# RobotX Team Minion Takes on RoboBoat 2025

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***Abstract*—Embry-Riddle Aeronautical University's Team Minion is competing in RoboBoat 2025 as part of a multi-year strategy aimed at excelling in the 2026 RobotX Challenge. This competition serves as a critical milestone for training members, migrating software from ROS1 to ROS2, and refining systems for future events. The team's goal for this competition cycle is to at least reach the semi-finals by focusing on navigation, mapping migration patterns, and docking—tasks common to both RoboBoat and RobotX.**

**The 2025 vehicle, MiniMinion, features a redesigned propulsion system and a watertight Pelican case for electrical components, ensuring modularity for future use. Innovations include a custom power distribution PCB with a new E-Stop circuit and redundant microcontrollers. MiniMinion also integrates a partial port of the 2024 RobotX software to ROS2, enabling improved task performance. Guided by their Minion Process, a systems engineering approach, the team emphasizes collaboration and efficient task execution to achieve competitive success.**

## I. Competition Strategy

### A. High-Level Goal

Team Minion's primary focus is to prepare for RobotX 2026. This multi-year, multi-competition strategy builds on the team's experiences and leverages advancements made in software, hardware, and team coordination as shown in Figure 1. The approach emphasizes using each competition as a milestone to iteratively train its team and advance its capabilities toward the 2026 RobotX competition.

*1) RobotX 2024 - Evaluating and Defining a Path Forward:* Following the conclusion of RobotX 2024, Team Minion conducted a thorough performance evaluation to identify areas for improvement. This analysis identified necessary upgrades, new initiatives, and organizational changes to improve future performance.

*2) RoboBoat 2025 - Establishing a Strong Foundation:* The primary focus for RoboBoat 2025 is to begin incorporating the new initiatives and organizational changes that will ensure future success. The most significant of these efforts are:

- **ROS 2 Migration:** Begin transitioning the software framework from ROS 1 to ROS 2 by migrating essential functionalities required to operate an Unmanned Surface Vessel (USV).
- **Hardware Testing:** Perform iterative hardware tests to validate and improve system reliability under competition-like conditions.
- **Competition Training:** Provide new members with valuable competition experience to promote growth and familiarity with the event environment.
- **Leadership Growth:** Foster new team leadership by using RoboBoat 2025 as a platform to train individuals for leadership roles and identify future candidates for these positions.

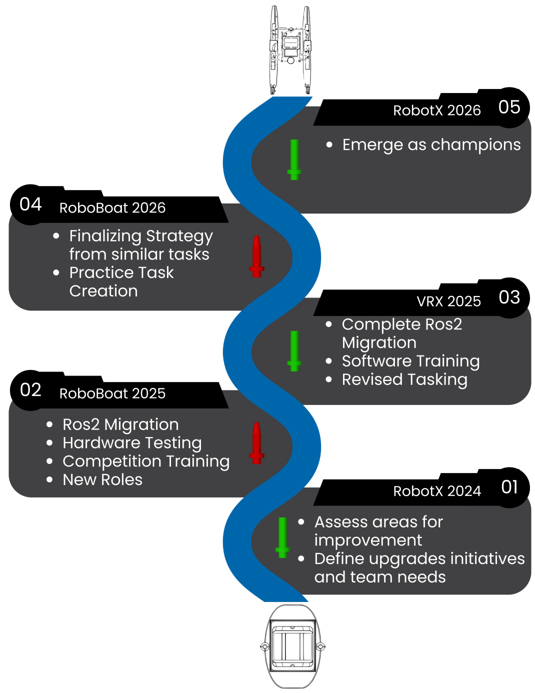


Fig. 1: Path to RobotX 2026 Success, which goes through the RoboBoat 2025 Competition

*3) VRX 2025 - Strengthening Core Software:* As the next milestone, VRX 2025 will focus on reinforcing core software systems and capabilities:

- **Full ROS 2 Migration:** Complete the migration of all software functionalities to ROS 2.
- **Software Team Training:** Equip new software team members with the skills and knowledge required to contribute effectively to Minion's software.
- **Revised Tasking:** Update and refine the tasking system to simplify the writing of tasks while maintaining the ability to adapt to new tasks and task requirements.

