2008 UC Basic Utility Vehicle

by

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Submitted to the
MECHANICAL ENGINEERING TECHNOLOGY DEPARTMENT
In Partial Fulfillment of the
Requirements for the
Degree of

Bachelor of Science
in
MECHANICAL ENGINEERING TECHNOLOGY

at the

OMI College of Applied Science
University of Cincinnati
May 2008

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2008 <u>B</u>asic <u>U</u>tility <u>V</u>ehicle
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ABSTRACT

Rural regions of Africa are in need of inexpensive, reliable transportation. This transportation would be used to transport school children, patients, and supplies to these remote regions. The Basic Utility Vehicle (BUV) solves this problem by providing an inexpensive, easy to maintain, rugged three-wheeled vehicle that is capable of a 1200 pound payload. In addition, the cargo bed is easily convertible to provide seating for nine children. The overall design had to be easy to repair, easy to build, and low in cost. An alternative energy source is installed to provide electricity for smaller applications without burning fossil fuels. The Institute for Affordable Technology (IAT) hosts a rigorous competition to test the overall performance of the BUV's from various colleges. IAT then takes the best designs and compiles them to be produced over in Africa.

The competition was held outside Indianapolis, Indiana on April 18th and 19th, 2008. The vehicle was funded from sponsors as well as the 2008 UC BUV team. The project was broken down into four systems; each system was delegated to one member of the group, which goes as follows:

1. The Chassis - Marcus Knapp
2. The Suspension - Andrew Morison
3. The Drive Train - Andrew Malatesta
4. The Cargo Bed/Electrical System - Josiah Brinkerhoff

The 2008 BUV team manager was Josiah Brinkerhoff with Dr. Janak Dave as the advisor.

The chassis section of the BUV meets all performance objectives and customer requirements through the use of research, surveys, a budget, and a schedule. Research for the conceptual development of the front clip examines existing and similar products on the market. Also, a customer survey was developed and distributed to 22 Peace Corps Volunteers in Africa and returned. The results of the survey were compiled into a quality function deployment chart to narrow down the most important needs of the customer.

Incorporating simple design features in the front clip section helped reduce the number of different parts. Also using standard or common parts reduced fabrication time as well as cost to manufacture. Plus common tools for repairs such as cutting, drilling, welding, and grinding are all features included in the front clip design of the chassis. The projected price for the chassis is projected to be less than one thousand dollars.

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INTRODUCTION

The chassis system of the BUV includes two major sections, the rear and front clip. The rear clip is based on the rear end of a small pickup truck. The front clip contains the front wheel, steering mechanism, front frame, driver's seat and controls. Key performance requirements for the chassis section such as 1200lb. payload delivery, 1000lb. gross vehicle weight, 15in. fording ability, and 10.5in. ground clearance were all considered for conceptual design. A copy of the IAT specifications are listed in full detail and located in Appendix A.

Currently BUV's are being utilized in many underdeveloped countries. The 2005 IAT competition BUV's were researched for designing the front clip. The 2005 University of Cincinnati and the Miami University were compared and contrasted for conceptual design. Each vehicle had two different from clip sections for the chassis. The two common shapes were the triangle and the box frame styles.

Similar products such as the Kawasaki Mule were also researched. The Kawasaki Mule is capable of carrying medium payloads with good fording ability. The frame is designed similar to a ladder; which helps reduce gross vehicle weight as well as great strength against vertical forces. However, utility vehicles such as the Kawasaki Mule are more commonly sold to developed countries and are higher in cost.

Other ideas were also taken from products that do not relate to BUV's. For example, the utility trailer also uses a triangle frame that connects the rear axle to a tow hitch. The frame is made with channel steel and is capable of transporting an 1800lb payload. The utility trailer consists of fewer parts, a simple assembly, and high-payload delivery.

A customer survey was developed and distributed to 22 Peace Cops Volunteers living and working in African communities. From the survey, the most important customer requirement for the chassis was ease of maintenance. Ease of maintenance in the front clip design was achieved by employing the following engineering characteristics: simple design features, standard or common parts, and common tools for repairs.

The important needs of the customer assisted in creating a preliminary budget. Completing the design on time was accomplished by weekly group meetings discussing individual and group schedules.

RESEARCH

EXISTING BUV'S

2005 University of Cincinnati BUV

The 2005 UC BUV chassis supports a three-wheeler application. The rear half of the chassis is from a small pickup truck. The front clip is manufactured to accommodate a motorcycle front suspension. Figure 1 displays the front clip of the chassis in more detail. The front clip of the chassis is similar to a box or rectangle. Sharp corners from the shape have more potential for unsafe egress/ingress to the driver seating apparatus. The 2005 IAT specifications required a minimum 1210lb payload. The UC BUV was capable of carrying 1500lbs. The ground clearance was almost 11in. which provided great fording ability in the swamp crossing event. The material selection consists of many different parts; resulting in a higher manufacturing cost. As seen in Figure 2, there is an inconsistency of common parts being utilized in the front clip of the chassis. Overall the rolling chassis demonstrates simplicity and rigidity. More information and detailed pictures for the 2005 UC BUV can be found in Appendix B.

Figure 1 – 2005 UC BUV Chassis

Figure 2 – 2005 UC BUV Detailed Chassis

2005 University of Miami BUV

The 2005 Miami University BUV chassis supports a three-wheeler application as well. The rear half of the chassis is from a small pickup truck. The front clip is manufactured to accommodate for a motorcycle front suspension. The front clip of the chassis is shaped more like a triangle. The triangle shape provides ease of egress/ingress for the driver. Figure 3 displays the BUV in more detail. The 2005 IAT specifications required a minimum 1210lb payload. The IAT website credits the Miami University team for reducing number of parts used, center of gravity, and emphasis on the steering and front suspension. Unlike the UC BUV, Miami used channel steel to make the front clip of the chassis. Channel steel costs more and adds more to the gross vehicle weight. Simple design features in the front clip section of the chassis resulted in a first place finish overall.

Figure 3 – Miami University BUV

SIMILAR PRODUCTS

Kawasaki Mule 3010

The Kawasaki Mule 3010 4x4 chassis is a ladder-type frame. The ladder-type frame supports large vertical loads, plus it is lightweight. Figure 4 shows the Kawasaki Mule in more detail. The frame rides on a DeDion rear leaf-spring suspension. The Mule can only deliver an 800lb payload. The cost is about $10,000 on average. The Kawasaki Mule is geared more towards developed countries. This utility vehicle is simple in design, easy to maintain, has fewer parts, and utilizes an effective frame design.

Figure 4 – Kawasaki Mule

Daihatsu Midget

Another vehicle that was considered was the Daihatsu Midget. Although this vehicle is no longer a production vehicle, it is a great example of an older utility vehicle. Figure 5 is a model being displayed in a museum. The Japanese developed this three-wheel vehicle with a multifunctional bed that is street legal. The frame of the Midget is easily manufactured, has reduced number of parts, and carries a 1000lb payload. What makes the Midget unique is the utilitarian design, ease of egress/ingress for the driver, and the multifunctional bed. Also, there are no sharp edges that cause potential risk or injury. There is plenty of room for a driver to sit comfortably.

Figure 5 – Daihatsu Midget

PRODUCTS FOR CONCEPTUAL DESIGN

Bicycle

A simple mountain bike frame was also used as inspiration for conceptual design of the front clip. The middle triangular structure is submitted to similar forces as a three-wheel vehicle. In Figure 6, the middle section of the frame is highlighted in red. The triangular middle section is capable of withstanding a large amount of combined forces created by the front tire. The design is simple, lightweight, has a reduced number of parts, and can carry a medium payload.

Figure 6 – Mountain Bike

Utility Trailer

A utility trailer is another example that utilizes a triangular structure for the frame. The trailer tongue of the frame attaches to a hitch of a vehicle. The utility trailer tongue is highlighted in red in Figure 7. The frame is capable of carrying heavy payloads. The front clip of the trailer is composed of different materials such as channel steel, angle iron, and box tubing. The use of channel steel provides great strength; however, the weight and cost are too high.

Figure 7 – Utility Trailer

CUSTOMER REQUIRMENTS

CUSTOMER SURVEY

Before a customer survey was distributed, two key customers were identified. A customer survey was developed to find out what was most important to the key customer. The first key customer is people living in Africa, specifically Mauritania. The second key customer was geared toward the work sector of underdeveloped countries. This includes individuals responsible for getting water, fuel, and food or transporting children and the elderly to schools and clinics. The survey was distributed to 22 Peace Corps Volunteers currently living and working in Africa. A full detailed survey is located in Appendix C. From the surveys, data and results were gathered and analyzed. The most important feature from the results that apply to the chassis section is the ease of maintenance which is shown in bold in Table 1. The ease of maintenance can be applied to the front clip by using simple design features, standard or common parts, and use of common tools for repairs. The complete list of survey results is located in Appendix D.

Table 1 – Survey Results

Features	Importance
Spare tire	4.86
Emergency road side repair kit	4.77
Ease of maintenance	**4.64**
Driver/Passenger seat belt	4.05
Auxiliary fuel can	4.05

QUALITY FUNCTION DEPLOYMENT RESULTS

To translate the customer requirements into engineering characteristics, a Quality Function Deployment (QFD) was created. The complete QFD chart is located in Appendix E. The ease of maintenance was the most important engineering characteristic that applies to the chassis. Table 2 shows the key customer requirements. The fabrication time relative importance is 0.14. The fabrication time was reduced by using fewer tools to construct as well as common material. The number of different parts relative importance is 0.136. The number of different parts will be kept to a minimum by utilizing one common material. The cost to manufacture relative importance is 0.125. Reducing the amount of material, number of cuts, and scrap will lower the cost to manufacture as well. Another important factor that applies to the chassis section is the overall weight. To perform well in the competition, the IAT recommends that the vehicle does not exceed a 1000lb gross vehicle weight.

