# HydroJan 1.0 – Technical Design Report Dreams of Bangladesh – RoboSub 2025

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***Abstract*—Team DOB HydroJan, part of Dreams of Bangladesh, is excited to make our first appearance in RoboSub 2025 with HydroJan 1.0, our very first autonomous underwater vehicle. Our team brings together university, high school, and middle school students, all driven by a shared passion to expand underwater robotics to Bangladesh. Being a debut team, we faced the challenges of limited experience and budget, but we embraced the mindset of "achieving the most with the least." HydroJan 1.0 is built to be simple, modular, and reliable. It's a low-cost platform designed to handle the key RoboSub tasks: navigating gates, interacting with buoys, and launching torpedoes. Our design combines rapid prototyping, computer vision, and custom control systems to make sure it performs smoothly and consistently. By focusing on adaptable mechanics, efficient electronics, and AI-powered autonomy using open-source tools, we created a system that balances flexibility with dependable operation. With HydroJan 1.0, we aim not only to compete effectively but also to build a national foundation for underwater robotics education and innovation in Bangladesh.**

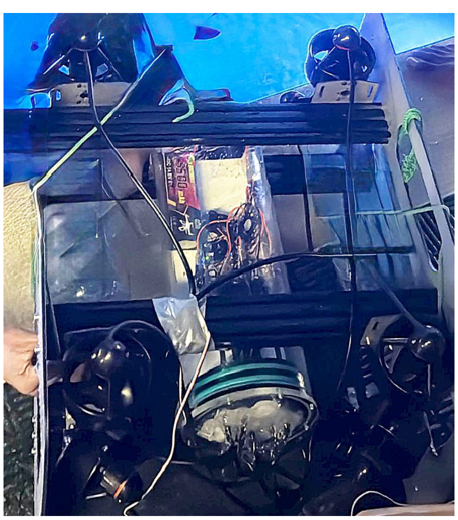

Fig. 1. HydroJan 1.0

## I. Acknowledgements

We would like to express our deepest gratitude to our mentors, Mridul Hasan, MD Mubassir Islam and MD Shohidul Islam Bulbul, whose constant technical guidance and encouragement have been invaluable throughout our journey. We are equally thankful to our advisors, Md. Moin Uddin and Ariful Hasan Opu, for their strategic insights, engineering direction, and continuous support. Special thanks to the Dreams of Bangladesh Research Center for providing the foundational resources and workspace that enabled our innovation and development from the ground up. We also acknowledge ROVMaker for supplying critical components and equipment that played a major role in our system's realization. We are grateful to DSCSC Sports Complex for accommodating multiple physical testing sessions for versions 0.1, 0.2, and 1.0 of HydroJan. Additionally, we thank DBox Sports Complex for supporting version 0.3 testing, which was essential in refining our underwater vision and control systems. Our participation in RoboSub 2025 would not have been possible without the collective contribution of these individuals and institutions. Their belief in our mission empowered a first-time team to pursue bold steps in underwater robotics.

## II. Technical Content

### A. Competition Strategy

As a debut team in RoboSub 2025, DoB HydroJan prioritizes reliability and gradual complexity over risky innovations. Our strategic vision emphasizes building a functional and adaptable system capable of excelling in foundational tasks while remaining expandable for future advancements. The overarching goal is to develop a robust, maintainable vehicle architecture that balances reliability with task-specific enhancements. This methodology stems from an understanding that system complexity must be managed carefully to avoid propagation of failure due to time constraints and limited experience.

Given the RoboSub framework [1] where start gate navigation is mandatory and other tasks are optional but cumulatively scored, our approach involves phased escalation of task complexity based on testing feedback. We have employed a hierarchical task structure:

- **Tier 1 (Priority):** Start Gate → Channel Navigation → Marker Drop in Bin
- **Tier 2 (If Stable):** Simple Torpedo Launching → Surface in Octagon
- **Tier 3 (Aspirational):** Ocean Cleanup Tasks (Object Detection and Basket Drop)

This structure helps focus limited time and resources on maximizing reliability in core tasks, while setting clear pathways for complexity enhancement. We deliberately designed for subsystem modularity, allowing independent development, debugging, and upgrades. We traded off highly sophisticated features like multi-sensor fusion and advanced path planning in favor of robust depth-hold, object recognition, and task actuation.

