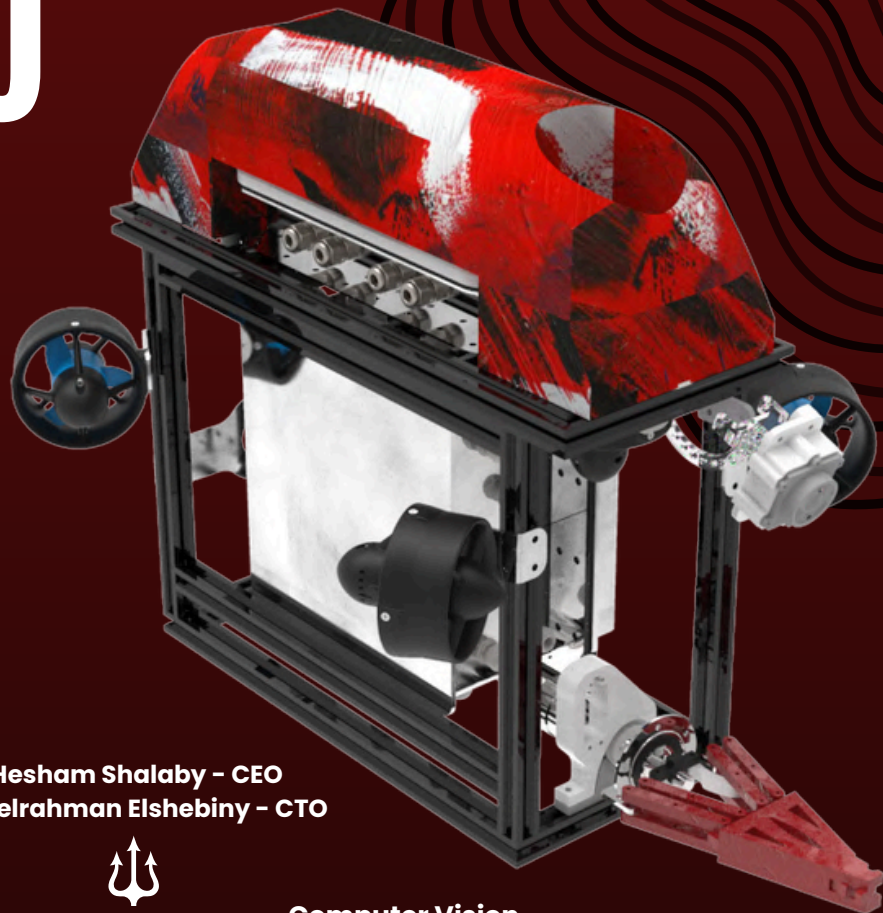


TORPEDO 2026

TRIDENT



Hesham Shalaby – CEO
Abdelrahman Elshebiny – CTO



Machine Learning
Abdelrahman Sharaf – Head
Abdulrahman Mahmoud
Belal Hamouda

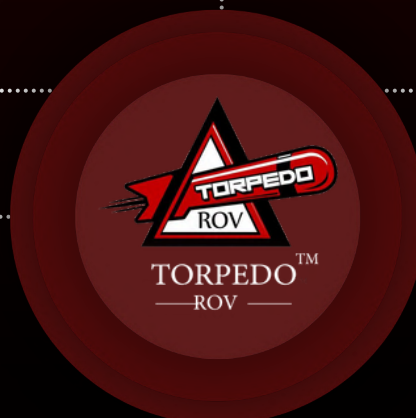
Computer Vision
Mustafa Alnashar – Head
Mohammed Hatem
Jana Amr
Ahmed Hassan



Electrical Team
Abdelrahman Salah – Head
Amr Zeina – Hardware
Ahmed Mohsen – Hardware
Marwan Aly – Software
Ayman Ragab – Software
Youssif Rushdy – Software



Mechanical Team
Youssef Ayman – Head
Assem Sheha
Abdelrahman Seddiek
Ahmed Waleed
Marwa Mohammed



Contents

I	Abstract	4
II	Design Rationale	5
1	Mechanical System	5
1.1	Design Evolution	5
1.2	Mechanical Structure	5
1.3	Propulsion System	7
1.4	Drag Calculations	7
1.5	Buoyancy and Ballast	8
2	Hardware System	8
2.1	Electrical System Design	8
2.2	Electrical Schematic (SID)	9
2.3	Main Control Board (MCB)	9
2.4	Primary Power Distribution Board (48V PDB)	10
2.5	Secondary Power Regulation & Distribution Board (12V PRDB)	10
2.6	Power and Fuse Calculations	11
3	Software System	11
3.1	Control System Design	11
3.2	Graphical User Interface	13
4	Mission Tools	13
4.1	Gripper System	13
4.2	Coral Garden Modeling	14
4.3	Mitigate Invasive Species	14
4.4	Iceberg Tracking	15
4.5	Float	15
III	Safety Rationale	16
1	Design Safety and Philosophy	16
2	Safety Checklist	17
IV	Project Management	18
1	Company Overview	18
2	Timeline	18
3	Budget Planning	19
4	Cost Analysis	20
5	Testing and Troubleshooting	21
5.1	Sealing Test	21
5.2	Playground Test	21
5.3	Challenges	21
6	Acknowledgments	22
7	References	22

List of Figures

1.1	ROVs build by Torpedo since 2014.	4
1.2	Trident	4
2.1	Main Frame	5
2.2	Camera Mount	6
2.3	Enclosures	6
2.4	Thruster Config	7
2.5	Thruster Fixations	7
2.6	Side Velocity Dist	7
2.7	Top Velocity Dist	8
2.8	Pressure Distribution	8
2.9	Foam	8
2.10	Electric SID	9
2.11	Main Control Board	9
2.12	PDB	10
2.13	PRDB	10
2.14	Our ROS System	12
2.15	Gripper	13
2.16	Pneumatic Circuit.	14
2.17	Float	15
4.1	Company Members	18
4.2	Timeline for 2025/2026.	18
4.3	Budget Plan	19
4.4	Trident Cost Analysis	20
4.5	Playground	21
4.6	Partners	22

I Abstract

Torpedo, a technical team at Alexandria University, focuses on the design and construction of remotely operated vehicles (ROVs) for underwater exploration. Every year, the team develops a new ROV, providing incoming members with hands-on experience while benefiting from the guidance of senior members and mentors. This ensures the continuity of technical knowledge and allows each generation to improve upon past designs.



Figure 1.1: ROVs build by Torpedo since 2014.

This year, we proudly present Trident, our latest ROV designed for maneuverability, stability, and modularity. Its thin hull improves sea-keeping, and a 360° rotational gripper with 5 degrees of freedom enables precise manipulation. Trident supports six electrical accessories and two pneumatic actuators, features vectored thrusters, a lightweight aluminum frame (15kg) with custom buoyancy foam, and PID-controlled stability. Photogrammetry capabilities allow efficient mapping and inspection.

