RoboBoat 2026: Technical Design Report
Navier USN

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Figure 1: The Navier team at home base after securing the win at Njord 2025

Abstract

RoboBoat 2026 represents the second phase of Navier's two-year development plan for an autonomous surface vehicle (ASV), shifting focus from foundational learning to performance optimization based on experience from RoboBoat 2025[1]. Lessons learned have directly influenced both technical design choices and competition strategy. To optimize the total achievable score within the competition, Navier focuses on mission tasks that best align with the team's system capabilities, including Emergency Response Sprint, Evacuation Route Return with Debris Clearance, Navigate the Marina, and the Supply Drop challenge with emphasis on water delivery. The ASV is developed using a modular and scalable architecture, enabling iterative improvements across mechanical, electrical, and software systems[2]. While the in-house hull design is retained, the propulsion and control systems have been refined to enhance maneuverability and robustness. Improved situational awareness is achieved through the integration of LiDAR and GNSS/INS sensors, supported by enhanced navigation, perception, and control algorithms[3], [4]. The 2026 development cycle emphasizes system integration, validation, and real-world testing to deliver a mature and competitive ASV platform.

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1 Competition Strategy

1.1 Course Overview and Task Selection

While RoboBoat 2026's tasks gradually increases system demands, it also focuses on essential autonomous skills: such as perception-driven navigation, avoiding obstacles, precise maneuvering and mission-level decision making.

That's why the team approached task selection by identifying the fundamental autonomy components shared across multiple challenges. Instead of treating each task as an isolated problem, Triton's mission planning relies on reusable perception, planning and control behaviors that can be combined and ordered based on the operational context.

As required, **Task 1 - Evacuation Route & Return** serves as the entry point, that the ASV has to complete it first during each scored run. Successful completion of this task validates Triton's core autonomy capabilities: identifying navigation gates, creating waypoints and maintaining stable motion control. All further missions depend on the reliability of this core process.

Beyond the mandatory Task 1, Triton is designed to tackle a carefully chosen set of the remaining challenges. These tasks were chosen to strike a balance between scoring potential and feasible system complexity, while strengthening fundamental abilities in perception, navigation, decision-making, and control:

Task 2 - Debris Clearance was chosen to demonstrate autonomous navigation in confined environments, effective obstacle-avoidance, and perception-based decision-making.

Task 3 - Emergency Response Sprint was selected to showcase quick perception, agile maneuvering and effective closed-loop control performance.

Task 4 - Supply Drop is attempted in a reduced scope. Triton is equipped to perform water delivery only, while ball delivery was intentionally excluded. Choosing to rely on a single, well-controlled interaction rather than multiple failure-prone mechanisms was an intentional compromise between mechanical complexity and overall system reliability.

Task 5 - Navigate the Marina was included as a high-value precision task to demonstrate docking autonomy and structured decision-making in constrained spaces.

Certain tasks were intentionally dropped, such as **Task 6 - Harbor Alert** due to limited development and test time, the added system complexities were assessed and proven to pose an unacceptable risk to overall mission stability.

In summary , the team's task selection approach reflects a balanced strategy to maximize points: prioritizing specific scoring opportunities by focusing on tasks Triton can perform consistently, while maintaining architectural flexibility to support adding further capabilities if the system's performance allows it during the competition.

1.2 Strategic Vision and Objectives

Triton represents a refined continuation of the 2025 Triton, rather than a complete redesign. The strategic objective for RoboBoat 2026 is to improve Triton's autonomy and system performance, adapted to this year's tasks, where its behavior under competition conditions is well understood and predictable. This continuity enables the team to utilize prior experience while improving the system's ability.

Success at RoboBoat 2026 is therefore not only measured by the number of completed tasks, but mainly defined by the quality of the adaptive autonomy demonstrated: the ASV's ability to perceive, decide and act reliably across multiple tasks. Through pursuing high reliability on selected tasks and selective pursuit of scoring opportunities, the team aims to maximize effective scoring through consistent task completion rather than maximizing points by attempting all tasks.

At the software level, this vision is achieved using an autonomy framework supported by a meticulously crafted behavior tree. Each task is implemented with clear entry conditions, execution logic and termination criteria. This modular structure allows Triton to transition cleanly between tasks while avoiding as many errors as possible.

Overall, the 2026 strategy strikes a balanced approach: advancing the system beyond its previous capabilities while staying rooted in what can be thoroughly tested and confidently executed. Triton serves as a refinement platform, reinforcing the team's autonomy foundations and prepare Navier Usn for future competitions.

