Basic Utility Vehicle
Drivetrain Design Team

April 23rd, 2009

Designer	Design Area
Craig Blough	Electrical Front Wheel Drive
Craig Roberts	Electrical Front Wheel Drive
Eli Jacobson	Diesel Drivetrain
Matt Londergan	Diesel Drivetrain

Challenge

Develop a 3 – wheel vehicle to be driven by polio survivors, landmine survivors, amputees, and others that no longer have use of their legs. In addition to hand controls and affordability, design emphasis is on the steering, front suspension and a third-wheel drive (front wheel). Design vehicle based on re-using the rear axles and suspension of a small pick-up truck. Design for small scale assembly operations in Africa. Minimize factory investment at a volume of one vehicle per day.

What is BUV?

Mission
To improve lives in developing countries by facilitating the spread of simple vehicles that can be assembled "*almost anywhere, by almost anyone.*"

Vision
The BUV will go:
…where the streets have no name
…where roads don't exist
…where people need hope
Basic Vehicles. Changed Lives.

Goal
To jumpstart an industry to bless the working poor

Design Objectives

Cost
- Minimize total lifetime cost of ownership.
- Use off the shelf components
- Also use salvaged or pre-existing components when possible
- Reduce number of moving parts by avoiding complex gearboxes

Performance
- Find the right balance between performance and simplicity
- Design drivetrain system with industrial components that can withstand punishment
- Allow for easy access of drivetrain components for fine-tuning and maintenance

Safety
- Protect driver and passengers from all moving parts and sharp edges
- Coordinate placement of components of drivetrain with weight distribution of vehicle
- Minimize controls needed to control drivetrain system

Manufacturing
- Group drivetrain components into subassemblies that can easily be bolted onto vehicle
- Simplify fabrication techniques when possible

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- Mid States Power (Harlan Vanderpool)
- Quality Drive Systems (Roy Navarette)

Others
- ABE Shop: Scott Brand & Gary Williams
- Purdue Quarter-Scale Team
- Purdue Central Machine Shop

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Diesel Drivetrain

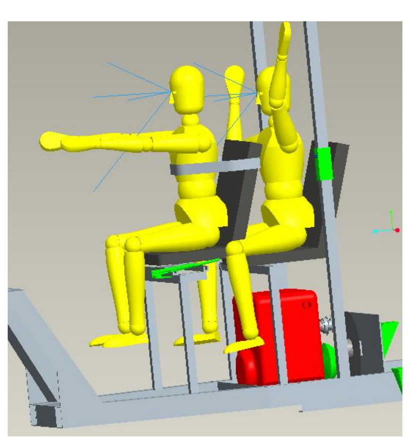
Design Criteria

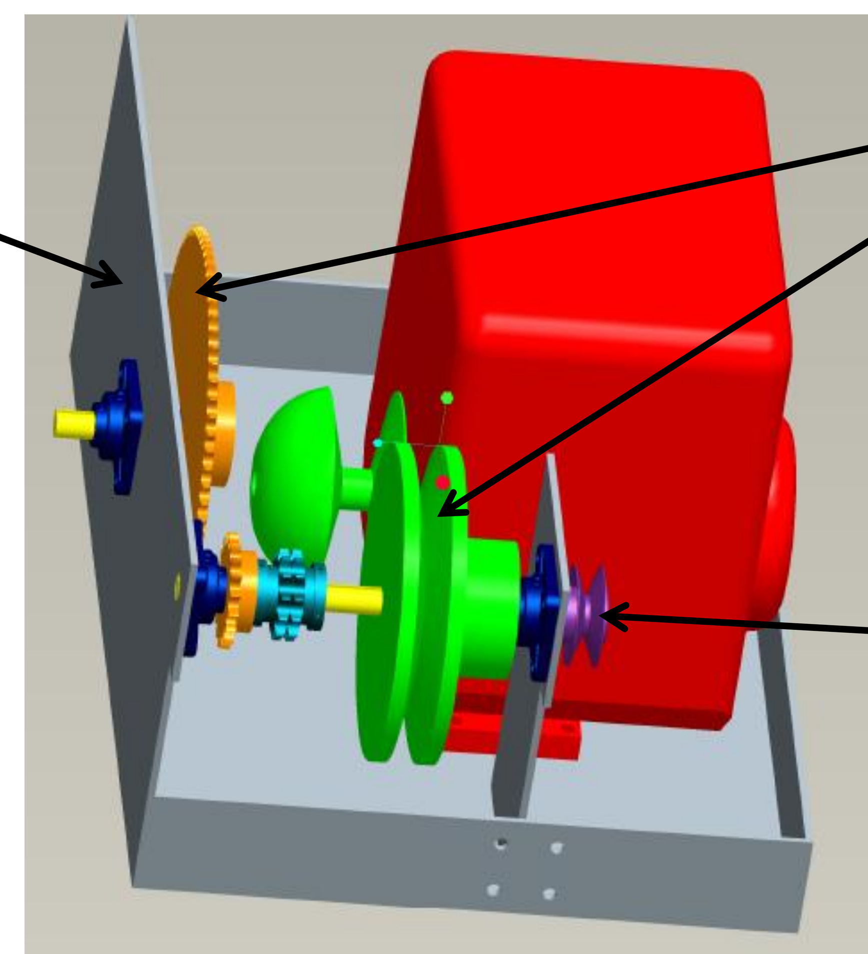
- Must use 10hp Yanmar diesel engine
- Make a modular design that can be integrated with the rest of the vehicle
- Provide a high torque at low speeds and provide 20mph top speed
- Design drivetrain capable of towing 1700lbs including a trailer loaded with 500 lbs
- Must be able to disengage driveline to power PTO pulley
- Simplify drivetrain controls (handicapped driver)