Developed through a multidisciplinary effort, Trident exemplifies compact, adaptable, and high-performance underwater operations



Figure 1.2: Trident

II Design Rationale

1 Mechanical System

1.1 Design Evolution

At the beginning of the season, we wanted to ensure that all members have enough knowledge, and skills and keep a great team spirit, so training sessions were held by our mentors to help new engineers start their journey in the ROV field. After the training phase and designing a new ROV, we started asking ourselves 2 simple questions: what needs to be improved? And what do we need to keep? From these simple questions, a lot of meetings were made, brainstorming ideas and discussing previous year's designs either we make a completely new design or stick with the latest version of our ROVs generation, we decided to take the benefits of previous designs and modify it with this year innovative ideas to meet the global needs.

1.2 Mechanical Structure

A Frame

ROV constructed from aluminum 6000 series material with a thickness of 2 cm This provides a balance between structural strength and reduced weight. The frame dimensions are:

- Length: 42 cm
- Width: 20 cm
- Height: 34 cm

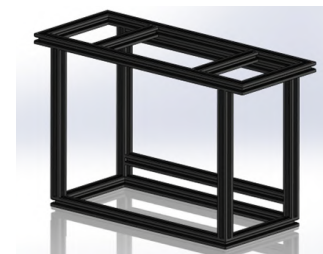


Figure 2.1: Main Frame

The use of aluminum profiles offers several advantages. The modular nature of the profiles allows for easy reconfiguration of the overall structure, enabling rapid design adjustments when needed. Additionally, the profiles provide multiple mounting options for mission tools and camera fixtures, making the ROV highly adaptable to different operational requirements.

B Camera Fixtures

All cameras used in the system are enclosed in cubic casings fabricated from Nylon 6 (PA6), providing adequate mechanical strength while maintaining lightweight properties. Effective sealing is achieved through chemical sealing using silicone-based compounds, ensuring reliable protection against water ingress. The cable entry is secured using a PG-9 cable gland, maintaining a watertight seal around the wiring.



Figure 2.2: Camera Mount

The gripper camera is mounted on a 3D-printed support made of PLA, allowing the pilot to easily adjust its orientation according to operational requirements. This mount provides two degrees of freedom, enabling precise positioning of the camera.

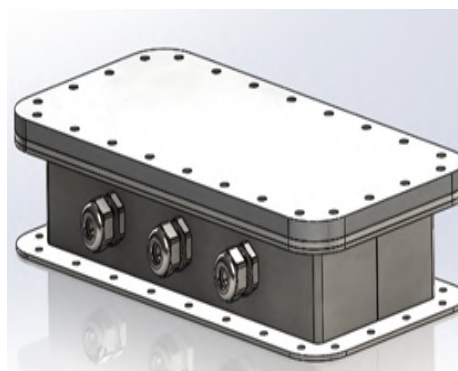
C Enclosures

The ROV incorporates two primary enclosures: the electronics box and the solenoids box. Both enclosures are rectangular in shape and are constructed from stainless steel grade 304. This material was selected for its high efficiency, excellent weldability, and good ductility, which are essential for reliable fabrication and long-term durability in underwater conditions.

To ensure proper sealing and protection of internal components, each enclosure is fitted with a gasket and securely fastened using bolts along the cover, providing effective resistance against water ingress.



(a) Electric Enclosure



(b) Solenoid Enclosure

Figure 2.3: Enclosures

1.3 Propulsion System

The ROV is equipped with six T200 thrusters from Blue Robotics, providing motion along five degrees of freedom: surge, sway, heave, yaw, and pitch.

Four inclined thrusters are mounted on the same plate at the top, each installed at an angle of 120° relative to the others to provide vectored control in horizontal directions. The remaining two thrusters are oriented upward on the same top plate, installed at a 90° angle to assist vertical motion.

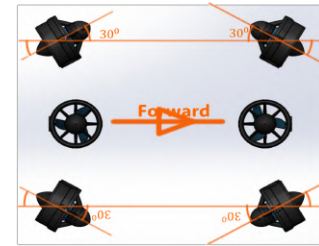
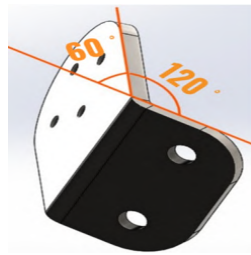
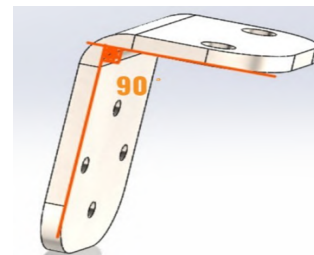


Figure 2.4: Thruster Config



(a) Angle 120 Fixation



(b) Angle 90 Fixation

Figure 2.5: Thruster Fixations

Each thruster produces a maximum thrust of 25 N, as measured experimentally in the vectored arrangement. Therefore, the total horizontal thrust contributed by the four inclined thrusters can be calculated as:

$$(2.1) \quad F_{\text{total}} = 4 \times 25 \times \cos(30^\circ) = 86.6 \text{ N}$$

1.4 Drag Calculations

This year, the ROV was designed to minimize drag in the surge and heave directions while maintaining moderate drag in the sway direction to enhance seakeeping. A CFD analysis was performed using the ANSYS Student software to evaluate the drag forces and the maximum velocity. The model was simplified for meshing and the computational domain was defined with the ROV centered, including a downstream length of approximately $2 \times$ the ROV length, an upstream inlet of $0.5 \times$ the length, and a height of $3 \times$ the ROV height. Tetrahedral meshing (patch-independent) was applied and the solution used a turbulent K-Omega flow model with a velocity of 1 m / s over 3000 iterations.

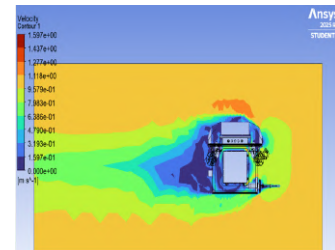


Figure 2.6: Side Velocity Dist

The CFD results showed a drag coefficient of 0.879 and a drag force of 53.8 N. With a measured thrust of 25 N per thruster in the vectored arrangement, the total horizontal thrust is given by Equation 2.1. Based on the drag force equation (Equation 2.2) and a projected area of approximately 0.098 m² (calculated in Rhino), the ROV can achieve a maximum speed of 1.42 m/s.

$$(2.2) \quad F = \frac{1}{2} \rho C_d V^2 A$$

The maximum working depth was determined experimentally by gradually increasing pressure on the enclosures. Deformation was observed at 2 bar, indicating that the ROV can safely operate up to a depth of 20 m.

1.5 Buoyancy and Ballast

One of the key design requirements for the ROV is to ensure slight positive buoyancy. This means that the buoyant force is slightly greater than the weight of the vehicle, ensuring that in the event of a power loss, the ROV will naturally float to the surface. At the same time, the buoyancy is kept only slightly positive to avoid overloading the vertical thrusters during downward motion.

