RoboSub 2026 Technical Design Report

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***Abstract*—For RoboSub 2026, the ITU AUV Team pursued a dual-vehicle strategy with Taluy and Taluy Mini, targeting all major tasks including Octagon collection, which could not be attempted in previous seasons. Taluy was equipped with a new parallel gripper and a revised hydrophone array for improved pinger localization, while Taluy Mini received new mission mechanisms — a marker dropper, torpedo system, and bottom-facing camera — significantly expanding its task coverage beyond Gate and Slalom. All developments were validated through rigorous bench, simulation, and pool testing.**

I. Competition Strategy

A. Core Strategy

In the previous season, limited integration time and schedule pressure forced our team to skip several tasks. For RoboSub 2026, our goal is simple: attempt every major task while maintaining high accuracy and reliability. To support this, both vehicles received multiple design changes and optimizations.

Taluy Mini's operational capability was extended so it can perform Gate, Slalom, Torpedo, and Bin tasks, giving the team a more flexible dual-vehicle strategy. Taluy Mini now has access to an DVL and better sensor hardware, which improves control stability during navigation-heavy tasks. Its new enclosed camera system is designed to increase perception reliability and task accuracy, especially for Slalom and Bin.

In the previous season, we could not attempt the Octagon Collection task with Taluy, but the new gripper gives us a practical path to include it as a solid objective.

These upgrades allow Taluy and Taluy Mini to share mission responsibility while reducing the risk of depending on a single vehicle.

We also improved our testing strategy with more structured bench, simulation, and pool tests. This allows each new capability to be validated with repeatable procedures and clear performance criteria before being added to the full mission.

1) Gate: Both vehicles are capable of completing the gate task, but Taluy Mini does it with some extra "style". Because of the new and heavier skid integration on Taluy, the roll-based motion is assigned to Taluy Mini, whose smaller form factor gives it better agility for this maneuver.

2) Slalom: Both vehicles are designed to complete the slalom task, since slalom is not only a scoring element but also a common obstacle during navigation across the competition field. For this reason, we wanted both vehicles to have reliable slalom capability so that mission execution remains flexible if the course layout requires it.

3) Torpedo: Both vehicles are equipped to attempt the torpedo task, but Taluy is currently the primary vehicle for this objective because it provides higher accuracy and better stability during alignment and firing. However, this strategy may still change depending on the final layout of the competition props, especially the relative position of the slalom and torpedo elements.

4) Bin: Both Taluy and Taluy Mini are equipped with marker droppers, and we plan to use both vehicles for the bin task when needed to improve overall mission flexibility and scoring reliability. Since Taluy experienced accuracy issues in both torpedo and bin tasks last year, extending this capability to Taluy Mini gives us a practical fallback option and reduces dependence on a single vehicle.

5) Octagon: Taluy is equipped with a parallel gripper, which enables it to attempt the Octagon collection task. Taluy also has access to a hydrophone array, allowing it to localize the random pinger and improve the likelihood of achieving full points on this task.

B. Dual Vehicle Strategy

Two-way acoustic communication is a central part of our dual-vehicle strategy. Both vehicles are designed to share task status and mission outcome information so that one vehicle can adapt its plan based on the progress of the other. This is especially important for the Bin task, where Taluy Mini may be deployed as a follow-up vehicle if Taluy reports an unsuccessful attempt. Last year, Taluy Mini demonstrated reliable Gate and Slalom performance; this year, we are extending its mission role so that it can also attempt Bin or Torpedo when needed.

1) Taluy

Taluy is our flagship vehicle, with its main strengths in pinger localization and underwater manipulation. For this reason, Taluy is our primary platform for the Torpedo and Octagon tasks, where precise sensing, alignment, and actuation are most critical. Depending on the final field layout and scoring opportunities, Taluy may also be assigned to Slalom and Bin when this offers a better strategic return.

Fig. 1. Taluy.

2) Taluy Mini

Taluy Mini is significantly smaller and has lower inertia compared to Taluy, which makes it easier to maneuver in movement-heavy tasks. This makes it particularly suitable for Gate-style execution, Slalom, and Bin, where agility and fast response are important. In our overall strategy, Taluy Mini complements Taluy by covering tasks that benefit from compact size while also serving as a reliable backup vehicle.

Fig. 2. Taluy Mini.

C. Risk and Experience from the Last Two Competitions

In last two years, we faced challenges in navigation and overall course interpretation and understanding. We also observed accuracy issues on Taluy during the Torpedo and Bin tasks. This year, we introduced major changes to improve mission performance and achieve more reliable results.

Taluy Mini also lacked some critical sensor components and suffered from power-related issues in the previous season. For this competition cycle, we focused on resolving those limitations and adding the necessary competition actuators to restore Taluy Mini as a fully capable vehicle. These changes were made specifically to reduce the risks observed last years.

II. Design Strategy

A. Mechanical

Our mechanical design strategy for Taluy this year focused heavily on resolving the operational bottlenecks and integration challenges experienced during previous seasons. By overhauling our mounting interfaces and optimizing task-specific actuators, we achieved significant improvements in both maintainability and mission reliability.

1) Skid Integration

During the previous year, integrating new components into Taluy proved to be an operational challenge due to the asymmetric mounting holes on the chassis, which severely restricted modularity. To resolve this, we transitioned to a unified skid system mounted beneath the vehicle. This new skid architecture features a uniform grid of mounting holes, allowing the underbelly to be compartmentalized seamlessly. Practically, this eliminates the integration bottlenecks of the past, making the vehicle highly functional and significantly reducing the time required for payload swaps and maintenance between deployments.

Fig. 3. New Skid integration.

2) Gripper

To address the limitations of our previous grabber designs, which struggled with larger props, we engineered a new servo-driven parallel gripper. Utilizing a rack and pinion mechanism with dual racks, this iteration provides a substantially wider opening angle, making it highly suitable for the diverse and wide geometries of this year's competition objects. Built using carbon fiber rods, the structure offers a high strength-to-weight ratio. Compared to last year's setup, this design dramatically simplifies assembly and in-field maintenance while ensuring consistent, parallel contact with targets.

Fig. 4. Gripper.

3) Torpedo Iteration and Launcher

Our torpedo system underwent rigorous aerodynamic and mechanical iterations to maximize range and stability. We adopted a NACA 66-012 hydrodynamic profile [1], [2], which shifts the center of pressure rearward for passive self-correction. Furthermore, we implemented an X-tail fin configuration to maximize fin span within strict dimensional constraints, ensuring that the fins operate in undisturbed water flow. We increased the torpedo length to 145 mm, optimizing the length-to-diameter ratio and increasing the mass to better retain momentum and travel further. The launcher mechanism was also redesigned to complement this improved projectile. We integrated PTFE tubes inside the barrel to minimize friction and prevent jamming. To resolve previous assembly difficulties, the camera mount was separated from the barrel, and the locking shaft was modified to remain inside the barrel, significantly simplifying removal. Finally, we upgraded the retention magnets to M8 to securely hold the torpedoes during aggressive vehicle maneuvers.

Fig. 5. Torpedo Assembly.

Detailed design iterations of the torpedo projectile across all versions are provided in Appendix H.

4) New Dropper Design

Building upon the need for a predictable descent, we developed a teardrop-shaped marker to ensure a straight trajectory through the water column. To guarantee stability, a metal ball is embedded at the bottom of the marker, effectively lowering the center of gravity below the center of buoyancy. The dropping mechanism utilizes a single servo to actuate two rigidly suspended markers. This system sequentially releases the markers by rotating to predefined angles. The rigid suspension completely eliminates the risk of premature drops, effectively reducing failure modes during the mission.

Fig. 6. Marker dropper assembly.

5) Taluy Mini Mechanical Updates

- **Tube Fixation:** The absence of a middle flange makes maintenance and internal access easier compared to Taluy. An additional internal tube fixation component was required to compensate for this structural change. The manually calibrated magnetic system from the previous year lacked sufficient precision. It was replaced with a more rigid and reliable cotter pin and rod assembly.
- **Modular Shaft Mounting:** The external frame adopts a two-piece shaft mounting system. Both pieces together provide maximum rigidity; alternatively, the secondary piece can be swapped for specialized applications. For example, extended secondary mounts serve as standoffs during shallow pool tests to protect the DVL from bottom contact.
- **Thruster Mounts:** Legacy 3D printed thruster mounts were upgraded to machined aluminum, improving structural rigidity without compromising the vehicle's lightweight profile.
- **Bottom-Facing Camera:** In alignment with the expanded dual-vehicle strategy, Taluy Mini is now equipped with a bottom-facing camera to actively participate in the Bin task, which were previously excluded from its mission scope.
- **Marker Dropper and Torpedo Actuation:** Integration of the marker dropper and torpedo actuation mechanisms is ongoing, as the compact chassis of Taluy Mini demands more careful design iteration.
- **Dome Replacement:** During high-pressure tests, structural deformations were observed in the dome components, posing a risk to long-term sealing reliability. A new dome certified for depths up to 1000 m was adopted and a custom adapter was manufactured to ensure compatibility with the existing vehicle structure; full details are provided in Appendix I.

B. Electrical and Acoustics

For Taluy and Taluy Mini, we built the electrical and acoustics architecture around a modular and testable system approach. We handle high-level processing on the Jetson, while our custom control boards manage low-level sensing, actuation, and power-control tasks. This year, we focused on improving dry-test readiness, adapting board integrations to both vehicles, strengthening CAN-based communication [3] and firmware update/debugging infrastructure, and validating the acoustic communication and pinger localization subsystems. The detailed electrical architecture is provided in Appendix J.

