PEP26 White Paper Submission

School Name: Massachusetts Maritime Academy

Team Name: Birddoggers

Division:

☐ Crewed – Planing
☐ Crewed - Displacement
☐ Uncrewed – Autonomy
☐ Uncrewed – Over-the-Horizon
☑ Uncrewed – Open
☐ Uncrewed – Budget Warrior

Photo of Team with Boat:

List of Members on Team: Knox Ackerman, Dhillan Maxwell-Coimbra, Michael Voci

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Background

Marine propulsion systems have historically been dominated by internal combustion systems that are inherently constrained by thermodynamic inefficiencies, mechanical complexity, and fuel-dependent operation. These limitations become more pronounced in unmanned platforms, where reliability, controllability, and system simplicity are critical design drivers.

As the global demand for efficient, sustainable, and resilient engineering solutions continues, efforts put forth in the maritime industry have further intensified while facing the challenges of reducing environmental impact while maintaining robust operational performance. Electric propulsion introduces an opportunity to address industry challenges under fundamentally different standards based on direct electromechanical energy conversion, enabling tighter system integration and improved controllability.

Within the PEP competition framework, this shift allows for a design approach centered on efficiency, modularity, and repeatable performance under constrained operational conditions. Team Birddoggers has worked to develop our vessel with these principles as the foundation for system-level optimization.

Technological Advancements

Advances in electric propulsion have been driven by increased battery power density, improved motor efficiency, and more capable embedded control systems. High-discharge energy storage supports dynamic loading, while modern motor controllers enable precise regulation of torque and speed through closed-loop control. Embedded computing platforms further allow real-time sensor integration and adaptive response. Together, these technologies enable highly responsive and tightly integrated propulsion systems.

Environmental Impact

From an environmental perspective, electric propulsion removes the need for onboard combustion, eliminating localized emissions and reducing environmental contamination. These systems also produce lower acoustic and vibrational signatures due to smoother operation and fewer moving components. This reduction in disturbance is especially important in marine environments, where noise and emissions can impact ecosystems. As a result, electric propulsion supports lower-impact marine operation.

Economic Considerations

Electric propulsion systems shift the cost from ongoing fuel consumption to initial system investment. Although upfront costs are higher, operational expenses are reduced through improved efficiency, lower maintenance requirements, and fewer failure points. The absence of fuel dependence also stabilizes long-term costs. For frequently operated systems, this results in a more favorable total cost of ownership.

Industry Challenges and Future Development

Key limitations of electric propulsion remain tied to energy storage capacity and system endurance. Battery constraints require careful power management, while additional challenges include thermal control, environmental sealing, and system reliability. Future work will focus on improving energy density, refining control strategies, and enhancing system robustness. Continued advancements will expand the performance and applicability of electric marine systems.

Design and Analysis

The initial design began with determining the vessel's design speed and duration to be competitive in the race. The design speed of 22 miles per hour was calculated from the average speed of the PEP25 Uncrewed-Open champion, 5 minutes and 58 seconds.

Electronics were given a team requirement to maintain an IP65 rating across all components across the system. This rating was determined based on the design goal of mitigating issues caused by water and weather entering a deck covering without sacrificing velocity.

Key Performance Parameters

The chart below outlines the most critical system-level performance parameters of the unmanned electric propulsion watercraft, beginning with the most important to the least important, that will yield effective results for a full-scale system:

Table 1: Key Performance Parameters

Importance	Parameter	Description
1	Payload	The watercraft shall carry an effective payload of 60 lbs without issue.
2	Battery Life	The watercraft shall have a full-load minimum runtime of 40 minutes.
3	Cost Effectiveness	The watercraft's operational costs shall be at least 25% less than the operational costs of a similar-use manned internal combustion engine watercraft.
4	Reliability	The watercraft shall complete at least 90% of missions with

		minimal issues.
5	Speed	The watercraft shall operate at a speed of at least 22mph with a full payload.
6	Scalability	The watercraft shall consist of a robust design where scalability and manufacturability are easily achieved.
7	Ease of Use	The watercraft shall be simple to operate and control, with full training requiring less than 30 minutes.

Hull

Initial hull design and selection began with estimating the total displacement of the vessel with full competition load. The initial weight estimate was 220 pounds. This estimate was based on selections made for a battery and propulsion motor, as well as other component weight estimates. The estimate of arrangeable ballast accounting for ~25% of the total weight allows for less concern to be given to the weight distribution of fixed components and the use of competition ballast to optimize weight distribution.