*4) RoboBoat 2026 - A dress rehearsal:* RoboBoat 2026 will serve as the final preparation stage before RobotX 2026, focusing on:

- **Strategy Finalization:** Develop and finalize strategies for tasks closely resembling those anticipated in RobotX 2026.
- **Practice Task Creation:** Design and implement practice tasks that simulate competition scenarios, ensuring thorough preparation for similar challenges.

*5) RobotX 2026 - Emerging as Champions:* Team Minion aims to demonstrate technical excellence, innovation, and teamwork at RobotX 2026, striving to emerge as champions in this flagship competition.

### *B. The Sprint - Designing in one month, Prototype in two, Compete in three*

Team Minion decided to compete in RoboBoat after the 2024 RobotX competition, leaving only 3 months to get ready for RoboBoat. As a result, Team Minion's on-course performance goal is to qualify for the semi-finals round of competition. Achieving this goal has three parts: 1) Re-use solutions from Minion, the team's RobotX platform, 2) prioritize tasks common to RobotX and RoboBoat, and 3) retro-fit an ASV hull created by a 2024 senior design team so that it can compete as MiniMinion in 2025.

### *C. Overlapping Components*

*1) Using Minion's Solutions:* Due to time constraints, Team Minion prioritized maximizing the reuse of RobotX software. As illustrated in Figure 2, several components of the software architecture — such as GB-CACHE, Task Manager, Path Planner, and ROI Extractor with Color Classification were repurposed for RoboBoat. GB-CACHE is in charge of point-cloud filtering and object classification. Task Manager is responsible for the order in which the tasks are executed, Path Planner utilizes Voronoi algorithms to determine the path MiniMinion will take, and ROI Extractor will identify regions of interest in images based on LiDAR points. In most cases this simply means re-calibrating the processes and updating tuning parameters. However, these components are ported to ROS2 which is part of a larger transition by team Minion to ROS2. The only new process that had to be developed was a RoboBoat-specific control module, which is required due to the different propulsion schemes between the two vessels.

*2) Prioritize Common Tasks:* There are four RoboBoat tasks that have high similarity with RobotX 2024 tasks. The Navigation Channel is in both competitions, Treacherous Waters closely resembled the RobotX Dock and Deliver task, Mapping Migration Patterns is a derivative of the RobotX Follow the Path task, and Return to Home is analogous to Exit Gate task. As a result, Team Minion had solutions in GB-CACHE and the ROI color extractor that could be used to solve these tasks. Re-use of these components provided an opportunity to train team members on their use from the ground up and make the systems even more robust through additional testing. It should also be noted that the Light Tower in the Race Against Pollution task is the same panel as the RobotX Scan the Code task and the Object Delivery task also overlaps with the RobotX competition. However, the MiniMinion is not equipped for speed and the team is still working to make its delivery system robust and accurate. Therefore these tasks are considered secondary and will only be attempted if the other three are working reliably.

*3) Retro-fitting an ASV to compete:* A 2024 senior design team had constructed and instrumented an ASV, but had made several critical errors in its design and construction. For instance, the motor assemblies had significant leaks around the bearing surfaces, its electrical components were not centrally located or properly sealed from rain, and its perception sensors were insufficient to detection object class, color, and location. However, the main hull was stable and robustly built which provided an excellent base to build upon for MiniMinion. Furthermore, the major electrical systems provided sufficient power distribution, communications, computing resources, and run time to compete in RoboBoat. Thus, team Minion retained these elements, which also saved time and money, while addressing the deficiencies of the hand-me-down ASV.

## II. DESIGN STRATEGY

### *A. Strategy Overview*

MiniMinion is founded on a unique systems engineering framework that prioritizes safety and modularity, while also seeking efficiency and performance. The framework's efficiency proved critical for addressing the final design of MiniMinion, particularly given the team's limited timeline.