Table 2 – QFD Results

Customer Requirements	Relative Importance
Fabrication time	14.0%
Number of different parts	13.6%
Cost to manufacture	12.5%

DESIGN

DESIGN ALTERNATIVES AND SELECTION

There were three conceptual designs for the front clip of the chassis. All the design concepts were entered in a decision matrix to determine the best conceptual design. Located in Table 3, each feature was assigned a weight percentage based on its level of importance to the final design. Features such as weight, number of different parts, and fabrication time were assigned weight percentages to match their significance. Weight is the most important feature of the chassis because the vehicle is recommended to be less than 1000lb gross vehicle weight.

The first design concept was styled like a box type frame. Figure 8 is a hand drawn concept. The box-style frame is similar to the frame utilized in the 2005 UC BUV team. Competition results for the UC BUV showed that the frame had great fording ability due to strength and ground clearance. However, the frame is composed of many different parts and poses an unsafe egress/ingress for the driver. When all the features were added up, the box-style frame was high in cost due to the number of different parts utilized. All of the reasons concluded that the box-style design was not the best option.

The second concept was styled like a trailer tongue. Figure 9 is an example of the trailer-tongue-style frame. The trailer tongue is common to a utility trailer. The frame is capable of caring heavy loads and is easy to assemble. However, the design requires many different parts such as channel steel, box tubing, and angle iron for component selection. Also, the weight is highest among each concept. All of these reasons concluded that the trailer-tongue-style was not the best option.

The ladder-style frame was the third design. The ladder-style design utilizes box tubing for all frame members. Figure 10 is a conceptual design for the ladder frame. The ladder-style frame is light in weight and is cheap to manufacture. By using one common part for the entire frame, the cost was the cheapest design. Although the strength was not as high as the trailer tongue, the ladder-style frame did provide resistance to impact loading conditions. The third design, ladder-style, was considered the best overall design and was ranked higher than the box-style and the trailer-tongue-style.

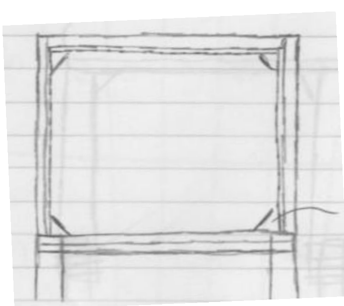

Figure 8 – Box Frame

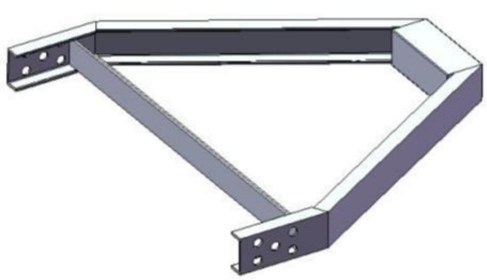

Figure 9 – Tongue Frame

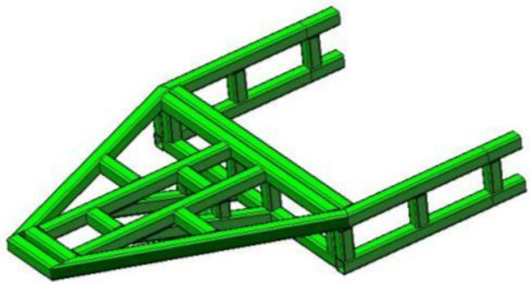

Figure 10 – Ladder Frame

Table 3 – Design Decision Matrix

Feature	Weight (%)	Box	Trailer Tongue	Ladder
Weight	35.0	1	1	3
Fab. Time	14.0	2	3	1
# of Parts	13.6	3	2	1
Cost to MFG	12.5	2	1	3
Strength	10	1	3	2
# of Welds	8	2	3	1
# of Cuts	6.9	3	2	1
Total	100	1.76	1.86	2.05

MATERIAL SELECTION

The material selection for the chassis was based off the fabrication time, cost to manufacture, and the number of different parts. In a meeting with professional engineers at ITE, box tubing was suggested. Box tubing is readily available worldwide, cheap in cost, provides great strength, and is lightweight. The material, 1.5in x 1.5in x 0.120in(wall) A36 Carbon HR Structural Steel box tubing was picked and used throughout the entire BUV.

Carbon Alloy Steel was used for the front clip. Standard sheet metal was used in the front clip design as well. The sizes included 1/8in and 1/ 4in sheet metal. The sheet metal was used for the floor board for the driver; also to support the battery, gages, and ignition switch. Gussets, tabs, and strips were cut from 1/4in sheet metal. Gussets were needed around the roll-cage for additional support in each of the four corners. Tabs were needed for removable members that support the driver's seat for ease of maintenance to the engine. The removable members support the driver's seat in the middle of the driver seating apparatus.

Zinc coated 3/8 - 16in bolts, nuts, and washers were also needed for the front clip of the chassis. The sizes varied from 2.5in for the seat tabs up to 8in for the battery. The diameter, 3/8, bolt was another material used throughout the entire BUV as well. Only 15 bolts were necessary for the front clip of the chassis. The removable members for the seat required 8 bolts for ease of maintenance on the engine.

Plastic 11in zip ties, foam padding, and bump caps also were used for safety. The bump caps were installed in the open ends of the tubing to avoid sharp corners. Zip ties were used to hold the foam padding all around the driver seating apparatus to prevent exposed hard surfaces.

COMPONENT SELECTION

The major component for the chassis section is the rear clip. The rear clip is from a 1999 Ford Ranger pickup truck. The component was selected from a junkyard and donated for free to the team. The rear clip was cut in half with an oxycetalyne torch. Figure 11 is a picture of the rear clip in detail. The spare tire, gas tank, muffler, differential, shocks, and wiring were all removed from the rear clip. Then the frame was pressure washed clean and sharp corners were all ground down. Figure 12 shows the truck frame with everything removed and cleaned up.

Figure 11 –Full Rear Clip

Figure 12 – Cleaned Rear Clip

Another component was a recycled riding lawnmower. The lawnmower was donated for free. The driver's seat, mounting brackets, seat springs, and gear shifter were all utilized. The mounting brackets were cut and bent to fit around the center members of the driver seating apparatus. The mounting brackets were given additional support to avoid buckling. The mounting brackets were made from small gage sheet metal. Support was from 1/4in sheet metal that was used in the material selection. The gear shifter was cut to length and topped with a recycled shift knob. The gear shifter was mounted on the left-hand side of the driver seat.

LOADING CONDITIONS

The front clip of the chassis was analyzed and designed for impact loading conditions. This is necessary because the BUV must be capable traveling through rugged terrain. The force is calculated by adding the gross vehicle weight plus the maximum payload while braking going down a 20% slope. The maximum force calculated was 2500lbs. The moment was distributed between the two members supporting the front clip of the chassis. The two members are shown in the bottom view of Figure 13 on page 11. Each member analyzed had a moment of 1875in*lbs. The section modulus was needed to find the maximum stress at the outer surfaces. The section modulus was $2.91x10^{-4}in^3$. The calculated maximum stress was 6438psi. Yield strength of structural steel is 36,000 psi. The safety factor was 5.59. The safety factor did meet impact loading conditions according to the Engineering Design textbook. The K and Q values were needed to find the torsional shear stress and torsional deformation. The calculated torsional shear stress was 3964psi. The shear stress and the deformation were reduced by utilizing box tubing. When finding the deformation, the length of 7in is used because that is the longest member without support. The longest unsupported member is calculated by subtracting the overall length of the front clip from the overall length of the roll-cage.

$$F = 2500lbs$$

$$a = 1.5in$$

$$M = F * a = 3750in*lbs$$

$$M = \frac{3750}{2_{members}} = 1875in*lbs$$

$$S_y = 36{,}000psi$$

$$S = 2.91x10^{-4}in^3$$

$$\sigma_{\max} = \frac{M}{S} = \frac{1875}{0.29123} = 6438.21psi$$

$$N = \frac{36{,}000psi}{6438.21psi} = 5.59$$

$$K = 0.325$$

$$Q = 0.473$$

$$\tau_{\max} = \frac{1875in*lbs}{0.473} = 3964.06psi$$

$$\vartheta = \frac{(1875in*lbs)*7in}{(30*10^6)(0.325)} = 0.0013°$$

DRAWINGS

Figure 13 is a detailed layout drawing of the front clip. The overall length is 4ft. The height is 6.38in. The width is 32.86in. The width was the most critical dimension to designing the front clip because it had to fit inside the rear clip of the truck frame. Also, the frame had to accommodate a front suspension as well. This was done by keeping a 7in wide nose on the front clip. Two members were needed up front to fit the 65° and 25° angles. Plus this allowed for more bracing to prevent deformation. In the side view, the 21in requirement of clearance was needed to house the engine cradle for the drive train as well.