Initial Design

Steel Enclosure

- Keeps drivetrain components safe, dry, and secure while being lightweight
- Modular design that bolts straight to front and rear frame modules
- Provides extra structural rigidity for drivetrain components
- Provides storage for tools, spare parts, and other accessories





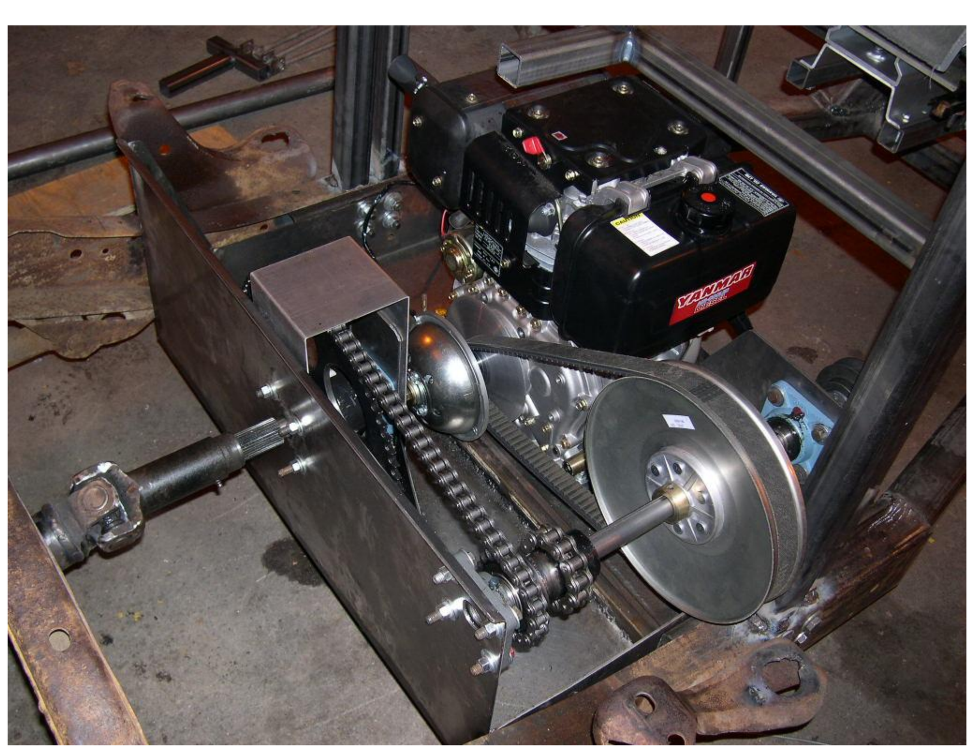
Main Drive System

- A combination of CVT and chain drive system was chosen over a straight belt drive or Tuff Torq transmission.
- This design choice produced a drivetrain package that is simple, lightweight, high performance, and easy to control and maintain
- Engine positioned low and in center of vehicle to improve weight distribution