1) Bench Setup for Dry Test

We developed a dry-test bench to verify the vehicle electronics without using the full vehicle hull. The bench reproduces the internal electrical system with control boards, ESCs, motors, regulators, power lines, sensor connections, and cabling close to the real vehicle layout. This allows us to test communication, power distribution, sensor readings, motor driving, and actuator control before pool deployment. We compare power-supply readings with onboard sensor measurements, and inspect power lines, signal lines, and CAN traffic using an oscilloscope, logic analyzer, and the Jetson Linux SocketCAN interface [4], [5]. This setup has allowed us to test firmware revisions and reproduce vehicle-side issues on real boards in a safer and more accessible environment.

2) Mainboard Iteration for Both Vehicles

Taluy and Taluy Mini share the same electronic architecture philosophy, which we adapt to their different physical constraints. This year, we tested a new Taluy mainboard revision with integrated regulators to save space inside the pressure tube, but it did not meet the required reliability, so we kept using the verified existing mainboard. Instead, we integrated this years additions through the existing board: gripper control through timer outputs, power for the torpedo camera, Ethernet switch, and hydrophone board, and support for the new Ethernet tether structure after removing Fathom. Taluys propulsion system remains in a separate ESC box with optocoupler-based isolation; even when the killswitch cuts motor power, the MCU side stays powered and can report the killswitch state. For Taluy Mini, we use a compact layout with two 4-in-1 ESCs connected to the mainboard and vehicle-specific voltage outputs such as the DVL supply. During actuator tests, we observed that gripper stress caused high current draw, disturbed the power line, and affected pressure sensor data flow, so we limited the gripper range in software for safer operation.

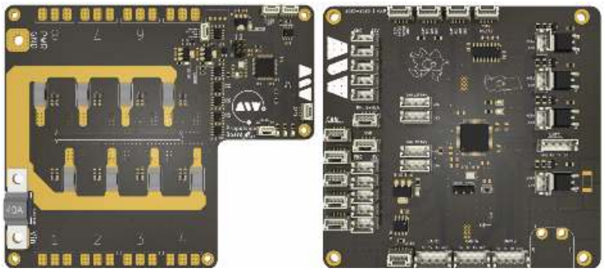

Fig. 7. Taluy Mainboard and Propulsion Board.

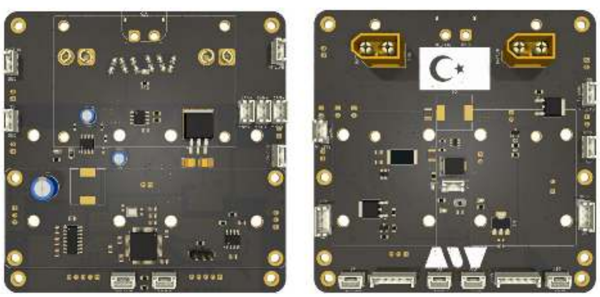

Fig. 8. Taluy Mini Mainboard.

3) Expansion Board Iterations

We simplified the expansion board to separate low-level embedded control from high-level ROS communication. In the previous design, the onboard microcontroller converted CAN messages into ROS messages and sent them to the Jetson over rosserial, which made updates harder. In the new design, we moved ROS conversion to the Jetson-side hardware interface and turned the expansion board into a simpler CAN transceiver interface that connects the Jetson directly to the CAN bus. On Taluy, the board also provides a level-shifted UART [6] interface for the DVL; on Taluy Mini, we adapted the layout to the different Jetson pinout and removed the DVL UART section. This change reduced the need to access a hard-to-reach internal board, accelerated interface updates, and was verified before vehicle integration.

Fig. 9. Expansion Boards.

4) Vehicle Communication and Firmware Updates

Although some components use UART [6], I2C, or Ethernet, we use CAN bus [3] as the main communication backbone between the control boards because it supports our modular multi-board architecture. To improve debugging, we developed repository helper scripts compatible with Linux CAN tools: candump outputs can be decoded using the vehicle CAN ID/payload structure, and cansend can transmit readable system-defined messages instead of raw frames. This made CAN traffic and firmware-update state transitions easier to observe during custom CAN bootloader testing. Firmware can now be updated over CAN through the Jetson without physical board access. On the embedded side, we moved CAN message handling to a queue-based structure to better support the repository architecture, nested interrupt cases, and message-triggered actions.

5) Inter-Vehicle Communication Acoustic Modem

The Acoustic Modem Board enables bidirectional underwater communication between Taluy and Taluy Mini by converting CAN messages into acoustic signals and received acoustic signals back into CAN messages. During development, we characterized piezo behavior in the 55–65 kHz range and updated the software transmission/reception settings according to the measured response. We verified the 8th-order, 4-stage band-pass filter and insulated and potted the piezos for underwater use. Since ASK modulation caused bit overlap under pool reflections, we updated the system to FSK [7], allowing data to be separated more reliably using frequency and timing information. After subcomponent tests, we tested the modem boards with software in an Olympic pool and verified bidirectional data flow between Taluy and Taluy Mini.

6) Hydrophone Array and Tests

The Pinger Localization Board allows Taluy to estimate the direction of an acoustic pinger using four Aquarian H2C hydrophones arranged in a rectangular geometry. This year, we revised the analog front-end by replacing high-noise op-amps with low-noise op-amps, which enabled cleaner channel comparison and moved the system from simple pinger detection toward direction estimation. The board uses an 8th-order, 4-stage band-pass filter, and we sample the filtered signals with the STM32H7 [8] ADC at 250 kHz. We detect signal onset times using energy and correlation differences, then estimate direction with TDOA [9], [10] from the arrival-time differences between hydrophones. Instead of sending raw ADC data over CAN, the board transmits processed time-difference and maximum-amplitude values required by the localization algorithm.

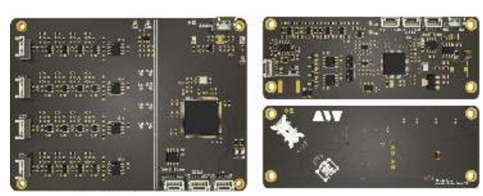

Fig. 10. Pinger Localization and Acoustic Modem Board.

C. Software

Both vehicles use nearly the same overall software architecture, which allows us to reuse perception, localization, control, and mission-planning components across platforms. This shared structure reduces integration effort and makes it easier to validate new capabilities on both vehicles.

The main software additions this year focus on better spatial understanding, more reliable task execution, and stronger motion control. We continue to use selected ROS1 [11] components from the legacy repository while integrating newly adapted and versioned software modules.

This approach allows us to build on proven systems, test new ideas without losing existing capability, and gradually migrate toward a more robust software architecture. The detailed software architecture is provided in Appendix D.

1) Perception

Our perception stack is centered on YOLO-based object detection [12] together with additional deep learning models for more precise spatial understanding. This year, we added new perception methods based on issues observed in previous competition runs, especially in object pose estimation and slalom interpretation. Detailed outputs and supporting results are provided in Appendix E.

a) Monocular Depth Estimation: We use the Depth Anything model [13] to estimate depth from monocular camera images. This helps us infer the relative pose of underwater objects and improves scene understanding during task execution. The output is especially useful when detection alone is not sufficient for accurate interaction with mission elements.

(a) (b)

Fig. 11. Monocular depth estimation pipeline and sample output.

b) Heatmap Usage: We encountered difficulties when mapping slalom positions consistently in a 3D underwater environment. To address this, we developed a heatmap-based representation that collects multiple slalom projections and merges them into a more stable layout estimate. This improves navigation planning for both vehicles by reducing the effect of noisy single-frame detections.

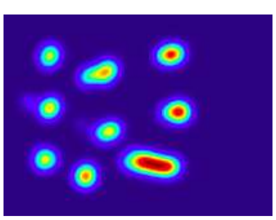

Fig. 12. Heatmap-based slalom layout estimation.

c) YOLO Models: YOLO-based models [12] remain the main detection backbone for mission objects. They provide real-time object detection for competition props and serve as the input layer for downstream pose estimation, task alignment, and mission decisions. The models are updated together with new real and synthetic datasets to improve robustness across different underwater conditions.

d) Synthetic Data Generation System: Our synthetic data pipeline converts UE5-based underwater scenes [14] into fully labeled YOLO detection and segmentation datasets. By using domain randomization, the system produces diverse underwater images without requiring large amounts of pool time, divers, or manual annotation. This allows us to update datasets quickly whenever new task objects or visual conditions must be added. It also helps generate rare edge cases that are difficult to capture in real dives but important for competition reliability.

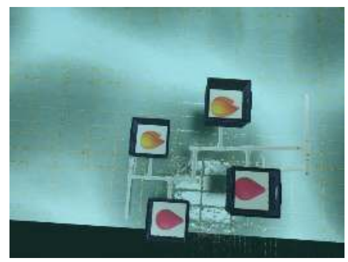

Fig. 13. Synthetic data generation pipeline from UE5-based scenes.

2) Localization

Localization is supported by both sensor feedback and the vehicle dynamic model. We perform sensor fusion using our well established Extended Kalman Filter [15], [16], which integrates measurements from the DVL, IMU, and pressure sensor to estimate vehicle state. This year, we also added model-supported estimation in conditions where direct sensor measurements may become unreliable. The same model is shared with the control system, which keeps the software structure consistent and reduces duplicated estimation logic. Additional localization results are provided in Appendix E.

