Basic Utility Vehicle （BUV）
Electrics and Braking System

A Baccalaureate thesis submitted to the
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in partial fulfillment of the
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Bachelor of Science

in Mechanical Engineering Technology

by

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Thesis Advisor: Moise Cummings

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

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

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

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

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ABSTRACT

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

INTRODUCTION

PROBLEM STATEMENT:

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

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

TEAM MEMBER RESPONSIBILITIES

Bethany Nickson - Chassis & Frame

Christopher Steward - Drive Train

Dickson Opoku - Front Suspension

Deamann Strefas - Irrigation System (Team Leader)

Guanchun - Brake system

RESEARCH AND BACKGROUND

CUSTOMER REQUIREMENTS

Below is the requirement for brake system from ITA organization.

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

INTERVIEWS

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

Information gathered:

1. Using Dual Wilwood High Volume Master Cylinder, because many teams use it, and work perfectly.
2. Must use brake hose to connect brake end with chassis end, because hard pipe might broke when rear suspension been compressed.
3. Make sure brake line use same type of connector, inverted flare or bubble flare, pipe and hose must connect with same type connector, different type connector will cause fluid leakage.
4. Use flex joint to connect brake pedal with master cylinder.

PREVIOUS BUV DESIGN

It's necessary to look at previous design to help build up a brief understanding of BUV.

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

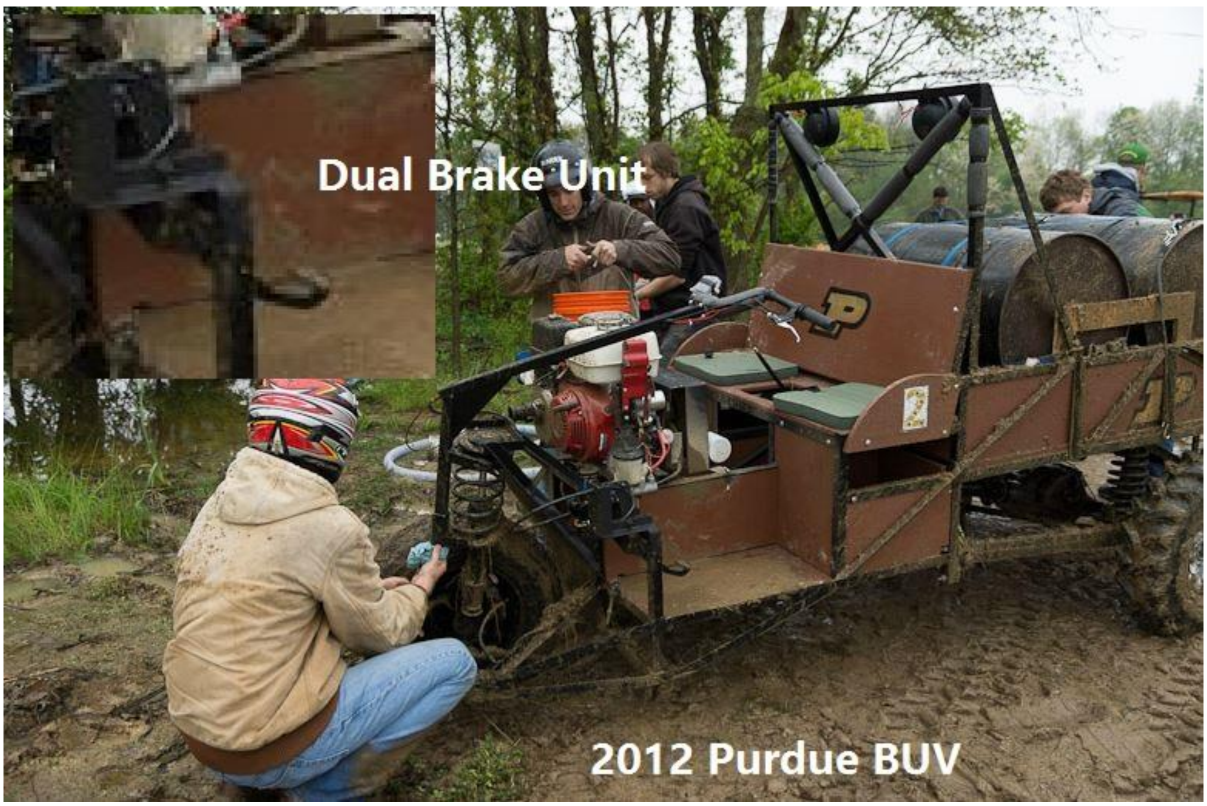

Figure 1. 2012 Purdue BUV (1)

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

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

Figure 2. 2014 UC BUV (2)

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

In 2016 & 2017, UC BUV club team use two brake unit system with different design (See Figure 3 & 4)

Figure 3. 2016 UC BUV club

Figure 4. 2017 UC BUV club

It’s clear that, dual brake unit with feet pedal become more popular after many years competition, it is a success design.

IDEA TO SOLVE PROBLEM:

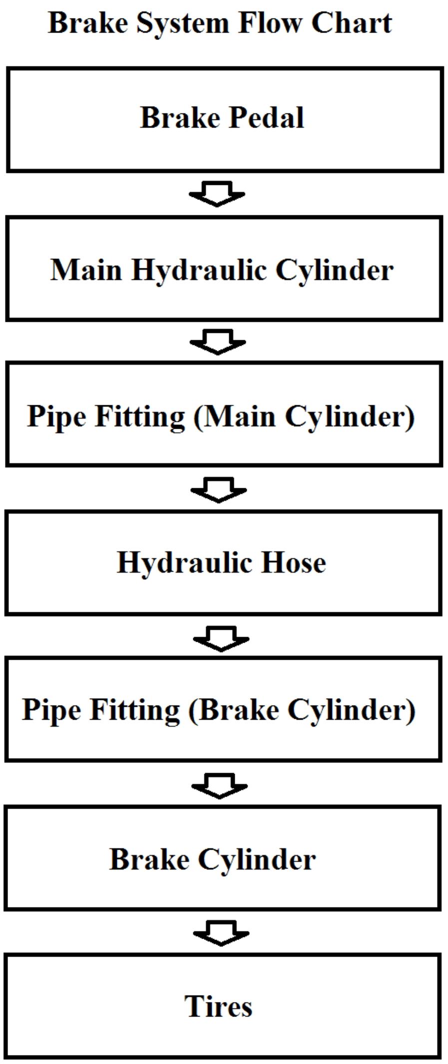

Figure 5. Flow chart of brake system

To design this dual brake system, the final target is to lock rear tires, because BUV normally don't have an Anti-Lock Braking System onboard, so when rear wheels locked, BUV will finally stop. To lock rear wheels, it's necessary to have friction factor between tire and ground, friction factor of brake. Calculate needed brake force first, and then calculate hydraulic pressure in hydraulic system. Finally calculate needed force apply on master cylinder. Brake pedal system use lever principle to increase output force. Input force and output force of pedal system is necessary for design a brake pedal system.

Data needed:

1. Estimate length, width and total weight of BUV.
2. Average pedal force of human.
3. Friction factor of brake, friction factor between ground and tires.

RESERACH

According to a report from National Highway Safety Bureau U.S. Department of Transportation Washington.
Average pedal force of male is around 250 lbs (See Figure 6)

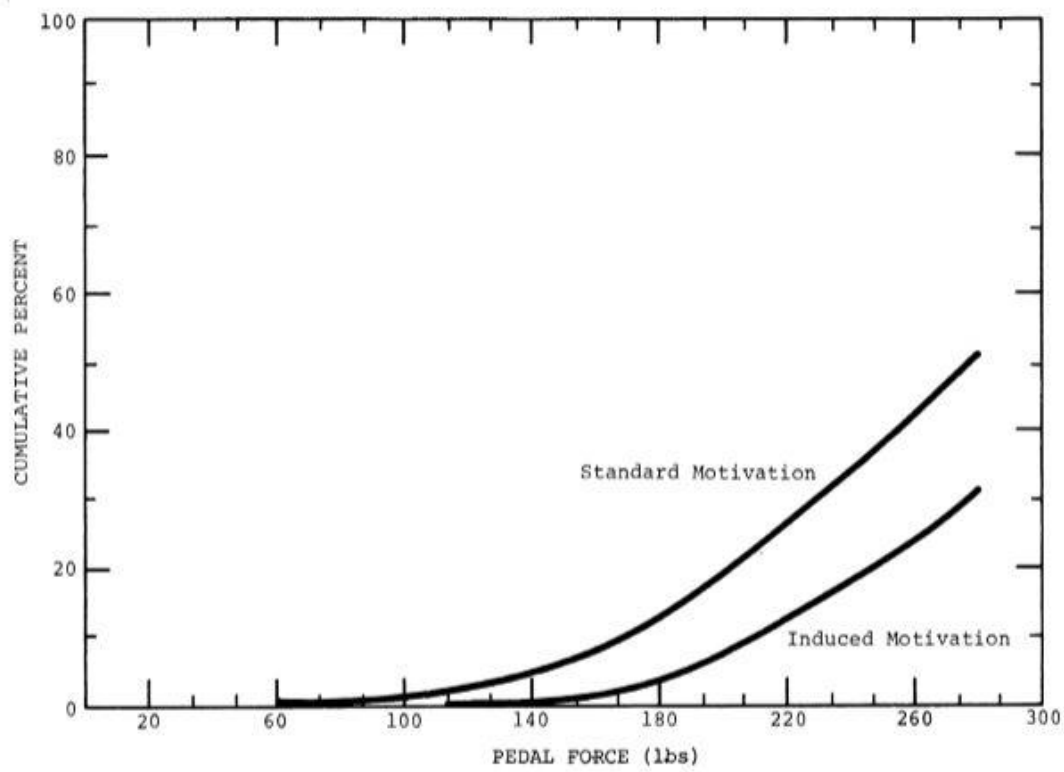

Figure 2.5. Cumulative percent pedal force for 323 males.