1.3 Trade-offs: System Complexity vs. Reliability

Experience from RoboBoat 2025 showed that system reliability is critical for competition performance. Consequently, Navier prioritized Core-level functionality for RoboBoat 2026, deliberately excluding advanced autonomy features such as dynamic task selection and parallel task execution. Task behavior is predefined using a Behavior Tree to ensure predictable and testable system operation.

A key trade-off was made between sensor count and calibration complexity. The system relies solely on a camera and LiDAR, postponing additional sensors due to integration risk and time constraints. Similarly, advanced AI solutions were avoided in favor of a single lightweight perception model that meets real-time and computational requirements. Tasks are executed sequentially to reduce system coupling and failure propagation, reflecting lessons learned from prior competition experience.

1.4 Resource Allocation and Schedule

The development of Triton for RoboBoat 2026 was carried out within the constraints of an academic semester, which meant that the team had to be more realistic when it came allocating time, personnel and testing opportunities.

These constraints ended up shaping a lot of our strategy and reinforced the decision to prioritize reliability over additional system complexity.

Development followed a semester-based progression, with early phases focused on aligning the system with the 2026 task requirements by utilizing lessons learned from past competitions and tests. Rather than chasing big new ideas, the team focused on steady and gradual improvements and stabilization of existing capabilities. This approach freed up more time for testing, tuning, tracking down issues and including new functionalities.

The team itself was spread across software, mechanical, hardware and electrical teams, with strong overlap and collaboration between teams. While autonomy related tasks such as perception and mission logic was covered by the software development. Mechanical, hardware and electrical efforts focused on making the platform sturdier. Consequently the teams managed integrating new functionalities such as the water delivery mechanism and RTK positioning, and ensured reliable operation under competition conditions.

On-water testing was conducted regularly at the university's swimming facility, usually on a weekly basis. Testing opportunities were limited by facility availability and seasonal conditions. These limitations forced the team towards designs that were easier to validate in small predictable environments, like modular behavior trees and predictable mission execution that could be validated in constrained test environments.

To conclude, resource allocation for RoboBoat 2026 reflects a deliberate strategic choice: the team invested time and effort into testing and system refinement. This philosophy directly supports the team's balanced competition strategy and increases confidence in Triton's ability to perform consistently when it matters.

1.5 Software Tools and Autonomy Stack

The autonomy stack is built on ROS 2, providing modular communication between perception, planning, and control subsystems[5]. NVIDIA Isaac ROS is used to accelerate vision and sensor-processing pipelines, enabling reliable real-time performance on embedded hardware[6]. System behavior and task execution are validated through lightweight analytical models prior to on-water testing, reducing integration risk. Continuous integration workflows ensure software stability, while logging and data recording support post-run analysis and iterative improvement. Together, these tools link competition strategy to system design and testing, enabling reliable execution of prioritized RoboBoat tasks.

2 Design Strategy

2.1 System Overview and Architecture

A high-level overview of the system architecture is provided in Appendix A (Fig.2). The system follows a modular architecture with clear separation between perception, planning, and control, coordinated through ROS 2. High-level task execution is managed by a behavior tree, while lower-level controllers handle motion and actuation. This design improves robustness, testability, and scalability.

2.2 Hull and Mechanical Design

For Roboboat 2026, Navier USN is entering the hull design “Triton”, which was also used for Roboboat 2025. Instead of making a new hull, the decision was made to use and improve the already existing trimaran because of its tried and tested stability and efficiency, experienced from previous competitions. The original boat is made by 3D-printing parts in PLA which is then casted in layers of glass fiber and a top layer of gelcoat.

Hull improvements

Based on experiences gained from RoboBoat 2025, several improvements were implemented for this year’s competition. One of the most significant changes was the repositioning of the propulsion system. By optimizing the placement of the propulsion system, the draft could be shallower. Thus, less weight is needed to weigh the vessel down to ensure complete submergence of the thrusters. This modification allow the vessel to be closer to Robobat’s max weight requirements, hopefully reducing the potential penalty points given.

Lids & Lights

Water intrusion has been a challenge in previous competitions. Therefore, two improvements have been made to the hull: The first is redesigned and improved lids, which were made thicker and stiffer. The forces from the locks would be spread more evenly along the gasket, generally improving water tightness along the entire edge of the lids. A wider lip was added to have a greater overlap with the hull, thus reducing opportunities for water to intrude. The previous triple light setup on the side-lids has been changed to a single light system, which also meant changes on the side lids themselves. They now have one central hole for the lights, improving structural integrity and reducing the number of openings that could cause leakage.