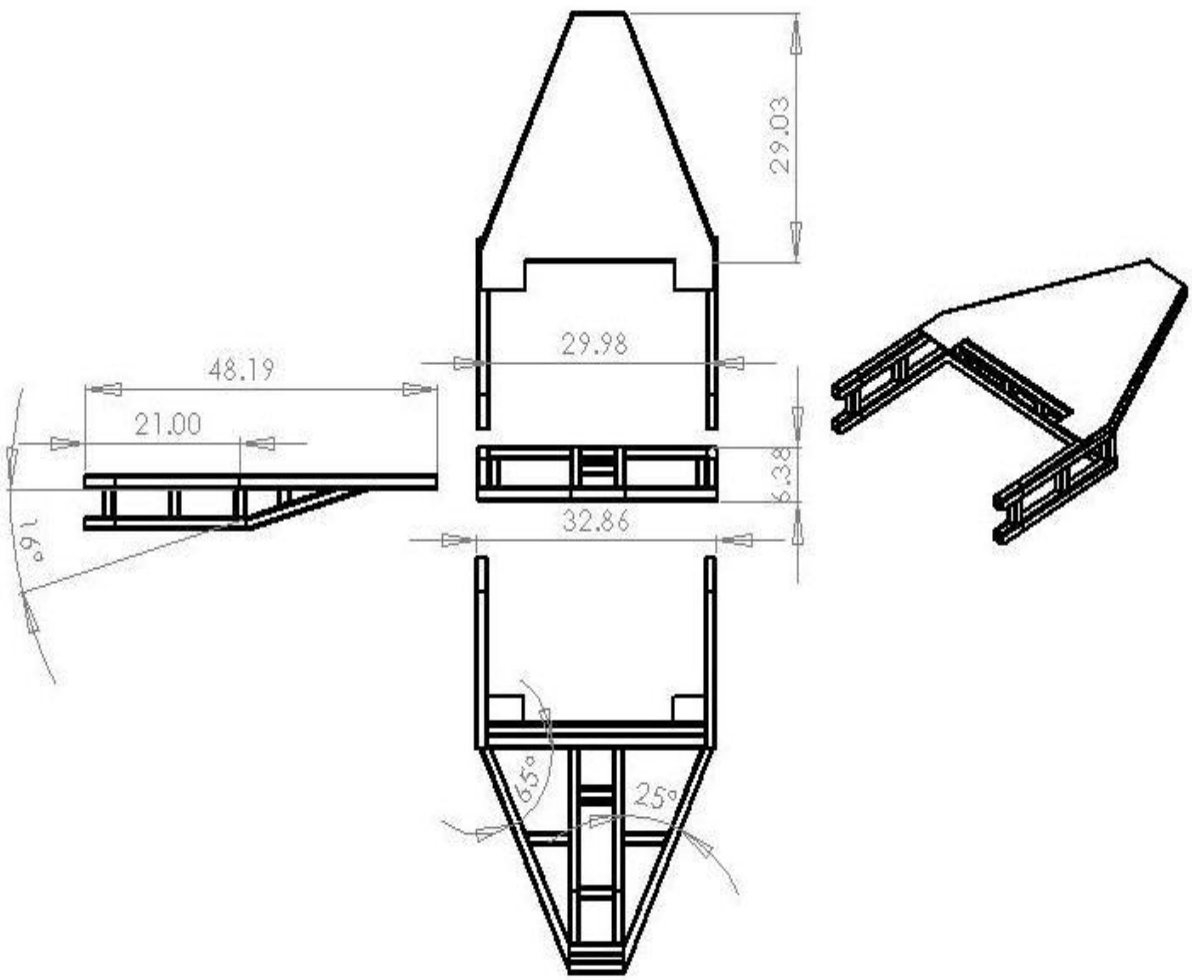

Figure 13 – Detailed Layout of Front Clip

The front clip of the chassis also included the driver seating apparatus and roll-cage. Figure 14 is a detailed layout of the roll-cage and driver seating apparatus. The length is 37.22in. The height is 53.5in. The width is 33.36in. The roll-cage was supported with gussets in all four corners as well as below. The two angle members were needed to house the brakes and provide support to vertical forces from the front suspension. The two center members of the seating apparatus are fully removable. This is needed to meet the customer requirement for ease of maintenance. Having two center members fully removable, allows the engine to be easily accessible for removal or repair. Also, on the top of the roll-cage is the support for the solar panel.

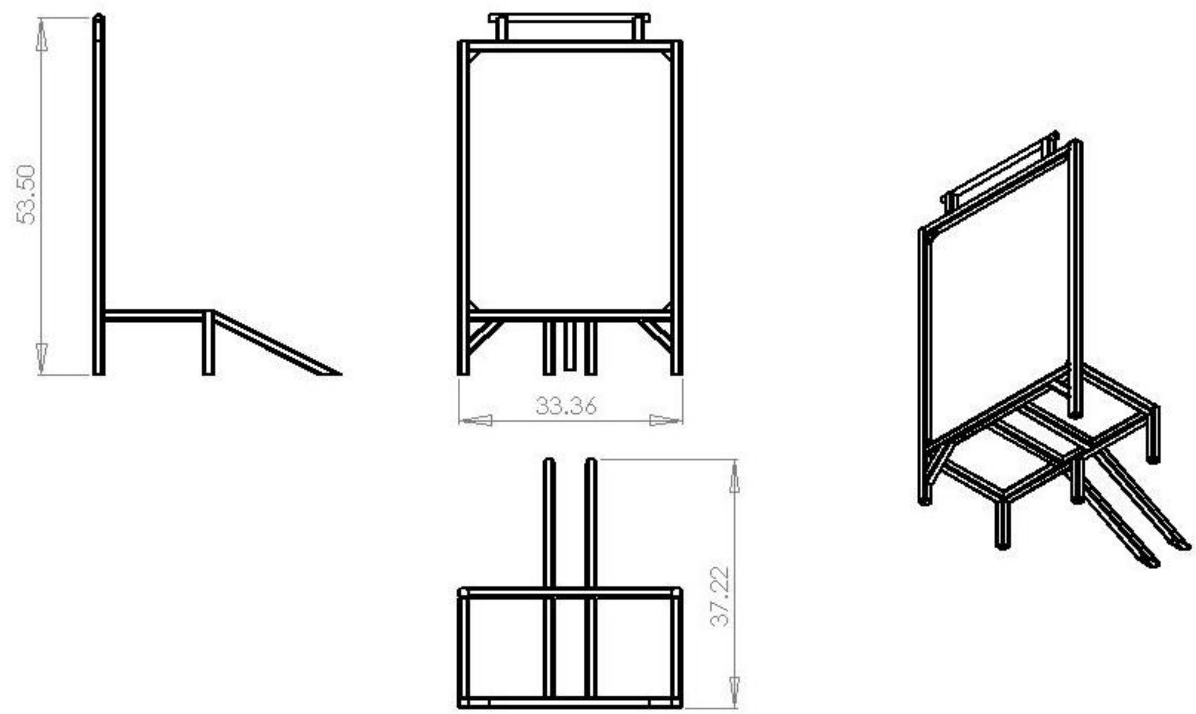

Figure 14 – Detailed Layout of Roll Cage/Driver Seating Apparatus

DESIGN ANALYSIS

There were a few factors of safety included in the front chassis section. The chassis is designed to support 1000lb gross vehicle weight. Under maximum loading conditions, the BUV will carry a payload of 1200lbs. That means each wheel will be subjected to a force over 700lbs. The majority of the load will be supported by the rear clip of the chassis. Figure 15 is a Finite Analysis on the Von Mises stress under dynamic loading conditions. The front clip was analyzed under the maximum loading conditions. The force was calculated to be 2500lbs under braking conditions going downhill on a 20% slope. The stress was calculated and checked in the Finite Analysis program to locate the highest stress area. The highest stress was located on the angled members that support the bottom of the front clip.

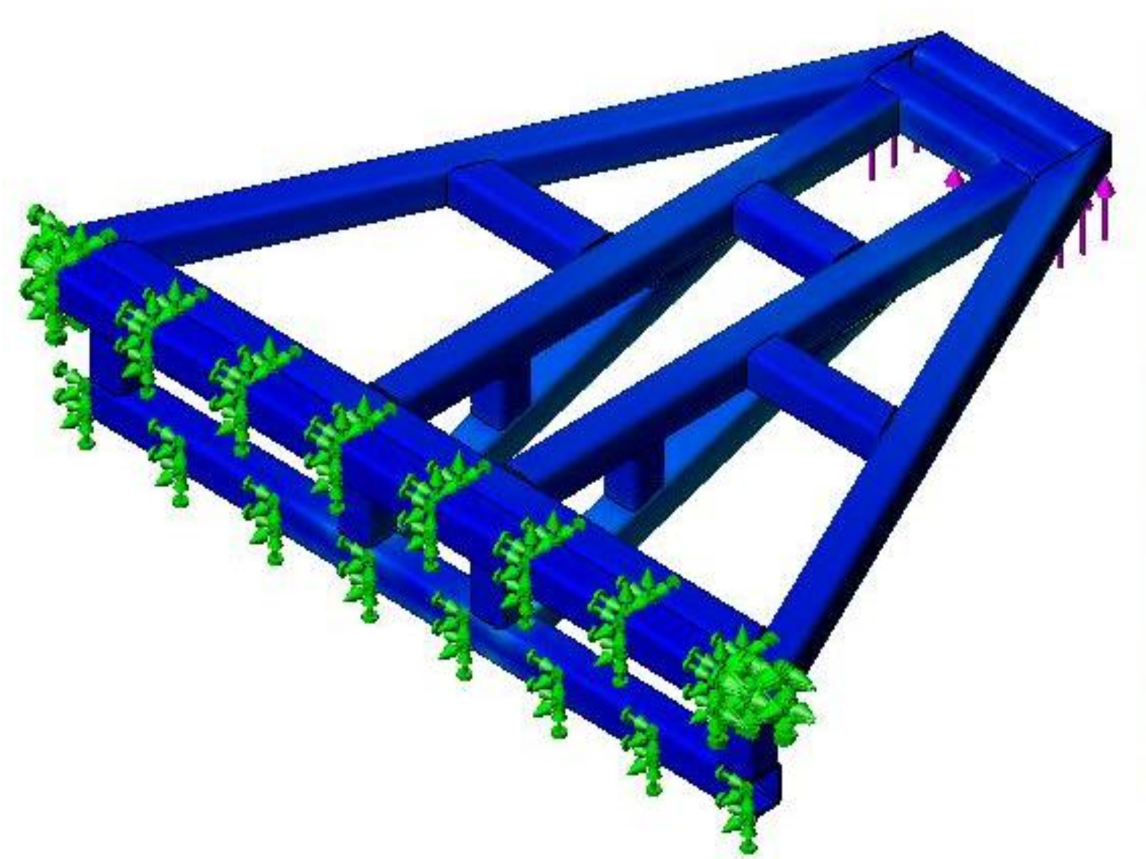

Figure 15 – FEA Von Mises Dynamic Stress Analysis

The dynamic displacement for the front clip is Figure 16. The displacement was calculated less than 0.25 inches. The displacement was keep to a minimum to reduce flexure and fatigue under impact loading conditions. The area of the highest displacement under maximum loading conditions was located on the members that make up the nose. This is where the front suspension is attached to the front clip.

