# Istanbul Technical University RoboSub 2025 Technical Design Report

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Abstract—This year, the ITU AUV team adopts a dual-vehicle strategy with Taluy and Taluy Mini to improve task efficiency, mission reliability, and overall scoring. Taluy is engineered for high-complexity missions, featuring a robust mechanical structure, mission-specific actuators, and an AI-powered perception pipeline for advanced decision-making. Taluy Mini serves as a compact, agile support vehicle, enabling redundancy, parallel task execution, and increased operational flexibility. Both vehicles operate in coordination, leveraging precise localization and adaptive control systems to respond effectively to dynamic underwater environments. This integrated approach highlights the team's focus on scalable, resilient, and innovative solutions in autonomous underwater robotics.

## I. Competition Strategy

The team plans to enter the competition with a dual-vehicle strategy featuring vehicle Taluy and Taluy Mini, aiming to optimize performance and maximize scoring opportunities within our current resource and development constraints. Our approach emphasizes reliable execution of high-value tasks while laying a strong foundation for future competitions.

This year, we focus on the following tasks:

- Heading Out - Coin Flip
- Collecting Data - Gate
- Navigate the Channel - Slalom
- Drop a BRUVS - Bin
- Tagging - Torpedoes
- Ocean Cleanup - Octagon
- Return Home

To complete the Heading Out - Coin Flip and Enter the Collecting Data - Gate task, Taluy begins by requesting a coin flip to set its orientation for extra points. It dives to the required depth, then either moves straight to the gate or aligns first based on the coin flip. Object detection guides gate location. Taluy performs two full roll rotations before entering the gate, temporarily disabling DVL input to avoid errors and relying on IMU and pressure sensors to track the 720° rotation. After rotation completion, torque stops, DVL resumes, localization resets to reduce drift, and Taluy proceeds smoothly through the gate.

Taluy Mini follows the same logic and execution sequence as Taluy for the Heading Out – Coin Flip and Collecting Data – Gate tasks. After successfully passing through the gate without performing a roll maneuver, Taluy Mini communicates with Taluy via acoustic communication to confirm mission success.

In the Navigate the Channel - Slalom task, the vehicle autonomously passes through slalom gates using vision and navigation systems. It detects colored pipes with its camera and clusters them into gates using a RANSAC-like algorithm to find straight lines. Potential gates are validated using geometric constraints, such as alignment with the vehicle's y-axis.

Confirmed gates are sorted left to right and checked for the color pattern: white pipe (left), red pipe (middle), white pipe (right). The vehicle calculates a waypoint between the red pipe and one of the white pipes, based on the navigation mode. The waypoints allow for a smooth, efficient navigation path through the slalom course.

For the Drop a BRUVS - Bin task, Taluy uses its forward camera to locate the bin. As it nears the target, both forward and downward cameras refine bin localization. If the downward camera doesn't immediately detect the marker drop zone, Taluy executes a ribbon-shaped search while continuously updating bin position with the forward camera. Once the drop area—selected during the previous task—is confirmed visually, Taluy aligns precisely and uses advanced control algorithms to accurately deploy the marker. If the designated bin side is unclear, Taluy adjusts dynamically to drop the marker on the alternate side, ensuring successful completion and maximum scoring.

The approach for the Mapping - Torpedoes task involves leveraging detection models to remotely identify and precisely localize the torpedo target within the mapped environment. Upon close approach, the vehicle employs point cloud data from the stereo camera to accurately compute the torpedo object's orientation, dynamically updating its reference frame. Utilizing this refined pose estimation, it executes a precise alignment maneuver to the designated hole, ensuring optimal firing trajectory. This integrated perception-to-action pipeline enables high-precision torpedo launches, maximizing task scoring efficiency.

For the Ocean Cleanup (Octagon) task, given our current workload, we have decided not to focus extensively on the manipulation aspect. Instead, we will approach this task primarily as a surfacing mission guided by visual recognition.

Our strategy is as follows: Based on the image of marine animals selected during the Collecting Data (Gate) task, the vehicle will perform a search pattern, rotating around its vertical axis until it detects the corresponding fish image using a [1] YOLO-based object detector. Once the correct image is identified, the vehicle will align its heading toward the image and surface within the octagon. This approach is designed to ensure we score points for surfacing in the octagon and facing the correct image, with minimal system complexity and reduced task overhead.