### *B. System Design*

When developing a new system or improving an existing one, the team follows a structured approach called Minion Process, illustrated in Figure 3. Minion Process adapts traditional systems engineering methodologies by incorporating elements of Agile, Scrum, and Lean approaches. Unlike professional applications with rigid timelines, Minion Process introduces flexible scheduling to accommodate the unpredictable commitments of student volunteers and variable timelines. Deadlines are re-evaluated as needed, with team leads or advisors providing approval, ensuring deliverables align with team capacity, competition goals, and system requirements. The iterative process includes the following stages:

- **Requirements Generation** Detailed specifications are defined based on competition rules and mission objectives.
- **Brainstorming** Collaborative sessions are conducted to explore potential solutions and refine subsystem designs. Input from advisors and members across hardware and software sub-teams ensures cross-disciplinary integration.
- **Prototype Development** Initial designs are evaluated using simulation tools (e.g., ANSYS, FUSION) and then subjected to physical testing. Rigorous design reviews follow, resulting in acceptance for final optimization or rejection, prompting further refinement and restarting the process.

The flexibility of Minion Process enables non-linear task completion and seamless sub-team integration, all while adhering to strict deadlines through flexible scheduling. For instance, during the development of new motor pod mounts for RoboBoat, the team software team took on the task of sensor and motor drivers to send and receive data. Minion Process strikes a balance between academic rigor, innovation, and

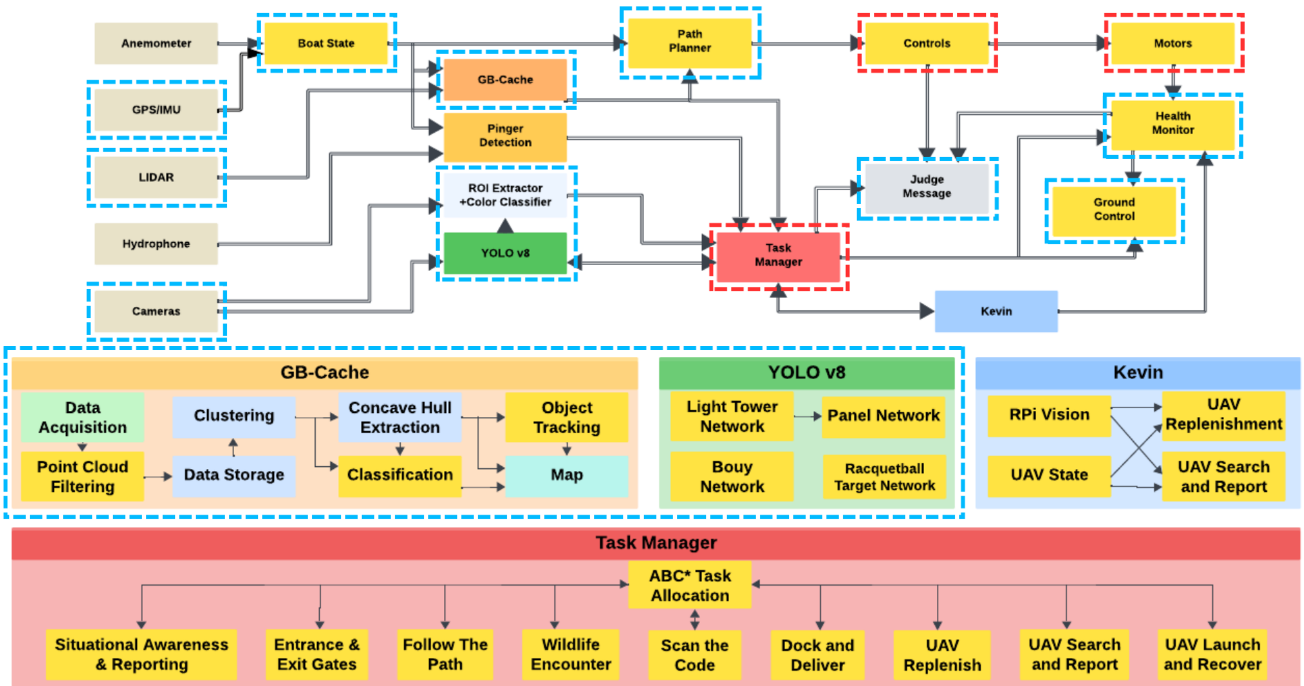


Fig. 2: Software Architecture Flow Chart for Minion. Components marked with dash rectangular boxes are re-utilized for MiniMinion. The components with blue dash box went through minor changes, while the components with red dash box are be rewritten to accommodate major changes.

