Basic Utility Vehicle Team

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

In partial fulfillment of the
requirements for the degree of

Bachelor of Science

in Mechanical Engineering Technology

By

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April 2018

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Professor Moise Cummings

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ABSTRACT

People in developing countries require the need for water. Some people walk miles to their water source every day. This demand for water depends on reliable transportation. Will Austin founded the Institute of Affordable Transportation (IAT) which aims to address this problem. Every year they host a BUV competition. The point of this competition is to design a vehicle capable of transporting large sums of water through rough terrain and at low costs. At the competition, college students from around the Midwest showcase their design and fabricated vehicles. Graduating seniors from the University of Cincinnati get the privilege to compete and show off their designs.

This year's MET group consists of five individuals. They are Bradley Sackett, Paul Kowall, Chris Saranita, Cole Rardon and El-Hassane Kamagate. They are all responsible for the initial design and fabrication of 5 different areas. The areas we decided to split up were irrigation, chassis, brakes, suspension and the drivetrain system. This report focuses on the frame and chassis of the basic utility vehicle, written by Paul Kowall.

This report will cover the research done in order to fabricate the chassis, the design phase, the fabrication and assembly, the testing of the completed project and the project management. The research will cover other vehicles similar to BUVs and past BUVs from other schools. The design phase will cover 3 concepts and the method used to selection the most practical.

Towards the end of the competition deadline, we faced problems with our driveshaft system and we were unable to solve them before the competition. However, we still fabricated the vehicle and performed performance tests on it. Although we didn't make the competition, the experience was a learning one and one I am glad to have gone through.

PROBLEM DEFINITION AND RESEARCH

PROBLEM STATEMENT

The project is to design a Basic Utility Vehicle. A basic utility vehicle is vehicle designed to help bring aid to people and communities in third world countries without access to basic necessities such as water. The design of this vehicle needs to be as simplistic as possible while abiding by the specifications laid out by the Institution of Affordable Transportation. Some of these specifications are low cost, agile performance, 1750 lb. pay load and a 20 MPH max speed.
Each member has a main section of the vehicle they are responsible to lead as listed above. Throughout the year we will collaborate and assist each member of our group in each other's' designated responsibilities to complete this project by April 2018.

RESEARCH

Background:

Will Austin founded the Institute of Affordable Transportation in the year 2000 after he realized the quality of life was dependent on cheap transportation. A year later the first annual BUV design competition was held. (*2*)Every year people try to improve upon the winning design. The idea is to design the cheapest, lightweight and durable vehicle for transporting water and aid for impoverished countries. The IAT sets out specific specifications that are to be abided by. These specifications include speed, weight payload and more.

The success of a BUV depends on the weight of the vehicle, and the vehicles ability to hold and transport large sums of water. Because of this, the strongest, most light-weight material will be used to build the chassis and frame of this vehicle.

Current State of the Art:
Irrigation:
Background:

- Ability to gather water
- Placed on the vehicle (side or full back)
- Better to use water pump to move the water in the barrels
- Irrigation system: hosing connected to a water pump, which is also connected to the barrels

Water pumping (different types)

- Gasoline water pump
- Electric water pump

Braking System:

In today's world there are two main categories of braking systems found on vehicles. There are hydraulic breaks which stem into single and duel-circuit breaks. Antilock brakes also fall under this category. The other category would be mechanical brakes. This is the kind of brakes you would find in large vehicles such as buses or trucks. Both of these kind of breaking systems can use discs or drums to stop the vehicle but just in different ways.

Both of these ways can be useful it just depends on what application you are using it for. For our use we will not need something with extreme power but we will want something with reliability.

Through my research it seems that both a mechanical and a hydraulic could both most likely work with this application. They both have some pros cons to their designs.

Mechanical:

Pros: Easy to fix, cheaper.

Cons: Dirt can get up into the cable which could cause the system to fail.

Hydraulic:

Pros: Powerful braking, Use fluid not a cable.

Cons: Harder to fix, can be a danger if not fixed properly, more expensive.

Chassis:

There are a number of designs that could be done for the chassis of this vehicle. A 3 wheeled frame or a 4 wheeled frame is the first question. There are pros and cons of each of these. Ultimately I think a 3 wheeled vehicle is more practical for this application. A four wheeled frame does add stability but the weight will be higher and weight is crucial in designing a BUV. The winners of the 2012 BUV competition used an angle iron frame to reduce weight and ultimately increase speed. This has been the standard since.

I will get information on the best possible frame of the BUV from past projects. The 2014 BUV Team used a ladder style chassis. The 2013 team used a sleek, triangle shaped frame. This uses less material. These two frames will be the inspiration for my concepts.

