

# RoboBoat 2026 – Technical Design Review

## Team TORONGO

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### Abstract :

**This Technical Design Review presents the design, architecture, and competition strategy of TORONGO-T1, Team TORONGO’s Autonomous Surface Vehicle (ASV) for RoboBoat 2026. Based on analysis of historical RoboBoat performance and common failure modes, the team adopted a reliability-first engineering philosophy, prioritizing mechanical robustness, fault-tolerant autonomy, and taskfocused system design over excessive complexity. TORONGO-T1 integrates a custom carbon-fiber hull, omnidirectional vector propulsion, multi-modal perception using LiDAR and RGB-D vision, and a split-architecture control system separating real-time stabilization from high-level autonomy. The ASV is designed to autonomously execute Tasks 1, 2, 3, and 5, targeting Disruptive-level performance in Tasks 2 (Debris Clearance), 3 (Emergency Response Sprint), and 5 (Navigate the Marina). System validation follows a staged testing methodology including simulation, controlled water testing, and open-water trials to ensure competition readiness.**

**Keywords : RoboBoat, Autonomous Surface Vehicle, Omnidirectional Movement, Stability, Autonomous.**

### 1. Introduction

RoboBoat 2026 challenges teams to design and deploy fully autonomous surface vehicles capable of operating in dynamic maritime environments while completing increasingly complex missions. As a first-year RoboBoat team, Our team approached the competition with a focus on engineering discipline, risk mitigation, and strategic task selection. Our primary source of information for the competition was the provided handbook [1] and third party sources like Youtube.

Rather than maximizing system complexity, our team emphasized:

- Proven marine-grade hardware
- Clear separation of control and autonomy layers
- Robust perception under variable environmental conditions
- Alignment between competition scoring and system capabilities

This document details the resulting design and strategic decisions behind TORONGO-T1.

### 2. Competition Strategy

#### 2.1 Selected Tasks and Capability Targets

Our team will attempt the following tasks during RoboBoat 2026:

Task	Name	Target Capability Level
Task 1	Evacuation Route & Return	Core
Task 2	Debris Clearance	Disruptive
Task 3	Emergency Response Sprint	Disruptive
Task 5	Navigate the Marina	Disruptive

Task 4 (Supply Drop) was intentionally excluded due to the mechanical complexity and additional failure risk introduced by payload delivery systems. This decision allows us to focus on autonomy-critical tasks with higher scoring efficiency.

## 2.2 Strategy Rationale

- **Task 1** - ensures reliable autonomous startup and qualification compliance.
- **Task 2** - leverages LiDAR-vision fusion for high-value reporting and mapping.
- **Task 3** - uses omnidirectional propulsion for rapid, precise movement.
- **Task 5** - emphasizes precision docking and decision-based slip selection.

This strategy balances scoring potential with system reliability, maximizing successful autonomous task completion.

## 3. System Architecture Overview

TORONGO-T1 follows a modular, split-architecture design:

- **Low-level control & stabilization:** Pixhawk Orange Cube
- **High-level autonomy & perception:** Raspberry Pi 5 (16 GB RAM)

This separation improves fault isolation, reduces real-time latency risk, and enhances overall robustness.

## 4. Mechanical Design

### 4.1 Hull Configuration and Rationale

TORONGO-T1 employs a custom-designed twin-pontoon catamaran hull, selected after evaluating monohull, trimaran, and planing hull alternatives. The catamaran configuration offers an optimal balance of static stability, hydrodynamic efficiency, and modular deck space, making it particularly well-suited for autonomous surface vehicle operations in RoboBoat [3].

The wide beam created by the dual hulls significantly reduces roll and pitch, ensuring stable sensor performance for LiDAR and vision systems. This stability is critical for accurate perception, especially during docking and debris field navigation.

Compared to monohull designs, the catamaran exhibits lower wave-making resistance due to its slender hull geometry. Trimaran designs were rejected due to increased structural complexity and mass, while planing hulls were deemed inefficient and unstable at the low-to-moderate speeds required for precise autonomous maneuvers.

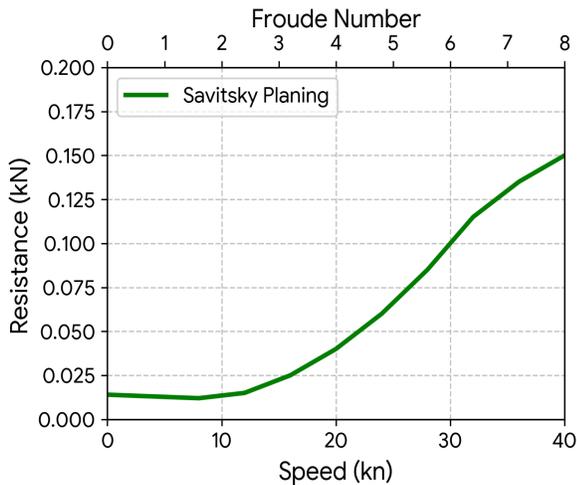
### 4.2 Hydrodynamic Analysis

Hydrodynamic performance of the hull was analyzed using Maxsurf Resistance with the Savitsky planning method [2]. The modeled hull parameters include a length at waterline (LWL) of 0.576 m, beam of 0.412 m, draft of 0.13 m, and a displaced volume of approximately 0.007 m<sup>3</sup>.