PTO Drive System

- A roller chain coupler was chosen to disengage power from driveline and power the PTO pulley
- A variable pitch pulley allows for use of a wide range of v belt sizes
- Speed of PTO is adjustable due to CVT
- A friction throttle allows for constant speed while using PTO

Fabrication and Testing

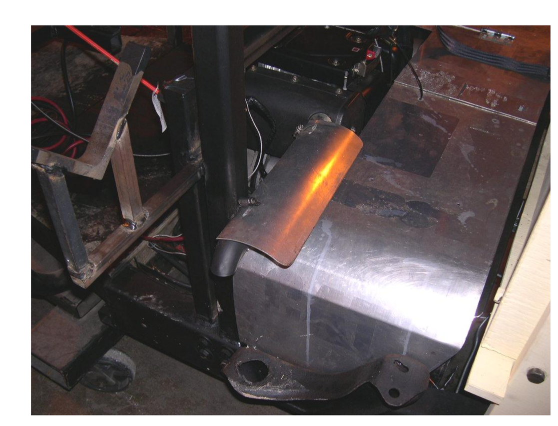


Easy to produce/assemble

- Wire feed and arc welding used to match processes available to theoretical micro-factory
- Used salvaged driveshaft parts from a 1993 S10 to produce custom driveshaft
- Brake and Electrical systems fully integrated into enclosure, allowing for simplified assembly

Optimized weight and performance

- 72T sprocket lightened by 5 lbs through simple machining
- Engine position made adjustable to account for belt wear and wet conditions
- Structural enclosure built with minimum amount of material
- Reinforcements added to increase rigidity after initial testing



Safety

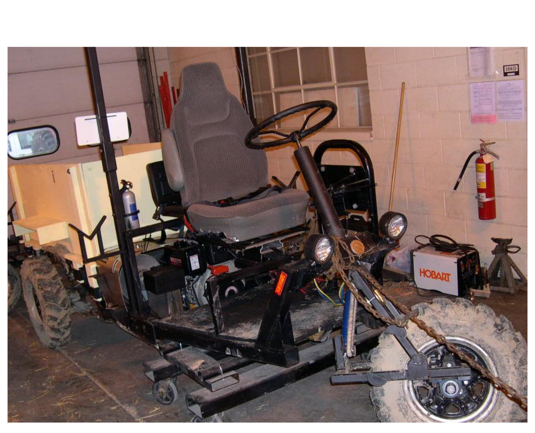
- Aluminum guards used to protect operator and passengers from moving parts and exhaust
- Kill switch lever integrated into operator's station to allow for quick deactivation of engine

BUV Competition Results

- There were issues with the throttle cable, but once fixed, the BUV performed well and obtained 2nd place in the sprint competition
- In the obstacle course, the vehicle did very well until the final obstacle, when the driveshaft fell off of the splined shaft connected to the 72T sprocket

Areas of Improvement

- The driveshaft needs to be lengthened to decrease the yoke angles and subsequent vibrations
- The throttle cable used was too rigid to make extreme bends, a braided cable should be used instead



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Calculations

Engine (Yanmar 100V, 10hp diesel engine)

Rpm	3600	3200	2500
Hp	9.1	8.7	7.4
Torque (ft-lb)	13.3	14.3	15.5

Comet 760 CVT

High Ratio	1:1	
Low Ratio	5.12:1	
Drive Pulley Diameter	7.25	in
Driven Pulley Diameter	11.26	in
V-Belt Thickness	1.25	in

Chain drive system

Gear reduction	4:1
Driver Sprocket	18T
Driven Sprocket	72T
Roller Chain Size	#50

Rear Differential

Gear Reduction	3.73:1

Wheel Dimensions

Outside Diameter	28	in
Width	6	in

Output at Low Ratio

Engine Speed	3600	rpm
Total Gear Reduction	76:1	
Max Vehicle Speed	4	mph

Output at High Ratio

Engine Speed	3600	rpm
Total Gear Reduction	15:1	
Max Vehicle Speed	20	mph

Cost

Engine

Item/Part	Cost	Qty	Subtotal
Yanmar 10hp Diesel	350	1	350

CVT - QDS

Item/Part	Cost	Qty	Subtotal
Comet 760 CVT Drive Pulley	195	1	195
Comet 760 CVT Driven Pulley	185	1	185
Comet CVT Belt	40	1	40