For the Return Home task, we leverage the communication system between the two vehicle units. Taluy Mini will remain stationary at the gate exit while Taluy proceeds to complete the subsequent tasks. Upon surfacing for the final task, Taluy sends a signal prompting Taluy Mini to initiate the Return Home sequence, that is, to navigate back through the gate. This strategy is adopted to address the difficulty of return navigation for Taluy, which will be positioned far from the gate and potentially obstructed by other props.

## II. Design Creativity

### A. Mechanical

This year, the ITU AUV team developed and deployed two distinct vehicles: Taluy and Taluy Mini. Taluy, our main vehicle from last year, features a robust mechanical architecture with an aluminum chassis, modular mission equipment mounts, and structural elements optimized for weight balance and rigidity. The chassis combines press-brake-formed aluminum and stainless-steel reinforcements to ensure strength under load, while the HDPE and aluminum plates provide durability and corrosion resistance. Thruster mounts are arranged to enable full 6-DOF motion and simplify maintenance. Internally, the layout supports high-power components and preserves buoyancy symmetry, allowing Taluy to perform demanding maneuvers such as roll rotations and torpedo launches.

Fig. 1: Taluy

Taluy Mini, developed to complement Taluy, is built on a lightweight carbon fiber frame that ensures mechanical simplicity while maintaining structural integrity. Its compact design allows for agile movement and rapid deployment, making it ideal for support roles and parallel task execution. Both vehicles reflect our focus on modularity, reliability, and mission-oriented mechanical design.

Fig. 2: Taluy Mini

1) Mission Tools:

Marker Dropper: To improve drop stability during underwater deployment, the marker was redesigned with a conical body and a hemispherical base. This shape encourages a vertical descent profile, reducing the risk of tumbling. A metal ball embedded in the lower section shifts the center of gravity downward, effectively minimizing lateral deviation. In parallel, the marker dropper system was refined to accommodate the new design. A servo-driven release mechanism was integrated to ensure reliable retention and consistent release performance across mission cycles.

Fig. 3: Marker Dropper

Fig. 4: Marker

Torpedo Launcher: The torpedo system features a spring-loaded dual-barrel design with vertically stacked launch tubes. Each torpedo is held by a magnetic lock, which releases upon command to trigger the spring-powered launch. This compact and reliable mechanism enables independent firing of two torpedoes with minimal mechanical complexity.

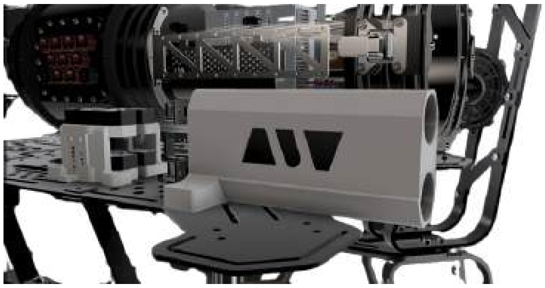

Fig. 5: Torpedo Launcher

Gripper: To overcome the limitations of last year's servo-actuated dual-claw gripper, a new mechanism was developed featuring a rail-guided sliding claw system. A servo motor winds a string to pull one comb-shaped claw toward a fixed one, enabling secure grasping of complex props like spoons and cups. Return springs ensure consistent reopening, while the linear motion provides more stable and adaptive gripping compared to previous designs. This setup improves compatibility with irregular geometries, simplifies underwater actuation, and offers modularity for quick adjustments. Tests with actual task props confirmed the system's effectiveness and reliability.

Fig. 6: Gripper

## B. Electrical

Electrical systems of the vehicle consist of power delivery & distribution, low-level data processing and Input Output (IO) operations. To achieve such features few printed circuit boards are designed by the electrical subteam members and utilized across the vehicle.

a) Power System: The primary power source of the vehicle is a 14.8V lithium-ion battery system. Initially designed as a custom 4S9P 18650 pack, it was replaced with two commercially available 8.5 Ah LiPo batteries due to time and transportation constraints.