Figure 6. Average pedal force of male (3)

Average Pedal force of female is around 150 lbs (See Figure 7)

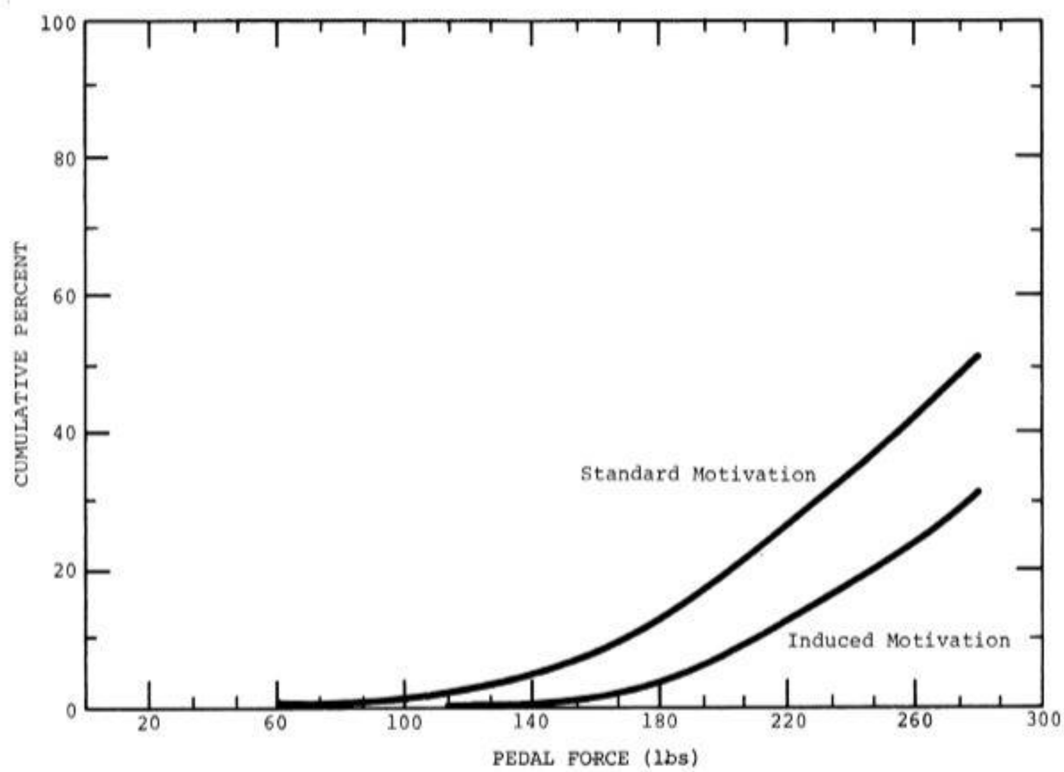

Figure 2.5. Cumulative percent pedal force for 323 males.

Figure 7. Average pedal force of female (3)

This BUV is design for both male and female drivers, so 150 lbs is selected as average pedal force.

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

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

Assume total length of wheel base is 100 In. Height of COG (center of gravity) = 30 In.

Total weight of BUV (Fully loaded) = 2841 lbs (See Figure 8)

Weight	
	Weight(lbs)
Driver	166
Passenger	166
No. of Passenger	1
BUV	1000
Barrels	40
Weight of water per barrel	463
No. of Barrels	3
Total Weight	**2841**

Figure 8. Total Weight of BUV

BRAKE CONCEPT SELECTION:

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

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

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

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

Brake Selection		Concept Alternatives					
		Hydraulic Disc Brake		Hydraulic Drum Brake		Wire Drum Brake	
Criteria	Importance Weight (%)	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating
high brake efficiency	15	4	0.6	3	0.45	2	0.3
high reliability	20	3	0.6	4	0.8	2	0.4
low maintenance	10	3	0.3	4	0.4	4	0.4
low cost	30	2	0.6	3	0.9	3	0.9
light weight	10	2	0.2	3	0.3	3	0.3
weather resistance	5	4	0.2	2	0.1	2	0.1
Total	100	NA	2.5	NA	2.95	NA	2.4
Rating		Value					
Unsatisfactory		0					
Just tolerable		1					
Adequate		2					
Good		3					
Very Good		4					
Conclusion: Hydrulic Drum brake is better than disc brake under the requirment of compition							

Table 1. Brake Concept Selection

CALCULATION

CENTER OF GRAVITY

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

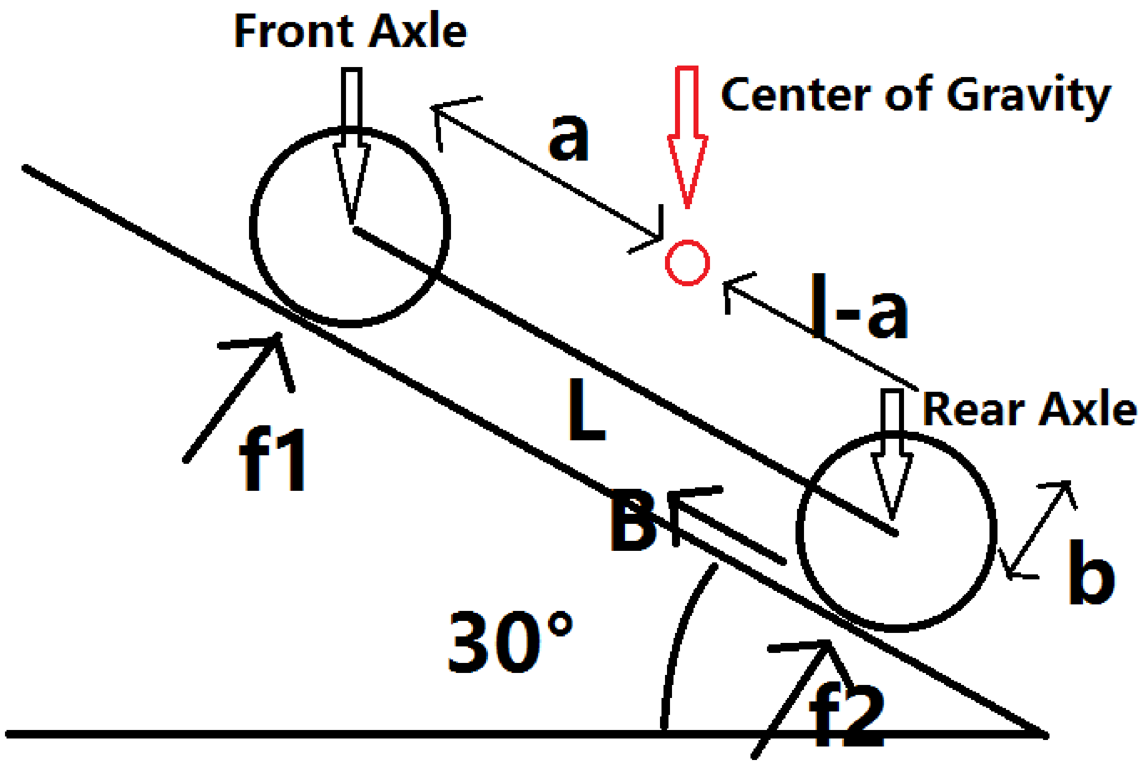

Figure 9. Center of Gravity

Let

Total Weight = W

wheel base = L

Distance from front axle to center of gravity = a

Distance from rear axle to center of gravity = L-a

Distance from wheel base to center of gravity = b

Ground force support front wheel = f1

Ground force support rear wheel = f2

Brake force = B

Slope Angle = θ

Then: $f1 * a + B * b = (L - a) * f2$ (1)

$f1 + f2 = W * \cos(\theta)$ (2)

$B = W * \sin(\theta)$ (3)

When center of gravity fixed, higher brake force will lower f1, make BUV easier roll over.

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

Combine equation 1, 2 & 3

$f1 = \frac{LWcos(\theta) - a*W*\cos(\theta) - W*\sin(\theta)*b}{L}$ (4)

When f1=0, which mean BUV about to roll over if center of gravity move backward.

Assume: L=100 In.

W=2841 lbs

$\theta = 30°$

B=30 In

Solve equation 5. a= 82.679 In.

Then the center of gravity should located around 80 In. from front wheel axle.

BRAKE PEDAL LEVEL RATIO

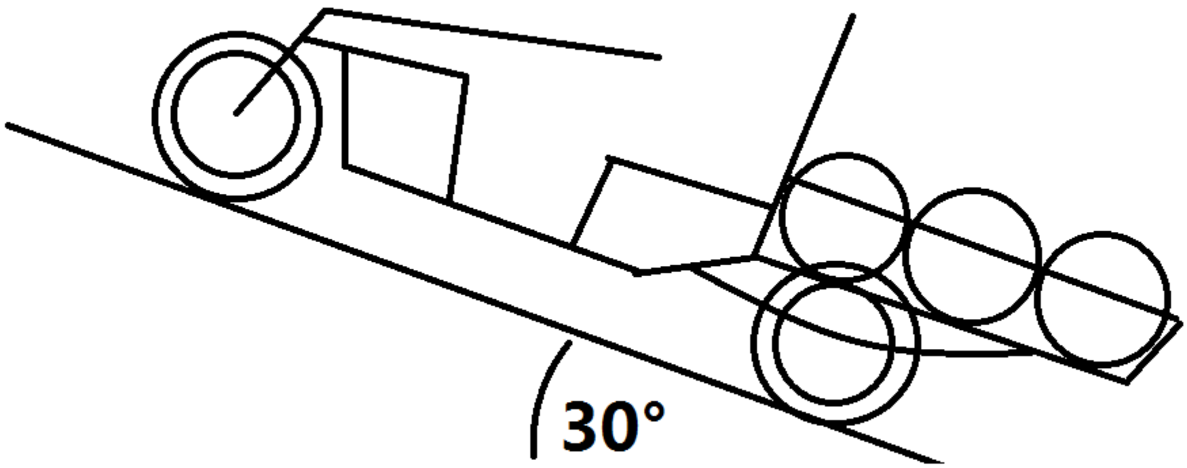

Figure 10. BUV Stop at 30 °slope

Safety Factor for Single Brake Unit = 1.5

Safety Factor for Brake System = 3

Force Applied on pedal = 150 lbs.

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

Maximum brake force to lock wheel = $\frac{Ground\ force}{2} * Ground\ Coefficient = \frac{2460.378Lbs}{2} * 0.5 = 615.0945\ Lbs$

Torque provided by drum brake = $Lock\ wheel\ force * Tire\ Loaded\ Radius = 615.0945Lbs * 13In. = 7996.2285In.Lb$

Force provided by brake cylinder= $\frac{Torque\ provide\ by\ brake}{Brake\ shose\ radius*2} = \frac{7996.2285Lbs}{\frac{9.5\ In}{2}*2} = 841.708\ Lbs$

Hydraulic pressure provided by brake cylinder = $\frac{Force}{Bore\ Area} * safety\ factor = \frac{841.708Lbs}{\frac{\pi*0.75^2}{4}} * 1.5 = 2857.855psi$

Assume there is no Hydraulic Pressure Loss, So Hydraulic inside brake line is equal, then

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

Force applied on master cylinder = $Hydraulic\ Pressure * Bore\ Area = 2857.855 * \frac{\pi * 0.75^2}{4} = 1262.562Lbs$

Lever Ratio = $\frac{Output\ Force}{Input\ Force} = \frac{1262.562Lbs}{150} = 8.42$

DESIGN

PEDAL CONCEPTS SELECTION:

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

Brake Selection		Concept Alternatives					
		Deisgn 1		Deisgn 2		Deisgn 3	
Criteria	Importance Weight (%)	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating
Size of brake unit	20	2	40	2	40	4	80
high reliability	20	4	80	4	80	3	60
Low cost	15	3	45	3	45	3	45
Esay to maintain	20	3	60	2	40	2	40
Easy to use	25	2	50	3	75	3	75
Total	100	NA	275	NA	280	NA	300

Rating	Value
Unsatisfactory	0
Just tolerable	1
Adequate	2
Good	3
Very Good	4

Design 3 is the best choice under this conddition

Design 1	Brake arm length (in)	Total lengthm (in)	Total Height (in)
	15.4086	12	16.72

Design 2	Brake arm length (in)	Total lengthm (in)	Total Height (in)
	8.42	17.57	6

Design 3	Brake arm length (in)	Total lengthm (in)	Total Height (in)
	8.42	9.15	6

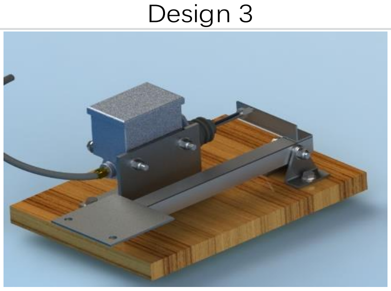

Table 2. Pedal Concepts Selection

DESIGN MODIFICATION:

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

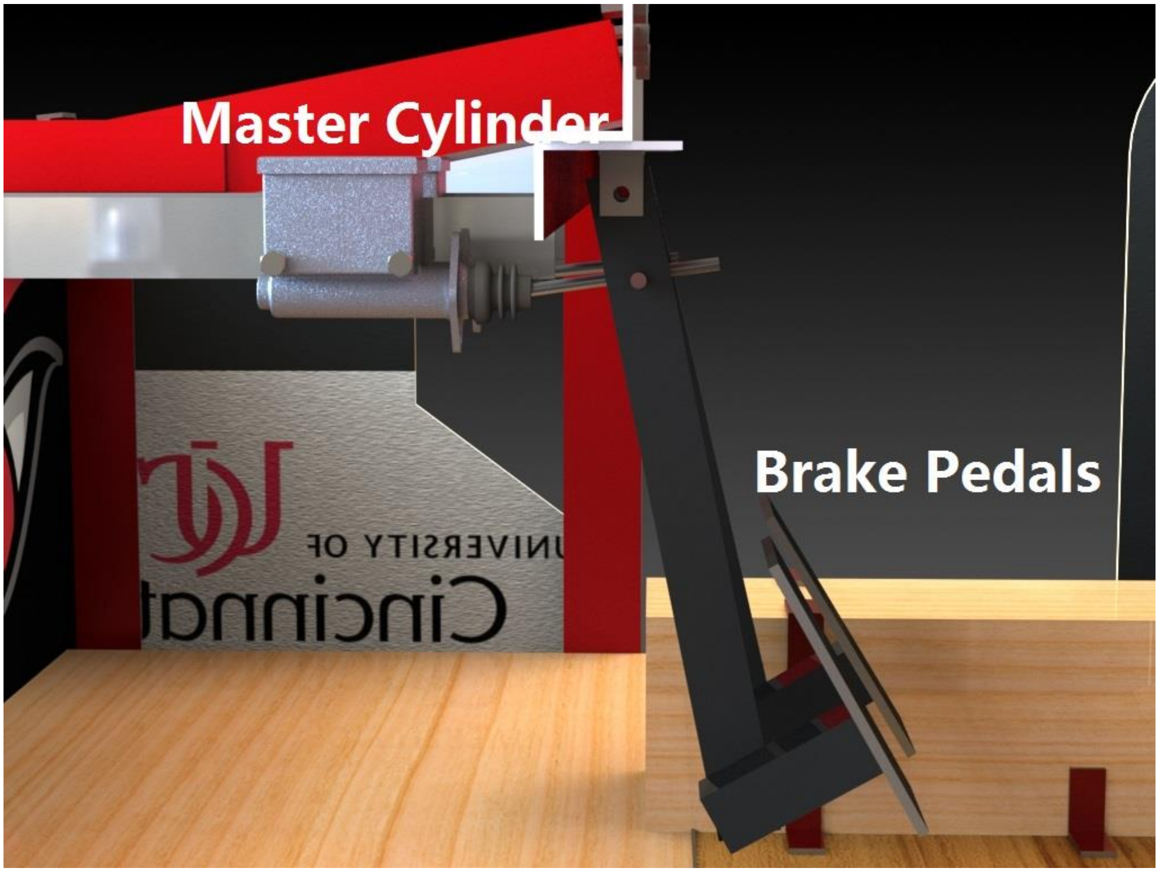

Figure 11. New Pedal Design

Benefit of this design:

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

FABRICATON

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

DRUM BRAKE UNIT ASSEMBLY

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

Figure 12. Chevy S10 Drum Brakes

It's not too bad inside, but for safety reason, spring kits, master cylinder and brake shoes must be replaced. It's easy to find those parts at local auto part store. Below is the list of replaced parts:

1. Two brake cylinder.
2. Two brake shoes set
3. All in one spring kits
4. Two self-adjusting Kits

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

Figure 13. Finished Drum Brake unit

BRAKE LINE ASSEMBLY

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

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

Brake line connection as Figure 14 shows

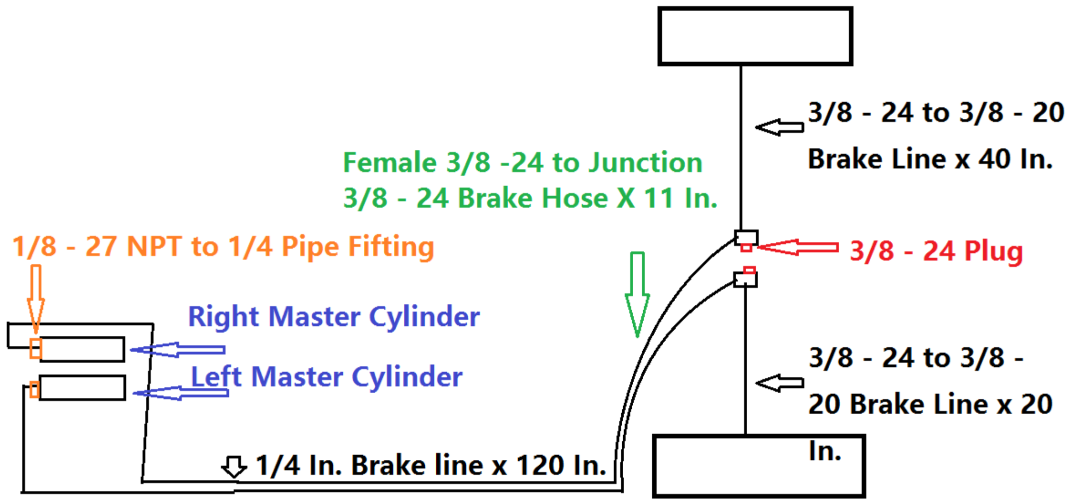

Figure 14. Brake line

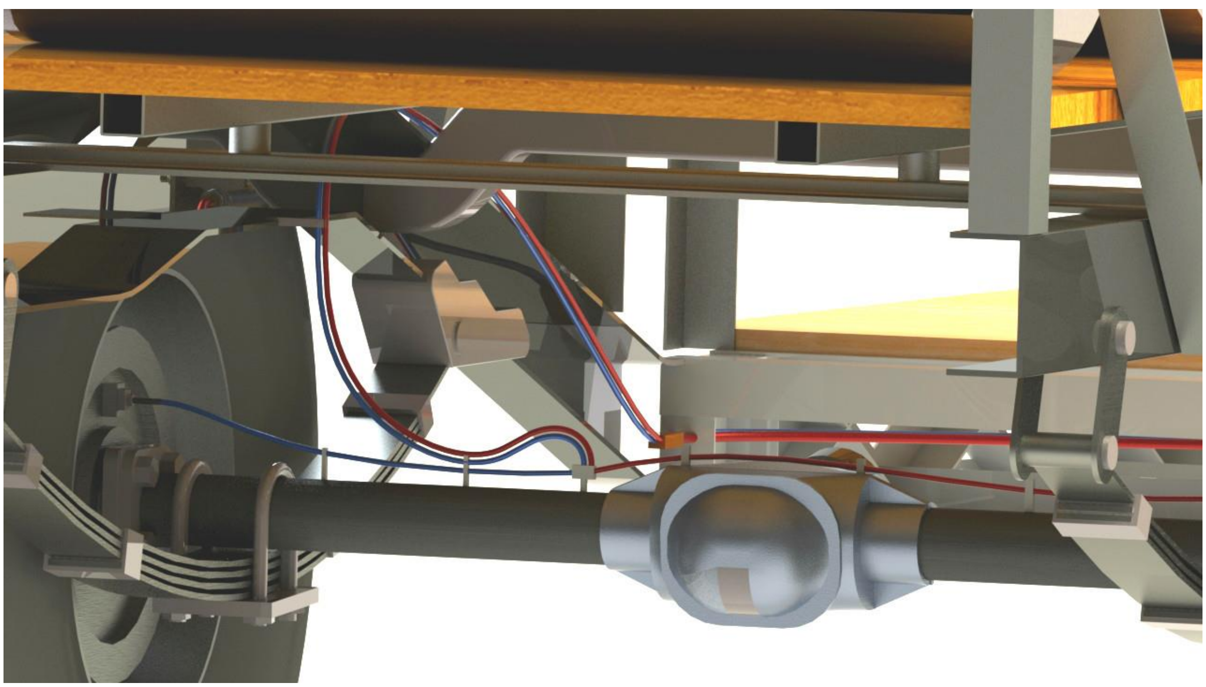

Figure 15. Brake line deisgn in Solidworks

Something must clear is, there are two type of pipe fitting, inverted flare and bubby flare. Inverted flare must connect with inverted flare, bubby must connect with bubby flare, is two different type fitting connected, hydraulic fluid will leak out from connect area.

Figure 16. Finished brake line assembly

Two master cylinders is bolted on steel strip with grade 8 bolts and self-lock nuts, so master cylinder will not come out when driving on Un-pavement road.

PEDAL ASSEMBLY

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

Figure 17. Finished Pedal

FILL BRAKE FLUID IN:

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

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

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

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

TEST

Apply same test method with IAT.

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

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

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

COMPETITION RESULTS

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

Figure 18. Result of 2017 MET BUV

PROOF OF DESIGN

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

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

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

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

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

CONCLUSION

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

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

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

And try to start fabrication as soon as possible; time will be very tight during last semester.

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APPENDIX A . 2017 BUV SPECIFICATION

BUV Farm Tanker & Transporter
2017 Design Specifications:

Engine	Use up to 11 horsepower unmodified engine. An auxiliary fuel tank may be added.
Exhaust	Stock muffler, which may be relocated, with additional heat shields as needed.
Gauges	An engine temperature indicator located in view of the driver.
Fuel	Retail pump fuel and oil with provisions to prevent spilling fuel on a hot engine.
Transmission	It is builder's choice, to meet event conditions, but should have reverse** and should have at least two forward speeds** not counting any variable drive features.
Power Takeoff	The ability to power auxiliary equipment** at approximately 1000 rpm. A V-belt drive is anticipated for auxiliary equipment.
Electrical	A 12 volt 35 amp or larger automotive alternator and an automotive battery are required**.
Cargo Bed	The bed must hold two, but may hold three 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 is seated upon. The roll bar must be completely padded above the seat height. It must have a cross member that covers the ends of the vertical structures, and adequate bracing to prevent the vehicle from rolling over.
Driver Safety	A helmet is required for each person aboard the vehicle. Seat belts are at the option of the team and the team advisor.
Safety Items	To participate in the event, you must have the following safety items: 1. An engine shutoff device marked with a nine-inch red streamer located within reach of the driver. 2. A ***dead man*** throttle with the spring located directly on the engine throttle linkage and not on the throttle control devices of vehicle. 3. Guarding from all moving parts and Padding of all sharp or dangerous areas. 4. Automotive horn, a fire extinguisher, and a high visibility safety flag above the vehicle.
Brake System	A redundant brake system** that will prevent total brake failure if a brake line is severed anywhere on the vehicle. The brakes must be located at the wheels and not on the drive-line. A front wheel brake is not required on three wheeled vehicles. The parking brake is not considered the redundancy that is required. Hydraulic drives may use reverse for brakes.
Parking Brake	A parking brake capable of overcoming the engine power. It may be on the drive-line.
Tires	Agricultural tread, or aggressive tire chains are required. Chains must be carried by the vehicle if removed from the tires.
Towing	Each vehicle must have a 20 foot looped-end tow strap. There must be an attachment point at the front of the vehicle for towing. The trailer ball will be the rear attachment point for towing.
Trailer Hitch	A 1-7/8 inch trailer ball must be mounted 15 inches above the ground when the vehicle is unloaded.
Weatherproof	The vehicle should have protection from the weather elements to provide better reliability and greater durability.
Speed	Maximum of 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**

August 11, 2016.