Suspension:

For the BUV team the suspension system and steering will be a big part of how the vehicle will handle certain environments and be able to show the mobility of the vehicle. One of the types of the suspension systems I found is called the double A arm suspension system. It is a suspension that is used primarily in motorcycles that can be for off road and tough environment situations which would be good for places that do not have paved or establish roads. The pros to this system are that is has a lot of good suspension to travel in rough environments and conditions, has good steering, and cost effective. The cons to this are that is not entirely light weight and that it can be a more complex system to construct/ repair. Another type of suspension system is the telescoping fork Design. This type is widely used in bikes. The pros to this systems are that is a more simplistic design, is very lightweight and can have great damping effects with springs. The cons to this system are that it can be expensive.

For the types of steering wheels ,there a couple different types that can help the driver steer the vehicle better and maneuver the vehicle in the best way possible. One of the possible ideas is to use a car steering wheel. The pros of using this wheel is that it has a lot of places to grip, it is easier to turn. The cons of this are that it is a big and clunky steering wheel design and that it is pretty heavy since it is so big. Another type of steering wheel would be bike handle bars. The pros of this design are that it is lightweight and very simplistic in its design, also it is very cost effective. The cons to this are that it is harder to turn in each direction as well as a smaller turn radius.

Drive Train:

For the competition requirements, the engine has to be a 10 hp engine. So the options for the rest of the drivetrain are using a clutch with a chain drive, a CVT with a driveshaft, or a clutch with a belt drive. The clutch and chain drive combination would be the simplest design. This would decrease cost with fewer components needed, make assembly easier, and it would be durable with fewer parts that can fail. The CVT and driveshaft combo would be the most expensive option because it would be a more complicated design with more expensive parts involved. This would lead to greater risk of failure and the nature of the system would decrease output power. The clutch and belt drive combination would be another simpler option, but it involves a constant amount of high force which can lead to failure

End User:

When constructing this basic utility vehicle, the end user kept in mind are people from third world countries. The end user will likely require a vehicle that can maneuver around tough environments, is easy to use and simplistic in repairs, can transport water efficiently. Making sure that the vehicle is very simplistic and overall durable are big keys to this vehicle. Making the vehicles too complex can really make it harder for the end user to operate and maximize the use out of the vehicle. Also, keeping it simplistic makes it easier to repair if it does brake down since people in third world countries to do not have the kind of resources and mechanical knowledge to fix complex systems. The Durability is important because this vehicle will most likely have to go over rough terrain and other unfished roads or pathways. With the limited resources, it is ideal to make the strength of the vehicle as best as possible so that it does not break down often and can efficiently perform the tasks many times before signs of mechanical failure. Allowing the vehicle to be mobile in all surfaces and environments will help ensure that the end user can get the most out of the vehicle. Finally, allowing the vehicle to carry as much water as it can so that it can so that it can take less trips and to maximize the potentially water carried from the vehicle each time without too much stress on the vehicle and its frame.

Conclusion:

In our research we learned that there is really no one true way to do all of these different tasks. It all depends on the application you are using the certain system for. For our project our goal is to keep our costs low while keeping functionality and durability.

As stated, our end user is not one who really cares about looks or ascetics. They need this vehicle to perform its daily tasks and not wear down often. As we get further along in the design process we are going to keep all of these things in mind and attempt to design the best possible vehicle for our end user.

CUSTOMER FEATURES

Affordable
Durable
10 HP engine
Max weight: 1250 lb.
Payload: 1750 lb.

PRODUCT OBJECTIVES

-Coming in under budget ($6500)
-Testing and finding optimal engine and drive train
-Finding most lightweight durable parts
-Speed tests with different loads
-Making sure vehicle is not bigger than allowed

