Basic Utility Vehicle (BUV)

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Bachelor of Science

in Mechanical Engineering Technology

by

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Thesis Advisor:

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TABLE OF CONTENTS

TABLE OF CONTENTS II
LIST OF FIGURES III
LIST OF TABLES III
ABSTRACT IV
PROBLEM DEFINITION AND RESEARCH 1
Problem Statement 1
RESEARCH 1
CUSTOMER FEATURES 2
PRODUCT OBJECTIVES 2
QUALITY FUNCTION DEPLOYMENT 3
DESIGN MANAGEMENT 4
Concept 1 – clutch-chain drive 4
Concept 2 – clutch-belt drive 4
Concept 3 – cvt-driveshaft 4
Design Selection 4
DETAILED DESIGN 5
Engine Selection 5
Transmission Selection 7
Clutch Selection 8
Driveshaft Coupler 9
Throttle 10
Finished Drivetrain 11
PROJECT MANAGEMENT 11
Team Responsibilities 11
Budget, proposed/actual 12
Schedule, proposed /actual 12
CONCLUSION 13
Results 13
Recommendations 14
WORKS CITED 15
APPENDIX A – IAT BUV DESIGN SHEET 16
APPENDIX B – BUV COMPETITION SPECIFICATIONS 17
APPENDIX C – DRIVETRAIN DRAWINGS 19
Engine 19
Transmission 19
Drivetrain Assembly 20
APPENDIX D – ENGINE SPEFICIFICATION SHEET 21

APPENDIX E – TRANSMISSION SPECIFICATION SHEET 22
APPENDIX F – CLUTCH SPECIFICATION SHEET 23
APPENDIX G – DRIVETRAIN CALCULATIONS 24

LIST OF FIGURES

Figure 1: QFD Diagram 3
Figure 2: Briggs and Stratton 10-HP Series INTEK I/C 6
Figure 3: Engine with base plate and support rails 6
Figure 4:Tuff Torq KT35 transmission mounted on rails 7
Figure 5: Comet Model 770 centrifugal clutch 8
Figure 6: Driveshaft coupler 9
Figure 7: Throttle pedal 10
Figure 8: Drivetrain 11
Figure 9: Completed BUV 13

LIST OF TABLES

Table 1: Concept Decision Matrix 4
Table 2: Budget 12
Table 3: Schedule 12

ABSTRACT

The concept of a basic utility vehicle (BUV) is a truck designed to be used in third world countries to provide simple transportation and utility. The goal is to be able to provide water and other resources in areas where normal vehicles are too expensive and there are no paved roads. The Institute of Affordable Transportation (IAT) puts on a competition every year for schools to design the best all-around BUV. This means a solid, simplistic design that allows for ease of manufacturing, maintenance and use as well as low cost, light weight, safety features, reliability, ability to haul barrels of water, high ground clearance to drive off road, and the use of standard automotive components. The IAT lays out specific design specifications for all teams to abide by such as size of the vehicle, drivetrain limits, and required safety features.

PROBLEM DEFINITION AND RESEARCH

PROBLEM STATEMENT

The project is to design a Basic Utility Vehicle. A basic utility vehicle is vehicle designed to help bring aid to people and communities in third world countries without access to basic necessities such as water. The design of this vehicle needs to be as simplistic as possible while abiding by the specifications laid out by the Institution of Affordable Transportation (IAT). Some of these specifications are low cost, agile performance, 1,750 lb payload and a 20 mph max speed.

RESEARCH

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

The success of a BUV depends on the weight of the vehicle, and the vehicle's ability to hold and transport large amounts of water. Because of this, the strongest, most lightweight material will be used to build the chassis and frame of this vehicle.

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

CUSTOMER FEATURES

- Affordable
- Durable
- 10-20 HP engine
- Max weight: 1,250 lb
- Payload: 1,750 lb

PRODUCT OBJECTIVES

- Coming in under budget ($6,500)
- Testing and finding optimal engine and drive train
- Finding most lightweight durable parts (Carbon fiber, aluminum, etc.)
- Speed tests with different loads
- Making sure vehicle is not bigger than allowed

QUALITY FUNCTION DEPLOYMENT

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

Figure 1: QFD Diagram

DESIGN MANAGEMENT

CONCEPT 1 – CLUTCH-CHAIN DRIVE

The first concept for the drivetrain would use a centrifugal clutch to drive an intermediate shaft. The shaft would operate a chain drive that would provide power to the rear through a transaxle. This would be a simple design that would be fairly easy to build and durable. The chain would need to be covered to protect it from dirt and debris and the Chevy S-10 rear axle would need to be replaced with a transaxle. However, this would make it so we would not need a separate transmission.