Chain Drive - Surplus Center

Item/Part	Cost	Qty	Subtotal
1" chain coupling half	16.95	2	33.9
coupling chain	9.75	3	29.25
1" X 3' Keyed Shafting	33.95	1	33.95
Driver 18T unfinished bore	5.25	1	5.25
10' of #50 Chain	18.99	1	18.99
1" 4 bolt flange bearing	8.95	4	35.8

Chain Drive - Mcmaster - Carr

Item/Part	Cost	Qty	Subtotal
Driven 72T	87.4	1	87.4
Variable pitch pulley	24.65	1	24.65

CVT

Item/Part	Cost	Qty	Subtotal
Comet 760 CVT Drive Pulley	195	1	195
Comet 760 CVT Driven Pulley	185	1	185
Comet CVT Belt	40	1	40

TOTAL	1459.19

Electrical Drivetrain

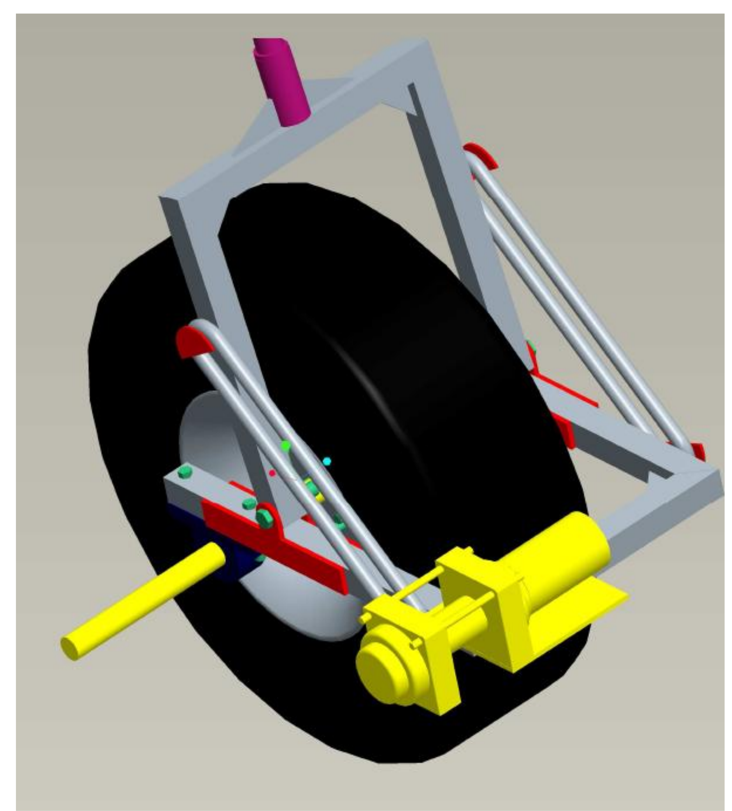
Design Criteria

- To be used in stop and go conditions encountered in trash pickup
- Must be able to propel the vehicle at 1mph in both forward and reverse
- Design as a modular package that can be easily installed on both past and present BUV's
- Simplify drivetrain controls (handicapped driver)

Design Process

Requirements at the Wheel

- Found Requirements at Wheel Hub
- Converted ground speed to rotation at hub
- Found torque required (from previous vehicle testing)
- Combined rpm and torque to find power required



Sizing the Winch

- Sized with power, torque and speed requirements required at
- the wheel
- Utilized drum diameter to determine maximum possible
- sprocket size
- Gear reduction chosen to match requirements at the wheel
- When powering the winch, we utilize a starter battery due to the
- high current required over a short time

