have suspension capable of handling the course terrain.
      i) Front suspension will have 3 in. of travel
      ii) Rake angle will be at most 20°
      iii) Rear suspension will handle a maximum payload of 2500 lbs.
      iv) Front wheel can handle the stresses of a 3 foot drop

4) Affordable (9%)
   a) Vehicle will cost less than $4000 to manufacture.
   b) Vehicle frame will have at least an 11” clearance off the ground.

5) Easy to Maintain (8%)
   a) Access to each component in the vehicle.
   b) Flat head screws will be used.
   c) Vehicle will be maintained using standard tools.

6) Easy to Manufacture (8%)
   a) Will use standard parts.
   b) Vehicle can be assembled without the use of custom tools or specialized professionals.

7) Easy to Operate (8%)
   a) Handle bars instead of a steering wheel.
   b) Turnkey or push button ignition.
8) Long life expectancy (8%)
   a) Standard paints and lubricants will be used to increase the life of vehicle parts.
   b) Engine, transmission, and electronic components will be enclosed to prevent water from damaging them.
   c) High grade materials such as steel or aluminum.
   d) Frame will be welded and all bolted components will use plated bolts and nuts.

9) Good Fuel Economy (8%)
   a) Vehicle will go 4 laps during the competition without refueling.
   b) Vehicle will have low-friction/efficient bearings.

10) Low center of gravity (7%)
    a) Maximum 2000 lbs. will be between the rear axle and the front wheel.
    b) A roll bar will be installed per competition specs

11) Safety (6%)
    a) Vehicle will be equipped with an engine kill switch.
    b) Vehicle will be equipped with a fire extinguisher.
    c) Vehicle will be equipped with a horn.
    d) Vehicle will be equipped with a roll bar.
    e) Padding on all sharp or dangerous places.
    f) Vehicle will have breaks on all wheels.
    g) Vehicle will be equipped with straps to secure the cargo.

12) Weather resistant (6%)
    a) Electronics, engine, and transmission will be enclosed.

13) Has the ability to tow (N/A)
    a) 1st and 2nd gear setting on the transmission.
    b) 1 7/8 inch trailer ball with top 15 inches above ground when unloaded (at rear of vehicle).
    c) 25 foot looped end tow strap with attachment provision at the front of the frame.

14) Small turning radius (N/A)
    a) Wheel base and handle bar range will be designed to allow a minimum 10ft. turning radius.

15) Has sufficient driver visibility (N/A)
    a) Headlight
    b) No windshield
    c) Cargo bed will not block drivers rear view

16) Operated by one person(N/A)
    a) Only one person required to drive the vehicle.
    b) One set of handle bars, and one foot pedal for the gas.
PROJECT MANAGEMENT

SCHEDULE

The following is a table of the projected schedule for the entire project. The schedule begins the second week of October 2012 with the proof of design agreement and ends with the final project report and presentation.

<table>
<thead>
<tr>
<th>Task</th>
<th>Projected</th>
<th>Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proof of Design Agreement</td>
<td>10/8/12-10/21/12</td>
<td>10/15/2012</td>
</tr>
<tr>
<td>Concept Sketches</td>
<td>10/15/12-11/4/12</td>
<td>10/22/2012</td>
</tr>
<tr>
<td>Concept Selection</td>
<td>11/5/12-11/11/12</td>
<td>10/25/2012</td>
</tr>
<tr>
<td>Preliminary Design</td>
<td>11/5/12-12/9/12</td>
<td>1/14/2013</td>
</tr>
<tr>
<td>Order Remaining Parts</td>
<td>1/21/13-2/4/13</td>
<td>2/16/2013</td>
</tr>
<tr>
<td>Assembly</td>
<td>1/21/13-3/17/13</td>
<td>3/18/2013</td>
</tr>
<tr>
<td>Final Testing</td>
<td>3/25/13-4/7/13</td>
<td>4/19/2013</td>
</tr>
<tr>
<td>IAT Competition Report</td>
<td>4/16/2013</td>
<td>4/16/2013</td>
</tr>
<tr>
<td>IAT Competition</td>
<td>4/20/2013</td>
<td>4/20/2013</td>
</tr>
</tbody>
</table>

See full projected schedule in Appendix C.

BUDGET

The total project cost for the BUV is $2,500 per the IAT competition specifications, not including the engine. The frame and chassis is most likely going to be the largest portion of the budget, estimating it at $1,100. Attempts are going to be made to try and reduce this expense as much as possible.

<table>
<thead>
<tr>
<th>Anticipated Costs</th>
<th>Actual Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frame</td>
<td>$1100</td>
</tr>
<tr>
<td>Braking</td>
<td>$600</td>
</tr>
<tr>
<td>Powertrain</td>
<td>$1000</td>
</tr>
<tr>
<td>Suspension</td>
<td>$400</td>
</tr>
<tr>
<td>Body</td>
<td>$400</td>
</tr>
<tr>
<td>Assembly Tools</td>
<td>$150</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>$200</td>
</tr>
</tbody>
</table>

See full budget list in Appendix D.
DESIGN CONCEPTS

Angle iron is a readily available material in most third world countries. This is why I have decided to make all three design concepts out of angle iron. The goal is to make a basic utility vehicle that would be able to be easily manufactured in a third world country. By making the frame of the vehicle completely out of angle iron, it would be easier for anyone to get the materials needed and make one.