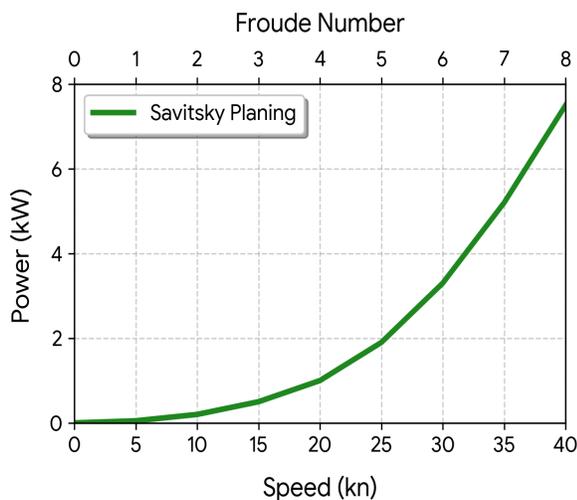
Simulation results indicate:

- Resistance remains below 0.1 kN up to operational speeds relevant for RoboBoat tasks [Figure-1]

- Required propulsive power remains under ~1 kW at moderate speeds, with power demand increasing sharply only at unrealistically high speeds for competition use [Figure-2]



**Figure-1 : Resistance vs Speed graph from simulation testing**



**Figure-2 : Power vs Speed graph from simulation testing**

These results confirm that the selected propulsion system provides sufficient thrust margin while maintaining high energy efficiency during typical mission profiles. The

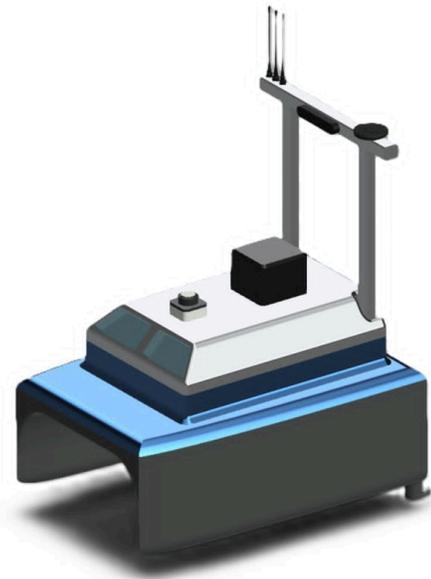
shallow draft further enables safe operation in constrained or shallow areas of the RoboBoat course.

### 4.3 Structural Fabrication

The hull was fabricated using carbon-fiber-reinforced epoxy resin material with 3D printed cast, providing high stiffness-to-weight ratio, impact resistance, and water tolerance. Carbon fiber rod profiles are integrated into the deck structure, enabling modular mounting of sensors, antennas, and electronics, and allowing rapid reconfiguration during testing and competition.

#### 4.1 Hull Design

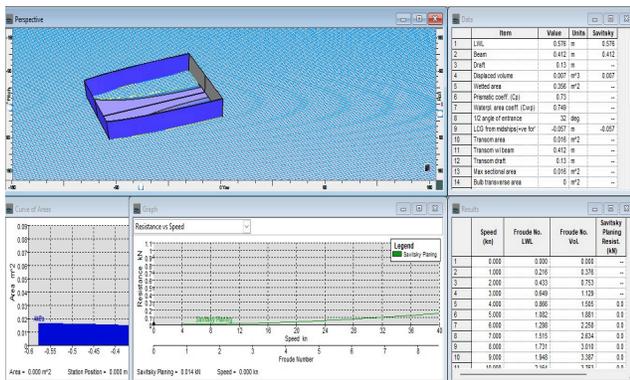
The ASV prototype was designed and refined through multiple iterations in Autocad Fusion 360 by our design team before its final version was approved [Figure-3].



**Figure-3 : Final design of ASV TORONGO-T1**

The ASV utilizes a custom-manufactured carbon-fiber hull, selected for its high stiffness-to-weight ratio, corrosion resistance, and long-term durability in freshwater environments. The custom hull allows

optimized internal volume allocation, controlled mass distribution, and improved stability compared to off-the-shelf platforms.



**Figure-4 : Simulation testing using Maxsurf**

Hydrodynamic analysis was performed using Autodesk Fusion 360, Solidworks and Maxsurf, including stability and resistance simulations [Figure-4]. The Savitsky planning method was applied to estimate hull resistance and ensure propulsion sufficiency under expected operating conditions [2].

## 4.2 Structural Fabrication

The hull was fabricated by multiple layers of carbon-fiber-reinforced epoxy resin on top of a 3D printed mold, balancing manufacturability, impact resistance, and cost. Aluminum T-slot profiles provide modular mounting points for sensors and electronics, enabling rapid reconfiguration and maintenance.

## 5. Propulsion and Mobility

TORONGO-T1 uses four Blue Robotics T200 thrusters arranged in an X-drive vector configuration and driven by 30 A bidirectional 6S ESCs.

