Technical Design Report
RoboBoat 2026: Technology in Action for Recovery and Relief

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Abstract

AquamaRUM is an Autonomous Surface Vehicle (ASV) developed by the UPRM RoboBoat Team for the RoboBoat 2026 competition, building upon a proven platform from RoboBoat 2025. The team's competition strategy prioritizes navigation-centric autonomy tasks, including the Navigation Channel, Follow the Path, and Speed Challenge, while selectively addressing higher-complexity tasks to balance system reliability and development risk. This strategy directly informed key design decisions in hull geometry, propulsion configuration, control architecture, and autonomy software.

To support stable and repeatable navigation performance, the vehicle employs a catamaran hull optimized for stability, modular aluminum framing, and dual T200 thrusters. Autonomy is enabled through a vision-based navigation system using a YOLOv8 object detection pipeline integrated with task-specific behavior trees. Testing was conducted through a combination of simulation, controlled pool experiments, and open-water trials to validate waterproofing, directional stability, and navigation robustness. Lessons learned from prior competition experience guided iterative design improvements and testing focus. The resulting system emphasizes reliability, modularity, and autonomy performance aligned with the team's competition objectives for RoboBoat 2026.

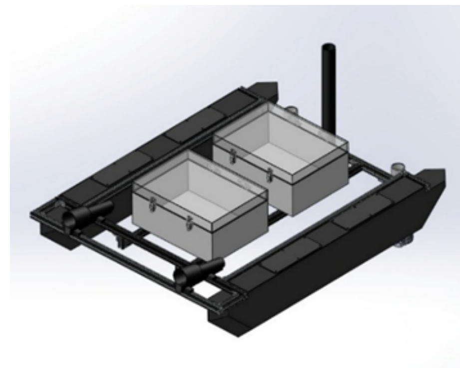

Figure 1: *ASV Assembly*

I. Competition Goals and Strategy

The UPRM RoboBoat Team's strategy for the competition focuses on prioritizing the navigation tasks, as they are fundamental to demonstrating AquamaRUM's core capabilities while maximizing points. The primary objectives include navigating the Evacuation Route & Return, successfully completing Follow the Path, Speed Challenge and the Water Delivery part of Task 4, demonstrating precise maneuvering, decision-making and consistent performance through robust control algorithms. Secondary objectives focus on advanced tasks, including Docking, and the Object Delivery part of Task 4 and 5.

This prioritization reflects a deliberate trade-off between system complexity and reliability. Given the limited development and testing time available, the team elected to focus resources on navigation-centric autonomy tasks, which historically provide a high return in points while relying on proven control and perception architectures.

The decision to improve AquamaRUM's design from the 2025 competition, rather than designing and manufacturing a new boat, allowed the team to focus on refining software systems and enhancing testing workflows, ensuring continuous in-water trials throughout the semester. This approach reduced integration risk and minimized the propagation of late-stage design changes across mechanical, electrical, and software subsystems. Based on prior competition experience and the system engineering capabilities of the team, reliability and repeatability were prioritized over introducing additional high-risk features. This strategic vision guided all major design and autonomy decisions.

B. Task Breakdown

Task 1 – Evacuation Route & Return - To successfully navigate autonomously through pairs of red and green buoys, AquamaRUM employs buoy detection and path planning techniques. It first identifies buoys by shape and color and manages to calculate the pair's relative coordinates enabling to find the midpoint between the buoys. After the midpoint calculation the vessel is instructed to move continuously through it.

Task 2 – Debris Clearance (Follow the Path) - Similar in principle to Task 1, AquamaRUM is programmed to identify a buoy gate and pass through its midpoint while executing a parallel decision tree combined with obstacle avoidance algorithms to enable safe passage through the path while avoiding debris. When encountering the red color indicator, the approach is to instruct AquamaRUM to avoid it, if it's a green color indicator the approach is to circle it by calculating three target points around the indicator and navigating to them. This task leverages existing navigation logic with minimal additional system complexity, aligning with the team's strategy to reuse validated behaviors whenever possible.

Task 3 – Emergency Response Sprint (Speed Challenge) - The approach for this task consists of locating the first set of gates and passing through them by calculating the midpoint. A parallel decision tree, similar to Task 2, will be employed for obstacle avoidance while looking for the color indicator to determine the correct circling behavior around the yellow buoy. Upon detecting the yellow buoy, AquamaRUM calculates three target points---right, behind, and left of the buoy---and navigates to each starting from the right or left of the buoy depending on the color indicator. After completing these maneuvers, the ASV exits through the starting gates by previously marking the location of the gates when passing through them initially. Although this task introduces additional coordination between perception, and control subsystems, it was selected due to its compatibility with the existing navigation architecture and high scoring potential.