To achieve this, buoyancy foam is incorporated into the ROV structure. The foam displaces approximately 5.5 liters of water, providing sufficient lift to maintain near-neutral buoyancy while underwater.

2 Hardware System

2.1 Electrical System Design

The electrical architecture is designed for high efficiency, robustness, and reliable power management under demanding conditions. Built around a 48V primary supply, the system delivers stable power to high-current propulsion components and sensitive control electronics through a modular and scalable design. Five high-efficiency buck converters handle power distribution: four 48V to 12V / 30A converters for high-power loads and one 48V to 12V / 20A converter for auxiliary and control subsystems. The design is organized across three dedicated PCBs—the Main Control Board (MCB), Primary Power Distribution Board (48V PDB), and Secondary Power Regulation

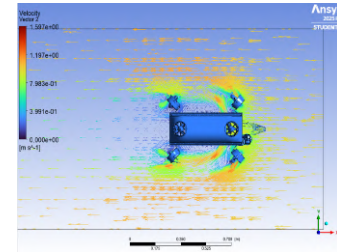


Figure 2.7: Top Velocity Dist

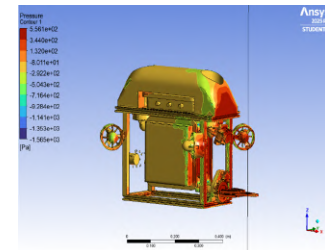


Figure 2.8: Pressure Distribution

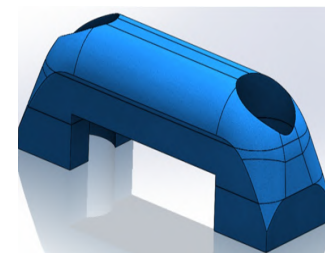


Figure 2.9: Foam

& Distribution Board (12V PRDB)—with the complete architecture illustrated in the electrical schematic (SID), showing power flow and subsystem interconnections.

2.2 Electrical Schematic (SID)

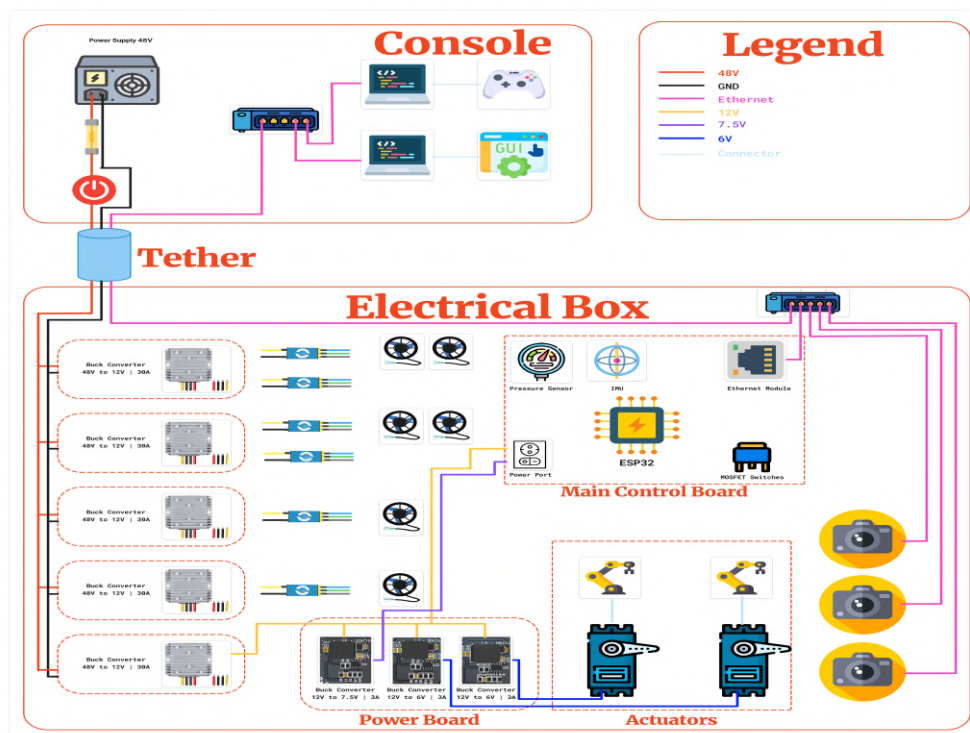


Figure 2.10: Electric SID

2.3 Main Control Board (MCB)

The MCB acts as the central control unit, integrating sensing, processing, and communication. It uses an ESP32 along with IMU and pressure sensors to monitor motion and depth, and includes Ethernet for high-speed data transfer.

The board operates using two carefully managed voltage rails:

- 12V rail: Powers up to eight output channels, enabling control of onboard mechanisms and lighting systems
- 7.5V rail: Further regulated through a two-stage conversion architecture ($7.5V \rightarrow 5V \rightarrow 3.3V$)

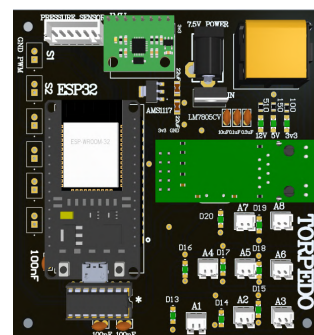


Figure 2.11: Main Control Board

This staged regulation approach significantly improves conversion efficiency and thermal performance, reducing power losses compared to single-stage regulation. Additionally, the MCB generates precise control signals for Electronic Speed Controllers (ESCs), ensuring accurate and responsive propulsion control.

2.4 Primary Power Distribution Board (48V PDB)

The Primary Power Distribution Board acts as the main power backbone of the system, responsible for distributing the 48V supply to all power conversion stages. It is designed to ensure stable and efficient power delivery under high-load conditions while maintaining strong electrical and thermal performance. Key design features include:

- Robust distribution of the 48V input to all buck converter modules, ensuring consistent and stable power delivery
- Advanced multilayer PCB design to optimize current flow, reduce impedance, and minimize power losses
- Carefully calculated trace widths to safely handle high currents and avoid thermal stress and voltage drops

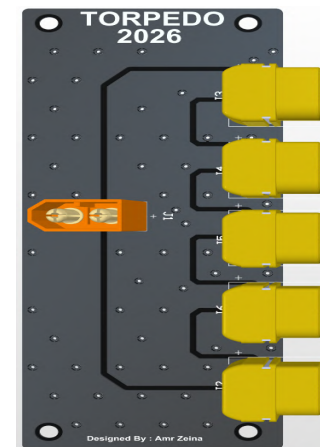


Figure 2.12: PDB

2.5 Secondary Power Regulation & Distribution Board (12V PRDB)

The 12V PRDB refines and distributes regulated power to subsystems with different requirements, ensuring both high-current delivery for propulsion and stable supply for control electronics.

