Hybrid Jet Drive Boat

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

in partial fulfillment of the
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Bachelor of Science

in Mechanical Engineering Technology

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Problem Statement

Our goal was to make an affordable jet drive boat with an electric option. We were trying to address the issue of the lack of hybrid drive systems in the marine industry. The electric motor allows the user to go hunting or fishing without scaring prey and can be taken to restricted no-gas waters. We will be designed, built and tested a jet pump propelled aluminum hull boat with a secondary electric motor. The electric and gas options were to be built-in to avoid buying a separate trolling motor and controls. There is immense drag on boats with outboard motors, which and has a negative effect on gas mileage, often less than 1 mpg. The jet drive system would help combat this problem with its higher profile in the water.

The jet ski motor, hull, and jet pump were to be removed from a jet-ski and grafted into an aluminum boat. The focus of the design process was deciding how to attach both power systems to the same drivetrain. This would give the user the ability to switch between the electric and gas as desired while using the same steering components. This electric feature allows users to navigate all types of waterways including environmentally protected areas or lakes where gas motors are not allowed. Fisherman can approach their fishing spots in a stealthy manner while having the long-range capability of the gas motor. The throttle system and other controls needed to be adjusted to fit the new length of the vessel.

Background

The problem we addressed is the lack of hybrid drive systems in the marine industry. While hybrid systems exist for large sea liners and cruise ships, not much is available for smaller civilian operated boats or personal river boats. The hybrid jet pump system is non-existent. Because of the immense drag on boats as they travel through water, most boats suffer from very poor gas mileage (3). On top of this, marinas can upcharge for gasoline. The boating community would be happy with an affordable and realistic hybrid option that only requires an overnight charge. There is an option for adding a solar trickle charge to the electric system on the water if desired.

Our electric drive system will not be high performance and is not meant for speed. Together with the gas motor the boat will have the best performance for both speed and practicality. Our design will be for boat idling speeds of 3 to 5 mph and is being specifically tailored for our aluminum boat, which is significantly lighter than its fiberglass counterpart.

State of the Art

One of the existing hybrid drive systems available for larger boats is from Volvo Penta. They have recently developed a hybrid system that allows electric-only propulsion (5). The electric-only mode allows entry into environmentally sensitive zones, as well as offering enhanced onboard comfort and boat handling characteristics. The system will be featured on much larger boats and helps the boat to get on plane using the additional electric motors. Volvo Penta's system is being rolled out soon and will be a "hybrid performance inboard system", or, IPS. (5). The issue with this model is affordability. The boat is very large and costs more than what most people make in a year.

Several other companies offer retrofitting electric motors for gas boats. Oceanvolt is one of the largest companies that offer several different electric drive systems for large sailing yachts up to 100 horsepower. Oceanport offers a series of variable pitch sail drive ServoProp motors that run off a 48-Volt system. They even offer lightweight and powerful systems for sailboat racing applications. Oceanvolt has even released their own yacht, the Q Yachts Q30, which has a top speed of 22 nautical miles per hour with a range of 45 nautical miles at cruising speed. While Oceanvolt has the sailing market covered, there is still no real solutions for average boat owners who either want a low-cost hybrid boat to purchase, or a low-cost way of retrofitting an electric motor into their drive system (4).

While there are "off the shelf" jet-boats, many of these boats are designed with one thing in mind, performance, and none of them feature an electronic drive feature. Our design will be aimed at performance as well but with a larger focus on outdoorsman usage, stability and flexibility.

Oceanvolt has also released electric motors for offshore sailing applications (5). These systems are very expensive and do not offer a gas engine option. Several other companies offer hybrid systems for boats.

Torqeedo is a marine engineering group that has been offering electric outboards for a few years (6). These electric outboards are relatively low-power and are meant for smaller boats. They can be mounted on virtually any boat and run on a large battery cell but are only used to supplement an existing gas engine. Torqeedo outboards also force the user to be at the back of the boat while operating the motor. Our system will have an advantage over these since the electric power can be controlled from the driver's seat at the front of the boat. The user will be able to use the drivetrain and steering wheel to operate both motors. This leads us to believe that nothing similar to our boat exists on the market. This also gives our idea opportunity in the market.

End User

Our end user will be an outdoorsman that wants a boat that is maneuverable, reliable, and practical. They would also be someone with a similar budget in mind as we do. The quiet motor won't scare away fish or other prey like the gas motor would. The electric motor will also allow the user to enter environmentally safe zones and not disturb any similarly protected areas. Since there is no outboard motor with a propeller in the water, the boat will be able to navigate through shallow waters and other debris that might stop other boats from accessing the same area.

Customer Survey

We created a customer survey to gauge what kind of requirements people had and to set priorities for design. The results below were from this survey with a scale of 1 to 5.

How important is speed to you? 3.75
How important is handling to you? 4.25
How important is seating to you? 2.75
How important is storage? 2.5
Is a long range for the electric motor important? 3
How satisfied are you with current hybrid boat technology? 1.7
Is speed important when using the electric motor? 1.85
Is low draft on plane important? 3.25
How important is safety to you? 3.75
Is durability important on this type of boat? 3

Customer Features/Weight:

1) Safety 13%
2) Maneuverability 15%
3) Seating capacity 13%
4) Speed 12%
5) Storage 8%
6) Durability 10%
7) Electric motor speed 7%
8) Electric motor range 10%
9) Low draft on plane 11%

Engineering Characteristics

Stability	Proper weight distribution with passengers
Top speed	At least 25 mph with the gas motor
Turning radius	Be able to turn the boat all the way around in 15 feet
Seat count	4 seats is the goal
Storage space	Include where possible depending on what boat is purchased
Quality of parts used	This will determine the longevity of our boat. We will purchase many components new but the gas motor and main drive line will be used.
Acceleration	We hope to get the boat on plane in less than 5 seconds
Horsepower	The gas motor will be a 750CC 85hp motor The electric motor will be 2.5 - 3.5hp
Draft on plane	We want the boat to draft less than 6” when on plane
Electric motor range	3-5 mile range with the electric motor should be achievable

House of Quality

	Customer Requirements	Importance wt.	Stability (proper weight ca	Top speed (mph)	Turning radius (ft)	Seat count (# of seats)	sorage space (cu.ft)	quality of parts used (new	Acceleration (0-25) [mph]	Horsepower (hp)	electric motor (hp)	Draft on plane depth (ft)	electric motor range (mi)				Total importance	Weight		
			1	2	3	4	5	6	7	8	9	10	11							
1	Safety	0.13	9	3			3	9												
2	Maneuverability	0.15	3	9	9	1														
3	Seating Capacity	0.13				9														
4	Speed	0.12							9	9			9							
5	Storage	0.08					9													
6	Durability	0.10						9												
7	Electric motor speed	0.07									9		9							
8	Electric range	0.10		3																
9	Low draft on plane	0.11		3								9								
	Total Importance	1.00	0.84	2.37	1.35	1.32	1.29	2.07	1.08	1.08	0.63	0.99	1.71				15	100%		
	Weight		0.06	0.16	0.09	0.09	0.09	0.14	0.07	0.07	0.04	0.07	0.11							
Performance	Current Product																			
	competitor A																			
	competitor B																			
	competitor C																			
	New Product Targets		6%	16%	9%	9%	9%	14%	7%	7%	4%	7%	11%							

Interaction Matrix

9 - stong, 3 - med, 1- negative	Engineering Requirements	Stability (proper weight capacity for boat	Top speed (mph)	Turning radius (ft)	Seat count (# of seats)	sorage space (cu.ft)	quality of parts used (new/used)	Acceleration (0-25) [mph]	Horsepower (hp)	electric motor (hp)	Draft on plane depth (ft)	electric motor range (mi)	0	Total importance	Weight
Engineering Requirements		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Stability (proper weight capacity for	1		3		9		3								
Top speed (mph)	2														
Turning radius (ft)	3														
Seat count (# of seats)	4							1				3			
sorage space (cu.ft)	5											3			
quality of parts used (new/used)	6								3	3					
Acceleration (0-25) [mph]	7								9	9	3				
Horsepower (hp)	8														
electric motor (hp)	9														
Draft on plane depth (ft)	10														
electric motor range (mi)	11														
0	12														
Total importance	13														
Weight	14														