Task 4 – Supply Drop (Water Delivery) - During this task, AquamaRUM will identify and approach the yellow vessels in the course. After the ASV accurately aligns with the vessel's black triangles using its vision system, the onboard computer will activate the Water Gun System. The ASV will release water streams for predetermined intervals, adjusting length based on its distance to the target while maintaining stability for accuracy.

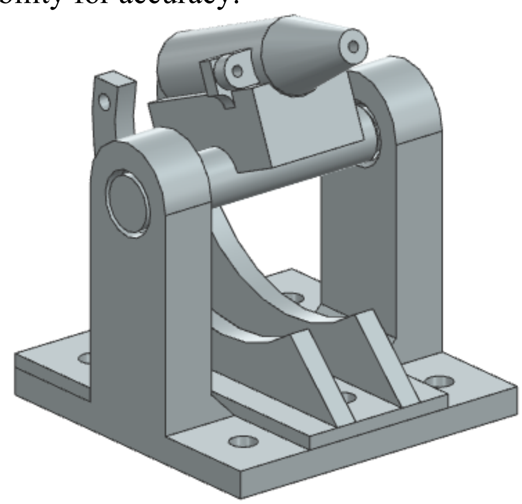

Figure 3. *Watergun Module*

Task 5 – Navigate the Marina (Docking) - The approach for this task consists of maneuvering into a dock marked with a green color slip by evaluating docks and bypassing the occupied ones. This ability relies on the computer vision model trained to identify shapes and colors that provide accuracy and high adaptability. Docking is treated as a secondary objective due to its higher sensitivity to environmental disturbances and perception uncertainty and is attempted after validating navigation performance.

II. Acknowledgements

Our team members' participation has excelled in hard work and dedication throughout the semester, and any success would be rightfully attributed to their efforts. We would also like to extend our appreciation to our advisor Prof. Juan Patarroyo, Ph.D. for the guidance regarding automation and robotics topics during the improvement phase of this project. Lastly, immense gratitude to General Motors and Lockheed Martin for their sponsorship, as all of this has been possible with their continuous support.

III. Design Strategy

- Mechanical Design

o Buoyancy and Propulsion System:

Buoyancy calculations were performed to verify that the ASV could support all onboard systems while maintaining adequate freeboard. Appendix F details the buoyant force generated by each hull and confirms sufficient margin to accommodate the total system mass [16]. The ASV is equipped with two T200 thrusters from Blue Robotics, selected for their high reliability and performance. As shown in Appendix F, each thruster produces a thrust of 9.9 lbf, while the corresponding hydrodynamic drag force at operational speeds is approximately 3.1 lbf. This favorable thrust-to-drag ratio enables efficient power usage, provides flexibility in speed control, and allows experimentation with different acceleration profiles. The propulsion selection and thrust-to-drag relationship are consistent with standard marine propulsion theory and small craft hydrodynamic modeling practices [11].

To address ergonomic challenges encountered during assembly and transportation, a new hinge-inspired thruster mounting mechanism was developed. This design allows the thrusters to be repositioned without requiring disassembly of the mount, significantly improving ease of handling during transport.

o Vessel Arrangement:

The vessel consists of two hulls connected by a 43-inch × 36-inch aluminum extrusion frame, with each hull measuring 4 feet in length and 4 inch in width. This configuration creates a 28-inch separation between the hulls, providing sufficient space for mounting onboard components. The frame supports two primary enclosures: a battery box, positioned toward the aft section to aid in load balancing, and a navigation box**,** located closer to the vessel's center of gravity to improve sensor accuracy and overall system performance.

Key geometric ratios were considered during the hull design process to balance stability and maneuverability, including the Hull Fineness Ratio (HFR) and the Hull Centerline Beam to Waterline Length ratio (BCL/LWL)**.** The HFR, defined as the ratio of hull length to beam width, was calculated to be 10:1, which falls within the typical range for cruising catamarans (8–12:1). The BCL/LWL ratio was evaluated at the estimated operating displacement of approximately 40 pounds, resulting in a value of 0.7**.** While the ideal range for cruising catamarans is generally 0.5–0.6**,** the higher ratio was intentionally selected to emphasize enhanced transverse stability.

Hull access points and removable covers were redesigned to replace gasket-based sealing methods with O-ring sealing solutions. This change improves repeatability, sealing reliability, and resistance to water exposure during operation. The O-ring dimensions, compression ratios, and material selection were determined according to standard O-ring engineering guidelines to ensure effective sealing under both static and dynamic loading conditions [15].

o Component Boxes:

This year, the components were separated between two IP67 ABS waterproof junction boxes, one for all the software computers and another one to meet robotics needs, using cable glands to make interconnections. The safety of components is ensured by screwing all the modules to a mounting plate, this also improves cable management and cleaner connection view.