CONCEPT 1:

This design is consists of a similar shape to the previous BUV team designs, however it is very different. This concept is one part made out of steel angle iron. The angle iron that would be used is 1” wide and 1/8” thick, because it is affordable and easy to find. The angled strips on the sides of the frame are at 90° angles as opposed to vertically up and down. This will help withstand the horizontal forces applied to the frame as it is starting and stopping. The frame will be welded together and will also be welded to the rear clip.

Figure 5: Concept 1 - Standard Shape Design

Pros:
- Durable

Cons:
- Heavy
- Lots of Welding
- Material Usage
- Hard to Manufacture
**Concept 2:**

This concept is similar to the current IAT production BUV. The narrow, triangle shape uses less material which is ideal for third world countries because the less material needed, the easier it will be to manufacture. 1” wide and 1/8” thick steel angle iron will be used to make the frame. This design will also have 3/8” plywood boards placed in the open areas to allow people to walk across it. These boards will also reduce the risk of someone stepping through the iron bars and hurting themselves. The angle iron will be welded together to make the frame one piece, and then the frame will be welded to the rear clip.

![Figure 6: Concept 2 – Sleek Design](image)

**Pros:**
- Good ground clearance
- Standard manufacturing process to build, such as cutting, bending, and welding
- Light Weight
- Durable
- Material Usage

**Cons:**
- Lots of Welding
**Concept 3:**

This concept is similar to previous BUV team concept designs. The angle iron thickness would be 1/8” and 2” wide. Angle iron would be wet cut and welded together, and then welded to the rear clip. The top would be covered with plywood to increase safety.

**Figure 7: Concept 3 - Box Design**

**Pros:**
- Durable
- Standard manufacturing process to build, such as cutting and welding
- Material Usage
- Easy to Manufacture

**Cons:**
- Larger Vehicle Weight
- Lots of Welding
- Shape is not ideal for front suspension
CONCEPT DESIGN

Each of the three concepts described were entered into a decision matrix with all the project objectives and ranked 0-4 on how well they met each objective. The weights were determined by what the team felt was most important. Below in Table 3 is the weighted decision matrix, which was used to choose the best design for the frame.

Table 3: Weighted Decision Matrix

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Weight %</th>
<th>Standard</th>
<th>Weight %</th>
<th>Sleek</th>
<th>Weight %</th>
<th>Box</th>
<th>Weight %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durability</td>
<td>30</td>
<td>4</td>
<td>1.2</td>
<td>4</td>
<td>1.2</td>
<td>2</td>
<td>0.6</td>
</tr>
<tr>
<td>Ease of Assembly</td>
<td>25</td>
<td>1</td>
<td>0.25</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>0.5</td>
</tr>
<tr>
<td>Weight</td>
<td>20</td>
<td>3</td>
<td>0.6</td>
<td>3</td>
<td>0.6</td>
<td>3</td>
<td>0.6</td>
</tr>
<tr>
<td>Low Cost</td>
<td>15</td>
<td>3</td>
<td>0.45</td>
<td>3</td>
<td>0.45</td>
<td>2</td>
<td>0.3</td>
</tr>
<tr>
<td>Material Usage</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>
</tr>
<tr>
<td><strong>100</strong></td>
<td></td>
<td></td>
<td><strong>2.7</strong></td>
<td></td>
<td><strong>3.05</strong></td>
<td></td>
<td><strong>2.55</strong></td>
</tr>
</tbody>
</table>

Design Concept 2 “sleek design” was selected for the BUV frame design based on the fact that it had the highest weighted percentage in the decision matrix. This design had the best combination of all the project objectives. The deciding factors for this decision were material usage, low cost, and ease of assembly.
MODELS

ASSEMBLY MODELS

The BUV Frame will consist of three major parts, the base frame that connects to the rear clip, the top cover that will be bolted onto the base frame, and the bench that will be bolted to the top of the base frame as well. The base frame is made from 2” x 2” x 1/8” A36 steel angle iron. Per competition specs the vehicle must be easy to manufacture in a third world country, this is why angle iron was chosen for the base frame, it is a material that is readily available in these parts of the world.

The top cover is made from plywood that is 3/8” thick. This cover is bolted to the top of the base frame. The bench is made from 3/8” thick plywood and 2” x 4” pieces of wood. The top of the bench is on a hinge to allow for easy access to the drive train for maintenance.

IAT specified that the BUV must have a bed that can hold 2 (may hold 3) 55-gallon steel drums. The bed was designed to hold 3 steel drums, for maximum points during the competition. To allow for 3 steel drums, the bed needed to be a minimum of 18 square feet, which is how the bed was designed. By designing the bed for the minimum allowable area, this allows the barrels to fit tightly into the bed, and will prevent rolling while the vehicle is in motion. The sides of the bed are 10” high. The entire bed was constructed out of 1” x 1” x 1/8” angle iron and the floor of the bed was constructed out of 3/8” thick plywood and welded directly on top of the rear clip.

The drive train assembly will sit under the bench on the base frame and will extend horizontally towards the rear differential. The base frame and the rear clip will be welded together.
DESIGN ANALYSIS

FINITE ELEMENT ANALYSIS RESULTS

Von Mises Diagram
When the suspension was designed for the front wheel of the vehicle, a maximum load of 1567lbs was calculated by that team member. The base frame was modeled in SolidWorks with 2”x2”x1/8” angle iron. The material selected was A36 steel, based on availability and cost. The 1567lb force is acting upward at the incline on the front of the BUV, based on how the front connection bolts to the front face. Below are the FEA results:

The fixed positions on the base frame for the simulation are the back ends of the frame where it is going to be welded into the rear clip.