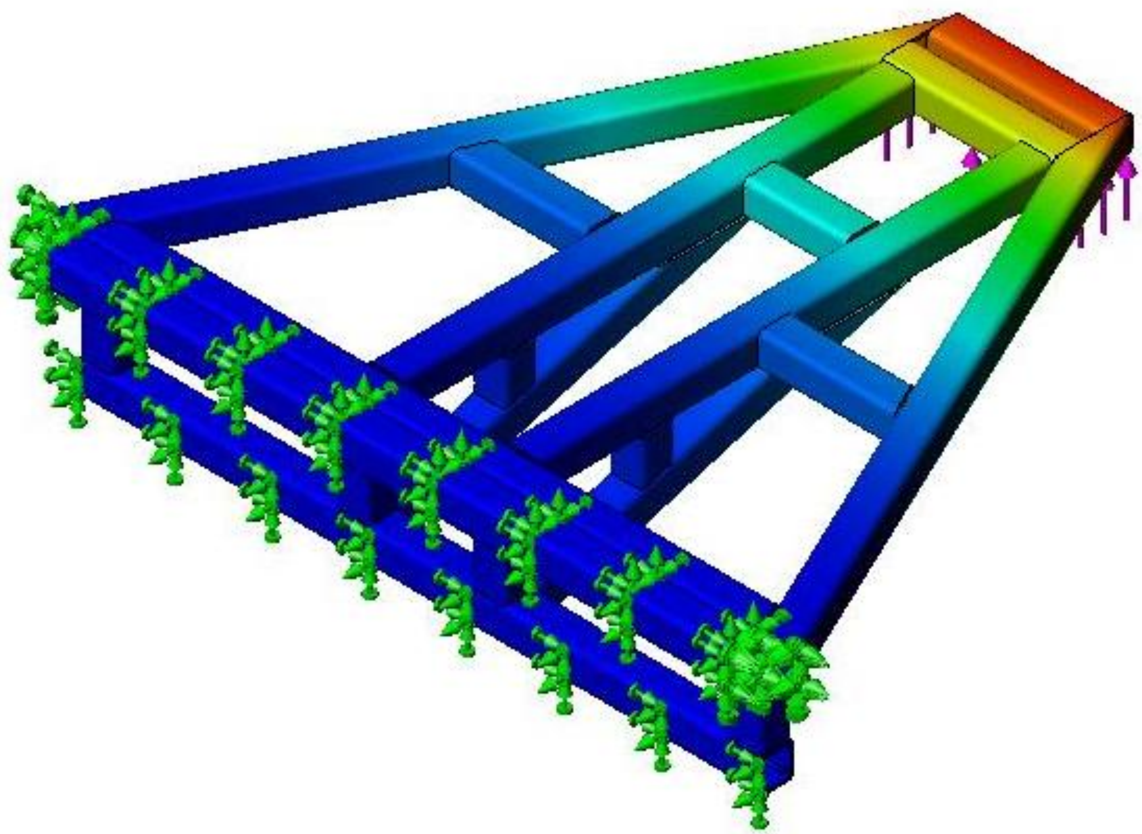

Figure 16 – FEA Dynamic Displacement Analysis

To find the members that would fail under a safety factor of 5.6, a Finite Analysis was performed. Figure 17 is a Finite Analysis under maximum dynamic loading conditions. Again, the member to fail first was the angled members that support the bottom of the front clip. This is due to the direction of the force being applied. The force is being applied upward from the front tire.

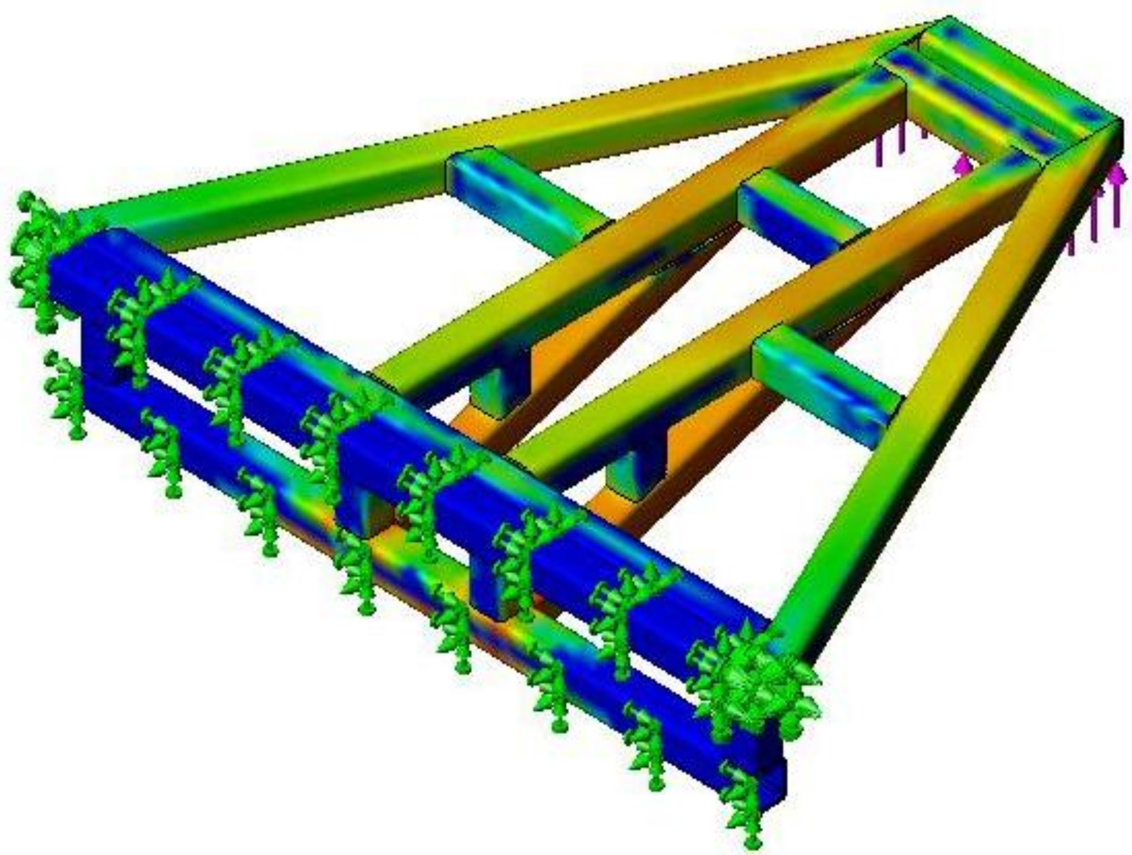

Figure 17 – Factor of Safety in Dynamic Loading Condition

PRODUCT OBJECTIVES

PRODUCT OBJECTIVES

According to the IAT, the goal of the BUV is to provide a low cost school bus for nine children in Africa. The vehicle must include a front unit, rear clip, drivable chassis, and school bus body with cargo bed. The front frame must be interchangeable to accommodate a rear clip from a Chevy S-10, GMC S-15, Nissan, or Toyota pickup cut near the cab/bed interface. The front clip consists of a motorcycle seating arrangement. The frame/chassis of our BUV can be divided into the following three subdivisions: size, performance, and safety.

Table 4 includes the complete list for product objectives, methods of testing, and final results for the chassis section. All the product objectives listed for the each subdivision were incorporated into conceptual design. Appendix F also provides a full features list developed from the customer survey and the IAT specifications.

Table 4 – Product Objectives

	Product Objectives	Methods of Testing	Final Results
Size	<12.5ft overall length	Measure with a tape measure	12ft overall length
	>10.5in ground clearance	Measure with a tape measure	13in ground clearance
	15in fording ability	Test drive through water	No water crossing event scheduled in competition
Performance	Load capacity of 1200lbs	Measure sand bags and test on closed course over a measured distance	Passed judges drive and endurance run fully loaded
	1000lb gross vehicle weight	Pallet or Skid Scale	1150lb gross vehicle weight
	Climbed 20% incline fully loaded	Test on a closed course over a measured distance	Climbed slope >20% at competition
Safety	Safe egress/ingress	No sharp corners or edges Padding and step holes	Installed bump caps, padding, and step holes for driver apparatus
	Anti – roll bar to prevent rotation at 1/4 roll	Simulated Solid Woks test on final detailed assembly model	Did prevent rotation at ¼ roll

All the product objectives were measured, tested, and checked before and during the IAT competition. The only final result that did not meet the product objective is the gross vehicle weight. To measure 1000lb gross vehicle weight the entire BUV was placed on a skid scale. The gross vehicle weight was only 150lbs over the recommended 1000lb total; which was close enough to still compete well in the competition. Other important product objectives such as: <12.5ft overall length and >10.5in ground clearance were measured with a tape measure. The 1200lb load capacity was measured with sand bags before and at the competition.