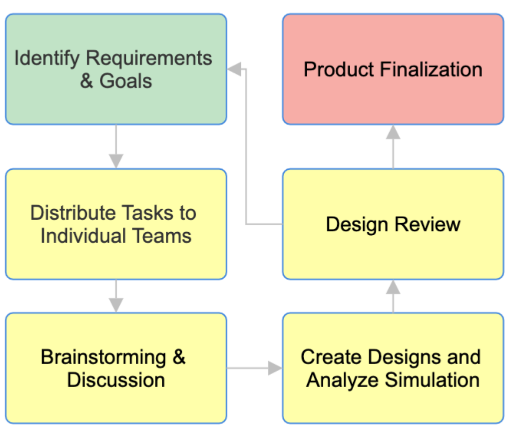


Fig. 3: Systems Engineering Adaptation: Minion Process

practical engineering. It enables the team to adapt to evolving requirements and limited schedules while consistently producing high-quality system elements.

### C. Minion Process Case Study - Electronics Enclosure

As previously discussed, team Minion inherited a set of electonic components capable of powering the ASV, but unsafely housed and poorly managed. As such, the team put Minion Process to work on solving this issue.

The team sought the design of an enclosure that houses the battery, power distribution system, communication and compute components. This design was a collaborative effort between the electrical and mechanical sub-teams focusing on:

- **Safety**: This was the teams number one priority through preventing water incursion, loose wiring, and potential for shorts.
- **Reliability**: Ensuring components and subsystems have a low failure rate or redundancy.
- **Creativity**: This was defined as the ability to use everyday objects for things they weren't traditionally used for in a way that amplifies their strengths
- **Portability**: The system needed to be able to be easily accessible to allow for repair and diagnosing. It was also desired to re-use the enclosure if the hull was re-designed for RoboBoat 2026.

After going through Minion Process (see Figure 3), the enclosure featured a rugged 24V Lithium Polymer drill battery, which has its own built-in Battery Management System and can be sourced locally if needed. A custom power distribution PCB, which includes an E-STOP circuit is used, components are fused, and redundant micro controllers are used to minimize failures. The entire enclosure was designed to fit in a pelican case that could easily be transferred to other robots making the entire system modular. This implementation of Minion Process was also conducted by team members with less than 1 year of team experience, highlighting our goal of training newer members in preparation for RobotX 2026.