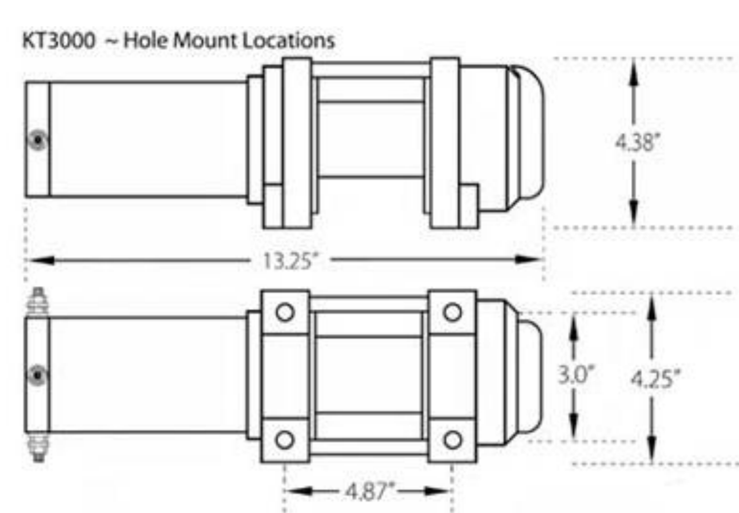
Winch manufacturer specifications

KT3000/KT3000C Line speed and Motor current (first layer)							
	Line Pull	Lbs	0	500	1000	2000	3000
		Kgs	0	227	454	907	1361
	Line speed	FPM	27	20	16	9	5
		MPM	8.3	6.1	4.9	2.7	1.5
	Motor Current	Amps	15	40	60	130	190

Line pull & cable capacity							
	Layer of cable		1	2	3	4	5
	Rated line pull per layer	Lbs	3000	2561	2234	1981	1779
		Kgs	1361	1162	1013	899	807
	Cable capacity per layer	Ft.	8.85	10.37	11.89	13.41	14.92
		M	2.7	3.16	3.62	4.1	4.55

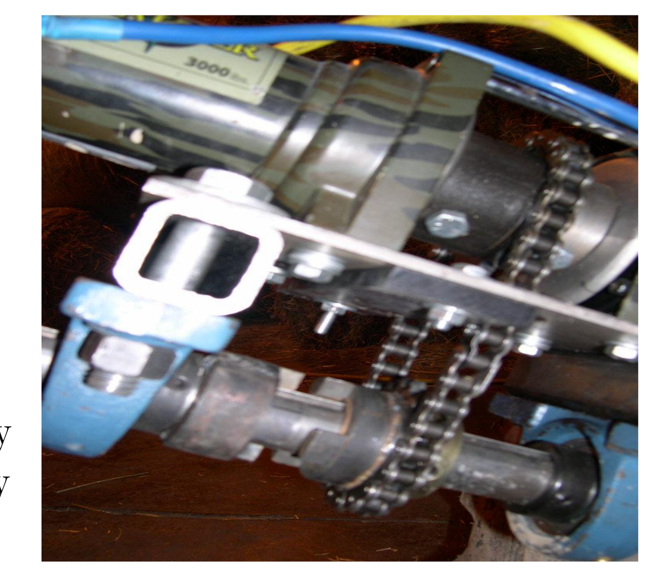
Rolling Load Capacities (first layer)					
	Slope*	10% (4.5°)	20%(9°)	40%(18°)	100%(45°)
	Lbs	15075	10251	6428	3854
	Kgs	6838	4650	2916	1748

*Slope: a one foot rise in 10 foot length is a 10% slope. Above information is based on a vehicle with its rolling abilities in good condition and the surface is hard and smooth. Performance data and specifications may vary.



Clutching Mechanism

- External mechanism needed due to high
- freewheel speeds that cause excessive
- wear to internal parts
- Dog clutch mechanism utilizing lovejoys
- Outer lovejoy keyed to shaft
- Inner lovejoy welded to sprocket, riding
- bushing
- Outer lovejoy is held normally out with
- ball bearing, spring and set screw assembly
- Manual engagement by sliding outer lovejoy
- inward to engage dogs



Part Selection

- Utilized common parts for easy sourcing to foreign
- countries
- 40 roller chain for ease of maintenance and variable sprocket sizes