3) Control

The vehicle control and navigation system uses PID-based feedback [17] together with an identified vehicle model [18] to maintain stability and precise maneuvering. This year, we extended the controller toward full trajectory control by refactoring the cascaded PID structure. The dynamic model is also used as a feed-forward component, allowing the controller to estimate required forces before feedback correction is applied. This reduces the load on the PID terms and improves tracking performance during precise maneuvers. Model parameters, especially hydrodynamic damping terms, are identified through pool testing so that the controller better matches the real vehicle.

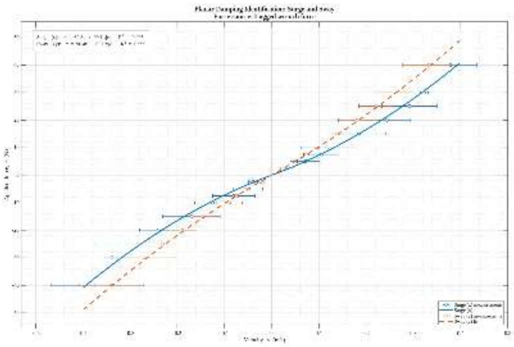

Fig. 14. System Id Results.

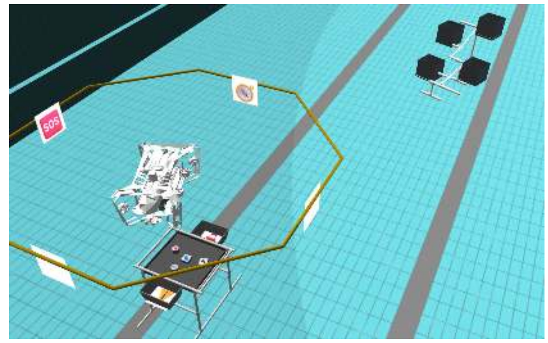

Fig. 15. ROS1-based Gazebo simulation environment with competition elements.

4) Mission Planner

We use SMACH [19] as the main execution framework for mission logic. This year, we expanded the planner with concurrency support and more acoustic-communication-aware task selection. These additions improve mission robustness by allowing the vehicles to react more effectively to task progress, communication updates, and changing mission conditions. As a result, the planner can navigate between tasks more efficiently while maintaining high execution accuracy.

III. Testing Strategy

A. Bench Testing

Bench tests are used to verify the mechanical, electrical, acoustic, and software subsystems in a controlled environment before pool deployment. Mechanical motion range, power stability, communication flow, sensor/actuator responses, acoustic signal/modem data transmission, and firmware behavior after reset or upload are checked. A test is considered successful when the expected behavior is achieved; issues are recorded with measurement data, communication output, test conditions, and observations. After a fix, the same test is repeated to confirm that the subsystem is ready for integration.

B. Simulation and Pool Testing

To support regression testing during our continuing software development process, we make extensive use of our ROS1-based Gazebo [20] simulation environment with competition elements. This simulation setup allows us to validate perception inputs, task logic, navigation behavior, and mission-planner decisions before deploying on hardware. By testing in simulation, we can iterate faster, detect integration errors earlier, and evaluate new software components without consuming limited pool time.

Pool testing is used to validate behaviors that depend on real-world conditions and cannot be fully reproduced in simulation. In particular, we test task interaction with physical props, DVL bottom-lock performance, system identification, model inference quality, and overall software behavior under GPU and CPU resource constraints. These tests help us verify that localization, control, and perception remain reliable in realistic underwater conditions. Sample pool test reports and real-life integration evidence are provided in Appendix F and Appendix G.

IV. Acknowledgements

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Fig. 16. Sponsor and Supporter Visual.

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Appendix A
Outreach and Community Activities

As part of our outreach efforts, the ITU AUV Team organizes activities to promote underwater robotics, engineering, and teamwork among students from different educational levels. We hosted a breakfast event that brought together high school and university underwater robotics teams from across Turkiye, creating an opportunity for networking, knowledge sharing, and community building. We also welcomed primary and middle school students to our workshop, introduced them to our autonomous underwater vehicle, explained our engineering process, and encouraged their interest in science and technology. Beyond these activities, we continuously strive to organize initiatives that contribute to the growth and wider recognition of underwater robotics and marine technologies in Turkiye.

Fig. 17. Community breakfast event uniting underwater robotics teams from different educational levels across Türkiye.

Fig. 18. Primary and middle school students visiting the ITU AUV Team workshop.

APPENDIX B
COMPONENT SPECIFICATIONS (TALUY)

Component	**Vendor**	**Model / Type**	**Specifications**
Buoyancy Control	ITU AUV	Custom	CNC-cut closed-cell foam blocks
Frame	ITU AUV	Custom	CNC-cut and press-brake bent aluminum sheets
Waterproof Housing	ITU AUV	Custom	10 mm acrylic tube, aluminum end caps, NBR O-rings
Waterproof Connectors	Blue Robotics	WetLink Penetrators	Modular, high-pressure resistant
Thrusters	Blue Robotics	T200 (×8)	8 thrusters, x–y plane movement and depth control
Motor Control	ITU AUV	Custom STM32F4	STM32F4-based custom 8× ESC controller board
High Level Control	ITU AUV	Custom	User-supervised autonomy via custom GUI
Actuators	Rovmaker	Underwater Servo	Waterproof servo and linkage systems
Propellers	Blue Robotics	Standard	Paired with T200 thrusters
Battery	Gens	Gens Ace	14.8 V, 8500 mAh
Converter	HOMELYLIFE	Buck-Boost Converter	13.8 V output
Regulator	ITU AUV	Custom	Switching-type regulator
CPU	NVIDIA	Jetson Orin AGX	64 GB
Internal Comm. Network	ITU AUV	CAN Bus	CAN-based communication system
External Comm. Interface	Blue Robotics	Tether	Twisted pair, Ethernet interface
IMU	Xsens	MTi-630	9-axis sensor with built-in fusion
DVL	Teledyne	WayFinder	600 kHz acoustic velocity sensor
Manipulator	ITU AUV	Custom	Servo-driven claw for object grasping and mission tasks
Algorithms	ITU AUV / OSRF	PID, EKF	Sensor fusion localization, feedback control, path planning
Vision	Ultralytics	YOLO (YOLOv26)	Real-time object detection
Acoustics	Aquarian	H2C Hydrophone (×4)	-180 dB re: 1 V/μPa, 10 Hz–100 kHz
Localization & Mapping	OSRF	robot_localization	EKF-based state estimation
Autonomy	OSRF	SMACH	State-based mission execution via ROS SMACH
Open Source Software	ITU AUV	auv-software	—
Inter-Vehicle Comm.	ITU AUV	auv-modem	55–60 kHz acoustic communication
Camera (Front)	Logitech	C920	USB, forward-facing
Camera (bottom)	OmniVision	OV2710	USB, bottom camera
Camera (Torpedo)	-	-	IP camera, torpedo target acquisition
Camera	Intel Realsense	D-435	Stereo camera
Algorithm: Vision	—	OpenCV, DepthAnything	—
Algorithm: Localization	—	Extended Kalman Filter (EKF)	—
Software Framework	—	ROS1, PyTorch	—
Simulation	ITU AUV	auv_sim	—
Programming Languages	—	C++ / Python	—
Pool Test Time	—	—	280 hours (estimated)
Testing: Simulation	—	—	100 hours

Appendix C
Component Specifications (Taluy Mini)

Component	Vendor	Model / Type	Specifications
Frame	ITU AUV	Custom	Carbon-fiber pipe and aluminum reinforcements
Waterproof Housing	ITU AUV	Custom	10 mm acrylic tube, aluminum end caps, NBR O-rings
Waterproof Connectors	Blue Robotics	WetLink Penetrators	Modular, high-pressure resistant
Thrusters	Blue Robotics	T200 ($\times 8$)	8 thrusters, x–y plane movement and depth control
Actuators	Rovmaker	Underwater Servo	Waterproof servo and linkage systems
Propellers	Blue Robotics	Standard	Paired with T200 thrusters
Regulator	ITU AUV	Custom	Switching-type regulator
CPU	NVIDIA	Jetson Orin Nano	67 TOPS
Internal Comm. Network	ITU AUV	CAN Bus	CAN-based communication system
External Comm. Interface	Blue Robotics	Tether	Twisted pair, Ethernet interface
Compass	Bosch Sensortec	BNO055	9-axis sensor with built-in fusion
IMU	VectorNav	VN-100	9-axis sensor with built-in fusion
DVL	NavQuest	NQ 600 Micro DVL	Acoustic velocity sensor
Algorithms	ITU AUV / OSRF	PID, EKF, A*	Sensor fusion localization, feedback control, path planning
Vision	Ultralytics	YOLO (YOLOv26)	Real-time object detection
Localization & Mapping	OSRF	robot_localization	EKF-based state estimation
Autonomy	OSRF	SMACH	State-based mission execution via ROS SMACH
Inter-Vehicle Comm.	ITU AUV	auv-modem	55–60 kHz acoustic communication
Camera (Front)	Luxonis	Oak	A1-lite
Camera (Bottom)	OmniVision	OV2710	USB, bottom-facing, bin task alignment
Algorithm: Vision	—	OpenCV, YOLO11, DepthAnything	—
Algorithm: Localization	—	Extended Kalman Filter (EKF)	—
Software: Autonomy	—	Py Trees	—
Software Framework	—	ROS1, PyTorch	—
Simulation	ITU AUV	auv_sim	—
Programming Languages	—	C++ / Python	—
Pool Test Time	—	—	100 hours (estimated)
Testing: Simulation	—	—	150 hours