Figure 10: Von Mises Diagram

The yield strength of the A36 steel is 36,000 psi, for this part the maximum amount of stress that will occur is 14593.3psi near the vertical beams on the sides of the base frame. Based on this analysis the frame will not fail under this load.
Factor of Safety Diagram
The Finite Element Analysis program also created a factor of safety diagram, with the fixed position and the applied force of 1567lbs in the same position as the Von Mises Diagram. The lowest factor of safety is 2.48. This is an acceptable factor of safety for the frame because the maximum load of 1567lbs is only when the BUV is under full load, driving up a 20° incline.

Deflection Diagram
The Finite Element Analysis program also created a deflection diagram, with the fixed positions and the applied force of 1567lbs in the same position as the Von Mises Diagram. The maximum deflection of the base frame is .002676in on the front end. This is a small amount of deflection that would not cause and plastic deformation in the part.
FABRICATION AND ASSEMBLY

Base Frame

Several pieces of 2” x 2” x 1/8”, 6 feet in length, A36 steel angle iron were cut to the correct lengths using an angle press. Once all the pieces for the base frame were cut to length they were MIG welded together to create the base frame. Figure 13 shows how the angle iron being welded together. Figure 14 shows the entire frame after being welded together.

Figure 13: The base frame all welded together
Figure 14: Welding the base frame together

After the base frame was all welded together, it was time to cut a sheet of plywood to bolt to the top of the frame. 3/8” thick plywood was used for the top of the frame, and it was cut using a cut-off saw. Once the plywood was cut, holes were drilled through the top of the frame and also through the plywood. This way the plywood can be bolted to the top of the base frame. The bolts that were used were ¼” in diameter and 1” long. 14 bolts were used to mount the plywood. Figure 15 below show how the plywood was bolted to the top of the frame.

Figure 15: Plywood on top of the base frame
**Base Frame to Rear Clip**

The base frame was going to be welded directly into the C-channel of the rear clip, however the frame has to sit slightly lower than the rear clip so the drive shaft lines up with the rear differential. To accommodate this, a bracket was made to weld directly to the rear clip and the base frame would be welded to the bracket. The bracket was made out of 4” x 4” x ¼” A36 steel angle iron. The angle iron was cut using an angle press and then it was MIG welded together. The bracket was then welded to the rear clip and then the frame was welded to the bracket.

![Figure 16: The frame welded to the bracket](image)

![Figure 17: The bracket welded to the rear clip](image)

**Cargo Bed**

The cargo bed was made the same way the base frame was made. It is made out of 1” x 1” x 1/8” A36 steel angle iron. The angle iron was cut to length using an angle press and then it was MIG welded together. Once welded together, plywood was cut to lay on the bottom of the bed so the three barrels would have something to lay on. The plywood was bolted into the bottom of the bed using ¼” bolts that were 1” long. Then the bed was welded to the top of the rear clip. However, since the rear clip is not perfectly flat, small pieces of steel tubing were added to allow for the bed to sit level. These pieces of steel tubing also added extra support for the bed.

![Figure 18: Cargo bed with plywood](image)

![Figure 19: Cargo bed welded to rear clip](image)
IAT COMPETITION RESULTS

COMPETITION SUMMARY

The competition started at 9:00 on April 20, 2013. This was purely an endurance event. The main objective for the competition was to see who could carry the most barrels full of water and complete the most laps around the course. This year there were 6 schools competing in the competition. Teams received 10 points for each completed lap plus 15 points for each full drum carried. At the end of the competition the scores were tallied and the top three scores received awards. The 2013 CAS Senior Design BUV placed third in the competition with a score of 35.5 points. The BUV completed 2 practice laps and 3 actual competition laps around the 2.1 mile long course.

COMPETITION PHOTOS

Figure 21: Getting ready to start the race
Figure 20: Driving through the wooded course
Figure 23: Driving through the mud
Figure 22: Third Place Champions
PROOF OF DESIGN TESTING

The proof of design was created just after all the research for the project had been completed. All members of the team had individual proof of design agreements based on their part of the project. This gives the team a way to evaluate their primary objectives for the whole BUV project. The frame and chassis proof of design objectives are listed below.

- Vehicle frame will be made out of angle iron (bonus points in competition)
- Vehicle will have an 11” ground clearance
- Vehicle will have a payload of 2000lbs including the driver and passenger while climbing a 20° slope
- Vehicle chassis will not have sharp edges
- Cargo bed area will be $18\text{ft}^2$ or more
- Production cost of the vehicle will be less than $2500$ (per competition specs)
- Cargo Bed will have an attached 1 7/8” trailer ball hitch
- Vehicle will have appropriate shielding for all moving parts
- Vehicle will be designed with a separate frame that will connect to the rear clip

All design specifications were met. The vehicle frame and bed are made entirely out of angle iron. During the competition, on the second practice lap the BUV was carrying 3 full barrels of water and 2 passengers. The weight of the 3 full barrels plus the passengers came out to be slightly over 2000lbs. There was a 20° slope the vehicle had to climb during the course. All the sharp edges of the vehicle had foam padding on them and it passed the vehicle safety inspection prior to the competition. The cargo bed was designed to have 18.7 square feet of area. The final production cost of the vehicle was $1894$ which is lower than the estimated $2500$ from the competition specs. The BUV has a 13” ground clearance. A 1 7/8” trailer ball hitch was attached at the rear of the vehicle at 13” above the ground. The engine, transmission, and torque converter are all encased in the base frame under the driver’s bench, this provided more than adequate shielding. After the competition the vehicle was covered in mud, and the drive train had zero mud on it. Lastly, the vehicle had a separate base frame that was welded into the rear clip.
CONCLUSION & RECOMMENDATIONS