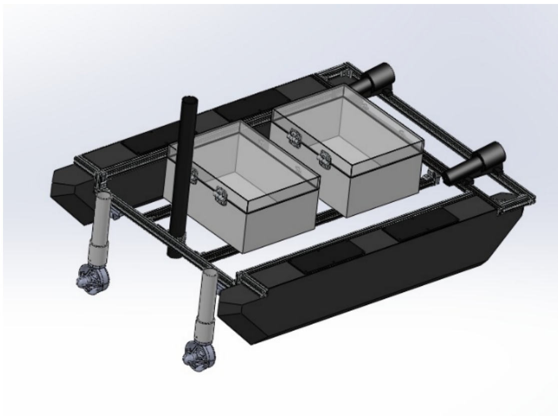

Figure 2: *Component Box Placement*

- **Electrical System Design**
  - **Thruster Battery Pack:**

The propulsion system, utilizing Blue Robotics T200 thrusters, requires a battery capable of sustaining full-throttle operation while providing sufficient energy to power the vessel throughout the duration of the complete course or challenge. Currently, the power system includes two Zeee batteries, configured in a 4S1P arrangement to deliver 14.8V with a capacity of 6.2 Ah each.

  - **System Battery Pack:**

The team has acquired two 7Ah 77.7Wh 11.1V Zeee battery packs. By connecting them in parallel the system will achieve a total capacity of 14 Ah to supply power to the 12V components through a power strip module. Based on calculations, the system consumes 65.6Wh with all components running at maximum power. Therefore, the system can operate at full power for 1.5 hours while retaining 37% of the battery capacity.

  - **Kill Switch**:

In addition to the physical kill switch, the vessel is equipped with a wireless kill switch integrated with one of the remote controller's switches. During testing conducted at full throttle, the activation of the wireless kill switch resulted in an immediate shutdown, effectively cutting power from the thrusters.

  - **Battery Telemetry:**

Batteries in use are equipped with a Bluetooth-enabled monitoring device connected via the cell balancer port. This setup enables accurate real-time monitoring of the battery, both during in-water operations and when the system is inactive.

- **Software Architecture**
  - **Navigation and Control**

AquamaRUM's autonomy framework is built around behavior trees to manage task sequencing, decision-making, and fault handling. This architecture allows for modular task execution and parallel monitoring of navigation, obstacle avoidance, and mission-specific behaviors. Behavior-tree-based autonomy frameworks are widely used in marine robotics and provide a structured control architecture for ASVs [12].

The navigation and control systems for AquamaRUM'S design ensure reliable task execution using a Python-based tech stack. It comprises two subsystems: vision and control. The control system manages the ASV's operational status, interfaces with the flight controller, and initiates movement subprocesses all while communicating with the Ground Control Station (GSC) to publish telemetry and system status. Behavior trees are implemented within this system using Python's Py-Trees library, to generate navigation commands based on vision pipeline data. These trees are customizable and task specific making them a modular design choice.

  - **Computer Vision**

AquamaRUM'S vision system leverages a RealSense D435 camera to receive data that's processed by an in-house-trained YOLOv8 model to identify specific object segments. It then produces outputs that include information such as object type, color and radial coordinates, enabling real-time navigation. To minimize processing overhead, frames are sent to the system at a specific rate ensuring reliable system performance.

The perception system utilizes a real-time object detection pipeline based on YOLO architectures integrated with onboard vision sensors. This approach enables robust buoy detection, classification, and localization under varying lighting and environmental conditions. The selection of YOLO-based models follows established practices in autonomous robotics and real-time object detection systems [14].

- **Network System**

A Wi-Fi network enhanced with 5G extenders ensures ASV to GCS communication. Configurable parameters, like channel width adjustments mitigate interference, while the extender's nodes router, repeater, and access point offer versatility for mission needs.

- **Ground Control Operations**

The Ground Control Station (GCS) connects to the ASV via SSH over a network link provided by an onboard antenna, allowing remote management of vision and control processes. The GCS provides access to dynamic persistence data, such as buoy counts and confirmed objects, tailored to the active decision tree. This ensures the operator and system have critical information for effective decision-making and monitoring.

IV. Testing Strategy

A. Testing Framework

The testing framework focuses on two main objectives: ensuring waterproofing and validating inherent directional stability. Waterproofing tests evaluate the vessel's ability to maintain a watertight seal at varying speeds in a controlled environment, allowing the team to identify any leakage issues. Pool-based waterproofing tests confirmed the effectiveness of the redesigned O-ring sealing system, with no observable leakage during static submersion tests and dynamic trials at operational speeds.

