Basic Utility Vehicle (BUV)
Team

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

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Bachelor of Science

in Mechanical Engineering Technology

by

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Thesis Advisor: Professor Moise Cummings

2017 Basic Utility Vehicle – Drive Train

Christopher Steward

Final Senior Design Report

UC Basic Utility Vehicle Competition Team

Group Member: Deamann Strefas, Dickson Opoku, Bethany Nickson, Guanchun Ye

Academic Advisor: Moise Cummings

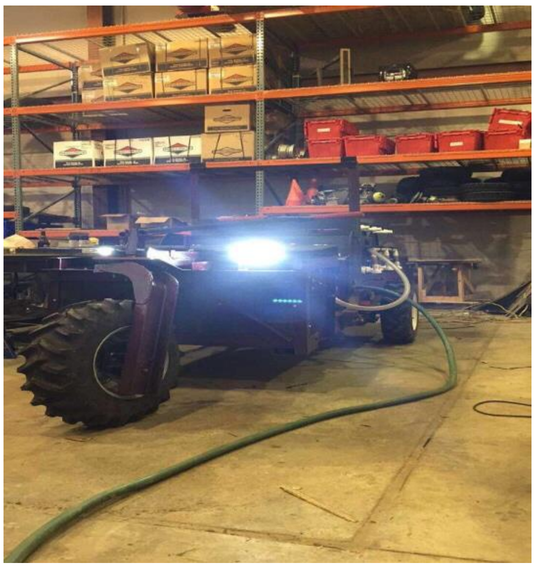

Figure 0: Completed 2017 BUV

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Acknowledgements

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Also, this senior design project would have not been completely without the help of Professor Dave Conrad, who's help in the workshop allowed for this project to be completed on time. Professor Conrad allowed us to use a transmission, engine, clutch and drive belt for free. Special Thanks to Pull-and-Pay for donating the rear frame and driveshaft of a Chevy S-10.

Finally, this would not have been completed without the support and encouragement of the friends and family of the team members. Special thanks to Emerging Ethnic Engineers Director, Cheryll Dunn for donating $250 so our team could register to participate in the BUV competition.

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ABSTRACT

The Institute for Affordable Transportation (IAT) has made a commitment to improve the quality of life in third world countries. IAT has done this through the Basic Vehicle Utility (BUV) Competition, where students design and build vehicles to be used in the third world countries. This year the competition was geared toward developing a 3-wheel vehicle that is used to transport and refill water over a rugged terrain. The design must be easy to assemble and inexpensive. The students took their designs and finished vehicles to the competition in Batavia, OH during the weekend of April 21th – 22th, 2017.

The Basic Utility Vehicle is broken up into five subassemblies. Those assemblies were drive train, chassis, suspension, brake system and irrigation system. Christopher Steward was responsible for the drive train development and Tech Expo presentation, Dickson Opoku was responsible for the front wheel suspension as well as the team welder. Guanchun Ye was in for steering, braking, machine shop fabrications and 3-D modeling. Bethany Nickson was responsible for developing the chassis and final product presentation. Deamann Strefas was the team leader, he was responsible for making sure all tasks were meet on time, as well as the development of the irrigation system.

To find the best possible design the team conducted surveys to get the best customer input. From the surveys, customer requirements were defined and product objectives were formed. The following were the product and competition requirements for the drive train section of the BUV that became the proof of design, which were: the ability to reach a top speed of 20 mph on grass, carry a payload of at least 1400 lbs. at a 15-degree angle slope, use an engine with a maximum output of 11 HP, and the capability of moving in a forward and backward direction.

Finally, once the fabrication and assembly process was completed, the testing process began. Testing was performed at the BUV competition before the team competed. The final cost to produce the BUV was $1555.40. The budget was cheaper than that of previous teams because of the donations that were given to the team.

Overall, the team stayed on schedule for 75% of the time. The team fell behind schedule because of a late state to the fabrication process. The team finished the vehicle in time for the competition on April 22nd and presented the vehicle to their peers, the Mechanical Engineering Technology Department, College of Applied Science, and the public on April 6, 2017 at the College of Applied Science Tech Expo. The final presentation for this senior design report was completed on April 14th, 2009 with the final report due on April 25th, 2017.

In the end the, BUV front wheel suspension broke during the race and was unable to finish the competition.

Introduction

Problem Statement

Every year since 2001 the Institute of Affordable Transportation (IAT) has held a Basic Utility Vehicle (BUV) competition. IAT is a non-profit organization located in Indianapolis, IN that is devoted to developing high-quality, low-cost transportation. The BUV should be developed to provide a durable, low cost vehicle that can be built and maintained in a third world country. The vehicle is designed for mobility, to transport people, water, and various other materials. 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 around April 2017.

We have delegated responsibilities for this project, however, we will be working closely as a team and that includes sharing ideas and supporting roles. I am responsible for the frame and chassis components. We are working closely with Professor David Conrad on every step of this project to ensure that we meet our time and design goals.

RESEARCH & BACKGROUND

Over the past 16 years there have been various designs in the Basic Utility Vehicle Competition hosted by IAT. The more recent submissions have yielded the best performances. Regarding the frame, the chassis has been highlighted as a 4-wheel design and later transformed to a 3-wheel design. I received information from previous BUV

Figure 1: First IAT BUV Competition Winner (2001)

competition teams and the BUV Club at UC and designs of past competition winners.

Figure 2: Current BUV in Production

Figure 3: Purdue BUV

(2012, 1st Place Winners)

In 2012, Purdue University came in 1st place at the IAT BUV Competition. The materials they used were mostly wood and angle iron. This made their BUV lighter in weight which would help to increase their overall speed. Since then, many teams have used angle iron for the chassis.

Also, in 2012, UC's BUV team used a small truck frame with a custom front end. We are aware that the weight of the vehicle is crucial to the overall performance and efficiency. My focus is aimed at designing the front-end chassis with angle iron that is low in weight with high in strength. This will in return increase the overall speed, lower costs, and increase efficiency.

Figure 4: UC BUV

(2012, 2nd Place Winners)

In 2013, the Senior Project BUV team proved their innovative and creative skill set by coming in 3rd place at the competition. A few of their technical specifications include an angled Iron frame and a 2000-pound payload. The use of wood and angle Iron helped to reduce the cost and weight of the BUV. (Wells, 2013) They recommend that future groups continue using the frame, chassis, truss design, and angle Iron for future models. (Wells,2013) Problems they encountered were a broken PVC barrel rotating out of place and front design of the suspension wasn't fit for a 3ft drop. (Stoll, 2013) They also suggested that future teams secure barrels before working on irrigation system and design the front suspension.

CUSTOMER PROFILE

The 2017 UC BUV team is focusing on improving items such as good gas mileage, hauling capacity/cargo capacity, ability to handle rough terrain, and ease of maintenance. We are designing our BUV to be affordable (less than $6500), durable (automotive parts), and utilizing (power pump, mill, compressor etc.).

Customer Features

Our main goal of the BUV Team is to develop a durable, low cost vehicle that can be built and maintained in a third world country. We must keep in mind that this vehicle will be used for transporting water and cargo, used in off road conditions, and have at least a 10-year life expectancy. We are developing our BUV to be shipped in the form of a kit and easily maintained over time.