ASSEMBLY

COMPONENT MANUFACTURING

The component manufacturing first started with the ordering of the A36 Carbon HR box tube, and 1020 1/8in and 1/4in sheet metal. The box tube steel was then cut into the necessary pieces using a horizontal and vertical band saw. The horizontal mill saw was used to cut pieces between 0 and 45 degrees. The pieces that required angles greater than 45 degrees were cut on the vertical band saw. After all the pieces were cut to appropriate lengths, they were dry-fit to make sure that the cuts were correct and straight. Some pieces were too small to be supported in a fixture or clamped so they were cut using an electric cut-off wheel.

The sheet metal used on the front clip was plasma cut in to the desired shape. Figure 18 is a picture of the plasma cutting process used to cut the floor board. The angles on the outside were cut first. A fence was used for a jig to make the cut as straight as possible. The fence was clamped down and insulated with wood.

Figure 18 – Plasma Torch Cutting Process

Sheet metal required for the tabs holding the middle members supporting the driver seat were cut using a hydraulic press. The same process was also used for the gussets supporting the roll-cage as well. The hydraulic press was used to cut the sheet metal strips evenly and quickly. The tabs were cut to strip length. The gussets were cut at 45 degree angles to fit the corners of the roll-cage.

Drilling process was also required to fit 3/8in bolts. Drill presses and hand drills were used for all the drilling processes. Holes were drilled through the middle members supporting the driver seat, as well as sheet metal to support the battery. Also both sides were drilled in the tabs supporting the center members holding the driver seat.

Deburring was also required on each piece cut. Deburring was necessary to remove any sharp edges and burrs left after the cutting processes. The deburring processes were done by vertical sander, sanding wheel, and grinding wheels.

The finishing process was done by wire wheels and files. The finishing process was needed to clean any debris, rust, burrs, and welds to prep for painting. The entire chassis including the roll-cage and driver seating apparatus were all finished to a smooth surface ready for paint.

FINAL ASSEMBLY

The final assembly was done in five major steps. The steps included outsourcing the front clip to be welded together, attaching the front and rear clip together, and fastener securing, finishing, and painting. The front clip was outsourced to a professional welder for accurate dimensional tolerances. The critical dimensions of the front clip were the width, length and correct angles. First the ladder type framing was made then the angle pieces were welded in place. The width was the most important dimension because the front clip needed to fit inside the rear clip. If the width was too big, the front clip would not fit inside the truck frame. If the width was too small, the front clip would have slack and not seat properly inside the truck frame.

The sub-assembly was returned and dry-fit to the rear clip ensuring proper dimensional accuracy. Then measurements were taken to locate the front clip. Measurements were taken to accommodate the engine cradle sub-assembly for the drive train as well. The engine cradle was designed to be attached to the frame of the front clip by welding. The engine cradle and front clip were tacked together using a MIG welder and double checked for dimensional accuracy. After all the appropriate dimensions were checked the front clip and the engine cradle were welded to the rear clip of the chassis. The assembly was welded in house with a standard automatic feed welder to reduce cost.

Once the front clip was welded in place, the roll-cage was mocked up for assembly. The skeleton of the roll-cage was all tacked in place before finally being welded. After all the appropriate members were tacked in place, each member was welded together. The angled members were dry-fit and welded in place to the front clip. The last part of the assembly was welding the gussets in place around the roll-cage. Each gusset was dry-fit, tacked in place, and welded. Figure 19 is a picture of the welding assembly process for the roll-cage.

Figure 19 – Welding Assembly Process

The fastener assembly process was required for the installation of the driver seat and the battery. Bolt size 3/8 – 16in were used ranging in length from 2.5in to 8in. The 2.5in bolts were used for securing the tabs to the middle members for the driver seat. The 8in bolts were used for securing the battery in place. Simple hand tools such as ratchet and sockets, and hex wrenches were used for fastening the bolts to the frame.

The finishing assembly process was to clean up any splatter, rust, sharp corners, and debris over the entire chassis. The finishing process was done with wire brushes, wire wheels, files, and sand paper. After the chassis was finished, it could be painted.

The last assembly process was to paint the entire chassis. The paint used was Rust-Nox to prevent corrosion on the raw steel. The BUV was expected to perform in off-road conditions that will be traveling in sand, water, mud, and heavy brush. Rust-Nox paint was used because the paint is commonly used for under coating on heavy equipment and production vehicles.

MANAGEMENT

BUDGET

The front clip estimated cost is $985 as represented in Table 5. Majority of the budget for the chassis section is in the front clip, rear clip, and the welding costs. Although the budget only includes materials to build the chassis, there are labor costs which are covered in the additional costs. The detailed list for the complete BUV can be found in Appendix G.

Table 5 – Chassis Budget

Chassis Break Down	
Front Clip Frame	$300
Floor Board – Front Clip	$125
Hardware	$20
Welding	$200
Paint	$25
Rear Clip Frame	$150
Additional Cost (20% of total)	$165
Chassis Subtotal	**$985**

BILL OF MATERIAL

Table 6 – Chassis BOM

MANUFACTURED COMPONENTS

PART #	PART DESCRIPTION	MATERIAL	MATERIAL DESCRIPTION	TOTAL
BUV-FF-131	Front Frame Steel Plate	0.125" Thick Plate	10" x 18"	$ -
BUV-RC-101	Front Frame Box Tubing	1.5" Square Steel Tubing x 0.125" Wall	50" Length	$ 4.20
BUV-RC-108	Roll Cage Gusset	0.25" Thick Plate	1.5" x 1.5"	$ -
BUV-RF-002	Rear Chassis Clip Assembly	Formed Channel Sheet Metal	99 Ford Ranger Truck Clip	$ 150.00
				$ 262.59
				0

PURCHASED COMPONENTS

PART #	PART DESCRIPTION	MANUFACTURER MODEL #	MANUFACTURER	TOTAL
BUV-F-201	Rustnox Black Gal	KENTRA431	Cincinnat Color Company, Inc.	$ 39.90
BUV-F-202	Enamelex Yellow Gal	KENTR1831	Cincinnat Color Company, Inc.	$ 28.95
BUV-F-203	Paint Thinner Qts.	REC83-321	Cincinnat Color Company, Inc.	$ 2.98
BUV-F-204	Welded Chassis Assembly	BUV-FF-001		$ 443.00
				$ 691.49
				$ 691.49

The bill of material for the front clip is shown in Table 6. The bill of material is a listing of the components required to manufacture the desired assembly. For the front clip, there are approximately 40 individual manufactured parts in the construction. Majority of the cost was to pay for the box tubing and the cost of outsourced welding.

When comparing the estimated cost for the budget and the final bill of materials the difference was $293.51. The reduced cost for material was due to the use of box tubing utilized in the chassis and throughout the entire BUV. Also, the rear clip was donated by Nick's Towing to reduce the cost by $150.00. The most expensive part of the front clip was the bill for professional welding. The estimated cost was only $200.00 but the actual cost was $443.00. In the budget a large amount was determined for the floor board. The floor board was priced out for diamond plate steel. The floor board was reduced in cost by using standard sheet metal. Other costs such as zip-ties, foam padding, stickers, reflectors, and various nuts and bolts are shown more in detail in Appendix G.

SCHEDULE

The schedule was created by the entire BUV team to collaborate and combine sub-assemblies and design concepts. A detailed schedule can be found in Appendix H. The important dates and scheduled tasks are listed in Table 7. Actual dates for the BUV preliminary design, ordering components, and the final test of the BUV were all accomplished on time or before the proposed dates. On the other hand, choosing the best concept, design freeze, fabrication, and assembly were not accomplished on time or before the proposed dates. This was mainly due to the fact the rear clip differential was removed and the Tuff-Torq transaxle was utilized. Due to the weathered condition of the differential and because the transaxle was donated by IAT the BUV team decided to remove the stock differential and install the transaxle. As a result, the assembly did take longer than expected, which also pushed back the preliminary test.

Table 7 – Student Schedule

Scheduled Task	Proposed	Actual
Choose Best Concept	12/9/2007	12/22/2007
BUV Preliminary Design	12/9 - 1/13	1/10/2007
Design Freeze	1/13/2008	1/14/2008
Order Components	1/28/2008	1/28/2008
Component Fabrication	1/28 - 3/16	3/21/2008
BUV Assembly	3/17 - 3/30	4/7/2008
Preliminary Test	3/31/2008	4/7/2008
Final BUV Test	4/07 - 4/17	4/14/2008
BUV Competition	4/18/2008	4/18/2008
CAS Tech Expo	5/22/2008	5/22/2008
Final Report Due	6/06/2008	6/09/2008

CONCLUSION

SUMMARY

The chassis section of the BUV does provide all the necessary requirements and features determined by the customers and the IAT. The front clip of the chassis is made primarily of 1.5in x 1.5in x 0.120in(wall) box tubing. The box tubing was chosen because it could be used throughout the entire BUV. The box tubing is lightweight, easy to manufacture, and readily available in many countries across the world. Once the front clip was completely assembled, the unit was attached to the rear clip to create a rolling chassis.

The front clip is designed to withstand a dynamic loading of 2500lbs going downhill on the brakes fully loaded. The safety factor of 5.6 is enough for the chassis to provide the necessary support required for all applications of off-road driving specified by the IAT.

The cost of the front clip is reduced by using one common part throughout the entire design. This ultimately reduces manufacturing cost, fabrication time, and number of parts. According to the product objectives, the front clip of the chassis will meet the size, safety, and performance requirements as well.