Product Objectives/Weight

Requirements	Weight
Stability	6%
Top speed	16%
Turning radius	9%
Seat count	9%
Storage space	9%
Quality of parts used	14%
Acceleration	7%
Horsepower	7%
Electric motor hp	4%
Draft on plane	7%
Electric motor range	11%

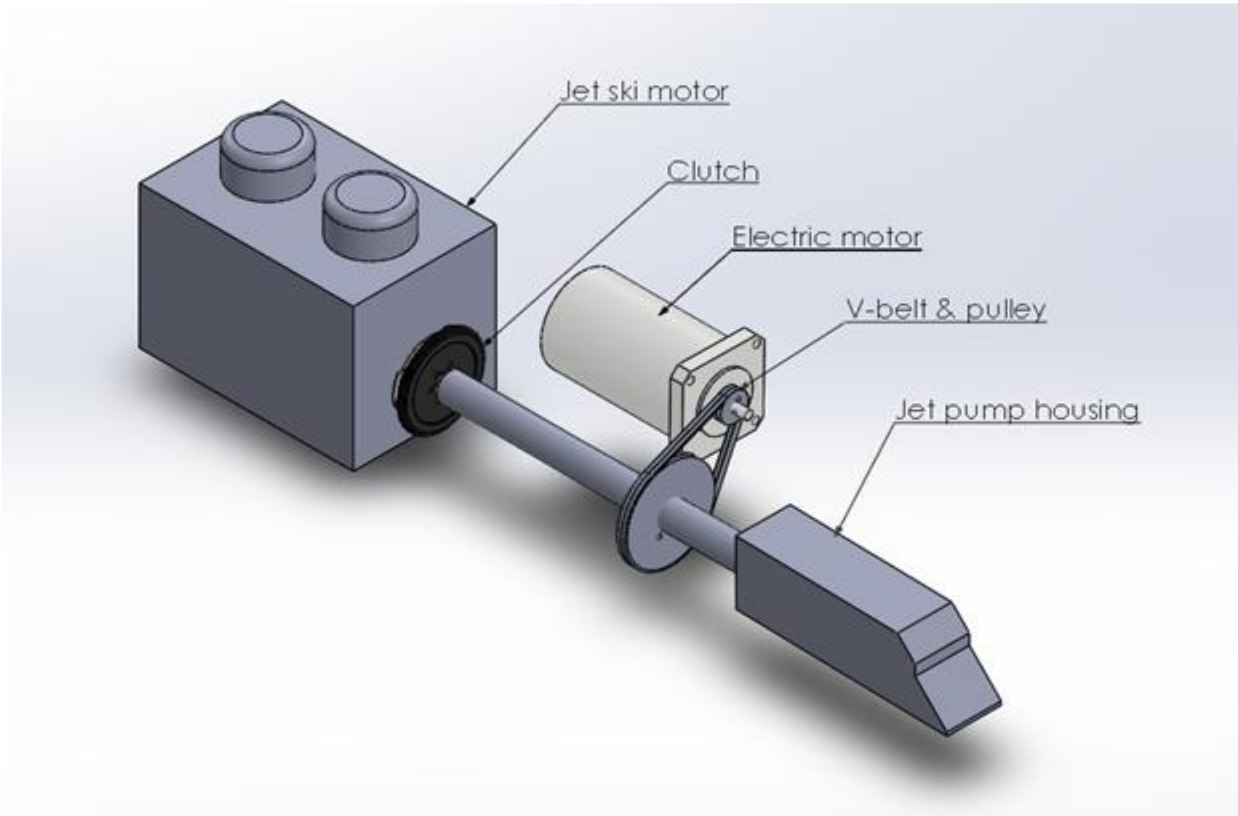
Additional Notes:

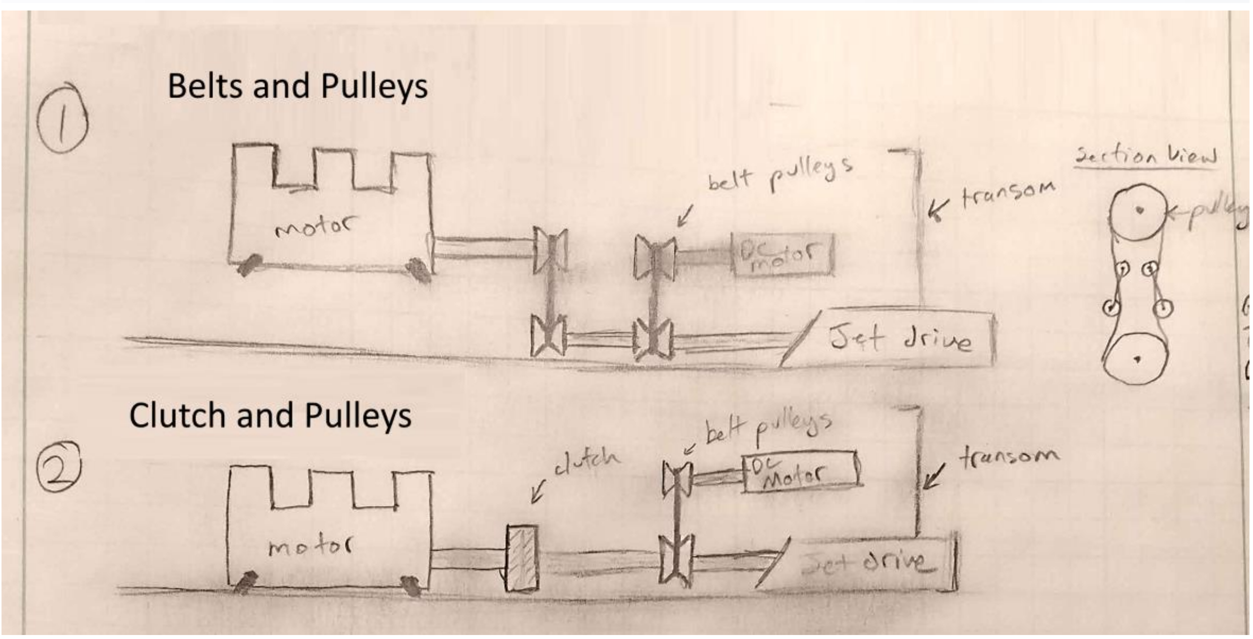
We wanted our boat to be durable enough to handle 2 to 3-foot waves and perform well years down the road. The shallow v-hull shape of our boat should help the wave cutting. We wanted to purchase all new components for the electric drive and then encasing the system in a waterproof housing before extensive use for longevity. We are hoping to get a range of 3 to 5 miles with the electric motor at speeds between 3 and 5 mph. We want the transition to electric power to be very easy with all the controls for both motors at the front of the boat.

We thought that mounting the motor about 2 feet from the stern of the boat would help the boat get on plane and stay there. S We may need to include some front ballast in the boat, and this should be easily achievable due to the fact we are planning to use a closed bow boat.

Concepts

The main goal of our designs was to isolate the gas engine from the electric motor in terms of drag. Each motor would need to run independently without drag from one another. This would require some type of clutching mechanism that would allow us to operate each system independently from the other.