Using this estimate, the required area for planing was calculated, with the equation from Performance by Design, to be 14.8 square feet. The unitless hull loading coefficient used was 6, based on the recommendation from *Performance by Design*.

$$Planing\ Area\ (ft^2)\ =\ Hull\ Loading\ Coefficient\ \times Displacement(ft^3)^{2/3}$$

This estimate was used to help inform initial design requirements for the boat. However, after analysis of available boat kits, it was determined that all available models would have sufficient planing area.

The model selected for construction was the Cocktail Class Racer from Chesapeake Light Craft. This model was selected because of the lightweight design was the smallest size kit that was readily available for construction, while having sufficient freeboard to satisfy reliability concerns relating to sea state during the competition. It also has approximately 16 square feet of planing area, meeting the calculated requirement.

Propulsion System

Initial considerations of the drivetrain and propulsion system included a jet drive, an inboard motor, and an outboard motor. The outboard motor was dismissed due to the number of moving parts and potential for failure introduced with such a system. A jet drive was strongly considered, particularly due to the ease of implementing an effective low drag steering system but was rejected due to concerns over fitting it into hull geometry and finding or designing a jet drive suitable for the application. The inboard powered propeller system was selected for its reliability and the greater commercial availability of components, providing a greater opportunity to select and modify components to optimize performance.

Drivetrain design began with an analysis of options for electric motors utilizing 48-volt power while maximizing power within our budget. Motor selection was also based on adherence to IP65 or better standard. The MotEnergy ME1718 motor was selected to drive our vessel, as this specific motor met our requirements to achieve the design speed of 22 mph when paired with our propeller. This 48V motor generates 6kW and 14.3 Newton-meters of torque at its maximum motor speed of 4,000 rpm. The Sevcon G4845 motor controller is paired with the ME1718 6kW motor, intended to operate with high efficiency, and is designed with IP66 protection, appropriate for marine applications. This motor controller was additionally selected due to its compact form factor, with dimensions of 8.9” x 6.7” x 3” that would allow for this motor controller to adequately fit within our designated control box.

To power this motor, our team researched highly capable 48V batteries that were widely available and suited our needs for high power and low weight. The battery selected was VEVOR’s 55.5V 105 Ah battery that provides ample energy storage to last the duration of the competition based on past PEP Competition course completion times. The following figure describes the general high voltage one-line diagram.

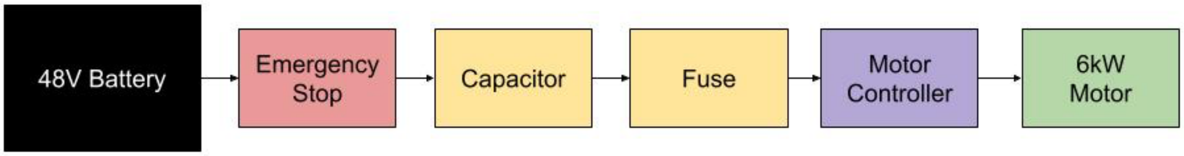


Figure 1: High voltage one-line diagram

In addition to its technical capabilities, the VEVOR 48V 105Ah battery features built-in overcharge control and management during charging and discharging, capable of handling short circuits as well as integrated safeguards for both high and low temperatures during charging and discharging.

$$Battery\ Depletion\ (mins) = \frac{80\% \times Capacity\ (Ah) \times Voltage\ (V) \times Battery\ Efficiency\ (\%)}{Load\ Power\ (W) \times Motor\ Efficiency\ (\%)} \left[\frac{60\ mins}{1\ hr}\right]$$

Using the table and above battery depletion estimate, the estimated time until the battery is depleted from a full charge is 41.6 minutes. Based on the previous PEP competition course completion times being in the 5-10 minute range, this no-load battery depletion estimate seemed adequate for competitive runtimes.

Table 2: Energy Consumption Metrics

Input	Value
Capacity	105 Ah
Voltage	48 V
Battery Efficiency	95.00%
No-Load Power Output	6,000 W (continuous)
Motor Efficiency	92.00%

Propeller diameter and pitch were determined by estimating slip using Gerr's slip chart from *The Nature of Boats*. At a design speed of 22 mph, slip was estimated at 0.26. From *Performance by Design,* a thrust reduction factor due to our shaft angle was taken as 0.1. The required pitch was calculated to be 8.6 inches for design speed.

From *The Nature of Boats*:

$$Required\ Blade\ Area\ (sq.in) = \frac{100 * horsepower}{knots * \sqrt{knots}}$$

At our design speed, the calculated required blade area was 9.7 square inches.

The propeller diameter will be machined down from the purchased propeller options to optimize the drivetrain performance. Several propellers have been purchased for final selection, dependent on trials.