QUALITY FUNCTION DEPLOYMENT

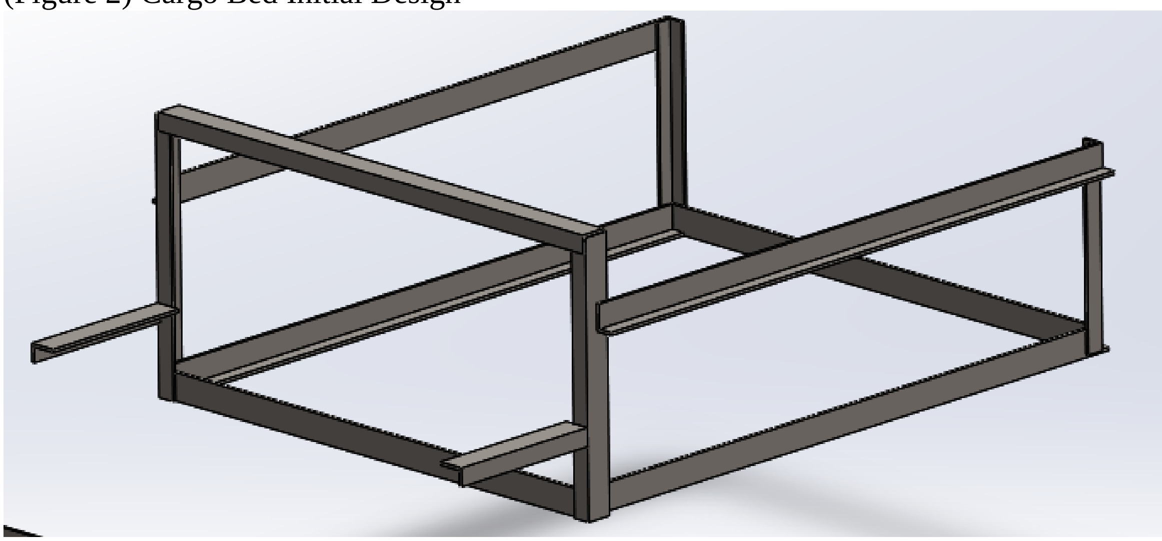
Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
				Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)															
				Quality Characteristics (a.k.a. "Functional Requirements" or "Hows") / **Demanded Quality** (a.k.a. "Customer Requirements" or "Whats")	money ($)	miles per gallon (MPG)	weight it can carry (lb)	vehicle life (years)	number of parts	Turning radius (feet)	length and width (Feet)	power (horsepower)	weight (lb)	maintaince cost ($)					
1	9	15.0	0.2	Affordable	Θ				▲					O					
2	9	5.0	0.1	good gas milage		Θ	▲					O	O						
3	9	10.0	0.1	carry heavy payload			Θ				▲	▲							
4	9	10.0	0.1	Durability	▲		▲	Θ					▲	O					
5	9	15.0	0.2	Easy to assemble	O				Θ		▲		▲						
6	9	5.0	0.1	meanuverability			O			Θ	O								
7	9	10.0	0.1	compact size		▲	O		O		Θ		▲						
8	9	15.0	0.2	Engine performance	O	Θ	O					Θ	▲						
9	9	10.0	0.1	lightweight vehicle		O	▲		▲		O		Θ						
10	9	5.0	0.1	maintainablilty	O			O	▲					Θ					
				Target or Limit Value															
				Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)															
				Max Relationship Value in Column	9	9	9	9	9	9	9	9	9	9					
				Weight / Importance	250.0	220.0	205.0	105.0	195.0	45.0	160.0	160.0	155.0	120.0					
				Relative Weight	15.5	13.6	12.7	6.5	12.1	2.8	9.9	9.9	9.6	7.4					

(Figure 1) Quality functional deployment

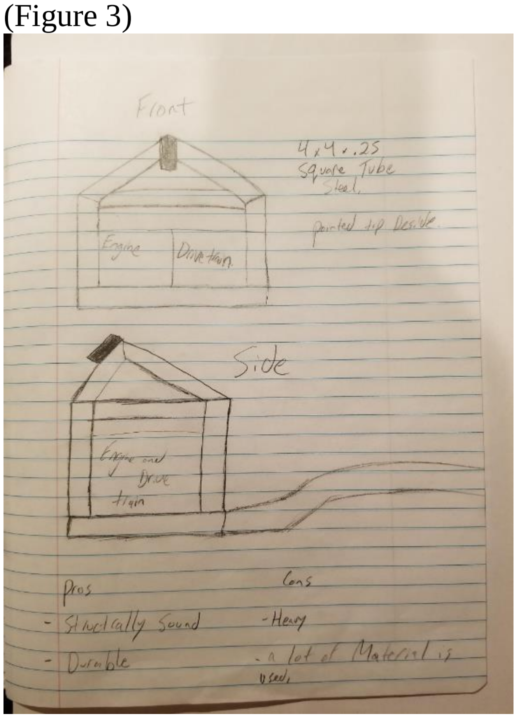
DESIGN ALTERNATIVES

I knew the cargo bed was going to be a set size and there was going to be little variance in the design process. I stuck with one concept for the cargo bed and chose to design three concepts for the engine and transmission housing. Below is my initial design for the cargo bed.

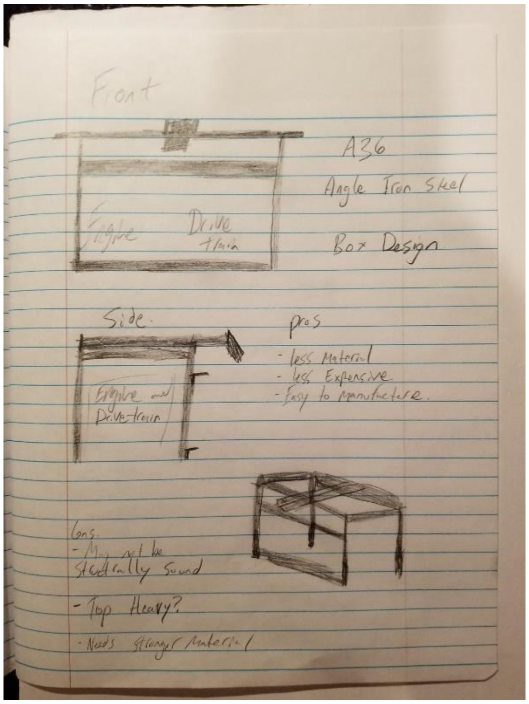
(Figure 2) Cargo Bed Initial Design



Concept 1
(Figure 3)