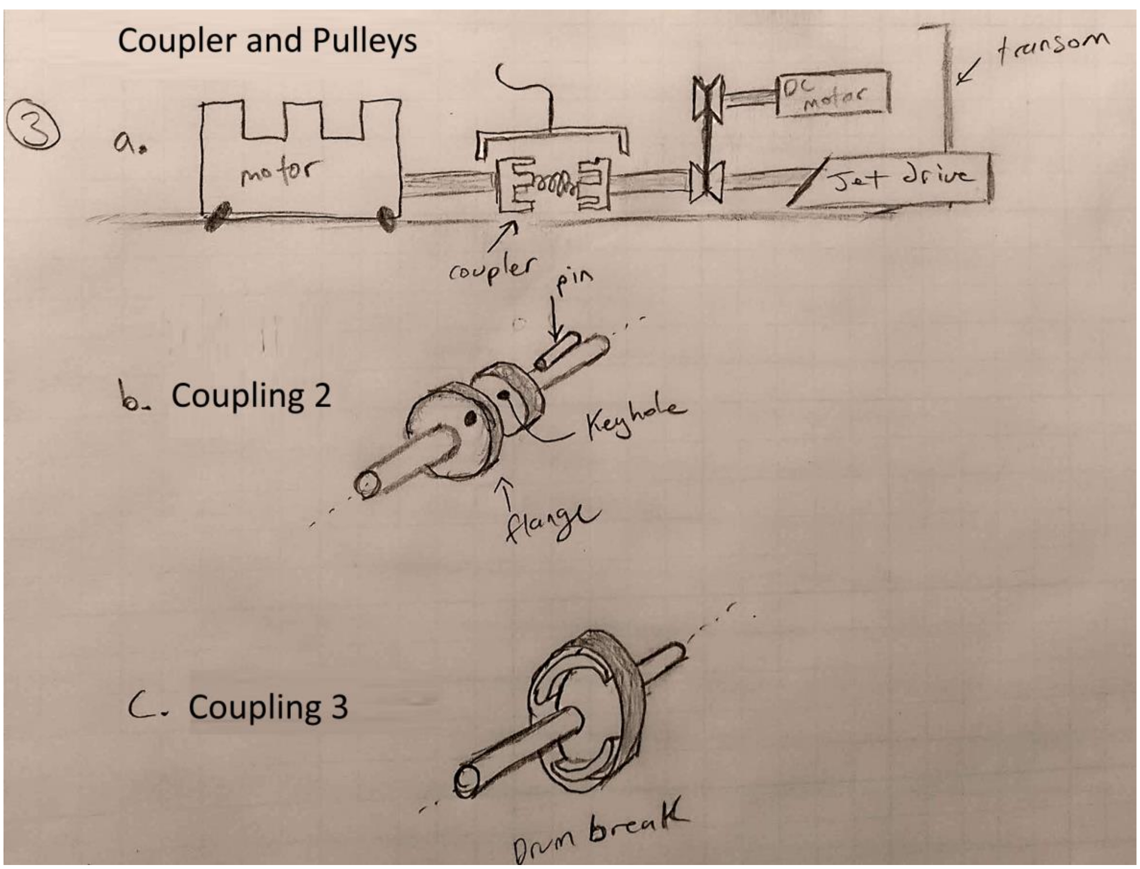


Concept 1:

Our first concept portrayed was to use v-belts and pulleys. The gas motor shaft would be raised above the height of the jet pump shaft connected using belts. The sections view shows our tensioning device that would be adjusted based on what motor was being run. This tensioner would give us the clutching action we needed to disengage the gas engine from the drive line when switching electric power. This design would work in theory but would have been difficult to manage the reliability and sturdiness for many moving parts with vibrations during use. We decided this would have been very complicated to execute. We also rejected this design because of the possibility of belt slippage, especially in a wet environment.

Concept 2:

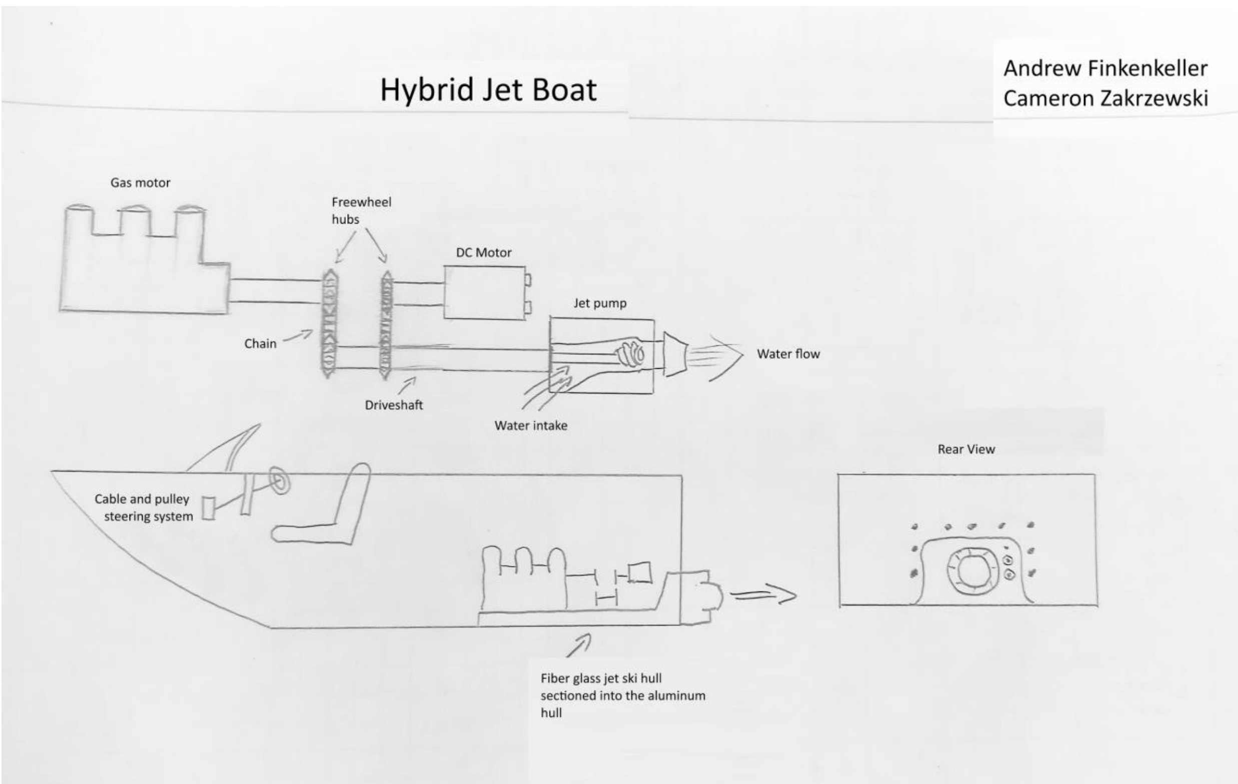
Our second concept was similar to the first. Instead of a belt tensioning device, we would use an electric clutch. This would remove the need to mount the gas motor higher and create another drive shaft. The electric clutch would sit in between the gas engine and the jet pump and the electric motor would sit between the clutch and the jet drive. The clutch would be controlled by an electric current which would give us the drive and neutral states we are looking for. This system would have worked nicely but the cost and availability of the electric clutch steered us away. This also did not eliminate drag from the electric motor.



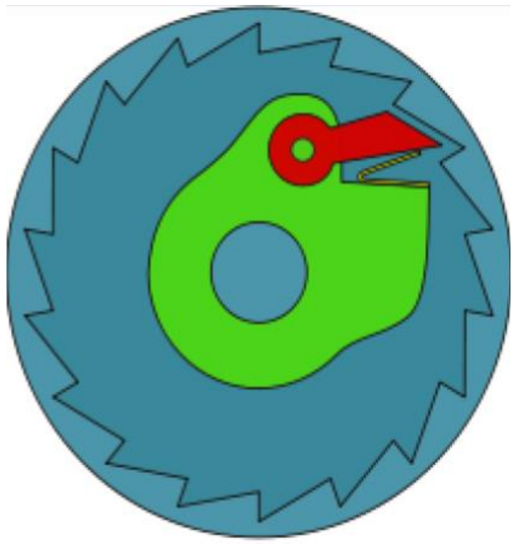
Concept 3:

The third concept came in three variations. Like our second concept, the motor is in line with the jet pump. The clutch is the varying design between a coupler, a pin and flange design, and a drum break design. The coupler design as well as the pin and flange design both require manual shifting. Concept C above would use an expanding drum like that of a drum brake. This design is the most complicated and would require a fluid pump to operate, despite being hands free. This would be challenging to accomplish with a 6000RPM drive train.

Concept 4:



This is our chosen concept. We decided to use freewheels to allow both motors to connect without needing to actuate a clutch or manually change power delivery. The motor will have to be mounted above the jet pump and additional shafts will be made to connect the power train. The most important part of this concept is the freewheel hubs that would be used as our clutching mechanism. The freewheels are one-way clutch bearing. The outer wheel of the bearing can spin freely until the inner drive wheel is rotated. It is the same mechanism as the rear wheel on a bike that allows you to coast down a hill without pedaling. The mechanism eliminates the drag on both motors as they run independently.