Competition Guidelines & Events

The 2017 IAT BUV Competition will be held on Friday & Saturday April 21st and 22nd at 2630 Herold Road in Batavia OH. Teams will be competing to finish an obstacle course where they must transport up to 150 gallons of water. This will be done by pumping pond water into vehicle irrigation system, carrying it for 3 full laps on a 2.2-mile course, and dumping and refilling back at the pond. This cycle will carry on for 7 hours.

See full IAT BUV Specifications in Appendix F

Product Objectives

In late April, we will test how well our BUV performs in the 2017 BUV Competition. During the 7-hour contest, the BUVs will run through an obstacle course in off-road conditions transporting water. Throughout our design, we will implement a variety of ways to improve past designs and effectively implement safety, easy maneuverability, comfort, quick and easy maintenance, and reliability. This can also be found in Appendix C

Table 1: Customer Features & Importance Ratings

	Customer Feature	Customer Importance Rating
1	Reliability	0.25
2	Price	0.15
3	Cargo Space	0.15
4	Easy Maintenance	0.15
5	Easy Assembly	0.10
6	Safety	0.08
7	Maneuverability	0.07
8	Other Capabilities (towing, etc.)	0.05

Proof of Design Objectives

- Able to reach a top speed of 20mph on grass
- Carry a minimum payload of 1400lbs on a 15-degree angle slope
- Use an engine with a maximum output of 11 HP
- Move in a forward and backward direction

Based on the objectives, three design concepts were produced to meet the guidelines of the competition. Then, these objectives were measured and tested to prove whether the designs fulfilled the needs of the IAT competition.

Project Management

Team Member Responsibilities:

- Christopher Steward – Drive Train: Engine, Transmission, Drift Shaft
- Bethany Nickson – Chassis and Frame
- Dickson Opoku- Front Wheel Suspension, Steering
- Deamann Strefas- Irrigation System (Team Leader)
- Guanchun Ye- Brake system, Electrical

Schedule:

Table 1: 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 – 4/20/2017
Testing	3/13/2017 – 3/27/2017	4/3/2017 – 4/21/2017
Modifications	3/27/2017 – 4/3/2017	4/4/2017 – 4/20/2017
Final Testing	4/1/2017 - 4/6/2017	4/21/2017
Tech. Expo	4/7/2017	4/6/2017
Final Presentation	4/14/2017	4/14/2017
BUV Competition	4/22/2017	4/22/2017

Budget:

Table 2: Budget

	Estimated Cost	Actual Cost
Frame / Chassis	$220.00	$454.54
Braking	$200.00	$164.40
Suspension	$160.54	$392.82
Drivetrain	$350.00	$314.17
Irrigation	$161.01	$22.92
Assembly Tooling	Free	N/A
Others / Miscellaneous	$100.00	$206.55
	Total = $1,091.55	$1,555.40

Design Management

Design Concept 1: Clutch- Chain Drive

Preliminary design concept 1 can be seen in Figure 5. This concept incorporates an engine that drives an intermediate shaft via a centrifugal clutch. The intermediate shaft in turn drives a transaxle via a chain drive.

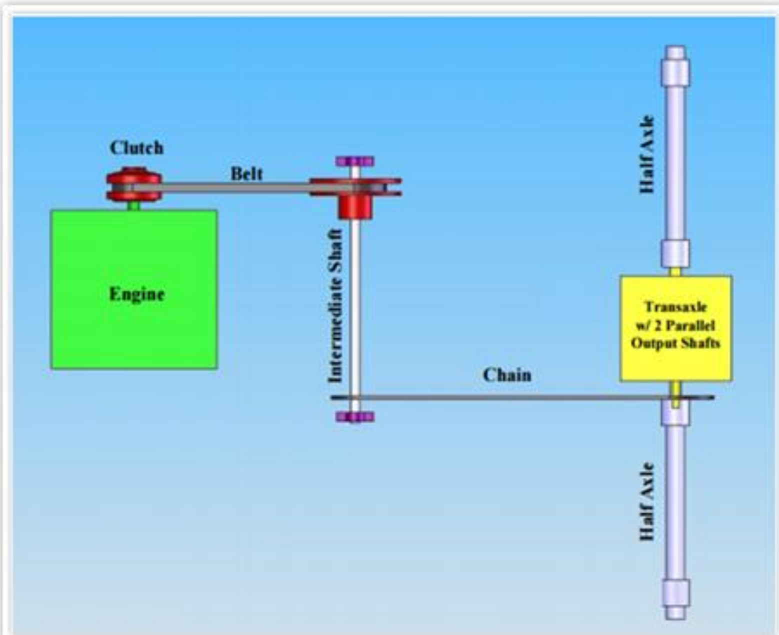


Figure 5: Design Concept 1: Clutch – Chain Drive 2008

This design is simple and minimizes the number of customized components needed for the vehicle to run. Aside from a mounting frame, the only major manufactured component needed for this design would be the intermediate shaft. The transaxle would have a forward, neutral and reverse gear selection. Because this design incorporates a chain drive means that regular lubrication will be required, and the chain will need to be protected so that will not be contaminated by outside elements. Using a transaxle would require the differential to be removed from the Chevy s-10 frame.

DESIGN CONCEPT 2: CLUTCH – BELT DRIVE

Preliminary design concept 2 can be seen in figure 6. This concept incorporates an engine that drives an intermediate shaft via a centrifugal clutch. This design differs from the first concept in that the intermediate shaft in turn drives a transaxle via a belt drive rather than a chain.

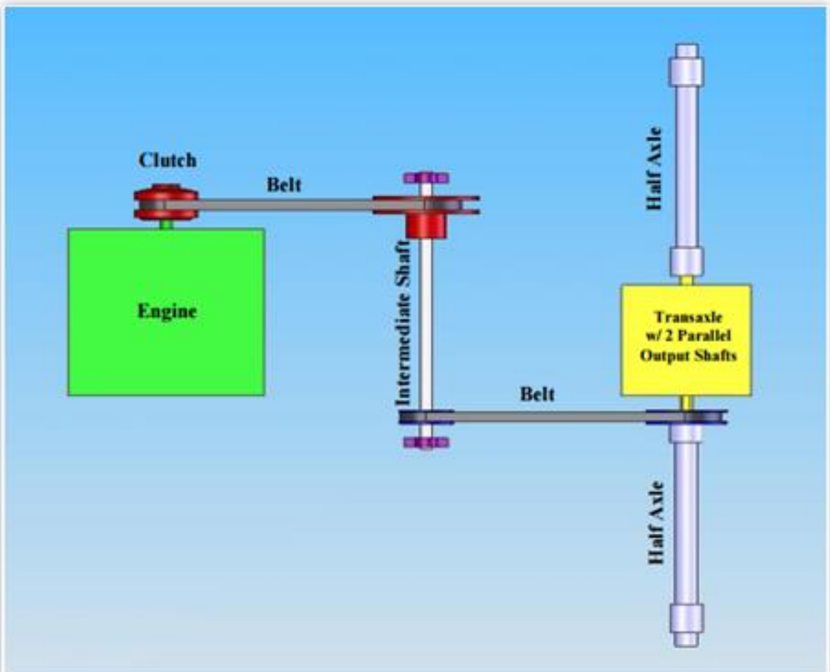


Figure 6: Design Concept 2: Clutch – Belt Drive 2008

This concept would incorporate the same engine, centrifugal clutch, and transaxle from the previous concept. Like the previous concept, the only major manufactured component besides a mounting frame would be the intermediate shaft. The major downside to this concept would be the use of a timing belt because of the high amount of tension that must be constantly maintained between the drive and driven sheaves. This will promote a faster wear on the intermediate shaft as it will have higher bending force acting on it. The primary advantage of using a timing belt drive is that once it is installed, there is no need for major maintenance.