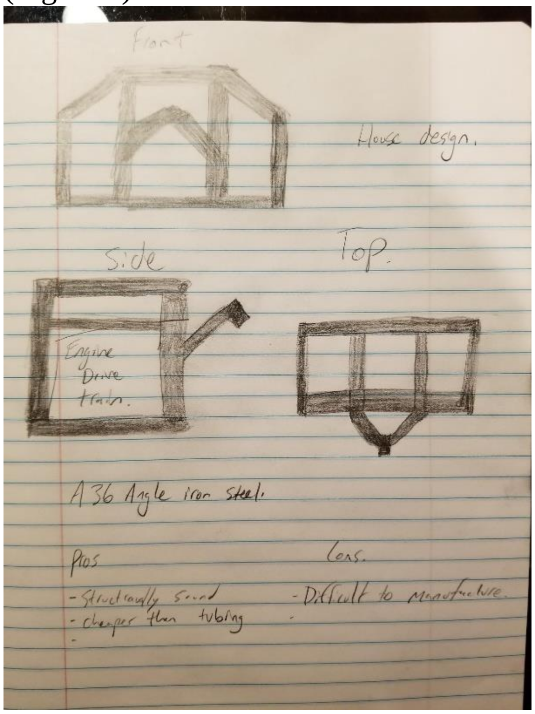
This was my first concept of the engine and transmission housing. I decided to design this with 4 x 4 x .25 square steel tubing. I made this decision because I wanted it to be durable and for it to be able to handle the vibrations of the engine. The pros of this design are that it is structurally sound, durable, and would be able to handle the application. The cons are that this may be too heavy. Also, there would be a lot of material used and this would result into a higher cost.



Concept 2
(Figure 4)

This concept was the concept that the previous year’s team recommended. It is a box design with support beams and is completely made up of the A36 angle iron steel. The advantages to this design is that the angle used is relatively inexpensive compared to other material, it uses less material than my other concepts and it would be relatively easy to manufacture. The disadvantage of this design is that it may not be structurally sound for this application.

Concept 3
(Figure 5)



This is my final concept. It uses angle steel. This design would most likely be structurally sound and it would be cheaper than steel tubing but it would also be the most difficult to manufacture compared to the other two concepts. Below is the table I used for my concept selection.

SELECTION

(Table 1)

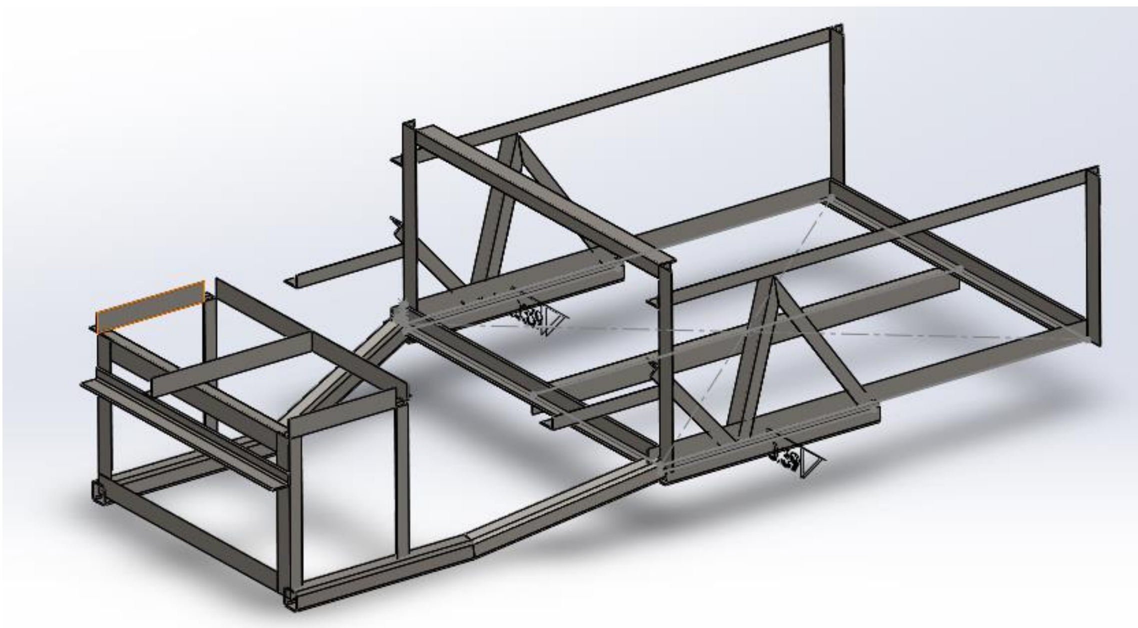
		Pointed Design		Box Design		"House" Design	
Requirement	Assigned Weight	Score	Weighted	Score	Weighted	Score	Weighted
Affordable	0.15	4	0.6	6	0.9	6	0.9
Carry Heavy Payload	0.25	6	1.5	5	1.25	7	1.75
Durable/Weather Proof	0.15	8	1.2	8	1.2	8	1.2
Easy to Manufacture	0.25	2	0.5	8	2	5	1.25
Light Weight	0.2	2	0.4	7	1.4	7	1.4
			4.2		6.75		6.5

