Alexandria, Egypt

Giulietta

MATE ROV 2025 Technical Report

CEO | Ziyad Eslam '25
CTO | Yusuf Borham '27
CFO | Mohamed Orfy '25

Supervisor | Prof. Dr. Mohamed Rizk

Mechanical Head | Salah Khaled '25
Mechanical Vice Head | Mohamed Abdelkader '25
Hardware Head | Ahmed Ramadan '26
Software Head | Abdelrahman Gado '26
Software Vice Head | Rahma Abdulhameed '25

Mechanical Member | Ahmed Hussein '25
Mechanical Member | Mohamed Sameeh '27
Hardware Member | Mohamed Nabil '25
Hardware Member | Rana Elmaalawy '25

Media & Marketing | Mohamed Khaled '27
Media & Marketing | Mohamed Shal '27

Software Member | Ahmed Zaki '27
Software Member | Sama Ahmed '25
Software Member | Youssef Samy '28
Software Member | Ahmed Elmasry '28
Software Member | Batoul Arafa '25
Software Member | Nadine Mohamed '26
Software Member | Habiba Eid '25

• Robotics is our Name • Robotics is our Game •

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Acknowledgments

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- **MATE Center** –for sponsoring this year's competition and offering generous awards.
- **Arab Academy for Science and Technology (AAST)** –for hosting and organizing the regional competition.
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- **Our Families and Friends** –for their constant motivation, patience, and emotional support.

Each of these contributions—whether in the form of funding, resources, knowledge, or moral support—has made a significant impact.

Figure 1: AUR's Acknowledgments.

1 Introduction

1.1 Abstract

AU-Robotics (AUR) is a student-led company based in Alexandria, a city renowned for its rich coastal waters, submerged historical artifacts, bustling marine traffic, and critical oil pipelines. Recognizing the growing need for remotely operated solutions, AUR is committed to developing underwater systems that enable efficient exploration, inspection, and maintenance, while minimizing the reliance on human divers and reducing associated risks.

Therefore this year, AUR proudly debuts its first underwater Remotely Operated Vehicle (ROV), **Giulietta**, a mission-focused, cost-effective solution engineered for efficient execution of complex underwater tasks. Designed with simplicity yet stability and innovation in mind, Giulietta features a lightweight PVC frame chassis and employs non-traditional propulsion through bilge pumps, enabling smooth and agile maneuverability across five degrees of freedom. Its modular electronics are securely housed in sealed HDPE enclosures, while two 3D-printed manipulator arms, powered by a reliable pneumatic system, provide robust object handling capabilities. For enhanced piloting precision and situational awareness, Giulietta is equipped with three wide-FOV USB cameras, delivering high-definition real-time video feeds, complemented by finely tuned onboard PID control, and telemetry and computer vision processing at the surface station. Every subsystem is carefully optimized to perform mission objectives with confidence and control.

Through rigorous design, testing, and iterative improvement, Giulietta showcases our team's engineering depth and commitment to delivering a high-performance vehicle capable of succeeding in dynamic underwater operations. Every member of AUR is equally proud to present Giulietta's rich arsenal of features, and the remarkable journey of its design and fabrication, through this technical documentation.

Figure 2: AUR's Team.

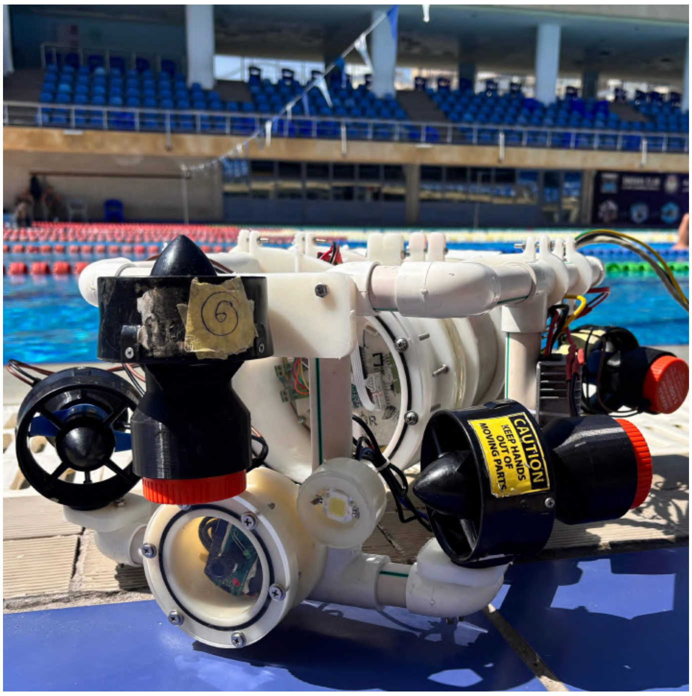

Figure 3: AUR's 2025 ROV, Giulietta.

2 Design Rationale

2.1 Innovations

Designing our first ROV was a significant challenge, requiring both foundational knowledge and creative problem-solving to balance performance, cost, and reliability. Throughout the brainstorming, design, and manufacturing process, simplicity remained a guiding principle; reducing complexity minimized potential malfunctions while improving stability. Giulietta was engineered to be straightforward, robust, and mission-capable, ensuring efficiency without unnecessary sophistication.