DESIGN CONCEPT 3: CVT – DRIVESHAFT

Preliminary design concept 3 can be seen in figure 7. This concept incorporates an engine that transmits power to a transmission using a CVT. From the transmission, a driveshaft transmits power to the differential.

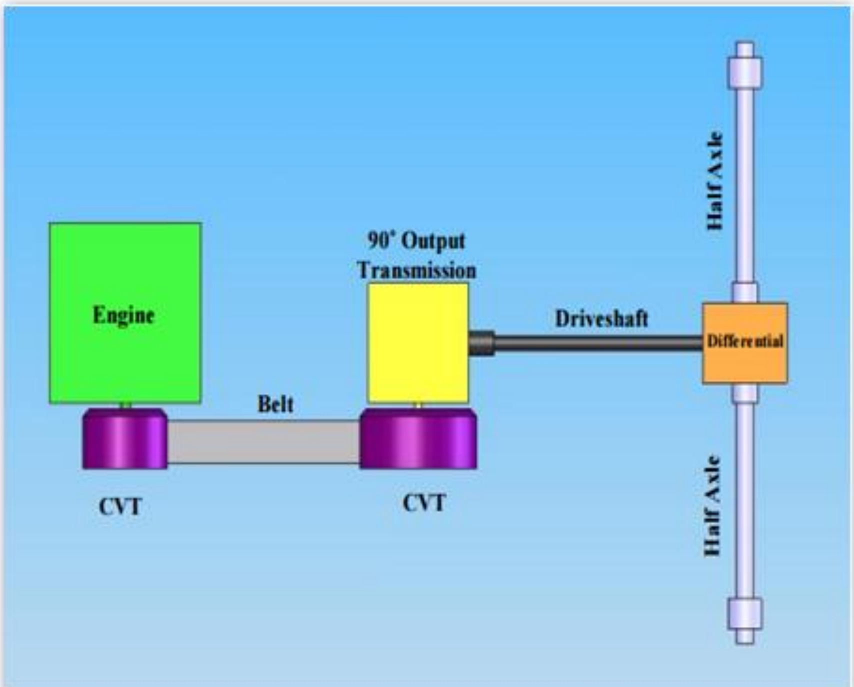


Figure 7: Design Concept 3: CVT – Driveshaft 2008

This design is slightly more complex than the other two concepts but easier to manufacture based on resources available. The transmission would have two speed selections; a low gear would be selected to begin moving a heavy load when water is in the barrels while a high gear would be selected to get the utility vehicle up to top speed. The driveshaft would have to be custom made to fit the output shaft on the transmission and the input of the differential. This setup would be quite expensive in comparison to the other two designs since there are more costly components. The main advantage of using a driveshaft is that there would be no need to remove the existing differential from the truck and it eliminates the opportunity for outside contaminant ruining the drive train system.

Design Selection

Of the three preliminary design concepts explained in the previous section, one needed to be selected for actual fabrication of the drivetrain. It makes sense that the chosen concept should provide the best possible solution to the design problem, so selection tools of product development were employed. A decision matrix was created to come up with the best possible design. The weighted decision matrix is a method that uses weighted decision criteria and a scoring system to determine the best possible design. The weighted decision matrix for the drivetrain of the BUV is shown in table 4.

Table 4: Weighted Decision Matrix

Decision Criteria	Weight Factor	Clutch and Chain Drive		Clutch and Belt Drive		CVT and Drive Shaft	
		Score	Rating	Score	Rating	Score	Rating
Fabrication Time	0.2	3	0.6	4	0.8	4	0.8
# Extra Components	0.2	2	0.4	3	0.6	3	0.6
# of Parts	0.2	3	0.6	3	0.6	3	0.6
Manufacturing Cost	0.15	4	0.6	4	0.6	4	0.6
Appeal	0.1	2	0.2	2	0.2	2	0.2
Safety	0.15	4	0.6	4	0.6	4	0.6
		Total	3	Total	3.4	Total	3.4

The criteria and the weight factors used in the decision matrix came from the engineering characteristics that were determined earlier. Each concept was rated with a relative score on a scale from one to four (four being the best). The concept with the highest total rating was decided to be the best possible solution. It is shown that there was a tie between “Clutch and Belt Drive” and “CVT and Driveshaft” which both scored a total of 3.40 out of 4.00. Because of this, it was decided to combine parts of each concept to create beast possible option. Instead of using a CVT, it was decided to use a Clutch and Driveshaft concept.

DETAILED DESIGN

The detailed design of the drivetrain includes all the calculations used to determine sizes and configuration of all required parts as well as the selection of all purchased components. The design of the 2017 UC BUV team 4 required all the members of the team to work together and communicate clearly to one another to get the BUV manufactured. The dimensions of the drivetrain components needed to align with the frame and certain suspension components to ensure proper fit without interference. The detailed design of the drivetrain began with the selection of some of its main components.

Engine Selection

During the conceptual stage of the drivetrain development, UC donated an engine for our team to us at no cost. Because the engine met the competition guidelines, there were on other options that were looked at because it was free and in great condition. This engine was a Briggs and Stratton 10 HP-Series INTEK™ I/C®. This engine was used in previous years' competitions. From the success that it had in the past, it was the best fit for our team to use.

The engine meet all the design requirements of the competition. A housing unit was created to help with the connection of the engine, clutch and transmission. This engine has displacement of 18.6 cu. In., a bore of 3.12 in., a stroke of 2.43 in., a 1 gallon engine and an oil capacity of 26 fl. oz. The engine also weighs 52 lbs. and a rpm of 3600. Another cool feature that the engine has is a Maintenance-free Magnetron® electronic ignition for quick and dependable starts. All the information listed came from the specification sheet seen in **Appendix H**.

Figure 8: Briggs and Stratton 10 HP-Series INTEK™

TRANSMISSION SELECTION

When selecting the transmission, the same situation happened that happened with the engine occurred where the KT 35 Tuff Torq transmission was donated by UC. The transmission has a maximum travel speed of 20 mph and the speeds can be in a forward, neutral, and reverse motion. The transmission has two output shafts with a diameter 1.18 inches, which are located on opposite sides of each other and the input shaft is located on the one side with a size of 0.75 inches. The rear axle output was 360 ft-lbs. and the peak axle output was 1930 ft- lbs. The maximum tire diameter for this transmission is 25 inches. Another key aspect that the transmission has is internal disc brakes on each side. This allows an independent braking of each axle. The gear reduction on the transmission is 15:1. The team decided to go with this transmission due to its quality and because it was free. The transmission weighs 65 pounds which will affect the overall weight of the BUV, so a reinforced engine and transmission panel must be created to hold both components. The specification sheet for the KT 35 Transmission can be seen in **Appendix I**.