APPENDIX B . HOUSE OF QUALITY

	Customer Requirements	Importance wt.	Payload Force (lbs)	Material Selection (Yes/No)	Start/Run Time(Seconds)	Hydraulic Brake(Yes/No)	Ground Clearance (inches)	Guarding (Yes/No)	Paint & Lubricants (Yes/No)	Steering Radius(ft)	Metric Fasteners(Yes/No)	# of Steps to Assemble (#)	Weight(lbs)				Customer Satisfaction Rating (0.00 - 1.00)			
			Engineering Requirements (units)																	
	Customer Requirements		1	2	3	4	5	6	7	8	9	10	11	12	13	14	CP	A	B	C
1	Durable	0.10	9	9		1	1	3	3											
2	Cost effective/Inexpensive	0.15		9				1	1			3	3							
3	Reliable	0.15	3	3		3	1	1			1									
4	All terrain/all weather	0.15	3	9			9	9	3				3							
5	Long life expectancy	0.05	3	3		3	1	1	9			3								
6	Easy to assemble	0.10		3								9	3							
7	Maintainability	0.10		3				3	9			3								
8	Fuel economy	0.05	9	1									9							
9	Easy to operate	0.10	3		9	3	1	1		9	1		3							
10	Clear visibility	0.05					3	3												
	Total Importance	1.00	2.7	4.85	0.9	1	1.9	2.55	2.25	0.9	0.25	1.8	1.95							
	Engineering requirement importance																			
Performance	Current Product																			
	competitor A																			
	competitor B																			
	competitor C																			
	New Product Targets																			

Interaction Matrix

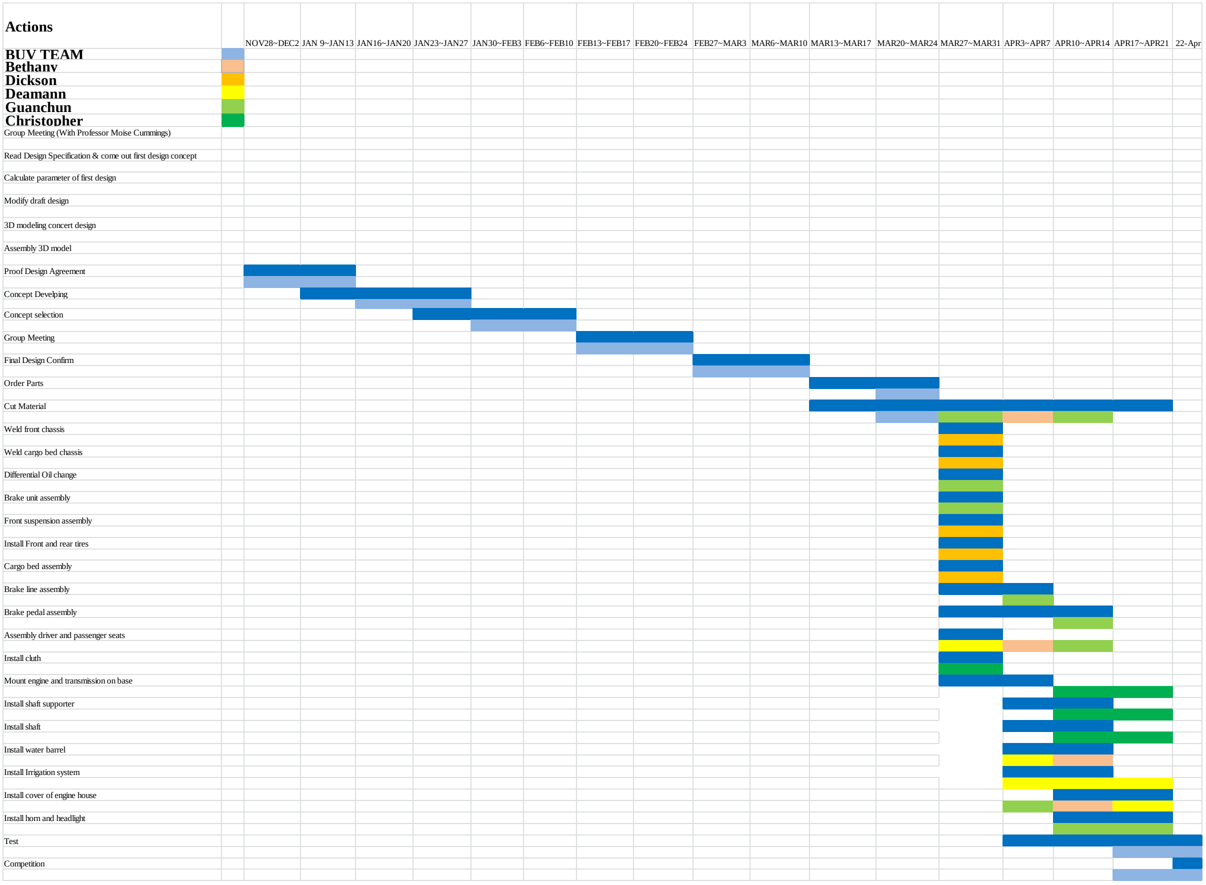
Engineering Requirements	Engineering Requirements	Payload Force (lbs)	Material Selection (Yes/No)	Start/Run Time(Seconds)	Hydraulic Brake(Yes/No)	Ground Clearance (inches)	Guarding (Yes/No)	Paint & Lubricants (Yes/No)	Steering Radius(ft)	Metric Fasteners(Yes/No)	# of Steps to Assemble (#)	Weight(lbs)	0	0	0
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Payload Force (lbs)	1		3		1		3			1					
Material Selection (Yes/No)	2						3					9			
Start/Run Time(Seconds)	3														
Hydraulic Brake(Yes/No)	4								1						
Ground Clearance (inches)	5														
Guarding (Yes/No)	6									9	3				
Paint & Lubricants (Yes/No)	7										3				
Steering Radius(ft)	8									3		3			
Metric Fasteners(Yes/No)	9										1				
# of Steps to Assemble (#)	10														
Weight(lbs)	11														
0	12														
0	13														
0	14														

APPENDIX C . BUDGET OF BRAKE SYSTEM

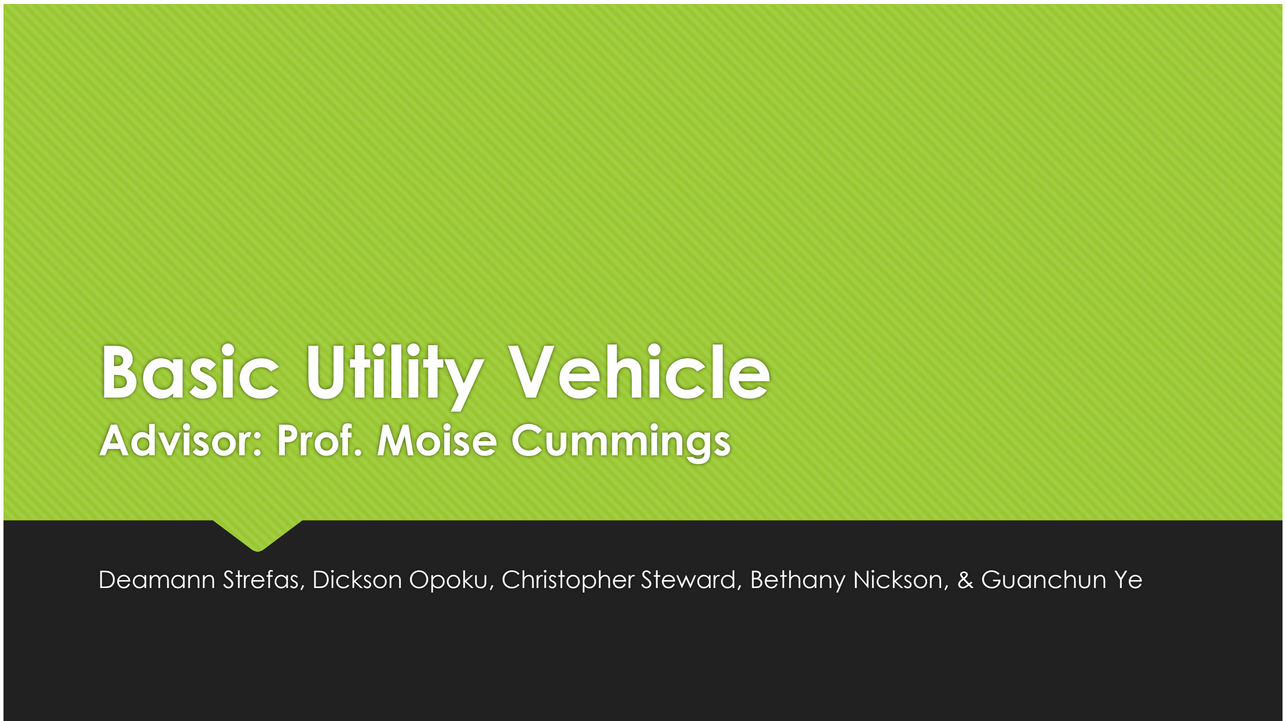
Items	Amount	Price($)
Hydrualic Hose adapter 3/8-24 NPT to 3/4 NPT	2	4.47
Wilwood Master Cylinder X 2	2	205.32
Bolts 3/8 - 18 Bolts X 4	2	3.71
Hose Plug 3/8-24 ID.	2	2.66
Brake Hose 3/8 - 24 Hose X 11 In. X 2	2	24.58
Hydrualic Line 3/8-24 to 3/8 - 24 X 51 In	1	20.3
Hydrualic Line 3/8-24 to 3/8 - 24 X 20 In	1	15.25
Hydrualic Line 1/4 X 20 In	1	14.96
Hydrualic Line 1/4 X 50 In	1	22.5
1/8-27 NPT to 1/4 Pipe Fifting	2	3.96
2 x 2 In. x 42 Angle iron	1	16
1 1/2 x 1 1/2 Square head pipe x 42 In.	1	20.6
3/8 In. self-lock Nuts	2	5.6
DOT3 Brake Fluid	1	12
Total		371.91