Below are the key innovations that define Giulietta and how they were tackled:

- **Frame:**
  Instead of traditional metals or composites, we opted for standard PVC piping, an affordable, corrosion-resistant solution that maintains and achieves strength and rigidness while keeping weight and costs low, and without sacrificing buoyancy or maneuverability. The modular design allows for easy repairs and adjustments.
- **Thrusters:**
  Rather than using expensive commercial thrusters, we repurposed bilge pumps, retrofitting them with second-hand nozzles and propellers. This unconventional approach delivered strong thrust at a fraction of the cost, enabling agile maneuverability.
- **Cameras:**
  USB cameras were selected for their ideal balance of low latency and high-definition video, avoiding the drawbacks of IP cameras (high latency) and analog systems (poor quality and noise susceptibility). This ensures real-time visual feedback without the cabling complexity of analog or the network overhead of IP systems.
- **Communication:**
  A Raspberry Pi 4 serves as the central communication hub, streamlining data transfer for video, telemetry, and control signals. This simplified architecture ensures fault-tolerant, real-time communication between the ROV and surface station.

2.2 Design Process

Our ROV's mechanical design focused on creating a robust and functional underwater vehicle for the MATE competition. The frame construction utilized 3/4-inch PVC piping, selected for its durability, corrosion resistance, and cost-effectiveness. For the critical electronic components, we designed a waterproof enclosure using HDPE (High-Density Polyethylene), incorporating cable glands to ensure watertight sealing for all electrical connections.

The manipulator system, also crafted from HDPE, features a pneumatic actuation system for reliable underwater operation. This design choice provided effective gripping capabilities while maintaining simplicity and reliability. The integration of these components required careful consideration of weight distribution and buoyancy, resulting in a well-balanced and maneuverable ROV suitable for competition tasks.

Through systematic testing and refinement, our mechanical design successfully combined structural integrity with practical functionality, creating an effective underwater vehicle that meets competition requirements while maintaining ease of maintenance and operation.

During the electrical design process, we faced significant constraints due to the cylindrical insulation box's limited dimensions. As hardware designers, much of our brainstorming focused on optimizing the PCB shape to maximize space utilization. After thorough analysis and many calculations, we determined that an octagonal design, Shown in figure 4, offered the highest space efficiency, making it the ideal solution for our layout.

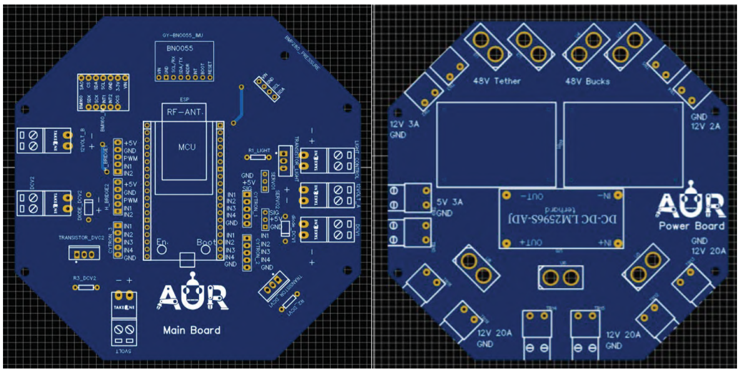

Figure 4: PCB Design

Another challenge was to make our system easily maintainable as possible, and surely a huge part of that was to make the system's connections easily detachable, so in order to achieve that we made sure to use easily detachable power input terminals such as XT60 connectors and detachable rosettes, we also used highly portable data cables and terminals such as JST connectors.

2.3 Manufacturing Process

2.3.1 Build vs Buy

While developing Giulietta, we tried to find a reasonable balance between building our own components from scratch and buying commercially available products, with our timetable, financials and quality of our product in mind. We decided to manufacture our own PCBs instead of having them fabricated by an external manufacturer, which was both more time and cost efficient for us. We also made our frame from 3/4-inch PVC pipes and custom HDPE electronics enclosure with cable glands for waterproofing, as these provided cost-effective and reliable solutions.

On the other side, we ended up buying some commercially available products such as buck converters, motor drivers, and thruster components (including used T100 Kort nozzles paired with bilge pumps and T100 propellers, connected via 3D printed adapters), as they proved to be more time efficient and provided higher quality for our product.

This hybrid approach of buying critical propulsion components while custom-building the frame and enclosures helped us optimize both performance and cost-effectiveness

2.3.2 Mechanical

During our ROV construction, we used different manufacturing techniques to build our components. For the waterproof parts like the main electronics enclosure, camera housings, and the box for pneumatic system valves, we chose HDPE as our main material and used a lathe machine to shape them. This gave us really good results, especially for making sure water couldn't get in.

We also used a CNC router to cut out the manipulator parts from HDPE sheets - this was great because it gave us really accurate cuts and made the manipulator strong and reliable. For connecting our thrusters together, we turned to 3D printing. This helped us make custom parts that perfectly fit our bilge pumps to the T100 propellers. The final touch was using a laser cutter for the acrylic end plates on our camera boxes and main enclosure. These came out super clean and fit perfectly, which was crucial for keeping water out.

By mixing these different manufacturing methods, we could make each part the best way possible. The lathe work gave us strong, waterproof housings, the CNC cuts made precise manipulator parts, 3D printing let us create custom connections, and laser cutting gave us perfect end plates. This combination really helped us build a reliable and well-working ROV.