Additionally, a new pressure-locking mechanism was added to the lids, speeding up the the unlocking process significantly. The new, quicker solution means more time available for prepping the hull for competition, when time is limited. The mechanism works as follows: a spring-loaded bolt with a metal plate is pressed down and rotated into position under the hull edge. When pressure on the spring-loaded bolt is released, the metal plate creates pressure between the lid and the hull, forcing it shut. A bespoke tool was designed and printed to easily rotate the locks on and off.

Leakage in the thruster canals were detected, likely due to a hard impact with a tool or hardware. Therefore, the second improvement to water intrusion prevention is padding, protecting the canals from future damage.

Water gun

The water gun system is mounted on the boat by securing a water pump in a 3D-printed custom-designed casing, attached with tec-7 adhesive at sea level on the hull. The casing is modelled to match the pump. This is to make it as small as possible, as well as being made in an organic shape to lessen the negative, hydrodynamic impact and drag occurred on the vessel. A hose extends from the top of the base and connects the pump to the nozzle holder. The nozzle holder is designed to promote simplicity and adjustability. The base is attached to the hull with glue, and a track is put in the base to hold the nozzle snug and stable. A screw is then tightened to keep the nozzle in place, and it can be loosened to adjust the angle or to remove the nozzle for maintenance.

During production of the base, several iterations were produced to get have the tightest fit. This was both because of human errors and the printer not being completely accurate and therefore having small anomalies in every print. The iteration that is attached to the boat, has been sanded down in the opening to help the pump fit better.

2.3 Propulsion and Actuation

Propulsion is provided by two primary thrusters and two auxiliary thrusters. They are used with 12V instead of their maximum 24V capability to enable precise low-speed maneuvering[7], [8]. This configuration is optimized for tasks requiring fine positional control, such as docking and navigation through narrow gates, instead of high speed. This also allows for lower power consumption.

2.4 Electrical and Power System

Earlier we had a system powered by three 12V batteries with a total of 90Ah capacity. This allowed for 12 hours of continuous active use. This is to maximize testing hours without the need for changing or re-charging the batteries.

Because of the weight limit, under the competition in Florida we are going to use 3 or 4 18Ah lithium-ion to aim for a weight as close to the weight limit as possible[9]. The electrical system is separated into a main system and propulsion. This is to make it easy to cut the propulsion if there is loss of contact with the boat or the emergency stop either on the boat or the controller is activated[10].

2.5 Sensors and Perception Stack

The perception system combines camera, LiDAR, and GNSS/INS sensors to provide complementary environmental awareness and localization[3], [4]. A dedicated RTK base station enables centimeter level positioning without reliance on external internet connectivity, significantly improving robustness and predictability during precision tasks[11].

2.6 Control and Autonomy Architecture

To ensure structured and reliable task execution, the system is organized into clearly separated processes for perception, decision-making, planning, and control. This layered architecture is implemented using the ROS2 enabling modular communication. This improves robustness and enables systematic testing and validation of each subsystem[12].

High level task coordination and decision making are handled using a behavior tree framework. The behavior tree is responsible for sequencing tasks, selecting appropriate actions based on system state, and managing transitions between different operational modes. This approach provides a scalable and transparent structure for mission execution while supporting fallback behaviors and safe interruption when required[13].

The task execution pipeline begins with object detection, where camera data is processed by a YOLO based model to identify relevant objects in the environment, such as buoys[14]. Detected objects are passed through a filtering node to remove spurious or short lived detections before being stored in a centralized object database. This database provides a consistent and reliable representation of the environment for downstream modules.

Based on the information stored in the object database, the path planner generates a reference path represented as a sequence of waypoints in a global coordinate frame. These waypoints define the desired trajectory for solving the current task.

The generated waypoint list is then processed by the Autopath module, which is responsible for executing the path and controlling the ASV. The Autopath module supports dynamic waypoint handling, allowing new waypoints to be inserted with higher priority or appended to the existing list during execution. This capability enables adaptive behavior, such as real time path modification for collision avoidance, without interrupting the overall task execution.