Based on the competition results the 2013 BUV performed very well. All proof of design goals set for the frame and chassis design were met. The design of the frame and chassis served its purpose in the BUV, however this is room for improvement. The Institute of Affordable Transportation recommends future teams continue to use angle iron in their design, but look into using a truss design for the vehicle. This is easier to manufacture because the material would all have 90° cuts. It is recommended that teams start fabrication of the vehicle much earlier, this will allow time at the end to perform more testing and modifications as needed. This will reduce a large amount of stress as is gets closer to the competition date.
WORKS CITED

Interview with previous BUV Club President, Adam Dehne, 15 Sep 2012

Discussed different innovative ideas for the group’s BUV:
- Cam-handle system for the hydraulic valves, the design had to go into the cam in order for the design to work properly
- Changed the shape of the steering mechanism, went with handles instead of a wheel
- Love-Joy connector for the (at the time) new engine

Discussed features he would recommend:
- Having the hydraulic system in place
- Design for one person operation, then most everything will be concise and optimize for anyone to operate it

Discussed the most important aspects of the BUV:
- The ability to move the weight in the fastest time
- Needs to have great agility
- Needs a low center of gravity while still being able to go over obstacles

Discussed the critical stresses on the vehicle:
- Front suspension due to having a single tire supporting the load
- Physical joints of the vehicle
- Twisting when going over an obstacle with a heavy load
- Power to the ground; Axels and drive train components must be able to move the weight and stay intact.
Interview with previous BUV Club President, Melanie Jump, 12 Sep 2012
Saw pictures of the vehicle assembled and at the competition.
Discussed what the hardest challenge of build/design was low cost
Discussed the pitfalls of the competition and what she wished her group had done differently
to avoid them.
Discussed the necessities of the vehicle; carrying large quantities is much better than comfort.
Needs to be made out of common materials that could be found in third world nations.
Needs to be easy to assemble.
Vehicle needs to be able to withstand the elements.

**Technical Features Found During Interview:**

- Foot pedal for throttle
- Hydraulic braking with disc brakes as emergency brakes
- Agriculture tires
- Drive components were in an enclosed hydraulic system, didn’t have to worry about mud and dirt messing with the drive components, it offered a lot of torque, and 3 wheel drive; was very expensive
- Front suspension was polypropylene strap, it was low cost, easy to install, and just as durable as springs
- Rear suspension was leaf springs
- Used conduit tubing BLC galvanized/(weatherproof) because it was cheap and light

**2012 Competition Rules (discussed during interview):**
- Easy to fix
- Easy to assemble
- Cost was over $6000, well above competition rules ≤ $2500
- Easier to steer with handle bars versus using a steering wheel; innovative
Purdue University won the 2012 BUV competition. This was their vehicle.

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
The Can-Am Commander is built in line with our tradition of designing ATVs and side-by-side vehicles fit for everything from racing to hunting trips to getting out on the trail with a friend for a long ride. No rec-utility side-by-side offers more power and versatility. You’re about to read all the ways we’ve made the Can-Am Commander a thrilling vehicle.

### Features
- Motion control shocks
- Adjustable tilt steering
- 27” Carlisle Black Rock tires
- 2” diameter, high strength steel cage
- 10” Front and Rear suspension travel

### 250cc Everest Quad UTV

The 250cc Everest Quad UTV is a compact and powerful side-by-side vehicle designed for varied terrains and versatile applications. Here are some of its features:

**Features**
- Front Drum Brakes
- Read Disc Brakes
- All terrain tire
- Water cooled 4 stroke motor
- Fully independent front suspension
- 700 lbs.
### Ranger XP 900

<table>
<thead>
<tr>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Easy engine access</td>
</tr>
<tr>
<td>1,500lb load capacity</td>
</tr>
<tr>
<td>2,000lb tow load</td>
</tr>
<tr>
<td>12” ground clearance</td>
</tr>
<tr>
<td>4-wheel hydraulic disc brakes</td>
</tr>
<tr>
<td>10” front and rear suspension</td>
</tr>
<tr>
<td>Under seat storage</td>
</tr>
</tbody>
</table>


9/12/2012

### 2013 Rhino 700 FI Auto 4x4

<table>
<thead>
<tr>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fully locked differential 4WD</td>
</tr>
<tr>
<td>Steel frame</td>
</tr>
<tr>
<td>12.1” ground clearance</td>
</tr>
<tr>
<td>Sealed drive case</td>
</tr>
<tr>
<td>400lb load</td>
</tr>
<tr>
<td>1,200lb tow</td>
</tr>
<tr>
<td>Low maintenance</td>
</tr>
</tbody>
</table>


9/12/2012

---

Appendix A5
Big Horn 700 UTV

The Bighorn 700 is built to handle anything you want to do -- no complaints. Its four-stroke, single cylinder 686 c.c., 33.5HP engine with automatic L-H-N-R-P transmission and on-demand 2WD/4WD drive takes you where you want to go. Hunting, farming, camping, fishing, carrying, pulling, or towing -- the Bighorn 700 can handle it all! Even better, the Bighorn 700 also meets safety requirements for a low-speed vehicle.

