

TECHNICAL REPORT



Alexandria, Egypt

Graduation Year * New Member

CHIEF EXECUTIVE OFFICER

26' Mohamed Ehab - Hardware Engineer

CHIEF TECHNICAL OFFICER

26' Mazen Ramy - Hardware Engineer

CHIEF OPERATIONS OFFICER

28' Mohamed Galal - Mechanical Engineer

SOFTWARE ENGINEERS

26' Ahmed Mansour - Lead
27' Ibrahim alkady - Co-lead
28' Habiba Hossny *
28' Mostafa Mansour *
28' Abdelrahman Rafiq *
28' Mariam Ibrahim *
28' Samer Mohamed *

MECHANICAL ENGINEERS

26' Tarek Antar - Lead
27' Ibrahim Faheem - Co-Lead
26' Youssef Mahmoud - CFO
27' Youssef Essam - PR lead
26' Mohammed Hamouda
27' Mostafa Mahmoud
28' Mennatullah Emad
26' Yousef Ragab *
28' Tasneem Reda *
28' Tasneem Mostafa *
28' Jasmine Aladdin *
28' Mariam Yasser *
28' Aisha Magdy *
28' Yousef Hussein *

HARDWARE ENGINEERS

26' Hassan Fathy - Lead
27' Eslam Abbasy - Co Lead
26' Kholoud Gamal Al_Deen - HR Lead
26' Shahd Sherif - DOC Lead
26' Mennatullah Waleed
26' Mirna Tamer
26' Rania Amr
26' Salma Ibrahim
26' Yousef Ebrahim
26' Rewan Amr
26' Nouran Ashraf
26' Yasmeen Salah
26' Mai Nagah *
27' Karim Ahmed *
27' Moataz Amr *
27' Youssef Ali *
28' Malak Bahy *

Dasyatis

TEAM MENTORS

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TEAM SUPERVISOR

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ROBO- TECH

ALEX-UNI

Abstract

While the world watches the rising tides, a more profound transformation occurs in the shadows of the Earth's frozen reaches. The cryosphere, a majestic and brittle expanse of ice and snow, holds seventy percent of our planet's freshwater. Today, this vital reservoir is under siege, and with it, the stability of our global climate. From the hidden coral gardens of the deep to the wind-whipped waves of the North Atlantic, the call for action has never been more urgent. At the "Eastern Edge" of the world, the margin for error is as thin as the ice itself.

In response to these global challenges, Robo-Tech introduces Dasyatis. Inspired by the low profile and steady movement of the stingray, Dasyatis is engineered to navigate the paradox of the deep, an environment that is simultaneously fragile and fierce. It is a witness to adaptive engineering, a designed natural extension of our curiosity within the unforgiving reality of the sub-zero frontier.

Dasyatis is purpose-built for the complexity of these shifting underwater environments. Guided by the principles of adaptability, simplicity, and modularity, it is optimized to operate efficiently in sensitive ecosystems while maintaining stability and maneuverability. To safeguard the delicate biodiversity of cold-water habitats, it was refined with stabilization for precise photogrammetry and non-invasive eDNA sampling, ensuring that its presence in these habitats is as seamless as it is effective. Even when the surface is sealed by frost, Dasyatis remains unbroken, maintaining a steady connection to the world beneath the ice.

Founded at Alexandria University, Egypt, Robo-Tech has been designing, building, and competing at the highest levels of the MATE ROV Competition since 2014. At Robo-Tech, we believe that if a technology can perform here, it can perform anywhere. Beyond the mechanics of the build lies a deeper purpose: the belief that our work should leave the world better than we found it. This year, we are documenting the resilience of our planet and moving from the ocean we have to the ocean we want—one mission at a time.



Figure i: Robo-Tech Company

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Figure ii. Benefactors' logos

I. Design Rationale

1. Vehicle Overview

Dasyatis is a sophisticated integration of multidisciplinary, high-precision engineering, optimized for MATE tasks. Drawing structural inspiration from the **Lymna** ray, the vehicle's reduced vertical profile significantly lowers hydrodynamic drag while maximizing internal volume for mission-critical hardware.

The hardware architecture adopts **modular circuitry** that allows individual boards to be seamlessly swapped or upgraded, facilitating rapid field repairs and effortless system scalability. For stable maneuvering in turbulent environments, the ROV is engineered for **passive stability** and employs an active **Proportional-Integral-Derivative (PID)** control system.

To ensure total situational awareness, **Dasyatis** is equipped with a high-bandwidth imaging suite comprising one stereo camera, one 360-degree panoramic camera, and two fixed-angle cameras, with the capacity to support up to **16 simultaneous feeds**. This provides the pilot with a clear view through challenging terrain and enables advanced computational features, including **3D photogrammetry**, **automated crab detection**, and **precise length estimation**.

Dasyatis is controlled via an intuitive, browser-based Graphical User Interface (GUI), displaying dedicated pilot, co-pilot, and computer vision telemetry on a 24-inch high-resolution monitor. Controlled via a familiar ergonomic joystick interface, the entire platform is designed for immediate "plug-and-play" deployment, successfully combining deep-sea durability with a user-centric operational philosophy.

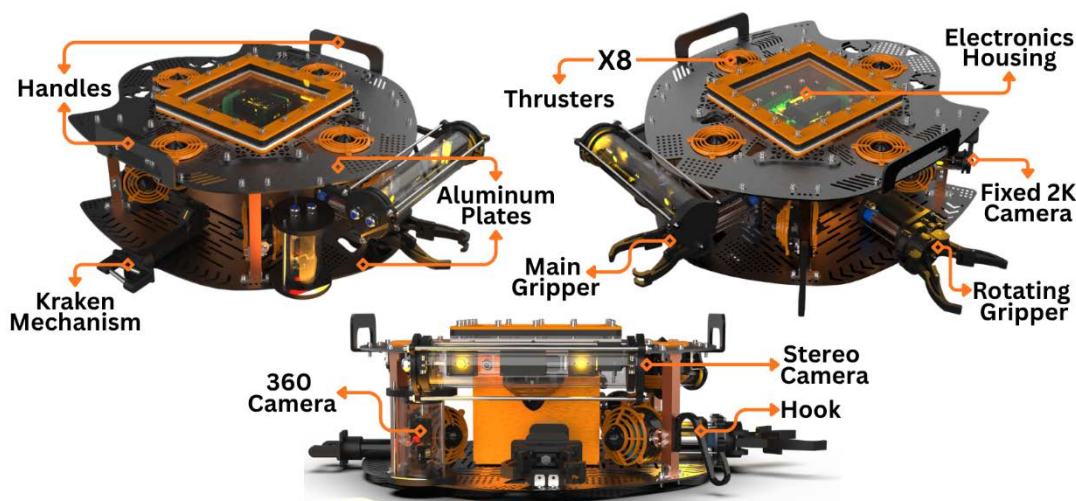


Figure 1: Dasyatis' Component Overview

2. Design Evolution

Drawing on a decade of underwater innovation and eight previous vehicle iterations, the development of **Dasyatis** began with a rigorous audit of legacy performance and emerging technologies. Our R&D process involves a systematic analysis of experimental data and previous operational challenges to identify critical optimization targets. These findings are then vetted by technical leadership to establish the core requirements, ensuring that every engineering decision serves as a data-driven advancement toward the next standard in ROV performance.



Figure 2: The Design Evolution of ROVs Built by ROBO-TECH Company

2.1. USB Hub

Our previous ROVS were limited to four cameras as the Raspberry Pi 4 could only support a maximum of four USB devices with limited power delivery. Hence, we custom designed a 4-Port USB Hub shown in figure 1.2, which allows for a total of 16 cameras if 4 USB HUBs were to be used. The USB Hub is externally powered to prevent power overload on the Raspberry Pi and is shielded with electrostatic discharge (ESD), reverse polarity and overcurrent protection.

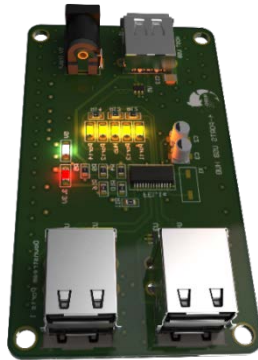


Figure 3: USB Hub

2.2. Cameras

A Significant enhancement to the visual system was the addition of two new camera technologies shown in figure 1.4. The newly installed stereo camera expands the pilot's field of view and can be used to generate a depth map for underwater length estimation and 3D modelling. Complementing the stereo camera is a 180 degrees fisheye camera incorporated to provide 360-degree images of the ROV's surrounding through **image stitching**. Both cameras provide proficient capabilities at more affordable prices than their traditional counterparts. The chosen stereo camera has a price tag of \$50 USD in comparison to the \$399 ZED2 camera. Similarly, the fisheye eye comes in at \$16 compared to the \$545 Insta360 camera.



Figure 4: Stereo and 180 Degree Cameras

2.3. Mechanical Structure

Inspired by the streamlined morphology of the *Taeniura lymma*, the 2025 design represents a significant structural evolution that prioritizes hydrodynamic efficiency and biological mimicry. This biomimetic approach led to a redesign that reduces the overall size by **45.5%** and nearly half the original length, resulting in improved maneuverability, reduced drag, and more efficient task execution. Complementing this, the replacement of previous landing gear with compact

Nylon dolphin pads allows the vehicle to maintain closer proximity to the seabed.

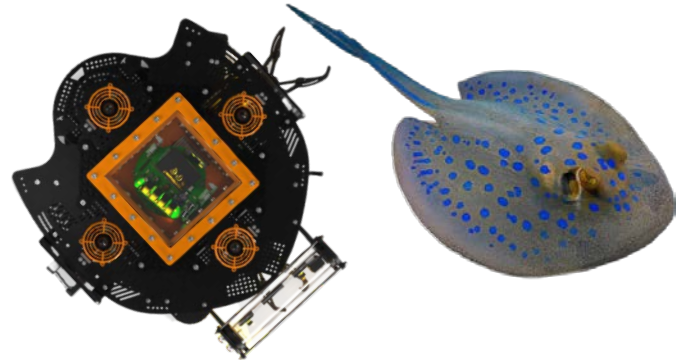


Figure 5: ROV VS real Dasyatis figure

The shift toward a symmetrical dual-plate configuration further stabilizes the vehicle by balancing the center of mass and enhancing hydrodynamic stability across the high-strength chassis. Complementing this, the main plates incorporate a standardized grid-like slot architecture, transforming the frame into a high-density "plug-and-play" interface. By eliminating the need for custom drilling, this modularity allowed for the rapid integration of complex mechanisms and manipulators, which proved critical for the recovery of the buoy anchor during MATE mission tasks.

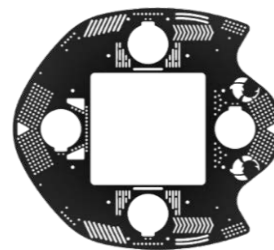


Figure 6: Upper Plates



Figure 7: Lower Plates

Additionally, the electronics enclosure was redesigned from a cylindrical to a cubic form factor. This geometric shift addresses the sealing complexities encountered in previous iterations.

2.4. Maneuverability

The propulsion system underwent a parallel evolution, transitioning from a traditional 6-thruster configuration to an advanced 8-thruster vectored layout. This expansion provides the ROV with 6 Degrees of Freedom (DOF), granting unprecedented maneuverability and the ability to execute complex diagonal and lateral movements with precision. To ensure peak hydrodynamic efficiency, optimal placement of the thrusters were determined through Computational Fluid Dynamics (CFD).