B. Simulation

AquamaRUM's simulation framework refines pathfinding algorithms without physical deployment. The environment replicates key subsystems like the vision pipeline and flight controller. ArduPilot SITL simulates vehicle dynamics, while a custom vision simulator creates buoy arrangements based on relative coordinates. This simulation framework was used to validate waypoint generation, obstacle avoidance logic, and task-specific decision trees prior to in-water deployment, reducing the number of required field iterations. The simulator's lightweight design enables rapid testing and iteration, ensuring seamless transitions from virtual to real-world testing. Additionally, the team is developing a Gazebo environment to expand testing capabilities, allowing for more detailed and realistic simulations of the ASV's interactions with its surroundings. Simulation-based testing was primarily used as a functional verification tool rather than performance validation, with final performance metrics obtained during physical testing.

C. Field Testing

- **Waypoint Tracking:**

Tests regarding AquamaRUM'S waypoint tracking capabilities allow for measurements on the system's ability to navigate predefined paths in a controlled environment. These tests focus on accuracy, stability, and responsiveness to real time conditions while metrics include waypoint precision, path stability, and control adjustments. The testing methodology and control objectives are consistent with established motion control practices for autonomous surface vehicles described in marine control literature [12].

- **Obstacle Avoidance:**

Tests regarding AquamaRUM's obstacle avoidance capabilities assess its ability to detect and navigate around obstacles in real-time scenarios. These tests involve placing various objects in the vehicle's path to evaluate its detection algorithms and pathfinding systems. Metrics include accuracy of obstacle detection, dynamic route adjustment, and responsiveness of control algorithms.

- **Test Locations and Logistics**

Testing is conducted in a pool and at the beach to evaluate the ASV's performance. The pool provides a controlled environment for waterproofing, buoy detection, and navigation trials with minimal external disturbances. The beach allows for open water testing to assess pathfinding, stability, and adaptability in real-world conditions. Open-water tests confirmed that the hull configuration maintained directional stability under variable wind and wave conditions typical of competition environments.

- **Endurance Testing**

The vessel has a total runtime of 1.5 hours with all systems operating at maximum power. During the Challenge course, the thrusters run intermittently at 50%–70% throttle. Calculations in Appendix C estimate the thrusters' total runtime to be approximately one hour. Endurance testing validated these estimates, confirming that the power system supports a full competition run with sufficient energy margin for multiple task attempts.

V. Conclusion

AquamaRUM’s readily manufactured state created an advantage as it permitted us to utilize this terms’ time and resources in vessel optimizations. The members focused in program, hull and organization betterment, and provided more time for testing and division development. By prioritizing the evacuation, follow the path and speed challenge, for the previously mentioned reasons, the team is ready to tackle this years’ competition with effort and spirit, and embark on this learning experience.

VI. References

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VII. Appendix

Appendix A. Component List

Component	Vendor	Model	Specifications	Custom / Purchased	Cost (USD)	Year
Robotics Division						
Waterproof Junction Box	Amazon	N/A	IP rated enclosure	Purchased	$ 65.99	2025
PETG Filament	Amazon	N/A	3D printing filament	Purchased	$ 20.00	2025
Software Division						
Autopilot Software	ArduPilot	ArduPilot	Autonomous navigation	N/A	N/A	N/A
Computer	NVIDIA	Jetson Orin Nano	6-core ARM CPU, 1024-core GPU	Purchased	$ 499.00	2024
Flight Controller	CubePilot	Cube Orange	IMX299 + STM32H7	Purchased	$ 499.00	2024
GPS Module	CubePilot	Here+ RTK	Multi-band GNSS	Purchased	N/A	2024
Camera	Intel	RealSense D435	RGB-D depth camera	Purchased	$ 199.00	2023
Microcontroller	Elegoo	UNO R3	ATmega328P	Purchased	$ 30.00	2021
Vision Library	OpenCV	OpenCV	Computer vision	N/A	N/A	N/A
ML Framework	Linux Foundation	PyTorch	Deep learning	N/A	N/A	N/A
Ground Control	Dronecode	QGroundControl	Mission planning	N/A	N/A	N/A
Comms Protocol	Dronecode	MAVLink	Telemetry protocol	N/A	N/A	N/A
Electrical Division						
LiPo Battery	ZEEE	4S1P	6200mAh 14.8V	Purchased	$ 115.99	2026
LiPo Battery	ZEEE	3S1P	7000mAh 11.1V	Purchased	$ 99.00	2024
Propulsion Thruster	Blue Robotics	T200	14.8V	Custom	$ 200.00	2025
Waterproof Junction Box	Amazon	N/A	IP rated enclosure	Purchased	$ 65.99	2025
Step Drill Bit	Home Depot	N/A	Sheet metal drilling	Purchased	$ 19.97	2025
Terminal Block	Amazon	N/A	30 A	Purchased	$ 12.99	2025
2-Channel Relay Module	Amazon	N/A	5V – 30A	Purchased	$ 10.50	2025
DC-DC Buck Converter	Aamazon	N/A	12 – 5 V	Purchased	$ 12.99	2025
Mechanical Division						
Aluminum Extrusion	McMaster-Carr	1x1 in	6061-T6	Purchased	$ 118.68	2025
Square Aluminum Tube	Home Depot	48 in	Structural support	Purchased	$ 36.99	2025
Mounting Brackets	Blue Robotics	N/A	Thruster mounting	Purchased	$ 8.00	2025
Fender Washer	Home Depot	3/16 in	Zinc plated	Purchased	$ 0.18	2025
Machine Screw	Home Depot	#10	Steel	Purchased	$ 1.76	2025
Flat Washer	Home Depot	#10 SS	50 pc	Purchased	$ 6.57	2025
Hull Maintenance	Local	N/A	Sealant & repair	Purchased	$ 150.00	2025
Aluminum Extrusion Profiles Corner	Amazon	1x1 in	1010 Series	Purchased	$30.00	2026
Bolts and Nuts	Amazon	For 10 series aluminum rails	M6 T Slot Nuts Bolts	Purchased	$20.00	2026