This configuration enables:

- Independent control of surge, sway, and yaw
- Precise lateral motion for docking and debris navigation

- Rapid heading adjustments without hull reorientation

The Pixhawk Orange Cube manages thrust vector mixing and stabilization using onboard IMU data, reducing computational load on the main processor and increasing control reliability.

## 6. Electrical and Power Systems

### 6.1 Custom Battery Pack Design

TORONGO-T1 is powered by a custom-designed lithium-ion battery pack built using Samsung SDI INR21700-40T cells. Each cell uses Lithium Nickel Oxide (LiNiCoO<sub>2</sub>) chemistry, selected for its high discharge capability, thermal stability, and reliability under dynamic load conditions common in marine propulsion systems.

The battery pack is configured in a 6S (6 cells in series) arrangement, providing a nominal voltage of 21.6 V with a rated capacity of 4.0 Ah, resulting in a total energy content of 84.4 Wh. The compact form factor (8.4 × 7.4 × 5.2 cm) and low mass (0.45 kg) enable efficient integration within the hull while maintaining a low center of gravity, directly contributing to vehicle stability.

This custom pack was chosen over commercial off-the-shelf batteries to allow tighter integration with the ASV's power distribution system, predictable discharge behavior under peak thruster loads, and improved safety through tailored current limits and protection circuitry.

Power distribution is isolated between propulsion and computing subsystems to reduce electrical noise affecting sensors and control electronics. Both hardware and software kill switches are implemented to immediately cut propulsion power in emergency scenarios.

Power is supplied by a high-capacity lithium-ion battery pack selected for energy density and discharge capability sufficient to complete the full course on a single charge.

Safety measures include:

- Hardware kill switch
- Software-based emergency stop
- Isolated power distribution for critical subsystems

## 7. Perception and Sensors

TORONGO-T1 uses a multi-modal perception system:

- **RPLIDAR A3:** 360° planar ranging up to 25 m for mapping, obstacle detection, and debris field navigation
- **Intel RealSense D435i:** RGB-D sensing for buoy color detection, close-range depth estimation, and docking confirmation
- **Integrated GPS & Compass (Pixhawk):** Global positioning and heading reference

Sensor redundancy mitigates lighting variability, reflective surfaces, and partial occlusions common in outdoor marine environments.

## 8. Software Architecture

All high-level autonomy is implemented within a ROS 2 framework, chosen for its robust visualization tools, modularity and vast and active community support [4], and pre organized into layered components:

- **Perception Layer:** Sensor drivers, object detection, and classification
- **World Model:** Local mapping and state estimation
- **Behavior Layer:** State machines governing task execution

- **Control Interface:** Velocity and heading commands to Pixhawk
- **Safety Layer:** Kill switch, task aborts, and failsafe behaviors

Simulation and validation are performed using Gazebo, allowing algorithm development prior to water testing.

## 9. Task Execution Methods

### Task 1 – Evacuation Route & Return (Core)

LiDAR-based buoy detection and centering logic guide the ASV through entrance and exit gates with conservative navigation parameters to maximize reliability.

### Task 2 – Debris Clearance (Disruptive)

The ASV constructs a grid-based map of the debris field using LiDAR, classifies hazards and survivors via RGB-D vision, and reports the latitude/longitude of all detected objects.

### Task 3 – Emergency Response Sprint (Disruptive)

High-speed traversal combined with color-based decision logic enables correct directional circling of the emergency buoy. Response time and beacon color are reported upon completion.

### Task 5 – Navigate the Marina (Disruptive)

Vision-guided docking logic identifies all available slips and selects the optimal dock based on beacon color and numeric priority. Omnidirectional motion enables precise station-keeping.

## 10. Testing and Validation

### 10.1 Simulation

- Gazebo-based mission simulation

- Logic stress-testing under sensor noise and drift
- Repeated safety interrupt validation

### 10.2 Subsystem Testing

- Extended water-immersion leak tests
- Thruster calibration and PWM-to-thrust mapping
- Sensor range and alignment validation

### 10.3 Field Testing

The 3D-printed catamaran hull prototype underwent comprehensive testing in an open body of water to evaluate both waterleak integrity and operational efficiency. The measured results corroborated the findings obtained during simulation tests. The team is now focused on completing the Autonomous Surface Vehicle (ASV) build in preparation for the final round of testing.



**Figure-5 : 3D-printed catamaran hull prototype testing.**

Final integration testing will be conducted at MIST Lake, replicating RoboBoat course elements prior to full autonomous trials.

### 11. Limitations and Future Work

Current limitations include restricted multi-vehicle coordination and simplified dynamic obstacle prediction. Future iterations will focus on advanced cooperative autonomy, improved localization accuracy, and enhanced reporting bandwidth.

### 12. Conclusion

TORONGO-T1 represents a disciplined, reliability-focused approach to autonomous surface vehicle design. By aligning system architecture with competition scoring strategy and emphasizing robust autonomy over excessive complexity, Our team aims to achieve consistent, high-value task execution at RoboBoat 2026.

### Acknowledgements

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