APPENDIX D . SECHDULE

Actions		AUG 22 ~ AUG 26	AUG 29 ~ SEP 2	SEP 5 ~ SEP 9	SEP12 ~ SEP 16	SEP 19~SEP23	SEP26~SEP30	OCT3~OCT7	OCT10~OCT14	OCT17~OCT21	OCT24~OCT28	OCT31~NOV4	NOV7~NOV11	NOV14~NOV18	NOV21~NOV25
BUV TEAM															
Bethany															
Dickson															
Deamann															
Guanchun															
Christopher															
Group Meeting (With Professor Moise Cummings)															
Read Design Specification & come out first design concept															
Calculate parameter of first design															
Modify draft design															
3D modeling concert design															
Assembly 3D model															
Proof Design Agreement															
Concept Develping															
Concept selection															
Group Meeting															
Final Design Confirm															
Order Parts															
Cut Material															
Weld front chassis															
Weld cargo bed chassis															
Differential Oil change															
Brake unit assembly															
Front suspension assembly															
Install Front and rear tires															
Cargo bed assembly															
Brake line assembly															
Brake pedal assembly															
Assembly driver and passenger seats															
Install cluth															
Mount engine and transmission on base															
Install shaft supporter															
Install shaft															
Install water barrel															
Install Irrigation system															
Install cover of engine house															
Install horn and headlight															
Test															
Competition															


Actions
NOV28~DEC2
JAN 9~JAN13
JAN16~JAN20
JAN23~JAN27
JAN30~FEB3
FEB6~FEB10
FEB13~FEB17
FEB20~FEB24
FEB27~MAR3
MAR6~MAR10
MAR13~MAR17
MAR20~MAR24
MAR27~MAR31
APR3~APR7
APR10~APR14
APR17~APR21
22-Apr
BUV TEAM
Bethany
Dickson
Deamann
Guanchun
Christopher
Group Meeting (With Professor Moise Cummings)
Read Design Specification & come out first design concept
Calculate parameter of first design
Modify draft design
3D modeling concert design
Assembly 3D model
Proof Design Agreement
Concept Develping
Concept selection
Group Meeting
Final Design Confirm
Order Parts
Cut Material
Weld front chassis
Weld cargo bed chassis
Differential Oil change
Brake unit assembly
Front suspension assembly
Install Front and rear tires
Cargo bed assembly
Brake line assembly
Brake pedal assembly
Assembly driver and passenger seats
Install cluth
Mount engine and transmission on base
Install shaft supporter
Install shaft
Install water barrel
Install Irrigation system
Install cover of engine house
Install horn and headlight
Test
Competition

Final Presentation



Problem Statement

IAT is a non-profit organization located in Indianapolis, IN that is devoted to developing high-quality, low-cost transportation to provide mobility, freedom and economic hope to people in rural areas of developing countries. The vehicle is designed to transport people, water , and various other materials. To develop a durable, low cost vehicle that can be built and maintained in a third world country. The vehicle should be suitable for farming and operating in areas without roads. The design should be in kit form and should be able to assemble with ease. Regulations for competition are given on the spec sheet provided by the Institute of Affordable Transportation. The vehicle is to be ready for competition on April 22nd 2018.

Background & State-of-the-Art

IAT has held this competition every year since 2001

More recent submissions has shown the best results

Purdue, 1st Place Winners (2012)

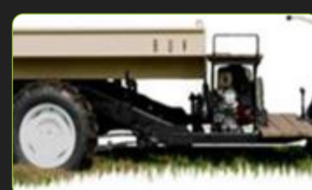
- Wood & Angle Iron Material
- Decrease overall Weight, increase speed

UC, 3rd Place Winners (2013)

- Recommend using angle iron and plywood for material; using truss design for chassis
- Weighted pressure was on the intermediate shaft which causes Drive train to have error

Current BUV in Production (2016)

- Cost about $5000 to produce



Competition Guidelines

Features
- Affordable – 20% of the cost of a small truck
- Flexible – easy to modify cargo area
- Comfortable – automotive suspension
- Durable – automotive parts

Performance
- 20 mph
- 1200 lb payload (and low ground pressure)
- 50+ mpg diesel
- power other devices (water pump, mill, etc.)

Specifications
- 10 hp engine (diesel or gas)
- 1000 lb vehicle weight (low ground pressure)
- 12' L x 5' W; cargo bed 6.5' L

Service / Maintenance
- common "off-the-shelf" parts
- easy access to engine and drivetrain
- 95% less parts than a typical car

Packaging & Shipping
- 8 assembled units per ocean container
- crate size 2'H x 2'H x 4'L for power kit
- farm classification (lower duty rates)

Automotive Grade Components
- suspension / axle / rear frame
- brakes / tires / wheels / hubs
- expected life: 20+ years for auto parts

Safety
- high driver visibility
- speed limited to 20 mph
- low center of gravity

Cultural Factors
- middle steering, gender friendly
- car-like operation; no shifting, no clutch
- easy to rescue
- customize as necessary (canopy, lights, etc.)

QFD & House of Quality

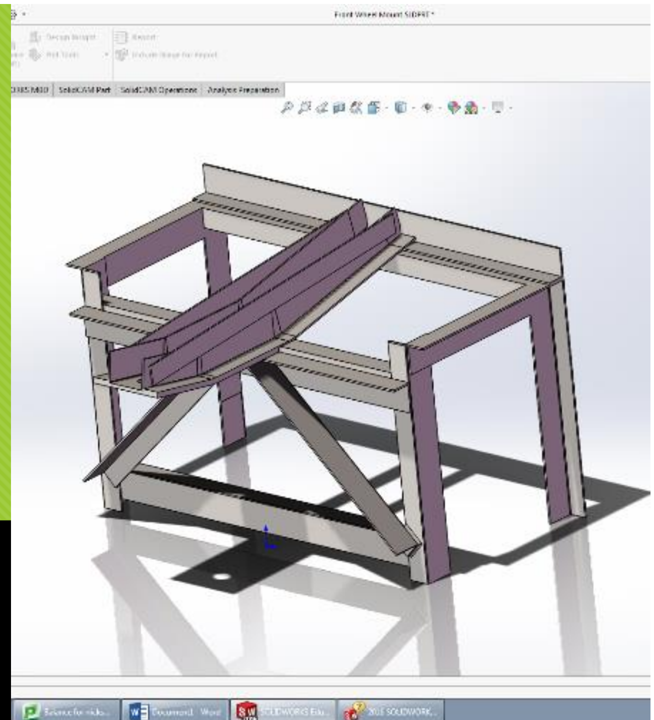
	Customer Requirements	Importance wt.	Payload Force (lbs)	Material Selection (Yes/No)	Start/Run Time(Seconds)	Hydraulic Brake(Yes/No)	Ground Clearance (inches)	Guarding (Yes/No)	Paint & Lubricants (Yes/No)	Steering Radius(ft)	Metric Fasteners(Yes/No)	# of Steps to Assemble (#)	Weight(lbs)				Customer Satisfaction Rating (0.00 - 1.00)			
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	CP	A	B	C
1	Durable	0.10	9	9		1	1	3	3											
2	Cost effective/inexpensive	0.15		9				1	1			3	3							
3	Reliable	0.15	3	3		3	1	1			1									
4	All terrain/all weather	0.15	3	9			9	9	3				3							
5	Long life expectancy	0.05	3	3		3	1	1	9			3								
6	Easy to assemble	0.10		3								9	3							
7	Maintainability	0.10		3				3	9			3								
8	Fuel economy	0.05	9	1									9							
9	Easy to operate	0.10	3		9	3	1	1		9	1		3							
10	Clear visibility	0.05					3	3												
	Total importance	1.00	2.7	4.9	0.9	1	1.9	2.6	2.3	0.9	0.3	1.8	2							
	Engineering requirement importance																			
Performance	Current Product																			
	competitor A																			
	competitor B																			
	competitor C																			
	New Product Targets																			

Interaction Matrix

Engineering Requirements	Engineering Requirements	1 Payload Force (lbs)	2 Material Selection (Yes/No)	3 Start/Run Time(Seconds)	4 Hydraulic Brake(Yes/No)	5 Ground Clearance (inches)	6 Guarding (Yes/No)	7 Paint & Lubricants (Yes/No)	8 Steering Radius(ft)	9 Metric Fasteners(Yes/No)	10 # of Steps to Assemble (#)	11 Weight(lbs)	12 0	13 0	14 0
Payload Force (lbs)	1		3		1		3			1					
Material Selection (Yes/No)	2						3					9			
Start/Run Time(Seconds)	3														
Hydraulic Brake(Yes/No)	4								1						
Ground Clearance (inches)	5														
Guarding (Yes/No)	6									9	3				
Paint & Lubricants (Yes/No)	7										3				
Steering Radius(ft)	8									3		3			
Metric Fasteners(Yes/No)	9										1				
# of Steps to Assemble (#)	10														
Weight(lbs)	11														
0	12														
0	13														
0	14														

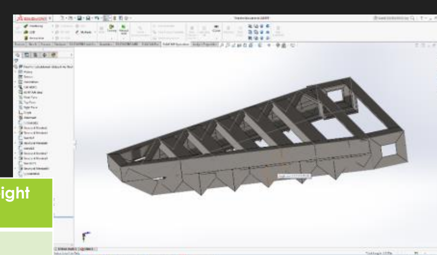
Chassis & Frame

Bethany Nickson



Design Selection

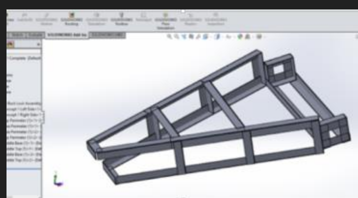
Concept 2 (Warren Truss Design) was Selected
Material A36 2x2x3/8 inch angle iron steel



Criteria	Weight %	Standard Design	Weight%	Warren Truss	Weight%	Howe Truss	Weight %
Ground Clearance	5	4	0.2	4	0.2	4	0.2
Easy Manufacturing	10	4	0.4	3	0.3	1	0.1
Durable & Strong	35	2	0.7	4	1.4	4	0.7
Amount of Material	20	4	0.8	3	0.6	2	0.4
Weight	30	4	1.2	4	1.2	3	0.9
	=100		=3.3		=3.7		=2.3

Concept Designs

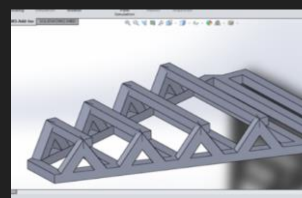
Concept 1: 2013 Design



Pros:
- Good Ground Clearance
- Standard Manufacturing
- Lightweight
- Less Material

Cons:
- Lots of Welding
- Strength & Durability

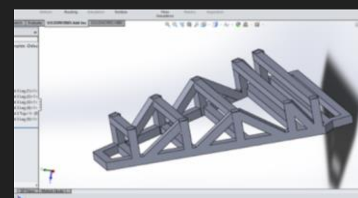
Concept 2: Warren Truss Design



Pros:
- Good Ground Clearance
- Standard Manufacturing
- Durable / Strong
- Lightweight

Cons:
- Lots of Welding
- Lots of Material

Concept 3: Howe Truss Design

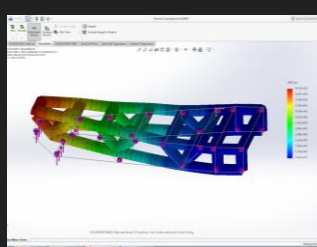


Pros:
- Good Ground Clearance
- Durable / Strong

Cons:
- Lots of Material
- Lots of Welding
- Multiple Size Members; Difficult Manufacturing