This hardware leap is managed by a sophisticated control architecture featuring active PID controllers for each of the six primary axes. This system ensures high-stability movement by dynamically compensating for cross-axis coupling; when the ROV initiates movement in one axis, the controllers automatically adjust the remaining thrusters to lock all other axes in place. This active stabilization results in remarkably smooth trajectories and rock-solid station-keeping, which is vital for high-precision mission tasks such as:

- Task 1.2 Coral garden ridge modelling,
- Task 1.3 Fly a transect over the coral garden,
- And Task 3.2 Powering an oil platform from a wind turbine

2.5. Thermal Considerations

The internal electronics architecture was significantly overhauled to address critical thermal challenges encountered during extended mission cycles. To mitigate the risk of thermal throttling in the Single Board Computer (SBC), the redesign incorporates a dedicated cooling system within a custom-engineered enclosure. This thermal management strategy integrates high conductivity heatsinks and cooling fans to maintain stable operating temperatures.



Figure 8: Raspberry Pi4 Casing



Figure 9: Raspberry Pi4 Cooling Fan

Furthermore, the system architecture now physically decouples the control electronics from the primary heat sources, such as power converters, by housing them in a separate compartment within the control box. This isolation prevents heat soak and ensures the long-term reliability of the ROV's processing unit.

3. Design Process

Dasyatis was designed from scratch, building on lessons learned from previous vehicles. Earlier issues were considered to improve performance and avoid repeated problems. The design focused mainly on simplicity and functionality, ensuring the ROV is reliable and modular while meeting MATE RFP requirements.

To overcome integration challenges experienced in previous designs, our team adopted a concurrent engineering approach. All stages of the product lifecycle are considered early during the design phase. This

proactive approach helps reduce issues that might appear later during assembly or operation.

3.1. Problem Definition

Guided by a commitment to sustainable underwater development, Robo-Tech conducts intensive annual research to address the complex challenges facing marine environments. This process begins by clearly defining mission objectives through a dual-lens approach: analyzing performance feedback from previous ROV generations and strictly adhering to the technical requirements of the MATE RFP. By carefully weighing these goals against identified technical limitations and resource constraints, the team ensures that every design choice fulfills mission tasks effectively.

3.2. Specifying Functional Requirements

After thoroughly understanding the mission landscape and challenges, Robo-Tech's engineers begin extracting the precise functional requirements necessary to address the challenges identified in the research phase, including but not limited to the requirements shown in **table 1**. The 2025 missions demand a vehicle that is highly maneuverable, steady, fault-proof, and equipped with mission tools customized for MATE RFP.

Table 1: Functional Requirements Snippet

Domain	ID	Requirement	Success Metric
Mechanical	M.1	Hydrodynamic Profile	Minimum drag coefficients and reduction in vertical profile.
	M.2	Pressure Integrity	Maintain sealing at 3.0 bar.
	M.3	Modularity	Allow for tool reconfiguration in under 5 minutes.
Electrical	E.1	Protection Features	Overcurrent, Reverse Polarity, Overvoltage, leakage detection, thermal overload protection
	E.2	Generality	Can support up to 16 cameras, 6 solenoids, 8 thrusters, 4 DC motors, 4 Servos.
Software	S.1	Active Stability	6-axis PID control must keep non-active axes within 0.5% of the setpoint during single-axis movement.
	S.2	Vision Accuracy	CV algorithms must identify and track Task 2.4 buoy anchors with > 90% confidence at 2 meters range.
Ergonomic	H.1	Safe Deployment	Integrated soft-grip handles must support 1.5x the vehicle's dry weight without deformation.

3.3. Conceptual Design and Prototyping

Following a clear definition of all functional requirements, the engineering departments initiate concurrent brainstorming sessions: the electrical team focuses on the Dasyatis' control system's architecture,

while the mechanical team utilizes free-hand sketches to explore a wide range of structural configurations. These initial ideas are subjected to rigorous, data-driven comparisons that prioritize functionality, feasibility, and ease of manufacturability, ensuring that the selected concepts align with the overarching goal of a versatile and high-performance ROV platform.

The most promising concepts are subsequently developed into detailed digital designs and physical prototypes. During this phase, the team focuses on creating solutions that remain simple and cost-effective while maintaining the technical capacity to perform complex mission tasks flawlessly. This stage relies heavily on cross-disciplinary collaboration, where both departments conduct thorough simulations and iterative prototyping to assess multiple options.

3.4. Testing, Refinement and Final Design

Prototypes undergo rigorous performance testing, with the results guiding multiple iterations of improvement to ensure the design is both refined and reliable. Once testing confirms that a subsystem meets all functional benchmarks, the final version is integrated into the ROV, prioritizing modifications that enhance performance and satisfy the MATE RFP requirements.

The finalization of mechanical and electrical architecture was supported by a suite of professional engineering tools. **SolidWorks** was utilized for 3D modeling and assembly, while **ANSYS** and **COMSOL** were employed for stress analysis and calculating drag and lift coefficients. Simultaneously, the electrical system was finalized using **Altium Designer** to produce manufacturing-ready Gerber files and a comprehensive Bill of Materials (BOM).

3.5. Manufacturing

Guided by **Design for Manufacturing Assembly (DFMA)** principles, high-precision fabrication was required for dimensional accuracy and surface quality. All enclosure components, including plates, gaskets, and the acrylic cover, were manufactured using **Laser Cutting** to minimize material waste while maintaining tight tolerances. Similarly, **CNC Routing** was utilized for the grippers links to ensure machining accuracy, providing the high-performance mechanical fit necessary for reliable underwater operation.

Custom Printed Circuit Boards (PCBs) were fabricated by JLCPCB, ensuring industrial-grade signal integrity

and structural durability. Following fabrication, Robo-Tech engineers performed the population and soldering of components, adhering to a strict internal code of conduct for quality control.

4. Systems Approach

Our design methodology is centered around a **systems engineering approach**, developing mechanical, electrical, and software domains as a single, concurrent entity. This ensures that every subsystem is optimized for seamless interoperability.

4.1. Digital Twin

By importing the mechanical design into the Gazebo simulation environment, the team accelerates development through virtual stress testing, parallel collaboration, and modular validation. This physics-based approach allows for the precise tuning of 6-axis PID constants within simulated water currents, protecting physical hardware from damage. Furthermore, cloud-based simulation enables software and mechanical designs to evolve in **parallel**, while allowing for the rapid testing of "plug-and-play" tool configurations against specific MATE RFP mission elements.

By resolving structural and logical bottlenecks within Gazebo first, the team shifts the focus of physical pool testing from "fixing" to "refining," ensuring a reliable, competition-ready platform.

II. Mechanical System

Dasyatis' Mechanical design achieves a balance of **cost-effectiveness, compact dimensions, and a lightweight structure**. Optimizing the vehicle's size slashed material costs and improved maneuverability. This iteration is a more modular version of the **Dasyatis**, with superior structural integrity and a modular framework that

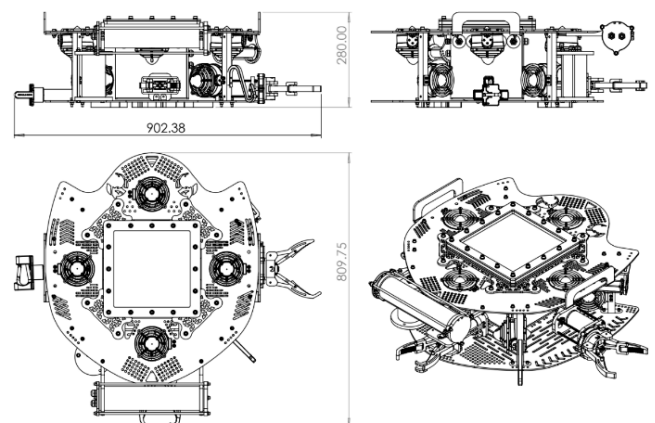


Figure 10: Dasyatis' Final Mechanical Design

facilitates rapid assembly and field upgrades. By prioritizing a streamlined design that balances agility with mission capability, Dasytis achieves the full scope of the MATE RFP within a significantly more efficient footprint.

1. Material Selection

When selecting the material and construction method for Dasytis, a trade-off matrix was developed to evaluate various metals and polymers. This evaluation considered key engineering factors such as cost-effectiveness, strength-to-weight ratio, corrosion resistance, and structural integrity.

Based on the trade-off matrix in **Table 2**, **Aluminum 1050-H14** was selected for the frame and control box due to its low cost, superior machinability, and low

Table 2: Material Tradeoff Matrix

Criteria	Acrylic (PMMA)	Aluminum 1050-H14	Stainless Steel	Nylon 101	PLA
Cost Effectiveness	3	2	1	4	4
Strength	2	4	5	3	2-3
Ductility	1	5	4	4	2
Density (g/cm ³)	1.2	2.7	8	1	1.24
Transparency	5	0	0	0	0
Thermal Conductivity	1	5	2	1	1
Corrosion Resistance	5	4	5	5	3

density. It provides the necessary compressive strength required by the MATE RFP, offering an effective balance between structural performance and weight reduction. Additionally, **Nylon 101** was selected for the gripper manipulators due to its high ductility and impact resistance. Its inherent toughness and flexibility allow the gripper to withstand significant clamping forces and concentrated loads without fracturing, ensuring reliable durability during high-stress mission tasks.

2. Frame

The frame is constructed from **aluminum alloy 1050-H14**. This alloy choice allowed improving structural strength of the ROV. To improve vehicle stability in water and achieve better load distribution across the frame, a symmetric structural configuration was adopted for both plates. The upper plate houses key components such as the control tube, propulsion system, and cameras. The lower plate is mainly used for mission-specific mechanisms. While the plates share an identical outer profile, their internal topology and cut-outs vary to accommodate a modular design. Standardized slots and

holes enable the integration of mission tools, facilitating assembly, tool expansion, and precise placement adjustments. This design approach ensures the ROV remains adaptable to diverse mission requirements while providing a stable, high-strength foundation for all subsystems.

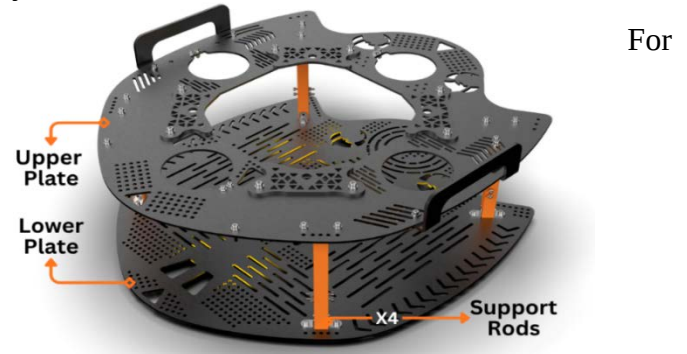


Figure 11: Dasytis' Frame

modularity, the control box rests on extension plates, which allow it to be removed independently without dismantling the upper plate.

Additionally, two padded handles were integrated into the primary chassis, positioned to ensure balanced weight distribution during deployment and retrieval, while providing comfortable grip.