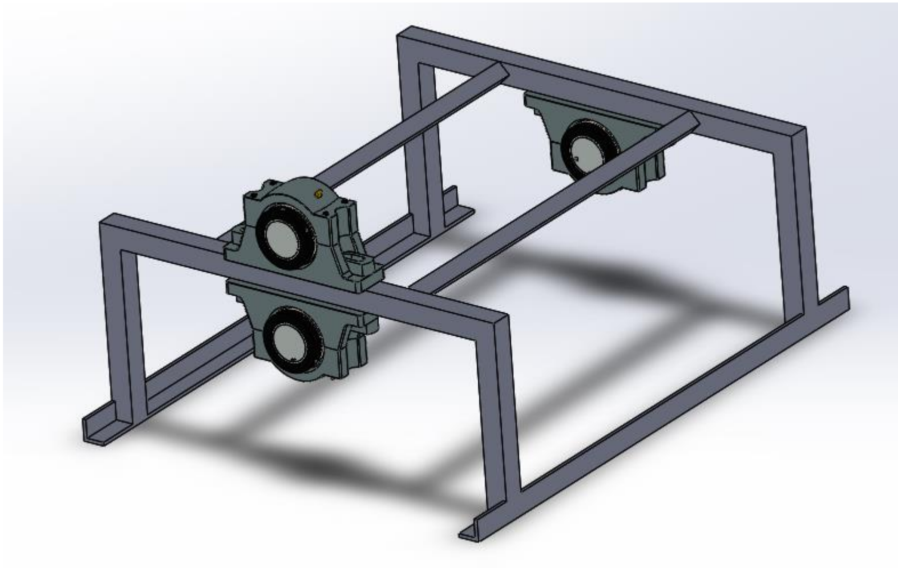


This diagram shows the section view of a freewheel hub and the ratchet and pawl system that allows the outer wheel to rotate freely.

We chose to use a toothed belt to avoid slippage. We would use our freehubs with the grooved belt cogs to assemble the powertrain. The cog would attach to the freehub and allow the inner portion of the freehub to spin independently from the rest of the drive-train. We would attach the two components with bolts.

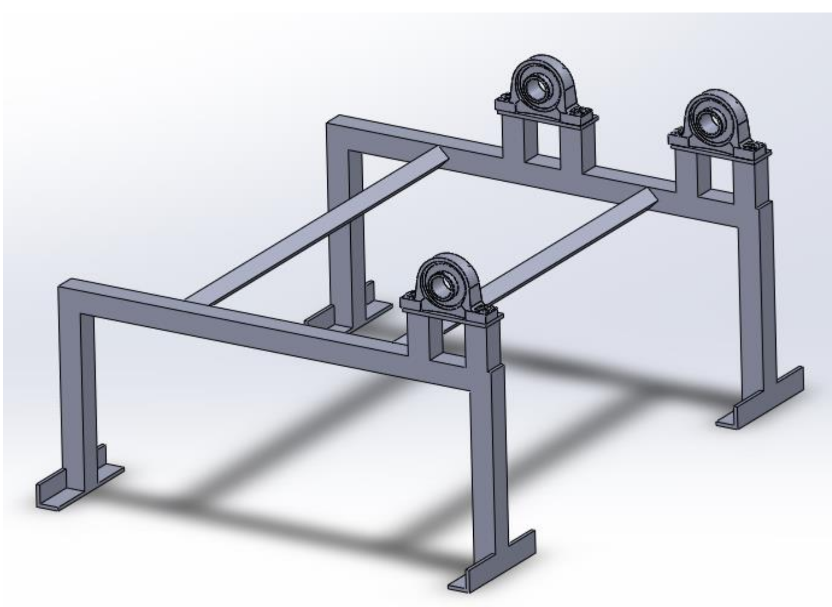
The left photo shows the freehub assembly. These are the free wheels and grooved belt cogs we chose. Each are rated for 100 horsepower.

3D Models



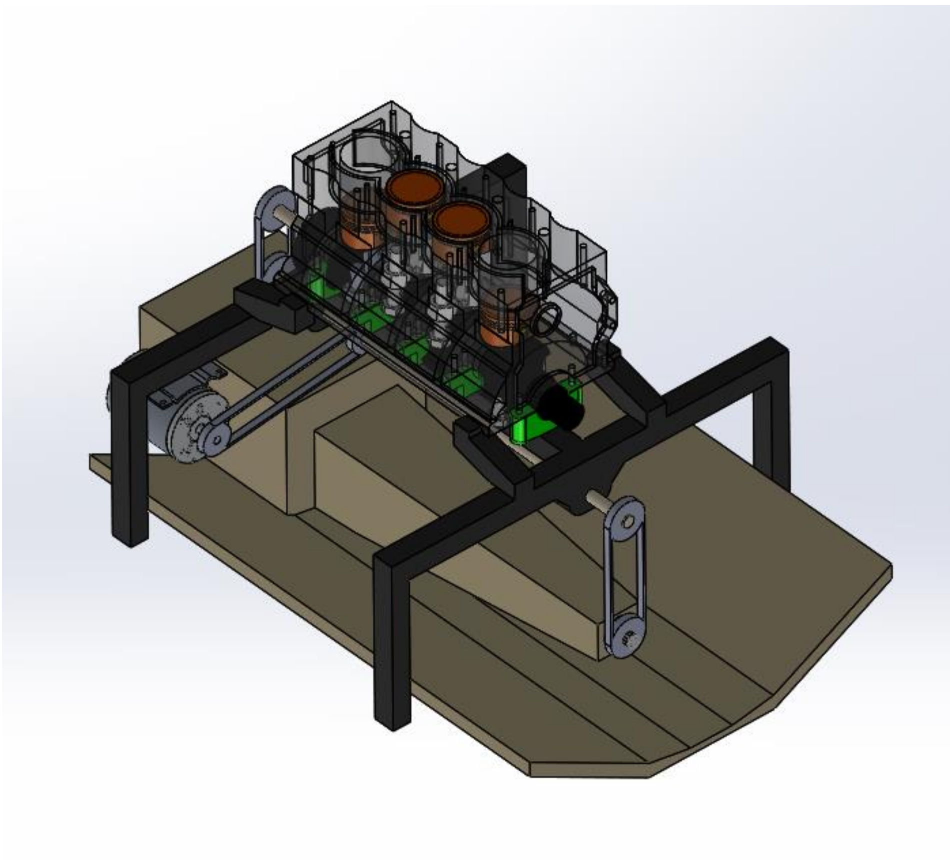
Motor Mount as seen from the back of the boat

This was our initial motor mount design. To center the weight and forces, we thought that the jack shafts would be mounted directly over one another underneath the motor. The frame would be mounted over the jet ski hull section and be through-bolted to the boat. Initially, our plan was to have the motor sit further to the middle of the boat, which was the original location of the motor in relation to the jet drive. We decided that the weight would be better distributed if the motor was mounted directly over the jet drive at the back of the boat. This would give more room for seating and plant the jet drive in the water while the boat gets on plane.



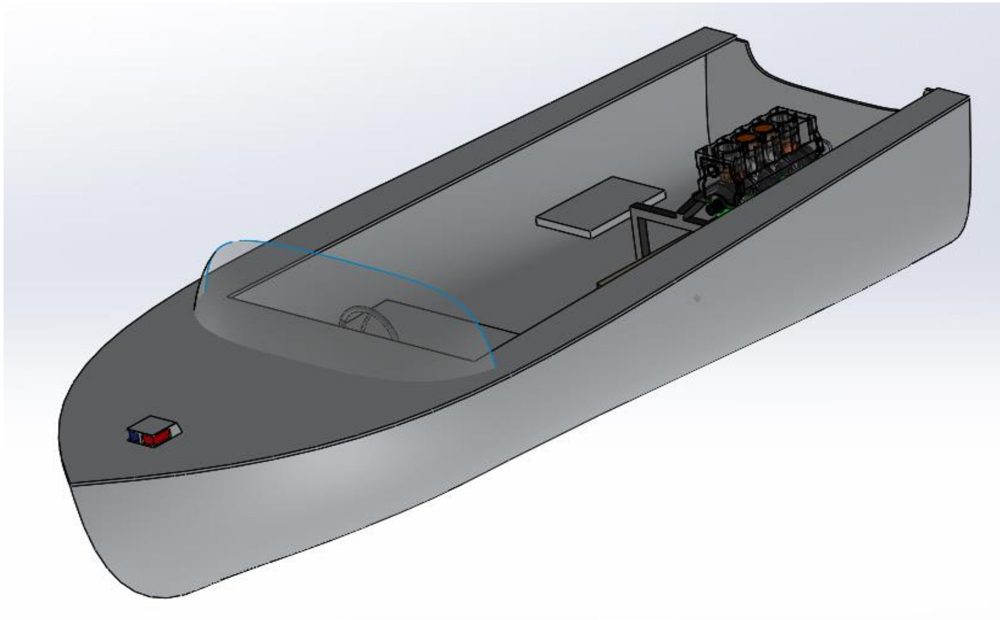
Motor mount as seen from the front of the boat

This is our modified frame design that sits in the boat today. We moved the jackshaft bearings on top of the frame, so the entire assembly would sit lower in the boat and lower the center of gravity. If the center of gravity were any higher we would have concerns about the boat handling turns. With this design, the legs were trimmed eight inches, which saved about eleven pounds. The legs on either side of the engine were to be mounted to three-foot 2 x 4 in. plank to absorb some vibration from the gas motor. This also helped us mount the frame in the right position with the irregular shape of the boat hull. The frame and 2 x 4s would be through bolted to the boat hull and water-sealed.