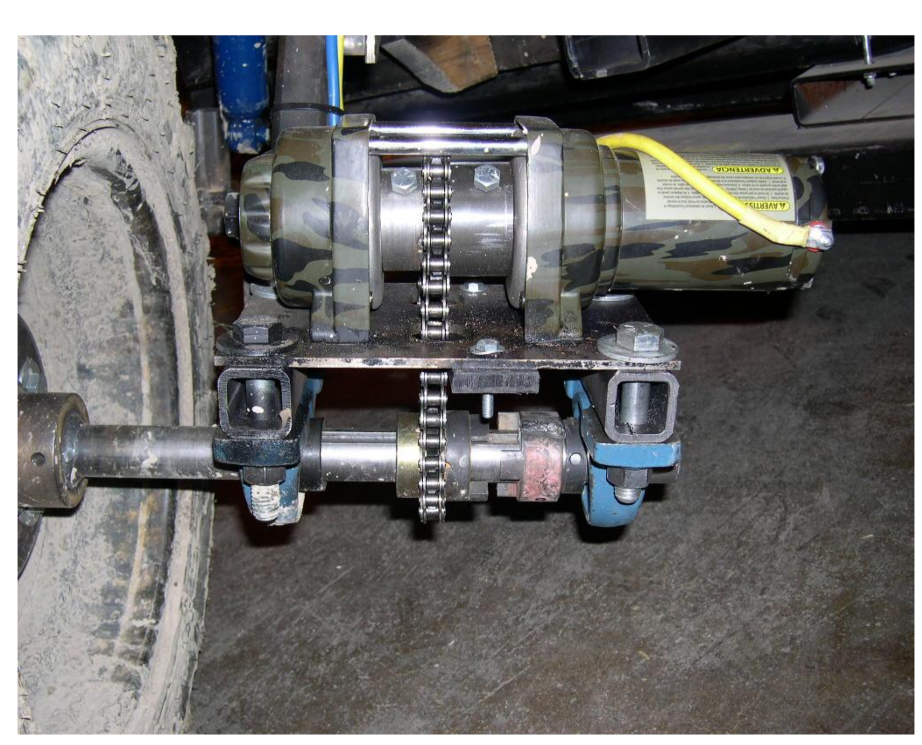
Calculations

Requirements for Wheel/Winch Interface		
Tire Size	27	in.
Target Speed	1	mph
	12.45	rpm
Drum rotation	5	fpm
	9.55	rpm
Drum Size	2	in.
Gear reduction	1.30	:1

Fabrication and Testing

Machining

- 5/16" keyway in axle shaft
- Outer lovejoy bored to 1 ¼", keyed
- Inner lovejoy bored to 1 ½", welded to small sprocket
- and pressed onto brass bushing
- Sleeve made for axle shaft, drum cut in half, connected
- to sleeve by shear bolts offset 180°
- Lock collar machined to ½" to conserve space inside
- pillow block
- Chain rub block to prevent inner lovejoy from 'walking out'
- and engaging shaft

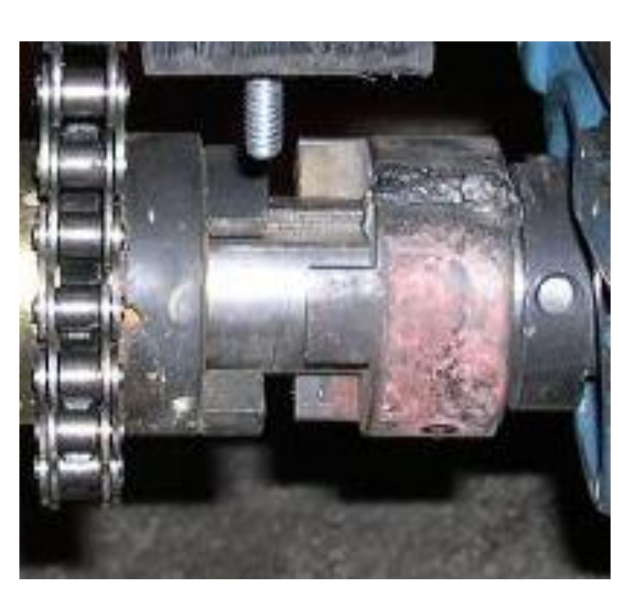


Testing & Competition

- The Electric FWD successfully powered the axle when jacked up
- and on pavement
- Lovejoy failed on soil with full load
- Failure along plane of set screw and keyway (180° offset)
- New lovejoy was machined out of stronger steel with the key
- offset 90° from the set screw.
- Second lovejoy failed in competition on soil under full load

Areas of Improvement

- The design was very sound, but failed due to an unexpected part failure
- The Electric FWD successfully powered the axle when jacked up and on
- pavement,
- Lovejoy failed on soil with full load
- Failure along plane of set screw and keyway (180° offset)
- New lovejoy was machined out of stronger steel with the key
- offset 90° from the set screw.
- Redesign would include a more heavy duty lovejoy or a sprocket & chain
- master link clutching assembly.
    - More difficult engagement, but less likelihood of failure
- An FEA analysis of the lovejoy would be effective in analyzing the failure
- mode.



Final Cost

Item	Qty	Subtotal
ATV Winch	1	$229.00
Pillow Block	1	$19.99
Bearing	1	$11.99
Lovejoy	2	$12.00
Sprocket	2	$10.59
40 roller chain	1	$3.00
	TOTAL	$286.57

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YANMAR BUV