To further refine the framework, support rods were replaced with Square Hollow Section (SHS) extrusion tubes, providing a more practical solution for mounting and assembly, as shown in the trade-off matrix (Table 3).

Table 3: Material Criteria Table

Criteria	Criteria Weight	V Slots	Threaded Rods	Aluminum Strips	Square Tubes
Cost Effectiveness	0.2	3	4	3	5
Strength	0.2	5	5	4	5
Corrosion Resistance	0.1	5	5	5	5
Weight	0.2	4	3	2	4
Mounting Ease	0.15	4	1	4	4
Hydrodynamic Drag	0.15	4	5	2	3
Total Score		4.1	3.8	3.2	4.35

2.1. Computational Structural Synthesis

Prior to fabrication, the frame plates underwent rigorous **Finite Element Analysis (FEA)** and **Topology Optimization** within ANSYS® to ensure mission reliability. By applying **Fully Stressed Design (FSD)** methods, the R&D team identified and eliminated low-stress material regions, achieving a **10% reduction in overall frame mass** while maintaining high mechanical integrity. The optimization results are shown in **Table.4**

Table 4: FEA Results Table

Criteria	Lower Plate	Upper Plate
Maximum Stress (MPa)	26.9	13.1
Max Deformation (mm)	0.25	0.182
Min Factor of Safety	9.2	3.2

The visual results of this optimization and the resulting stress distributions are illustrated in the figures below.

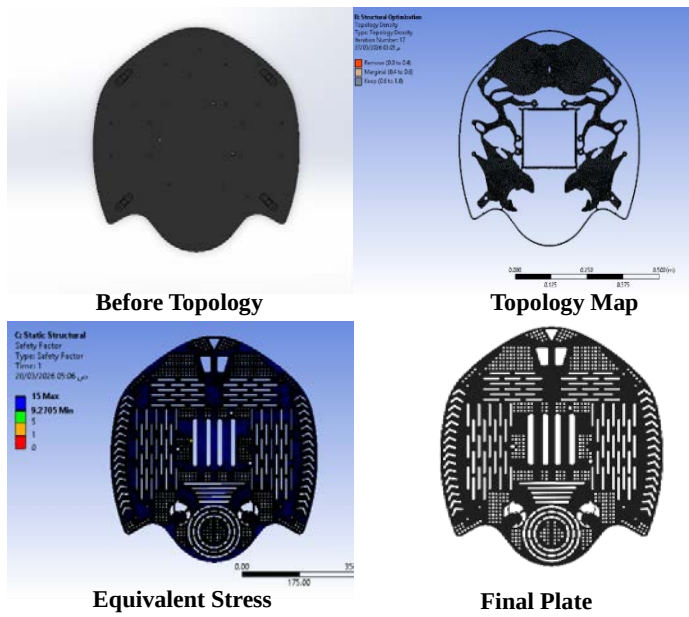


Figure 12: Lower Plate Topology Optimization and stress analysis

3. Electronic Housing

Dasytis features a custom centralized control box constructed from **5 mm Aluminum 1050-H14**. Moving from a dual-box configuration to a single **21 cm cubic** geometry optimized the Design for Assembly (DFA) by reducing system complexity and maximizing cable gland accessibility. Following a multi-criteria trade-off analysis (Table 5), the cube was selected for its superior space efficiency and sealing reliability.

Table 5: Electronic Housing trade-off analysis Table

Criteria	Weight	Slot Shape	Rectangular	Cuboid	Horizontal Cylinder	Vertical Cylinder
Free Hand Sketch						
Space Efficiency	0.15	3	4	5	2	3
Ease of Sealing	0.2	4	5	5	3	3
Cable Gland Integration	0.2	4	5	5	3	2
Component Accessibility	0.15	4	3	4	1	2
Manufacturing Complexity	0.15	4	2	2	3	5
Hydrodynamic Stability	0.15	2	3	4	3	2
Drag Force	0.1	2	2	2	3	5
Total Score		3.75	4	4.45	2.85	3.3

To facilitate direct visual inspection of internal electronics, a transparent Acrylic cover was integrated and validated via Static FEA at a target mission depth of **15m (1.5 bar)**. The simulation recorded a peak **Equivalent Stress of 33.02 MPa**, maintaining a **1.36 Factor of Safety** against the material's tensile limits.

A gasket serves as the primary sealing interface, while Aluminum washers were utilized to distribute clamping

forces preventing localized brittle fracture ensuring long-term seal integrity under hydrostatic load.

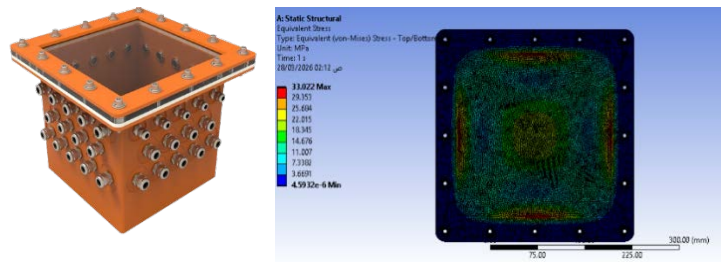


Figure 13: Dasytis' control box FEA

4. Payload and Tools

4.1. Cameras and Sensors

At Dasytis' core is a **BNO085 Inertial Measurement Unit (IMU)**, combining an accelerometer and gyroscope to track motion and orientation across three axes. With a rotation vector accuracy of $\pm 2.5^\circ$, it feeds an active PID control loop for real-time stabilization.

Depth is monitored using the **MS5837 water-depth sensor**, supporting vertical stability and depth holding. For safety, an **MH-RD raindrop sensor** at the lowest point of the electronics enclosure detects leaks; if triggered, high power is shut off.

As for the vision system, a **stereo camera (Gxvision-LSM36156)** is mounted front and center as the primary navigation camera, servo-controlled for rotation and tilt. It estimates depth using dual sensors (90° FOV, adjustable baseline).

A **fish-eye (photosphere) camera** is mounted on the lower plate to view both “Mr, Krabs” and “Kraken”. It rotates to scan the workspace, provides 180° coverage, and is used for coral garden modelling and photogrammetry. At **\$16**, it is a cost-effective alternative to the **Insta360 (\$545)**.



Figure 14: Servo & Photosphere Camera

A **fixed 2K resolution camera** monitors the rotating gripper and “Captain Hook”. All onboard cameras use precision O-ring sealing to maintain watertight integrity.

The combined sensors and cameras provide continuous feedback, enabling accurate depth control, navigation, and manipulation under varying conditions.

4.2. Manipulators and Mechanisms

a. Main Gripper “Mr. Krabs

Mr. Krabs was engineered to prioritize high gripping force, kinematic reliability, and operational simplicity. To minimize failure points in subsea conditions, the mechanism uses a minimalist linkage architecture, reducing part count while ensuring predictable actuator response.

The mechanical advantage is derived from a **toggle-linkage configuration**. As the mechanism approaches its terminal closing phase at a critical angle ($\theta < 5^\circ$), the transmission ratio increases significantly, allowing the gripper to exert maximum clamping force with minimal input torque. Operating at a nominal pressure of 1.5 bar and a 14 cm maximum aperture, the system generates a baseline gripping force of 55.5 N, ensuring reliable clamping across the operating range.

To enhance payload security, the jaws feature a serrated zigzag profile to concentrate contact stress, combined with nylon fiber pads to increase friction and prevent slippage.

The DCV system is enclosed in a custom-designed casing for improved durability and operational safety.



Figure 15: Mr Krabs

b. Rotating Gripper

A second gripper was developed based on the “Mr Krabs” design due to its proven reliability, with an added rotation at the end effector. This idea emerged during **Task 2.5**, where removing biofouling from the Holyrood subsea observatory camera was required. The added rotation enables a scrubbing motion, making cleaning more effective while maintaining the original gripping function. Having two grippers also allowed the ROV to handle multiple tasks simultaneously.

Rotation is achieved using a DC motor placed at the end effector, with motion transmitted through aligned gears. A dedicated housing was designed for underwater operation, sealed with O-rings at the joints and a shaft seal at the output to prevent water ingress while allowing

rotation. The cable entry is also sealed, and the enclosure is tightly secured to protect internal components from water and pressure.

c. Non-ROV Device (Float)

The movement of the float is powered by the buoyancy engine. The engine mechanism is driven by a DC motor with a torque of 50 kg·cm and a water-sealing piston. By changing the piston’s position, the volume of the closed compartment of the float decreases. The design follows a DFA approach.



Figure 16: Float

The summary of all mechanisms is presented in **table 6**:

Table 6: Mechanisms

Mechanism	Description
	“Captain Hook” An open hook that is used to carry some fixed particles from the ground, as in real life you can use it to gather waste accumulated in the ocean or collect coral reefs that affect the environment negatively. Its main task is Task 1.1
	“Kraken” A mechanism designed to be attached to objects with handles or any hollow piece in it. Once the object is attached, the cap separates from the main body while remaining connected through a flexible long wire that is wound around a reel fixed on a torsional spring, allowing the ROV to attach and pull objects attached without needing any direct contact throughout the process, the whole mechanism is fixed on the ROV plate. Its main task is Task 2.4
	“Rotating gripper” A dual-jaw gripper equipped with a DC motor that can grip surfaces and rotate to remove debris and buildup. The motor is carefully sealed using appropriate static and dynamic sealing methods to ensure reliable underwater operation. Its main task is Task 2.5
	“Mr. Krabs” A multi-purpose manipulator with dual jaws, designed to securely grasp and reliably handle objects of different geometries, including PVC pipes. Can be used in all other tasks

5. Propulsion System

Dasytis utilizes a vectored propulsion system comprised of eight Blue Robotics thrusters to achieve full **six degrees of freedom (6-DOF)**. This configuration ensures high maneuverability and stability through the following arrangement:

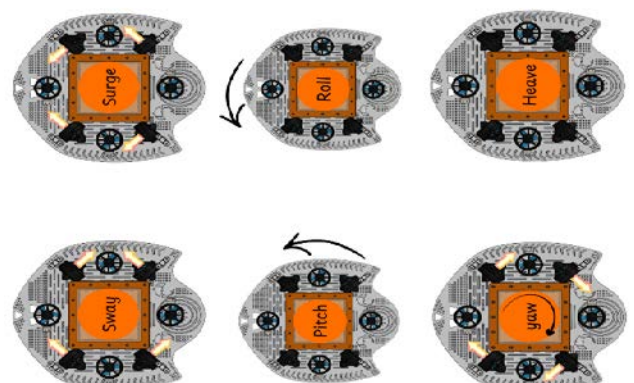


Figure 17.: Dasytis' Thruster Configuration

- **Horizontal (45° X-Configuration):** Four **T200** thrusters enable surge, sway, and yaw, generating **91.96 N** of effective forward thrust.
- **Vertical (Lateral Axis):** Two **T200** thrusters located at the front and rear manage heave and pitch control via differential thrust.
- **Roll Stabilization:** Two **T100** thrusters added to the longitudinal sides enhance vertical distribution and enable controlled roll motion.

With a combined vertical lift of **119.08 N**, this architecture allows Dasyatis to counteract hydrodynamic forces and maintain precise control during complex underwater operations.