The first vehicle consumes about 350W on average, providing roughly 35 minutes of operation, while the second vehicle consumes around 300W, powered by a 14.8V four-cell lithium-ion system. Both setups ensure sufficient runtime for competition tasks, with a backup battery available for the first vehicle.

b) Propulsion System: The propulsion system is controlled by a custom PCB featuring an STM32F4 microcontroller and eight ground-isolated ESCs directly soldered onto the board, with each thruster monitored by dedicated power sensors to enable accurate thrust estimation for precise control and performance analysis. To minimize electromagnetic interference with sensitive navigation components such as the magnetometer and IMU, the brushless DC motors and board are housed in

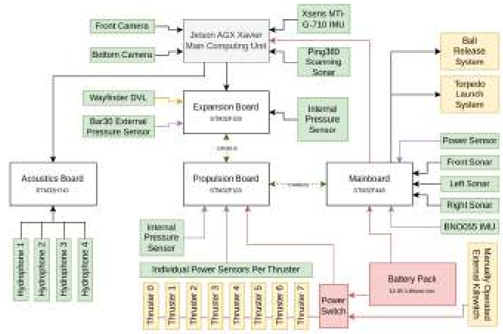


Fig. 7: Taluy System Integration Design

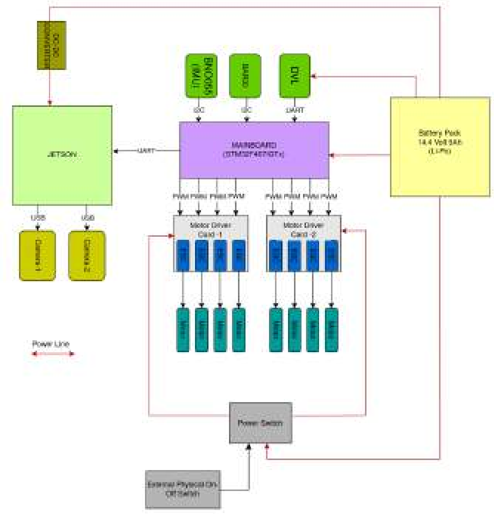


Fig. 8: Taluy Mini Integration Design

| Component | Average Power | Observed Peak Power |
|---|---|---|
| 8 Thrusters | 270W | 1250W |
| Jetson AGX Xavier | 30W | 65W |
| Wayfinder DVL | 3W | 10W |
| Active Sonars | 10W | 15W |
| Sensors & Cameras | 10W | 15W |
| Total: | 323W | 1355W |

TABLE I: Taluy Power Budget

| Component | Average Power | Observed Peak Power |
|---|---|---|
| 8 Thrusters | 270W | 1250W |
| NavQuest600 Micro DVL | 5W | 85W |
| Jetson Orin Nano | 15W | 25W |
| Sensors & Cameras | 10W | 15W |
| Total: | 300W | 1375W |

TABLE II: Taluy Mini Power Budget

an external enclosure.

For safety, the system includes an externally accessible kill switch that directly cuts power to all thrusters in case of emergencies. Its status is monitored by the microcontroller and communicated to the main control software via the CAN bus protocol, ensuring reliable and robust operation.

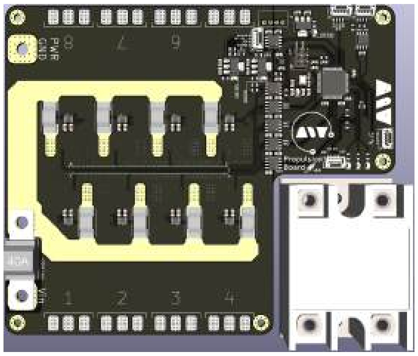

Fig. 9: Propulsion System Board 3D View

c) Sensor and System Integration: Both vehicles use their mainboards to interface with sensors, control actuators, and manage power distribution. The first vehicle provides regulated 12V and 5V outputs for the torpedo firing system and ball dropping mechanism. The second vehicle steps down its 16.6V LiPo battery to 5V and 3.3V using onboard linear and switching regulators to power sensors and 4in1 ESCs. These systems enable precise actuator control for tasks such as Drop a BRUV - Bin, Tagging - Torpedoes, and Ocean Cleanup - Octagon.