The four 12V / 30A buck converters supply the ESCs, providing stable current for propulsion under dynamic loads. A separate 12V / 20A line powers the Main Control Board directly, while a custom 12V → 7.5V buck converter ensures accurate feedback control with over-voltage and over-current protection. Two additional 12V → 6V converters supply the servo motors in the mechanical subsystems.

The PCB layout is carefully optimized to ensure accurate trace width sizing for high-current paths, balanced current distribution to prevent localized overheating, and minimal voltage drop across critical power lines. This design approach ensures stable operation, efficient power utilization, and long-term reliability across all connected subsystems.

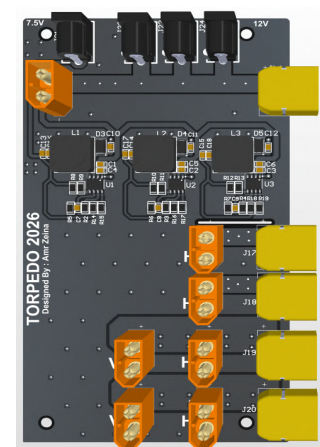


Figure 2.13: PRDB

2.6 Power and Fuse Calculations

Power Consumption Summary			
Item	Quantity	Power (W)	Total (W)
Thrusters	6	156	936
Cameras	3	8	24
Solenoids	2	3	6
Switch	1	9	9
ESP32	1	3	3
Ethernet Module	1	0.5	0.5
Servo Motors	2	12	24
MPU6050	1	0.0132	0.0132
MS5540C	1	0.0066	0.0066
Total Power			1002.5 W

Given the total power consumption and electrical parameters:

- Input Voltage: 48 V
- Converter Efficiency: 95%
- Overload Factor: 1.25
- Current Drawn = $\frac{1002.5}{48 \times 0.95} \approx 22 \text{ A}$
- Fuse Rating = $22 \times 1.25 = 27.5 \text{ A}$, select nearest standard fuse: 30 A

3 Software System

3.1 Control System Design

The ROV's control software architecture is distributed across a high-level processing environment (surface laptop) and a low-level execution node (ESP32 microcontroller), connected via an Ethernet tether.

High-Level Software (ROS 2):

The surface laptop runs ROS 2, acting as the central processing hub for pilot inputs and high-level mission logic. The ROS 2 ecosystem is structured into several nodes that publish and subscribe

topics. Pilot commands are captured from the joystick, translated into target velocity, and formatted for transmission. Using ROS 2 provides a highly modular framework, allowing us to seamlessly integrate sensor data and future autonomy features without disrupting the core teleoperation code.

Low-Level Firmware (ESP32):

The onboard ESP32 serves as the primary hardware interface. Its firmware is responsible for two critical tasks: executing real-time control loops and bridging communication between the ROS 2 environment and the physical hardware (motor ESCs and sensors).

Control logic & Nodes Implemented:

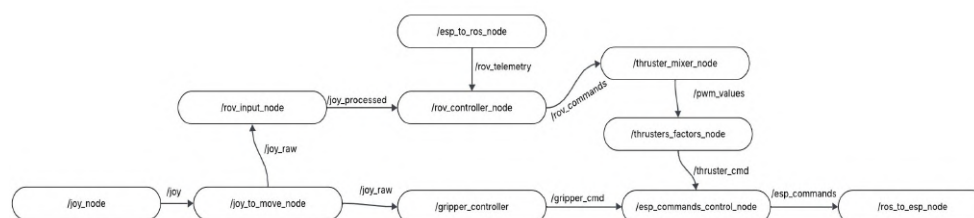


Figure 2.14: Our ROS System

- **Input & Filtering (“JoyToMove” & “ROVInput”)** : Raw joystick inputs are captured and packaged into JSON payloads. The “ROVInput” node extracts needed axes and buttons. It also continuously evaluates a boolean flag to determine if the pilot is actively providing input.
- **State Machine & PID Control (“ROVController”)** : This is the “brain” of the ROV. It manages three custom Proportional-Integral-Derivative (PID) controllers for Yaw, Depth, and Pitch. When the ROV is in “manual mode” (joystick is active), direct pilot commands bypass and route directly to the thrusters. When the ROV is in “hold mode” (joystick is released), the node instantly latches the current depth and yaw as target setpoints. It automatically engages the PIDs to actively hold the ROV’s exact position in the water.
- **Kinematics & Mixing (“ThrusterMixer”)** : Translate 3D spatial commands (x, y, z and yaw) into specific power outputs for the ROV’s 6-thruster configuration (4 vectored horizontal, 2 vertical). The node safely normalizes outputs if the combined vector exceeds maximum thrust, preventing directional skewing. Finally, it maps the vectors to standard ESC PWM signals (1100µs to 1900µs, with 1500µs acting as neutral).
- **Tether Bridge (“RosToEsp” & “EspToRos”)** : These nodes act as the gateway between ROS 2 and the microcontroller. “RosToEsp” transmits mixed PWM and gripper commands, while “EspToRos” listens for incoming IMU/Depth telemetry.

ROS to MCU Communication:

Communication between the surface laptop and the ESP32 operates over a direct Ethernet connection using the UDP (User Datagram Protocol). Data is packaged into custom payloads containing thrust vectors, sensor telemetry, or joystick inputs. UDP was specifically chosen over TCP for real-time control; in the event of packet loss, UDP allows the system to instantly process the newest incoming command rather than waiting for an outdated packet to retransmit.

3.2 Graphical User Interface

The GUI is developed using PySide6 in Python and is organized into a general-purpose tab and task-specific tabs. The general-purpose tab provides a real-time overview of the system by displaying all camera feeds along with key sensor data, including depth and odometry-based speed and orientation. Task-specific tabs support mission objectives such as:

- **Invasive Species Tab:** A live camera feed and capture function allow images to be processed with bounding boxes highlighting detected European Green Crabs and displaying their count.
- **Iceberg Tracking Tab:** The operator selects four points on a captured image to define a reference object and a target. The system computes pixel distances, then uses the known reference length (default 15 cm) to estimate the real-world size of the target. Points can be adjusted individually, allowing error correction without restarting the process.

4 Mission Tools

4.1 Gripper System

A Gripper Design and Operation

The ROV is equipped with a versatile gripper capable of picking up, holding, moving, and placing objects underwater. The end effector is fabricated from Nylon 6 (PA6), providing strength while remaining lightweight. The gripper can rotate 360° using a gear mechanism, allowing precise manipulation of objects in various orientations. Actuation is achieved via a pneumatic piston, which provides secure and reliable grasping.