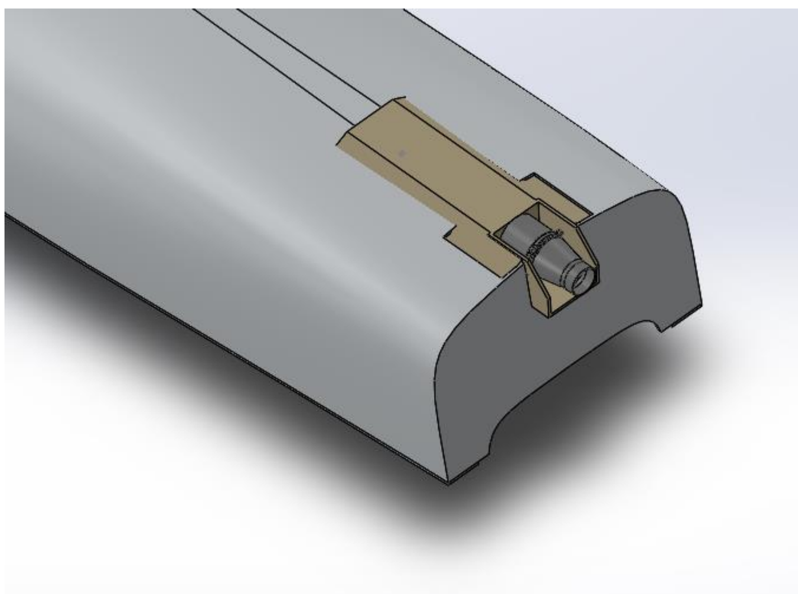


Hybrid system and jet drive as seen from the front of the boat

This 3D model shows the original frame design with both motors and the completed drivetrain. This shows our initial design where the jackshaft would still be under the motor. To the left is the electric motor that would be attached to the jackshaft via a chain. The gas motor in can be seen connected to the jackshaft in the rear. The jackshaft is then connected to the jet drive in the front of the model, carrying the power from either motor.



Upright view of the boat with hybrid jet system in place



Sectioned boat hull with jet drive in place

For us to see how our components would fit into the hull, we needed to make an exact model of the boat. We had very little Solidworks experience, but we were able to come up with this 3D model to work with. The top picture shows how the back seat would have to be removed to fit the motor assembly and jet ski hull. The second picture is the hole we planned on cutting into the bottom of the boat where the jet ski hull would lay. We needed to match the curvature of the bottom of the boat hull with the bottom of the jet ski hull to allow for proper water flow. The hole needed to account for the water intake and the skid plate, which protects the jet drive from debris.

Calculations

Torque and Horsepower

$$85\ HP = \frac{Torque * RPM}{5252}$$

$$Torque(\max) = \frac{85\ HP * 5252}{6250\ RPM} = 71.4\ lbft$$

Reynolds Number and Coefficient of Drag

$$Re = \frac{U_\infty L}{v}$$

$$v\ @73F = .000010098 ft^2/s$$

$$Re = \frac{\left(\frac{25\ miles}{hr}\right)\left(\frac{1}{3600\ \sec}\right)\left(\frac{5280ft}{mile}\right)\left(\frac{62in}{12ft}\right)}{.000010098ft^2/s}$$

$$Re = 1{,}876{,}059 = 1.8x10^6$$

$$C_D = 0.003\ from\ table$$

Drag Force and Thrust

$$D_f = \frac{\rho U_\infty A(C_D)}{2}$$

$$D_f = \frac{\left(1.936\frac{slugs}{ft^3}\right)\left(44\frac{ft}{s}\right)^2\left(\frac{62\ in\ x\ 50in}{144in^2/ft^2}\right)(0.003)}{2}$$

$$D_f = 121.03\ lbf$$

Thrust (Tf) = 550 lbf from Jet Ski Manual

Tf > Df

Free Hub Strength

Torque on freewheels under heavy riding conditions				
250 pound rider				
Average crank length 7"				
Torque Applied = 7 in x 200lbs = 1400 in.lbs				
1400 in.lbs = 117 ft. lbs				

Since free hubs are found in bicycles we calculated the torque a rider would put on the system. Our gas motor puts out a maximum of 71.4 lbf which is less than the 117 lbf that the freewheel system can comfortably take.

Gear Ratio

Gear ratio throughout the drive train will be 1:1. This means the applied torque will be the same throughout our system.

Power to Weight Ratio

The Jet Ski original weighted 530 lbs and had a top speed of 52 mph. The following are items in the estimated weight of the finished boat:

- Bare aluminum boat weight without motor: 330lbs
- Weight of motor: 150 lbs
- Weight of motor mount: 37 lbs
- 12V battery weight: 9 lbs x 4 = 36

We estimate the boat will be able to reach 25 mph.

Belt and Chain Strength

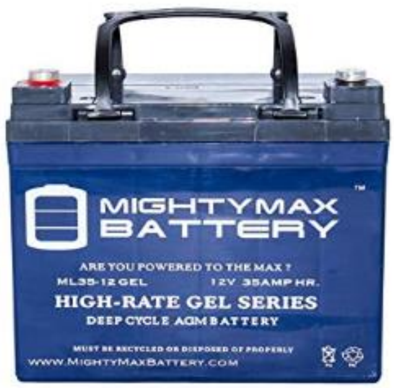
The maximum rpm for the gas motor and the electric motor are 6,200 RPM and 4,300 RPM respectively. Our chosen belt is rated for 8,000 RPM. Applied standard belt tension given for a 1100mm belt and 5 ⅛" cogs. The chain strength for the electric motor has a max tensile load of 2,000 lbs. The electric motor puts out 2.6 hp which does not put nearly enough torque to come close to this figure. Connecting the jack shaft and the jet drive is an ANSI #40 roller chain with a ½" pitch. This chain has a maximum tensile load of 3,700 lbs. The gas motor only puts out 71.4 lbf.

Chosen Components

Electric Motor

The electric motor we chose is a brushless DC motor rated at 2000 watts, or about 2.6 horsepower. The max RPM of the motor is 4300 and it will run on four 12-Volt batteries connected in series.

Batteries



Our motor has a 33 amp draw at full throttle. We chose batteries that would allow for at least one hour of run time. The chosen batteries were 35Ah and would be enough for just over an hour of run time. At 4 to 5 miles per hour, this would give us a range of 4 to 5 miles.

Bearings

Our design requires a total of three shafts to connect the power train. These pillow block bearings permanently hold the shafts to the frame. We chose Grainger High-Speed 12,000 RPM MAX Corrective Ball Bearings. The max RPM of the gas motor is 6000 which results in safety factor of 2. The dynamic load capacity is 3150 lbs and the static load capacity is 1760 lbs. We chose corrective bearings to be able to match the angles and concentricity of the original jet drive shaft.

Chosen Watercraft

Original craigslist ad for the boat.