Steering

The design for our steering system was based on the desire to minimize drag in the water and the analysis of the course, indicating a lack of need for rapid maneuverability. To accomplish steering, motor-actuated trim tabs that can be lowered during steering and raised on straightaways were selected. The trim tabs selected for this purpose were the Bennet Marine SLT6 with the Fuserish electric conversion kit. The electric conversion kit uses 12V inputs to extend or retract the struts, controlled by the Raspberry Pi 3/Navio2 controller.

Controls

The control system was designed to maximize the versatility of the vessel and the reliability of the electronic systems. The main controller selected was a combination of a Raspberry Pi 3B+ and a Navio2 autopilot hat. This combination was selected as it includes extensive documentation and open-source software, as well as a suite of sensors that could be used to implement autopilot and additional features. The Navio2 system includes a GPS, compass, accelerometer, gyroscope, and 14 pulse width modulation (PWM) outputs.

The on-board receiver communicates with the operator's handheld radio transmitter. The radio receiver communicates with the Raspberry Pi/Navio2 flight controller. This controller manages the two trim tab actuators through reversing relay packs, controls motor direction forward or reverse via a built-in relay contactor and regulates motor speed using a servo motor that manipulates the throttle control's three-pin potentiometer.

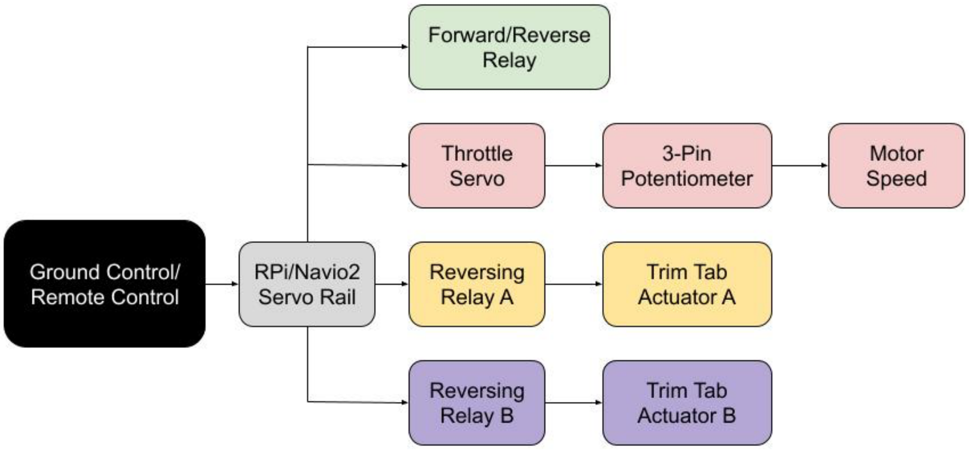


Figure 2:Control System Diagram

The control system was engineered to draw power from an independent 12V Lithium Polymer (LiPo) battery. This dedicated battery supplies power to the controller, the servo rail, the trim tab actuators, and the bilge pumps. This separate battery system was chosen to ensure a power source distinct from the propulsion system's supply, thereby mitigating the complications associated with utilizing a 48V battery to power a 12V system.

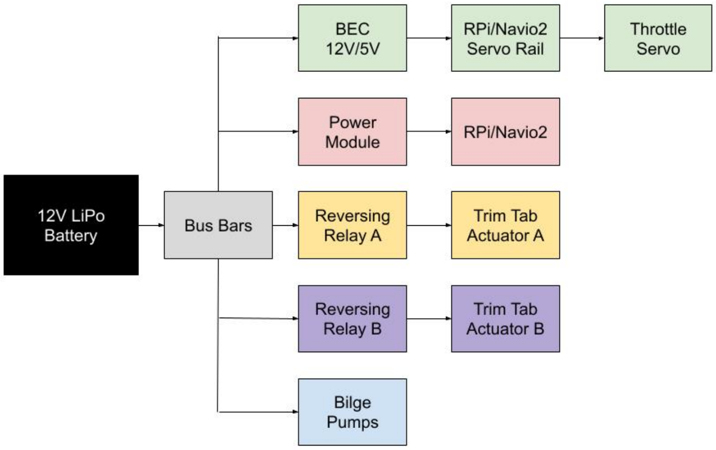


Figure 3:Low voltage power distribution

Overview of Build and Fabrication Processes

Hull

Hull construction was conducted according to the instructions provided by Chesapeake Light Craft for the Cocktail Class Racer. Minor modifications were made to reduce weight by only placing fiberglass along interior seams rather than full panels in each interior compartment.