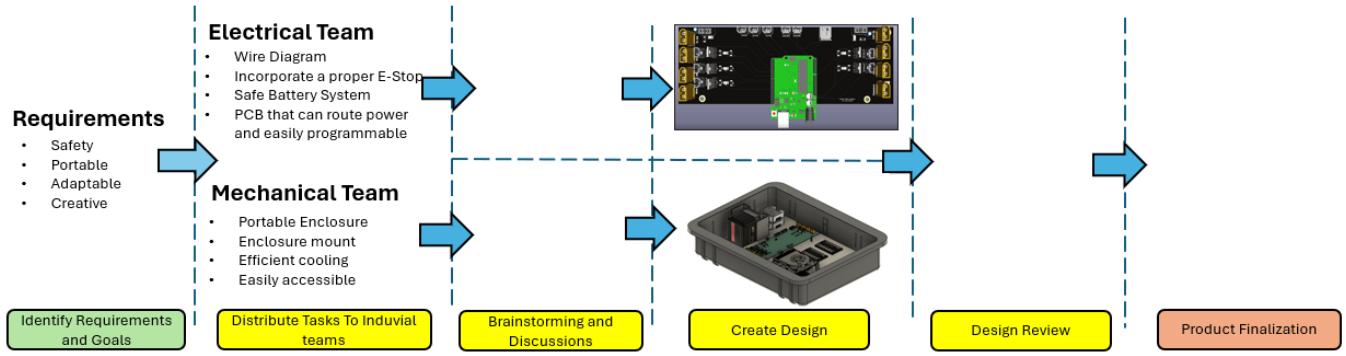


Fig. 4: Enclosure Design using minion process

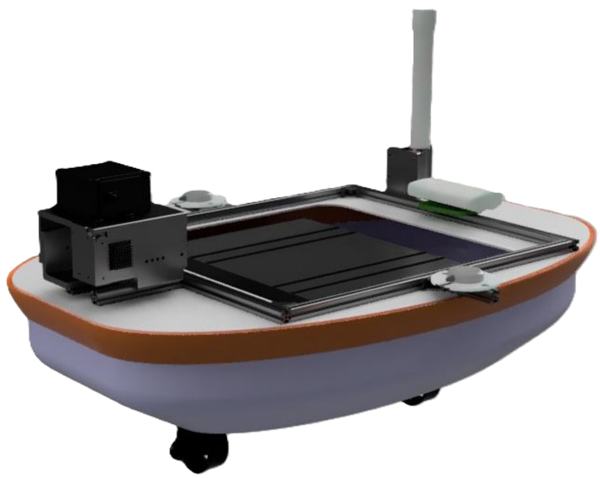

Fig. 5: Render of our current boat design

## D. Hardware Design

The format of our boat is built to resemble a tugboat for greater stability and ease of construction, as shown in figure 5. Our core electrical components are mounted in a 1520 pelican case inside the hull of the boat. Our sensor suite and communication equipment are secured onto the deck and are meant to mirror that which was used successfully on minion. Having hardware overlap over the two boats means that we can easily transfer the experience gained from RoboBoat directly onto RobotX.

## E. Propulsion & Electrical

The motor configuration and electrical design of our boat were constrained by holes already put into the platform for propulsion, which included one bow- and one stern-mounted azimuth motor assembly. While this provided platform control, it suffered from structural issues, such as leaks in the motor mounts. Consequently, we prioritized redesigning the motor mounts to address these deficiencies. To minimize system complexity and accommodate the limited project timeline, we opted for a simplified design with fixed motor positions, replacing the previous azimuthing motor mounts (see Figure 6).

Our propulsion system consists of two BlueRobotics T200 thrusters. One motor is aligned to provide forward and reverse thrust, while the other is positioned orthogonally at a 90° angle to enable rotational motion. This was a trade-off in complexity for reliability, as the modification transitioned the system from an overactuated configuration to an underactuated one. So the vessel only controls surge and yaw degrees of freedom and does not control sway.

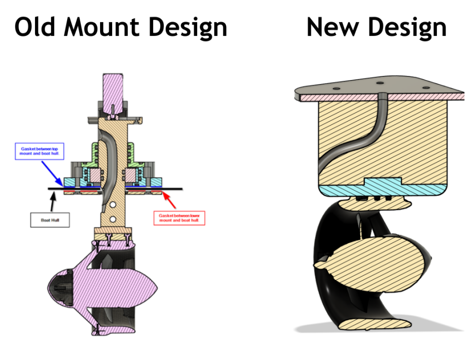


Fig. 6: Motor Mount Change from the old to the new version

## F. Hardware Stretch Goals

Our team has several objectives that are not required to be finished before heading to competition due to time constraints, but would still serve to expand our capabilities and motivate the team to go beyond their comfort zone.

*1) Implementing Improved Racquetball Launcher:* An example of one of these stretch goals would be to finish the development of our new redesigned RobotX racquetball launcher and implement it in our RoboBoat ASV. This would be an excellent test of our new system while expanding the capabilities of our boat by allowing it to complete the Object Delivery Task.

*2) Water Delivery Task:* A water delivery pump was included with the inherited hull, but it is untested and not integrated with any of our other hardware or electrical systems. Implementing water delivery into our ASV would have very few transferable applications onto RobotX, meaning it is not a top priority. However, having such a capability would make the team more competitive during competition and would provide valuable general engineering experience for new and existing members.

### G. Software Design

With ROS 1 reaching its end of life in May 2025, the team decided to migrate to ROS 2 following the conclusion of the RobotX 2024 Challenge. This transition necessitated rewriting all software packages and libraries using updated syntax and terminologies. Recognizing the complexity and importance of this process, the software sub-team outlined a streamlined approach to manage the migration effectively:

- Identify whether the package or library is a core component.
- Break the package/library into smaller chunks to simplify debugging.
- Update the syntax or rewrite the code in chunks.
- Build and debug each chunk incrementally.
- Repeat the process until all core packages and libraries are updated.
- Prioritize competition tasks based on available capabilities, resources, and development time.
- Update task-specific nodes accordingly.
- Test updated nodes and functionalities in the VRX simulation environment.
- Perform final testing in water.