Recommendations such as shorter overall length, grab-handles on the roll-cage, fully detachable front clip, and driver seat-belt. Reducing the overall length of the front clip can reduce weight, costs, and time to manufacture. The reduced length also reduces the amount of material needed as well. Grab-handles on the roll-cage would be useful for driver egress/ingress. Plus the grab handles can be used for additional passengers. The ladder-type frame provides foot holes and grab handles that would provide a place to hold on to when traversing though rough terrain. Also a fully detachable front clip would be desirable for shipping purposes. Being able to have a fully removable front clip could allow for quick change-over's, easy repairs, and reduced time for assembly. A driver seat-belt would be a final recommendation. The driver seat-belt is debatable for many reasons but would allow the driver the option to wear a seat-belt if necessary.

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APPENDIX A DESIGN SPECIFICATIONS

PROJECT DESIGN SPECIFICATIONS

BUV School Bus for Africa

www.driveBUV.org

Basic Utility Vehicles for Developing Countries

Institute for Affordable Transportation (IAT)

Challenge: Design a 3-wheel vehicle based on the rear clip of a *small* pick-up truck. Design a school bus attachment which connects to the rolling chassis. The bus is intended to serve school children and orphanages in Africa. In addition to low cost, design emphasis is on the steering and front suspension. Design for small scale assembly operations in Africa. Volume is one vehicle per day. Minimize factory investment.

Photo is for reference only…these vehicles do not meet this design specification

SYSTEM REQUIREMENTS

Front Unit – includes front wheel, steering mechanism, front frame, driver's seat & controls, engine, transmission, PTO

Rear Clip – the rear end (i.e. the axle, suspension, wheels, frame, brakes, etc) of a Chevy S-10, GMC S-15, Nissan, or Toyota pickup cut near the cab/bed interface. Excludes the sheet metal pickup bed.

Drivable Chassis – a front unit attached to a rear clip. Ready to drive. Various bodies can be attached to the drivable chassis.

School Bus Body / Cargo Bed – a body that attaches to the drivable chassis that is multi-purpose, and can carry both cargo as well as children is a safe manner.

SPECIFICATION – DRIVABLE CHASSIS

Cost:	Not to exceed $1300 for kit (all non-truck parts). Does not include final assembly, freight, duties.
Engine / Fuel:	10 hp motor
Transmission:	Not specified. No automotive transmissions.
Seating:	Room for 9 children. Seating surface must provide a 5-7" drop for legs.
Reverse:	Provide a powered reverse (not human powered) Electric reverse is permissible.
Noise Level:	Within OSHA standards for driver, and for children.
Front Seat(s):	Motorcycle seating arrangement
Payload:	1200 lbs (includes driver). Do not count the cargo bed as part of the payload.
Top Speed:	20 mph on grass (governed)
Front Suspension:	Type not specified. Min 2" wheel travel. Do NOT use a motorcycle front suspension.
Throttle:	Mount on steering mechanism. No foot throttle.
Rear Brakes:	Use existing truck brakes with hydraulic activation via foot pedal.
Parking Brake:	Use existing truck emergency brake operable from drivers seat. Activation method not specified
Length:	<12.5 ft long overall
Ground Clearance:	> 10.5" except at differential, leaf springs, or lower shock mounts
PTO Pulley:	Disengage driveline. Power items on board or off-board vehicle.
Color theme:	School bus yellow
Children Safety	Allow safe egress/ingress. Provide grab handles, rounded edges, padding, belts, sun/rain protection
Safety Equipment:	Horn, kill switch, tow hooks (fore/aft), on-board fire extinguisher, passenger handles/ropes, "anti-roll" protection (shoulder height roll-bar helps stop vehicle rotation at ¼ roll and helps shield driver from cargo), 1 headlight, 2 tail-lights, 2 brake lights, two light reflectors per side, fenders.

PERFORMANCE REQUIREMENTS

- Capable of climbing 20% slope (fully loaded)
- Fording Ability: 15 inches of water
- Brake(s) will lock during an emergency stop (on pavement, fully loaded)
- 5 minute conversion (or less) for 2 people to convert from bus mode to cargo mode.

DESIGN OBJECTIVES

- Minimize total lifetime cost of ownership
- Utilize off-the-shelf components or recycled components where possible to minimize cost.
- Minimize the number of part numbers, and the part count to simplify purchasing, logistics, service, etc.
- Require only two people to assemble vehicle. Utilize Design For Assembly (DFA) methods
- Utilize simple, durable, low maintenance design
- Minimize center of gravity to increase stability
- Minimize number of common tools required to service / repair vehicle
- Minimize machining, welding, and fixtures for African assembly to reduce investment/skill required
- Emphasize safety in all aspects of design. Protect driver and passengers from moving parts
- Emphasize reliability and ease of service
- Gender friendly

OTHER DATA THAT JUDGES WILL COLLECT

	Number of "off-the-shelf" parts (not including fasteners)
	Number of fabricated or custom parts
	Number of fasteners used.
	Total Number of Parts
	% of fabricated parts to Total Number of Parts
	The number of different Part Numbers (i.e. 4 screws of the same type count as 1 part number),
	Number of Special Tools or fixtures used in fabrication or assembly
	Area of cargo bed (inside dimensions)
	Distance from ground to bottom of engine (inches)
	Estimated man-hours of assembly time of front kit
	Inches of weld on prototype
	Noise level (decibels). Measured at drivers head (R and L side) at full throttle. Drive by measurement at 10 ft.
	Time to convert from school mode to cargo mode
	Ability to power other devices
	Canopy
	Weight of front unit (detached from rear)
	Total weight of vehicle
	Corrosion Prevention Methods used
	Multi-purpose Service Tool. If you have designed one for your vehicle (not required), please show the judges.
	Estimate Production Cost (fully assembled)

COSTING INFORMATION

For engines, use $26 per horsepower OEM cost (i.e. 10 hp engine is $260)
For the truck rear clip – use $150 (no matter the actual cost)
For purchased parts, use 50% of retail price, for fabricated parts & painting, use industry quotes (based on monthly orders of 100 units/mo.)
Volume assumption for sourcing parts: 300 BUVs per year (roughly 1 BUV per day)
Use $1/hour labor rate. Use new equipment retail pricing on investment.

ENGINEERING REPORT

Follow your class requirements. Additionally, IAT wants a costed Bill of Material (BOM) with part number, source, weight info and a cost breakdown by system (power train, front frame, rear-clip, etc) in the report (include system weight as well). Also include a summary of the assembly process, equipment required, assembly time, and micro-factory costs. Determine labor content per unit, equipment investment required, factory layout for 4000 sq ft, and staffing for a 1 unit per day micro-factory. Predict which three parts are most likely to fail first.

COMMON ERRORS TO AVOID

Heavy and over-designed vehicles: a good target is 1000 lbs to perform well at the competition
Inappropriate Gearing: ensure that you have at least a 50:1 reduction in your powertrain in low gear
Inappropriate Tires: car tires and tires over 30" in diameter generally do not perform well in the competition.
Center of gravity: please minimize!
No sharp burrs on any surface.
Do not forget to design against mud, sand, water intrusion. If necessary, use debris guards to prevent service issues and protect vehicle.

Contact: will.austin@drivebuv.org 317-213-1088

Competition BUVs donated to IAT will be sent to humanitarian organizations in developing countries (assuming the vehicle is safe).

APPENDIX B RESEARCH

PREVIOUS COMPETITION BUV'S

 2005 Senior Project Author Scott Mcaffry Chassis and frame 10-01-07 The specifications called for the vehicle to carry a minimum of 1210 lb payload with room to carry up to 5 passengers not including the driver. The team used a 1990 Ford Ranger pick up for the rear chassis and frame. The bed was constructed from wood and mesh cargo netting. The frame and the bed cost $350.95 and the grand total of the entire project was 1664.94	Costs $1664.94 1500 lb payload 10 hp Gas engine 10.5 in of ground clearance Wood/ cargo netting for bed High number of different parts


<table>
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2005 Senior Project
Miami University
10-01-07

The specifications called for the vehicle to carry a minimum of 1210 lb payload with room to carry up to 5 passengers not including the driver. Miami University of Ohio won first place with BUV powered by a single cylinder Kohler engine.</td>
<td>Won 1st place
Lightweight
10 hp
Gas engine
Good ground clearance
Wood for bed
No mud flaps
Flexible front end
Simple rigid design
High number of different parts</td>
</tr>
</table>

SIMILAR PRODUCTS ON THE MARKET

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http://www.kawasaki.com/Products/Detail.aspx?id=170
Kawasaki Mule reviews
Kawasaki.com
10-01-07