Appendix B. Testing Plan

I. Scope

The scope of this testing plan focuses on addressing critical design and performance issues identified through previous competition experience, while refining the vessel's functionality through targeted hardware and software improvements. The testing effort prioritizes system reliability, robustness, and repeatability under competition-relevant conditions. Key areas of focus include:

Hull Integrity and Waterproofing:

- Redesigning hull covers and access points to eliminate leakage issues by replacing gasket-based seals with O-ring sealing solutions, ensuring a reliable and watertight enclosure during both static and dynamic operation.

Electrical Enclosures and Cable Management:

- Replacing general-purpose component boxes with purpose-built electrical enclosures designed for marine environments, featuring waterproof connectors and improved internal layout.
- Validating the organization, strain relief, and routing of power and signal cables to reduce the risk of water ingress, connector failure, and electrical faults during operation and transportation.

Battery Monitoring and Power Management:

- Integrating a Bluetooth-enabled battery monitoring system to provide real-time visibility of battery voltage and state of charge, enabling informed operational decisions and reducing the risk of power-related failures during in-water testing and competition runs.

Software and Autonomy Optimization:

- Enhancing software performance through improvements in buoy detection, path-planning algorithms, and decision-making logic.
- Refining system integration between sensors, control systems, and autonomy frameworks to ensure reliable task execution and seamless transitions between operational modes during competition.

II. Schedule

August 2025

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SAT/SUN
				1	2/3
4	5	6	7	8	9/10
11	12	13	14 1st Leads Meeting	15	16/17
18	19 Onboarding Meeting!	20	21 Regular Meeting	22	23/24
25	26 Regular Meeting	27	28 Regular Meeting	29	30/31

September 2025

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SAT/SUN
1	2 Regular Meeting	3	4 Regular Meeting	5	6/7
8	9 Regular Meeting	10	11 Regular Meeting & Venta Hot Dogs	12	13/14
15	16 Regular Meeting & Registration as Student Association (Dept. Actividades Sociales)	17 La Cuevita Fundraiser	18 Regular Meeting & Venta Pinchos	19	20/21
22 Off The Wall Fundraiser	23 Regular Meeting & 2nd Leads Meeting	24 (Mechanical) Hull design	25 Regular Meeting & Venta Pretzels	26	27/28
29	30 Regular Meeting & Team Photos!				

October 2025

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SAT/SUN
		1 (Robotics) Assemble and test water gun	2 Regular Meeting & Team Photos!	3	4/5
6 Tentative Registration Start	7 Regular Meeting & Update meeting	8 (Electrical) Buy new component boxes	9 Regular Meeting	10	11/12
13 Competition prep (video)	14 Regular Meeting	15 (Mechanical) Meet w/ hull manufacturer & Fundraiser Cuevita	16 Regular Meeting & 3rd Leads Meeting	17	18/19
20 Competition prep (video & website) Open House prep	21 Regular Meeting & Venta Hot Dogs en Asamblea	22 (Business) Start updating website (Electrical) Electrical School Prep	23 Regular Meeting & Open House / Venta Open House	24	25/26 26 Torneo Volleyball
27 Competition prep (website & TDR)	28 Regular Meeting	29 (Software) Test simulator	30 Regular Meeting & Venta Pizza	31	