2.3.3 Electrical

The entire electrical manufacturing process was conducted in-house at our workshop. We fabricated all PCBs ourselves using premium-grade materials and a comprehensive suite of PCB production and testing equipment.

This end-to-end control over manufacturing allowed us to maintain rigorous quality standards while optimizing production efficiency at every stage.

2.4 Vehicle Structure

When we built Giulietta, we started with a simple but effective frame made from 3/4-inch PVC pipes. We chose PVC because it's strong, doesn't rust, and honestly, it's pretty easy on our budget. The frame design turned out really well - it gives us plenty of spots to mount our equipment and makes it easy to fix things when we need to.

For keeping Giulietta's electronics safe from water, we machined several enclosures from HDPE using a lathe. This includes our main electronics box, camera housings, and a special box for our pneumatic valve system. We sealed everything up using cable glands and clear acrylic plates that we laser cut to fit perfectly. It took some trial and error, but we got them completely waterproof!

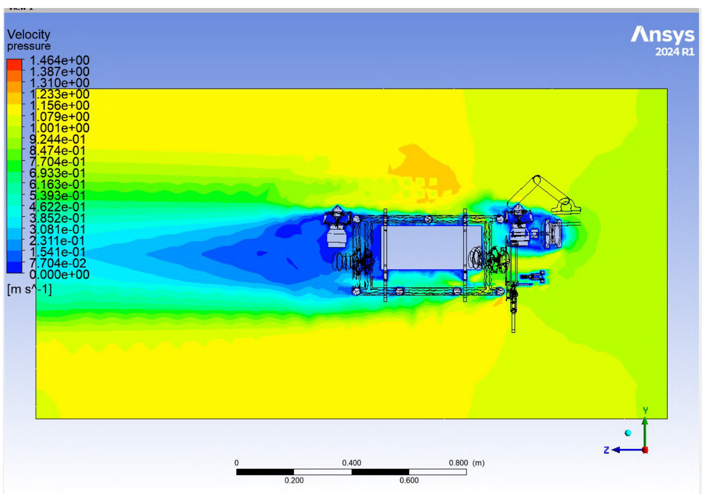

Figure 5: Velocity Flow Simulation

Giulietta's thruster system was kind of a mix-and-match approach. We used bilge pumps as the base, added T100 propellers with their Kort nozzles (we found some used ones that worked great), and 3D printed special parts to connect everything together. This saved us money and actually worked better than we expected.

The manipulator was another interesting build. We CNC-routed it from HDPE sheets and used a pneumatic system to make it move. It's pretty strong and can grab things reliably underwater, which is essential for Giulietta's competition tasks.

As for the vehicle's structure from an electrical point of view, Giulietta consists of three interconnected systems, these being the station, from which all the control signals are sent and all sensor readings and camera feeds are received, the underwater electrical system, which integrates our power, thrusting and control systems, and our tether cable, which is responsible for all power and data transferring between the station and the underwater electrical system.

2.5 Core Systems

2.5.1 Mechanical

Frame

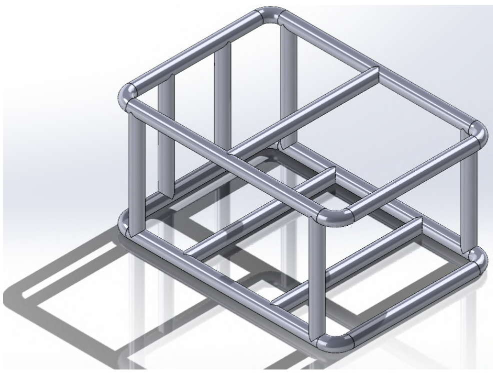

Figure 6: PVC Frame Design

Giulietta's frame is constructed from 3/4-inch PVC pipes, designed in a compact cube-like shape for optimal stability and maneuverability. We used PVC adhesive to permanently bond all connections, creating a single solid structure that's stronger than traditional mechanical joints. The pipes serve a dual purpose - providing structural support while also acting as compartments for our ballast weights. This simple but effective design gives us a clean, hydrodynamic profile while maintaining the strength needed for underwater operations. The white PVC material makes damage inspection easy, and the overall design provides secure mounting points for all our components like thrusters, cameras, and manipulator.

Propulsion

The propulsion system of our ROV is designed to offer reliable, multidirectional maneuverability using a total of six thrusters. These include four horizontal thrusters dedicated to handling sway, yaw, and surge motions, and two vertical thrusters responsible for managing pitch and heave. The thrusters are strategically positioned to optimize control and response across these five degrees of freedom. Each thruster is a hybrid design, combining the structural base of an automatic bilge pump with the performance advantages of a T100-style thruster. This custom approach provides a cost-effective yet efficient propulsion unit tailored to our specific underwater navigation needs.