CONCEPT 2 – CLUTCH-BELT DRIVE

The second concept is similar to the first but it would use a belt to drive the transaxle instead of a chain. This would also be relatively simple to build and it would not require much maintenance. However, using a belt requires a constant amount of high tension and could lead to quicker part failure, especially on the intermediate shaft and it's housing.

CONCEPT 3 – CVT-DRIVESHAFT

The last concept is a more complex design that would use a CVT connected to a driveshaft. The driveshaft would then provide power to the rear axle through the differential. The benefit of this system would be that we could use the stock rear end from the Chevy S-10 and it would be reliable as no contaminants would be able to get into the drivetrain. The downside would be that it uses the costliest components, is more complex to build, and the CVT would only be able to transmit 90% of the power is receives from the engine.

DESIGN SELECTION

Decision Criteria	Weight Factor	Clutch-Chain Drive		Clutch-Belt Drive		CVT-Driveshaft	
		Score	Rating	Score	Rating	Score	Rating
Manufacturing Time	0.2	3	0.6	4	0.8	4	0.8
Cost	0.2	4	0.8	4	0.8	4	0.8
Number of Parts	0.2	3	0.6	3	0.6	3	0.6
Number of Extra Components	0.15	2	0.3	3	0.45	3	0.45
Safety	0.15	4	0.6	4	0.6	4	0.6
Appeal	0.1	2	0.2	2	0.2	2	0.2
		Total	3.1	Total	**3.45**	Total	**3.45**

Table 1: Concept Decision Matrix

After using the concept decision matrix to compare the different options, the clutch-belt drive and CVT-driveshaft combinations tied as the best drivetrain options. After discussing with Dave Conrad about the parts we had on hand to use as well as the complexity of the designs, we decided to combine these two combinations and use a clutch with a driveshaft. This is a layout used by teams in the past that has been simple and effective while reducing overall costs.

DETAILED DESIGN

ENGINE SELECTION

The engine for our BUV was provided to us by Dave Conrad. It is a Briggs and Stratton 10 HP-Series INTEK I/C that has been used in past years and is still in nice shape. It is a 10 hp gas engine which meets the criteria for the competition. Due to it meeting the criteria and being provided at no cost, this was the only engine we considered using. When deciding how to mount it to the car, we ended up making a long set of rails out of angle iron. This is because last year's team mounted the engine and transmission directly to the plywood floor which caused drivetrain issues when the belt tightened up and the plywood was not strong enough to withstand the strain. So our rails were made long enough to be able to bolt the engine as well as the transmission to them. We created a base plate to go between the base of the engine and the rails that was slightly adjustable so that we could move the engine to get the tension in the belt properly tight when mounting it in the car.

Some key features of the engine are that it weighs 52 lbs, operates at 3,600 rpm, has a displacement of 18.6 in^3, and has a one gallon gas tank. It also has a spring attached to the throttle lever to help return the throttle to idle when the pedal is not engaged. The full specification sheet is listed in **Appendix D.**