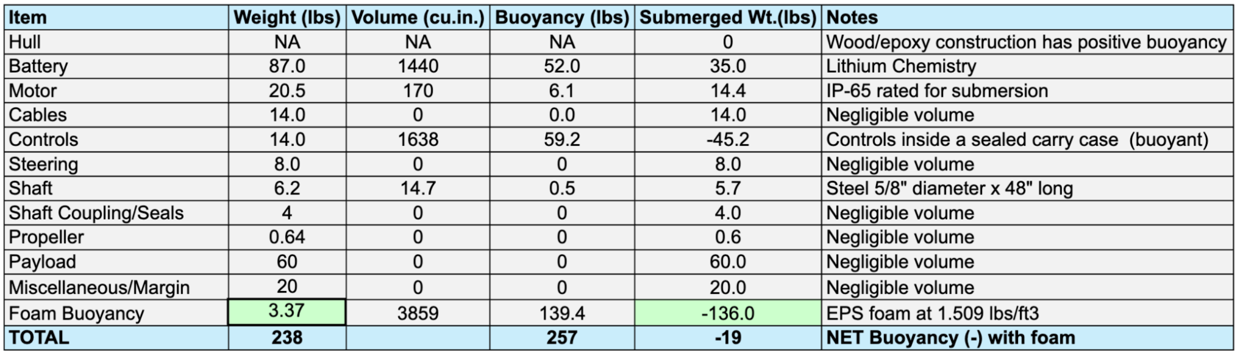
The precut plywood boards were drilled to provide spots for the temporary wire ties. Sections of plywood were glued together for the transom and the midship bulkhead. These pieces were placed, and the plywood sections were tied together using copper wire ties to form the hull. The interior compartments were epoxied along the seams with a wood-thickened epoxy, then fiberglassed over top. The interior was finished by coating all bare wood surfaces with two coats of epoxy resin. The boat was then flipped over, where the harsh angles were rounded to enable the fiberglass wrap to remain strong. The entire exterior of the boat was fiberglassed with an overlap along the keel and the edges of the transom. This fiberglass, once cured, received a second layer of semi-thickened epoxy to fill in low spots. This layer was then sanded smooth.

Closed-cell foam was cut out from sheets and installed in empty compartments to satisfy the positive buoyancy requirement.

$$Floatation\ per\ Pound\left(\frac{lbm\ water}{lbm\ foam}\right) = \frac{Density\ of\ Water\left(\frac{lbm}{cu.ft.}\right) - Density\ of\ Foam\left(\frac{lbm}{cu.ft.}\right)}{Density\ of\ Foam\left(\frac{lbm}{cu.ft.}\right)}$$

The equation provides the required mass of foam to be installed. This enables the foam installed to be measured by mass rather than volume.

Table 3:Buoyancy of components



Item	Weight (lbs)	Volume (cu.in.)	Buoyancy (lbs)	Submerged Wt.(lbs)	Notes
Hull	NA	NA	NA	0	Wood/epoxy construction has positive buoyancy
Battery	87.0	1440	52.0	35.0	Lithium Chemistry
Motor	20.5	170	6.1	14.4	IP-65 rated for submersion
Cables	14.0	0	0.0	14.0	Negligible volume
Controls	14.0	1638	59.2	-45.2	Controls inside a sealed carry case (buoyant)
Steering	8.0	0	0	8.0	Negligible volume
Shaft	6.2	14.7	0.5	5.7	Steel 5/8" diameter x 48" long
Shaft Coupling/Seals	4	0	0	4.0	Negligible volume
Propeller	0.64	0	0	0.6	Negligible volume
Payload	60	0	0	60.0	Negligible volume
Miscellaneous/Margin	20	0	0	20.0	Negligible volume
Foam Buoyancy	3.37	3859	139.4	-136.0	EPS foam at 1.509 lbs/ft3
TOTAL	**238**		**257**	**-19**	**NET Buoyancy (-) with foam**

Drivetrain

Drivetrain construction began with routing a slot in the bottom of the vessel for the shaft to pass through. This slot was located by placing a disk the size of the propeller on the end of the shaft tube and locating the spot where penetration through the hull was necessary.

The shaft tube then had the shaft and motor installed to ensure proper clearances were met as components were aligned. The shaft was installed into the tube with two radial bearings on each end to support the shaft inside the tube. With all the components aligned, the motor mount was epoxied into place along with the shaft tube. Minor misalignment between the motor and shaft tube was handled by adjusting the motor with shims on the mount and the flexible coupling on the motor shaft.

The propeller was installed by machining the hub of the propeller down to the size of the shaft and drilling a cross-hole through the shaft for a pin to prevent rotation of the propeller on the shaft. The main thrust bearing was installed between the propeller hub and the end of the shaft tube.