2013 Mule 4000

http://www.bennche.com/products/Bighorn_700_UTV.htm

9/12/2012

Features
- 13” ground clearance
- 400lb load
- 1200lb tow
- Shaft drive
- Locking differential
- 25” tires

Features
- 1,330lb load capacity
- 7.5” ground clearance
- Rack and pinion steering
- 4W hydraulic drum brakes
- Top speed : 25mph
- 11.0 ft. turning radius
### 800cc UTV

Vehicles that can handle the tough jobs while going easy on the turf. 800 cc utility vehicle has the hauling power you would not expect from an electric vehicle.

<table>
<thead>
<tr>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>800cc gasoline engine</td>
</tr>
<tr>
<td>CVT transmission</td>
</tr>
<tr>
<td>Independent front and rear suspension</td>
</tr>
<tr>
<td>25” tires</td>
</tr>
</tbody>
</table>

![800cc UTV Image](http://www.baohuamotoercycle.com/utility-vehicle/865647.html)

9/12/2012

### Heavy Duty Utility Trailer


<table>
<thead>
<tr>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>1800lb payload</td>
</tr>
<tr>
<td>2000lb rated axle</td>
</tr>
<tr>
<td>Warranty</td>
</tr>
<tr>
<td>$339.76</td>
</tr>
</tbody>
</table>

![Heavy Duty Utility Trailer Image](http://www.deiequipment.com/s.nl/it/A/id.10517/f?gclid=CJba_PzqsLICFelaMgodq1MAOA)

9/12/2012
APPENDIX B – PRODUCT OBJECTIVES

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. The product objectives will focus on a basic utility vehicle for developing communities in impoverished areas. The vehicle will be designed and built to meet competition guidelines.

17) Has sufficient capacity (12%)
   a) Maximum payload will be 2000 lbs. including the driver.

18) Durable (11%)
   a) Materials and parts will be selected from mathematical analysis to withstand the stresses the vehicle will face on the course.
   b) COSMOS will be used to find the maximum stresses existing on the frame.

19) Handle rough terrain (10%)
   a) Vehicle will be equipped with off-road tires.
   b) Vehicle will have suspension capable of handling the course terrain.
      i) Front suspension will have 3 in. of travel
      ii) Rake angle will be at most 20°
      iii) Rear suspension will handle a maximum payload of 2500 lbs.
      iv) Front wheel can the stresses of a 3 foot drop

20) Affordable (9%)
   a) Vehicle will cost less than $4000 to manufacture.
   b) Vehicle frame will have at least an 11” clearance off the ground.

21) Easy to Maintain (8%)
   a) Access to each component in the vehicle.
   b) Flat head screws will be used.
   c) Vehicle will be maintained using standard tools.

22) Easy to Manufacture (8%)
   a) Will use standard parts.
   b) Vehicle can be assembled without the use of custom tools or specialized professionals.

23) Easy to Operate (8%)
   a) Handle bars instead of a steering wheel.
   b) Turnkey or push button ignition.
24) Long life expectancy (8%)
   a) Standard paints and lubricants will be used to increase the life of vehicle parts.
   b) Engine, transmission, and electronic components will be enclosed to prevent water from damaging them.
   c) High grade materials such as steel or aluminum.
   d) Frame will be welded and all bolted components will use plated bolts and nuts.

25) Fuel Economy (8%)
   a) Vehicle will go 4 laps during the competition without refueling.
   b) Vehicle will have low-friction/efficient bearings.

26) Low center of gravity (7%)
   a) Maximum 2000 lbs. will be between the rear axle and the front wheel.
   b) A roll bar will be installed per competition specs

27) Safety (6%)
   a) Vehicle will be equipped with an engine kill switch.
   b) Vehicle will be equipped with a fire extinguisher.
   c) Vehicle will be equipped with a horn.
   d) Vehicle will be equipped with a roll bar.
   e) Padding on all sharp or dangerous places.
   f) Vehicle will have brakes on all wheels.
   g) Vehicle will be equipped with straps to secure the cargo.

28) Weather resistant (6%)
   a) Electronics, engine, and transmission will be enclosed.

29) Has the ability to tow (N/A)
   a) 1st and 2nd gear setting on the transmission.
   b) 1 7/8 inch trailer ball with top 15 inches above ground when unloaded (at rear of vehicle).
   c) 25 foot looped end tow strap with attachment provision at the front of the frame.

30) Small turning radius (N/A)
   a) Wheel base and handle bar range will be designed to allow a minimum 10ft. turning radius.

31) Has sufficient driver visibility (N/A)
   a) Headlight
   b) No windshield
   c) Cargo bed will not block drivers rear view

32) Operated by one person(N/A)
   a) Only one person required to drive the vehicle.
   b) One set of handle bars, and one foot pedal for the gas.
## APPENDIX C – PROJECTED SCHEDULE

<table>
<thead>
<tr>
<th>TASK</th>
<th>DATE (BEGIN MONDAY)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proof of Design Agreement</td>
<td>14-Oct</td>
</tr>
<tr>
<td>First Draft Report</td>
<td>21-Oct</td>
</tr>
<tr>
<td>Concept Sketches</td>
<td>28-Oct</td>
</tr>
<tr>
<td>Fall Report Due</td>
<td>4-Nov</td>
</tr>
<tr>
<td>Concept Development</td>
<td>9-Nov</td>
</tr>
<tr>
<td>Choose Best Concept</td>
<td>11-Nov</td>
</tr>
<tr>
<td>Preliminary Drive Train Design</td>
<td>14-Nov</td>
</tr>
<tr>
<td>System Requirement Calculation</td>
<td>21-Nov</td>
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<tr>
<td>Engine and Transmission Selection</td>
<td>28-Nov</td>
</tr>
<tr>
<td>Clutch</td>
<td>5-Dec</td>
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<tr>
<td>Gearing</td>
<td>12-Dec</td>
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<tr>
<td>Driveshaft</td>
<td>19-Dec</td>
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<td>Gear Shifting</td>
<td>26-Dec</td>
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<tr>
<td>Preliminary Frame and Body</td>
<td>3-Jan</td>
</tr>
<tr>
<td>Frame</td>
<td>10-Jan</td>
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<tr>
<td>Bed</td>
<td>17-Jan</td>
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<tr>
<td>Chassis</td>
<td>24-Jan</td>
</tr>
<tr>
<td>Water Barrel Connection</td>
<td>31-Jan</td>
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<td>Chassis to Frame Connection</td>
<td>7-Feb</td>
</tr>
<tr>
<td>Hitch Connection</td>
<td>14-Feb</td>
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</table>