Appendix D
Overall Software Architecture

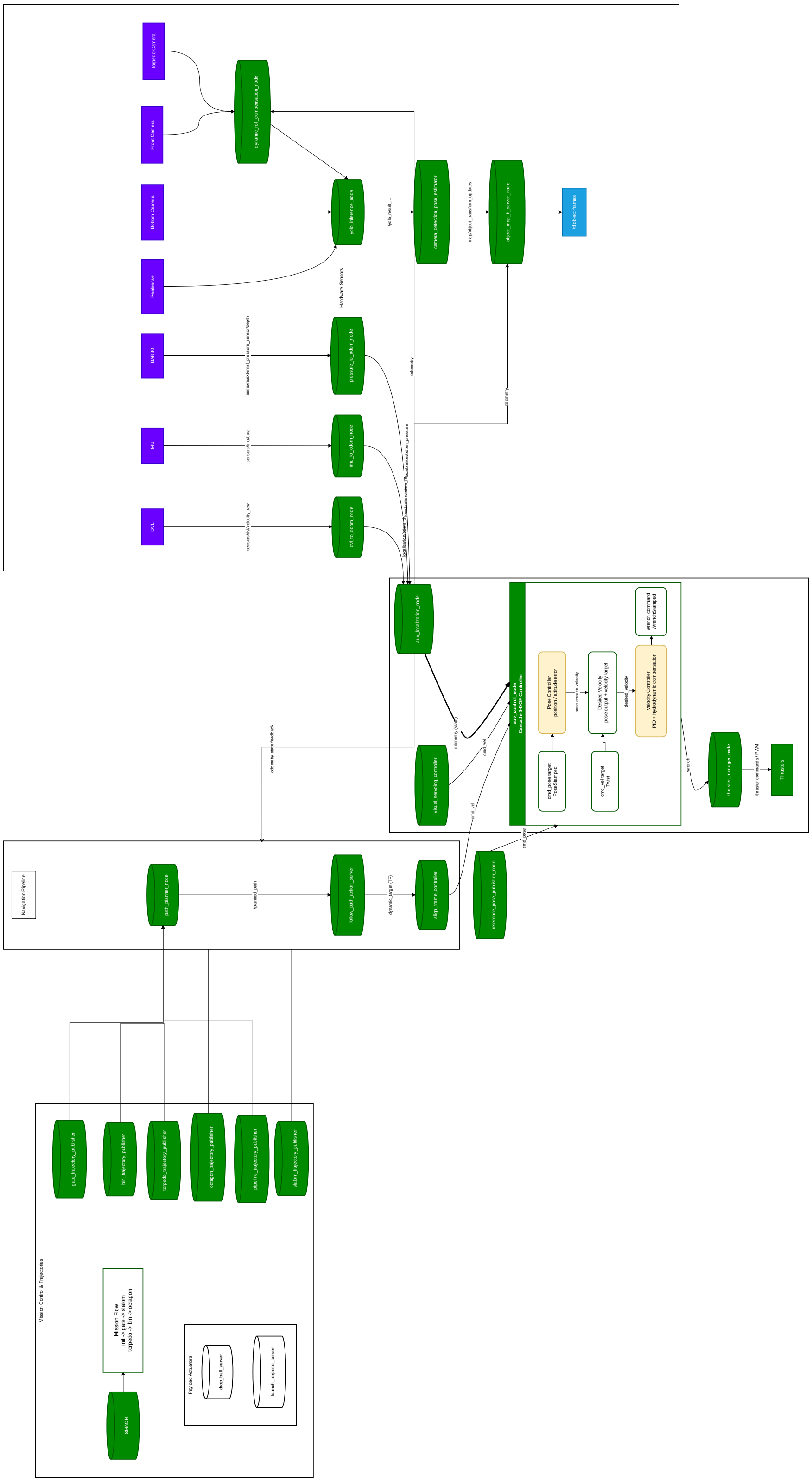
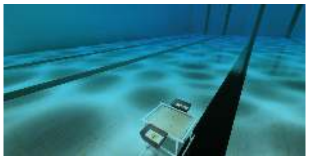
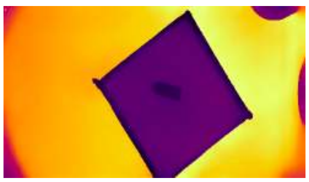
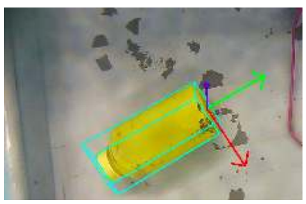


Fig. 19. Overall software architecture graph.

Appendix E
Software Additions and Results

TABLE III
Software additions and validation summary.

Concept	Preview	Validation & Result
Synthetic Dataset Generation		**Method:** UE5 rendering with domain randomization; registry-driven per-class generator merged into a unified multi-class YOLO dataset. **Result:** Adopted. Pixel-exact labels via SceneCapture2D differential mask; eliminates pool time and manual annotation; edge cases generated with a single registry edit.
Dynamic Model	—	**Method:** Pool system identification; Fossen marine dynamics model [18] fitted to commanded inputs and measured velocities. **Result:** Adopted. DVL bottom-lock fallback during low-altitude tasks (Octagon); feed-forward PID term reduces feedback burden and improves tracking in precise maneuvers.
Monocular Depth Estimation (DA3)		**Method:** Depth Anything v3 evaluated on front and bottom camera streams. **Result:** Adopted for applicable scenarios. Provides relative depth cues for object interaction where single-frame geometric detection is insufficient.
Megapose		**Method:** 6-DoF pose estimation trials across competition object classes. **Result:** Abandoned. Erroneous detections in multiple cases; inference latency incompatible with real-time AUV operation.

APPENDIX F
SAMPLE POOL TEST REPORTS

TABLE IV
SAMPLE POOL TEST REPORTS ACROSS TIMELINE.

Date	Tasks Tested	Key Results
3 Dec 2025	• Octagon-Gripper: SMACH integration trial • Bottle detection: bag recording • Torpedo: SMACH structure, external control, mechanism trigger	• SMACH blocked — YOLO failed to stably detect table • Oscillation in turns/alignments (PID); external SMACH OK • Torpedo triggered but underwater launch failed (old torpedoes used) • Teleop freeze on joystick; serial sync lost every $\sim$30 min (Jetson–Expansion contact)
17–18 Dec 2025	• Torpedo camera: new integration + dome repositioning • Front camera calibration (Logitech) • Depth PID optimisation • SW redundancy: Xsense IMU loss scenario	• Torpedo camera: adequate FOV; bag collected for model training • Front cam horizontal FOV 48.3° $\rightarrow$ 55.0° (+13–15%); vertical centre alignment fixed • Depth oscillation fully resolved after PID tuning • Xsense dropout caused erroneous motion — BNO fallback code missing
15 Jan 2026	• IMU comparison: Xsense G710 vs VN100 odometry • 7 full autonomous runs (Gate, Octagon, Bin, Torpedo) • Dynamic model: damping/Coriolis; DVL-free state estimation	• Both IMUs similar after bias cal ($\sim$10–20 cm drift/5 min, $\sim$5° heading) **• 8/9 torpedo shots on target** (9 fired, 8 through hole); Gate $\times$6 (1 leg hit); Bin 2/2 consecutive; Octagon drift at descent when DVL lost; 1 voltage collapse run • Vehicle tracked route well without DVL except at sudden stops
14 May 2026	• End-to-end Slalom + Gate sequences • Octagon: new model + sequential basket alignment test	• Slalom/Gate: TF-map start-line issues resolved; 8/8 final runs passed **• Octagon: 4/4 baskets scored** — object grabbed and dropped into each basket; later run directed to wrong basket after basket 4 • HW failures: gripper broke under stress; killswitch random False $\rightarrow$ SW remap; Bar30 inconsistent after battery swap

Appendix G
Real-Life Integrations and Props

The ITU AUV Team conducts in-water testing at covered and open swimming pools available through institutional and municipal agreements. Logistics include replicas of competition elements built by the our team, power apparatus, battery supplies, and network equipment for tethered monitoring and on-site software deployment.

Fig. 20. ITU indoor swimming pool.

Fig. 21. Open pool test logistics.

Before each session, the team aligns testing goals and completes preliminary bench checks. Pool conditions and active component configurations are recorded for reproducibility. Sessions span a full day with electrical members on standby for battery replacements.

Fig. 22. Gate element during pool testing.

Beyond individual software validation, pool tests reveal blind spots that only emerge in full in-water deployments. Some example findings that shaped the team's strategy:

- **Bin marker dropper accuracy:** Markers were not descending vertically, missing the elevated bin target. This motivated the teardrop-shaped marker redesign with an embedded metal ball, lowering the CoG below CoB for a stable vertical descent.
- **IMU drift in long-duration runs:** Cumulative heading and position drift caused localization failures across multi-task missions, motivating a new object-based mapping system for position anchoring via re-observation of known competition elements.
- **Resource constraints on computing units:** Running YOLO, monocular depth, and heatmap processing concurrently caused GPU/CPU overload and pipeline latency, motivating selective model activation per mission state and profiling-driven stack optimization.