Figure 2: Briggs and Stratton 10-HP Series INTEK I/C

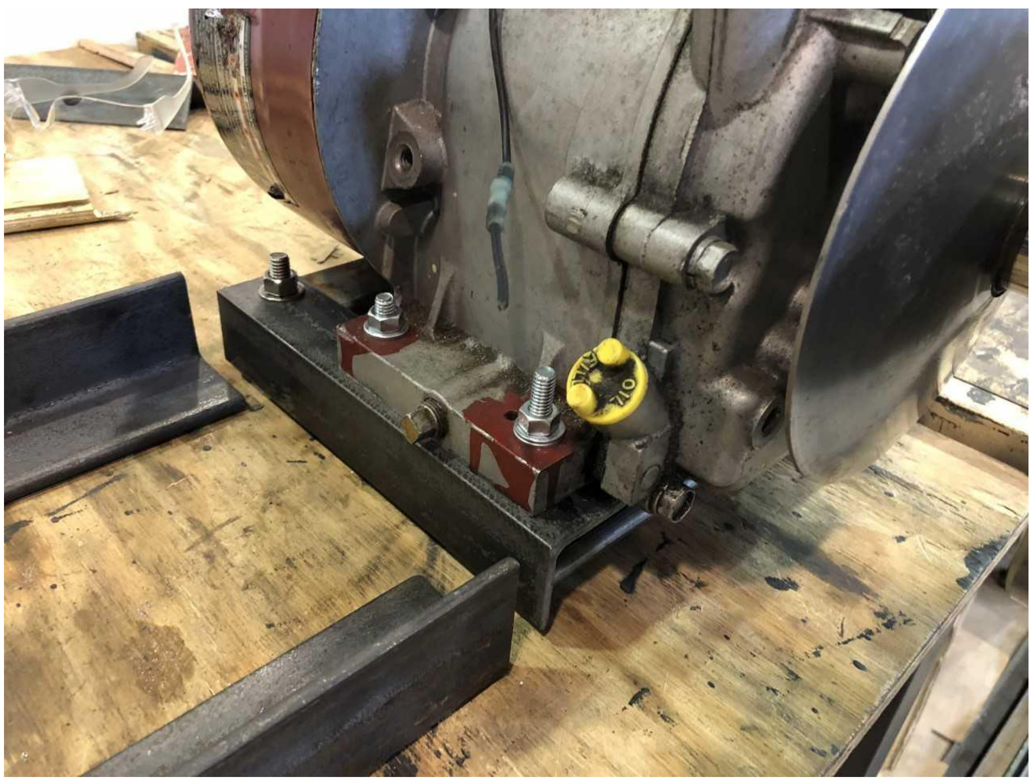


Figure 3: Engine with base plate and support rails

TRANSMISSION SELECTION

The transmission was another component used by previous BUV teams that was available for us to use. It is a Tuff Torq KT35 transmission that was originally used in a John Deere Gator 4x2. This is the perfect transmission to use because it has a maximum speed of 20 mph and has forward, neutral and reverse functions. This meets the competition criteria so we also decided to use this transmission for this reason as well as it being provided at no cost.

The transmission was mounted on the same angle iron rails as the engine for stability. It's mounting location was permanent since the engine was able to be adjusted for proper belt tension between the two. We had to make a J bolt out of a regular bolt to securely hold the output shaft selector clamp in place. This transmission has two output shafts and when the clamp is loose, the wrong output shaft is selected. Our J bolt made it so that correct output shaft would reliable be selected.

We also fabricated a simple shift lever to attach to the small shifter on the top of the transmission. It is a flat piece of steel with a round piece that slides over the shifter and attaches with two set screws. The long flat piece sticks out from under the hood and can easily be slid to the right for forward, middle for neutral, and left for reverse.

Figure 4:Tuff Torq KT35 transmission mounted on rails

CLUTCH SELECTION

The last major component of the drivetrain was the clutch. We used a Comet Model 770 centrifugal clutch that was included with the engine and transmission. It also was originally used with the Tuff Torq on a John Deere Gator so we know they work well together. It is compatible with engines up to 18 hp and can operate at up to 5,500 rpm so this works with the Briggs and Stratton engine. The other nice thing about this clutch is that it engages automatically based off throttle input so the driver does not have to manually engage it. The full specification sheet is in **Appendix**