### BUV:
- Nathan Gertz
- Mark Stoll
- James Voet
- Sara Wells

<table>
<thead>
<tr>
<th>TASK</th>
<th>DATE (BEGIN MONDAY)</th>
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<tbody>
<tr>
<td>Concept Development</td>
<td>15-Mar</td>
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<td>4-Apr</td>
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<td>Clutch</td>
<td>11-Apr</td>
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<tr>
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<td>18-Apr</td>
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<tr>
<td>Frame</td>
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<tr>
<td>Bed</td>
<td>2-Mar</td>
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<tr>
<td>Chassis</td>
<td>9-Mar</td>
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<tr>
<td>Water Barrel Connection</td>
<td>16-Mar</td>
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<td>Chassis to Frame Connection</td>
<td>23-Mar</td>
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<td>Hitch Connection</td>
<td>30-Mar</td>
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Appendix C1
### Appendix C2

<table>
<thead>
<tr>
<th>BLV:</th>
<th>Nathan Gertz</th>
<th>Mark Stoll</th>
<th>James Voet</th>
<th>Sara Wells</th>
</tr>
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<tbody>
<tr>
<td>DATE (BEGIN MONDAY)</td>
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<td>14-Oct</td>
<td>21-Oct</td>
<td>28-Oct</td>
</tr>
<tr>
<td></td>
<td>1 Nov</td>
<td>8-Nov</td>
<td>15-Nov</td>
<td>22-Nov</td>
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<tr>
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<td>26-Nov</td>
<td>3-Dec</td>
<td>10-Dec</td>
<td>17-Dec</td>
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<td></td>
<td>24-Dec</td>
<td>30-Dec</td>
<td>6-Jan</td>
<td>13-Jan</td>
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<tr>
<td></td>
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<td>27-Jan</td>
<td>3-Feb</td>
<td>10-Feb</td>
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<td></td>
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<td>3-Mar</td>
<td>10-Mar</td>
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<td>24-Mar</td>
<td>31-Mar</td>
<td>7-Apr</td>
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<td>28-Apr</td>
<td>5-May</td>
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#### Preliminary Control Design

- 25-Nov
- 2-Dec

#### Throttle

- 28-Nov
- 5-Dec

#### Brakes

- 25-Nov
- 2-Dec

#### Gauge Cluster

- 28-Nov
- 5-Dec

#### Redundant Braking

- 25-Nov
- 2-Dec

#### Lights

- 28-Nov
- 5-Dec

#### Start/Stop

- 25-Nov
- 2-Dec

#### Fabrication

- 28-Nov
- 5-Dec

#### Preliminary Suspension

- 25-Nov
- 2-Dec

#### Steering

- 25-Nov
- 2-Dec

#### Front Suspension

- 25-Nov
- 2-Dec

#### Front Wheel Connection

- 25-Nov
- 2-Dec

#### Rear Suspension

- 25-Nov
- 2-Dec

#### Final Designs

- 25-Nov
- 2-Dec

#### Final BOM

- 25-Nov
- 2-Dec

#### Design Phase

- 25-Nov
- 2-Dec

#### Design Report

- 25-Nov
- 2-Dec

#### Oral Design Presentation

- 25-Nov
- 2-Dec

#### Order Remaining Parts

- 25-Nov
- 2-Dec

#### Fabrication

- 25-Nov
- 2-Dec

#### Testing

- 25-Nov
- 2-Dec

#### Modifications

- 25-Nov
- 2-Dec

#### Final Testing

- 25-Nov
- 2-Dec

#### Competition Final Report

- 25-Nov
- 2-Dec

#### BUV Competition

- 25-Nov
- 2-Dec

#### Demonstration to Faculty

- 25-Nov
- 2-Dec

#### Final Project Presentation

- 25-Nov
- 2-Dec

#### Final Project Report

- 25-Nov
- 2-Dec
## APPENDIX D – BUDGET

<table>
<thead>
<tr>
<th>Item</th>
<th>Anticipated Costs</th>
<th>Actual Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frame</td>
<td>$1100</td>
<td>$348</td>
</tr>
<tr>
<td>Braking</td>
<td>$600</td>
<td>$216</td>
</tr>
<tr>
<td>Body and Cockpit</td>
<td>$400</td>
<td>N/A</td>
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<tr>
<td>Powertrain</td>
<td>$1000</td>
<td>$946</td>
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<tr>
<td>Safety and Driving Gear</td>
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<tr>
<td>Assembly Tools</td>
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<td>Travel</td>
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<tr>
<td>Miscellaneous</td>
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<tr>
<td>Team Apparel</td>
<td>$100</td>
<td>$20</td>
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</table>

**Total Costs**

$4400 $2101
Dear ___________:  

I am a senior at the University of Cincinnati studying Mechanical Engineering Technology. One of the College of Engineering graduation requirements is to take part in a senior design project which includes designing, building and testing a product. To fulfill this requirement, we have formed the University of Cincinnati, Basic Utility Vehicle, “BUV”, senior design team. This year we are determined to bring an excellent vehicle to the competition. Our team is determined to bring their best into the competition by designing and building a new vehicle in hopes of a more efficient BUV and higher ranking. Unfortunately, we are unable to complete our project without sponsor support. With companies and individuals alike tightening their budgets, it has made our project impossible to complete. Time is of the essence as graduation is right around the corner.