Jet Ski

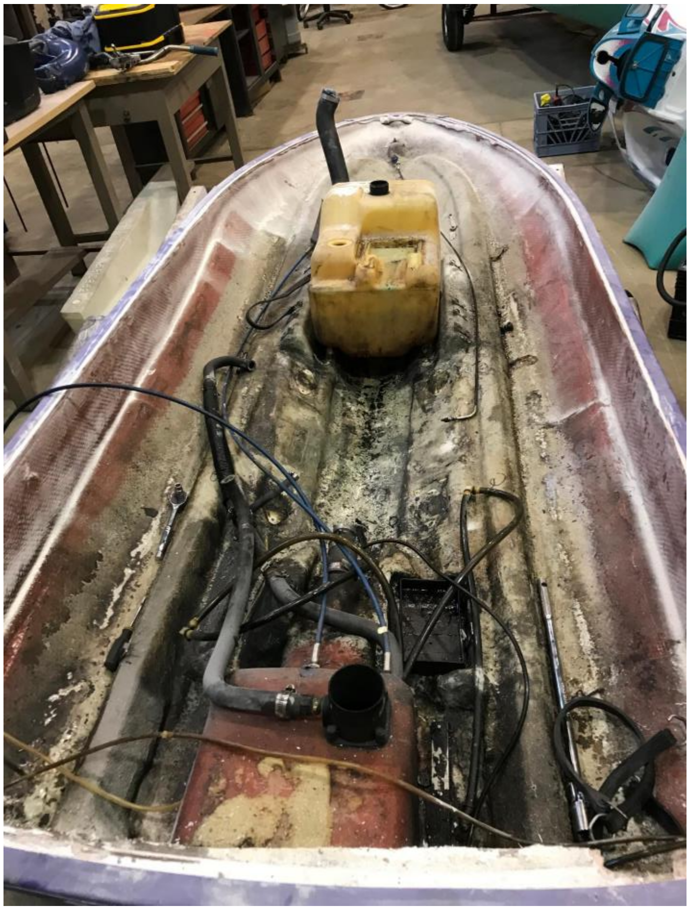
Our chosen jet ski is a 1995 Polaris SLT 750. The motor is a 744cc, 3 cylinder 2-stroke, rated at 85 horsepower. It featured a stock reverse bucket option. The engine had an upgraded fuel pump as well as aftermarket Vortex Ocean Pro air intakes. The motor was also rebuilt and has new pistons and gaskets.

Fabrication

Preparation

Split jet ski hull

Motor removed



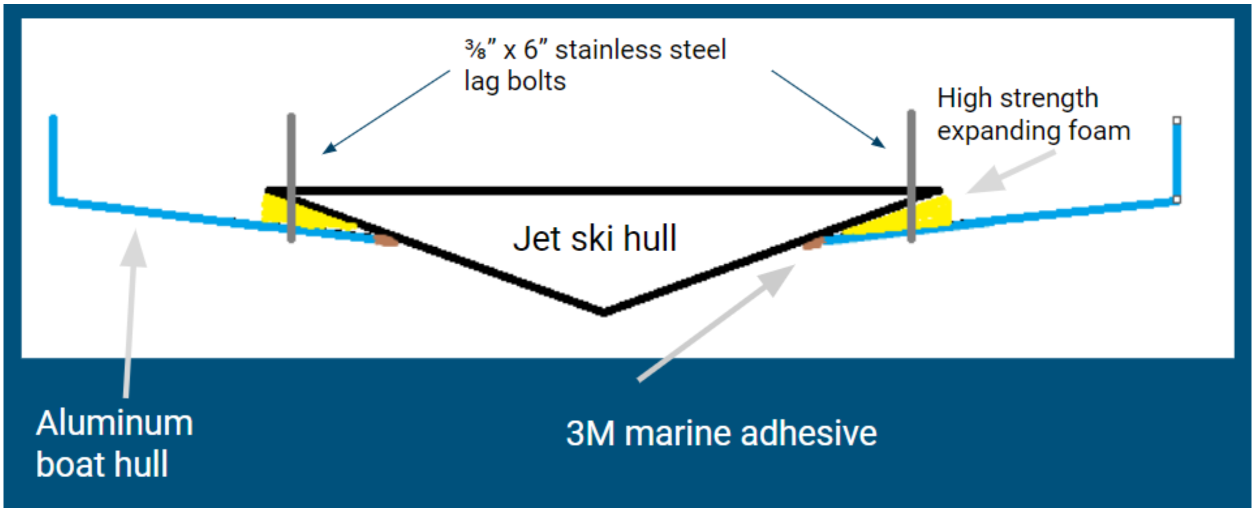
Bare jet ski hull after motor has been removed. All the vacuum lines for the bilge pumps and cooling are still attached.

With the motor pulled we could then see how much of the jet ski hull we would need. The hull will have to be prepped for a good bond to aluminum hull.

First test fit of the fiberglass hull in the aluminum hull. The skid plate is perfectly aligned with the keel of the aluminum boat.

Expanding foam added to fill gap between jet ski and aluminum hulls.
Foam trimmed away and covered in 3M marine adhesive. The right side of the hull is seen before the foam has been trimmed away, and the left is after it has been trimmed away and 3M adhesive was added to seal the gap.

Hull Section View



This section view is from the rear of the boat looking toward the bow.

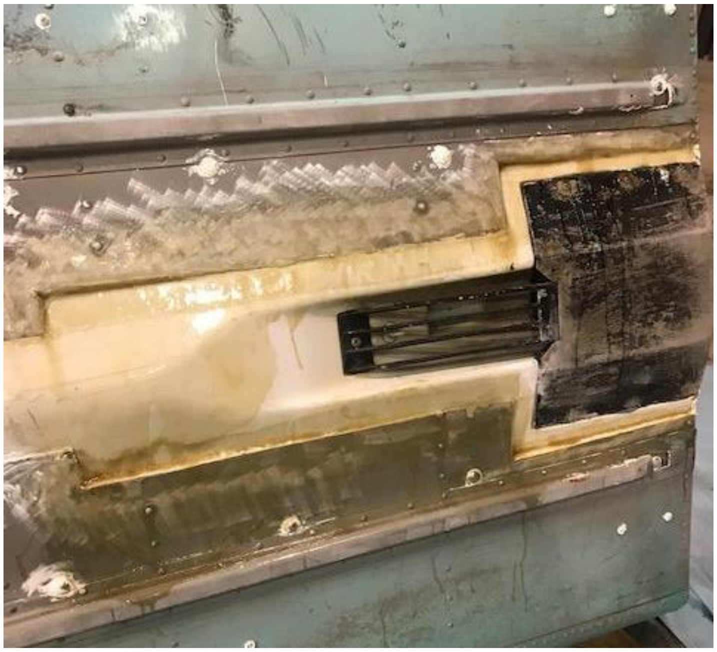
After the fiberglass hull was sealed using expanding foam and 3M, the top of the hull was secured to the aluminum with fiberglass resin and mats. Over 1 quart of resin was used for this top portion.

After the fiberglass cured, we used ⅜" lag bolts to secure the hulls together. 4 bolts were used one each side.