There were a number of factors that I took into account like making this table and deciding which concept would be the best for the BUV. The requirements were affordability, carry the heavy payload, durable/weather proof, easy to manufacture and being lightweight.

The assigned weight is how important the requirement is. Based off of the assigned weight and the score given to each concept by me, the design with the highest score was determined. The concept that had the highest score was the box design.

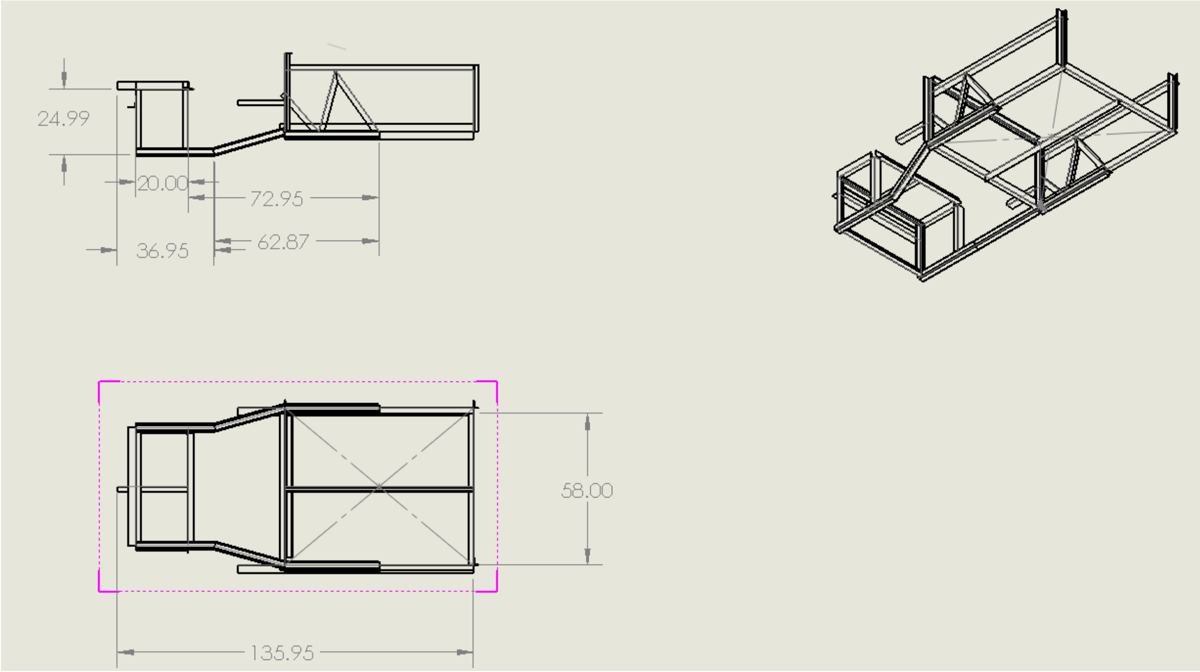
DRAWINGS

(Figure 6) Solidworks Assembly



This figure shows the solid works assembly with a few minor modifications. I added side trusses for added support and I mounted the cargo bed and the front housing onto a model representative of a Chevy S-10 frame.