November 2025

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SAT/SUN
					1/2
3 Competition prep (website & TDR)	4 Regular Meeting	5	6 Regular Meeting	7	8/9
10 Testing #1	11 Regular Meeting	12	13 Regular Meeting	14	15/16
17 Testing #1 fixes	18 Regular Meeting & 4th Leads Meeting	19	20 Regular Meeting	21 Update meeting	22/23
24 Competition prep (TDR)	25 Regular Meeting	26	27 Regular Meeting	28	29/30

December 2025

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SAT/SUN
1 Competition prep (TDR) Testing #2	2 Regular Meeting	3	4 Regular Meeting Testing #2 fixes & 5th Leads Meeting	5	6/7
8	9 Regular Meeting	10	11 Regular Meeting	12	13/14
15	16	17	18	19	20/21
22	23	24	25	26	27/28
29	30	31			

January 2026

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SAT/SUN
			1	2	3/4
5 Competition prep	6	7	8	9	10/11
12 Competition prep	13	14 TDR Due! Video Intro Due! Website Due!	15	16	17/18
19 Final testings & Competition prep	20 Regular Meeting	21	22 Regular Meeting & 6th Leads Meeting	23	24/25
26 Finishing touches before shipping next week! & Competition prep	27 Regular Meeting	28	29 Regular Meeting	30	31/1

February 2026

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SAT/SUN
Meeting w/ Patarroyo & Competition prep					31/1
2	3 Regular Meeting	4 Ship boat!! Ship batteries!! (check shipping requirements Fedex or UPS)	5 Regular Meeting	6	7/8
9	10 Regular Meeting	11	12 Regular Meeting & 7th Leads Meeting	13	14/15
16	17 Competition prep Meeting	18 Flight to Sarasota	19 Competition Date	20 Competition Date	21/22 Competition Date
23 Competition Date	24 Competition Date	25 Flight to PR	26 Regular Meeting	27	28/1

III. Environment

- Testing environments are carefully selected to evaluate the ASV's performance under both controlled and real-world conditions:

Pool Testing:

- Conducted in a controlled environment to focus on waterproofing verification, buoy detection, navigation logic, and autonomy behavior validation with minimal external disturbances.
- Provides an ideal setting for validating sensor performance, software algorithms, and the integrity of mechanical and electrical enclosures, including waterproof connectors and internal cable management under static and low-speed dynamic conditions.

Beach Testing:

- Performed in open water to assess the ASV's pathfinding, directional stability, and adaptability to real-world conditions such as waves, wind, and currents.
- Offers a realistic environment to test the robustness of the vessel's hull design, electrical enclosures, and cable routing under sustained exposure to spray, motion, and environmental loading.

IV. Risk Management

System Performance Risks:

Waterproofing and Electrical Enclosure Failures:

- Risk: Water ingress through enclosure interfaces, connectors, or cable routing points during pool or beach testing.
- Mitigation: Use of purpose-built waterproof electrical enclosures, sealed connectors, organized internal cable routing, and pre-test inspections to verify enclosure integrity before each deployment.