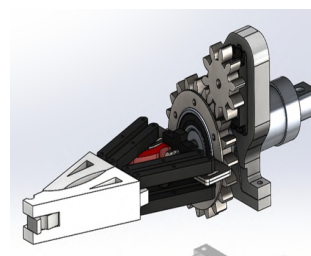


Figure 2.15: Gripper

B Pneumatic System

The gripper is powered by the ROV's pneumatic system. Compressed air is delivered by a compressor at 8 bar and 145 L/min. Pressure is regulated to 2.5 bar using a Pressure Relief Valve (PRV).

and a Pressure Reducing Valve for safe operation. Movement of the gripper piston is controlled by a 32×25 mm double-acting pneumatic cylinder actuated through a 5/2 solenoid directional control valve. A non-return valve prevents water ingress at the end of the circuit. An additional pneumatic line is available to accommodate a potential second gripper in the future.

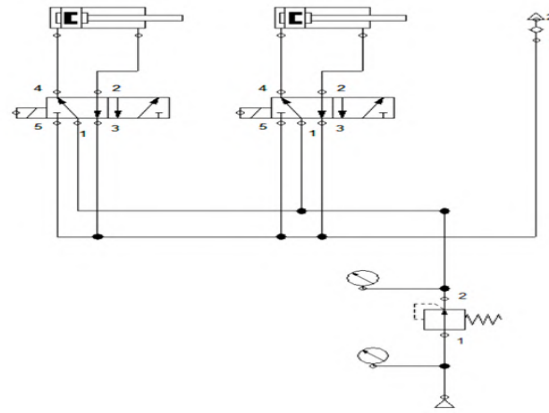


Figure 2.16: Pneumatic Circuit.

4.2 Coral Garden Modeling

The ROV captures overlapping imagery of the PVC structure to generate a rotatable 3D model via an automated SfM and NeRF pipeline. This system is optimized to resolve all eight 10 cm×10 cm target squares, providing a high-fidelity digital twin for structural analysis.

To achieve metric accuracy, the system calculates an initial scaling factor using a known reference object. Once the true length is verified, the model is dynamically rescaled, allowing the operator to accurately extract the final height measurement—from the base to the top PVC.

4.3 Mitigate Invasive Species

Underwater imaging presents challenges such as distortion, lighting variation, and color attenuation, which reduce the reliability of traditional vision methods. To address this, a YOLO-based deep learning model is used, enabling robust object detection directly from underwater data without explicit image correction.

The model was trained on a custom dataset of approximately 150 images collected under varying conditions using an underwater camera setup. After splitting the dataset (70/20/10) and fine-tuning, the model achieved approximately 80% detection performance. A confidence threshold of 60% is applied to classify and count European Green Crabs.

4.4 Iceberg Tracking

A monocular vision approach is used to estimate real-world dimensions from image data. The method relies on computing a pixel-to-metric scaling factor using a known reference length. This factor is then applied to the target measurement to estimate its actual size.

This approach provides a simple and effective solution for extracting real-world dimensions using a single camera, without requiring additional sensors or stereo vision.

4.5 Float

The vertical profiling float is designed within a compact 17 cm × 70 cm footprint, using a 114 mm PVC pressure hull with polyamide end caps and O-ring seals for watertight integrity. Its internal structure follows a modular, layered design, with electronics and batteries positioned at the top, while strategically placed lead weights at the bottom ensure stability by maintaining the center of gravity below the center of buoyancy and achieving slight positive buoyancy.

Vertical motion is achieved through an active buoyancy engine that varies internal volume using four 60 mL syringes driven by a JGA25-370 DC motor. A power screw mechanism converts rotational motion into linear displacement, allowing the system to draw in water for descent and expel it for ascent. Limit switches are incorporated to prevent overtravel and protect the mechanical components.

The system is powered by a 12V Ni-MH battery pack, with voltage regulation providing 5V and 3.3V rails for sensors and control electronics. An ESP32 microcontroller manages sensing, control, and communication, using a pressure sensor for depth tracking and a PID algorithm for vertical navigation. Data is collected, stored, and transmitted wirelessly via UDP upon surfacing, with RTOS-based task management ensuring reliable and efficient operation.



Figure 2.17: Float

III Safety Rationale

1 Design Safety and Philosophy

Safety is a fundamental principle guiding all stages of the Torpedo Robotics engineering process. All design decisions prioritize safety alongside performance and reliability, with a focus on preventing risks rather than reacting to them. Mechanical, electrical, and software systems are developed with protective measures such as insulated circuits, enclosed electronics, and structurally safe designs.

This design philosophy directly ensures the safety of all team members during manufacturing, testing, and operation. Appropriate Personal Protective Equipment (PPE), including safety goggles, gloves, and masks, is used when working with tools or hazardous materials. Workspaces are maintained clear of obstacles to prevent tripping hazards, and members avoid working alone when handling machinery or electrical systems. Additionally, fail-safe mechanisms such as emergency power disconnection and controlled system behavior ensure that the ROV transitions into a safe state in the event of a malfunction.

Equipment Safety Overview

Mechanical Safety

- Components are securely fastened before operation.
- Sharp edges are removed or smoothed.
- Moving parts are properly enclosed or guarded.
- Equipment is inspected before use.
- Safe distance is maintained during operation.
- Strain relief is applied to prevent cable stress and damage.
- End caps are used to eliminate sharp edges.
- Thrusters are fitted with protective shrouds.

Electrical Safety

- Circuits are insulated and enclosed.
- Fuses protect against overcurrent.
- Connections are verified before power-up.
- Emergency power cutoff is implemented.
- Safe handling during soldering and testing.
- PCBs are designed with protective measures and appropriate design standards.
- Insulation integrity is verified after any enclosure opening or maintenance.

2 Safety Checklist

Operations & Mission Check-Off Sheet

Task Description	Pre-Trial	Post-Trial	Lead Sign-off
1. Transportation			
Deck path is verified clear of trip hazards.	☐	☐	
Equipment is team-lifted to/from the station.	☐	☐	
2. Station Setup			
Tether is unspooled safely without loops.	☐	N/A	
All monitors and control boxes are secure on the table.	☐	N/A	
Anderson connectors are secured and voltage is checked.	☐	N/A	
DRY TEST: All personnel clear of thrusters before power-up.	☐	N/A	
3. Deployment			
Team is positioned securely at the pool edge.	☐	N/A	
Pilot gives verbal clearance for launch.	☐	N/A	
Tether is actively managed to prevent tripping during dive.	☐	N/A	
4. Retrieval			
Pilot confirms manipulator is open and deactivated.	N/A	☐	
ROV is lifted safely using the knees, avoiding back strain.	N/A	☐	
5. Breakdown & Wrap Up			
Proper power-down sequence is followed; battery disconnected first.	N/A	☐	
ROV and tether are dried; deck puddles are wiped up.	N/A	☐	
ECOS is completed to ensure no lost equipment.	N/A	☐	

1. Transportation

Deck path is verified clear of trip hazards.

☐
☐

Equipment is team-lifted to/from the station.

☐
☐

2. Station Setup

Tether is unspooled safely without loops.

☐

N/A

All monitors and control boxes are secure on the table.

☐

N/A

Anderson connectors are secured and voltage is checked.