5.1. CFD Hydrodynamic Analysis

To evaluate the hydrodynamic performance of the vehicle, a Computational Fluid Dynamics (CFD) analysis was conducted using ANSYS Fluent. The simulation modeled the ROV operating in a steady underwater environment with a flow velocity of 0.5 m/s.

$$F_D = \frac{1}{2} \cdot \rho \cdot V^2 \cdot A \cdot C_D$$

Where $\rho = 997 \text{ kg/m}^3$, $V = 0.5 \text{ m/s}$, $A \approx 0.2304 \text{ m}^2$

Based on these parameters, the simulation yielded a drag coefficient of approximately **0.89** and a hydrodynamic drag force of **14.18 N**. These results confirm that the propulsion system provides sufficient thrust to overcome hydrodynamic resistance while maintaining effective maneuverability.

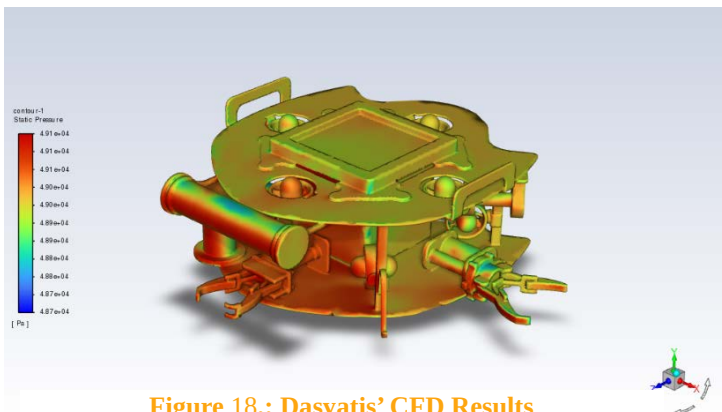


Figure 18.: Dasyatis' CFD Results

6. Buoyancy and Ballasting

Per Archimedes' principle, ROV was engineered to maintain slight positive buoyancy, reducing thruster load during missions, enhancing stability, and ensuring surfacing in emergencies. To achieve this, SolidWorks

was utilized to model the Dasyatis' physics and predict buoyancy requirements. A comprehensive Mass Budget Matrix was developed, accounting for the volumes and masses of all sub-assemblies. The analysis determined a **total weight of 223.6 N** against a **buoyant force of 146.79 N**, resulting in a net downward force of 76.8 N as shown in **table 7**.

Table 7: Buoyancy Effects

Type	Quantity	Displaced Volume (cm ³)	Mass Outside water (g)	Buoyant Force (N)
Electronics Enclosure	1	6268.2	8012.2	61.49
Main Plate	1	760.3	2053.33	6.9
Lower Plate	1	1044.4	2820.06	9.66
ROV legs	3	276.1	320.28	2.4
Stands	4	84.3	237.12	0.8
Thruster	8	2814.48	1494.8	28.1
stereo Camera Casing	1	1253.78	750.60	12.3
Photosphere Camera Casing	1	687.57	555.04	6.75
Fixed Camera Casing	1	139.5	183.5	1.2
T&M gripper	1	315.3	309.2	2.8
Rotating gripper	1	650.1	620.1	6.2
Hook	1	22.2	22.8	0.2
Kraken	1	182.5	198.3	1.6
Solenoid Valve	2	203.4	544	2.01
Glands	45	227.7	805	2.1
Extension Plate	4	143.73	388.8	1.39
Bolts	96	77.2	608.35	0.71
Nuts	116	8.45	159.92	0.08
Washers	186	11.49	89.2	0.105
TOTAL		15,170 cm³	20.17Kg	146.8N

To counteract negative buoyancy and achieve neutral stability, a modular ballasting system was integrated. It utilizes high-density, non-toxic **EVA foam** (repurposed from swimming kickboards) paired with dual air tanks. The foam was selected for its high buoyancy-to-weight ratio, closed-cell structure to prevent water absorption, and ease of integration within the modular frame.

Since changing mechanisms naturally shifts the vehicle's **center of gravity (CG)**, the ballasting system was designed to allow for precise adjustments of the **Center of Buoyancy (CB)**. By positioning the high-density EVA foam and air tanks at the upper plate, the team ensured **the CB remains vertically offset above the CG**. This configuration creates a restoring torque that automatically levels the ROV, preventing pitch and roll instability during heavy payload operations. A quick comparison between Dasyatis and its predecessor is presented in **table 8**

Table 8: different weight and buoyancy

Criteria	LEVI X 2025	Dasyatis 2026
Weight (N)	241.3	223.6
Buoyancy Force (N)	166.34	147.8

III. Electrical and Control System

1. Electronic Design and Cabling

Empowering Dasytis to operate reliably, its electronic system was designed around modularity, robustness, and efficiency. This ensures reliable operation in an underwater environment while allowing rapid debugging, component replacement, and future upgrades.

Polarized connectors (Figure 19), including **IEC14**, **XT60**, and **SBS50 Anderson** for power, and **JST** and **ribbon cables** for data, are used to eliminate misconnection failures. Given Dasytis' vibration-intensive environment, all connectors include secure locking mechanisms to prevent accidental disconnection. Strain relief is applied at both the ROV and TCU ends in compliance with **ELEC-025E**, protecting against tether tension. Cables and connectors are color-coded and labeled by power buses to reduce wiring errors and simplify maintenance. The cabling system is designed to withstand mechanical wear and thermal stress during continuous operation.

The electronic housing is designed for compactness and modularity. Mechanically sealed inlets/outlets with bullet connectors enable rapid assembly, while double-row headers eliminate the need for interfacing cables. A custom ESC holder organizes and secures wiring. Overcurrent and overvoltage protection are implemented system-wide, supported by a leakage detection system that triggers immediate shutdown of the main power.



Figure 19 Polarized Connectors

2. Top-side Control Unit

Dasytis custom plug-and-play TCU serves as the pilot's command center, powered by an Intel Core i3 processor. A managed LAN switch interconnects all onboard devices, while a 24" FHD LCD provides a clear video feed. Safety is addressed through a dedicated red kill switch, name-tagged cables, color-coded power/signal lines, and foolproof connectors. Anderson Power Pole

connectors handle the high-current DC line, while a CAT6 shielded RJ45 simplifies Ethernet interfacing. This year, we have included status monitoring through a digital voltmeter and ammeter. Additionally, a PS5 controller is now used for a more user-friendly interface.

3. Tether

Securing the connection between the TCU and the ROV, Dasytis' tether was extended from 22m to 30m to increase range. As shown in Figure 3.2, it comprises a shielded CAT6 (SFTP) cable, a polyurethane pneumatic hose, and two 11 AWG PVC-insulated wires carrying 48 V, wrapped in a braided nylon sheath and maintained neutrally buoyant through distributed foam. Strain relief is implemented at both ends. The 11 AWG pair have a total resistance of 0.30 Ω to minimize voltage drop as follows:

$$\therefore V_{drop} = I_{wire} * R_{wire} = 7.92V$$

$$\therefore \%V_{drop} = \frac{V_{drop}}{V_{Total}} * \frac{7.92}{48} * 100\% \approx 16.5\%$$

This system supplies the ROV with 40.12 V, safely above the undervoltage shutdown limit of the DC-DC converters. **CAT6** shielded cables handle camera video transmission and TCU communication, chosen for their high signal-to-noise ratio to minimize interference and crosstalk. An **Anderson connector** at the surface interface prevents power line misconnection. Before deployment, the tether is uncoiled, and strain relief is secured. After use, it is disconnected, strain relief is removed, and the tether is recoiled to prevent damage and tripping hazard

4. Onboard Electronics

The robustness and flexibility of Dasytis' control system stem from its modular onboard electronics, structured into two subsystems: the **Main Board** and **Auxiliary Boards**. The auxiliary boards connect via double-row female headers, enabling a plug-and-play architecture that allows easy removal, replacement, and servicing, improving maintainability and reducing downtime. To support rapid debugging, unit testing, and fault detection, voltage indicator LEDs are distributed throughout the system.

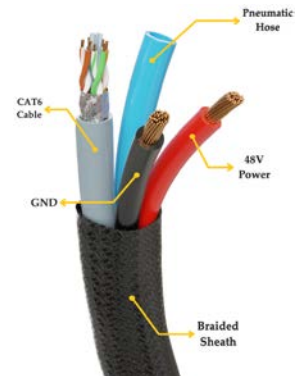


Figure 20 Tether

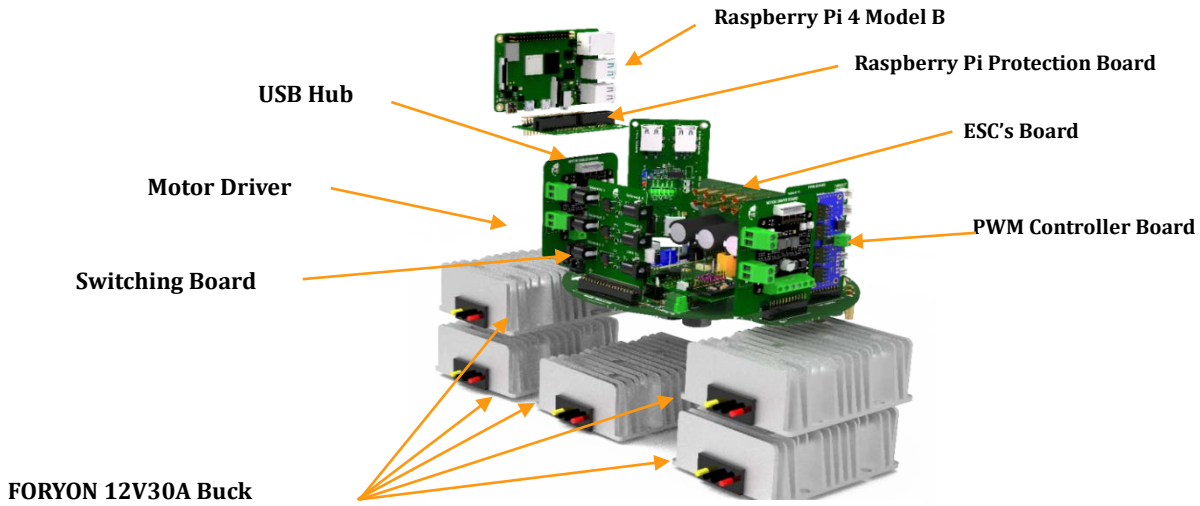


Figure 21. Dasyatis' Hardware system

4.1. Main Board

The Main Board is 4-layer board with the sole purpose of distributing power to the system, generating and processing signals, and acting as a convergence zone to multiple auxiliary boards. It is further modularized into three main units: Power Regulation Unit (PRU), Main Control Unit (MCU), and Feedback Unit (FBU).

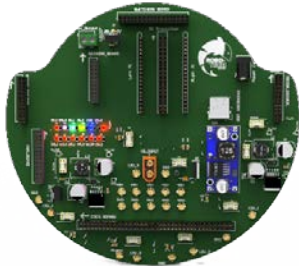


Figure 22: render main

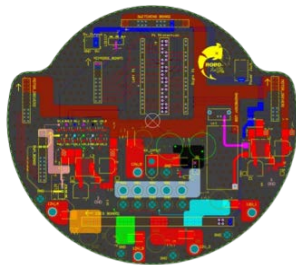


Figure 23: layout main board

a. Power Regulation Unit (PRU)

The PRU employs multi-stage isolated power architecture to deliver regulated **3.3 V**, **5 V**, and **12 V** rails. To optimize size, cost, and reliability, the design utilizes custom converters and regulator stages for tighter integration and improved performance.