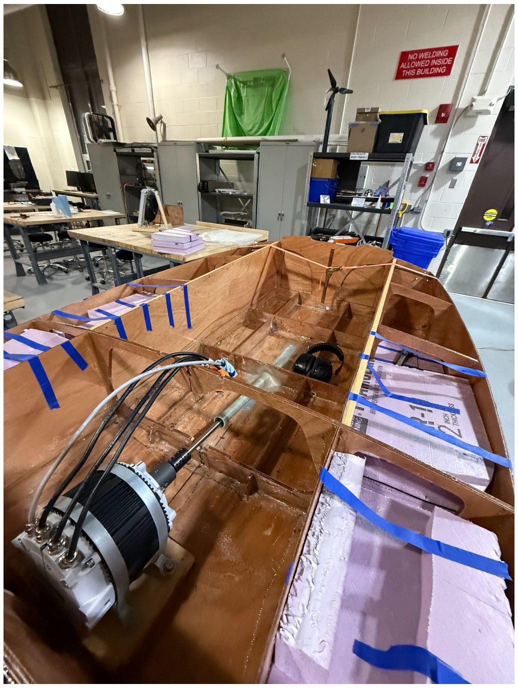


Figure 4:Shaft and motor installation

Our team chose a standard pool pump motor seal for the propeller shaft due to its proven suitability for water-heavy environments, offering superior waterproofing and reliability compared to traditional seals like stuffing boxes. This choice was also driven by performance considerations, as the mechanical seal design produces significantly less friction, contributing to higher efficiency and helping the boat achieve its target speed of 22 mph. Furthermore, the selection was highly practical from a logistics and budget standpoint, as these commercial components are readily available, cost-effective, and feature a cartridge-style design that simplifies both installation and quick maintenance or repair. Relying on a robust, mass-produced component to ensure a reliable, low-drag interface between the drivetrain and the water supports our mission to maximize competitive runtime while minimizing complexity and cost.

Steering

The trim tabs were placed as far apart as possible on the transom to maximize the total turning moment. The default height of the trim tab actuators was defined by setting the most retracted spot of the trim tabs to be ¾ of an inch above the bottom of the vessel when fully retracted. This positioning was selected to maximize the speed of the vessel when going straight ahead, while allowing sufficient actuation of the trim tabs into the water to provide the turning moment from the trim tabs.


Figure 5: Trim tab for steering control

Controls

A Raspberry Pi 3+ (RPi) was selected as the main computer module; when paired with the Navio2 Autopilot hat, controls integration was a seamless process. The Navio2 component served as the interface between our Ground Control and the RPi. The Navio2 was specifically selected for its expandability and ease of use, allowing for the addition of a camera as well as fully autonomous capabilities for drone control. The Navio2 allowed for individual control of each trim tab, motor speed & rotation, and bilge pump control through its servo rail that utilized pulse-width modulation (PWM) to send control signals to these components.

In addition to its ease of implementation, the Navio2 was selected due to its robust and redundant systems. If wireless telemetry fails, the Navio2 has the option to utilize remote control transmission as a backup failsafe. In the event that the voltage regulator that directly powers the Navio2 via its power module fails, the Navio2 will reroute and receive power from the servo rail.

After identification of the vessel's functional requirements, a control system specification was performed to identify our system's operational modes and transitions between these modes while referencing our functional requirements. The following table describes the vessel's control components and their associated role in our system:

Table 4:Control system elements

Control Component	Description
Remote Controller	User input interface for propulsion and directional commands to the system.
Remote Controller Antenna	Communicates user interface input commands to the on-board receiver.
On-Board Receiver Antenna	Receives user interface input and transfers information to the On-Board Receiver.
On-Board Receiver	Communicates user input to our on-board controller module (Raspberry Pi).
On-Board Controller	Outputs signal (reflective of user input commands) to the Electric Propulsion Control component (Motor Controller) and directional component (Servo Motor). The controller also integrates the entirety of the on-board systems for effective communication and operation.
Electric Propulsion Control (Motor Controller)	Acts as an intermediary between the battery + controller/transmitter and the motor to control its speed and direction. It takes signals from

	the transmitter, translates them into timed electric signals for the motor. This allows the user to start, stop, and run the motor at various speeds and to reverse its direction.
Directional Control (Trim Tab Actuation)	Translates user input signals from the remote controller into specific trim tab actuation, allowing for steering and maneuvering of the vessel.