### B. Design Strategy

*1) System Architecture:* Our system architecture embodies a modular and layered approach driven by our competition strategy. High-level computation and autonomy are handled by the Jetson Orin Nano[2] , chosen for its GPU-accelerated performance and compatibility with real-time vision algorithms. Low-level motion control, including heading and depth hold, is managed by the Pixhawk[3] flight controller using a customized PID system.

The selection of open-source platforms and local sourcing was not only budget-conscious but strategic—supporting easy customization, repairability, and scalability. Each subsystem was chosen or built with specific task goals in mind: for instance, the DIY acoustic velocity sensor substitutes a commercial DVL, enabling localization with acceptable performance without incurring excessive cost or integration risk.

*2) Mechanical Design:* The frame of HydroJan 1.0 uses 6061-T6 aluminum with stainless steel reinforcement to balance structural strength and weight. Our waterproof housing, sourced from ROV Maker[7], features acrylic enclosures sealed with double O-rings to maintain 100m depth rating.

Our buoyancy control combines active and passive components: a custom-built ballast system using a 12V air pump, pressure valve, and PVC tank for dynamic control, paired with EVA foam blocks for passive lift. Propulsion is achieved using T200-type thrusters, selected for their thrust-to-efficiency ratio.

Mechanical innovation is evident in our manipulator arm. Developed in-house, the arm integrates waterproof high-torque servos into a modular frame, allowing grasping and deployment tasks without relying on expensive commercial hardware. Additionally, all connectors and sealings were tested with PG-rated cable glands and immersion trials.

*3) Electrical and Systems Integration:* A distributed control architecture connects high-level and low-level processors through a robust internal network of UART, I2C, and CAN. This ensures fault isolation and simplifies debugging. Our power system includes Holybro and Pololu modules providing regulated voltage to various subsystems, with overcurrent protections for safety.

A custom external communication interface uses a microcontroller with analog-to-digital and digital-to-analog converters to support acoustic signal encoding/decoding for underwater messaging—designed to be lightweight and adaptable to different frequencies.

*4) Sensor Stack:* HydroJan integrates multiple sensors for localization and stability: built-in Pixhawk compass (IST8310)[8], IMU (ICM20689, BMI055), and depth sensors form the foundation. A custom-built Doppler velocity log using piezo transducers extends localization capabilities while reducing reliance on expensive commercial sensors. Object recognition is achieved using YOLO on real-time video, enabling the FSM to guide navigation.

*5) Software and Autonomy:* The software stack uses ROS2[4] nodes to manage communication and task execution. Mission planning follows a Finite State Machine (FSM) structure, mapping specific behaviors (e.g., alignment, actuation) to system states triggered by sensor input. The vision pipeline is optimized for the Jetson's CUDA capabilities and runs with minimal latency using OpenCV [6] and TensorRT enhancements.

Code is written in Python and C++: Python drives the mission logic and image processing, while C++ handles low-latency motion and actuator control.

*6) Manipulator and Torpedo System:* The torpedo launching mechanism is a custom-built subsystem designed to perform precise and reliable torpedo deployment during the competition. Our design features a lightweight launcher integrated with waterproof servos, capable of accurate aiming and firing underwater.

The torpedoes themselves are 3D printed using durable, corrosion-resistant materials optimized for underwater hydrodynamics to ensure stability and range. The launcher mechanism is controlled by the main flight controller via PWM signals to the servos, enabling rapid actuation and reset between launches.

Extensive dry-run testing has been conducted to calibrate the launch force and servo timing, while in-water tests are planned to finalize trajectory control and ensure consistent task completion.


Fig. 2. HydroJan 1.0 Torpedo Launcher Mechanism

### C. Testing Strategy

Our testing methodology is structured in progressive layers to ensure stability and readiness:

*a) Component-Level Testing:* Initial tests focused on individual verification: thrusters were calibrated, servos were tested for torque and waterproofing, and the power system was stress-tested under full load. Waterproof housings and connectors were submerged for prolonged durations to ensure seal integrity.