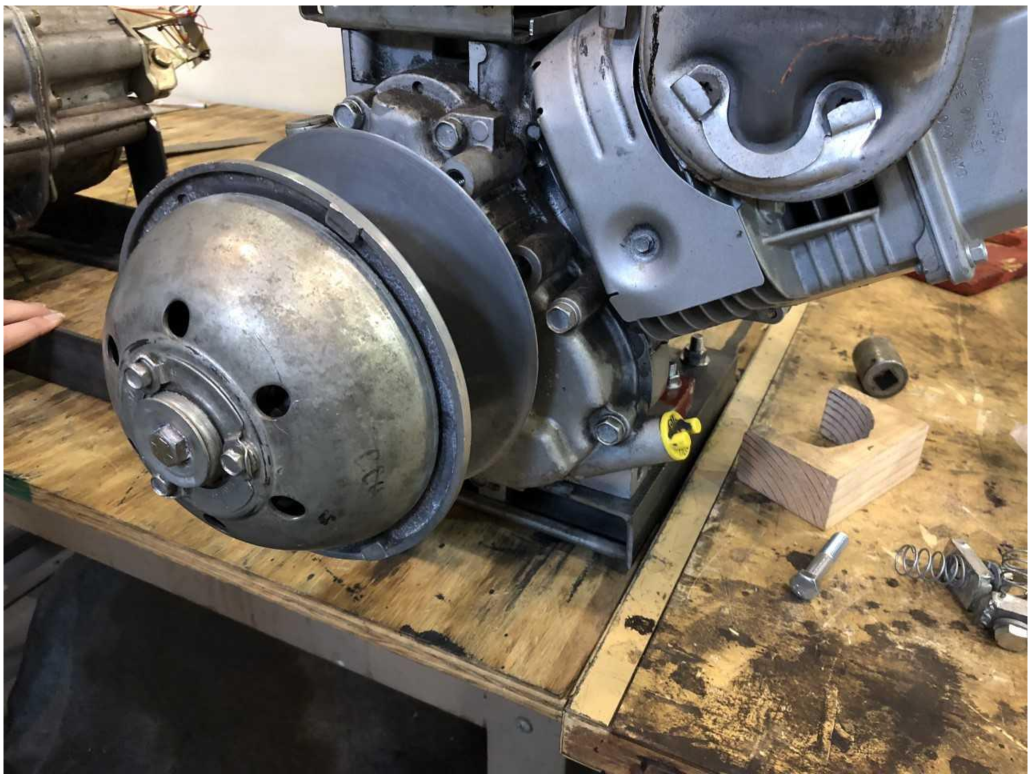


Figure 5: Comet Model 770 centrifugal clutch

DRIVESHAFT COUPLER

The only custom part that needed to be made in order to connect the Chevy driveshaft with the Tuff Torq transmission was a coupler that Dave Conrad made for us in the machine shop. It is a simple piece that has an input shaft on one side that the output shaft of the transmission slides into and then an output shaft on the other side that the driveshaft slides around. We bolted it down to some angle iron for stability at the height needed for the output shaft of the transmission. The universal joints in the driveshaft allow the driveshaft to have a lot of flexibility in where the coupler was positioned.

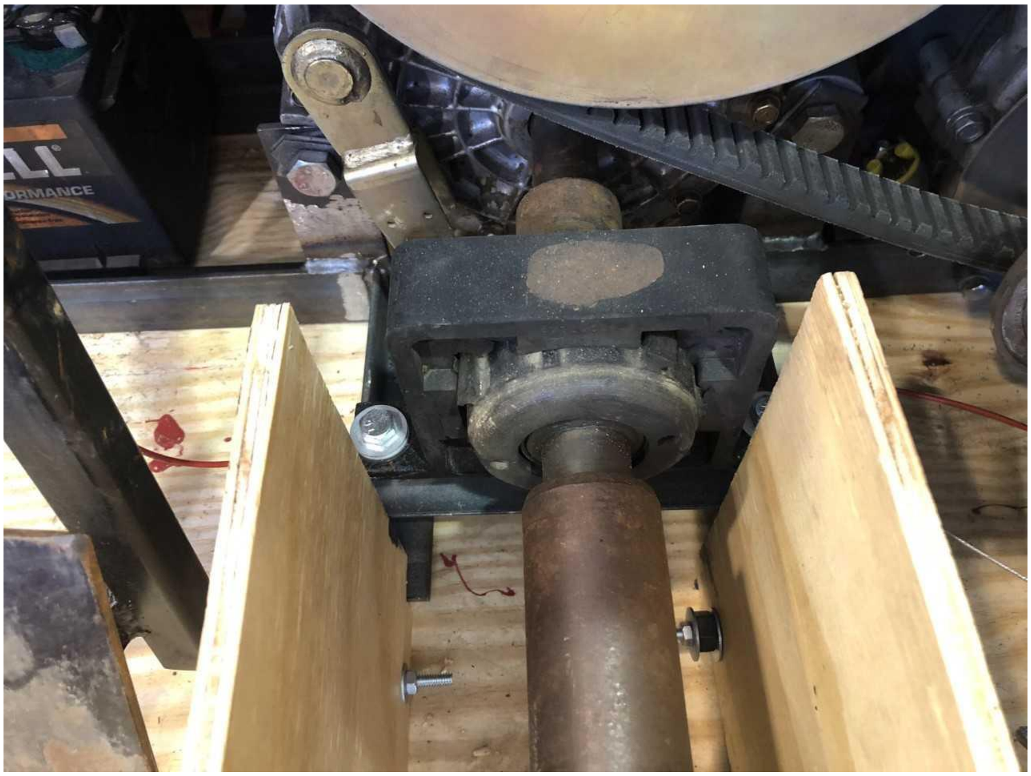


Figure 6: Driveshaft coupler

Throttle

The last piece of the drivetrain was making a throttle for the driver. We fabricated a throttle pedal using two pieces of angle iron. One piece serves as the mount which is bolted to the floor and the other piece serves as the pedal which is bolted to the end of the mount to create a hinge. We ran the throttle cable around the top of the transmission and out through a hole in the engine cage that comes out above the pedal. There is a support made of flat metal that stops the wire housing and allows the wire itself to pass through and this is then attached to the top of the pedal. The spring on the throttle lever makes it so the pedal stays up when no throttle is being used. Lastly, we installed a bolt in the throttle mount that serves as a stop so the pedal can't travel further than it needs to for full throttle.