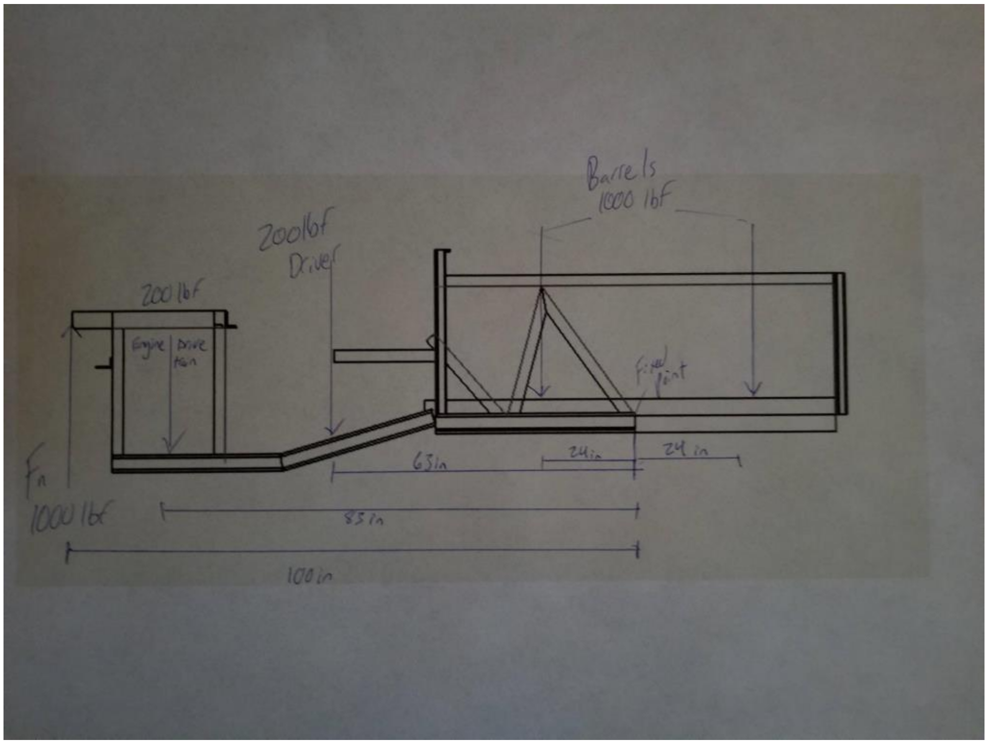
(Figure 7) Solidworks Drawing



This drawing shows the dimensions of the vehicle. It is within size of the competition guidelines.

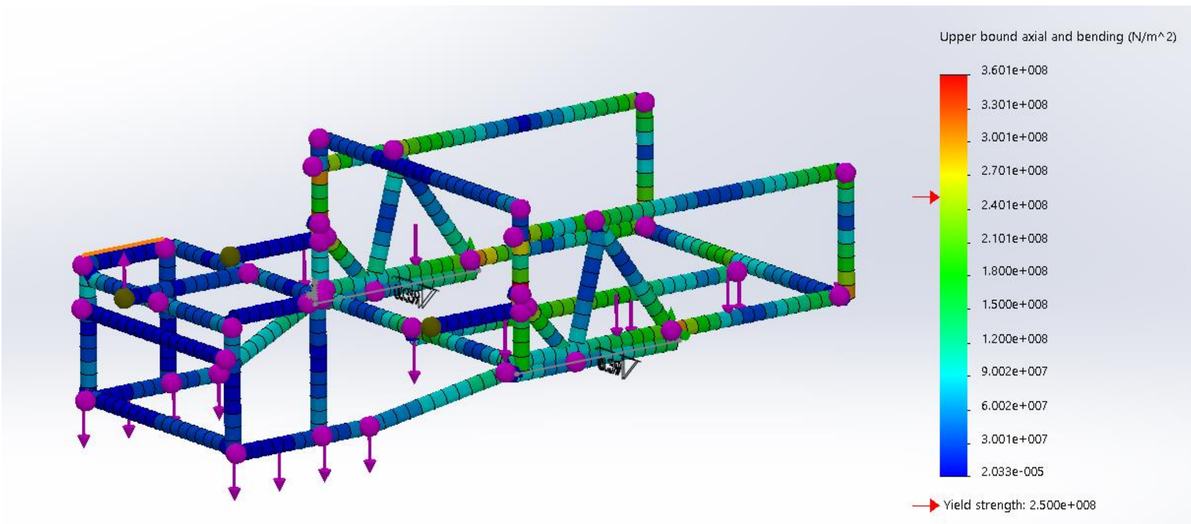
LOADING CONDITIONS

(Figure 8) Moment Diagram.



The moment diagram above shows the pounds of force that will be acting on the chassis. This distances and forces will be used to calculate the safety factor and to perform loading conditions in solidworks using finite element analysis.

(Figure 9) FEA



This figure shows the FEA carried out on the chassis. There is about 200 lb. acting on the front housing. And 200 lb. acting on the seat accounting for the weight of the driver. Finally there is 1000 lb. of force acting on the cargo bed. With all of these forces acting on the chassis, it has a yield strength of 36.27 ksi. This means it is structurally sound and can carry the load.