Design Selection Calculations

Von Mises Stress

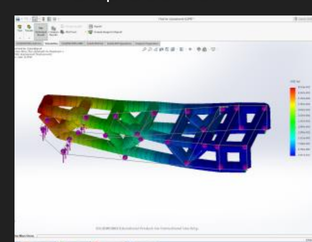


When applying 1500lbs of continuous force:
- Max: 36,000 psi
- Did not Pass

Factor of Safety

When applying 1500lbs of continuous force:
- Highest FS = 2.45

Displacement



When applying 1500lbs of continuous force:
- Max: 4.52 in
- Faulty

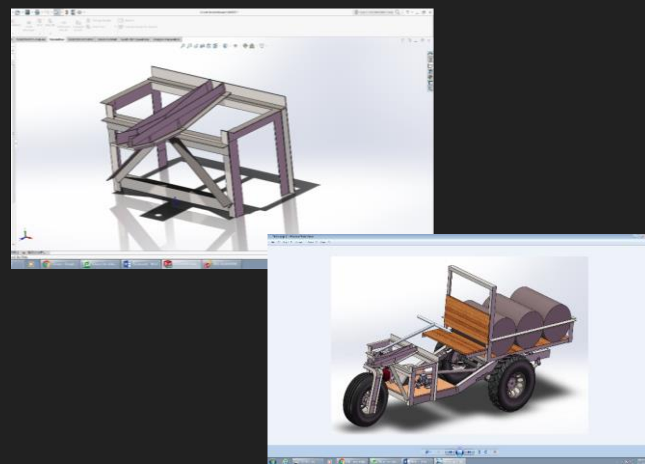
Design Modifications

Thoughts:

- Needs to have a higher payload
- Support the drivetrain, brake system, and front suspension with the front chassis
- Less Material
- Easier to Fabricate (Less Welding)

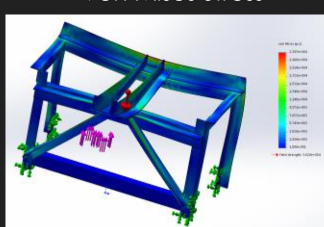
Conclusion:

- Use more of the truck frame
- Material: A36 3x2x3/8 angle iron steel
- Build up, not out
- Payload = 2840 pounds



Final Design Calculations

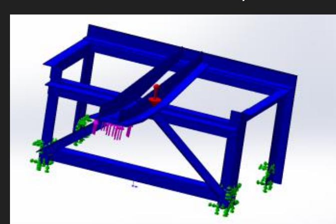
Von Mises Stress



When applying design load of 2840 pounds:

- Max: 36,000 psi
- Highest: 20,380 psi

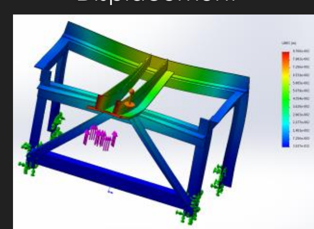
Factor of Safety



With a 2840 pound design load:

- Min: 2.07

Displacement



When applying 2840 pounds of force:

- Max: 0.0871 inches

Fabrication & Modifications

Fabrication Process

- 1994 Chevrolet S10 Frame from U-Pull & Pay
- MIG Welding – of Front Chassis, S10 Frame, & Lower Cargo Bed Rail
- Bolt – upper Cargo Bed Rail (allow removal of barrels)

Modifications

- Used 2x2 angle iron for cargo bed

Fabrication: Finished Frame & Chassis

Front Suspension & Steering

Dickson Opoku

Concept Designs

Concept 1: Earle's Fork suspension

Advantages
- Good damping
- Precise steering
- Dynamic compensation

Disadvantage
- Expensive
- Complex
- High maintenance

Concept 2: Unit-Strut spring and shock

Advantages
- Durable
- Good damping
- Great turning

Disadvantages
- Complex
- High maintenance
- Expensive

Concept 3: Unit-Strut- Chosen Design

Advantages
- Simple to manufacture
- Low Maintenance cost
- High Agility
- No skills required

Disadvantages
- Poor damping on tarred road
- Poor aesthetic

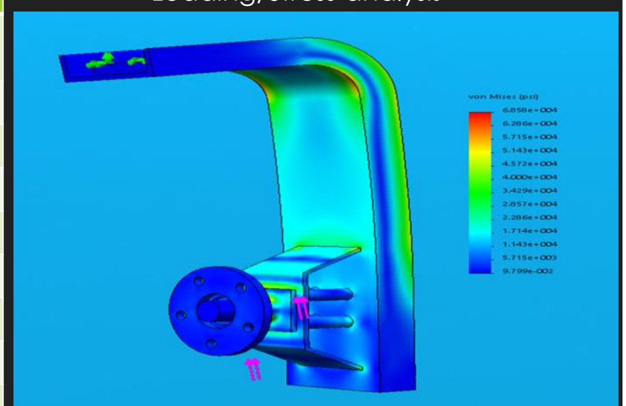
Alternative concept/Embodiment Evaluations

		Earle's Fork		Unit-Strut-Spring		Unit-Strut	
Criteria	Weight (%)	Rating	Wt. Rating	Rating	Wt. Rating	Rating	Wt. Rating
Cost	20	2	0.40	2	0.40	3	0.60
Durability	10	3	0.30	4	0.40	4	0.40
Maintainability	8	1	0.08	1	0.08	3	0.24
Manufacturability	8	1	0.08	1	0.08	3	0.24
Light Weight	5	1	0.15	2	0.10	2	0.10
Reliability	10	3	0.30	4	0.40	3	0.30
Safety	20	3	0.60	2	0.40	3	0.60
Customer Appeal	14	2	0.28	2	0.28	1	0.14
High Agility	5	1	0.05	1	0.05	2	0.10
		N/A	**2.24**	**N/A**	**2.19**	**N/A**	**2.72**
	Rating	Value					
LEGENDS	Satisfactory	0					
	Just Tolerable	1					
	Adequate	2					
	Good	3					
	Very Good	4					

Finite Element Analysis/Simulations (Test)

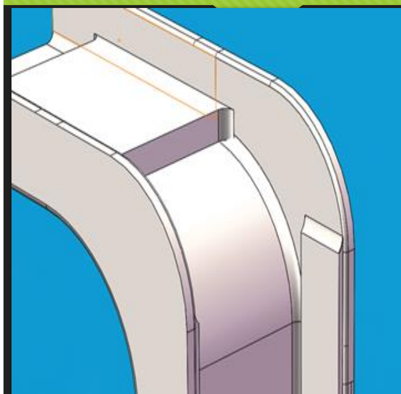
Selected Material	Parameters/Properties
ASTM A36 Structural Steel C-Channel	
Density	0.284lb/in3
Tensile Strength, Ultimate	58,000-80,000 psi
Tensile Strength, Yield	36,300 psi
Modulus of Elasticity	29,000 ksi
Compression Yield Strength	22,000psi
Shear modulus	11,500 ksi
Weight of BUV	1,200 lbs
Applied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