To ensure safety, risks are communicated before each session. A standby member monitors battery voltage, internal pressure, and thruster health, and is ready to activate the kill switch if needed.

APPENDIX H
TORPEDO DESIGN ITERATIONS

The primary design objective for the torpedo projectile is to maximize speed and ensure stability over extended ranges by minimizing hydrodynamic drag. To achieve passive self-correction, the center of gravity must be located forward of the center of pressure. When the CP is positioned aft, hydrodynamic forces generate a restoring moment that prevents yaw and maintains a stable trajectory. Tail fins are incorporated specifically to shift the CP rearward. In our initial iteration, the fins were positioned externally; however, lacking active control, this configuration offered no aerodynamic advantage and instead penalized performance by increasing drag. Consequently, the third iteration adopted an integrated fin profile tapering toward the aft. This streamlined design promotes laminar flow, significantly reducing overall drag and minimizing the low-pressure wake zone behind the projectile.

(a) Version 1 — Isometric

(b) Version 1 — Back View

(c) Version 2 — Isometric

(d) Version 2 — Back View

(e) Version 3 — Isometric

(f) Version 3 — Back View

(g) Version 4 — Isometric (Final Form)

(h) Version 4 — Back View (Final Form)

Fig. 23. Torpedo design iterations from Version 1 to Version 4. Version 4 is the final form.

During the final design iteration, we identified opportunities to maximize both physical and hydrodynamic performance within the RoboSub dimensional constraints. Operating within the $51 \times 51 \times 152$ mm bounding box, the torpedo's overall length was extended from 112 mm to 145 mm while the NACA 66-012 profile [1], [2] was geometrically scaled for a 170 mm reference length. This extension increased the projectile's internal volume and mass, thereby enhancing momentum retention upon launch for greater range and effective water penetration. Hydrodynamically, the increased length to diameter (L/D) ratio creates a more slender body, which naturally improves directional stability and ensures a highly accurate, self-stabilizing trajectory.

APPENDIX I
DOME ADAPTOR MANUFACTURING

During high-pressure tests, structural deformations were observed in the dome components used on our vehicles. Since this posed a risk in terms of long term durability and reliability, a new dome certified for depths up to 1000 meters was adopted. To ensure compatibility between the new dome and the existing vehicle structure, a custom adapter component was designed and manufactured.

Fig. 24. Deformed dome component observed after high-pressure testing.

(a) Front View

(b) Back View

Fig. 25. Dome adaptor views.

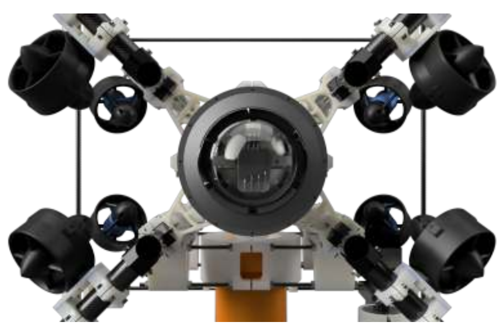


Fig. 26. Taluy Mini with the new dome and adaptor installed.

APPENDIX J
VEHICLE ELECTRONICS ARCHITECTURE

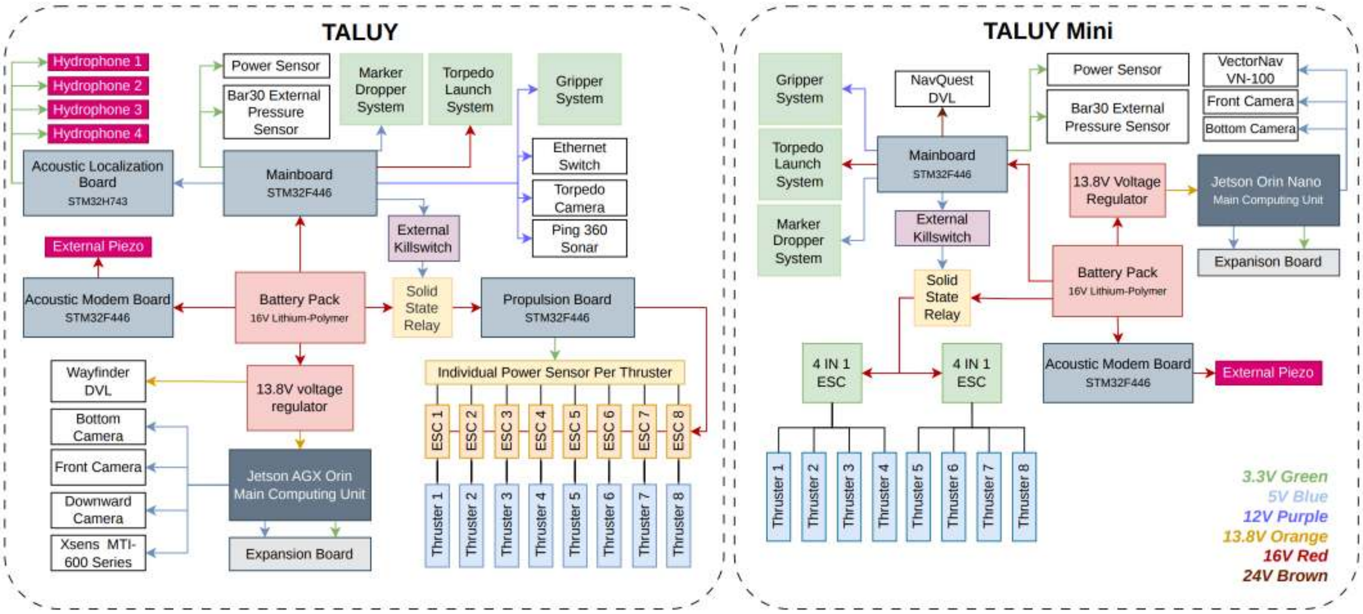


Fig. 27. Taluy and Taluy Mini Power Distribution Schema.

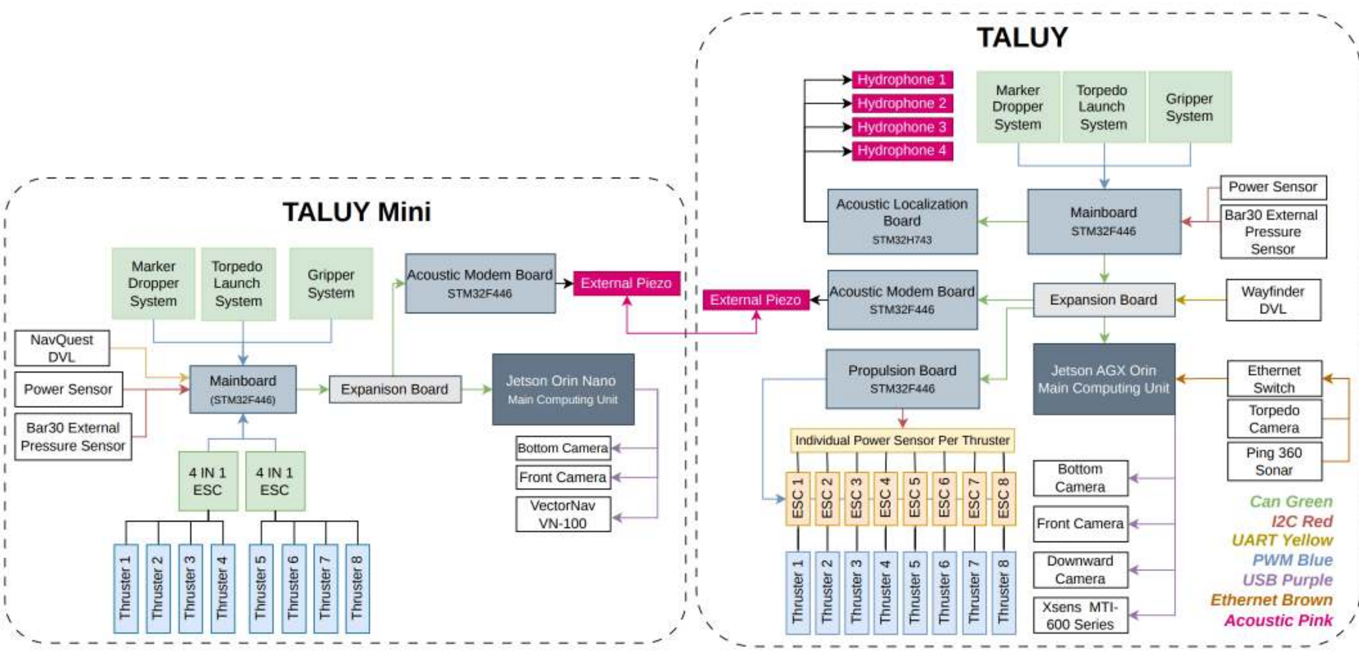


Fig. 28. Taluy and Taluy Mini Communication Schema.