Fiberglass resin and mats used to seal and reinforce expanding foam and hull

Eight ⅜" stainless steel lag bolts once fiberglass was cured

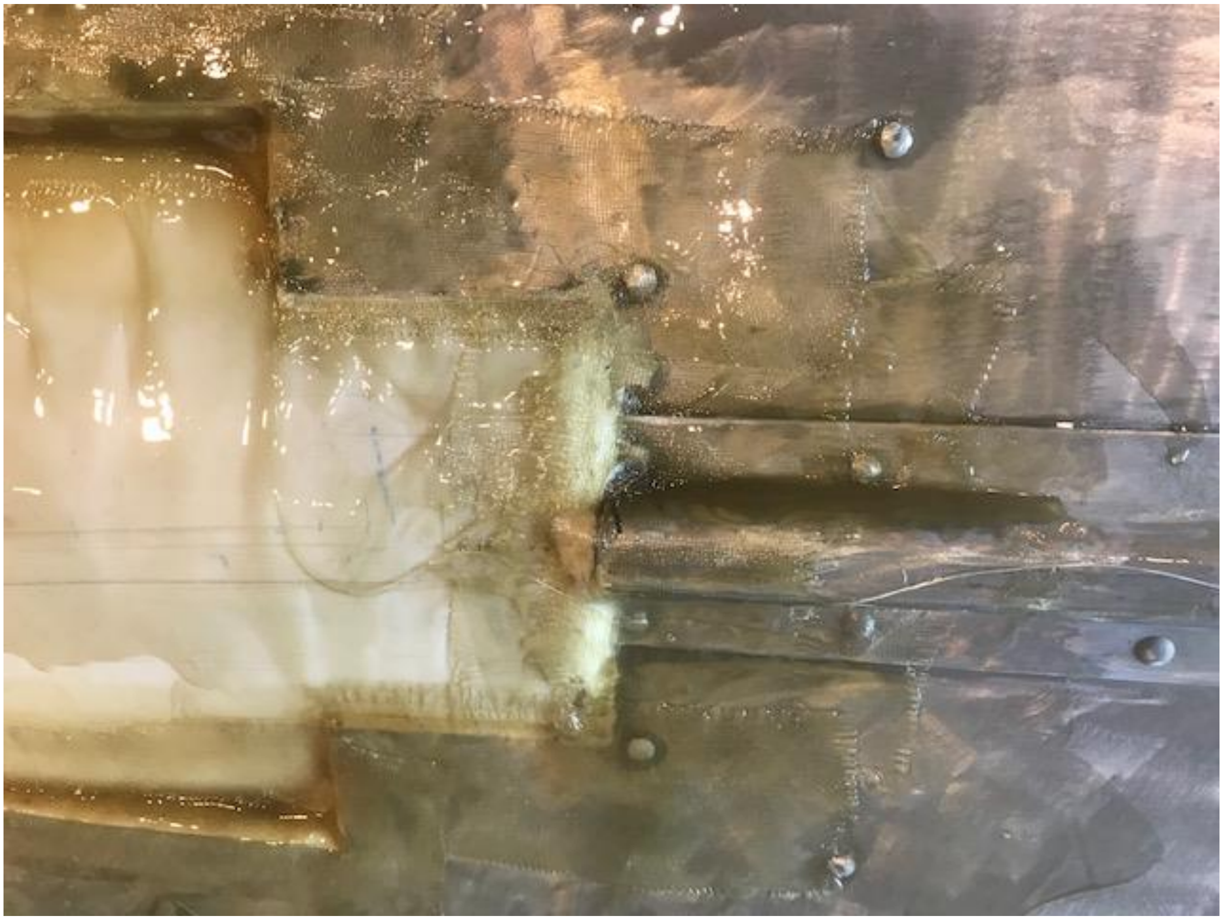
7500 psi of shear stress on each bolt, equal to thrust



The ⅜" lag bolts were sealed from the bottom using more 3M marine sealant. After the sealant dried, a layer of fiberglass resin and fiberglass mats was laid over the entire bottom surface and bolts.

Bottom coated with two layers of fiberglass resin and fiberglass matting

The bottom surfaces were then sanded with pneumatic and hand sanders to a smooth finish.



Close-up to show consistency of dried fiberglass.

Shafts

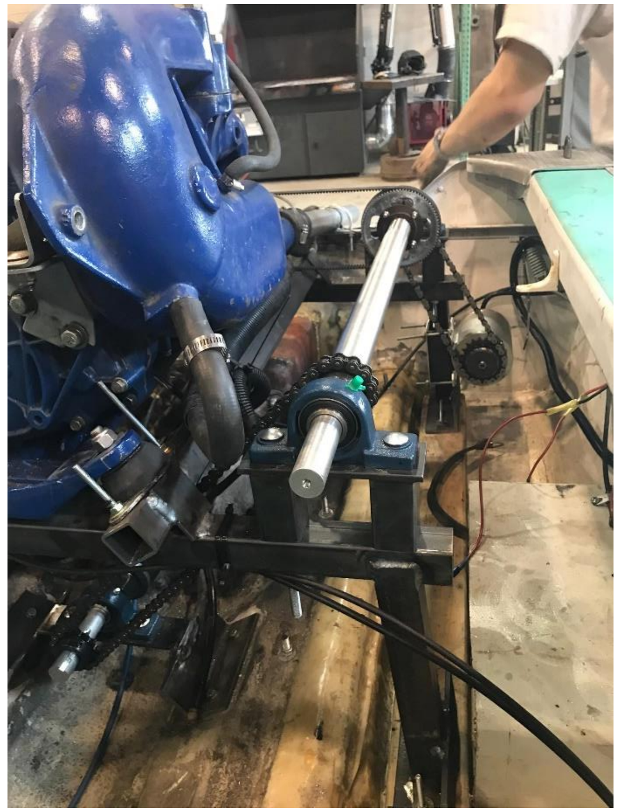
Began with 2 ¼” 2011 Aluminum round bar that would be turned down to a 1.5” in diameter. Each end would need to be turned down to 1” to fit the bearings. We had a tolerance of +- .005” for the 1” ends to match the tight tolerance of the bearings. M35x1 threads needed to be machined for sprockets and freewheels. The shaft was 32” long so we needed a center support to minimize vibrations.

Second drive shaft stemming from engine. Needed to be threaded to M35x1 to fit sprocket. We had to do a M24x2 interior tap in one end of the rod to thread onto the engine drive shaft, we ended up making our own tap for this. Opposite end had to be machine down to 1" to fit into pillow block.

We threaded M24x2 end to fit original engine spline coupler. Shaft will connect a chain driven sprocket which will turn the original impeller shaft. Both shafts required a ¼" keyway as shown above to mount the 1" sprockets. These would connect our #40 chain to the jet drive.

Engine shaft with belt sprocket.

Jackshaft mounted with belts and chains.



Freewheel clutches for gas and electric.

Alternate view of drivetrain.

¼" x 2 x 2 angle steel used for lower drive bearing mount.

Used original rear engine mount holes and hardware.

Sprockets and cogs before being mounted.

Custom made lock nuts for the sprockets and freewheels. The rare thread pitch required this since there were no lock nuts available with the same pitch.

We used hexagonal 1018 steel bar.

Re-surfaced and installed dash.

Original mahogany dashboard was un-usable
Covered with sheet aluminum and mounted buttons and MFD display using epoxy

Used original steering handle trimmed down for new steering control. Simple forward and back movement.

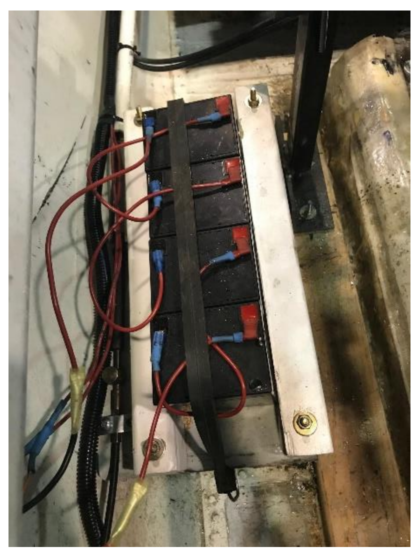
The original push/pull cable was used for steering linkage. Aluminum brackets were riveted into place to hold steering cable.

Push/Pull cable being bolted into our repurposed handlebars. A custom bracket had to be fabricated to support the handle. The bracket was riveted into the front of the front seat.

Cockpit with steering and gas/electric throttle installed. Seating yet to be finished.

The original reverse cable was seized so we had to remove all old hardware and re-install new cables, sheaths, and push pull rod.

Electric motor mounted to the rear leg of the motor frame. Once the chain was on, it could be tensioned by sliding the motor down and re-tightening bolts.



Motor controller was attached using rivets and epoxy. The top of the old back seat was used as battery rack. We would water proof in the future (still are sealed batteries).

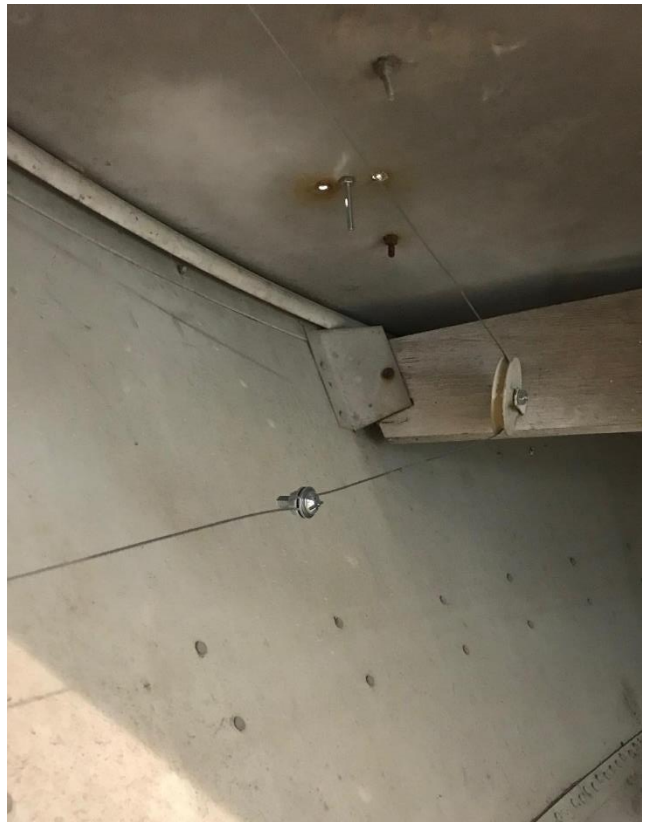
Twist grip throttle welded to angle steel and bolted to the original boat throttle mounting plate. Right picture is an alternate view of electric motor, controller, and battery packs.