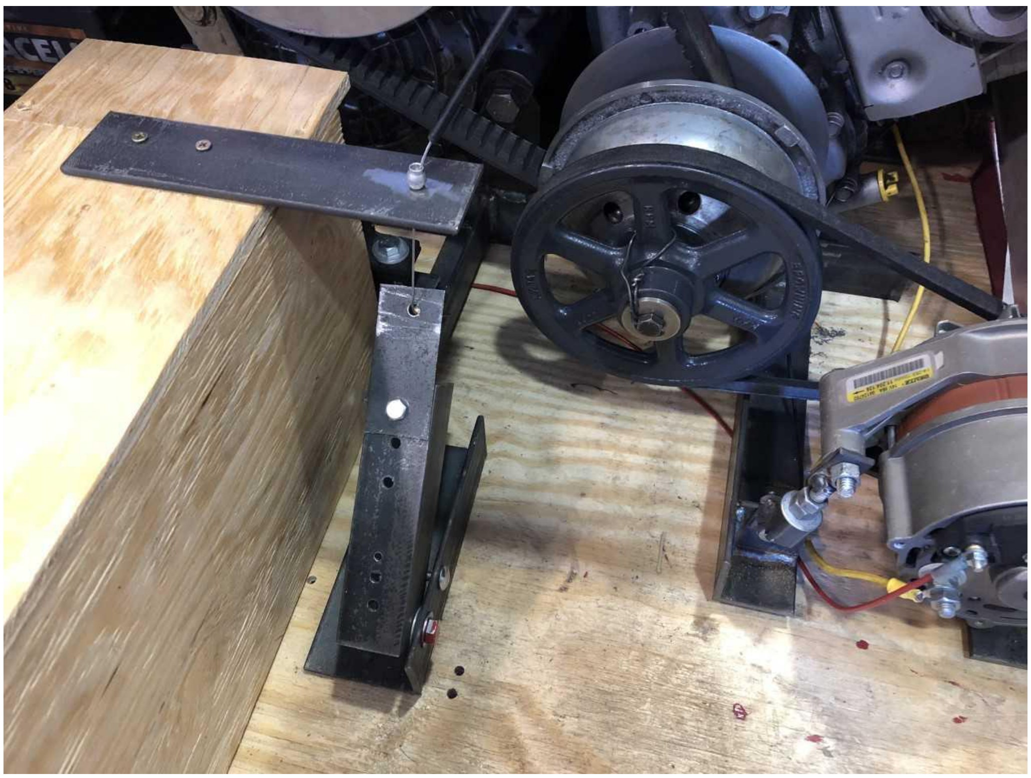


Figure 7: Throttle pedal

FINISHED DRIVETRAIN

After everything was mounted and installed properly, we made a housing for the driveshaft out of plywood. This makes it so there is no safety concern of the driver's leg being able to contact a spinning driveshaft. The picture below shows the drivetrain with the engine, transmission, clutch, driveshaft coupler, and most of the driveshaft housing.

Figure 8: Drivetrain

PROJECT MANAGEMENT

TEAM RESPONSIBILITIES

- Cole Rardon - Drivetrain
- Paul Kowall – Frame/Chassis
- Christopher Saranita – Steering/Suspension
- Bradley Sackett – Braking
- El Hassane Kamagate - Irrigation

BUDGET, PROPOSED/ACTUAL

	Estimate Cost	Actual Cost
Drivetrain	$560.00	$210.00
Frame/Chassis	$1,060.00	$310.00
Braking	$360.00	$130.00
Steering/Suspension	$460.00	$85.00
Irrigation	$160.00	$300.00
Total	$2,600.00	$1,035.00

Table 2: Budget

SCHEDULE, PROPOSED /ACTUAL

Task	**Projected Start Date**	**Actual Date**
Design Concept	10/2/17	10/2/17
Team Responsibilities	11/2/17	11/2/17
Bill of Materials	11/11/17	11/11/17
Detailed Design	11/16/17	11/16/17
Completed CAD Design	12/30/17	12/30/17
Schedule for Manufacturing	1/1/18	1/18/18
Proposal Presentation	1/26/18	1/26/18
Design Modifications	1/31/18	3/1/18
Order Parts	2/1/18	3/10/18
Manufacturing	2/2/18	3/15/18
Spring Break	3/12 – 3/18/18	3/12 – 3/18/18
Testing	4/1/18	4/18/18
Tech Expo	4/5/18	4/5/18
Final Presentation	4/20/18	4/20/18
Competition	4/21/18	4/21/18

Table 3: Schedule

CONCLUSION

RESULTS

We finished almost all of the BUV before the competition. When we completed the drivetrain, we took it outside for a test drive. It successfully drove in the parking lot for about 30 seconds. Unfortunately, it stopped working and we were unable to figure out what was wrong. The engine was running properly but there is something preventing that power from getting transmitted to the driveshaft. Due to the lack of time and the fact that the irrigation system was only 90% complete, we unfortunately were not able to bring the car to the competition.