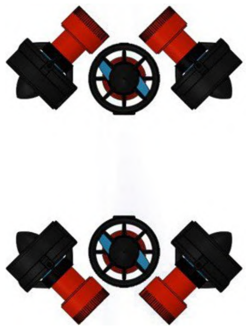

Figure 7: 6-Thruster Configuration

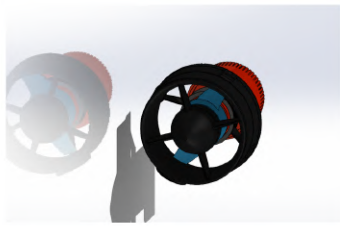

Figure 8: Thruster Assembled

At the core of the propulsion system is a high-speed copper wire motor, originally part of the bilge pump assembly. This motor operates at 6600 RPM, offering robust and consistent torque suitable for aquatic applications. Its durability and simplicity make it ideal for continuous operation in a submerged environment. Attached to the motor is a propeller, which is responsible for generating thrust by accelerating water through a confined flow path. This flow is directed through a T100-style nozzle, which not only increases the output thrust but also helps maintain system efficiency by controlling the flow rate. The nozzle plays a critical role in converting motor torque into linear motion and maintaining directional control.

The connection between the motor shaft and the propeller is made using a coupler, which is precision-machined from HDPE. This component ensures reliable torque transfer and reduces vibration while operating underwater. A nozzle holder secures the nozzle

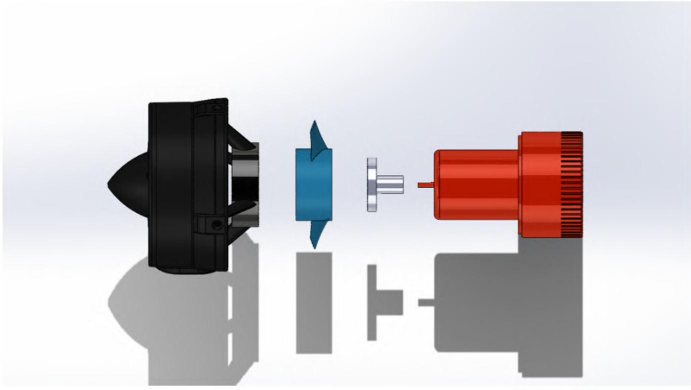

Figure 9: Thruster Parts Separated

assembly to the bilge pump housing, completing the propulsion unit. This holder maintains alignment and structural integrity, allowing the nozzle to operate under optimal conditions without compromising stability or performance.

Canisters

The main canister, solenoid canister, and camera canisters are all made of HDPE. The manufacturing process used for all three is lathing, which allows precise shaping of the components to achieve accurate fits and effective sealing.

Main Canister

The main canister houses all the electrical components and is open from both sides:

- Front Side: Sealed using an plexiglass plate, which is fixed and sealed with radial sealing using an O-ring. The plate is transparent allowing for easy debugging and observance of the main board and other interiors.
- Back Side: Sealed using three O-rings — two for axial sealing and one for radial sealing — ensuring robust protection against water ingress and pressure. This side also houses all the insulated cable glands, which is responsible for delivering the cables from outside to inside without letting in water.

Solenoid Canister

Also made of HDPE and lathed, the solenoid canister is sealed using radial sealing, providing sufficient insulation and protection for the solenoid circuit.

Camera Canister

The camera canister follows the same material and manufacturing process, and it is sealed using radial sealing to protect the internal camera board.

Figure 10: Main Canister Plexiglass Plate

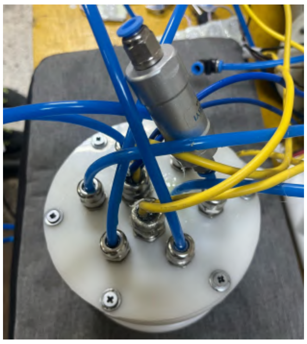

Figure 11: Solenoid Canister Back

Figure 12: Camera Canister Front

Mission Tools

Dual Pneumatic Grippers

The ROV is equipped with two arms, both primarily constructed from High Density Poly Ethylene (HDPE) due to its durability and resistance to harsh underwater conditions. Some complex parts were fabricated using 3D printing technology, allowing for precise customization and lightweight construction.

The arms are strategically mounted in two orientations: one horizontally and the other vertically. This configuration was specifically chosen to maximize the pilot's ability to interact with mission tasks efficiently and intuitively, enabling smooth handling of various objects regardless of their position or orientation.

To enhance the ROV's ability to manipulate mission elements, particularly PVC pipes, the arms are designed to open and close effectively. Gripping is facilitated by a pneumatic system powered by an MLA 20×20 air cylinder. This compact cylinder provides reliable linear motion to open and close the grippers with enough force to securely grasp objects underwater.

The system is controlled using two-way DC solenoid valves, which direct airflow to either side of the cylinder to extend or retract it. When the pilot sends a command, the valves switch positions to open or close the gripper as needed. This setup allows for fast, responsive control and ensures consistent performance in underwater conditions.

Air is supplied via a dedicated pneumatic line system that includes pressure regulators and tubing rated for submersion. The design is simple, robust, and effective for mission-critical handling tasks. This system ensures that the manipulator can securely grasp and maneuver objects as required in different mission scenarios.

Figure 13: Horizontally-Mounted Gripper

Figure 14: Vertically-Mounted Gripper

Static Hook Design

The static hook is a compact yet highly functional tool that plays a crucial role in completing mission tasks. It was identified as essential early in the design phase, specifically for engaging with rope loops attached to coral props.

The tool is composed of a 3D-printed custom mount paired with a bolt-style metal hook. Its placement was carefully engineered—positioned 12 mm above the ROV's lowest legs—to ensure it never touches the seafloor before the ROV does, maintaining safe and stable contact during operations.