Figure 9: KT35 Tough Torq Transmission

REQUIRED GEAR RATIOS

When looking at the required torques and speeds of the BUV, the proper gear ratios needed to be calculated to determine if the proof of design objectives would be meet or not. The first calculations that had to be completed were the minimum torque and force to climb a 15-degree slope. The minimum force required was 1646 lbs. and the minimum torque required was 1777.68 ft- lbs. These calculations used a payload of 2840 lb. Next, after calculating the minimum torque and force, the minimum gear ratios were calculated. The minimum low gear ratio was 100:1 and this equation used the minimum torque and rated engine torque of 14 ft-lb. The minimum high gear ratio was calculated at 15:1. This calculation used the engine rpm of 3600, the 20 mph which is the highest speed the competition requires, and the expected tire diameter of 28 inches. After figuring the gear ratios for the other components, the BUV will not exceed the maximum speed of 20 mph. The BUV will achieve a maximum speed of 15.47 mph and a maximum torque of 1410 ft-lbs. The calculations for the remaining ratios can be seen in **Appendix J**.

CLUTCH SELECTION

When selecting a clutch, we chose to look at the 2009 BUV team. Their research showed that the other teams had great success with the centrifugal clutches. This clutch allows the driver not to have to engage the clutch manually. The clutch works by one pulley increasing its radius, the other decreases its radius to keep the belt tight. This allows for infinite number of gears ratios. UC supplied a Comet centrifugal clutch Model 770, which was ideal because both the clutch and transmission come from the same standard 4X2 John Deere gator. The engine rating for the 700 series is an engine up to 18 hp and has a rotational speed of 5,500 rpm. The pulley ratios on the clutch are at a low of 3.95: 1 and a high of 0.76: 1. This choice was perfect because it was essentially free, the team just had to purchase the input connector that's attached to the transmission. The specification sheet can be seen in **Appendix K**.

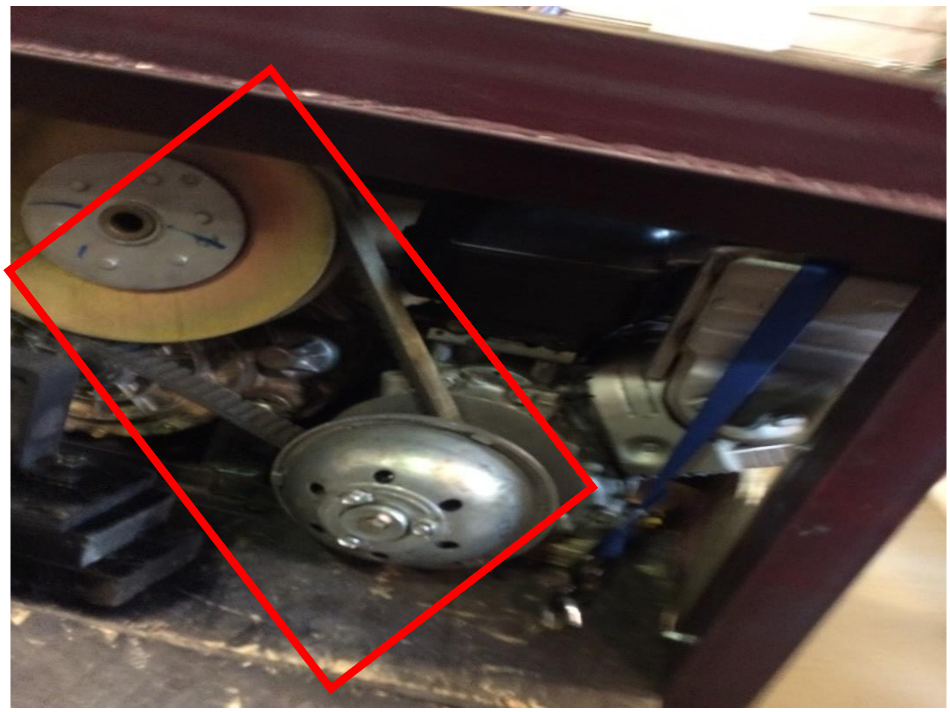


Figure 10: Comet centrifugal clutch Model 770

BELT DRIVE SELECTION

There are two primary types of belt drives available: V-belt drives and synchronous belt drives. Synchronous belt drives are typically more expensive than V-belt drives, but the belts and sheaves have mating teeth that will not slip even when wet. There where belts supplied by UC for the team to use, so ultimately the team went with the free synchronous belt. A picture of a common synchronous belt is shown below. Also, the synchronous belt must be installed under a high amount of tension since the belts are lined with Kevlar for high strength and durability.

Figure 11: Standard synchronous belt

The gear ratio of the synchronous belt drive was 1.45:1. Combining this with the gear ratios of the transmission and the centrifugal clutch, the final low gear ratio obtained was 85.9:1, and the final high gear ratio obtained was 16.5:1. These final performance specifications satisfied the requirements for the 2017 UC BUV competition, so connect the driveshaft of the Chevy S-10 to the John Deere gator transmission.

Connection of Driveshaft

The driveshaft was connected by using a coupler shaft and stand that was created by Dave Conrad. The stand had both an input and output connection that connected the driveshaft to the transmission. Below is a picture of the connection.

Figure 12: Manufactured coupler shaft

The drive shaft was then cut to the length needed to reach the coupler then welded on to coupler connector to make the connection complete. After that was complete, a housing unit was installed around the driveshaft to keep the driver from hitting it.

Figure 13: Driveshaft connected to transmission

Figure 14: Driveshaft cover

DESIGN SUMMARY

At the end of the design phase of the project, the list below of components was purchased based off the selection made:

- Engine: Briggs and Stratton 10 HP-Series INTEK™ I/C®
- Transmission: Tuff Torq KT35
- Clutch: Comet 770 Series Centrifugal Clutch
- Drive Belt: Standard synchronous belt
- Intermediate Shaft Stand and Connector: Custom Made by Dave Conrad
- Drive Shaft: Chevy S-10

After the selection, these parts were then modeled using Solidworks and added to the final design of the BUV. Guanchun Ye oversaw all 3-D and 2-D modeling. He also created a final rendering of an installation video of each component of the BUV.

Figure 15: Final 3-D rendered drawing of 2017 BUV

Fabrication and Assembly

The fabrication process for the drive train was from February 27th to April 21th. The reason for this long-time period was due to waiting for the chassis and frame to be properly installed. Things were constantly changed and that space that was needed was changed multiple times. The fabrication for all the manufactured parts was machined in the College of Applied Science North Laboratory under the supervision Professor Dave Conrad and his assistant Nick. The custom manufactured parts for the drive train where all made by Dave Conrad because he donated them to the team and will be retrieving them after the competition, these pieces where the driveshaft, and transmission to driveshaft coupler. Christopher Steward made engine and transmission frame housing. The material for the frame was cut also cut, drilled, and milled by Christopher, whoever Dickson Okopu welded the frame together. The drive shaft could not be machined and assembled until the transmission assembly, engine and clutch were placed in the BUV. The drive shaft was measured from the connection point at the transmission and rear clip of the S-10. Then the shaft was cut using a horizontal bandsaw. After the cutting process, the end adapter to the drive shaft was welded onto the shaft by Dave Conrad. Guanchun Ye designed and fabricated a shifter that would be used to change the motion of the BUV. By having Dickson Okopu weld most the BUV; the team saved a lot of money and time. On all the parts, a grinding wheel was used to clean up edges. The following is a list of the equipment used to machine the custom drive train parts.