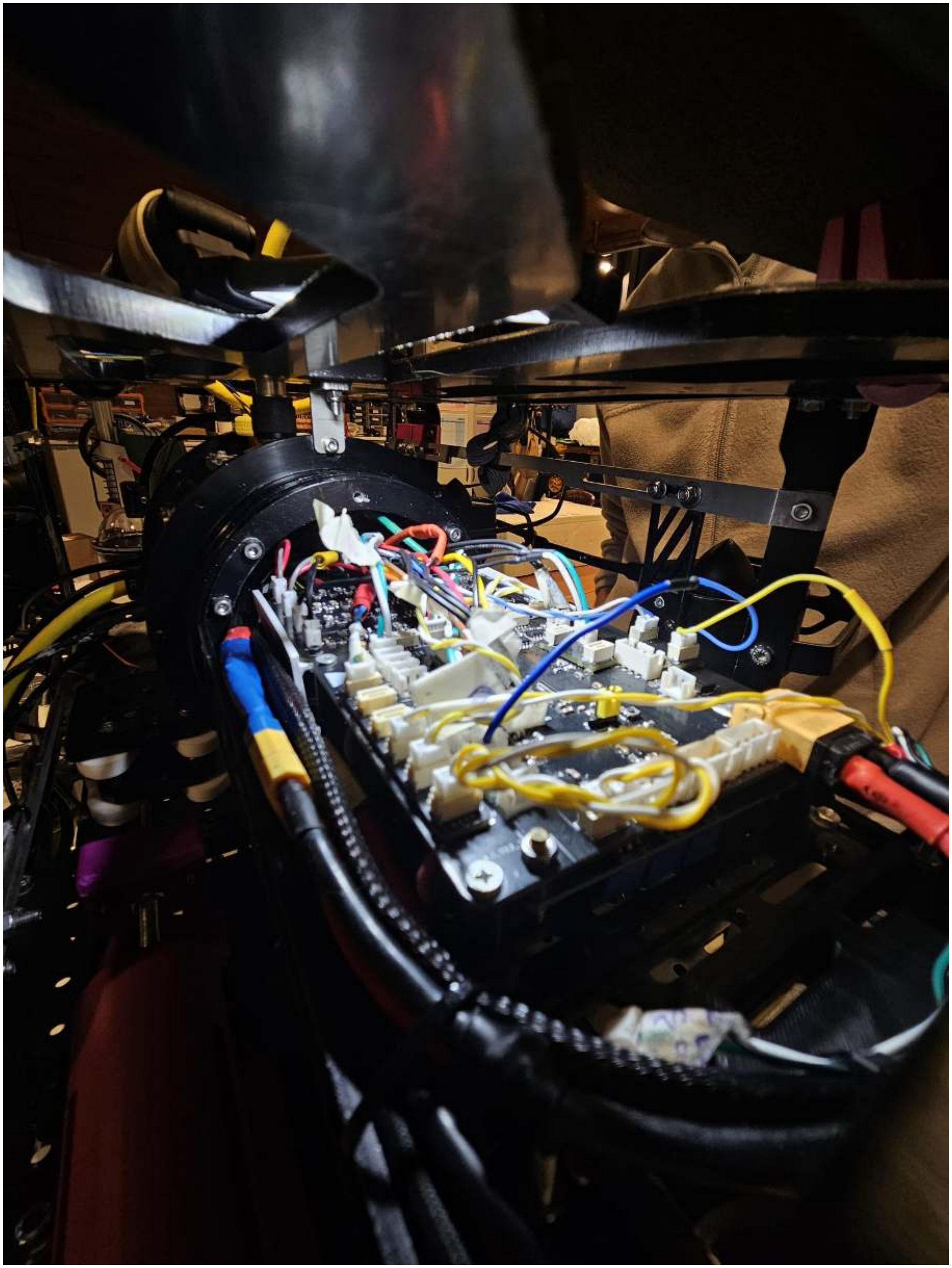


Fig. 29. Taluy Electronics.

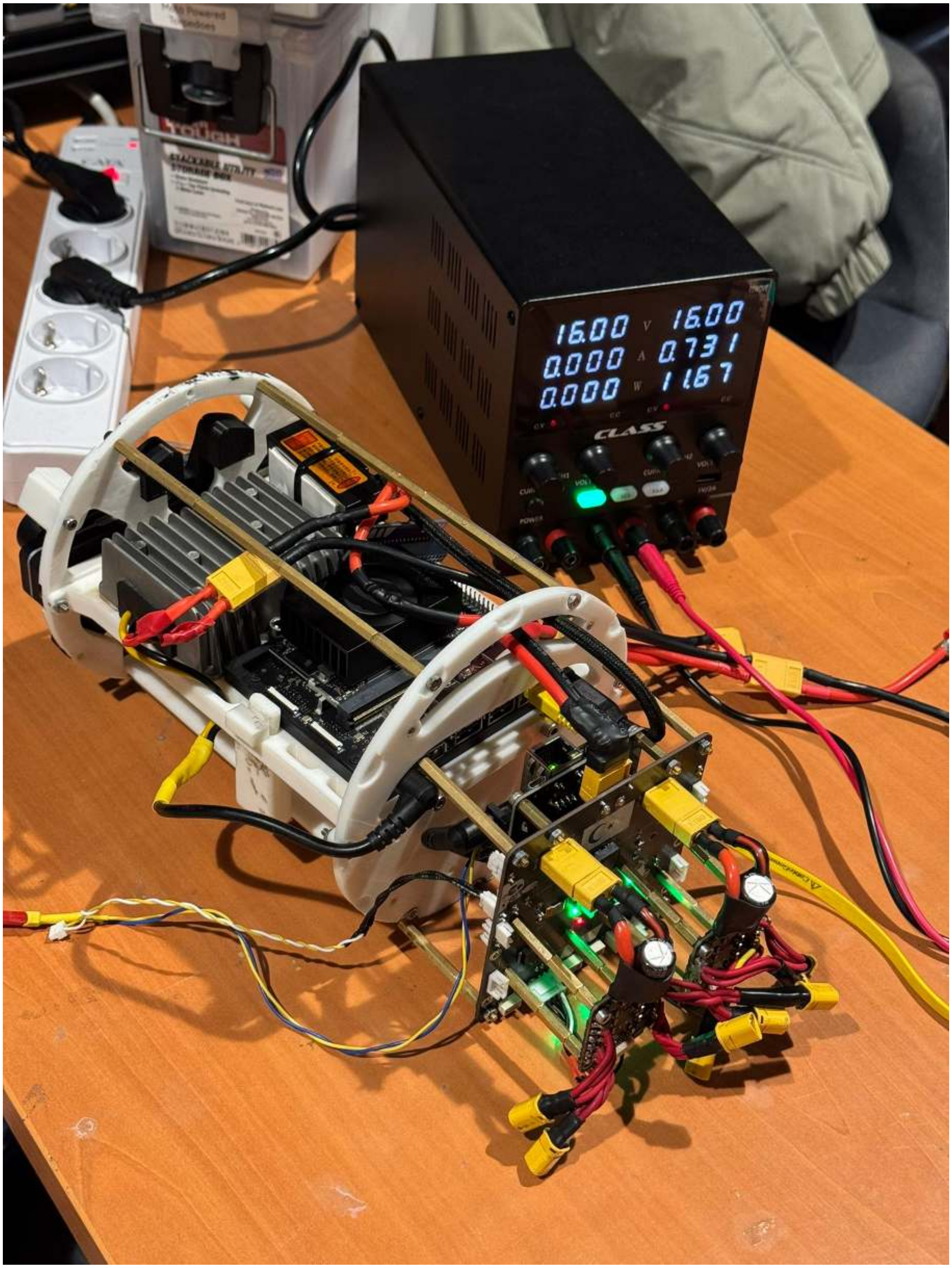


Fig. 30. Taluy Mini Electronics.

APPENDIX K
ELECTRICAL TESTS

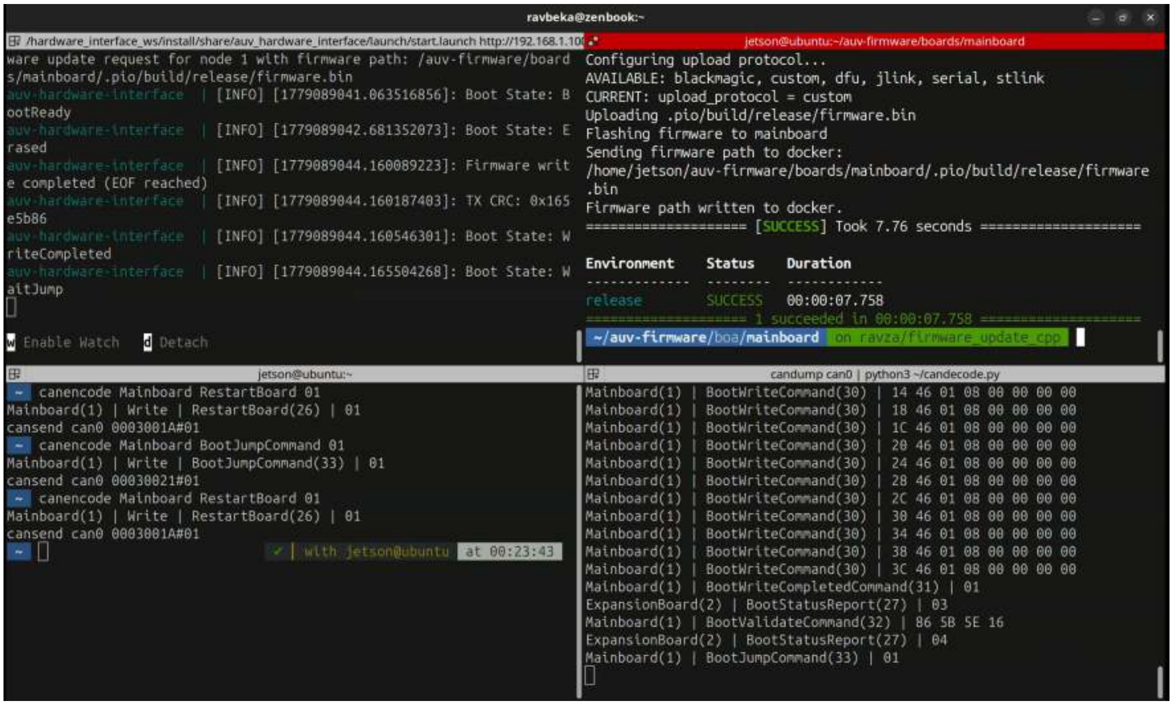


Fig. 31. Firmware Update with Custom Bootloader.