Loading/Stress analysis

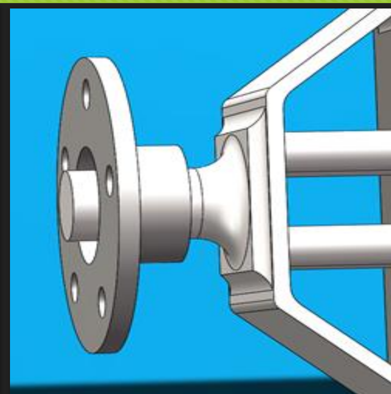


Result: 68,880psi>36,300psi

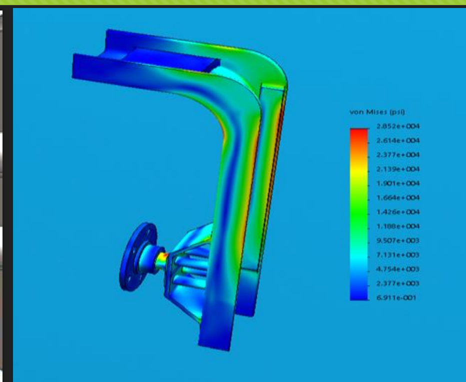
Modifications



Reinforce web & steering column 4inx1in steel plate



Increase thickness of hub mount plate 1/2in plate to reinforce flange



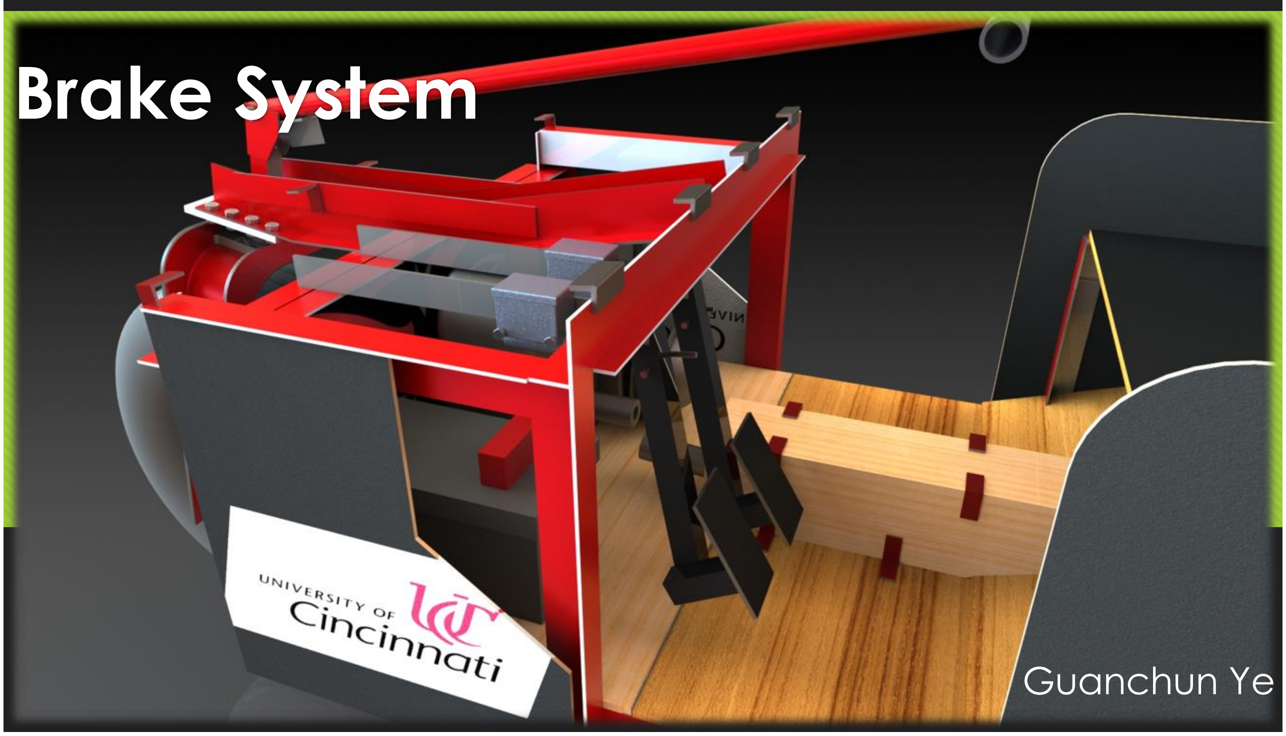
Final Result: 28,520psi<36,300psi

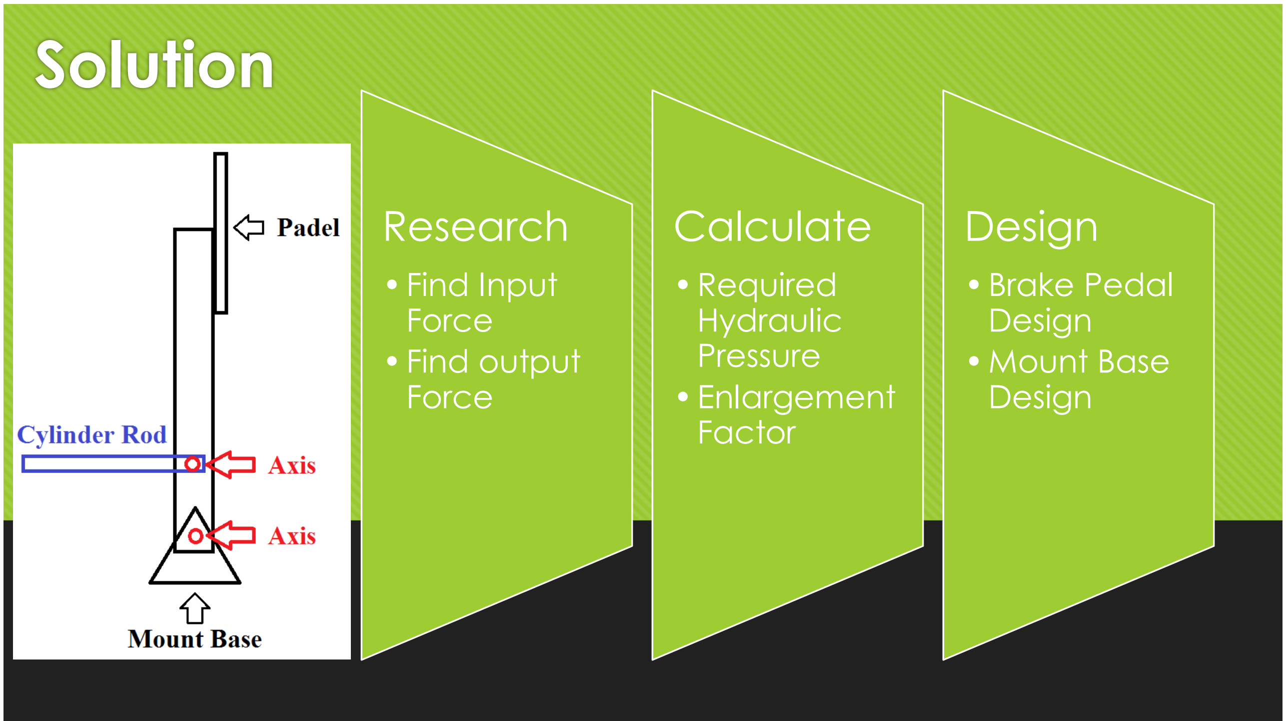
Fabrication & Proof of Design

Finish touches

Front tire mounted onto suspension


Final Assembly of Front suspension and Steering (two 3/2in seamless steel pipe)
Steering
Suspension


Brake System
UNIVERSITY OF Cincinnati
Guanchun Ye



Research

Set the Input Force equal to 150 Lbs

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

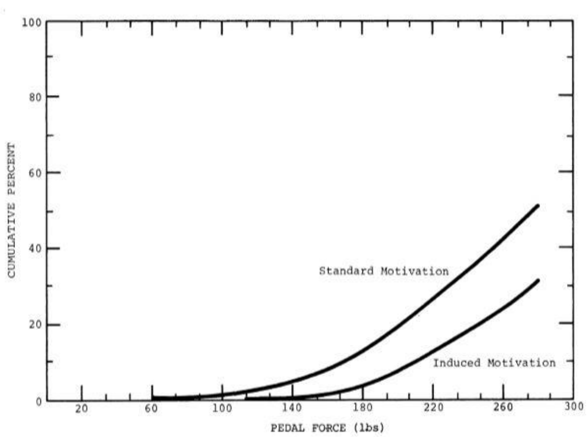


Figure 2.5. Cumulative percent pedal force for 323 males.

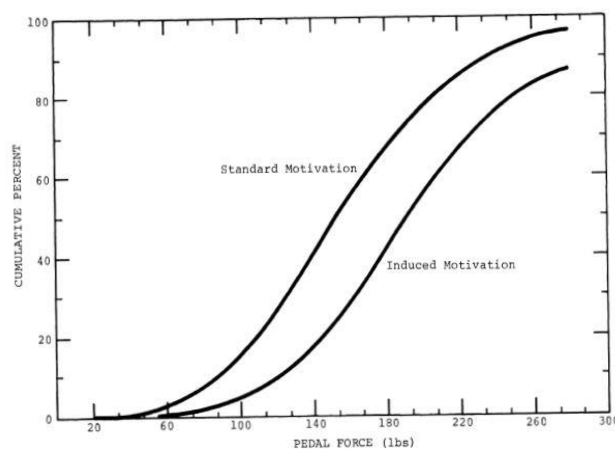


Figure 2.4. Cumulative percent pedal force for 276 females.

Research

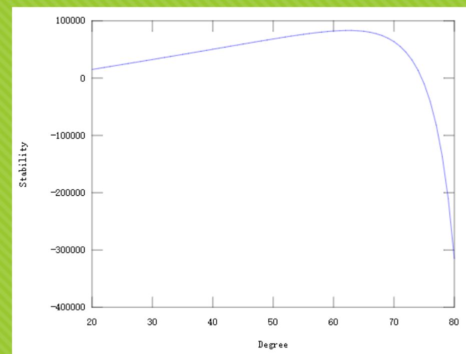
Target: Find out Maximum Brake Force

Safety Factor = 1.5 （Single Unit） 3 （Dual Unit）
Here we using Single Brake
Desired Result: Stop braked wheel rotation
Total Weight of BUV is around 2840 lbs

Table 2. Examples for 4 different soil conditions (used tire: 540/65R30)

		Stubble field	Grass land	Ploughed	Cultivated
Tire and soil parameters	k_{cover}	0.5	0.9	0.0	0.0
	$k_{strenth; A}$	0.6	0.7	0.0	0.25
	$k_{strenth; B}$	0.8	0.8	0.1	0.6
	k_{clay}	0.5	0.5	0.5	0.5
	$k_{moisture}$	0.5	0.6	0.5	0.5
	k_{tire}	0.6	0.6	0.6	0.6

Excerpt: Influence of soil and tire parameters on traction



Center of Gravity is located at 70%

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

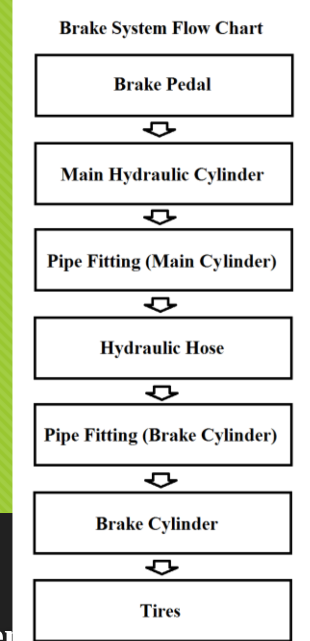
Detailed Calculations will showed on Final Report

Calculation

Torque provided by brake cylinder =4504.95 lbf

Hydraulic Pressure of brake cylinder and master cylinder = 2683.453 psi

Force applied on master cylinder = 1185.513 lbf



Input Force = 150 lbf & Output force is 1185 lbf, So the er
ratio = 7.9

Brake Selection

Brake Selection		Concept Alternatives					
		Hydraulic Disc Brake		Hydraulic Drum Brake		Wire Drum Brake	
Criteria	Importance Weight （%）	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating
high brake efficiency	15	4	0.6	3	0.45	2	0.3
high reliability	20	3	0.6	4	0.8	2	0.4
low maintenance	10	3	0.3	4	0.4	4	0.4
low cost	30	2	0.6	3	0.9	3	0.9
light weight	10	2	0.2	3	0.3	3	0.3
weather resistance	5	4	0.2	2	0.1	2	0.1
Total	100	NA	2.5	NA	2.95	NA	2.4
Rating		Value					
Unsatisfactory		0					
Just tolerable		1					
Adequate		2					
Good		3					
Very Good		4					
Conclusion: Hydrulic Drum brake is better than disc brake under the requirment of compition							

Brake Pedal Design

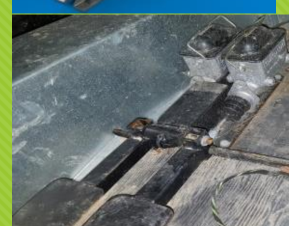
Enlargement Ratio = 7.9

Brake Selection		Concept Alternatives					
		Deisgn 1		Deisgn 2		Deisgn 3	
Criteria	Importance Weight （%）	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating
Size of brake unit	20	2	40	2	40	4	80
high reliability	20	4	80	4	80	3	60
Low cost	15	3	45	3	45	3	45
Esay to maintain	20	3	60	2	40	2	40
Easy to use	25	2	50	3	75	3	75
Total	100	NA	275	NA	280	NA	300
Rating		Value					
Unsatisfactory		0					
Just tolerable		1					
Adequate		2					
Good		3					
Very Good		4					

Select Design 3

Design 1

Total Length = 12 In.
Total Height = 16.72 In.



Design 2

Total Length = 17.5 In.
Total Height = 6 In.

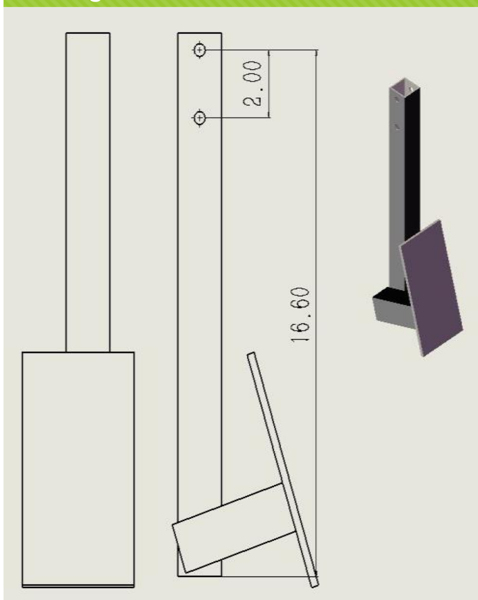
Design 3

Total Length = 9.15 In.
Total Height = 6 In.

Final Design

Problem: No enough ground space for brake units

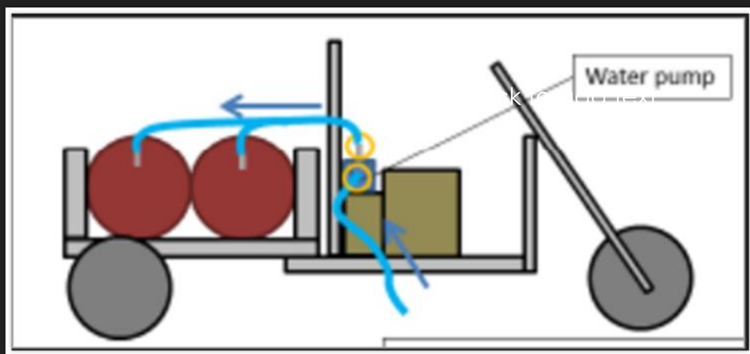
Enlargement Ratio = 7.9 2 x 7.9 = 14.8 In. < 16.6 In.