High-current thrusters are powered by four dedicated **Foryon buck converters**, each supplying a pair of thrusters. This segmentation isolates inductive loads, mitigating voltage spikes, electrical noise, and back-EMF from propagating to other subsystems. A separate Foryon converter powers auxiliary electronics, ensuring stable supply for control and sensing circuits.

This architecture enhances reliability through partial redundancy, where faults in one branch do not affect others. Secondary regulation stages generate stable **5V** and **3.3V** rails for embedded processors, microcontrollers, and sensors.

Table 9: chosen converters

Converter	Output volt (V)	Current (A)	Load	Features
Foryon Buck (x4)	12V	30A	Thrusters (2 per converter)	Dedicated isolated paths, prevents voltage spikes, handles inductive loads
Foryon Buck (Aux)	12V	20A	Auxiliary electronics	Array of protection from voltage and current
XL4005	5V	5A	Raspberry Pi	High current capability and Compact design
LM2596HVS	5V	3A	General 5V electronics	Reliable and cost-effective
LD1117 regulator	3.3V	1A	Sensors & PCA	Low noise output and ideal for sensitive circuits

As summarized in Table 10, the maximum system power consumption is approximately **1133.75 W**, drawing **22.86 A** from a **48 V** supply. Applying a **1.25 safety factor** yields **28.58 A**, for which a **30 A fuse** is selected.

Table 10: Power Consumption

component	Input volt (V)	Max. Current (A)	Quantity	Power (W)
Thrusters	12V	10.4A	8	998.4W
DCV	12V	0.33A	2	7.92W
Motor Driver	12V	3A	1	36W
USB hub (powered 4 cameras)	5V	2A	1	10W
Raspberry pi	5V	3A	1	15W
servos	5V	2A	3	30W
sensors	5V	0.02A	4	0.4W
PCA (Servo driver)	3.3V	0.01A	1	0.033W
Total	-----	-----	-----	1097.75W

b. Main Control Unit (MCU)

The **Raspberry Pi 4B** was selected after comparison with the Nvidia Jetson Nano and Raspberry Pi 5. While Jetson offers higher GPU compute and the Pi 5 higher clock speeds, the Pi 4B provides the best balance of performance, ROS compatibility, USB bandwidth for four cameras, and cost-effectiveness, meeting Dasyatis' requirements without over-engineering. Communication with the PWM interface board and peripherals is handled via **SPI** and **I2C**.

4.2. Auxiliary Boards

a. ESCs Board

The Electronic Speed Controllers (ESCs) board offers comprehensive support for up to eight ESCs, providing the necessary power needed by each thruster. The board has been designed such that each thruster is linked to it through a pluggable bullet connector. Decoupling capacitors are placed at each connector to suppress switching transients.

b. Motor Driver Board

A custom full H-bridge design using **RU3560** N-channel MOSFETs and **IR2111** gate drivers, delivering up to **10 A** continuous at **12 V**. The decision to develop a custom board, rather than using an off-the-shelf module, was driven by supply chain constraints and the need for precise current and form-factor compatibility. Optocoupler isolation between control and power stages ensures signal integrity.

c. Switching Board

Playing a key role in the ROV control system, the switching unit controls a flash and up to five solenoid valves, all requiring precise synchronization. The board supports additional switching channels to accommodate future expansion. It receives control signals and power from the main board and activates loads using a **BJT-MOSFET configuration**. For safe operation, it monitors current load and temperature.

d. Controller Interface Board

The Pi is complemented by a controller interface board that generates PWM and digital signals for actuators and motors. It has two variants: one based on a **PCA9685** and another using an **STM32**. Both provide the required PWM for motor drivers (gripper positioning), ESCs (thruster control), and servos, while the STM32 variant adds up to **8 ADC channels** for analog sensing. The board is electrically isolated to maintain signal integrity. An edge connector enables hot swapping between variants without rewiring, preserving flexibility.

e. Protection Board

As a critical and costly component, the **Raspberry Pi** is protected from common electrical hazards using a dedicated protection board. It includes GPIO voltage clamping, current limiting, and overvoltage protection on the power rail. The board also features integrated

status LEDs for real-time monitoring, along with an active cooling fan to maintain thermal stability during sustained operation.

IV. Software System Design

1. GUI

Our Graphical User Interface was designed to provide a highly efficient and intuitive control environment for ROV operations, enabling seamless interaction between the pilot, co-pilot, and onboard systems through real-time monitoring and flexible control tools.

1.1. Figma

To decouple interface design from development, the GUI was prototyped in **Figma** before implementation. This enabled early validation of layout, usability, and operator workflow without software overhead. Figma's real-time collaboration supported concurrent team review and iterative refinement, ensuring critical elements (telemetry, control inputs, and camera feedback) were logically organized before implementation, minimizing integration errors and reducing rework.

1.2. Pilot View

The Pilot View provides full ROV control and real-time monitoring from a single interface. A live health bar displays CPU load, RAM usage, temperature, connection status, and active alerts. A 3D orientation module visualizes yaw, pitch, and roll for accurate situational awareness. The camera system supports multiple live feeds, with full operator control over drag, resize, flip, rotate, and enable/disable actions through a dedicated editor panel. Pilots can save and switch between three custom layouts, and a capture button supports photogrammetry acquisition. A side panel provides quick access to Debug and Autonomous Mission modes, enabling smooth transitions during operation.

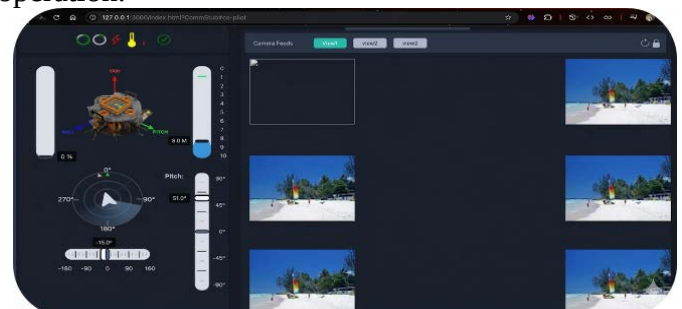


Figure 24: GUI Pilot View

Co-Pilot View

A full navigation panel on the left exposes speed, depth, yaw, and pitch sliders for gradual adjustments, complemented by a radar display to assist with orientation in confined spaces. A collapsible log panel provides system diagnostics, including power fluctuations and sensor fault alerts, without cluttering the primary interface, balancing information density with operational clarity.

2. Control System

Robo-Tech's control system is based on the open-source Robot Operating System (ROS2), running on a Raspberry Pi 4. ROS2 serves as the core control framework, managing real-time data exchange between sensors, actuators, and onboard nodes. The ROS-Bridge-Server enables seamless communication between the onboard system and the GUI through ROS-defined topics and services.

The system is organized into various ROS packages, as depicted:

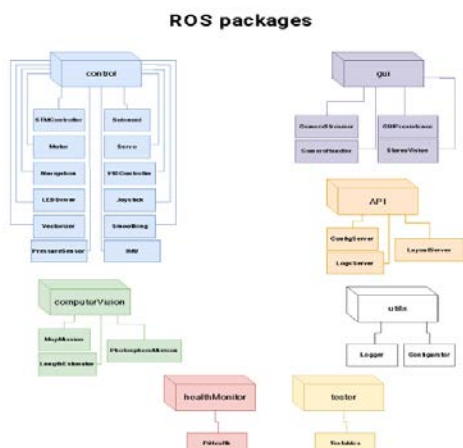


Figure 25: System Architecture (ROS)

2.1. Control

The control system is engineered as a **bifurcated processing pipeline** that separates high-level mission logic from low-level hardware timing. This architectural decision assigns intensive data processing to the Raspberry Pi 4, while delegating PWM generation and GPIO toggling to an ESP32. By offloading real-time actuation to dedicated hardware, motor signals remain jitter-free and independent of the Linux kernel's scheduling latencies. High-level drivers abstract these hardware interactions into a unified API, allowing the navigation layer to command complex maneuvers through standardized ROS2 topics and services.

2.2. Sensor Feedback

Unlike conventional IMUs that output raw measurements, the BNO085 performs internal fusion using embedded algorithms, delivering stabilized orientation data directly to the controller. This reduces computational load on the Raspberry Pi, minimizes control loop latency, and improves noise robustness. IMU data is fused with hydrostatic pressure readings from the depth sensor to form a reliable feedback loop enabling accurate state estimation, stable station-keeping, and precise depth control.

2.3. PID control system

The control system implements a parallel PID architecture to regulate motion under nonlinear hydrodynamic effects, including drag, buoyancy variation, and added mass. The proportional term (**k_P**) provides immediate corrective action; the derivative term (**k_D**) introduces damping to suppress overshoot during rapid vertical motion; and the integral term (**k_I**) compensates for steady-state errors caused by buoyancy imbalance, tether forces, and environmental drift. An anti-windup mechanism prevents actuator saturation and maintains control responsiveness.

A dynamic gain scheduling strategy adjusts PID gains (**k_P**, **k_D**, **k_I**) in real time based on operating conditions such as depth, velocity, and error magnitude, ensuring consistent performance across varying hydrodynamic regimes.



Figure 26: PID Control Flow

2.4. Motion processing

Vectorization and smoothing modules operate alongside the PID controller to convert operator inputs into coordinated thruster commands. The system computes the required output per thruster to achieve the desired global velocity vector, while ramp-based smoothing algorithms prevent abrupt power changes and reduce mechanical stress. A dedicated switching node bypasses the main navigation pipeline to directly control the gripper via joystick input, ensuring fast and responsive actuation during precision manipulation tasks.

2.5. Control pipeline

The pipeline concludes with a telemetry and visualization layer bridging the ROV and surface station. Joystick post-processors normalize and scale raw HID inputs before passing them to the navigation node, which manages the full pipeline from command interpretation to actuation. Real-time video is handled by a high-bandwidth camera streaming module on the Raspberry Pi 4, delivering low-latency feeds from all onboard cameras, including the stereo system, to support navigation and obstacle avoidance in low-visibility conditions.

2.6. Utils

The utils package serves as the architectural backbone of our system, ensuring operational consistency through centralized configuration and structured telemetry. By implementing a real-time logging pipeline, the package captures and relays diagnostics to the GUI, facilitating immediate fault detection and system-state monitoring.

To ensure a maintainable and scalable codebase, we prioritized splitting hardware dependencies from core logic. The configurator is the cornerstone of this philosophy, abstracting pin assignments and module interfaces into high-level configuration files. This eliminates the need for intrusive code modifications, allowing the system to evolve without compromising its integrity. Furthermore, by exposing PID parameters and controller mapping for real-time adjustment through the GUI, we have moved from static programming to dynamic system optimization, making the tuning process both intuitive and responsive.

3. Computer Vision

Integrating computer vision into modern underwater missions is essential for transforming raw visual data into the meaningful environmental insights required for autonomous analysis. By converting these images into actionable information, computer vision algorithms significantly enhance situational awareness and support more efficient decision-making throughout the mission. To facilitate these operations, our system features a dedicated Computer Vision panel within the graphical user interface (GUI). This unified and streamlined interface allows operators to seamlessly execute mission-specific algorithms, manage captured data, and visualize processing results in a single, professional environment.