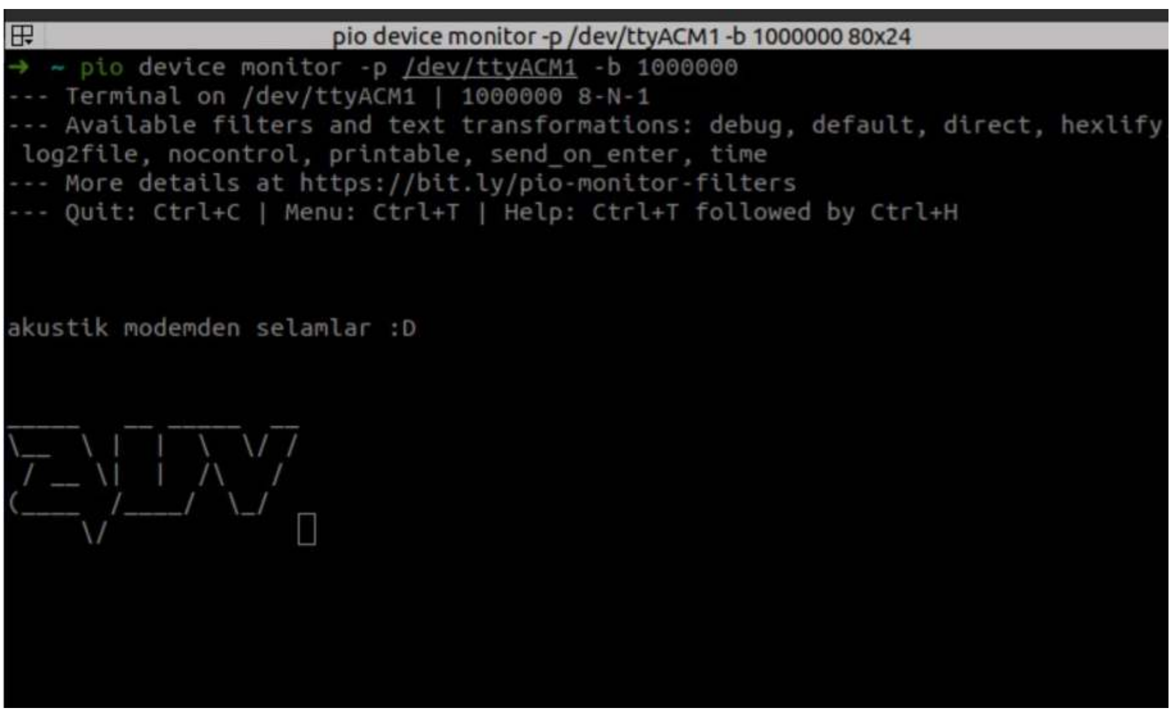


Fig. 32. Received message from acoustic modem, translated to Hello From Acoustic Modem.

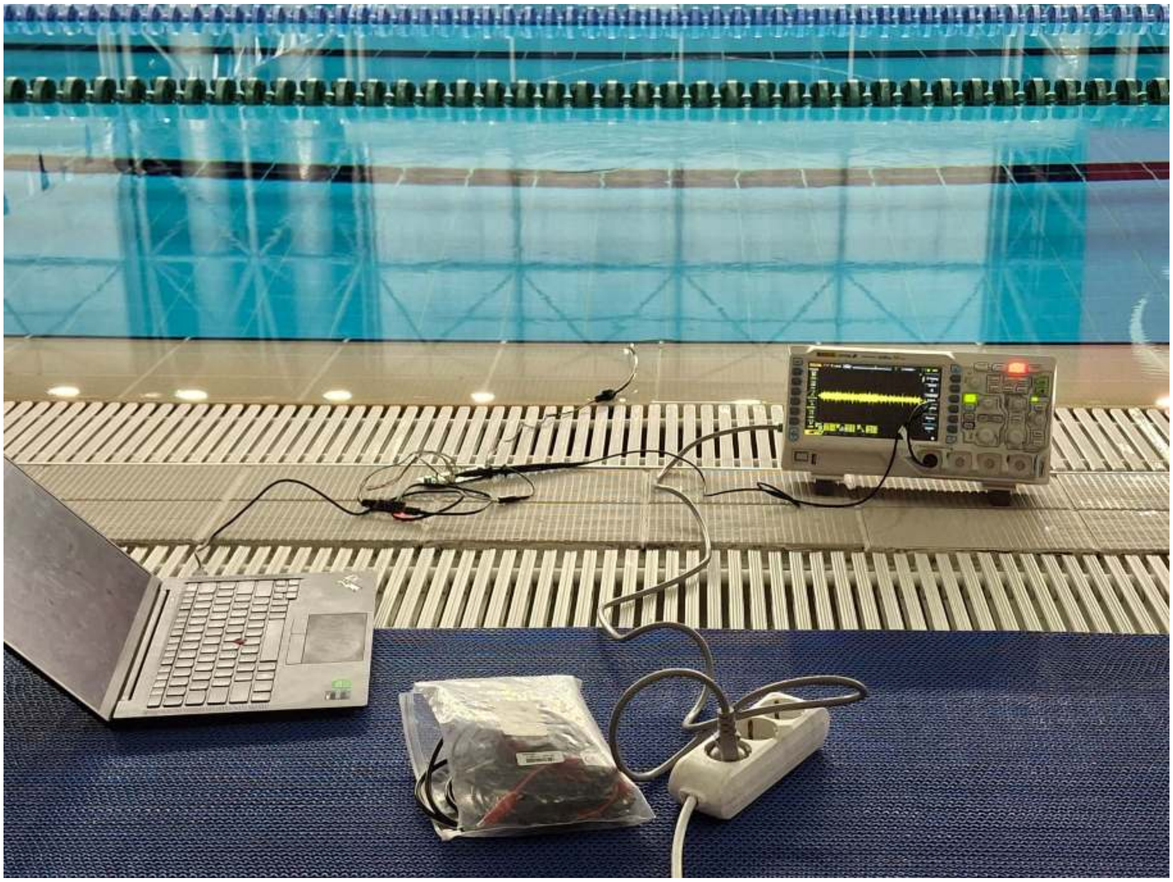


Fig. 33. Acoustic Modem Pool Test.

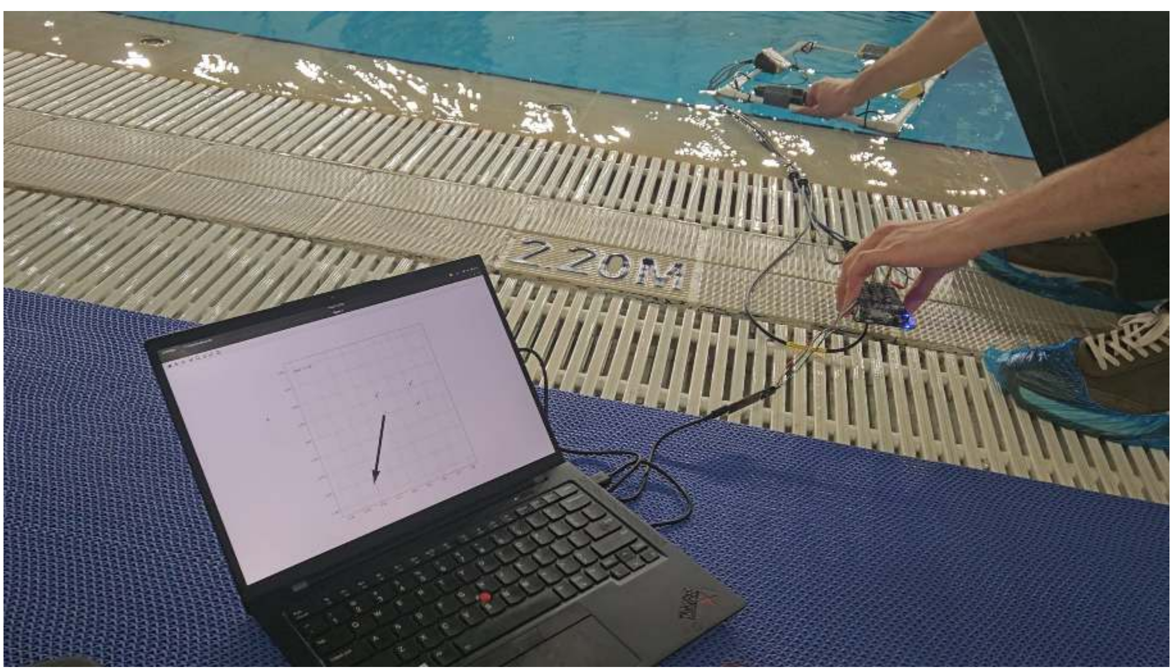


Fig. 34. Pinger Localization Pool Test.