The chassis of the Mule 3010 4x4 is a ladder-type frame that rides on a DeDion rear leaf-spring suspension designed to carry heavy loads yet provide a smooth ride when the cargo bed is empty. MacPherson struts handle front suspension duties, while rack-and-pinion steering is light and maneuverable over rough terrain. Four hydraulically operated, self-adjusting drum brakes that are sealed to protect from water, mud and other debris provide stopping power, and 23-inch tires provide a comfortable ride and maximum traction over a variety of surfaces. The Mule 3010 4x4 utility vehicle can carry 803 pounds in its steel cargo bed and can tow up to 1,200 pounds.
</td>
<td>
Costs $8799
Gasoline engine
800 lb payload
24.7 hp
Ladder type frame
4x4
</td>
</tr>
</table>

http://en.wikipedia.org/wiki/Daihatsu_Midget Wikipedia Review Wikipedia.com 12-02-07  The Daihatsu Midget is a single-seat mini-truck made by Japanese automaker Daihatsu. Several distinct vehicles have borne the Midget name over the years, but all have had in common a single-seat utilitarian design, with an enclosed or semi-enclosed cab. The original Midget was made from 1957 to 1972. It had three wheels, two in the back, and one in the front. Early versions also had motorcycle-like handlebars in place of a steering wheel. The engine was an air-cooled 2-stroke design of 305 cc which produced 12 hp (9 kW). The Midget I has also been sold outside Japan as the "Bajaj", "Tri-Mobile", or "Bemo	Costs $9899 1630 lb payload 21.6 hp Diesel or gas engine 8.3in of ground clearance 3 speed transmission Warranty

http://www.huffybikes.com/bikes/index.html Huffy Mountain Bikes Huffybikes.com 1-21-08 	Few parts Triangular structure Low cost Easy to manufacture Carry medium payloads Similar force applications to frame of a 3 wheel vehicle

http://www.sportutilitytrailers.com/LongChih/745TC-TS45S.htm**745TC-TS45S Utility Trailer** sportutilitytrailers.com 1-21-08  The utility trailer frame is constructed of 3/32" 2" W x 3" H steel U-Channel with black powder coat finish. Complete utility trailer and steel stake sides kit includes: heavy-duty leaf spring suspension, axle, hubs, wheels, tires, steel fenders, safety chain, DOT approved rear and side lighting, wiring, connectors, hardware, Certificate of Origin, Vehicle Identification Plate, slots in frame for 1 x 4 stakes, steel stake sides, removable tail gate, step-by-step assembly instructions booklet, 1-year parts replacement warranty. Assemble with socket wrenches, box end wrenches, and channel locks or pliers.	Costs $577.00 1800 lb payload 12in of ground clearance Warranty 333lbs Simple Assembly

APPENDIX C SURVEY

Basic Utility Vehicle
Product Improvement Survey

A group of students in the MET department is attempting to improve the design and usefulness of the basic utility vehicle. Please take a few minutes to fill out the customer survey and return it to the student marketer.

What terrain is primarily in the area of travel? (Circle at most 2 please)

Mud Swamp Rocky Gravel Sand

What power source is primarily available? (Circle one)

Gasoline engine Diesel engine Electric motor

Please list the common types of lumber available.

____
____
____
____

Please indicate the level of importance you attach to the following aspects of a basic utility vehicle.

	(1 = low importance				5 = high importance)
Auxiliary Lights	1	2	3	4	5
Medical Devices	1	2	3	4	5
Water Pump Attachment	1	2	3	4	5
Plow Attachment	1	2	3	4	5
Auxiliary fuel can	1	2	3	4	5
Shaded cargo bed	1	2	3	4	5
Emergency road side repair kit	1	2	3	4	5
Spare tire	1	2	3	4	5
Trailer hitch	1	2	3	4	5
Winch	1	2	3	4	5
Driver/passenger seat belt	1	2	3	4	5
Fire Extinguisher	1	2	3	4	5
First Aid Kit	1	2	3	4	5
Cargo Bed Step Ladder	1	2	3	4	5
Ability to transport fragile cargo	1	2	3	4	5
Ability to transport patients	1	2	3	4	5
Ease of Maintenance	1	2	3	4	5
Waterproof Passenger/Cargo	1	2	3	4	5
Bug Shield Passenger/Cargo	1	2	3	4	5

Please elaborate on any other suggestions.

____
____
____
____

Thank you for participating in this important basic utility vehicle evaluation survey. Your input is important and greatly appreciated.

-2008 UC CAS BUV Team – J. Brinkerhoff, M. Knapp, A. Malatesta, A. Morison

APPENDIX D SURVEY RESULTS

22 Survey Results for 2008 BUV	AVERAGE						
			Range				
mud, gravel, swamp, rocky, sand							
Gasoline engine, diesel, electric motor	gas = 17, diesel = 4		1	2	3	4	5
lumber available							
Auxiliary Lights	3.68		0.00	6.00	0.00	11.00	5.00
Medical Devices	2.86		4.00	4.00	7.00	5.00	2.00
Water Pump Attachment	2.68		4.00	6.00	7.00	3.00	2.00
Plow Attachment	2.27		9.00	5.00	3.00	3.00	2.00
Auxiliary fuel can	4.05		2.00	0.00	3.00	7.00	10.00
Shaded cargo bed	3.45		2.00	4.00	5.00	4.00	7.00
Emergency road side repair kit	4.77		0.00	0.00	2.00	1.00	19.00
Spare tire	4.86		0.00	0.00	0.00	3.00	19.00
Trailer hitch	3.18		2.00	4.00	6.00	8.00	2.00
Winch	3.14		0.00	6.00	8.00	7.00	1.00
Driver/passenger seat belt	4.05		2.00	1.00	3.00	4.00	12.00
Fire Extinguisher	3.09		2.00	6.00	6.00	4.00	4.00
First Aid Kit	3.64		1.00	2.00	7.00	6.00	6.00
Cargo Bed Step Ladder	2.73		6.00	5.00	4.00	3.00	4.00
Ability to transport fragile cargo	3.09		2.00	3.00	9.00	7.00	1.00
Ability to transport patients	3.27		1.00	6.00	4.00	8.00	3.00
Ease of Maintenance		4.64	0.00	0.00	2.00	4.00	16.00
Waterproof Passenger/Cargo		2.50	9.00	1.00	7.00	2.00	3.00
Bug Shield Passenger/Cargo		2.32	4.00	9.00	8.00	0.00	1.00

APPENDIX E QUALITY FUNCTION DEPLOYMENT

strong positive	
positive	
negative	
strong negative	
strong	9
moderate	3
weak	1

IMPT CHARACTERISTIC
LOW IMPORTANCE

		Cost of manfuacture	Power consumption	Fuel efficienty	Stength of Material	Hours of Operation before Maintenance	Hours of Operation before failure	Fabrication Time	Number of parts	Ground clearance	Number of Auxillary Components	Weight	Area covered	Time to covert cago bed	Cuustomer importance	Modify improvement ratio	Relative weight
		1	2	3	4	5	6	7	8	9	10	11	12	13			
Auxillary Lights	1		3						1		9				3.68	3.68	0.053
Medical Devices	2								1		3				2.86	2.86	0.041
Water Pump Attachment	3		1			1			1		3	1			2.68	2.68	0.039
Plow Attachment	4		3	3				9	3	1		3			2.27	2.27	0.033
Auxillary Fuel Can	5								1			1			4.05	4.05	0.058
Shaded Cargo Bed	6							3	1				9	3	3.45	3.45	0.050
EM Roadside Repair Kit	7								1						4.77	4.77	0.069
Spare Tire	8								1			1			4.86	4.86	0.070
Trailer Hitch	9				1			3		1		1			3.18	3.18	0.046
Winch	10		3					1				1			3.14	3.14	0.045
Driver/Passenger Seat Belt	11							1	1						4.05	4.05	0.058
Fire Extinguisher	12								1						3.09	3.09	0.045
First Aid Kit	13								1						3.64	3.64	0.053
Cargo Bed Step Ladder	14							1	1						2.73	2.73	0.039
Transport Fragile Cargo	15				1									3	3.09	3.09	0.045
Transport Patients	16				1									3	3.27	3.27	0.047
Ease of Maintenance	17						3								4.64	4.64	0.067
Waterproof passenger/cargo	18				1								1	3	2.50	2.50	0.036
Bug Shield Passenger/cargo	19								1						2.32	2.32	0.033
Cost to manufacture	20	9													5.00	5.00	0.072
Abs. importance		0.650	0.432	0.098	0.174	0.039	0.201	0.725	0.707	0.079	0.718	0.357	0.484	0.533	5.20	69.27	1.000
Rel. importance		0.125	0.083	0.019	0.033	0.007	0.039	0.140	0.136	0.015	0.138	0.069	0.093	0.103	1.000		

APPENDIX F FEATURES LIST

1. Able to travel through Mud, Water, Sand, Gravel, Dirt, Blacktop
2. Top speed 20mph
3. External equipment includes lights, horn, kill switch, tow hooks, with the possibility of medical devices, water pump, wench, trailer hitch
4. Incorporated alternative energy resources
5. Ability to transport passengers(up to 9), patients, food, building supplies
6. 1200 lb minimum payload
7. Safety Features include seat belts for the driver/passengers, grab handles, rounded edges, padding, roll bar, first aid kit, fire extinguisher
8. Material availability includes car parts, tires, truck beds, lumber, belts, chains, oil
9. Forward and reverse geared transmission
10. Manual or automatic transmission
11. Ease of maintenance
12. Noise level within OSHA standards
13. Steering mounted throttle
14. Greater than or equal to 10.5” of ground clearance
15. Less than 12.5’ overall
16. Capable of climbing 20% slope when fully loaded
17. Fording ability through 15” of standing water
18. 3 wheel vehicle: all tires must be smaller than 30” dia.
19. Gross weight of unloaded vehicle of 1000lbs
20. 10 hp Briggs and Stratton engine

APPENDIX G CHASSIS BUDGET AND BOM

2008 UC BUV Team
BUV Budget
J. Brinkerhoff, M. Knapp, A. Malatesta, and A. Morison

BUV Sub-Assemblies	**PRICE**
1. Drive Train Total	$1,470
2. Front Unit/Suspension	$1,320
3. Rear Clip/Chassis	$985
4. Cargo-Passenger Bed/Electrical	$765
TOTAL	**$4,540**

Andrew Malatesta
1. Drive Train Break Down

COMPONENT	**PRICE**
Engine	
Transmission	FREE
Belts/Chains/Driveshaft	$350
Pulleys/Sprockets	$100
Clutch	$50
Mounts	$200
Bearings	$80
Shift Linkage	$50
Throttle	$70
Motor Starter	$120
Bolts	$150
Shaft	$10
Additional Cost (20% of total)	$50
	$240
Drive Train Subtotal	
	$1,470