FACTOR OF SAFETY CALCULATIONS

$$+\Sigma moments\ of\ fixed\ points = (-333\ lbf * 24\ in) + (-333\ lbf * 24\ in) + (-200 lbf * 83 in) + (-200 lbf * 63 in) + (1000\ lbf * 100\ in) = 54{,}816\ lb * in$$

$$+\Sigma moments\ of\ a\ single\ fixed\ point = \frac{54{,}816 lb * in}{2} = 27{,}408\ lb * in$$

$$\sigma_{\max of\ a\ fixed\ point} = \frac{M_c}{I} = \frac{27.41 kLb * in * 1 in}{1.24 in^4} = 22.1\ ksi$$

$$Factor\ of\ safety = \frac{strength\ of\ material}{\max stress} = \frac{80ksi}{22.1ksi} = 3.6$$

Bill of Material (Table 2)

BOM		
Material	Size	Cost
Angle steel	2 x 2 x 3/16 in.	$178.00
	3 x 2 x 3/16 in.	
	1.5 x 1.5 x 3/16 in.	
	2 x 2 x 1/8 in.	
	1.5 x 1.5 x 1/18 in.	
plywood	5/8 in. thick	$89.00
	3/8 in. thick	
Various nuts and bolts	3/8 in , 1/4in, 5/16 in.	$30.00
1998 Chevy S-10 Frame	n/a	Donated

The total cost of the chassis was $297.00.

FABRICATION AND ASSEMBLY

The fabrication of the chassis was probably the simplest of the project. We started with the Chevy S-10 frame and cut the front end off. Once that was complete, we used the 3 x 2 x 3/16 angle iron steel to build the front engine housing. The pieces of angle were cut to length. Once all of our pieces were cut, welding was the next step. MIG welding was carried out on almost all parts of the chassis.

(Figure 10) Completed front engine housing with guards.

(Figure 11) Top view of the engine housing

The next step in the fabrication process was to build the cargo bed. The cargo bed was designed to hold three 55 gallon barrels. This means that the cargo bed will be about 22 feet squared, allowing enough room to hold the barrels and the irrigation system. The bottom base of the bed was welded to the top of the back end of the frame. The top rails of the frame were bolted into place so if the barrels needed to be removed for some reason, it would be easier. Also, the top rails being bolted to the cargo bed allowed for easier installation of the irrigation system.

(Figure 12) Side view of the cargo bed.

Figure 12 shows the side view of the cargo bed and how the barrels and corresponding irrigation system sits within it.

(Figure 13) Seat and roll bar

Figure 13 shows the seat and roll bar assembly. The seat juts out from the end of the cargo bed and has two support beams in the front. The seat also has 2 cross members as well. This was all done with welding. The roll bar had to be 36 inches about the seat as per the competition specifications. Our roll bar abides by this.

TESTING

After all fabrication was complete we needed to test our vehicle. At first we just wanted to see if the vehicle would run. We drove the vehicle around the parking lot of the victory parkways north lab a view times. The vehicle seems to handle this quite well actually. We then wanted to test our vehicles speed. With a stopwatch and a set distance. We calculated our top speed to be about 15.5 MPH. The guideline of the competition was a max speed of 20 MPH so we were within the guideline specifications.

We then decided to see if our vehicle could handle driving on an incline. This is where we ran into some problems. As our vehicle was driving up the incline of Cypress Street, the driveshaft of the vehicle locked up. We tried to figure out what the problem was but failed to do so. The competition was the next day so we were unable to attend because of the problems we faced while testing.

CONCLUSION

A lot of the problems we faced was due to not being able to get our frame in the early stages of the manufacturing semester. We learned that we were not getting the frame handed down to us from last year's project which is usually the case. Also, there was no funding available to us. This made us try and find our own frame and this took some time. We then learned of a relationship between David Conrad and the manager of U-pull n Pay. By the time we got our frame ready for fabrication, we had only about 6 weeks to manufacture the vehicle. This made us rushed and didn't leave a lot of time for the problems we faced during fabrication. We were able to finish the project but we were unable to attend the competition.

RECOMMENDATIONS

I recommend that groups doing this project in the future have an initial meeting with David Conrad as early as possible and understand exactly how they are going to get a Chevy S-10 and disassemble it for its frame. I recommend using the same A36 angle iron steel for the cargo bed and for the front engine housing. I also recommend that if given the opportunity to see other completed BUVs, take it. I think that going to the competition before starting the project would have been very beneficial.

PROJECT MANAGEMENT

(Table 3) Proposed/Actual Schedule

Task	**Proposed Start date**		**Task**	**Actual Start date**
Design concept	October 2nd 2017		Design concept	October 2nd 2017
Detailed outlook of each role	November 2nd 2017		Detailed outlook of each role	November 2nd 2017
Bill of materials	November 11th 2017		Bill of materials	November 11th 2017
Detailed design	November 16th 2017		Detailed design	November 16th 2017
Completed design in CAD	December 30th 2017		Completed design in CAD	December 30th 2017
Layout scheduling for manufacturing	January 1st 2018		Layout scheduling for manufacturing	January 1st 2018
Presentation Proposal	January 26nd 2018		Presentation Proposal	January 26nd 2018
Order parts	January 31th 2018		Order parts	March 7th 2018
Design modifications/manufacturing	February 1st 26th 2018		Design modifications/manufacturing	March 8th 2018
Start Testing	March 1st 2018		Start Testing	April 18st 2018
Spring break	March 12th -18th 2018		Spring break	March 12th -18th 2018
Testing modifications	April 1st 2018		Testing modifications	April 18st 2018
Final test	April 15th 2018		Final test	April 20th 2018
Competition / Final Presentation	April 20nd 2018		Competition / Final Presentation	April 21nd 2018