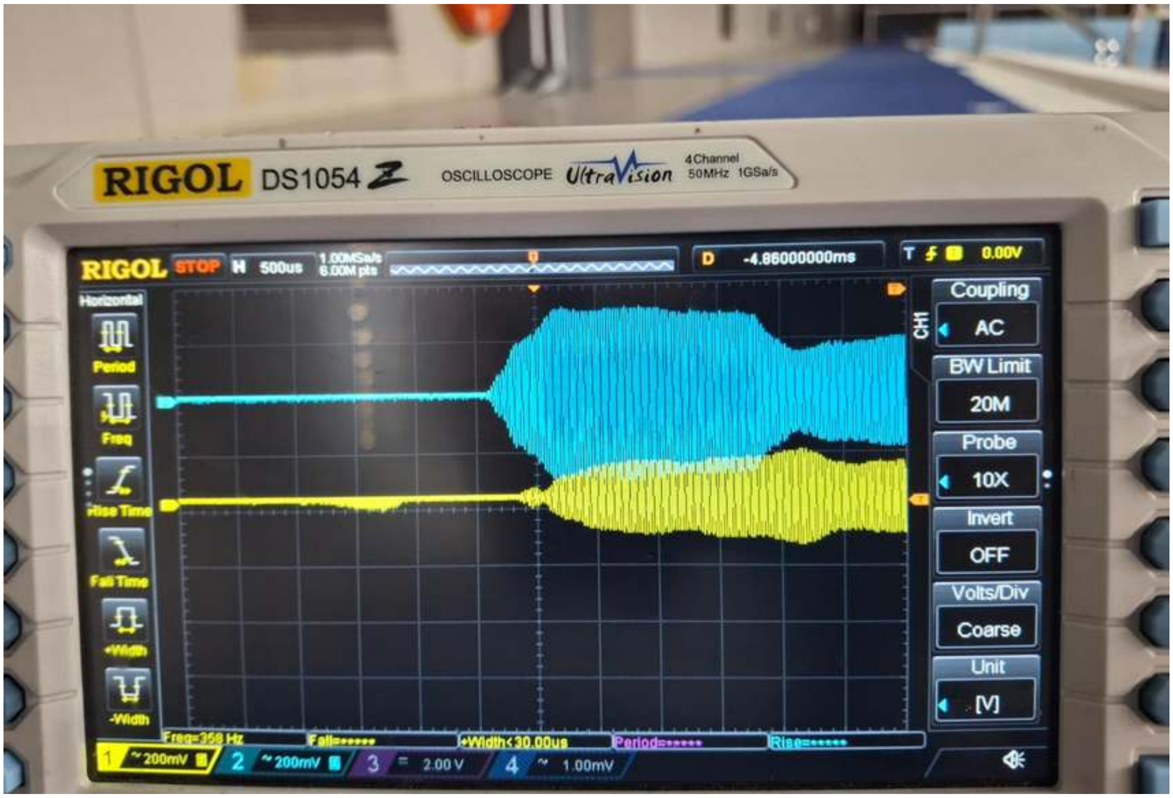


Fig. 35. Time Difference.

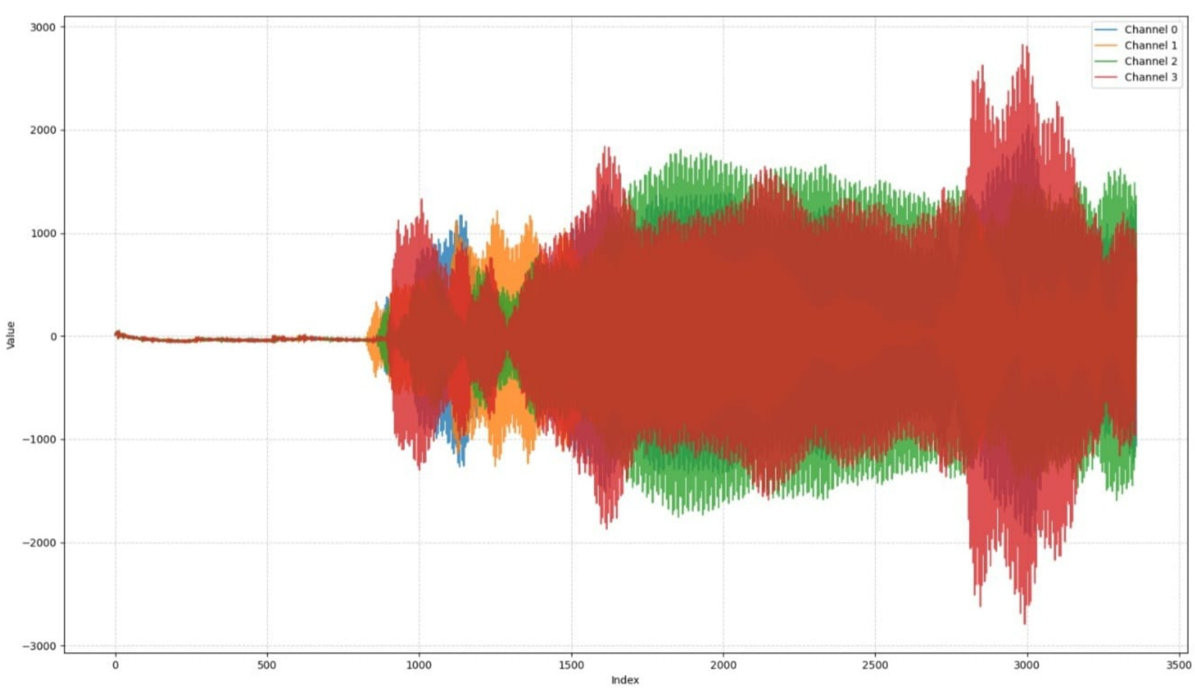


Fig. 36. Hydrophone Correlation Data.

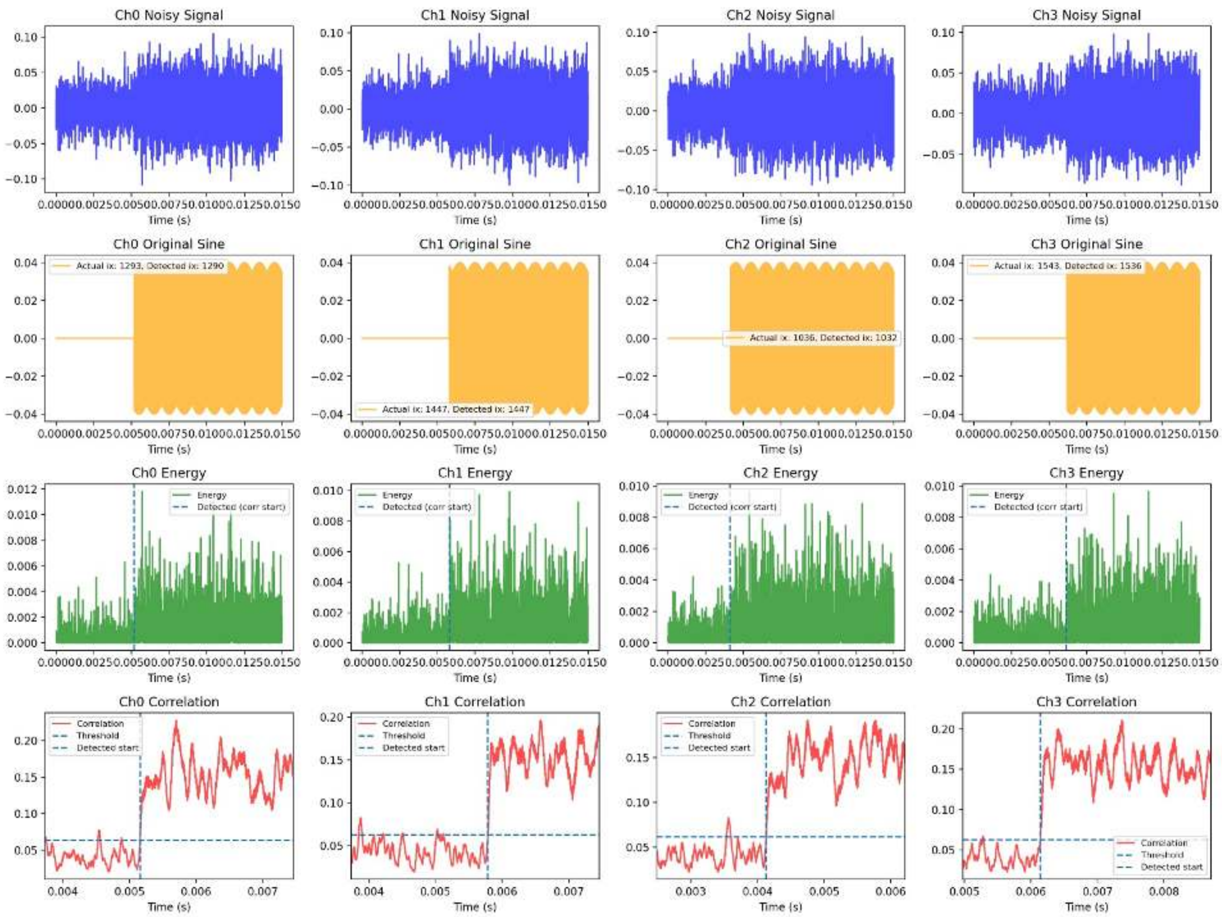


Fig. 37. Simulation of Pinger Localization.

APPENDIX L

Fig. 38. Meko, Panda and Taluy Mini.