- Welder
- Grinding wheel
- Lathe
- Drill press
- Horizontal bandsaw

Figure 16: Cincinnati drill press

Testing and Proof of Design

After assembly, some of the testing began at the College of Applied Science Victory Parkway lab, the rest of the testing took place before the competition on April 21st and 22nd. The tests at the college consisted of actual product specifications while tests at the competition consisted of physical tests.

Test Methods

There were four test methods that took place for the drive train. These objectives and methods of testing can be seen in table 5.

Table 5: Testing Methods

Product Objectives	Method of Testing
Max Speed of 20 mph	Stopwatch
Carry a payload of 1400lbs on 15-degree slope	Visual Verification
Use a 11 hp engine	Engine Specification Sheet
Will have ability to reverse	Physical Shift to Reverse and Visual Verification

Proof of Design Results

At the competition, the product objectives where all proven to be true. All results can be seen in table 6.

Table 6: Proof of Design Results

Product Objectives	Results
Max Speed of 20 mph	15mph on gravel (No grass was present)
Carry a payload of 1400lbs on 15-degree slope	1700lb payload at competition
Use a 11 HP engine	10 HP Gasoline Engine
Will have ability to reverse	Vehicle successful shifted and reversed

Conclusion and Competition Results

The team could successfully build a BUV in time for the competition. The team came together to build a successful BUV that could compete. Unfortunately, during the competition a bearing in the front wheel suspension broke because it was not properly secured with a screw. Because of this, we were unable to complete the competition as seen in figure 17.

Recommendations

The BUV had a successful drivetrain that could move in both a forward and backward direction. The engine and transmission performed great together and allowed the vehicle to run smoothly. The combinations of both design concepts really went well and was inexpensive because most the equipment was donated. I would encourage all teams to make use of donations because this can be a very expensive project. I would also encourage that there is a clear opening for a connected engine and transmission system to be placed in the vehicle. It was very difficult to design a drivetrain with very little space available. I would also suggest that everyone on the team help with each system instead of going missing when a system in finished. Having everyone together to help with assembly and fabrications would have made the process of building the BUV much better. If teams follow these recommendations, there is no way that their drivetrain will not be successful.

Figure 17: 2017 BUV Team with broken front wheel

Works Cited

1. AUGENSTEIN, Jeremy. 2009 Basic Utility Vehicle Drive Train. [online]. 31 May 2009. [Accessed 1 February 2017].
2. MALATESTA, Andrew. 2008 Basic Utility Vehicle Drive Train. [online]. 9 June 2008. [Accessed 1 February 2017].

Appendix A- Research

Initial Discussion with Professor Conrad and UC BUV team members

- Use differential and driveshaft of old truck frame (Chevrolet S10)
- Recommended going to U-Pull-&-Pay
- Using donated materials to save money (lightweight material)
- Create shifter to change vehicle direction

Discussion with Professor Conrad for Design Modifications

- Create strong transmission and engine frame
- Secure Engine and Transmission

APPENDIX B – HOUSE OF QUALITY

Interaction Matrix

Engineering Requirements	Engir	Paylo 1	Mater 2	Start/I 3	Hydra 4	Grour 5	Guard 6	Paint 7	Steeri 8	Metric 9	# of S 10	Weigh 11	0 12	0 13	0 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														

Engineering Requirements (units)

	Customer Requirements	ortan	Paylo 1	Mater 2	Start/I 3	Hydra 4	Grour 5	Guard 6	Paint 7	Steeri 8	Metric 9	# of S 10	Weigh 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																			

Customer Satisfaction Rating (0.00 - 1.00)

Performance		1	2	3	4	5	6	7	8	9	10	11	12	13	14
	oduct														
	competitor A														
	competitor B														
	competitor C														
	New Product Targets														

APPENDIX C – PRODUCT OBJECTIVES

	Customer Feature	Customer Importance Rating
1	Reliability	0.25
2	Price	0.15
3	Cargo Space	0.15
4	Easy Maintenance	0.15
5	Easy Assembly	0.10
6	Safety	0.08
7	Maneuverability	0.07
8	Other Capabilities (towing, etc.)	0.05

APPENDIX D – 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 – 4/20/2017
Testing	3/13/2017 – 3/27/2017	4/3/2017 – 4/21/2017
Modifications	3/27/2017 – 4/3/2017	4/4/2017 – 4/20/2017
Final Testing	4/1/2017 - 4/6/2017	4/21/2017
Tech. Expo	4/7/2017	4/6/2017
Final Presentation	4/14/2017	4/14/2017
BUV Competition	4/22/2017	4/22/2017

APPENDIX E – BUDGET

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 Diff	$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

APPENDIX F – COMPETITION SPECIFICATIONS

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.

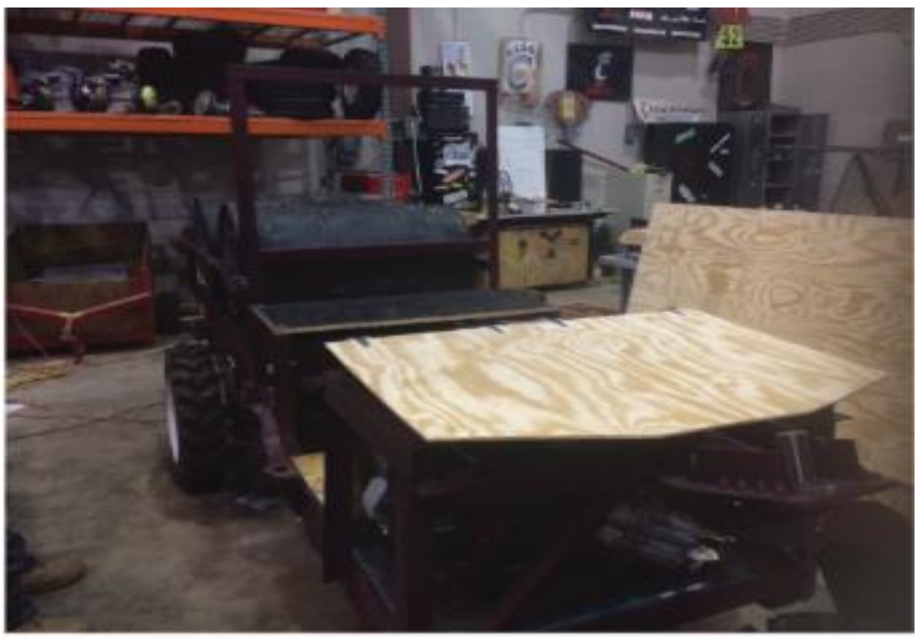
**** See Tech Inspection Sheet for deductions if this feature is missing**