3.1. Crab Detection

The goal of this task is to automatically detect and count green crabs in underwater images. Automating this process reduces the need for manual analysis and enables faster environmental monitoring during the mission.



Figure 27 Crabs Detection

The crab detection system utilizes the YOLOv8 object detection architecture, selected specifically for its optimal balance between high detection accuracy and real-time processing capabilities. To ensure robustness under diverse underwater conditions, including varying orientations and shifting lighting, the model was trained on a comprehensive dataset encompassing multiple crab species.

The detection pipeline follows a structured three-step process: initial image acquisition via the onboard camera, object detection using the trained model to predict bounding boxes and class labels, and precise filtering to isolate the specific green crab class required for mission objectives. Finally, the system generates an annotated image displaying bounding boxes and class labels while providing a definitive count of the total detected green crabs for immediate operator analysis.

3.2. 3D Environment Modeling

The 3D environment reconstruction system generates high-fidelity models of underwater structures from mission-captured imagery, providing a powerful tool for structural inspection and longitudinal analysis. By leveraging photogrammetric techniques, raw visual data is transformed into accurate 3D representations for monitoring subsea integrity over time. The workflow begins with data collection, where stereo image pairs are captured via the GUI and stored in a centralized directory. Images are acquired with sufficient overlap and multiple viewpoints to ensure accurate reconstruction. A CLI command then triggers an automated **Agisoft Metashape** pipeline, performing feature detection, point matching, and mesh generation to convert 2D images into 3D spatial data. The final output is a standardized **FBX file**, enabling seamless visualization and analysis in Metashape or other CAD software.

3.2.1 Comparison of 3D Reconstruction Approaches

a) Traditional Depth Maps Approach:

Depth maps were acquired from sensors or depth-capable cameras. Each map was converted into a point cloud and merged into a single model using stitching techniques such as **ICP**(Iterative Closest Point) and **RANSAC**). Alignment relied heavily on depth accuracy, making the process sensitive to noise and measurement errors.



Figure 28: Traditional Depth Maps Model

b) Metashape-Based Approach:

The process utilizes image-based reconstruction instead of raw depth maps to create detailed 3D environments. It begins with feature detection, where algorithms such as **SIFT** align images by identifying matching points and estimating camera positions. **Depth** is then derived to generate depth maps, which are converted into dense point clouds and subsequently processed into a 3D mesh.

Automatic optimization improves alignment accuracy, reduces noise effects, and enables efficient generation of high-quality 3D models.



Figure 29: Metashape Model

Key Takeaway:

The traditional approach depends on raw depth data with more manual intervention and higher error potential. Metashape delivers a more precise, automated, and reliable reconstruction workflow, resulting in superior 3D models.

3.3. Length Estimation

Estimate the real-world length of underwater objects using stereo camera images without direct contact.

The system uses stereo vision, where two cameras capture the same scene from different viewpoints. The operator selects corresponding points on the object through the GUI, and the system estimates their depth using stereo geometry. The spatial distance between these points is then calculated to determine the object's real-world length.

The estimated length is displayed through the GUI, along with a visual confirmation of the selected points on the stereo images.

3.4. keel Depth Analysis & Threat Evaluation

Yellow: 5 – 10 nautical miles, Red: < 5 nautical miles, Green: >10 nautical miles.

If the iceberg keel depth exceeds 110% of the ocean depth, the iceberg will ground before reaching the platform and the threat level becomes Green. For subsea assets, the threat level is determined by comparing the keel depth with the ocean depth.

The system reports the threat level for surface platforms and subsea infrastructure, allowing operators to quickly identify potential hazards through the interface.

V. Safety

"Safety doesn't come with luck; it has to be prepared." At Robo-Tech, the safety of our team is the foundation of our workflow. We implement a rigorous safety culture that meets all **MATE guidelines** to ensure a smooth, injury-free environment.

This commitment begins with **comprehensive training**; new members are never allowed to work independently. Instead, they undergo extensive on-ground tutorials led by senior mentors, progressing from close observation to independent tasks only after demonstrating a firm grasp of lab protocols.

1. Lab Safety Protocols

PPE Requirements: Everyone is assigned appropriate PPE, including safety glasses, closed-toe footwear, and gloves for machining, welding, or pneumatic assembly.

Operational Rules: High-pressure testing requires physical barriers, and electrical work is preceded by insulation tests.

Collaborative Safety: A strict "two-engineer rule" is enforced during fabrication and testing to ensure immediate assistance.

Maintenance & Hygiene: Fire extinguishers and first aid kits are regularly inspected, hazardous materials are labeled and stored in designated areas, and equipment use is tracked via a sign-in sheet.



Figure 30: Lab Safety Protocols

2. ROV Safety Architecture:

Safety is integrated into the very DNA of our ROV, Dasyatis. The vehicle is designed with redundant mechanical, hardware, and software fail-safes to protect both the operator and the equipment.

2.1. Mechanical Safety Features

Dasyatis features a streamlined frame with no sharp edges and capped bolts to prevent handling injuries. All propellers are shrouded with safety guards on both sides. To manage pneumatic risks, a pressure **relief valve** is integrated into the compressor, set to **1000 kPa** (our maximum allowable pressure), while multiple O-

rings provide sealing redundancy to prevent single-point failures.

2.2. Hardware Safety Features

Adhering to strict electrical standards, the system incorporates a multi-layered safety and protection strategy. **Regarding stress mitigation**, strain relief is applied at both ends of the tether to protect sensitive connectors from mechanical fatigue. **Moving into electrical isolation**, the design utilizes polyvinyl chloride-insulated 11 AWG power cables alongside color-coded, polarized connectors to prevent reverse polarity. **Transitioning to circuit protection**, Over-Voltage (OVP) and Over-Current Protection (OCP) are implemented, featuring a 30A main fuse on the tether and secondary fuses on individual blocks for granular safety. **Finally, for thermal and emergency control**, heat sinks effectively manage heat dissipation, while a leakage detection mechanism provides an automated system shutdown upon water ingress, complemented by a fast access Kill Switch located at the surface station.

2.3. Software Safety Features

Our software fail-safes ensure real-time resilience during missions, starting with **Emergency Surfacing**, where the ROV automatically initiates an ascent if a leak is detected to prevent vehicle loss. **Transitioning to the Health Monitor**, the UI provides continuous visibility into critical telemetry, including Raspberry Pi temperature, undervoltage status, CPU, and memory usage to track internal stability. **Moving into Diagnostic Alerts**, if any component fails, an alert icon immediately notifies the pilot with a detailed error message and the specific component name for rapid diagnosis. **Finally, regarding manual overrides**, a specialized ROS service allows pilots to manually refresh camera feeds via the UI if the stream is ever disrupted, ensuring constant visual feedback.

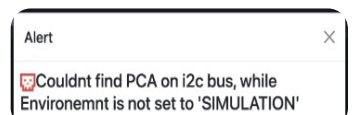


Figure 31: Health Monitor

3. Operational Safety

Operational safety is maintained during pool testing through our **Tether Management Protocol**, which governs tether deployment and retrieval to prevent tangling and mechanical strain. Combined with supervised operation, this ensures missions are executed with precision and minimal risk.

VI. Testing and Troubleshooting

At Robo-Tech, innovation is validated through a rigorous, multi-tiered testing and troubleshooting framework. Our methodology bridges the gap between theoretical design and operational reliability by ensuring that every component survives a "fail-fast" iteration cycle before system integration.

1. Prototyping & Simulation

During the initial prototyping phase, the **Mechanical** subteam conducts Finite Element Analysis (FEA) to identify stress points and performs "test to failure" on components like the hook to ensure high safety factors, while the **Electrical** subteam simulates PCBs on LTSpice to verificate logic. The **Software** subteam, in parallel implies Gazebo to test control logic.

2. Unit Testing

To ensure system-wide reliability, the **Mechanical** subteam subjects physical subsystems like the gripper to varying pressures and vibrations to confirm structural integrity, while the **Electrical** subteam all boards individually testing, and intensive load testing to verify thermal stability, and the **Software** subteam utilizes a custom GUI Debug View to execute unit tests on thrusters, sensors, and actuators while logging real-time performance data.

3. Integration

Following unit validation, we perform **Incremental System Integration**. Boards are sequentially assembled to localize potential faults using **ROS automation** for scripted validation routines.

Sealing Validation: Potential leakage points identified during design are addressed via a specialized pressure test. Components (control box, camera housing, and motor casings) are pressurized with air and treated with a soap solution; the absence of bubbles confirms a waterproof seal. Any detected leaks undergo immediate rectification and retesting.

4. Full-System Validation & Troubleshooting

Once the ROV assembly is complete, we transition to a comprehensive validation process that begins with **dry testing**, where a full integration test of thrusters, pneumatics, and vision modules verify software-

hardware synchronicity. **Moving into Root Cause Analysis (RCA)**, any malfunction detected during these dry runs triggers a formal evaluation to resolve faults before the vehicle ever touches the water. **Finally, during wet testing and buoyancy**, in-field deployment scenarios assess buoyancy dynamics, structural resilience, and maneuverability, while real-time telemetry analysis allows for rapid fault isolation.

5. Mission Simulation & Vehicle Readiness

The final phase of our workflow is the **Vehicle Validation** cycle. Our pilots execute real-life simulations in an environment that acts as a carbon copy of MATE competition guidelines. This indoor **Pool Testing** refines driver maneuvering skills and object manipulation. If any discrepancy is detected during these missions, the vehicle is sent back into the testing cycle, ensuring the ROV meets mission-critical benchmarks before the final deployment.

VII. Management

Innovation naturally involves trial and error, which is why Robo-Tech's management strikes a vital balance between a plan-first strategy and adaptive execution. Our leadership follows hierarchical management structure that balances long-term strategy with technical execution:

The High Board acts as the team's compass, managing resources and ensuring generational knowledge transfer. **The Executive Board** translate strategy into daily operations, overseeing cross-functional collaboration and maintaining professional standards. **Project Managers** serve as the bridge between strategy and action, ensuring all technical milestones and mission-specific requirements are met on schedule.

1. Project Schedule

This framework, supported by strict bylaws for accountability and resource management, ensures all individual efforts are aligned with our broader MATE mission requirements



Figure 32: Project Schedule

VIII. Logistics

1. Team Structure and Workflow

ROBO-TECH follows a structured and collaborative organizational model divided into technical and non-technical divisions. Led by the CEO and supported by the COO and CTO, the team is organized into Mechanical, Hardware, and Software departments, each managed by specialized leads and supported by sub-boards to ensure innovation and focus. Non-technical divisions such as PR, Documentation, HR, and Financials support communication, outreach, and internal development. This structure allows for efficient task distribution, cross-functional collaboration, and ongoing mentorship, ensuring smooth integration and strong performance throughout the season.