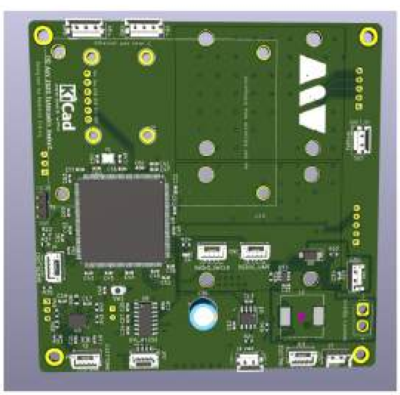

Fig. 10: Taluy Mini Mainboard

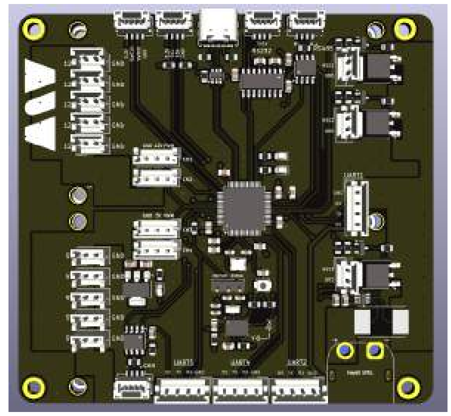

Fig. 11: Taluy Mainboard 3D View

For internal communication, the first vehicle uses the CAN bus protocol to enable synchronized data exchange between its electronic boards. Although the Jetson module includes CAN TX and RX pins, it lacks integrated CAN transceivers needed to drive the CAN-H and CAN-L lines. To address this, a custom-designed expansion board was developed. This board is capable of converting Jetson's CAN signals to differential CAN signals and translates incoming CAN messages into rosserial over UART.

In contrast, the second vehicle features a more compact communication setup. Given the physical proximity of the Jetson and the mainboard, a direct UART-based rosserial connection was chosen to provide a low-latency and robust link for both control and sensor data exchange.

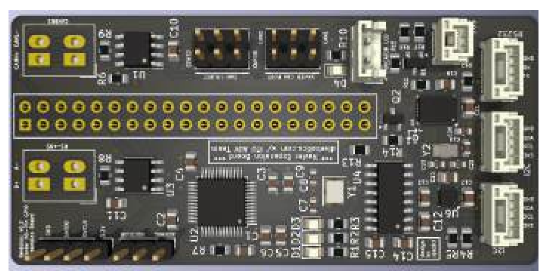

Fig. 12: Expansion Board 3D View (Rotated)

d) Acoustic Signal Processing Board: In our first vehicle, Taluy, an acoustic signal processing board was developed to detect the pinger's direction using Time Difference of Arrival (TDoA) between four hydrophones. The design consists of a central STM32H7 microcontroller unit and four peripheral boards for hydrophone connections and analog filtering. This setup enables precise directional localization, directly supporting the Acoustic Pinger Localization task.

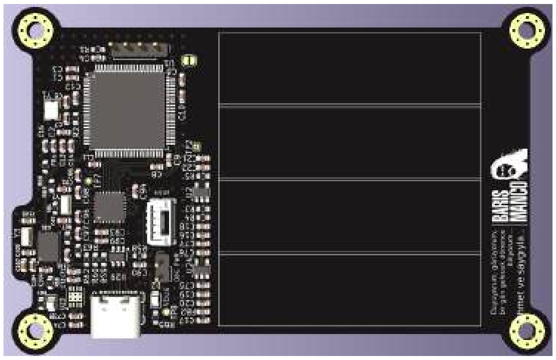

Fig. 13: Acoustic Signal Processing Board 3D View

In addition to the hydrophone board, Taluy and Taluy Mini are also equipped with a fully custom-designed acoustic modem developed by our team to enable underwater communication between vehicles for Inter Vehicle Communication task. The modem operates at 65 kHz and uses a piezoelectric ceramic transducer with both transmit (TX) and receive (RX) capabilities. To drive the transducer, a high-frequency H-bridge circuit was designed to generate pulse signals suitable for piezoelectric operation. The same line is used to receive acoustic signals, enabling bidirectional communication.