August 11, 2016

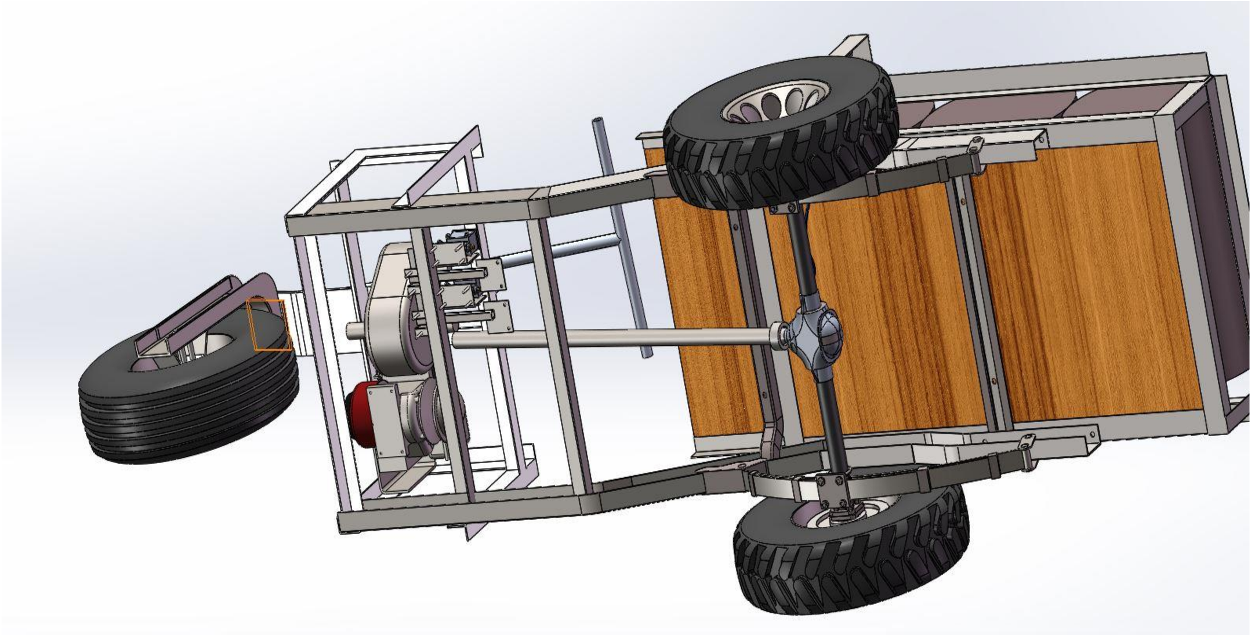
APPENDIX G – ASSEMBLY DRAWINGS

ISOMETRIC VIEW

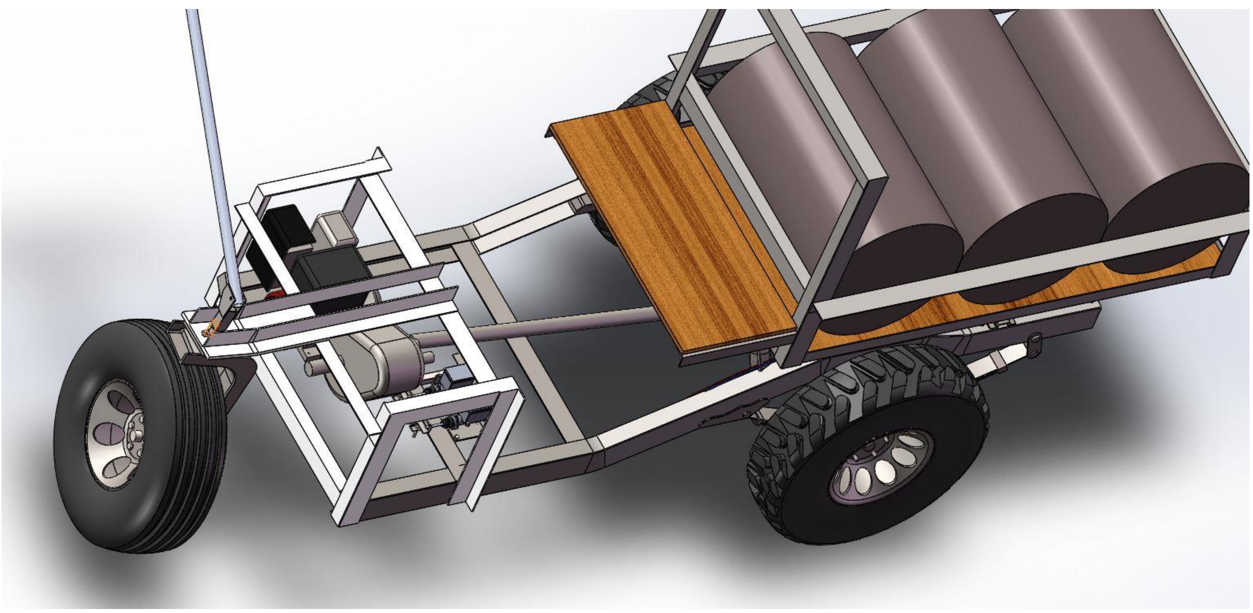
FRONT VIEW



Bottom View

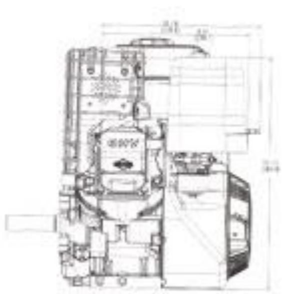


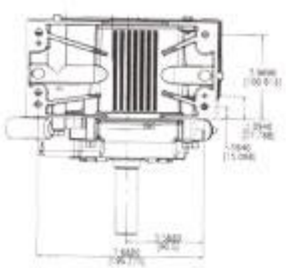
Top View

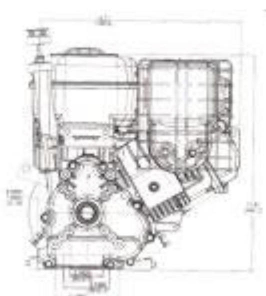


Appendix H- Engine Selection

Briggs and Stratton 10 HP-Series INTEK™ I/C®





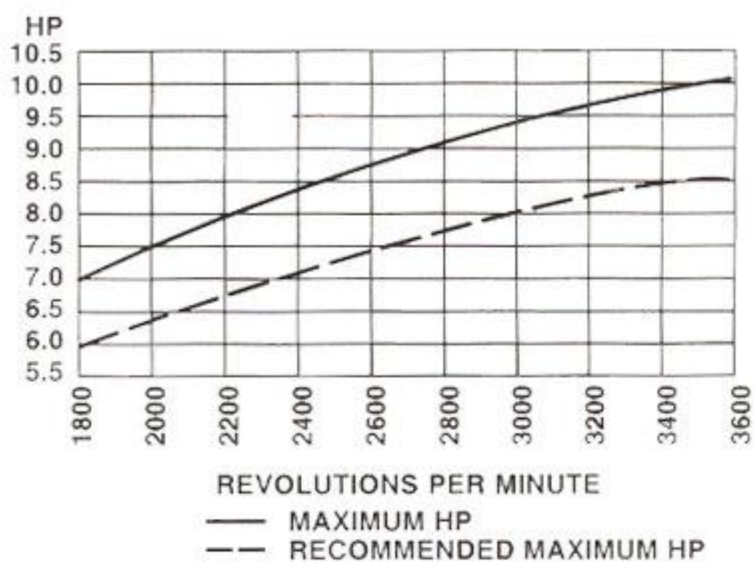


10 HP INTEK I/C ENGINES

- **Model Series 205400**
- Displacement 18.6 cu. in. (305 cc)
- Bore 3.12 in. (79 mm)
- Stroke 2.43 in. (61 mm)
- Oil Capacity 26 fl. oz. (0.70 l)

Features

- Dura-Bore™ cast iron cylinder sleeve for extended life.
- Maintenance-free Magnetron® electronic ignition for quick, dependable starts.
- Dual-Clean™ air cleaner pleated paper filter with a foam pre-cleaner ensures maximum protection for extended engine life.
- Overhead valve design (OHV) for cooler operation and longer valve life.
- Buyer protection package provides two-year consumer engine warranty.