☐

N/A

DRY TEST: All personnel clear of thrusters before power-up.

☐

N/A

3. Deployment

Team is positioned securely at the pool edge.

☐

N/A

Pilot gives verbal clearance for launch.

☐

N/A

Tether is actively managed to prevent tripping during dive.

☐

N/A

4. Retrieval

Pilot confirms manipulator is open and deactivated.

N/A

☐

ROV is lifted safely using the knees, avoiding back strain.

N/A

☐

5. Breakdown & Wrap Up

Proper power-down sequence is followed; battery disconnected first.

N/A

☐

ROV and tether are dried; deck puddles are wiped up.

N/A

☐

ECOS is completed to ensure no lost equipment.

N/A

☐

IV Project Management

1 Company Overview

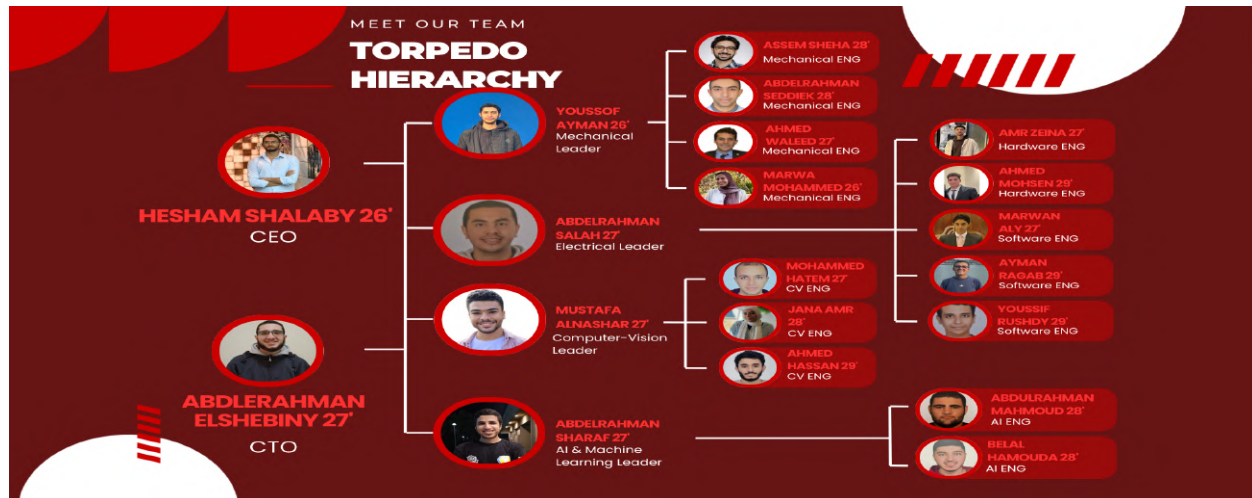


Figure 4.1: Company Members

2 Timeline

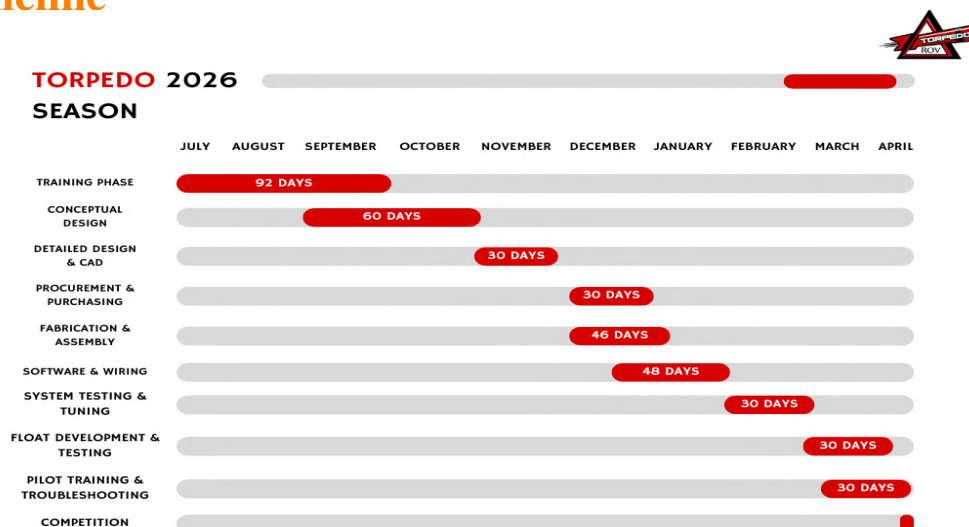


Figure 4.2: Timeline for 2025/2026.