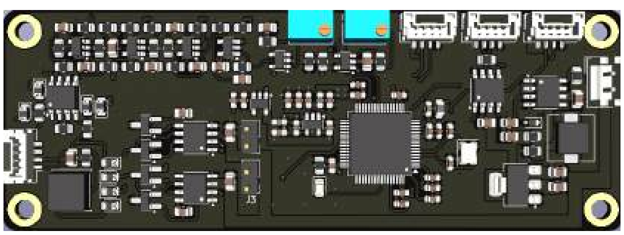

Fig. 14: AUV Modem Board 3D View

### C. Software

Taluy and Taluy Mini operate on a unified software framework with distinct robot descriptions and configuration files adapted to their unique features and mission requirements. Although they share similar sensor suites, their task-specific software is optimized for their respective operational roles. Continuous inter-vehicle communication facilitates real-time coordination and collaborative task execution, enhancing overall mission effectiveness.

*a) Control & Navigation:* The control and navigation system of the vehicle ensures stability and precise maneuvering using a PID controller paired with an accurate vehicle model. It integrates sensor data from the DVL, IMU and Bar30 pressure sensor to achieve precise control.

The team's main goals are vehicle stability and effective mapping. To achieve this, adaptive control adjusts dynamic parameters, and sensor fusion is performed using an Extended Kalman Filter (EKF)[2] that integrates data from the DVL, IMU, and pressure sensor. This year, the EKF was implemented via the ROS[3] robot localization package, enhancing state estimation accuracy and simplifying debugging.

*b) State Machine:* The mission is managed by state machines-finite behavior models that transition between states based on current conditions and input data. Each task has a dedicated state machine designed to execute quickly and make accurate decisions when facing challenges. During competition, these state machines allow the vehicle to perform tasks efficiently and adapt to unexpected situations, ensuring reliable and precise operation.

*c) Computer Vision:* This year, the vision system is enhanced using YOLOv11[1], trained on a combined dataset of Blender-generated synthetic images and manually labeled real pool test images. A stereo camera provides depth data to determine object positions and orientations precisely. Together, these enable the robot to generate accurate transform frames for detected objects. Additionally, a bottom-facing camera helps estimate positions of the competition props.

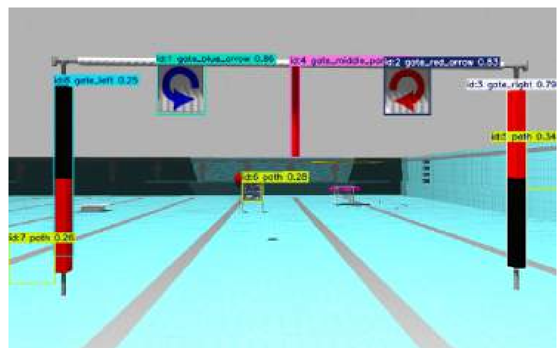

Fig. 15: Detection Image

## III. Experimental Results

- A custom-designed thruster was developed for Taluy Mini, featuring a team-designed ducted propeller and motor housing. The integrated design optimizes thrust efficiency and structural compactness, ensuring reliable performance in a lightweight form factor. This tailor-made solution enabled precise control while reducing dependency on commercial components.
- The estimation of underwater pose uses stereo camera point clouds corrected for refractive distortions via underwater optical models to produce consistent 3D data. Real-time DVL altitude and Bar30 pressure sensor measurements set depth bounds to remove points from the surface or seabed.
- The team initiated the design and development of an in-house acoustic modem to enhance underwater communication capabilities. The modem was designed to operate in low-bandwidth underwater environments, enabling reliable short-range data transmission. It features an analog front-end with custom filtering

[1] YOLOv11: Real-Time End-to-End Object Detection

circuits, high-resolution ADCs, and a signal processing unit based on the STM32 microcontroller. During underwater testing, the system demonstrated low noise levels and clear signal separation, enabling successful unidirectional communication in prototype form.

[1] YOLO-based detector ROIs constrain and semantically label filtered point clouds, creating a compact, noise-reduced representation that supports robust six-degree-of-freedom pose computation against known object geometries.

- For monocular camera pose estimation, we adopt NVIDIA's DOPE (Deep Object Pose Estimation) framework to estimate object orientations directly from single images. A comprehensive dataset of synthetic renderings—generated in BlenderProc by placing detailed 3D models of the competition props under varied lighting, background, and viewpoint conditions—serves to train and validate the network. This synthetic-to-real approach ensures generalization to challenging underwater scenes, enabling accurate, marker-less estimation of each object's 6D pose in the operational environment.