Seat count and storage space both equally as important to customers according to the survey.
Lift up back seating for easy access to life jackets, fire extinguisher, cooler.

Repurposed aluminum panel from boat seats bolted to engine frame to support CPU box.

Throttle and Reverse

Salvaged throttle from 70s Chris Craft to control reverse bucket and gas throttle.



Jet ski choke control re-used and epoxied into dash. Simple pulley system used to run cable back to engine.

Testing

On our first test, we found a small leak along passenger side pump housing wall.
We sealed the seam with additional layers of fiberglass and marine sealant.

We also discovered one through bolt had a small leak which we sealed with 3M sealant.

After we had our first test run and all leaks were sealed, we decided to paint parts of the boat that were still bar or had fiberglass resin spots.

Painting the wave deflectors and gunnels.

Finished paint on the rear and side deflectors.

Towing

We purchased a bolt on trailer hitch for a 2008 Chevrolet Impala for transportation. A 1-7/8" ball with a 4" riser bar was used.

Registration

Registration proved to be very challenging with a 60-year-old boat from Michigan. We had to get a notarized bill of sale, have the boat inspected, and then get the boat registered. The state of Ohio requires permanently attached motors and boats longer than 14' to have certain paperwork that was not issued in the state of Michigan due to the high volume of boats.

Project Management

Project Budget Limit

Proposed Budget	Item
Item	Estimated
Jet ski with damaged hull	500
aluminum boat	500
Steering Components	200
Dc motor and batteries	500
Electronic motor controller	200
Clutch system	?
Wood Flooring	100
Steel for enging brace	200
sealing caulk and fiberglass	100
nuts and bolts	25
welding materials	100
misc. electronic switches/lights	100
carpeting	50
possible radio/speakers	150
replacement jet pump parts	250

Projected budget total was $3000 without including the price for a clutch system which we did not have a concept for at the time this table was made.

Actual Budget

Item	Price	QTY	Andrew paid	Cameron Paid
Boat	300	1	150	150
jet ski	0	1	0	0
Bike light	9.96	2	19.92	
Batteries	5.47	1	5.47	
Gas	35	1	35	
Gas	32.68	1	32.68	
Spare Wheel	60	1		60
Trailer hitch 3-ball		1		
angle grinder	15	1		15
grinder wheels	10	1	10	
trailer hitch	19.98	1	19.98	
trailer ball	7.98	1	7.98	
Fiberglass resin 1qt	14.98	1	14.98	
locktite foam	5.38	1	5.38	7
3M marine sealant	23.98	1	23.98	
Caulk gun	2.68	1	2.68	
sprayfoam insul.	8	1	8	
gas	35	1		35
beer	20	1		20
bolts	2	8		16
hitch receiver	25	1		25
angle and square tube	56.71	1	28.35	28.35
aluminum rod	14.72	1	14.72	
liquid nails	2.77	1	2.77	
brush	3.58	1	3.58	
whit plastidip	5.97	1	5.97	
battery cable 49"	9.99	1	9.99	
battery cable 60"	15.99	1	15.99	
free hub bolts & nuts	4.71	1	4.71	
cable crimps	1.24	2	2.48	
braided wire 1/16"	11.24	1	11.24	
carriage bolt 3/8"/nut	1.61	4	7.01	
Rubber bands	2.98	1	2.98	
boat registration	33	1	33	
marine grease	3.97	1	4.21	
rubber washer	2.42	1	2.42	
boat letters	7.71	1	7.71	
hinges	2.27	1	2.27	
spray paint	4.48	2	8.96	
painters tape	3.73	2	7.46	
80 tooth cog+ship	43.7	1	43.7	
Belt/cogs/clutch	98.4	1	98.4	
master link #40	6.28	1	6.28	
electric motor	136.99	1	136.99	
sqaure tube	10.7	1	10.7	
bike chain	9.31	1	9.31	

Cost and Labor

The total cost of our completed project was $1,173.60 which is a 60% reduction from our expected cost. This low cost was achieved in part because of our resourcefulness when re-using original parts from the jet ski and also our bargain hunting. While searching on craigslist, we came across a jet ski and trailer for sale. The seller learned about our school project and decided to donate the jet ski to us, since they really bought the set to have the trailer. The boat was also found on craigslist for less than we anticipated spending. The electric motor and batteries were a portion of the build we thought we may spend the most on. We found a plug-n-play electric motor kit that came with a throttle and controller. The batteries we used were more for proof of concept and could be upgraded in the future for improved battery life. In addition to the bargain hunting, we did all of the fabrication and assembly ourselves, which was around 500 hours, which could've been valued at over $15,000.

Key Milestones

- Purchasing the Boat - getting the best price during the fall/winter
- Cutting the hull and mounting the jet ski motor - February
- Steering, electronic drive and trial and error testing during the following months
- Final adjustments and carpeting/decking depending how furnished we want it to be

Proposed and Actual Milestones

Task	Proposed date		Actual date completed
Initial tear down of jet ski	12/11-12/21		4-Jan
fiberglass hull installed	5-Jan		6-Jan
first engine start	10-Jan		10-Jan
dash installed	21-Jan		21-Jan
design/build/install frame	1-Feb		1-Feb
engine mounted	10-Feb		10-Feb
throttle/choke	12-Feb		10-Feb
route wiring	14-Feb		11-Feb
route fuel lines	17-Feb		17-Feb
electronics completed	20-Feb		22-Feb
shafts designed and finished	1-Mar		1-Mar
test fit belts/sprockets	5-Mar		5-Mar
machine locknuts	7-Mar		7-Mar
Electric motor mounted	8-Mar		7-Mar
first live test with belts	9-Mar		9-Mar
batteries/controls wired	10-Mar		7-Mar
electric motor tested	11-Mar		7-Mar
test motor w/chains	13-Mar		13-Mar
forward and revere controls	15-Mar		16-Mar
seating	21-Mar		17-Mar
boat inspected and registered	1-Apr		8-Apr
first float test	5-Apr		8-Apr
first top speed	10-Apr		9-Apr
painted	16-Apr		17-Apr

Results

Parameters	Actual Results
Top speed of at least 25 mph under gas engine	Our best recorded speed was 32 mph vs. 25-30 mph stock using 40hp outboard
Capable of “no wake zone speeds” under electric power	Electric motor ran quietly at 5 mph
Storage and seating capacity are priorities	Seats four people and has under-seat storage
Maneuverability to make navigating shallow and debris filled water safer	Boat was able to make sharp turns at low and high speeds
Navigating shallow and debris filled water safely	Able to launch from the trailer right into the lake without having to raise an outboard motor. Never had trouble with shallow areas

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TRAILER

References

1. **Adey, .** Electric and Hybrid Boats. *BoatUS Magazine.* [Online] Boat US, 2012. [Cited: 12 October 2018.] www.boatus.com/magazine/2012/april/run-silent-run-green.asp.
2. **DeVo, .** 12' Mini Jet Boat Build 200hp. *BDoutdoors.* [Online] 20 September 2018. [Cited: 12 Octover 2018.] www.bdoutdoors.com/forums/threads/14-mini-jet-boat-build-200hp.669523/.
3. **Fuel Price Reports**. *Waterway Guide: The Cruising Authority.* [Online] Waterway Guide Media LLC, 2018. [Cited: 12 October 2018.] www.waterwayguide.com/fuel-price-report/14.
4. **Oceanvolt**. *Oceanvolt.* [Online] 2017. [Cited: 12 October 2018.] www.oceanvolt.com.
5. ***Volvo Penta.*** [Online] Volvo, 2017. [Cited: 12 October 2018.] https://www.volvopenta.us/.
6. 1995 Polaris PWC SLT 750 Jet Ski Manual