The good news is that we did successfully prove the design of the drivetrain in the short time frame we had. It was able to shift into forward, reverse, and neutral. If we had the chance to keep it running longer, we would have been able to test the top speed and gradeability.

Figure 9: Completed BUV

RECOMMENDATIONS

Building a BUV is a tough and extensive project but it is doable. Had we had just a few more days, we would have been ready for the competition. I would recommend to future teams to start the manufacturing process at the beginning of Spring semester. We got very far behind schedule due to difficulties getting a frame. We tried to buy one off a private seller but could not successfully transport it to school and by the time we finally got the donor truck from U-Pull-&-Pay to tear apart, it was already Spring Break. So the key to timing the project right is finding a frame as soon as possible and then designing the drivetrain, steering, and irrigation as the frame is being built. That will make the build time much more efficient as well as preventing other problems such as not having enough room for the drivetrain. Our design was effective but the engine cage could have been designed better for more room for the big components. Dave Conrad was a huge help in advising us how to put everything together.

WORKS CITED

1. **Administrator.** BUV. *Drivebuv.* [Online] January 2010. [Cited: October 6, 2017.] Drivebuv.org/about-iat .
2. **Institute of Affordable Transportation. [Online] January 2010. [Cited: September 24, 2017.] www.drivebuv.org/buv-design.**
3. *Jack's Small Engines.* [Online] [Cited: 11 8, 2017.] https://www.jackssmallengines.com/bs10intekic.html.

APPENDIX A – IAT BUV DESIGN SHEET

This spec sheet is from the IAT's website. These are all the specs of the BUV model they actually have in production and this is what BUVs for the competition are supposed to be modeled off of. The only difference is that BUVs for the competition can have any engine with a maximum of 11 horsepower. It can be diesel powered like the IAT's model or gas powered like our car.

Features

- Affordable: $6500 US($)
- Durable: automotive parts
- Utility: power water pump, mill, compressor, etc.

Specifications

- 10 hp engine - diesel
- 1250 lb vehicle weight and low ground pressure
- 12′ length x 63" width
- 2-wheel drive with differential
- automotive hydraulic brake

Automotive Grade Components

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

Service / Maintenance

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

Performance

- 1750 lb payload
- 40% gradeability - high torque
- 30+ mpg diesel
- Turns sharp like a scooter
- 20 mph max speed

Safety

- Low center of gravity
- Excellent driver visibility
- Controlled speed - 20 mph max
- Hydraulic brakes

APPENDIX B – BUV COMPETITION SPECIFICATIONS

BUV Farm Tanker & Transporter

2018 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 will sit upon. The roll bar must be completely padded above the seat height. It must have a cross member that covers the ends of the vertical structures, and adequate bracing to prevent the vehicle from rolling over.

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

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

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

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

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

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

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

Trailer Hitch A 1-7/8 inch trailer ball must be mounted at a height of 15 inches above the ground when the vehicle is unloaded.

Weatherproof The vehicle should have protection from the weather elements to provide better reliability and greater durability.

Speed Maximum of 20 MPH.

Load Maximum of 165 gallons of water, weighting roughly 1376 pounds.

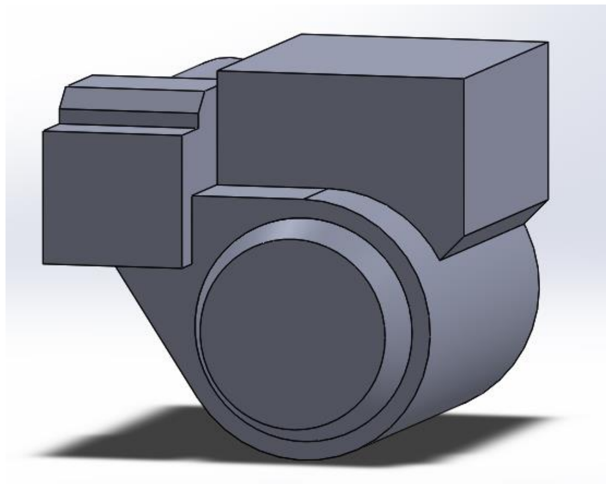
Water Pump Ability to fill 55-gallon drums from within 15 feet of a pond. All pumping equipment and hoses must be carried on the vehicle during the event. Pump driven form PTO device only.