*b) Subsystem Analysis:* PID tuning for heading and depth hold was validated using logged IMU and pressure sensor data in a stationary tank. Vision systems were tested under simulated underwater lighting with mock targets to measure YOLO [5] inference accuracy and frame rate.

*c) System Integration:* Integrated tests confirmed consistent communication across Jetson, Pixhawk, and microcontrollers. The communication stack was tested with packet loss simulations. ROS2-based FSMs were run under mixed-input loads from sensors and actuators.

*d) Mission-Based Testing:* Tasks such as gate traversal, object detection, marker dropping, and simulated torpedo launches were practiced in controlled water environments. Each test was logged for sensor fusion quality, actuator reliability, and real-time response.

*e) Simulation and Dry Runs:* CAD-based spatial simulations were used to test mechanical clearance, and Unity simulations helped visualize task sequences. A scaled-down water testbed with gate and marker mockups allowed practical practice runs.

*f) Risk Management and Safety:* All early water trials were tethered. LiPo battery circuits were protected with overcurrent modules. An emergency kill switch was integrated with Pixhawk. Thermal monitoring was done during stress tests to avoid overheating.

*g) Test Outcomes:* Feedback from testing informed improvements including better PID parameters, enhanced waterproofing of actuators, and optimized power routing to avoid brownouts. These outcomes demonstrated that HydroJan is capable of stable autonomous operation, prepared for execution of multiple RoboSub missions.

### D. Mission Planning and Control Flow

HydroJan's mission control relies on a custom finite state machine (FSM)[9] that integrates sensor inputs and vision data to make autonomous decisions underwater. The FSM enables task sequencing, error handling, and smooth transitions between behaviors.

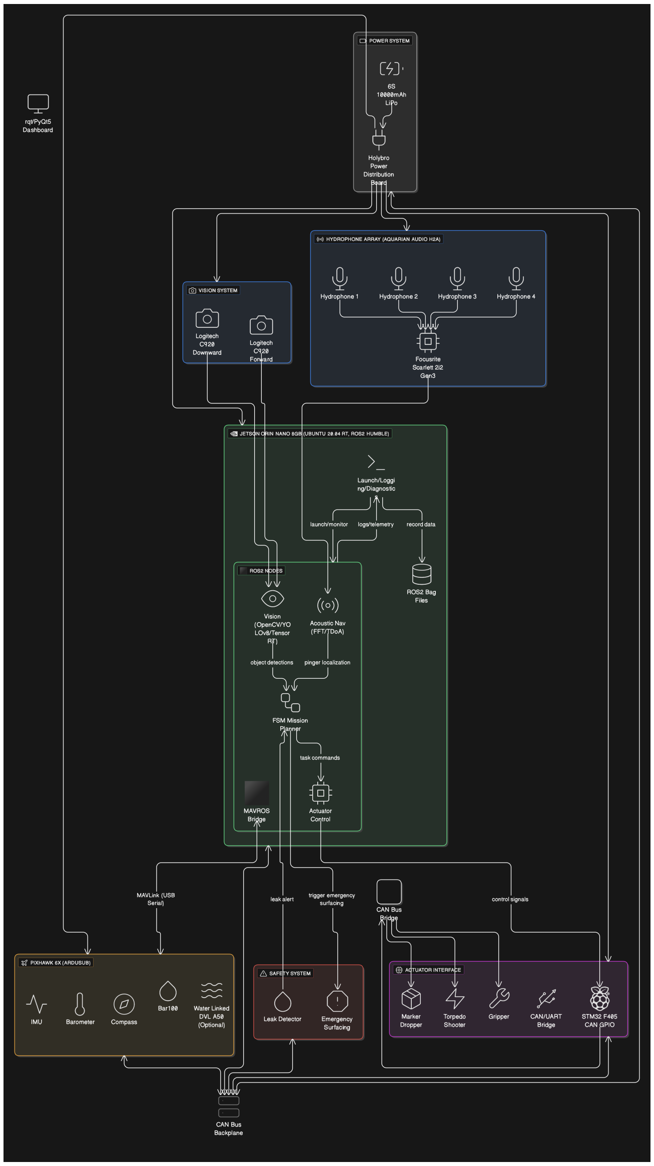


Fig. 3. Mission Planning and Control Flowchart of HydroJan 1.0

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## III. Appendix

## Test Plan and Results

### A. HydroJan Development Versions

The evolution of HydroJan from version 0.1 to 1.0 followed a systematic approach emphasizing testing and iterative improvements. Each version introduced new features and validated critical systems under controlled environments.