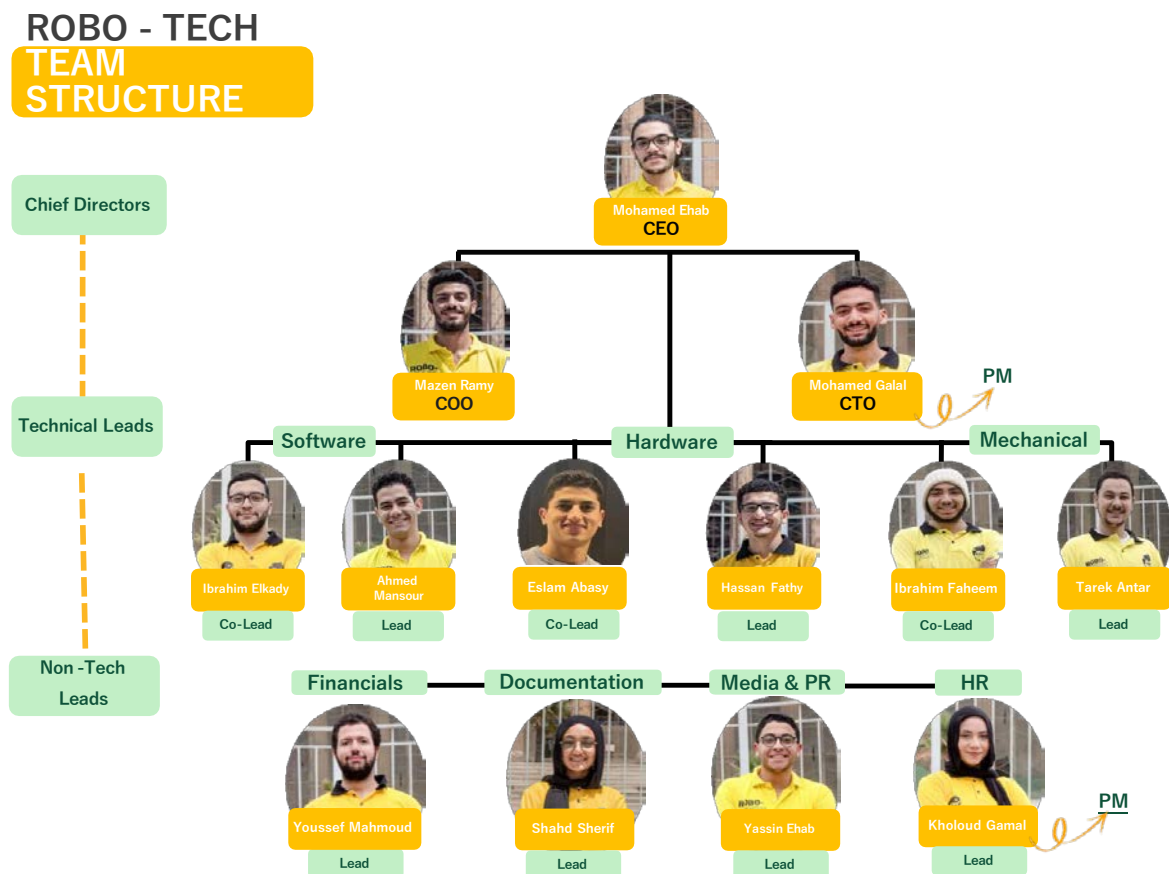


Figure 33: ROBO-TECH Company Structure

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X. Appendices

Appendix 1: Hardware SID

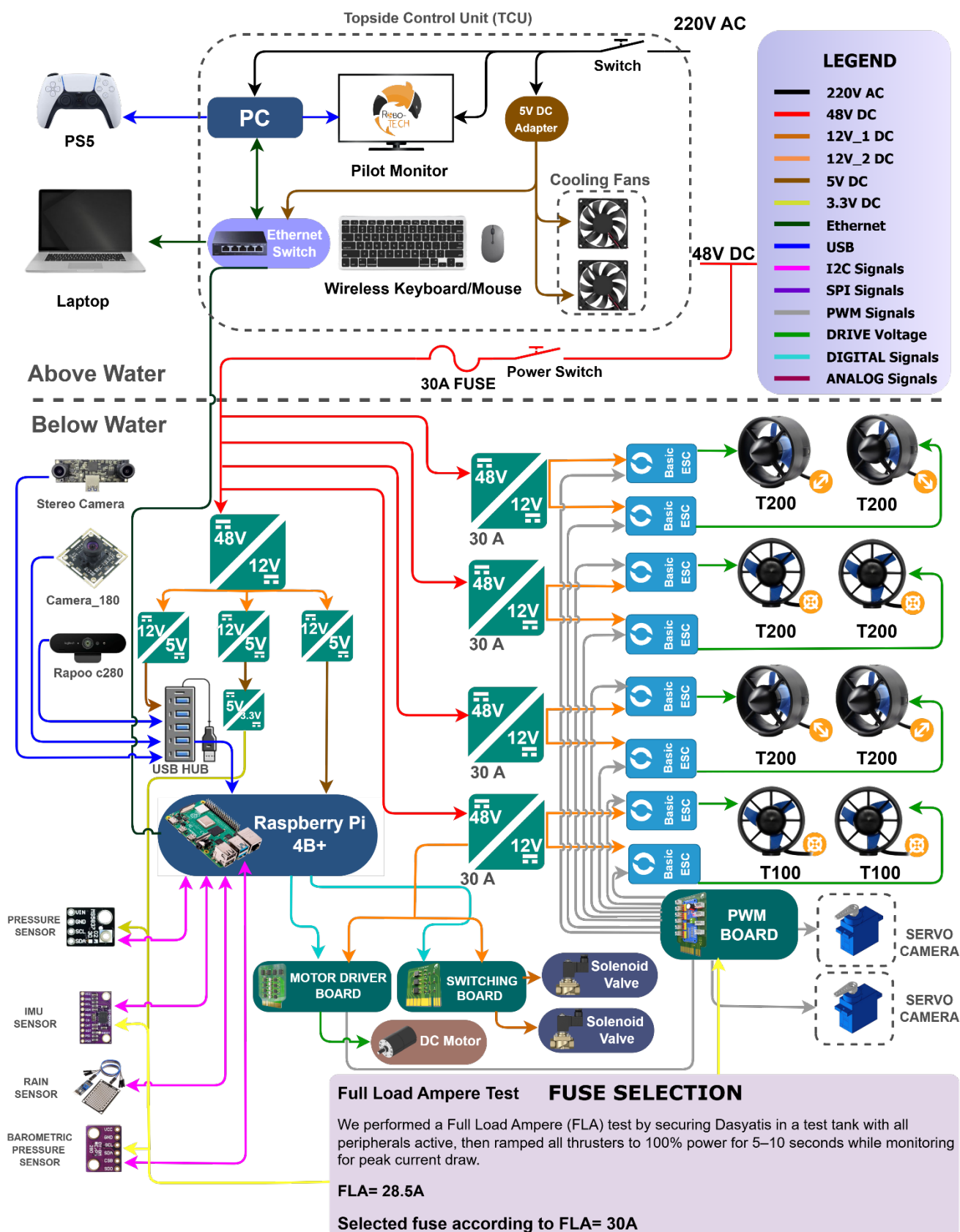


Figure 34: Hardware SID

Appendix 2: Pneumatic SID

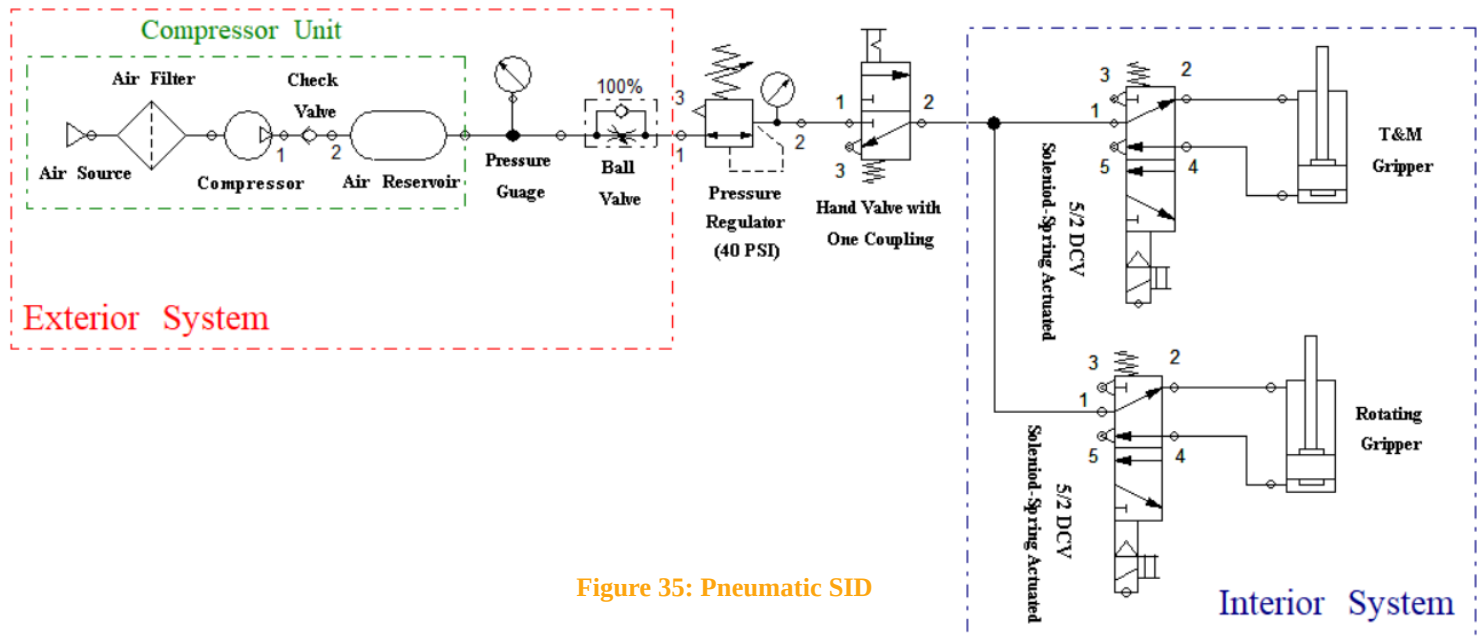


Figure 35: Pneumatic SID

Appendix 3: Software SID

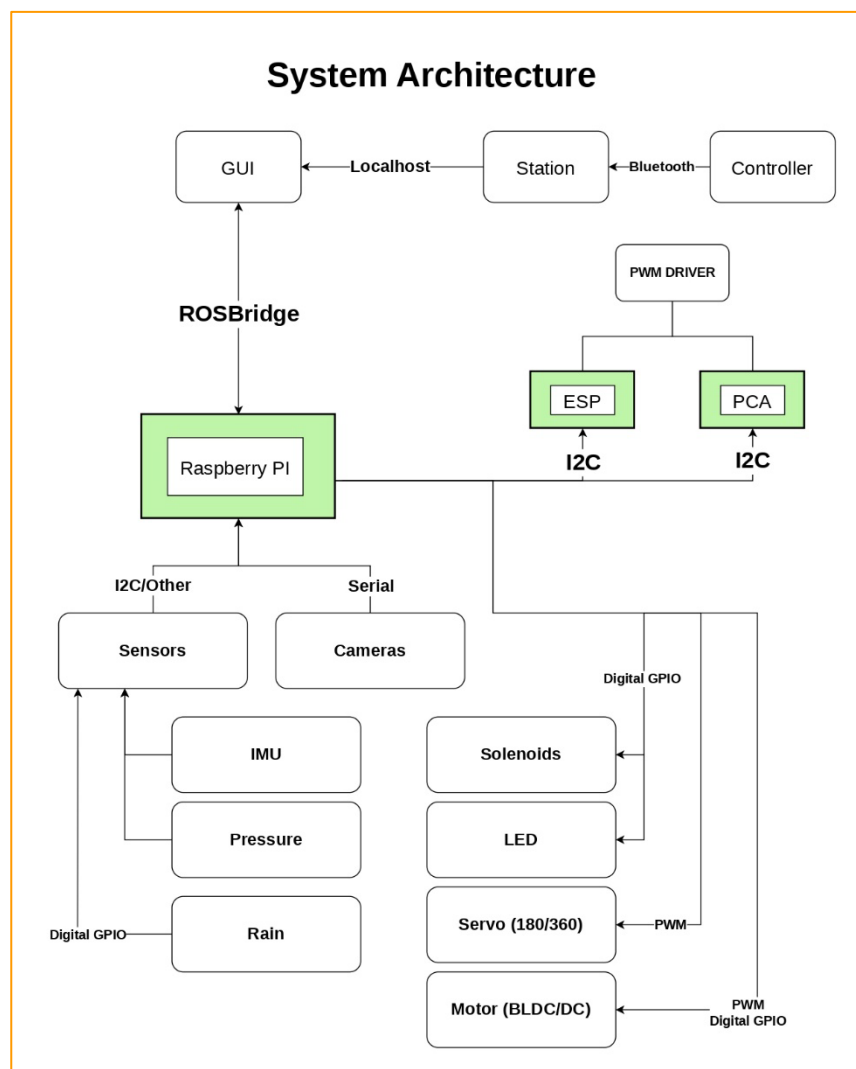


Figure 36: Software SID

Appendix 4: Build vs. Buy, New vs. Used

Robo-Tech prioritizes efficiency by reusing proven components that meet our requirements. This lowers costs and boost's reliability, allowing us to focus on solving current performance bottlenecks. Last year, we successfully implemented a customized manipulator and electronics system. This design allowed us to integrate specialized, high-performance tools tailored for every MATE task. Following that success, our primary goal this year was to refine the manipulator system and optimize the size of the ROV, while enhancing its overall maintenance and speed.

Table 11: Build vs. Buy, New vs. Used

Components	Statue	Justification
Thruster Shrouds	New + Built	IP2X rated, minimal drag, compatible with T200 & T100 thrusters
Manipulators	New + Built	Specialized custom-built tools, help in handling objects for MATE tasks
48V-12V Converter	New + Purchased	
PS5 Controller	New + Purchased	Control Scheme, Pilot Controller & reliability
Raspberry Pi 4B 4GB	New + Purchased	Commercially available & higher rating value for ROV's system & thrusters
Compressor	New + Purchased	Commercially available & to replace the previously damaged tether.
DC Motor Casing	Re-Used + Built	Well-maintained, Cost-effective, reliable sealing for DC motor
Station Casing	Re-Used + Built	Well-maintained, Cost-effective, well-handled control inputs
Tether	Re-Used + Built	custom built for MATE requirements, high reliability
Float Stability System	Re-Used + Purchased	high reliability, compact in size
DC Motor	Re-Used + Purchased	Well-maintained, Cost-effective, reliable performance & provide rotation actuation for MATE tasks (ex. Task 2.5 (rotating disc))
Cameras	Re-Used + Purchased	Guarantee visibility for pilot & Co-Pilot during MATE tasks (ex. Task 1.2)
T200 & T100 Thruster	Re-Used + Purchased	provides thrust & maneuverability for MATE tasks compatible 6 DOF for this year's design

Appendix 5: Budget & Project Costing

To start the season, **Robo-Tech** developed a comprehensive budget by analyzing our expenses and income from **2024** and **2025**, which included ROV production, MATE competition registration, research and development, and new workstation equipment. Facing both local and global inflation, we carefully tracked our purchasing decisions and relocated to a new shop space, investing funds to organize it efficiently for our needs. To keep costs manageable, we placed a strong emphasis on securing discounts and reusing materials.

Table 12: Budget & Project Costing

Robo-Tech Project Cost						
The Exchange Rate: 1\$ = 50 L.E			Estimated Time: 6/8/2025 - 20/4/2026			
Expenses		Description	Value		Status	Total (USD)
			Paid	Budgeted		
Mechanical System	Artelon (Sheet & Rods)	Grippers, Camera Holders , Camera End Caps, Float End Caps & Legs	\$40.80	\$40.80	Purchased	\$407.88
	Acrylic (Sheet & Rods)	Camera Casing , Electric Enclosure Cover	\$76.00	\$76.00	Purchased	
	Stainless Steel Accessories	Bolts, Nuts, Washers, & Rods	\$54.68	\$54.68	Purchased	
	5mm 1050 Aluminum Sheet	Electric Enclosure, Supports, Upper & Lower Plates	\$124.00	\$124.00	Purchased	
	Manufacturing	Laser Cutting, Plasma Cutting,Router & Welding	\$85.10	\$85.10	Purchased	
Electrical System	3D Printing (FDM)	Thrusters Shrouds & Gears	\$27.30	\$27.30	Purchased	\$321.60
	Digital & Rapoo Cameras	Maneuvering View	-	\$95.00	Re-used	
	Microcontrollers	Control System	-	\$15.81	Re-used	
	PCBs	For PCB Fabrication	-	\$10.00	Re-used	
	Edge connectors	Signal Connection	-	\$5.64	Re-used	
	DC-DC converter 50A	Converts from 48V to 12V	\$210.00	\$210.00	Purchased	
	ESCs	T200 & T100 Thrusters Control	-	\$180.00	Re-used	
	Raspberry Pi 4B 4GB	Main Controller	\$111.60	\$111.60	Purchased	
	Drivers	PWM driver, Motor driver	-	\$30.00	Re-used	
	Sensors	Raindrop, IMU & Pressure Sensor	-	\$83.36	Re-Used	
	DC Motor	Manipulators	-	\$14.00	Re-Used	
	T-200 Thruster x6 T-100 Thruster x2	ROV's Maneuvering	-	\$3,360.00	Re-used	