To maximize effectiveness, the hook was made as large as possible while remaining compatible with standard screw hooks, allowing for secure and reliable interaction during retrieval or placement tasks.

Buoyancy & Ballast

Getting Giulietta's buoyancy just right was a crucial part of our design process. We started by calcu-

Figure 15: Static Hook

lating the buoyant force from all our components - the PVC frame, HDPE enclosures, and other parts naturally wanted to float. To counter this, we came up with a clever ballast solution.

We utilized the hollow space inside our PVC frame pipes as natural compartments for our ballast system. By inserting weights directly into selected sections of the 3/4-inch PVC pipes, we achieved two things at once: we got the weight we needed while keeping everything protected and streamlined. This was a really efficient solution because it didn't add any external components that could create drag, and it kept our ROV looking clean and professional.

The weight distribution was pretty important too. We carefully chose which pipes would hold the weights, making sure they were evenly distributed on both sides of Giulietta. This helped her stay level underwater and maintain stability during operations. After some pool testing and adjustments, moving weights between different pipe sections, we found the perfect balance where she's easy to maneuver but still heavy enough to stay steady when using the manipulator or fighting against currents.

It took a few tries to get it just right - too much weight and she'd be sluggish and use more power, too little and she'd be fighting to stay down. But now, Giulietta sits perfectly in the water, with her ballast system neatly hidden away inside her frame, ready for her competition tasks.

2.5.2 Electrical

Giulietta's Underwater Electrical system consists mainly of 2 PCBs: Power distribution unit and main control unit, our objectives were creating an electrical system that is highly efficient, yet is simple and easily maintained.

Control

Giulietta's primary processing unit is an ESP32 module, selected for its high performance, low power consumption, cost-effectiveness, and widespread availability. For more demanding computational tasks, we incorporated a Raspberry Pi, leveraging its superior processing power and versatility.

Our control unit is a single-layer PCB that serves as the central hub for managing all control and communication signals within Giulietta. This PCB shown in figure 16 houses the ESP32 module, which is responsible for sending control signals to the thrusters, directing signals to the Directional Control Valves (DCVs) in the pneumatic system, and handling all sensor readings and sending them to the Raspberry Pi. The BNO055 was chosen as the onboard Inertial Measurement Unit (IMU) which provides the ROV's attitude (yaw, pitch, and roll), due to its excellent accuracy and built-in sensor fusion of gyroscope, magnetometer, and accelerometer.

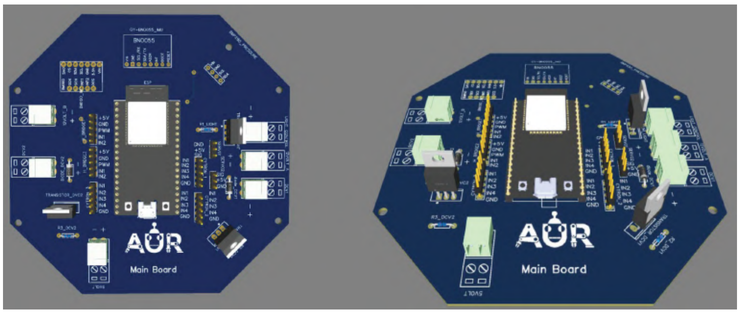

Figure 16: Main Board.

To efficiently manage our six-motor thrusting system, we developed a hybrid motor drive system. This system incorporates two Cytron MDD10A motor drivers shown in figure 17—each capable of controlling two motors—to control the four horizontal thrusters. Additionally, two BTS7960 motor drivers shown in figure 18, each dedicated to a single motor,control the two vertical thrusters, ensuring optimal performance during both diving and ascent maneuvers. All motor drivers employed in our system are MOSFET-based H-bridge configurations, characterized by significantly low voltage drops, thereby maximizing overall power efficiency.

Power

Giulietta's power system is primarily powered by a single 48V input. This input supplies two external waterproof high-power buck converters, which step down the voltage from 48V to 12V to power the thrusting system.

Additionally, the 48V input feeds into the power board, the central distribution unit that delivers power to all electrical components in the system.

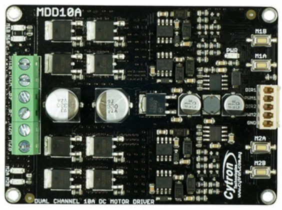

Figure 17: Cytron Motor Driver

Figure 18: BTS Motor Driver

Our Power Board houses three buck converters in total as shown in figure 19. Two of these step down the 48V input to 12V, supplying power to all 12V components in the system, including directional control valves (DCVs) and LEDs. The third buck converter further reduces a 12V input to 5V to power the ESP32 microcontroller and Raspberry Pi. Additionally, the power board efficiently distributes the 12V output from the external buck converters to the thrusting system.

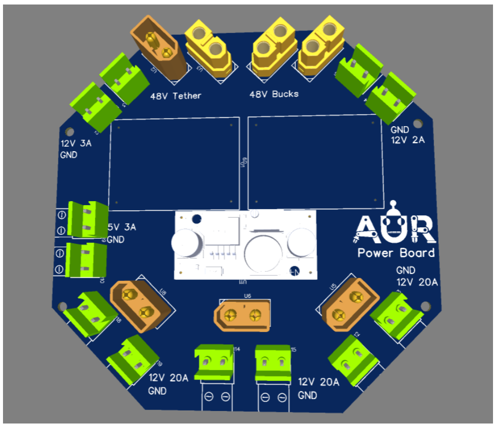

Figure 19: Power Board.