Andrew Morison
2. Suspension Break Down

Steel Tubing	
Bushings	$200
Shocks	$6
Steering Head Bearings	$300
Steel Plate	$20
	$100

2. Suspension Cont'd
COMPONENT

Handlebars	$20
Front Rim	$150
Front Tire	$70
Front Brakes	$100
Axle	$15
Bolts	$25
Seat	$30
Leaf Springs	$60
Additional Cost (20% of total)	$220
Suspension Subtotal	$1,320

Marcus Knapp
3. Chassis Break Down

Front Clip Frame	**$300**
Floor Board – Front Clip	**$125**
Hardware	**$20**
Welding	**$200**
Paint	**$25**
Rear Clip Frame	**$150**
Additional Cost (20% of total)	**$165**
Chassis Subtotal	**$985**

Josiah Brinkerhoff

4. Cargo-Passenger Bed/Electrical

Roll Bar	$40
2”x4”	$80
Plywood	$40
Hardware	$30
Hinges	$40
Cargo Netting	$80
Limit Switch	$30
Wire	$15
Hardware (Electrical)	$20
Solar Panels	$150
Charge Controller	$60
Deep Cell Battery	$50

Cargo-Passenger Bed/Electrical

Cont’d

COMPONENT

Additional Cost (20% of total)	$130
Mod. Cargo Bed/Electrical Subtotal	$765

CHASSIS BILL OF MATERIALS

MANUFACTURED COMPONENTS

PART #	PART DESCRIPTION	MATERIAL	MATERIAL DESCRIPTION	COST / UNIT	QUANTITY	TOTAL
BUV-FF-001	Front Chassis Clip Assembly	Steel Plate and Square Tubing				
BUV-FF-101	Front Frame Box Tubing	1.5" Square Steel Tubing x 0.125" Wall	22" Length	$ 1.20	2	$ 4.40
BUV-FF-104	Front Frame Box Tubing	1.5" Square Steel Tubing x 0.125" Wall	3.25" Length	$ 1.20	10	$ 3.25
BUV-FF-105	Front Frame Box Tubing	1.5" Square Steel Tubing x 0.125" Wall	18" Length	$ 1.20	2	$ 3.60
BUV-FF-107	Front Frame Box Tubing	1.5" Square Steel Tubing x 0.125" Wall	30" Length	$ 1.20	2	$ 6.00
BUV-FF-108	Front Frame Box Tubing	1.5" Square Steel Tubing x 0.125" Wall	30" Length	$ 1.20	2	$ 6.00
BUV-FF-110	Front Frame Box Tubing	1.5" Square Steel Tubing x 0.125" Wall	7.5" Length	$ 1.20	2	$ 1.50
BUV-FF-112	Front Frame Box Tubing	1.5" Square Steel Tubing x 0.125" Wall	22.5" Length	$ 1.20	2	$ 4.50
BUV-FF-115	Front Frame Box Tubing	1.5" Square Steel Tubing x 0.125" Wall	4.5" Length	$ 1.20	3	$ 2.70
BUV-FF-116	Front Frame Box Tubing	1.5" Square Steel Tubing x 0.125" Wall	30" Length	$ 1.20	1	$ 3.00
BUV-FF-119	Front Frame Box Tubing	1.5" Square Steel Tubing x 0.125" Wall	6" Length	$ 1.20	2	$ 1.20
BUV-FF-121	Front Frame Box Tubing	1.5" Square Steel Tubing x 0.125" Wall	2" Length	$ 1.20	2	$ 0.40
BUV-FF-125	Front Frame Box Tubing	1.5" Square Steel Tubing x 0.125" Wall	21" Length	$ 1.20	2	$ 4.20
BUV-FF-128	Front Frame Steel Plate	0.125" Thick Plate	32" x 32"	$ 47.84	1	$ 47.84
BUV-FF-130	Front Frame Steel Plate	0.125" Thick Plate	7" x 11"	$ -	1	$ -
BUV-FF-131	Front Frame Steel Plate	0.125" Thick Plate	10" x 18"	$ -	1	$ -
BUV-RC-101	Front Frame Box Tubing	1.5" Square Steel Tubing x 0.125" Wall	50" Length	$ 1.20	2	$ 4.20
BUV-RC-102	Front Frame Box Tubing	1.5" Square Steel Tubing x 0.125" Wall	30" Length	$ 1.20	3	$ 3.60
BUV-RC-103	Front Frame Box Tubing	1.5" Square Steel Tubing x 0.125" Wall	11" Length	$ 1.20	4	$ 4.20
BUV-RC-104	Front Frame Box Tubing	1.5" Square Steel Tubing x 0.125" Wall	9" Length	$ 1.20	2	$ 2.40
BUV-RC-105	Front Frame Box Tubing	1.5" Square Steel Tubing x 0.125" Wall	22" Length	$ 1.20	2	$ 4.20
BUV-RC-106	Front Frame Box Tubing	1.5" Square Steel Tubing x 0.125" Wall	7.5" Length	$ 1.20	1	$ 1.20
BUV-RC-107	Front Frame Box Tubing	1.5" Square Steel Tubing x 0.125" Wall	5" Length	$ 1.20	2	$ 4.20
BUV-RC-108	Roll Cage Gusset	0.25" Thick Plate	1.5" x 1.5"	$ -	4	$ -
BUV-RC-109	Seat Support	0.25" Thick Plate	2" x 1"	$ -	4	$ -
BUV-RC-110	Seat Support	0.25" Thick Plate	1.5" x 4"	$ -	2	$ -
BUV-RF-002	Rear Chassis Clip Assembly	Formed Channel Sheet Metal	99 Ford Ranger Truck Clip	$ 150.00	1	$ 150.00

MANUFACTURED COMPONENTS TOTAL COST: $ 262.59

PURCHASED COMPONENTS

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PART #	PART DESCRIPTION	MANUFACTURER MODEL #	MANUFACTURER	COST / UNIT	QUANTITY	TOTAL
BUV-F-201	Rustnox Black Gal	KENTRA431	Cincinnat Color Company, Inc.	$ 19.95	2	$ 39.90
BUV-F-202	Enamelex Yellow Gal	KENTR1831	Cincinnat Color Company, Inc.	$ 28.95	1	$ 28.95
BUV-F-203	Paint Thinner Qts.	REC83-321	Cincinnat Color Company, Inc.	$ 2.98	1	$ 2.98
BUV-F-205	Hard ware	N/A	Lowes	N/A	N/A	$ 59.60
BUV-F-206	Hard ware	N/A	Ace Hardware	N/A	N/A	$ 16.68
BUV-F-207	Hard ware	N/A	Ace Hardware	N/A	N/A	$ 3.88
BUV-F-208	Hard ware	N/A	Lowes	N/A	N/A	$ 7.57
BUV-F-209	Hard ware	N/A	Lowes	N/A	N/A	$ 3.83
BUV-F-210	Hard ware	N/A	Lowes	N/A	N/A	$ 42.10
BUV-F-211	Hard ware	N/A	Lowes	N/A	N/A	$ 43.00
BUV-F-204	Welded Chassis Assembly	BUV-FF-001		$ 443.00	1	$ 443.00

MANUFACTURED COMPONENTS TOTAL COST: $ 691.49

TOTAL FRAME COST: $ 691.49

APPENDIX H STUDENT SCHEUDLE

2008 BUV SCHEDULE MARCUS KNAPP

DATE (begins every Monday)	10/22 - 10/28	10/29 - 11/04	11/05 - 11/11	11/12 - 11/18	11/19 - 11/25	11/26 - 12/02	12/03 - 12/09	12/10 - 12/16	12/17 - 12/23	12/24 - 12/30	12/31 - 1/06	1/07 - 1/13	1/14 - 1/20	1/21 - 1/27	1/28 - 2/03	2/04 - 2/10	2/11 - 2/17	2/18 - 2/24	2/25 - 3/03	3/03 - 3/09	3/10 - 3/16	3/17 - 3/23	3/24 - 3/30	3/31 - 4/06	4/07 - 4/13	4/14 - 4/20	4/21 - 4/27	4/28 - 5/04	5/05 - 5/11	5/12 - 5/18	5/19 - 5/25	5/26 - 6/01	6/02 - 6/08
TASK																																	
Schedule	23																																
Total BUV Budget (1-4):	23																																
1. Drivetrain	23																																
2. Suspension	23																																
3. Chassis	23																																
4. Electrical/Bed	23																																
Administer Survey	23																																
Proof Of Design Contract(1-4)																																	
1. Drivetrain		29																															
2. Suspension		29																															
3. Chassis		29																															
4. Electrical/Bed		29																															
Compile Survey/Create QFD				12																													
Concept Development																																	
1. Drivetrain					25																												
2. Suspension					25																												
3. Chassis					25																												
4. Electrical/Bed					25																												
Choose Best Concept						2																											
Preliminary Design												7																					
Rear Half of Frame									21																								
Driver Seat Mounting									21																								
Front Half of Frame												7																					
Floor board												7																					
Long Delivery Components												13																					
Design Freeze												7																					
Final Design														27																			
BOM														27																			
Design Report																					10												
Oral Design Presentation																			25														
Order Components																	17																
Component Fabrication																					16												
Rear Half of Frame																		19															
Front Half of Frame																					12												
Floor board																					13												
Driver Seat Mounting																					14												
BUV Assembly																							30										
ASME Conference Presentation																							27										
Test BUV																								31									
BUV Modification																									12								
Final BUV Test																										16							
BUV Competition Final Report																										17							
BUV Competition																										18							
Final Design Report Revision																														13			
CAS Tech Expo																															22		
Oral Final Presentation																																27	
Final Report Due																																	6