(Table 4) Proposed/Actual Budget

BUV Section	**Estimated Cost**		**BUV Section**	**Actual Cost**
Chassis	$1,060.00		Chassis	$310.00
Braking system	$360.00		Braking system	$130.00
Irrigation	$160.00		Irrigation	$300.00
Steering/Suspension	$460.00		Steering/Suspension	$85.00
Drive Train	$560.00		Drive Train	$210.00
Total Cost	$2,600.00		Total Cost	$1,035.00

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APPENDIX A

QUALITY FUNCTIONAL DEPLOYMENT

Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
				Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
				Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)															
				Quality Characteristics (a.k.a. "Functional Requirements" or "Hows") / **Demanded Quality** (a.k.a. "Customer Requirements" or "Whats")	money ($)	miles per gallon (MPG)	weight it can carry (lb)	vehicle life (years)	number of parts	Turning radius (feet)	length and width (Feet)	power (horsepower)	weight (lb)	maintaince cost ($)					
1	9	15.0	0.2	Affordable	Θ				▲					O					
2	9	5.0	0.1	good gas milage		Θ	▲					O	O						
3	9	10.0	0.1	carry heavy payload			Θ				▲	▲							
4	9	10.0	0.1	Durability	▲		▲	Θ					▲	O					
5	9	15.0	0.2	Easy to assemble	O				Θ		▲		▲						
6	9	5.0	0.1	meanuverability			O			Θ	O								
7	9	10.0	0.1	compact size		▲	O		O		Θ		▲						
8	9	15.0	0.2	Engine performance	O	Θ	O					Θ	▲						
9	9	10.0	0.1	lightweight vehicle		O	▲		▲		O		Θ						
10	9	5.0	0.1	maintainablilty	O			O	▲					Θ					
				Target or Limit Value															
				Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)															
				Max Relationship Value in Column	9	9	9	9	9	9	9	9	9	9					
				Weight / Importance	250.0	220.0	205.0	105.0	195.0	45.0	160.0	160.0	155.0	120.0					
				Relative Weight	15.5	13.6	12.7	6.5	12.1	2.8	9.9	9.9	9.6	7.4					

APPENDIX B

SCHEDULE

Task	Proposed Start date		Task	Actual Start date
Design concept	October 2nd 2017		Design concept	October 2nd 2017
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Competition / Final Presentation	April 20nd 2018		Competition / Final Presentation	April 21nd 2018

APPENDIX C

BUDGET

BUV Section	Estimated Cost		BUV Section	Actual Cost
Chassis	$1,060.00		Chassis	$310.00
Braking system	$360.00		Braking system	$130.00
Irrigation	$160.00		Irrigation	$300.00
Steering/Suspension	$460.00		Steering/Suspension	$85.00
Drive Train	$560.00		Drive Train	$210.00
Total Cost	$2,600.00		Total Cost	$1,035.00

APPENDIX D

BUV TECH SPECIFICATION SHEET

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

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

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

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

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

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

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

Cargo Bed The bed must hold two, but may hold three 55 gallon standard steel drums**. The drums must be located on their sides with the small hole at the top. The drums must be located as low as possible in the bed. The drums must not be stacked in any manner. The front of the cargo bed must have a 16 inch minimum high bulkhead between the driver and the cargo. The other sides of the bed must be a minimum of 8 inches high. Drums should be easily removable for cargo**.

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

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

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

1. An engine shutoff device marked with a nine-inch red streamer located within reach of the driver.
2. A ***dead man*** throttle with the spring located directly on the throttle linkage of the engine and not on the throttle control devices of vehicle.
3. Guarding from all moving parts and Padding of all sharp or dangerous areas.
4. Automotive horn, a fire extinguisher with a rating of 5 B-C or higher, and a high visibility safety flag above the vehicle.

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

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

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

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

Trailer Hitch	A 1-7/8 inch trailer ball must be mounted at a height of 15 inches above the ground when the vehicle is unloaded.
Weatherproof	The vehicle should have protection from the weather elements to provide better reliability and greater durability.
Speed	Maximum of 20 MPH.
Load	Maximum of 165 gallons of water, weighting roughly 1376 pounds.
Water Pump	Ability to fill 55-gallon drums from within 15 feet of a pond. All pumping equipment and hoses must be carried on the vehicle during the event. Pump driven form PTO device only.
Name Plate	The school name and team number displayed in 4-inch font on all sides of the vehicle.

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