As shown in table 1, The maximum power consumption of the ROV is approximately 451.22 W, drawing nearly 9.52958 A of current from the 48 V power supply. The peak current is then multiplied by a 1.5 factor of safety, resulting in a maximum current of 14.29 A, for which a 30 A fuse is installed. It is important to note that the thrusters are not operated at full power to stay within our power limit.

To safeguard the Raspberry Pi from power faults, we developed a dedicated protection board implementing crowbar circuit technology shown in figure 20, on which the 5V buck power the PI is placed, This compact solution (46.2mm × 49.4mm) instantly shorts any voltage exceeding safe thresholds to ground, while maintaining efficient power delivery. The board provides

Component	Input Voltage (V)	Max. Current (A)	Quantity	Consumed Power (W)
Thrusters (Bilge)	12V	6A	6	432W
DCV	12V	0.33A	2	7.92W
Raspberry Pi	5V	3A	1	15W
ESP32	5V	0.5A	1	2.5W
Total	--------------	--------------	--------------	457.42W

Table 1: Power Calculations.

continuous protection without compromising the Pi's power supply integrity.

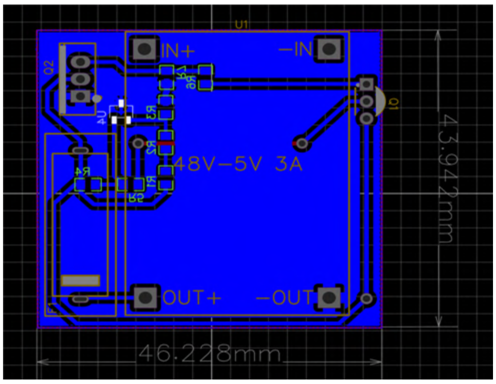

Figure 20: Overvoltage Protection Board.

Tether

Our tether cable serves as the main power and data transfer medium between the station and the ROV itself, as for power cables, we used high power premium quality copper cables in order to avoid any voltage drops or power losses, we also used a CAT6 ethernet cable for noise-prune data transfer processes and a high quality pneumatic tube for our pneumatic system. The tether is 30 meters long and is encased in a protective sheath for enhanced durability and protection.

In the following figure 21, a cross section of our tether cable is illustrated.

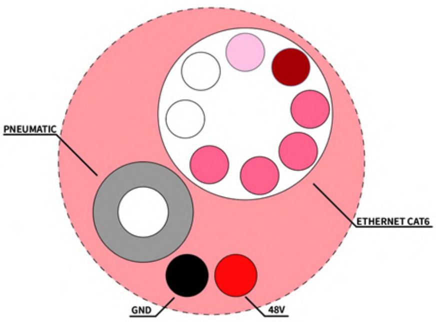

Figure 21: Cross Section Of Tether.

Cameras

The ROV integrates three waterproof USB HD cameras with 108° wide-angle lenses, delivering real-time visual feedback to the pilot's interface. These cameras are mounted in custom-engineered waterproof housings consisting of pressure-resistant HDPE canisters with polished plexiglass windows, ensuring both durability and optical clarity. Their strategic placement provides comprehensive coverage of the ROV's surroundings and manipulator workspace, enabling precise navigation and tool operation during missions (see Figure 22).

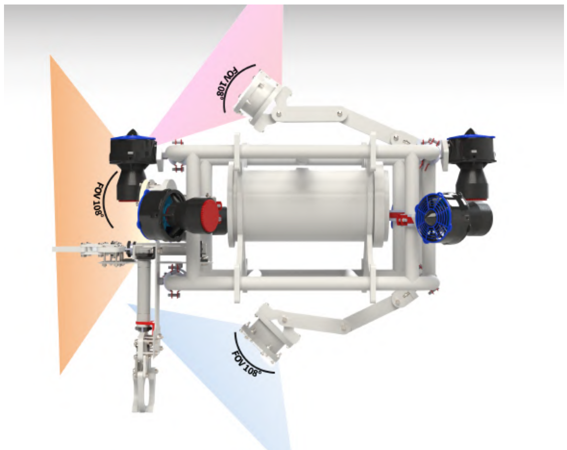

Figure 22: Cameras' FOVs.

Video transmission is optimized through the Raspberry Pi's encoding algorithm, which reduces bandwidth requirements while maintaining high frame rates and low latency. For operations in low-visibility environments, the system incorporates adjustable waterproof LED arrays positioned to eliminate shadows and provide uniform illumination of the work area.

2.5.3 Software

Station

The **Graphical User Interface (GUI)** is a critical component of the ROV, enabling the pilot to monitor camera feeds and vital values such as depth, yaw angle, and pitch angle. We decided to develop a desktop-based app using **PyQT**, a set of Python bindings for the Qt application framework. PyQT was chosen for its advanced UI design capabilities, cross-platform compatibility, and seamless integration with **OpenCV** and **PySerial**.