To ensure a smooth migration, the system was prepped by identifying and installing appropriate drivers for all external components interfacing with the platform. Dependencies and utilities were resolved early in the process to provide a robust foundation for migrating individual competition mission scripts. This systematic preparation and testing ensured that the transition to ROS 2 maintained system reliability and readiness for upcoming challenges.

## III. Testing Strategy

### A. Path to Success

Upon return from the RobotX 2024 competition, Team Minion unanimously voted to compete in the 2025 RoboBoat. However, with limited time and a goal of reaching the semi-final round of the competition, project management has become a critical tool for Team Minion's testing strategy.

### B. Project Management

To increase the probability of success for Team Minion, a new leadership position has been established, the project manager. The role of project manager is to be responsible for planning the test day and improving communication between team members and subteams. When a component requires testing, a student will write a brief test procedure and an estimate of how long the test would take. The day before each test, the project manager would review the list of tests and create a schedule for the test day, taking into account each requested test duration, transition time between tests, setup time, and pack-up time. This system ensures that all team members were aligned on the schedule, and if a student was unprepared during their designated time, their test would be rescheduled to another date or, if time allowed, after all other tests were completed. This approach improved communication within the team and ensured that each member had a fair opportunity to conduct their tests without wasting time on setup or preparation.

*1) Hardware Testing:* MiniMinion follows the team's proven hardware testing strategy from the last three successful RobotX cycles, progressing from low-risk, minimal-effort tests to full-scale integrated system trials.

The stages of the hardware test strategy are:

- Computer-Aided Analysis: Software tools like SolidWorks, ANSYS, LT-Spice, and ADS are used to rapidly evaluate design solutions for form, fit, and function. This stage involves sizing components, testing loading conditions, and assessing electrical performance.
- Bench Tests: Initial prototypes are tested in a safe, controlled setting to verify functionality and identify failure points. These insights guide further testing or design iterations.
- Boat Integration: This phase involves integrating components into MiniMinion, pausing other testing activities. This phase includes in-lab tests to ensure new installations communicate and function seamlessly with existing systems.
- On-Water Testing: Held bi-weekly once the platform is capable of RC driving, these tests evaluate both hardware and software through predefined objectives and criteria. Each test requires an RC driver and a ground station operator. On-water time is managed by the bidding system to ensure fair allocation of testing time for subsystems. Test plans are used when possible items are tested to further organize testing and maximize efficiency.

*2) Software Testing:* An in-lab vehicle shakedown is performed the day before on-water testing to verify recent updates and ensure compatibility between modified code and previous iterations. This step reduces the risk of losing valuable on-water time addressing compatibility issues. Key checks include:

- Verifying successful code compilation.
- Ensuring all required dependencies are installed on the ASV.
- Testing propulsion system responsiveness.
- Confirming proper sensor networking.

During on-water tests, ROS bag files are used to capture all sensor data and inter-algorithm communication. These bags can be used later for performance assessment and algorithm testing by treating the recorded data as live observations.

After each on-water test, the team holds a debrief with all members about key accomplishments and issues. This forms the foundation for planning the next testing cycle, ensuring a focused approach to improvements and future preparations.

*3) Testing Schedule:* Table I presents each RoboBoat task ordered by the expected success rate, as voted on by the team members. The first task, Navigation Channel, is the first required task and mirrors what the team has previously done for RobotX. But this requires the platform's base hardware