Appendix C. Power Consumption Calculations

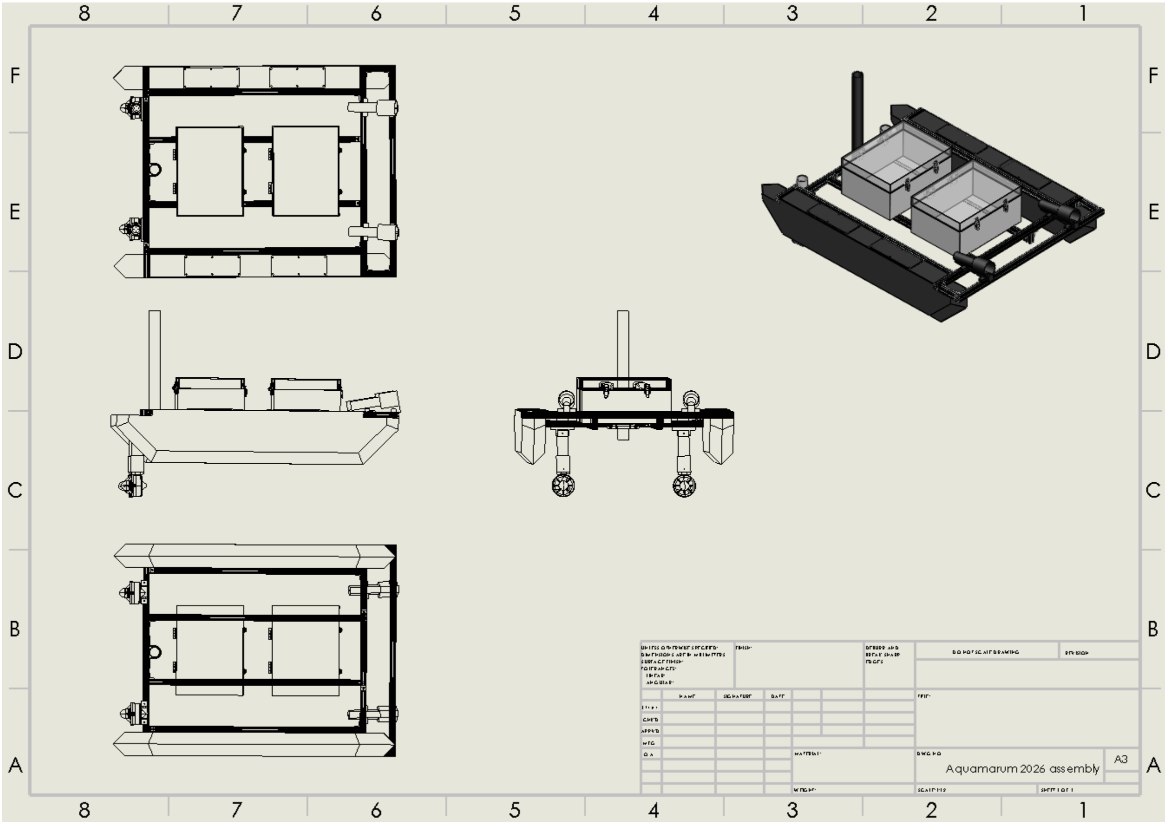
Computers Circuit			
Components	Voltage (V)	Current/hour (Ah)	Power (Wh)
Jetson Orin Nano	12	1.25	15
The Cube Orange	5.7	2.5	14.25
Antenna	24	0.5	12
Receiver	5	0.04	0.2
Arduino UNO	5	0.2	1
Zeee	11.1	7	77.7
Total Consumption for one hour	42.5		
Total With Safety Precautions	48.8		
Maximum Working Time (mins) (Based On Battery Capacity)	95.5 One and a half hour		

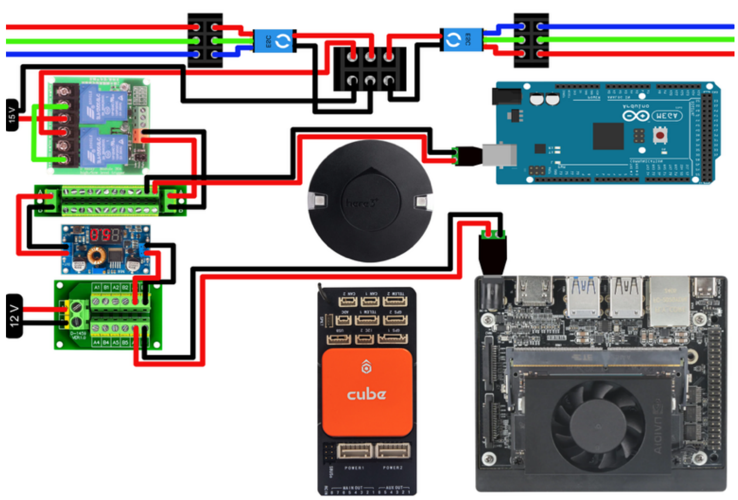
Thrusters Circuit			
Components	Voltage (V)	Current/hour (Ah)	Power (Wh)
T200 Thrusters (2) Intermitent	14.8	10	296
Total Consumption			296.00
At full throtle the battery will last for 12 minutes			
Zeee	14.8	10	148

Battery Specs	Voltage (V)	Capacity (Ah	Power (Wh)	Cell
Zeee	11.1	7	77.7	3SIP
Zeee	14.8	10	148	4S1P
Ovonic	22.2	1.6	35.52	6S1P

Robotics Circuit			
Components	Voltage (V)	Current/hour (Ah)	Power (Wh)
Arduino MEGA	5	0.8	4
Digital Servo SG90 (3)	5	0.75	3.75
DC Submersible Water Pump	12	1.71	20.52
L298N Module	12	1.71	3.58
DHT22 Sensor (2)	5	0.0021	0.0105
ST7920 LCD Display	5	0.06	0.3
DC N20 Motor	5	0.08	0.4
Zeee	11.1	7	77.7
Total Consumption for one hour	32.6		
Total With Safety Precautions	37.4		
Maximum Working Time (mins) (Based On Battery Capacity)	124.5 Two Hours		