3 Budget Planning

			Torpedo 2026 Product Cost Analysis								
			Type	Cost Type	Category	Expense	Sources/Notes	Qty	Amount per one	Total	
Net Cost Of ROV Vehicle	Product Costs	Electrical System	Re-used	Electronics	Actuation	Motor Driver	Basic ESC	6	\$40.00	\$240.00	
			Purchased	Electronics	Communication	Camera/ solenoids cables	Cables	1	\$2.00	\$2.00	
			Re-used	Electronics	Communication	Ethernet Module	Communication Module	1	\$7.00	\$7.00	
			Re-used	Material	Communication	Tether	Ethernet CAT6	1	\$15.00	\$15.00	
			Re-used	Electronics	Control	Joystick	PC Controller	1	\$20.00	\$20.00	
			Re-used	Electronics	Control	ESP32	Microcontroller	1	\$10.00	\$10.00	
			Re-used	Electronics	Control	Camera	IP	3	\$18.00	\$54.00	
			Re-used	Electronics	Control	Water Depth Sensor	M55540C	1	\$15.00	\$15.00	
			Re-used	Electronics	Control	IMU Sensor	MPU6050	1	\$15.00	\$15.00	
			Re-used	Electronics	Power	DC-DC Converter	48-12V 30A Output	4	\$30.00	\$120.00	
			Re-used	Electronics	Power	DC-DC Converter	48-12V 20A output	1	\$24.00	\$24.00	
			Purchased	Electronics	Power	SMD Bucks	3A Bucks	3	\$2.20	\$6.60	
			Re-used	Material	Power	Bullets (Pairs)	Motor Connector	18	\$0.50	\$9.00	
			Re-used	Electronics	Power	Ethernet Switch	5 port-switch	1	\$6.00	\$6.00	
			Re-used	Material	Power	Tether	Power Cable 10AWG	1	\$48.00	\$48.00	
			Purchased	Electronics	Power	Other PCB Components	Passive Elements	1	\$5.00	\$5.00	
			Re-used	Material	Power	XT60 Connectors	Pairs	10	\$0.50	\$5.00	
			Re-used	Electronics	Power	Fuse and Holder	Protection (20A)	1	\$2.00	\$2.00	
			Re-used	Material	Structure	Tether Cover	Braided Sleeve	1	\$13.00	\$13.00	
		Mechanical System	Re-used	Material	Actuation	Gripper	PA	1	\$1.80	\$1.80	
			Re-used	Electronics	Actuation	T200	Thruster	6	\$200.00	\$1200.00	
			Re-used	Material	Pneumatics	Solenoid Box	Stainless Steel	1	\$8.50	\$8.50	
			Re-used	Material	Pneumatics	Solenoid Box Lid	PA	1	\$1.00	\$1.00	
			Re-used	Material	Pneumatics	Tether	PU Hose 6mm	1	\$14.00	\$14.00	
			Re-used	Electronics	Pneumatics	Solenoid Valve	12V	2	\$8.00	\$16.00	
			Re-used	Material	Pneumatics	Pneumatic Piston	Double Acting	1	\$15.00	\$15.00	
			Purchased	Electronics	Pneumatics	Compressor	20 Liter	1	\$90.00	\$90.00	
			Re-used	Material	Structure	Camera Housing	Stainless Steel	3	\$4.00	\$12.00	
			Re-used	Material	Structure	Electric Enlosure	Stainless Steel	1	\$18.00	\$18.00	
			Re-used	Material	Structure	Frame	Aluminium Profiles	1	\$16.00	\$16.00	
			Re-used	Material	Structure	Camera Mount	PLA	1	\$3.00	\$3.00	
			Purchased	Material	Structure	Bolts & Nuts	Stainless Steel	0.23	\$6.47	\$1.49	
			Re-used	Material	Structure	Bolts & Nuts & Brackets	Stainless Steel	80	\$0.07	\$5.60	
			Re-used	Material	Structure	Gland PG9	Sealing	19	\$1.05	\$19.95	
	Services	Re-used	Fabrication	-	PCB Fabrication	Power Board	1	\$15.00	\$15.00		
		Donated	Fabrication	-	PCB Fabrication	MCB by NORI	1	\$18.00	\$18.00		
		Purchased	Fabrication	-	Machining (Welding & CNC Cutting & Others)	-	1	\$50.00	\$50.00		
				Total Product Costs Invested In ROV Vehicle							\$2121.94
	Product s Cost	Tether Control Unit	Re-used	Electronics	Power	Power Supply	48V 30A Mean Well	1	\$15.00	\$15.00	
			Re-used	Electronics	Communication	Ethernet Switch	5 port-switch	1	\$15.00	\$15.00	
Re-used			Electronics	Power	Power Cable	AC Power	1	\$5.00	\$5.00		
										\$2156.94	
Period Costs	Extra	Purchased	Service	-	Competition Registration Fees	-	1	\$575.00	\$575.00		
		Purchased	Service	-	Pool Rent	-	1	\$200.00	\$200.00		
		Purchased	Service	-	Workplace Rent	-	1	\$550.00	\$550.00		
		Purchased	Service	-	Transportation	-	1	\$110.00	\$110.00		
		Purchased	Service	-	Marketing	Flyers, T-shirts, Others	1	\$120.00	\$120.00		
			Total Period Costs Invested							\$1,555.00	
			Total Expenses							\$3,711.94	
			Reused + Donated Expenses							\$2,001.85	
			Total Expenses without Reused or Donated							\$1,710.09	

Figure 4.3: Budget Plan

4 Cost Analysis

			Torpedo 2026 Product Cost Analysis							
			Type	Cost Type	Category	Expense	Sources/Notes	Qty	Amount per one	Total
Net Cost Of ROV Vehicle	Product Costs	Electrical System	Re-used	Electronics	Actuation	Motor Driver	Basic ESC	6	\$40.00	\$240.00
			Purchased	Electronics	Actuation	Servo Motor	MG995 Continuous	1	\$3.60	\$3.60
			Purchased	Electronics	Communication	Camera/ solenoids cables	Cables	1	\$2.00	\$2.00
			Re-used	Electronics	Communication	Ethernet Module	Communication Module	1	\$7.00	\$7.00
			Re-used	Material	Communication	Tether	Ethernet CAT6	1	\$15.00	\$15.00
			Purchased	Electronics	Control	Joystick	PC Controller	1	\$20.00	\$20.00
			Re-used	Electronics	Control	ESP32	Microcontroller	1	\$10.00	\$10.00
			Re-used	Electronics	Control	Camera	IP	2	\$18.00	\$36.00
			Purchased	Electronics	Control	Camera	IP	1	\$18.00	\$18.00
			Re-used	Electronics	Control	Water Depth Sensor	M55540C	1	\$15.00	\$15.00
			Re-used	Electronics	Control	IMU Sensor	MPU6050	1	\$15.00	\$15.00
			Re-used	Electronics	Power	DC-DC Converter	48-12V 30A Output	4	\$30.00	\$120.00
			Re-used	Electronics	Power	DC-DC Converter	48-12V 20A output	1	\$24.00	\$24.00
			Purchased	Electronics	Power	SMD Bucks	3A Bucks	3	\$2.20	\$6.60
			Re-used	Material	Power	Bullets (Pairs)	Motor Connector	18	\$0.50	\$9.00
			Re-used	Electronics	Power	Ethernet Switch	5 port-switch	1	\$6.00	\$6.00
			Re-used	Material	Power	Tether	Power Cable 10AWG	1	\$48.00	\$48.00
			Purchased	Electronics	Power	Other PCB Components	Passive Elements	1	\$3.50	\$3.50
			Purchased	Material	Power	XT60 Connectors	Pairs	7	\$0.80	\$5.60
			Re-used	Material	Power	XT60 Connectors	Pairs	10	\$0.80	\$8.00
			Purchased	Electronics	Power	Fuse and Holder	Protection (30A)	1	\$2.00	\$2.00
			Re-used	Material	Structure	Tether Cover	Braided Sleeve	1	\$13.00	\$13.00
			Purchased	Material	Actuation	Gripper	PA	1	\$1.80	\$1.80
			Purchased	Material	Actuation	Gears	Acrylic	1	\$2.00	\$2.00
			Re-used	Electronics	Actuation	T200	Thruster	6	\$230.00	\$1380.00
			Re-used	Material	Pneumatics	Solenoid Box	Stainless Steel	1	\$8.50	\$8.50
			Re-used	Material	Pneumatics	Solenoid Box Lid	PA	1	\$1.00	\$1.00
			Re-used	Material	Pneumatics	Tether	PU Hose 6mm	1	\$14.00	\$14.00
			Re-used	Electronics	Pneumatics	Solenoid Valve	12V	2	\$8.00	\$16.00
			Re-used	Material	Pneumatics	Pneumatic Piston	Double Acting	1	\$15.00	\$15.00
	Re-used	Electronics	Pneumatics	Compressor	20 Liter	1	\$90.00	\$90.00		
	Purchased	Material	Structure	Camera Housing	PA	3	\$1.50	\$4.50		
	Purchased	Material	Structure	Bearing	Metal Bearing	1	\$0.70	\$0.70		
	Re-used	Material	Structure	Electric Enlosure	Stainless Steel	1	\$18.00	\$18.00		
	Re-used	Material	Structure	Frame	Aluminium Profiles	1	\$16.00	\$16.00		
	Purchased	Material	Structure	Gasket + Paste	Silicon	1	\$7.00	\$7.00		
	Purchased	Material	Structure	Boyancy Foam	Foam	1	\$1.15	\$1.15		
	Purchased	Material	Structure	Camera Mount	PLA	1	\$3.00	\$3.00		
	Purchased	Material	Structure	Bolts & Nuts	Stainless Steel	0.23	\$6.47	\$1.49		
	Re-used	Material	Structure	Bolts & Nuts & Brackets	Stainless Steel	80	\$0.07	\$5.60		
	Purchased	Material	Structure	Gland PG9	Sealing	6	\$1.05	\$6.30		
	Re-used	Material	Structure	Gland PG9	Sealing	19	\$1.05	\$19.95		
	Re-used	Material	Structure	Gland PG29	Sealing	2	\$4.00	\$8.00		
	Services	Purchased	Fabrication	-	PCB Fabrication	PDB and PRDB	1	\$15.00	\$15.00	
		Donated	Fabrication	-	PCB Fabrication	MCB by NORI	1	\$18.00	\$18.00	
Purchased		Fabrication	-	Machining (Welding & CNC Cutting & Others)	-	1	\$50.00	\$50.00		
			Total Product Costs Invested In ROV Vehicle							\$2330.29
Product s Cost	Tether Control Unit	Re-used	Electronics	Power	Power Supply	48V 30A Mean Well	1	\$15.00	\$15.00	
		Re-used	Electronics	Communication	Ethernet Switch	5 port-switch	1	\$15.00	\$15.00	
		Re-used	Electronics	Power	Power Cable	AC Power	1	\$5.00	\$5.00	
										\$2365.29
Period Costs	Extra	Donated	Service	-	Competition Registration Fees	Paid by University	1	\$575.00	\$575.00	
		Purchased	Service	-	Pool Rent	-	1	\$200.00	\$200.00	
		Purchased	Service	-	Workplace Rent	-	1	\$100.00	\$100.00	
		Donated	Service	-	Workplace Rent	Workshop Provided by University	1	\$0.00	\$0.00	
		Purchased	Service	-	Transportation	-	1	\$110.00	\$110.00	
		Purchased	Service	-	Marketing	Flyers, T-shirts, Others	1	\$120.00	\$120.00	
			Total Period Costs Invested							\$1,105.00
			Total Expenses							\$3,470.29
			Reused + Donated Expenses							\$2,786.05
			Total Expenses without Reused or Donated							\$684.24