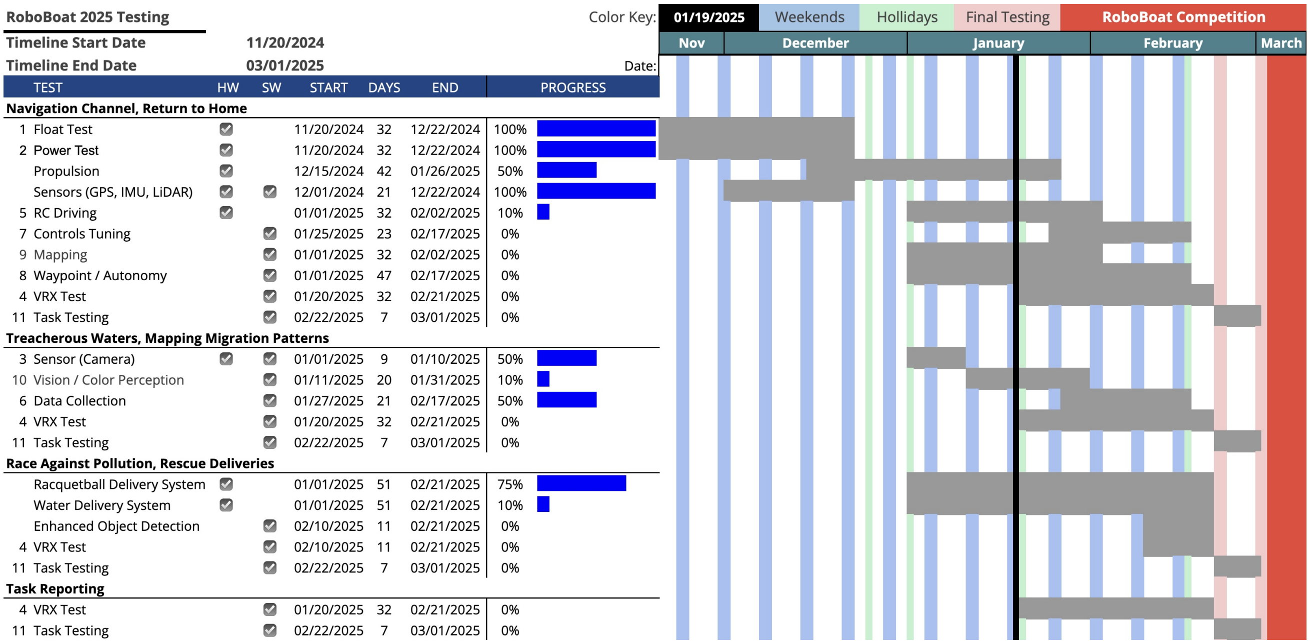


Fig. 7: Minion Testing Timeline

(power and propulsion), sensors (GPS and VectorNav), and software (mapping and control) systems to all function as expected. With this basic criteria met, we also believe that the task Return to Home will be easily achievable. Given it requires only GPS-based navigation. The subsequent tasks rely on additional hardware and software subsystems that require additional tuning and reliability testing. The Treacherous Waters and Mapping Migration Patterns tasks will require integrating perception systems, and are the next tasks set for testing. The remaining tasks: Race Against Pollution, Rescue Deliveries, and Task Report will require specific enhancements to hardware design, perception systems, or software, and are designated stretch goals.

TABLE I: Task Priority by Team Confidence Level (0 - no confidence, 100 - perfect confidence). Tasks 4, 5, and 7 are left as stretch goals for the RoboBoat 2025 Competition.

| **Task Name & Number** | **Confidence (0-100)** |
|---|---|
| 1. Navigation Channel | 99 |
| 6. Return to Home | 99 |
| 3. Treacherous Waters | 80 |
| 2. Mapping Migration Patterns | 50 |
| ——————————- | – |
| 4. Race Against Pollution | 10 |
| 5. Rescue Deliveries | 10 |
| 7. Task Reporting | 5 |

Based on the task priority identified in Table I, and the subsystems required for each of these tasks are prioritized and scheduled for testing accordingly. This schedule is presented in Figure 7.

## Acknowledgment

Team Minion would like to thank our generous external partners for their support with equipment and technical support: Yamaha Motor Company, Volz, Torqeedo, RoboNation, Copenhagen Subsea A/S, Glenair, Mathworks, Northop Grumman, ClickBond and DS Solidworks. Team Minion would also like to thank their internal partners: the Embry-Riddle Aeronautical University College of Engineering, Mechanical Engineering Department, and Student Government Association. Many individuals have contributed significantly to the success of team Minion, but the team would like to give a special recognition to our wonderful alumni, who continue to support the team after many years through technical assistance. The team would also like to thank Bill Russo for manufacturing assistance, Mike Potash for electrical support, and Christina Groenenboom for logistics support.

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