Irrigation System

Deamann Strefas

2014 Irrigation Design

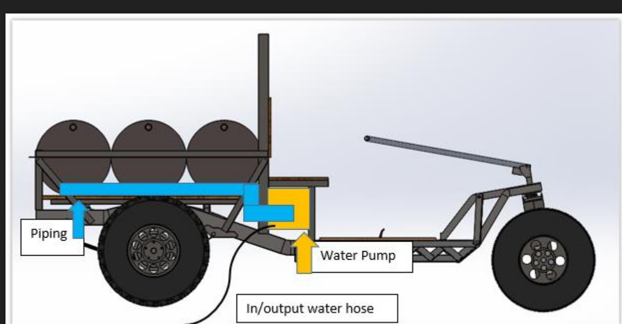


Similar to 2013, water is pumped in through the top of the barrels but is also pumped out through the same holes.

Pros:
Faster than 2013 design
Minimal material use

Cons:
Easily Damaged

Modifications



Relocated water pump under the seat.

Designed quick connect system.

Pros:
Minimal material usage
Eliminates risk of damage during transit

Cons:
To be determined

Modifications

Designed quick connect pumping system.

Easy to use, durable and time efficient.

Eliminates break factor while in transit.

Water Pump Selection

		Pump 1		Pump 2		Pump 3	
Criteria	Importance Weight %	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating
Affordable	25	3	75	2	50	4	100
Easy to Use	15	4	60	2	30	3	45
Reliability	40	3	120	2	80	2	80
Pumping Rate	20	2	40	4	80	1	20
Total	100	N/A	295	N/A	240	N/A	245

Rating	Value
Satisfactory	0
Just Tolerable	1
Adequate	2
Good	3
Very Good	4

Pump one was picked based on the results of the Weighted Rating Method.

This pump is easy to use and affordable.

By choosing this pump, the complexity of the irrigation system is significantly reduced.

Pump Specifications

- Pacific Hydrostar 1" Clear Water Pump

Horsepower (hp)	1.5
Impeller Material	Aluminum Alloy
Maximum Discharge Flow (gph)	2220
Maximum discharge flow (gpm)	37
Maximum Discharge Pressure (psi)	45.5
Self priming	Yes
Submersible	No

Calculations

Hazen – Williams Equation

$$V = kCR^{0.63}S^{0.54}$$

where:
V is velocity
k is a conversion factor for the unit system (k = 1.318 for US customary units, k = 0.849 for SI units)
C is a roughness coefficient (150 for PVC and Plastic)
R is the hydraulic radius
S is the slope of the energy line (head loss per length of pipe or h_f/L)

The Equation must be modified to solve for volumetric flow rate.

Hazen Williams Equation for Flow in Pipe due to Gravity

$$Q = \left(\frac{h_f c^{1.85} d^{4.87}}{10.67L}\right)^{0.54}$$

$$Q = \left(\frac{2 * 150^{1.85} 1^{4.87}}{10.67 * 20}\right)^{0.54}$$

$$Q = 11.986\ gal/min$$

$$Q = 719.16\ gal/hour$$

$$Q\ for\ Pump\ is\ 2220\ gal/hour$$

Pacific Hydrostar: Empty and Fill Times	
Time to Fill	Time to Empty
4:03	2:51

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

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

Fabrication

Up Until Now

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

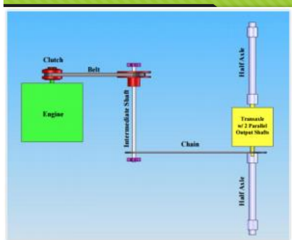
In Progress

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

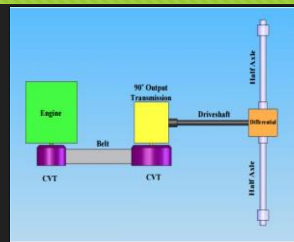
Drive Train

Christopher Steward

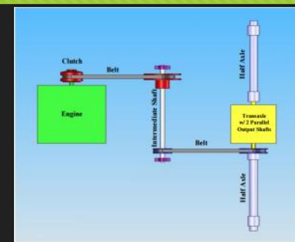
Design Concepts



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



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



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

Design Comparison's

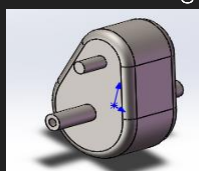
Rating	Value
Satisfactory	0
Just Tolerable	1
Adequate	2
Good	3
Very Good	4

Decision Criteria	Weight Factor	Concept 1		Concept 2		Concept 3	
		Score	Rating	Score	Rating	Score	Rating
Fabrication Time	0.2	4	0.6	3	0.6	4	0.8
# Extra Components	0.2	3	0.6	3	0.6	3	0.6
# of Parts	0.2	4	0.8	2	0.4	3	0.6
Manufacturing Cost	0.15	4	0.6	2	0.3	4	0.6
Appeal	0.1	3	0.4	2	0.2	2	0.2
Safety	0.15	4	0.6	4	0.6	4	0.6
		Total	3.6	Total	2.7	Total	3.4

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

Drive Train Equipment

Actual drawing

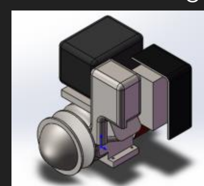


Solidworks drawing

Transmission: Tuff Torq KT35

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

Actual drawing



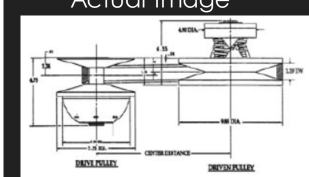
Solidworks drawing

Engine: 10 HP INTEK I/C

- Electric ignition for quick start
- Bore: 3.12 in.
- Stroke: 2.43 in.
- Oil Capacity: 28 fl. oz.

Drive Train Equipment

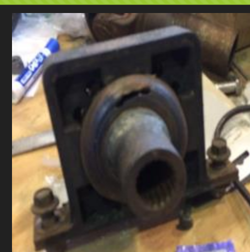
Actual Image



Solidworks drawing

Comet 770 Series Centrifugal Clutch

- The pulley ratios on the clutch are:
  - Low: 3.95: 1
  - High: 0.76:1



Actual image

Solidworks drawing

Intermediate shaft and mount

- Custom Made
- Donated from Dave Conrad
- Connects chevy s-10 transaxle to 4x2 John Deere gator transmission

Fabrication & Modifications

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

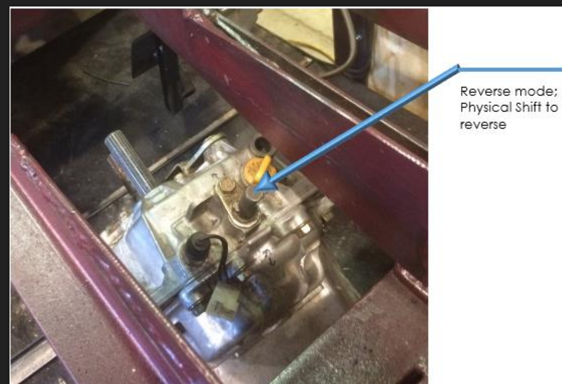
- SF: 3
- hold 65lb Transmission up off the ground

Current Progress

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

Proof of Design

- Light Weight angle iron Material
- 10 inch ground clearance
- 2840lbs Payload, w/ 20 degree incline
- Cargo Bed area is approx. 20 ft^2
- Production Cost is relatively low; under $2000
- 10 hp engine: Product Specification Sheet (Drive train)
- Will have a reverse mode Physical Shift to Reverse: Visual Verification (Drive Train)



Up-to-Date Schedule

Task	Project Date	Actual Date
Design Agreement	10/5/2016	10/5/2016
Separation of Duties	11/9/2016	11/9/2016
Bill of Materials (BOM)	11/18/2016	12/18/2016
Design Phase	12/14/2016 – 2/12/2017	12/14/2016 – 2/24/2017
Oral Presentation	2/13/2017	2/13/2017
Design Modification	2/13/2017 - 2/20/2017	2/13/2017 - 2/27/2017
Fabrication	2/13/2017 – 3/20/2017	2/27/2017 - ongoing
Testing	3/13/2017 – 3/27/2017	4/3/2017 - ongoing
Modifications	3/27/2017 – 4/3/2017	4/4/2017 - ongoing
Final Testing	4/1/2017 - 4/6/2017	N/A
Tech. Expo	4/7/2017	4/6/2017
Final Presentation	4/14/2017	4/14/2017
BUV Competition	4/22/2017	4/22/2017

Up-to-Date Budget

Total Cost of Production = $1,555.40

Bill of Materials			
Component	Material	Cost ($)	Total Cost ($)
Frame & Chassis	Chevrolet S10 Frame	Donateded by U-Pull & Pay	
	Plywood (1/4 1/2 & 3/4 In.)	$73.51	
	Bolts and Nuts	$159.36	
	Angle Iron (3x2x3/8 in & 2x2x3/8 in)	$221.67	$454.54
Suspension	Wheel Hub Slugs M12 x 1.5 x 3 Inch	$20.45	
	Front Wheel Hub and 14 In. Rim	$123.77	
	Wheel Nuts	$63.44	
	Flex Joint and Steering Bar	$49.72	
	Steel Plate and 2x2 inch Angle Iron	$42.80	
	Special M12 x 1.5 x 110 mm Bolts X4	$27.64	
	Steering Hub (From David Conrad)	$65.00	$392.82
Brake System	Hydrualic Hose adapter 3/8-24 NPT to 3/4 I	$4.47	
	Hose Plug 3/4 ID.	$2.66	
	Hydrualic Joint Plug 3/8-24 Brass	$12.06	
	Brake Hose Flex 3/8 - 24 Hose X 24 In. X 2	$24.58	
	Brake Shoes, Brake Cylinders X 2	$64.68	
	Brake Lines	$41.42	
	Hydrualic Line Adapter	$14.53	$164.40
Irrigation System	3 Barrels	Provided by UC	
	PVC Adapters	$7.14	
	Bushing	$4.14	
	PVC Thread	$11.64	$22.92
Drive Train	Engine	Provided by UC	
	Transmission	Provided by UC	
	Powershaft	Provided by UC	
	Transaxle	Provided by UC	
	Differential Cover for Chevy S10, DOT 3 Dif	$60.30	
	Wilwood Master Cylinder X 2	$105.21	
	Axle Drive Shaft Coupler	$46.67	
	1 X 1 X 40 In.Angle Iron	$20.99	
	Drive Train Coupler	$65.00	
	U-Bolts and Screws	$10.00	
	Aluminum Sheet Metal	$6.00	$314.17
Other/Miscellaneous	Sand Paper and Disposable Glove	$14.96	
	Hand Drill and Drill Bits	$79.10	
	Truck Rental	$20.14	
	Welding Wire 11 Lbs X 2	$30.35	
	Spray Paint	$62.00	$206.55
	Competition Registration Fee	Donated	
		Total BUV Production Cost	$1,555.40

Current Build

Current Progress

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

Competition Expectations

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

Recommendations

- Design for a better Ground Clearance
- Develop drive train frame while other fabrications are taking place
- Don't wait for chassis to complete to being working drive train
- Better Front Wheel Selection to eliminate pivot point issues
- Instead of current water pump use an electric pump and connect to the battery.

Overview

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