Appendix I - Transmission Selection

KT35 Tuff Torq Transmission


TUFF TORQ®

DRIVING YOUR BEST IDEAS

All Terrain Vehicle & Transporters

KT35

Compact. Field Proven. Durable by Design. Built "Tuff Torq Tough," this rugged transaxle features full constant mesh forward, neutral and reverse shifting with automotive type bevel gears in the differential.

- Differential lock is standard.
- Neutral start switch is standard.
- Carburized gears are standard.
- Reinforced, high density die cast aluminum transaxle housing is standard.
- Ball and needle bearings throughout.
- Oil and liquid seal waterproofing.
- Wet disc brake on each output shaft.

SPECIFICATIONS

Application	All Terrain Vehicle & Transporters
Rated Axle Output	390 ft lbs
Maximum Tire Diameter	25 inches
Peak Axle Output	1930 ft lbs
Max. Input Speed	3700 rpm
Reduction Ratio	Forward: 15:1 – Reverse: 15.3:1
Output Shaft Size	1.18 inches
Weight	65 lbs
Speeds	Forward-Neutral-Reverse (full constant mesh)
Differential	Automotive Type, Bevel Gears Differential Lock Standard
Lubrication	Oil Bath with Filter Drain Plug Breather
Maximum Travel Speed	20 mph
Input Shaft Size	0.75 inches

TUFF TORQ.
6043 Commerce Boulevard
Morristown, TN 37814
423-585-1990
Fax: 423-585-2003
www.tufftorq.com

APPENDIX J – PERFORMANCE AND GEAR RATIO CALCULATIONS

A. Minimum Force to climb 15-degree slope when loaded

- where the payload is 2840 lbs.

Fmin = μ × Wt × cos (θ)
Fmin = 0.6 ft × 2840 lb × cos (15)
Fmin = 1646 lb

B. Minimum Torque required

- where the 1.08 ft is the radius of the wheel when loaded and with a flattening of 1"

Tmin = Fmin × r wheel
Tmin = 1646 lbs.× 1.08 ft
Tmin = 1777.68 ft- lbs.

C. Ideal Gear Ratios to obtain the desired performance

- Where the tire diameter is 28 inches, the engine rated rpm is 3600, and the top speed for the competition is 20 mph and the engine torque is 14 ft-lbs.

Min. High Gear Ratio = (rpm × tire diameter) / (mph × 336)
Min. High Gear Ratio = (3600 rpm × 28 inches) / (20 mph × 336)
Min. High Gear Ratio = 15: 1

Min. Low Gear Ratio = Torque min / Torque Engine
Min. Low Gear Ratio = 1412 ft –lb / 14 ft – lbs.
Min. Low Gear Ratio = 100: 1

D. Gear Ratios between the 700 Series Comet Centrifugal and the Tuff Torque KT 35

- Where the high gear ratio of the clutch is 0.76: 1 and the low gear ratio of the transmission is 3.95:1. The gear ratio for the transmission is 15:1. These numbers come from the product specification sheets.

High Gear Ratio = High gear ratio (Clutch) × Gear Ratio (Transmission)
High Gear Ratio = (0.76) × (15)
High Gear Ratio = 11.4: 1

Low Gear Ratio = Low gear ratio (Clutch) × Gear Ratio (Transmission)
Low Gear Ratio = (3.95) × (15)
Low Gear Ratio = 59.25:1

E. Final Performance Speed and Torque

Final Top Speed = (rpm × tire diameter) / (Final High Gear Ratio × 336)
Final Top Speed = (3600 rpm × 28 inches) / (19.38 × 336)
Final Top Speed = 15.47 mph

Final Torque = Torque engine × Final Low Gear Ratio
Final Torque = 14 ft-lbs. × 100.73
Final Torque = 1410 ft-lbs.

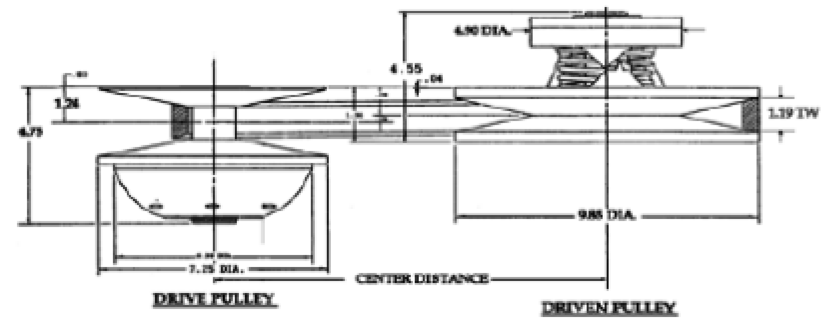
APPENDIX K - CLUTCH SELECTION

QDS 1/97

COMET INDUSTRIES

MODEL 770
AUTOMATIC
TORQUE CONVERTER

LAYOUT DIMENSIONS:



SPECIFICATIONS

ENGINE RATING: 2-Cycle - 30 H.P. ***MAX RPM:*** 12,000
4-Cycle - 18 H.P 5,500

BORE SIZES: DRIVE - 7/8",1",& 30MM TAPER
DRIVEN - 3/4",7/8",& 1" (note: Some splined bores on request)

PULLEY RATIOS: LOW - 3.95:1 (SHOWN ABOVE)
HIGH - .76:1
OVERALL - 5.20:1

NOTE: *NEVER OPERATE A TORQUE CONVERTER WITHOUT A SUITABLE SAFETY SHIELD.*

NOTE: *DO NOT RUN AN ENGINE EQUIPPED WITH A DRIVE PULLEY IF THE BELT IS NOT ENGAGED WITH THE DRIVEN PULLEY.*

DISTRIBUTED BY:

QDS P.O. BOX 6910, ALHAMBRA, CALIFORNIA 91802 TEL. (626) 293-6770 / FAX. (626) 281-3392

Basic Utility Vehicle

Advisor: Prof. Moise Cummings

Deamann Strefas, Dickson Opoku, Christopher Steward, Bethany Nickson, & Guanchun Ye

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

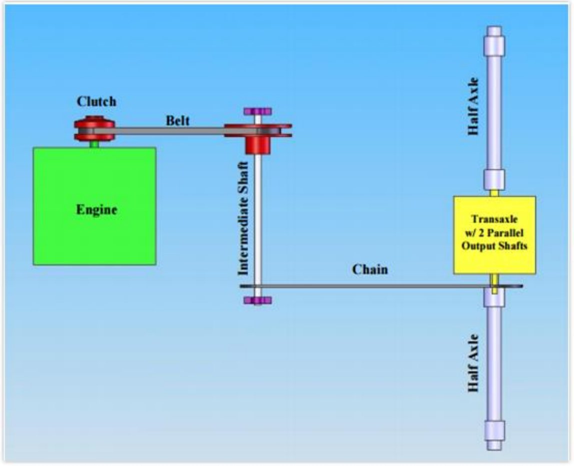
Safety
- high driver visibility
- speed limited to 20 mph
- low center of gravity