3 Testing Strategy

3.1 Testing Philosophy and Objectives

Our testing philosophy is based on the principle of "test early, test often"[15]. Subsystems are validated from the earliest stages of development and continuously tested during integration to ensure reliable performance. The main objective is to verify safe, stable, and repeatable autonomous operations in competition-relevant scenarios. Testing also reduces critical risks such as sensor misalignment affecting perception, GNSS degradation, communication dropouts, and control instability during dynamic maneuvers and docking.

3.2 Simulation and Digital Twin Testing

Rather than relying on full scale physics simulations or a digital twin in development and validation of planning and control algorithms we used a lightweight analytical model using simple 2D modeling in Python. This approach was used to enable rapid development.

The model focused in the vessels motion and waypoint-following algorithms to debug easy to fix logical issues before testing in the water.

3.3 Component and Subsystem Testing

Individual subsystems are tested in controlled setups to evaluate detection accuracy, positional precision, and robustness. The camera and LiDAR assess object detection under varying lighting and motion conditions, while the combined IMU, GPS antenna, and RTK system is verified against reference points to achieve approximately 1.4 cm position accuracy. Thrusters and the power system are tested for thrust response, maneuverability, and station-keeping performance. Communication subsystems are evaluated for latency, signal stability, and telemetry reliability. Safety-related subsystems, including the emergency stop, are tested by verifying that both the RC failsafe and physical stop button activate the safety contactor to immediately cut power to the thrusters.

3.4 Integrated System and Field Testing

Integrated system testing is conducted in an indoor pool during winter and at a nearby harbor during summer to simulate competition conditions. Testing progresses from manual control to semi-autonomous navigation and finally full autonomous mission execution. Typical scenarios include buoy detection, channel navigation, obstacle avoidance, and dynamic positioning. Performance metrics such as success rate, positional error, course completion time, and detection accuracy are recorded and analyzed to guide iterative improvements.

3.5 Risk Management and Iterative Improvement

Key technical risks include sensor calibration errors, GNSS loss, communication dropouts, thruster failures, and software instability. These are mitigated through redundancy, fallback modes, and manual override, including the emergency stop. Sensor fusion between GNSS, IMU, and vision improves reliability when individual sensors degrade. Test results are used to guide design improvements, such as refining YOLO models for better buoy detection, tuning thruster control, and improving communication reliability. This iterative process ensures safe, reliable, and competition-ready autonomous operation.