Our team has high expectations for the outcome of their vehicle; however, we cannot do it without sponsor support. Please help the BUV team for the upcoming Competition in 2013 and support the University of Cincinnati. Assistance from sponsors, no matter how large or small, is more important than ever to ensure a competitive team while providing real-world experience available nowhere else.

I have enclosed a Sponsor Proposal package, which outlines the BUV Background, Benefits, and an Estimated Budget. If you have any questions, please do not hesitate to contact me.

Thank you for your consideration of this request.

Sincerely,

Sara Wells
APPENDIX F – COMPETITION SPECIFICATIONS

BUV Farm Tanker and Transporter

2013 Design Specifications:

Challenge: Develop a vehicle to tanker irrigation water and carry produce from the farm to the market.

Scoring:
- Endurance Event: 80%, This will be your event points earned
- Cost to Build: 10%, This will be added to your event points for a $1500 vehicle
- Durability: 10%, This will be added to your event points for a ten year vehicle

Specifications:
- Cost Target: $1500, with a maximum of $2500 for cost to build percentage
- Engine: Up to 11 hp unmodified
- Transmission: Builders choice to meet event conditions
- Exhaust: Stock muffler, with additional heat shielding as needed. Muffler may be relocated
- Cargo Bed: Must hold two, but may hold three, 55 gal. Steel drums cradled securely on their sides, with the small opening at the top. Sixteen inch high side behind the driver, all other sides eight inches to contain the drums
- Maximum Load: 160 gallons of water, approximately 1320 pounds with three drums
- Maximum Speed: 20 MPH with empty barrels
- Brakes: Brakes on all wheels not on the driveline. Must have redundancy
- Parking Brake: Capable of overcoming engine power, it may be on the driveline
- Gages: Engine temperature indication in view of driver
- Hitch: 1 7/8 inch trailer ball with top 15 inches above ground when unloaded
- Roll Bar: Minimum of 36 inches above seat, located between the driver and the cargo, and must be strong enough to substantially rock the vehicle
- Electrical System: 12 volt, minimum 35amp automotive alternator with a battery
- Irrigation Water: Ability to fill 55-gallon drums from a pond during the timed endurance event. This will be done several times during the event after dumping the water back into the pond. Two team members are allowed to assist the driver. You will be within 12 feet from the edge of the pond. The irrigation system must be carried on the vehicle during the event
- Driver Safety: Helmet are required for each person aboard the vehicle. Seatbelts are at the option of the team
- Towing: 25 foot looped end tow strap with attachment provision at the front of the frame. Trailer ball will be rear attachment point for towing
- Fuel: Fuel and oil for an expected eight-hour event. Engine must be off during refueling
- Tires: Agricultural tread, or aggressive tire chains are required. Chains must be carried in vehicle if removed from the tires
- Weatherproof: Design to allow for protection from the weather elements
Appendix F2

July 10, 2012

Safety Items
To participate in the event you must have the following items: An engine shutoff device marked with a nine-inch red streamer located within reach of the driver. A spring return throttle with the spring located directly on the throttling device and not on the control linkage. Guarding from all moving parts, and padding of all sharp or dangerous places. Automotive horn and a fire extinguisher. A high visibility bicycle style safety flag above the vehicle.

Name Plate
University name and team number in 4-inch font on both sides of the vehicle.

Costing Information:
- Do not list engine cost
- $450 for automotive transmission
- $300 for truck axle with brakes and springs
- $150 for small pickup frame
- 50% retail cost for all other parts, or U-pull & Pay Cincinnati prices from their web site

Report
A standard report template will be provided to all registered teams for ease of cost and part documentation.

Course
The course will be around a grain field. It will be 2.1 miles long with little grass but mostly dirt or mud. There will be a trail through a wooded area that will have hills and obstacles to contend with. The pond for irrigation water is in the middle of the course. The vehicle must back up to the pond to fill, or to dump the water.

Judging
There will be minimal judging for the event. The event will be scored on the number of laps completed under power before 5:00 PM. Teams will score 10 points per lap plus 15 points for each full drum carried. Friday will be tech inspection and practice driving and filling from the pond. Filling from a pond is not easy. Have your procedure well developed before the endurance event on Saturday.

Endurance Event
The endurance event will start at 9:00am and run until 5:00 pm. The event may end early depending on conditions and point status. There will be no lunch break, just a continuous event. Food and fuel are available a mile away, NAPA auto parts is within three miles, and Tractor Supply is twelve miles away. Any disabled vehicles will be towed to the pit area for repairs. That lap will not count for them, but they may start the lap over when repaired.

Support Equipment
We expect to have a welder, air compressor, generator, and a pressure washer available to the teams. There will be two tractors to support parking and event needs on a first come first served basis.
Team Equipment

Each team should have equipment to get themselves out of the mud. This may be faster than waiting for the support tractor. There are several trees near the muddy areas for tie-offs.