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

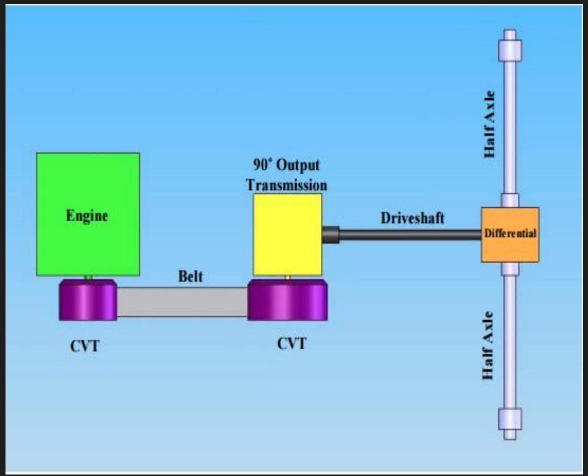
Drive Train

Christopher Steward

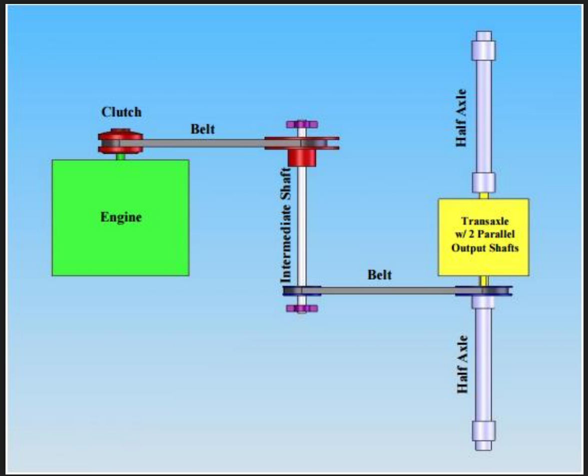
Design Concepts



- 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

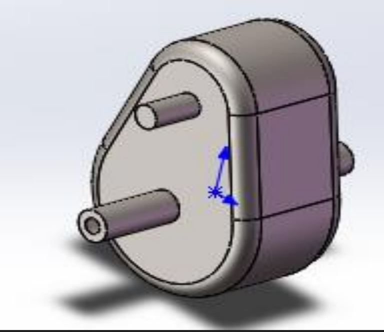
Rating	Value
Satisfactory	0
Just Tolerable	1
Adequate	2
Good	3
Very Good	4

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

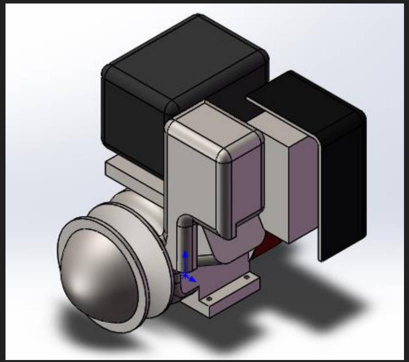


Solidworks drawing

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



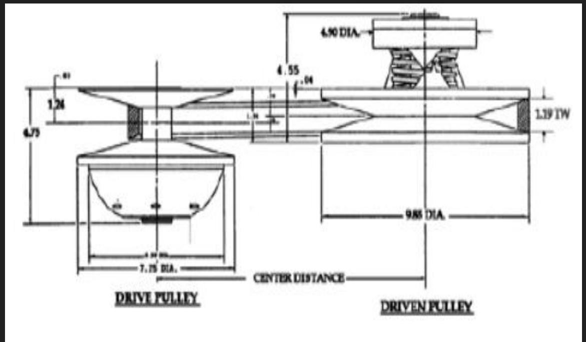
Solidworks drawing

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

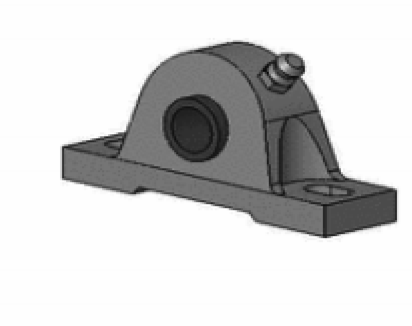


Solidworks drawing

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

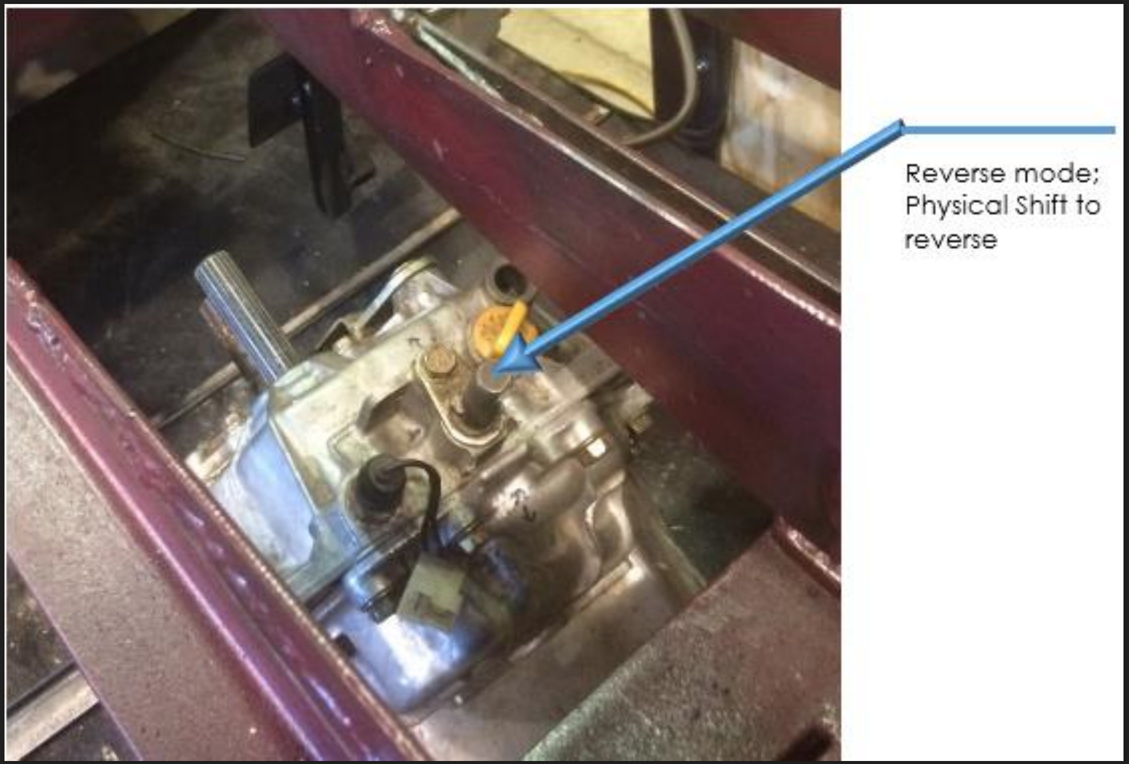
- SF: 3
- hold 65lb Transmission up off the ground

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)



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Up-to-Date Budget

Total Cost of Production = $1,555.40

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	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.

Questions