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4 APPENDIX

4.1 Software diagram

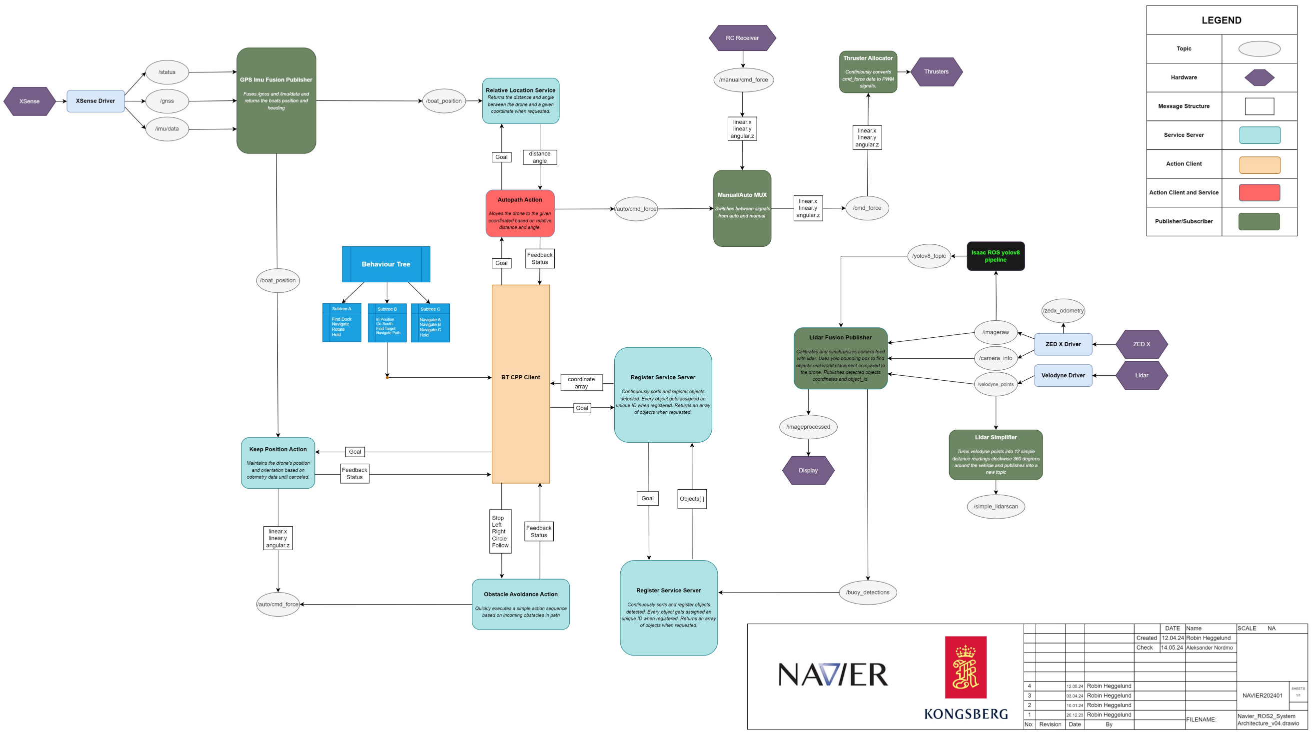

Figure 2: Navier USN ROS2 system architecture.

4.2 Behaviour Tree

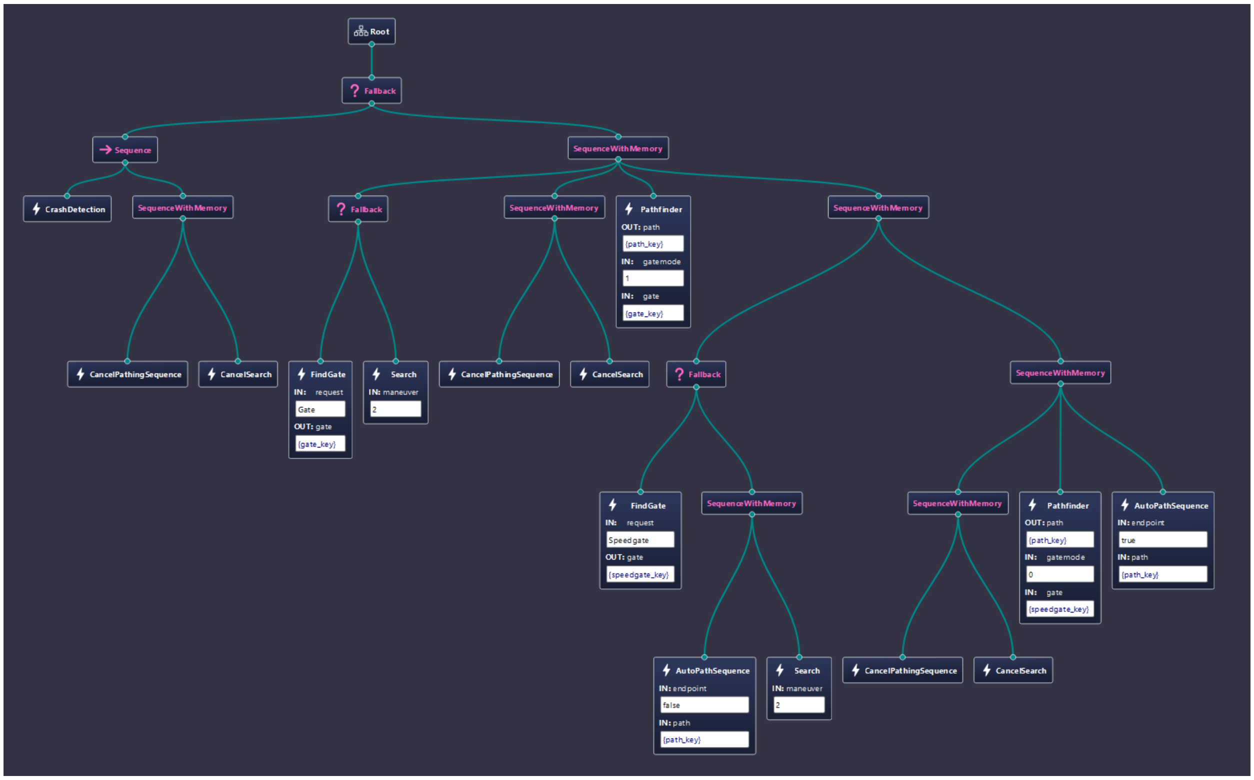

Figure 3: The figure illustrates an example mission in the ROS2 Behaviour Tree.