Durability Factor

The BUV is expected to have a ten-year life. Automotive or agriculture components are considered to have a ten-year life. Sport vehicle and properly shielded industrial components should last five years. Lawn mower type components should last two years. Unprotected chain, belts, and bearings have a one-year life expectancy. Your endurance event score will be adjusted by the combined Durability Factor of the major systems of your vehicle.
APPENDIX G – ASSEMBLY SCREEN SHOT

ISOMETRIC VIEW
FRONT VIEW
SIDE VIEW
APPENDIX H – DRAWINGS

<table>
<thead>
<tr>
<th>Base Frame</th>
<th>A36 Steel</th>
<th>2&quot;x2&quot;x1/8&quot; Angle iron</th>
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</table>

<table>
<thead>
<tr>
<th>Frame</th>
</tr>
</thead>
</table>

Appendix H1
2013 Senior Design
BUV Team
Advisor: Dr. Janak Dave

Nathan Gertz - Drive Train
Mark Stoll - Suspension/Irrigation System
James Voet - Brakes/Electrical System
Sara Wells - Frame/Chassis
Problem Statement

The challenge is to design and develop a vehicle to tanker irrigation water and carry produce from the farm to the market.
Research

- Previous BUV Teams
- Current IAT Design
- 2012 Purdue University Vehicle
- Existing Products
Competition Requirements

• Cost Target of $1500 for the assembled BUV
• Up to 11hp unmodified engine
• Maximum payload of 1320 lbs plus the driver and one passenger
• Maximum speed of 20mph
• Onboard irrigation system
• Bonus points of the vehicle is made out of angle iron and rebar
Product Objectives

- Has Sufficient Capacity
- Durable
- Handle Rough Terrain
- Affordable
- Easy to Maintain
- Easy to Operate
- Long life expectancy
- Has the ability to tow
- Safety
- Weather Resistant
Competition Requirements

• Must be able to carry 2 (may hold 3) 55 gallon steel drums
• Maximum payload of 1320 lbs (plus driver and passenger)
• 1 7/8 inch trailer ball hitch
• Roll Bar – minimum 36” above seat
• **Bonus Points**: Frame made out of angle iron and rebar
Design Analysis
Concept 1: Standard Shape

- 1” x 1” x 1/8” angle iron
- 1 part welded together
- Welded to rear clip
- Plywood across top
Concept 2: Sleek Design

- 2” x 2” x 1/8” angle iron
- 1 part welded together
- Welded to rear clip
- Plywood across top
- Narrowed design
Concept 3: Box Design

- 2” x 2” x 1/8” angle iron
- All 90° cuts
- 1 part welded together
- Welded to rear clip
- Plywood across top
## Concept Design

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Weight %</th>
<th>Standard</th>
<th>Weight %</th>
<th>Sleek</th>
<th>Weight %</th>
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<td>0.3</td>
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<td>2.7</td>
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<td><strong>3.05</strong></td>
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<td><strong>2.55</strong></td>
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Concept 2: Sleek Design was chosen for the frame design based on the fact it had the highest weighted percentage in the decision matrix.
Solid Model Assembly
Cargo Bed

- Angle iron
- Plywood
- Will hold 3 steel drums
- Welded on top of rear clip
Finite Element Analysis (FEA)
Loads

1567 lbs

600 lbs

1567 lbs
Stresses

Max Bending Stress: 34.8 ksi
Yield Strength of A36 Steel: 36.0 ksi
Factor of Safety: 3.37
Component/Material Selection

- Angle iron (2” x 2” x 1/8” and 1” x 1” x 1/8”) – A36 Steel
- Plywood (3/8” thick)
- Steel Barrels (3)
- 1 7/8” Trailer Hitch
- Chevy S10 Rear Clip
- Steel tubing – for roll bar
Fabrication/Assembly
Frame
Cargo Bed
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<tr>
<th>Task</th>
<th>Projected</th>
<th>Actual</th>
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<tbody>
<tr>
<td>Proof of Design Agreement</td>
<td>10/8/12-10/21/12</td>
<td>10/15/2012</td>
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<td>10/15/12-11/4/12</td>
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## Actual Budget

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<th>Component</th>
<th>Description</th>
<th>Cost</th>
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<tr>
<td>Front frame</td>
<td>2&quot;x2&quot;x1/8&quot; angle iron frame welded together (160 inches of welds)</td>
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<td>Brackets, fasteners</td>
<td>1/4&quot; Bolts to hold down plywood on top of the front frame. (qty: 14)</td>
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<td>Rear frame, roll bar</td>
<td>Chevy S10 rear clip, roll bar - 1 1/4&quot; steel tubing (2.5&quot; of welds)</td>
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<tr>
<td>Trailer hitch</td>
<td>1 7/8&quot; trailer ball hitch</td>
<td>4.38</td>
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<tr>
<td>Brackets, fasteners</td>
<td>1/4&quot; bolts (qty:18)</td>
<td>4.50</td>
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<tr>
<td>Cargo bed, seat</td>
<td>1&quot;x1&quot;x1/8&quot; angle iron bed, welded together (62 inches of welds), seat - wooden bench with screws, held to frame with 1/4&quot; bolts (qty:4)</td>
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<td>Padding, shielding</td>
<td>Foam padding around roll bar, plywood and plastic tarp are used for shielding.</td>
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<td><strong>Sub-totals</strong></td>
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<td>347.73</td>
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**Estimated Budget: $1,100**  **Total: $347.73**
Testing

- Final testing will occur Friday 4/19 on the competition course.

Competition Course
Finished Vehicle
Questions?