The following table describes the system's operational modes, inputs, and processes:

Table 5:Control processes

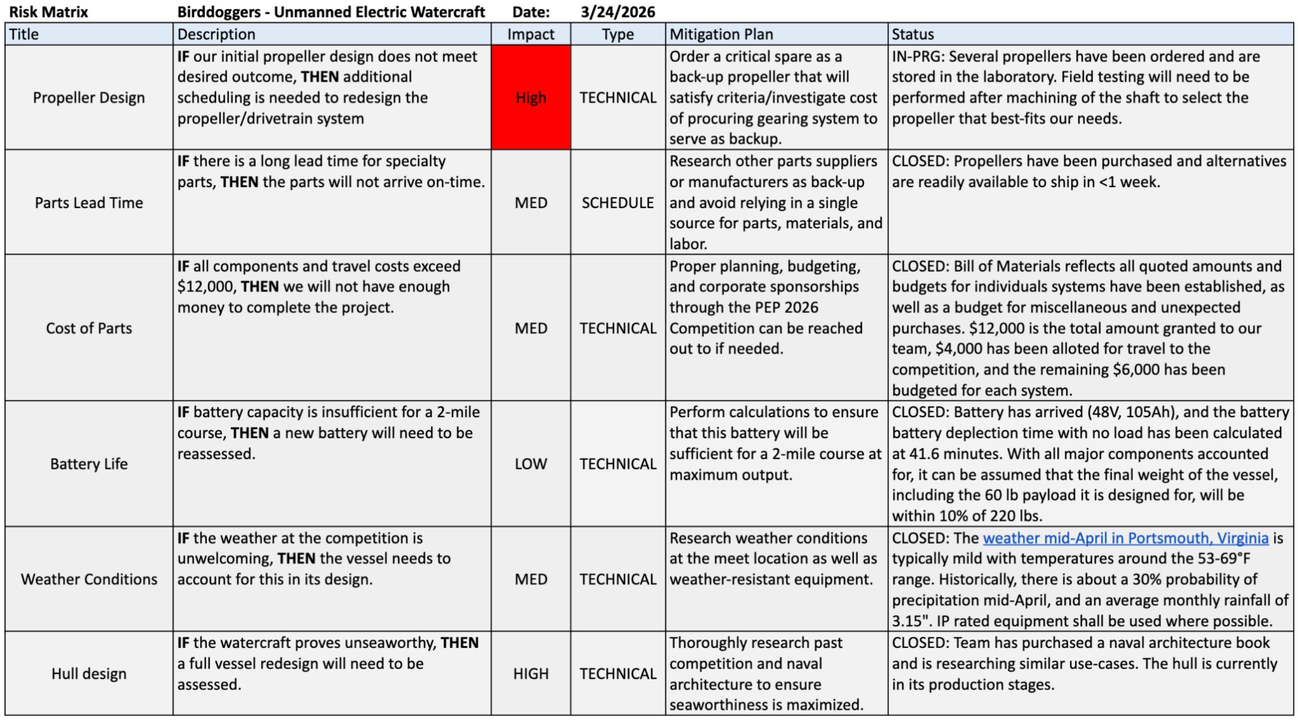
Operational Mode	Input	Process
Power Off	The vessel should receive no power when the Main Disconnect is in the (OFF) position.	Main Disconnect position turned to OFF will stop the flow of power to the vessel from the battery system.
Power On	The vessel should be receiving operational power when the Main Disconnect is in the (ON) position.	Main Disconnect position turned to ON will allow the flow of power to the vessel from the battery system.
Propulsion Forward Direction	The vessel should move in the forward direction when the user interface input moves the propulsion control to the upward (forward) position.	User interface input should be communicated to the on-board receiver, then to the controller module (Raspberry Pi), which will communicate with the motor controller. The motor controller will signal this request to the motor, which should then turn in the clockwise direction at a relative speed based on the user input.
Propulsion Reverse Direction	The vessel should move in the forward direction when the user interface input moves the propulsion control to the downward (reverse) position.	User interface input should be communicated to the on-board receiver, then to the controller module (Raspberry Pi), which will communicate with the motor controller. The motor controller will signal this request to the motor, which should then turn in the counterclockwise direction at a relative speed based on the user input.
Turn Vessel Left	The vessel should turn to the left when the user	User interface input should be communicated to the on-board receiver, then to the controller

	interface input moves the directional control to the left position.	module (Raspberry Pi), which will communicate with the servo motor. The servo motor, along with the attached rudder, will then turn to the left at an angle relative to the user input.
Turn Vessel Right	The vessel should turn to the left when the user interface input moves the directional control to the left position.	User interface input should be communicated to the on-board receiver, then to the controller module (Raspberry Pi), which will communicate with the servo motor. The servo motor, along with the attached rudder, will then turn to the left at an angle relative to the user input.

Risk

Initial design and manufacturing required understanding the risks and issues associated with the fabrication and execution of a remote-controlled payload-capable high-speed vessel. Risks such as propeller design, battery life, time management, and cost of materials were factored into our component decisions and largely impacted our final design result.