Name Plate The school name and team number displayed in 4-inch font on all sides of the vehicle.

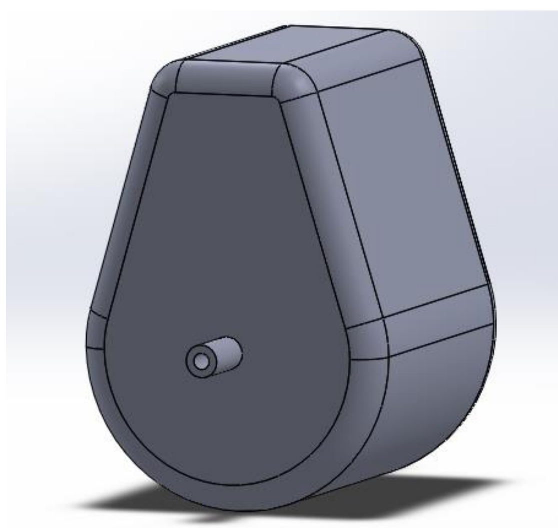
**** See Tech Inspection Sheet for deductions if this feature is missing**

APPENDIX C – DRIVETRAIN DRAWINGS

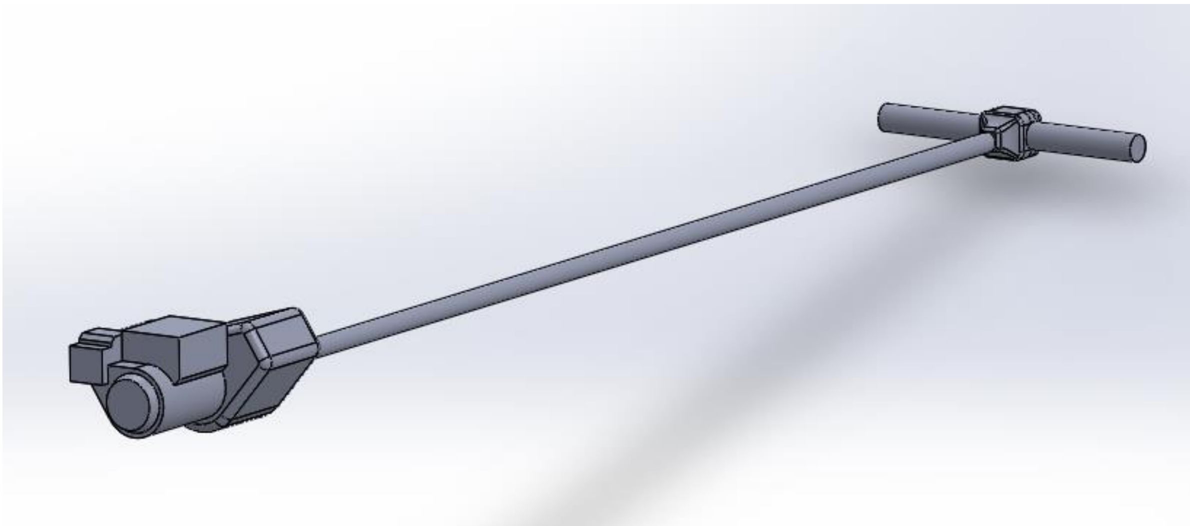
Engine



Transmission

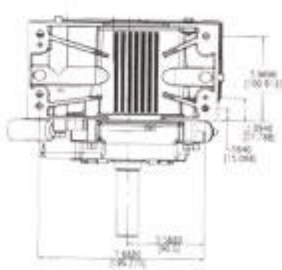


DRIVETRAIN ASSEMBLY

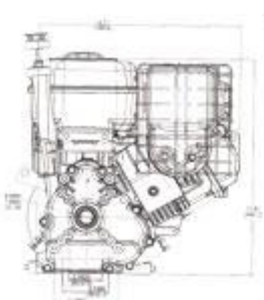


APPENDIX D – ENGINE SPEFICIFICATION SHEET

Click on image to Enlarge.



Click on image to Enlarge.



Click on image to Enlarge.