Top Control Unit	24 "LED Display Screen	Displaying Cameras' View for Pilot	-	\$40.00	Re-used	\$84.00
	PC i3 4th generation	Handling Cameras' Signals & ROS Communication	-	\$94.70	Re-used	
	Network Switch	LAN Network	-	\$10.00	Re-used	
	Keyboard & Mouse	PC control	-	\$11.00	Re-used	
	PS5 Controller	Pilot Controller	\$84.00	\$84.00	Purchased	
Tether	Casing	For Station Assemble	-	\$80.00	Re-used	\$0.00
	Fuse & Holder	Safety	-	\$49.90	Re-used	
	SBS-50 Anderson Connector	Connect power from competition's supply	-	\$6.00	Re-used	
	Tether-Station Connector	Signals Connection to the TCU	-	\$2.00	Re-used	
	Power Cables 10 AWG	ROV's Tether GND and +48	-	\$31.00	Re-used	
Sealing & Pneumatic	CAT6 Cable	Tether Signals Transition Cables	-	\$13.44	Re-used	\$44.60
	Tether Mesh	Covering ROV's Tether	-	\$63.00	Re-used	
	Sealing Materials	Gasket,O-Rings, Tephlon	\$7.20	\$7.20	Purchased	
	Sealing Components	Mechanical Seal,Oil Seal & Glands	\$37.40	\$37.40	Purchased	
	Solenoid Valves	5/2 DCV Soleniod Actuated 12V 30mA	-	\$16.50	Re-used	
Administrative	Pneumatic System	Pistons, Hoses, Fittings, Connectors	-	\$22.40	Re-used	\$1,330.10
	T-shirts	-	\$100.00	\$100.00	Purchased	
	Registration	-	\$650.00	\$650.00	Purchased	
	Workspace	-	\$558.00	\$558.00	Purchased	
	Safety	-	\$22.10	\$22.10	Purchased	
Overheads	Total Compressor 24L	Pneumatic Feed & Accessories	\$76.00	\$76.00	Purchased	\$245.78
	Prop Building	Pipes, Ropes & PVC Connectors	\$24.32	\$24.32	Purchased	
	Transportation	Outside Alexandria	\$26.20	\$26.20	Purchased	
	Fabrication Materials	Paper, Stickers, Chemicals & Epoxy	\$90.86	\$90.86	Purchased	
	Buoyancy Testing	Foam Rods & Fender	\$28.40	\$28.40	Purchased	
R&D	Workspace Improvement	Tools, Sensors, Steppers & Arduinos	\$24.84	\$24.84	Purchased	\$51.52
	Testing & innovation	Sealing Techniques, PCB Chemicals & ESCs	\$26.68	\$26.68	Purchased	

Income		
Source	Type	Value
University	Fund	\$650.00
Members	Sharing	\$2,504.25
Total Income		\$3,154.25

Total Project Cost	\$6,719.23
Total Expenses Cost	\$2,485.48
Total Re-used Cost	\$4,233.75
Ending balance	\$668.77

Appendix 6: Safety Checklist

1. Construction Checklist

1.1. General Checklist

- Ensure workplace is clear, no tripping hazards.
- PPE is worn when appropriate.
- No loose clothing is worn.
- Long hair tied back.
- No open-toed shoes.
- Check all equipment before use.
- Not working alone.

1.2. Soldering and chemical reactions

- Wear safety glasses and a face mask to prevent inhalation of gases.
- Working in ventilated space.
- Ensure no wires are live.
- Inform others that you are soldering.

1.3. Using Power Tools

- Wear safety glasses, gloves, and masks when appropriate
- Ensure the workspace is clean.
- Inform others that you are using those tools

2. Operational Checklist

2.1. Setup, Boot, and launch

- All company crew is in place.
- Launching area is clear, no tripping hazards
- Tether flaked out on the deck by tether man.
- Tether is connected to strain relief.
- Tether is securely connected to the electronics housing.
- Tether is securely connected to the control unit
- 30A fuse is placed.
- Laptops are booted up.
- Plugs and sockets are connected to the control unit.
- Attach the ROV's power supply, connect the compressor and control box to 120VAC power
- Connect the compressor to the pneumatic system.

- ROV is powered on.
- The pilot calls out when power is turned on to alert the crew.
- Deploy the ROV.
- ROV is neutrally buoyant and balanced in all directions
- Start arms, thrust, sensors test and adjust cameras.
- Continue to launch procedures if no issues arise.

2.2. Dry-Test Maintenance

- Warning labels are placed.
- ROV parts are securely attached to the base.
- Thrusters are guarded and secure.
- Thrusters are spinning freely.
- Screws and nuts are tightly fastened.
- Visual inspection of electronics for damaged wires, and loose connections.
- Deploy while powered off to visually inspect for water leaks.
- Electronics are in working order, and all sensors are reading correctly.

2.3. Leak detection protocol

- Surface immediately
- ROV is powered off
- Check loses
- Remove electronics

2.4. Communication loss protocol

- Reboot the ROV Communication system.
- Power down ROV, Check tether and control unit connections
- If communication is restored, confirm there are no leaks, resume operations.

2.5. ROV Retrieval

- Pilot alerts deck crew that the ROV is surfacing.
- Deck crew pulls up the ROV.
- Pilot stops timer.