Table 6:Risk Matrix



Risk Matrix **Birddoggers - Unmanned Electric Watercraft** **Date:** **3/24/2026**

Title	Description	Impact	Type	Mitigation Plan	Status
Propeller Design	**IF** our initial propeller design does not meet desired outcome, **THEN** additional scheduling is needed to redesign the propeller/drivetrain system	High	TECHNICAL	Order a critical spare as a back-up propeller that will satisfy criteria/investigate cost of procuring gearing system to serve as backup.	IN-PRG: Several propellers have been ordered and are stored in the laboratory. Field testing will need to be performed after machining of the shaft to select the propeller that best-fits our needs.
Parts Lead Time	**IF** there is a long lead time for specialty parts, **THEN** the parts will not arrive on-time.	MED	SCHEDULE	Research other parts suppliers or manufacturers as back-up and avoid relying in a single source for parts, materials, and labor.	CLOSED: Propellers have been purchased and alternatives are readily available to ship in <1 week.
Cost of Parts	**IF** all components and travel costs exceed $12,000, **THEN** we will not have enough money to complete the project.	MED	TECHNICAL	Proper planning, budgeting, and corporate sponsorships through the PEP 2026 Competition can be reached out to if needed.	CLOSED: Bill of Materials reflects all quoted amounts and budgets for individuals systems have been established, as well as a budget for miscellaneous and unexpected purchases. $12,000 is the total amount granted to our team, $4,000 has been alloted for travel to the competition, and the remaining $6,000 has been budgeted for each system.
Battery Life	**IF** battery capacity is insufficient for a 2-mile course, **THEN** a new battery will need to be reassessed.	LOW	TECHNICAL	Perform calculations to ensure that this battery will be sufficient for a 2-mile course at maximum output.	CLOSED: Battery has arrived (48V, 105Ah), and the battery battery deplection time with no load has been calculated at 41.6 minutes. With all major components accounted for, it can be assumed that the final weight of the vessel, including the 60 lb payload it is designed for, will be within 10% of 220 lbs.
Weather Conditions	**IF** the weather at the competition is unwelcoming, **THEN** the vessel needs to account for this in its design.	MED	TECHNICAL	Research weather conditions at the meet location as well as weather-resistant equipment.	CLOSED: The weather mid-April in Portsmouth, Virginia is typically mild with temperatures around the 53-69°F range. Historically, there is about a 30% probability of precipitation mid-April, and an average monthly rainfall of 3.15". IP rated equipment shall be used where possible.
Hull design	**IF** the watercraft proves unseaworthy, **THEN** a full vessel redesign will need to be assessed.	HIGH	TECHNICAL	Thoroughly research past competition and naval architecture to ensure seaworthiness is maximized.	CLOSED: Team has purchased a naval architecture book and is researching similar use-cases. The hull is currently in its production stages.

These risks were identified in order of highest impact to lowest impact and were sub-categorized by the type of risk, with the technical type defined as a risk that affects design and schedule, and a schedule type defined as a risk that mainly affects our design and fabrication schedule.

Mitigation plans were established to be prepared for these risks.

Understanding that this vessel is intended to be remotely controlled in all-conditions meant the procurement of weather-resistant and marine-grade components. When waterproof components were unavailable, our team’s solution was to select the Apache 3800 case to contain and protect sensitive hardware. The Apache 3800 water-tight carrying case was specifically selected for its size and waterproof capabilities, allowing all critical components to reside within the case and prevent water ingress. Watertight grommets were installed on the case to allow for connection between our trim tab actuators, motor, and battery.

The most critical risk identified was the selection of the propeller. Intensive research was conducted, utilizing *The Nature of Boats* by Dave Gerr as well as consulting local industry experts. To combat this risk, multiple types of propellers were purchased according to design criteria. These propellers are then to be tested, and a final selection made based on performance.

In addition to these risks, our team has integrated two 12V submersible aquarium pumps as bilge pumps into the vessel's design; minimal, unpreventable water ingress into the hull is an expected risk. These pumps act as a critical safeguard against minor leaks and ingress from our propeller’s shaft, preventing water accumulation that could damage non-IP-rated components. Active dewatering is essential for maintaining the designed light displacement and weight distribution, which directly supports our team’s ability to achieve the target speed of 22 mph by preventing increased drag from water weight. Managing water ingress ensures the long-term reliability of all electronic and control systems, enhancing the vessel's endurance to complete the entire competition course, even in challenging sea conditions. The 12V pumps are powered by the dedicated low-voltage control battery, ensuring their operation is independent of the main 48V propulsion system. These pumps were selected for their minimal power consumption and are to be controlled via our main RPi controller.