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 E – TRANSMISSION SPECIFICATION SHEET


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	1300 ft lbs
Max. Input Speed	3700 rpm
Reduction Ratio	Forward: 15:1 – Reverse: 15.3:1
Output Shaft Size	1.18 inches
Weight	68 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®
5943 Commerce Boulevard
Morristown, TN 37814
423-585-1990
Fax: 423-585-2003
www.tufftorq.com

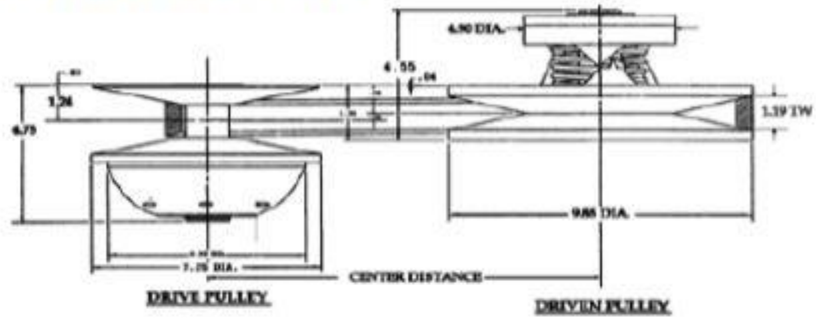
APPENDIX F – CLUTCH SPECIFICATION SHEET

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) 293-5770 / FAX. (626) 281-3392

APPENDIX G – DRIVETRAIN CALCULATIONS

- Minimum Force to climb a 15º slope
  - Max payload = 3,000 lbs
  - $F_{min} = \mu \times \cos(\sigma)$
  - $F_{min} = (0.6\ ft) \times (3{,}000\ lbs)(\cos(15°)) = 1{,}738.7\ lbs$

- Minimum Torque Required
  - $r_{wheel} = 1.08\ ft\ while\ loaded\ (1"\ flattening)$
  - $T_{min} = F_{min} \times r_{wheel}$
  - $T_{min} = 1{,}738.7\ lbs \times 1.08\ ft = 1{,}877.8\ ft \cdot lbs$

- Gear Ratios
  - $D_{tire} = 28\ in, engine\ rpm = 3{,}600$
  - $V_{max} = 20\ mph, engine\ torque = 14\ ft \cdot lbs$
  - $Min\ High\ Gear\ ratio = \frac{(rpm \times D_{tire})}{mph \times 336} = \frac{3{,}600\ rpm \times 28\ in}{20\ mph \times 336} = 15{:}1$
  - $Min\ Low\ Gear\ ratio = \frac{T_{min}}{T_{engine}} = \frac{1{,}877\ ft{\cdot}lbs}{14\ ft{\cdot}lbs} = 134{:}1$

- Gear Ratios between clutch and transmission
  - Product specs:
    - Clutch high gear ratio = 0.76:1
    - Transmission low gear ratio = 3.95:1
    - Transmission gear ratio = 15:1
  - $High\ gear\ ratio = clutch\ high\ gear\ \times trans.gear\ ratio = 0.76\ \times 15$
    - High gear ratio = 11.4:1
  - $Low\ gear\ ratio = clutch\ \times trans.gear\ ratio = 3.95\ \times 15$
    - Low gear ratio = 59.25:1

- Intermediate Pulley Ratio
  - $Intermediate\ Pulley\ Ratio = \frac{\min low\ gear\ ratio}{low\ gear\ ratio} = \frac{134}{59.25} = 2.26{:}1$

- Final High Gear Ratio
  - $Final\ high\ gear\ ratio = clutch\ high\ gear\ ratio\ \times trans.gear\ ratio\ \times intermediate\ pulley\ ratio$
  - $Final\ high\ gear\ ratio = \ 0.76\ \times 15\ \times 2.26 = 25.76{:}1$

- Final Low Gear Ratio
  - $Final\ low\ gear\ ratio = clutch\ low\ gear\ ratio\ \times trans.gear\ ratio\ \times intermediate\ pulley\ ratio$
  - $Final\ low\ gear\ ratio = 3.95\ \times 15\ \times 2.26 = 133.91{:}1$

- Performance
  - $Final\ Top\ Speed = \frac{rpm \times D_{tire}}{Final\ high\ gear\ ratio \times 336}$

- $Final\ Top\ Speed = \frac{(3{,}600\ rpm) \times (28\ in)}{(25.76) \times (336)} = 11.65\ mph$
- $Final\ Torque = T_{engine} \times Final\ low\ gear\ ratio$
  - $Final\ Torque = 14\ ft \cdot lbs \times 133.91 = 1{,}874.74\ ft \cdot lbs$