The general outline of the GUI is shown in Figure 23, and each widget's function is as follows:

- **Camera Feed Widgets:** Display the live video stream from the ROV's cameras.
- **Orientation Widget:** Shows the IMU data to help the pilot stabilize the ROV during maneuvers
- **Tasks Widget:** Helps the pilot and co-pilot track completed tasks by checking off completed tasks.
- **Controller Widget:** Displays the controller's connection status and the current placement of the joystick and buttons, helping detect malfunctions such as joystick drift or stuck buttons.
- **Thrusters' Speeds Widget:** Displays the speeds of the thrusters, ensuring that control data is transmitted correctly.

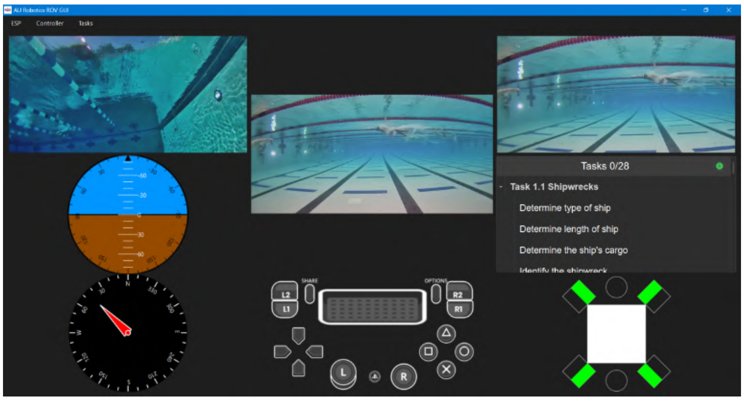

Figure 23: GUI overview.

Communication

Our ROV's communication system is designed to enable seamless data transmission, video streaming, and control commands between the control station and the underwater control board. Ensuring the balance of efficiency, latency, and reliability.

The communication architecture is composed of:

- **Ethernet and Serial Communication:**
  Our system uses Ethernet as the main communication medium between the control station and the underwater ROV. It's used for high speed data transmission. The tether integrates Ethernet and serial data transmission, reducing complexity and increasing the reliability of the system.
  Telemetry data, including sensor readings, pressure levels, and other information, is transmitted serially from the ESP microcontroller back to the GUI at the onshore station.
  The GUI sends control commands serially to the ESP, which processes these commands to execute tasks such as manipulator movements and sensor activation.
- **Raspberry Pi:**
  The onboard Raspberry Pi acts as a central hub for all onboard cameras and a network bridge for sensor and control data, ensuring synchronized communication between the cameras, the ESP, and the topside GUI.
  This system achieves minimal latency and better quality for real-time monitoring while ensuring all data streams are processed efficiently, enabling real-time communication without delays.
- **Video Streaming:**
  Our setup employs USB webcams that are directly connected to the onboard Raspberry Pi, which processes the cameras' feed and sends it to the control station.
  The Raspberry Pi is responsible for encoding and compressing the video streams before transmitting them through the tether.
  The choice of USB webcams was driven by their ability to provide live video feeds that can be processed and transmitted while maintaining video quality and conserving bandwidth.
- **Communication Architecture:**
  Our ROV employs a hybrid network topology where various data types are handled by separate communication components. Each data stream follows a predefined path with specific transmission protocols. A labeled diagram showing the data flow for the whole communication system is shown below in Figure 24.

Overall, our communication system is not only reliable but also efficient. It integrates multiple techniques to create a cohesive framework that meets the unique demands of underwater exploration, balancing cost, simplicity, and performance.

Motion

The motion control system is responsible for ensuring that the ROV can navigate through the water, maintain its position, and perform position-sensitive tasks such as collecting data or samples.

The control system is designed to be modular and flexible, allowing for easy integration of new sensors and actuators as needed. The system is also designed to be robust and reliable, with built-in redundancy and fail-safes to ensure that the ROV can continue to operate even in the event of a failure.

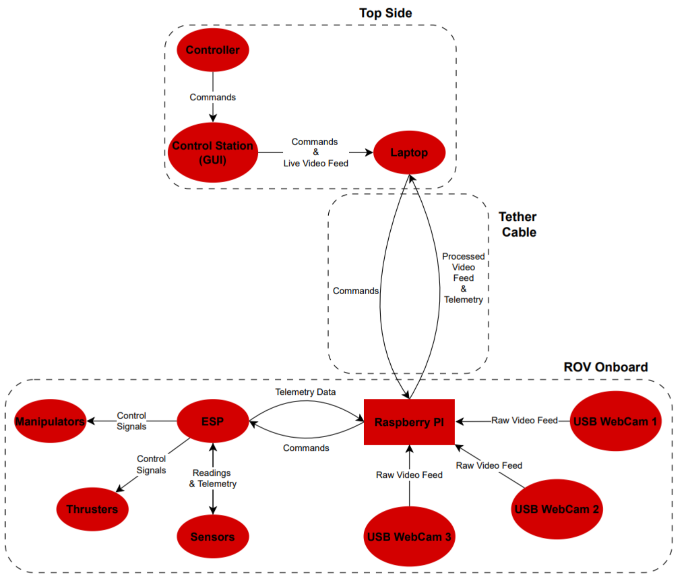

Figure 24: Communication system architecture.

Thruster Model

The thruster model is a critical component of the ROV's control system. The thrusters are responsible for providing the thrust needed to move the ROV through the water, and their performance can have a significant impact on the ROV's overall performance.