Appendix A: Bill of Materials

Our team’s Bill of Materials

Unmanned Electric Propulsion Watercraft Bill of Materials									
				Total Cost:		***$8,097.31***		***NOTE: Line items marked YELLOW have been ordered***	
				Remaining Budget:		***$3,902.69***			
ID#	***Item Description***	***Make Buy***	***Lead Time***	***Unit Cost ($)***	***Qty***	***Extended Cost***	***Cost Basis***	**BOM Notes**	**Product Online Link**
	Hull Assembly ($2000 Budgeted)					$1,808.38			
6	Cocktail Class Racer Hull Plywood Kit	B	2 wk	$1,269.00	1	$1,269.00	Q	delivered	CLCboats.com
4	Clear HP Epoxy Kit	B	1 wk	$192.99	1	$231.59	Q	delivered	TotalBoat.com
7	Fiberglass sheet	B	2 wk	$70.56	1	$84.67	Q	delivered	TotalBoat.com
11	1-1/4" OD, 1" ID Fiberglass Round Tube	B	1 wk	$17.97	1	$17.97	Q	delivered	MGS,Inc.
	Control System ($1500 Budgeted)					$1,335.38			
14	Transceiver (Navio2)	B	1 wk	$268.18	1	$268.18	Q	delivered	HiPi.io
21	Trim tab electric conversion kit	B	<1 wk	$219.99	1	$219.99	Q	delivered	Amazon
20	Trim tab	B	<1 wk	$124.22	1	$124.22	Q	delivered	Amazon
12	Raspberry Pi 3	B	1 wk	$40.00	1	$40.00	Q	delivered	PiShop.us
35	Remote Controller with Transceiver	B	1 wk	$59.99	1	$59.99	Q	delivered	Amazon
40	SiK Telemetry Radio (100mW 915MHz)	B	1 wk	$58.99	1	$58.99	Q	ordered	Holybro
13	12V Battery	B	1 wk	$56.10	1	$56.10	Q	delivered	Newark.com
32	Reversing Relay Modules	B	1 wk	$46.99	1	$46.99	Q	delivered	Amazon
17	Steering Servo Motor	B	1 wk	$37.97	1	$37.97	Q	delivered	Amazon
34	Battery Eliminator Circuit (BEC)	B	1 wk	$16.99	1	$16.99	Q	delivered	Amazon
33	Reversing Relay Module	B	1 wk	$13.99	1	$13.99	Q	delivered	Amazon
	Propulsion System ($4000 Budgeted)					$3,426.36			
41	Motor & Motor Controller	B	3-4 wks	$2,690.00	1	$2,690.00	Q	delivered	ElectricMotorsport.cor
43	7/8" x 5/8" Stepdown Coupling	B	<1 wk	$179.38	1	$179.38	Q	delivered	Stafford
46	Solas Amita Three Blade propeller (7.25 X 5P)	B	1 wk	$68.99	1	$68.99	Q	delivered	WholesaleMarine
47	Vibration-Damping Flex Shaft Coupling	B	1 wk	$33.93	2	$67.86	Q	delivered	McMaster-Carr
49	Clamping Shaft Collar	B	1 wk	$46.77	1	$46.77	Q	delivered	McMaster-Carr
42	Driveshaft	B	<1 wk	$27.22	1	$27.22	Q	delivered	McMaster-Carr
47	Shaft Seal	B	1 wk	$8.74	1	$8.74	Q	delivered	Amazon
	Electrical ($1200 Budgeted)				1	$1,151.20			
57	48V Battery w/ Charger	B	4 days	$770.99	1	$770.99	Q	delivered	Vevor
60	2/0 Red Wire	B	1 wk	$7.68	8	$61.44	Q	delivered	West Marine
61	2/0 Black Wire	B	1 wk	$7.68	8	$61.44	Q	delivered	West Marine
58	Disconnect	B	1 wk	$40.99	1	$40.99	Q	delivered	WestMarine.com
67	2/0 Gauge Power Connector	B	1 wk	$35.95	1	$35.95	Q	delivered	Grainger
65	Connector terminals	B	<1 wk	$33.45	1	$33.45	Q	delivered	Grainger
64	12V Terminal Bus Bar	B	1 wk	$16.99	1	$16.99	Q	delivered	Amazon
62	Fuse holder	B	1 wk	$15.30	1	$15.30	Q	delivered	West Marine
59	Wiring Harness	B	1 wk	$0.00	1	$0.00	Q	Purchase if lab doesn't have	N/A
	Miscellaneous ($1000 Budgeted)					$375.99			
70	Ballast for competition	M	1 wk	$69.41	3	$208.23	Q	delivered	McMaster-Carr
72	Weight Bags	B	1 wk	$48.10	2	$96.20	Q	delivered	McMaster-Carr
69	Bilge Pumps	B	1 wk	$24.99	1	$24.99	Q	delivered	Ebay.com