Appendix D. Technical Drawings





Appendix E. Water Gun Calculations & Testing Data

Area:

$$\text{Area} = \frac{\pi d^2}{4} = (3.14 \cdot (10\ \text{mm})^2)/4 \approx 78.54\ \text{mm}^2 \approx 7.8\times10^{-5}\ \text{m}^2$$

Height:

$$\text{Height} = \frac{P}{\rho g} = 758{,}423.6\ \text{Pa} / (1000\ \text{kg}\cdot\text{m}^{-3} \cdot 9.81\ \text{m}\cdot\text{s}^{-2}) \approx 77.3\ \text{m}$$

, where P = pressure, ρ = density, g = gravity

Velocity:

$$\text{Velocity} = \frac{Q}{A} = (7.5\times10^{-5}\ \text{m}^3\cdot\text{s}^{-1}) / (7.8\times10^{-5}\ \text{m}^2) \approx 0.955\ \text{m}\cdot\text{s}^{-1}$$

Volumetric flux:

$$Q = \text{volumetric flux} \approx 4.52\ \text{L}\cdot\text{min}^{-1} \approx 7.5\times10^{-5}\ \text{m}^3\cdot\text{s}^{-1}$$

Time:

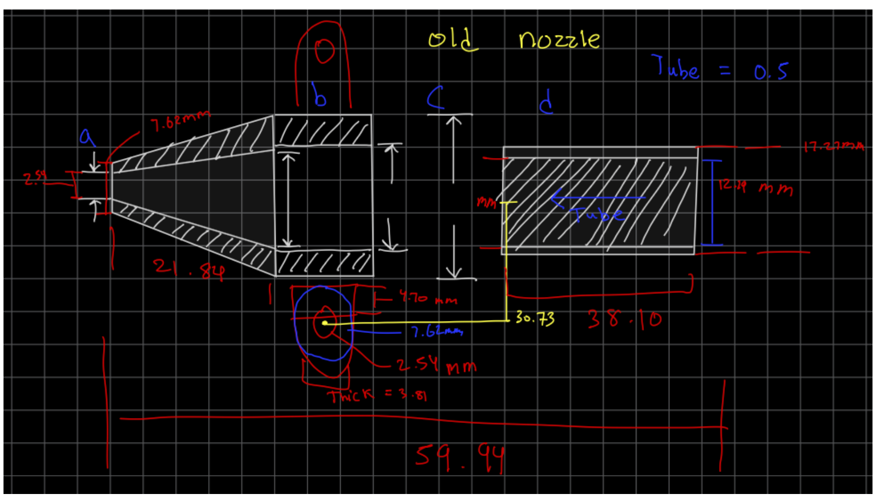
$$\text{Time} = \frac{2 V \sin\theta}{g} = 2(0.955)(\sin 45°) / 9.81 \approx 0.1385\ \text{s}$$

Horizontal distance:

$$\text{Horizontal distance} = \frac{V^2 \sin(2\theta)}{g} = (0.955^2 \cdot \sin 90°)/9.81 \approx 0.093\ \text{m}$$

Vertical distance:

$$\text{Vertical distance} = \frac{V^2 \sin^2\theta}{2g} = (0.955^2 / 2) / 9.81 \approx 0.023\ \text{m}$$



Appendix F. Propulsion and Buoyancy

Variables:

Drag Coefficient:

$$C_d \approx 0.02$$

Reference Area of Contact:

$$A = 0.1574\, ft^2$$

Thrust Force:

$$F_T = 9.9 lb_f$$

Fresh Water Specific Weight:

$$\gamma = 62.4\, \frac{lbf}{ft^3}$$

Gravitational Acceleration:

$$g = 32.174\, \frac{ft}{s^2}$$

Displaced Volume (For each hull):

$$V_d = 0.357 ft^3$$

Calculations:

Converting to mass density

$$\rho = \frac{\gamma}{g} = \frac{62.4}{32.174}$$

$$\rho = 1.94\, \frac{slug}{ft^3}$$

Drag Force

$$F_d = 0.5 * C_d * A * v^2 * \rho$$

$$F_d = 0.5 * 0.02 * 0.1574\, ft^2 * 31.9\text{ft} * 1.94\, \frac{slug}{ft^3}$$

$$F_d = 3.1 lb_f$$

$$9.9 lb_f > 3.1 lb_f$$

Buoyancy Force (For each hull)

$$F_b = \rho * V_d * g$$

$$F_b = \gamma V_d$$

$$F_B = (62.4)(0.357) = 22.3 \text{ lbf}$$

$$F_{B,\text{total}} \approx 44.6 \text{ lbf}$$