## Acknowledgment

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## References

[1] R. Khanam and M. Hussain, Yolov11: An overview of the key architectural enhancements, 2024. arXiv: 2410.17725 [cs.CV]. [Online]. Available: https://arxiv.org/abs/2410.17725.

[2] S. J. Julier and J. K. Uhlmann, "A new extension of the kalman filter to nonlinear systems," Proceedings of Signal Processing, Sensor Fusion, and Target Recognition VI, vol. 3068, pp. 182–193, 1997.

[3] M. Quigley, K. Conley, B. P. Gerkey, et al., "ROS: An open-source robot operating system," in Workshops at the IEEE International Conference on Robotics and Automation, 2009.

TABLE III: Component Specifications

| Component | Vendor | Model/Type | Specs | Custom/Purchased | Cost |
|---|---|---|---|---|---|
| ASV Hull Form/Platform | ITU AUV | Custom designed center hull | Acrylic tubes | Custom | $180 |
| Waterproof Connectors | BlueRobotics | Wetlink Penetrator | link | Purchased | $250 |
| Propulsion | BlueRobotics | T200 | link | Purchased | $1600 |
| Motor Controls | BlueRobotics | Basic ESC | link | Purchased | $38 ea |
| CPU | Nvidia | Jetson AGX Xavier | link | Purchased | $950 |
| External Comm Interface | BlueRobotics | Fathom-X Tether Interface Board | link | Purchased | $250 |
| Compass | Xsens | MTi-G-710 | link | Purchased | Legacy |
| Inertial Measurement Unit | Bosch Sensortech | BNO055 | link | Purchased | $15 |
| CDoppler Velocity Logger | Teledyne | Wayfinder DVL | link | Purchased | Legacy |
| 360 Sonar | BlueRobotics | Ping 360 | link | Purchased | $2650 |
| 1D Sonar | BlueRobotics | Ping Sonar | link | Purchased | $410 ea |
| Gripper Servo | Rovmaker | 40KG Micro Servo | link | Purchased | $150 |
| Camera(s) | Logitech | C922 Pro | link | Purchased | $100 |
| Hydrophones | Aquarian Audio | H2C Hydrophones | link | Purchased | $600 |
| Vision | Ultralytics | YOLOv11 | link | Custom | |
| Localization and Mapping | OpenRobotics(OSRF) | robot-localization | link | Custom | |
| Autonomy | OpenRobotics(OSRF) | ros-smach | link | Custom | |
| Open-Source Software | ITU AUV TEAM | Vehicles' software repository | link | Custom | |

## Appendix B: Outreach Activities

Throughout the year, the ITU AUV Team has been involved in outreach activities to build the underwater robotics community in Türkiye and inspire future engineers.

This year, the team organized a nationwide breakfast event, gathering high school and university underwater robotics teams from across Türkiye. During the event, teams shared their project experiences and challenges. This helped them make valuable connections and create a network for collaboration, which is expected to improve underwater robotics development in the country.

Fig. 16: Breakfast Organization

The team also took part in various national fairs and industry expos, including the Bosphorus Boat Show, ExpoMaritt, and Petroleum 2025, where they displayed their AUVs, provided insights about underwater technologies, and expanded their professional network through conversations with leading companies and experts.

Fig. 17: Petroleum 2025 Fair

Furthermore, team members delivered presentations at various conferences and university events, sharing their technical journey and design innovations. This year, the team was honored to receive an award from the university Rector, recognizing their achievements and contributions to underwater robotics.

Through these activities, the ITU AUV Team demonstrated its commitment to knowledge sharing, innovation, and inspiring the next generation of engineers.

Fig. 18: Award Received From ITU Rector

In addition to this event, the team continued its mentorship programs with Cağaloğlu Anatolian High School, Beşiktaş Anatolian High School and Adana Science High School. The mentorship sessions focused on the basics of underwater robotics, design principles, and competition preparation. These efforts aimed to motivate students to consider careers in STEM fields.

Through these outreach activities, the ITU AUV Team has shown its dedication to sharing knowledge, continuous learning, and inspiring the next generation of engineers to explore underwater technology and innovation.