- **Version 0.1:** First conceptual prototype. Focused on frame design, buoyancy test using EVA foam and ballast system. Thruster calibration conducted on dry rig. *Outcome:* Frame unstable, buoyancy inconsistent. Lessons: shifted to reinforced aluminum for frame and added ballast tank.

Fig. 4. HydroJan 0.1

- **Version 0.2:** Introduced basic electronics integration—Pixhawk + ESC + 4 thrusters.

Conducted first waterproofing trials. *Outcome:* Waterproof casing partially failed; ESC heating noted. Lessons: Improved sealing and added cooling protocols.

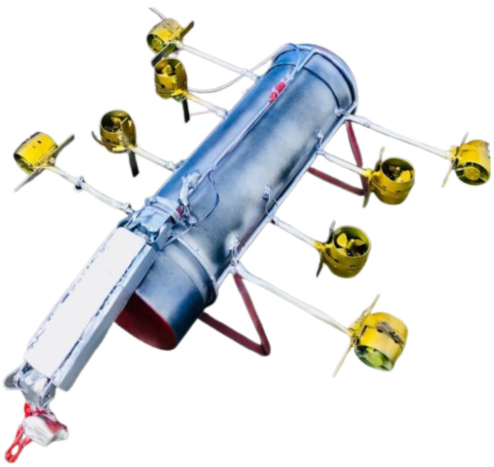

Fig. 5. HydroJan 0.2

- **Version 0.3:** Implemented Jetson Orin Nano and YOLO vision pipeline. Simulation environments created in Unity. *Outcome:* Vision reliable in simulation; latency issues in real hardware. Fix: Optimized vision scripts using TensorRT.

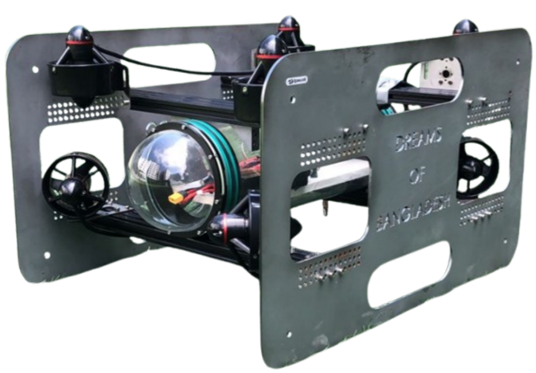

Fig. 6. HydroJan 0.3

- **Version 1.0:** Full integration of all systems—thrusters, ballast, vision, manipulator, FSM logic in ROS2. Pool tests executed. *Outcome:* Stable operation, marker drop successful, gate traversal complete. Performance meets RoboSub entry-level task completion requirements.

| **Test** | **Component / System** | **Version** | **Result** |
|---|---|---|---|
| Dry Rig Thruster Test | Motor, ESC, Pixhawk | 0.1 | PWM range incomplete. Fixed calibration in 0.2 |
| Waterproof Housing Submersion | Acrylic tube, double O-ring seals | 0.2 | Minor leaks observed. Improved with better sealants. |
| YOLOv5 Detection Accuracy | Jetson Orin Nano | 0.3 | 80–85% accuracy under daylight pool conditions. |
| Buoyancy Reaction Test | Air Pump System | 0.2–1.0 | Response time improved from 3s to 1.2s |
| Marker Drop Test | Servo-based Manipulator Arm | 1.0 | All 3 test drops successful in target zone. |
| System Integration Dry Run | Jetson, Pixhawk, ROS2 FSM | 1.0 | Fully autonomous behavior confirmed. Stable runtime. |

TABLE I
SUMMARY OF TESTS CONDUCTED ACROSS VERSIONS

### B. Lessons Learned

- Importance of early waterproof testing – prevented failures in later integration.
- Vision optimization with TensorRT significantly reduced latency and improved FPS.
- Modular architecture allowed faster debug and reconfiguration.
- Safety protocols such as kill switches and power isolation were essential in preventing damage during early full-load testing.