5 Testing and Troubleshooting

5.1 Sealing Test

The ROV shall be assembled with all mechanical components securely tightened to ensure proper sealing. No electrical components are installed at this stage; only the directional control valves (DCVs) are connected to test the pneumatic system, and all cable glands are properly fitted to seal external ports.

After connecting the pneumatic lines, the compressor is set to the required working pressure. The ROV is then placed in a test pool, where the pneumatic system is activated and monitored for air leaks. The test is considered successful if no air leaks are detected and internal pressure remains stable, confirming proper sealing and readiness for electrical integration.

5.2 Playground Test

A mission playground shall be constructed to simulate the competition environment in accordance with the specifications outlined in the rulebook. PVC pipes with the specified diameters shall be cut to the required lengths and assembled to accurately replicate the mission layout, including all tasks and obstacle geometries.

As illustrated in Figure 4.5, representative elements such as Task 3.1 (micropile) and Task 2.5 (eDNA sensor) shall be incorporated to ensure realistic testing conditions and proper validation of the ROV's capabilities.



Figure 4.5: Playground

5.3 Challenges

- **Thruster Imbalance:** We discovered that not all the thrusters produced equal power, which affected the stability and maneuverability of the ROV. To address this, we implemented compensation factors in our control system to balance the output, allowing the thrusters to operate more uniformly and improving the overall movement control of the ROV.
- **Limited Hardware Workforce:** A relatively small number of members focused on hardware development increased the workload on the team. To manage this, efforts were made to simplify designs where possible without significantly affecting performance, including reusing and adapting proven designs from previous iterations.
- **Limited Workshop Access:** The team faced inconsistent access to university workshop facilities, with periods of relocation or complete unavailability. This required temporary reliance on external rented spaces, which impacted workflow continuity. The university is currently taking steps to address and improve this issue.

6 Acknowledgments

Torpedo Company would like to thank the following benefactors:

- Prof. Mohamed Rizk, for his technical/non-technical assistance, and for being supportive all the time.
- Seif Wael, Yehia Ehab, Muhamed Tarek, Islam Ihab for transferring their experience from past years.
- Faculty of Engineering, Alexandria University, for Logistics and Transportation.
- Makers Electronics, for providing reduced electronic parts rates.
- El-Warsha, for providing all the tools and materials, for their loyalty to the team.
- MIT Technologies, for their financial sponsorship and trust in our potential.
- Alex Target, for providing us with a place to train new members and hold team meetings
- NORI Solutions, for their partnership and for providing PCB manufacturing services at a discounted rate.



Figure 4.6: Partners

7 References

- [1] *Control of Mobile Robots* online course. Georgia Institute of Technology.
- [2] ROVotron Underwater Robot Control System. (2010, April 23). Retrieved October 10, 2019, from <http://www.cathodecorner.com/rovotron/sw-desc.html>.
- [3] Bohm, H., Moore, S. W., & Jensen, V. *Underwater Robotics: Science, Design & Fabrication*.
- [4] Versteeg, H. K., & Malalasekera, W. *An Introduction to Computational Fluid Dynamics*. 2nd edition.
- [5] Sciavicco, L., & Siciliano, B. *Modeling and Control of Robot Manipulators*.
- [6] Margolis, M. *Arduino Cookbook*. 2nd edition.
- [7] Kernighan, B., & Ritchie, D. *The C Programming Language*. 2nd edition, 2011.
- [8] "Optimization of Thrust Allocation in the Propulsion System of an Underwater Vehicle."
- [9] Blue Robotics' T200 Thrusters Documentation.
- [10] Al-deen, S., Hamad, A., & Enzi, A. (2022). Design for manufacturing a stamping die to predict the thinning of 6061 aluminum sheet. *AIP Conference Proceedings*, 2660, 020059.
- [11] Ramadan, N., & Boghdadi, A. (2020). Parametric Optimization of TIG Welding Influence On Tensile Strength of Dissimilar Metals SS-304 And Low Carbon Steel by Using Taguchi Approach. *American Journal of Engineering Research*, 9, 7–14.
- [12] Jin, S., et al. (2015). Six-Degree-of-Freedom Hovering Control of an Underwater Robotic Platform With Four Tilting Thrusters via Selective Switching Control. *IEEE/ASME Transactions on Mechatronics*, 20, 2370–2378.