The thruster model is based on the following assumptions:

- The thrusters are assumed to be linear devices, meaning that the thrust produced by the thrusters is proportional to the input voltage.
- The thrusters are assumed to be independent, meaning that the thrust produced by one thruster does not affect the thrust produced by another thruster.
- The thrusters are assumed to be in a steady state.

Matrix A maps the output force of each thruster to the resulting force and torque on the ROV. It is called the kinematic matrix.

Matrix F is a vector of the resulting forces on the ROV in all directions.

Matrix T is a vector of the thruster forces.

$$F = A \cdot T$$

$$\begin{bmatrix} F_x \\ F_y \\ F_z \\ T_y \\ T_z \end{bmatrix} = A \cdot \begin{bmatrix} T_1 \\ T_2 \\ T_3 \\ T_4 \\ T_5 \\ T_6 \end{bmatrix}$$

We will now make some adjustments to the matrices T and F to better reflect the behavior of the system. Starting with matrix F, which represents the net forces and torques acting on the ROV in each direction:

From system dynamics, we know that the relationship between force (or torque) and velocity (or angular velocity) in each direction can be approximated as a first-order system. However, under steady-state conditions, we can simplify this further and assume that the velocity in any given direction is directly proportional to the corresponding force (or torque) acting in that direction.

Therefore:

- The linear velocity in the x-direction is proportional to the force along x and so on for the other axis

Given this, matrix F can be renamed to V, representing the velocity vector (both linear and angular) in all controlled directions.

Similarly, the thrust generated by each thruster is approximately proportional to the input voltage applied to it. Thus, matrix T, originally representing thrust, can be renamed to E, which now represents the input voltages to the thrusters.

$$V = A \cdot E$$

$$\begin{bmatrix} V_x \\ V_y \\ V_z \\ \theta_{yaw} \\ \theta_{pitch} \end{bmatrix} = A \cdot \begin{bmatrix} E_1 \\ E_2 \\ E_3 \\ E_4 \\ E_5 \\ E_6 \end{bmatrix}$$

$$A = \begin{bmatrix} 1 & 1 & 1 & 1 & 0 & 0 \\ -1 & 1 & 1 & -1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 \\ 1 & -1 & 1 & -1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & -1 \end{bmatrix}$$

We can invert matrix A to calculate the input voltage vector:

$$E = A^{-1} \cdot V$$

$$A^{-1} = \begin{bmatrix} 0.25 & 0.25 & 0.25 & 0.25 & 0 & 0 \\ -0.25 & 0.25 & 0.25 & -0.25 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0.5 & 0.5 \\ 0.25 & -0.25 & 0.25 & -0.25 & 0 & 0 \\ 0 & 0 & 0 & 0 & -1 & 1 \end{bmatrix}$$

This matrix is called the inverse kinematics matrix.

Manual Mode

In manual mode, the ROV is controlled by a human operator using a joystick. The joystick sends velocities to the ROV in all directions. The ROV uses the inverse kinematics matrix to calculate the input voltage for each thruster.

Before sending the voltage to the thrusters, we ensure it does not exceed 12 volts. If it does, we scale down all voltages accordingly.

Then, the voltage is converted to a PWM duty cycle, which is sent to the motor drivers connected to the thrusters.

Semi-Autonomous Mode

In semi-autonomous mode, the ROV stabilizes itself in yaw or pitch directions using a PID controller when no commands are received.

The PID controller calculates the required velocity to maintain a given angle. This velocity is then used to compute the input voltage using the inverse kinematics matrix.

The transfer function for yaw:

$$G_{yaw}(s) = \frac{s^3 + 3s^2 + 1.4s + 2}{s^6 + 2s^5 + 3.45s^4 + 1.32s^3 + 9.2s^2 + 0.7s + 9}$$

The transfer function for pitch:

$$G_{pitch}(s) = \frac{2.3s + 4}{s^4 + 1.01s^3 + 2.9s^2 + 13.9s + 10}$$

Actually in order to arrive this transfer functions first we modelled the dynamic system of the ROV and we found that the system has 3 zeros and 6 poles in the yaw case then we tested the ROV in the wate by giving a step input for the syetem and monitoring the output angle as the response of the system , then this data is entered into the system identification toolbox in matlab to get the transfer function of the system. The same was done for the pitch case.

This transfer function will be very helpful in tuning the PID constants to get the best response for the system and to be robust to any disturbance in the system.

PID Controller

The PID controller is a widely used feedback control mechanism in industrial systems. It consists of three components: Proportional (P), Integral (I), and Derivative (D). The controller continuously computes the error between a desired setpoint and the current process variable and applies a corrective action based on the weighted sum of the three terms: proportional to the error, integral of the error over time, and the derivative of the error.

In our system, we implement two separate PID controllers—one for yaw control and the other for pitch control. Initial tuning of the PID parameters is performed using the Auto Tune toolbox in MATLAB. Further fine-tuning is carried out manually by testing the ROV in water and adjusting the PID gains to achieve optimal response.

The PID controllers are implemented manually in the ROV's firmware. The implementation includes several important features:

- The ability to adjust PID constants dynamically through the GUI.
- Disabling the integral term when the controller output is saturated, to prevent integral windup.
- Automatic activation of the PID loop when no external command is sent for yaw or pitch.

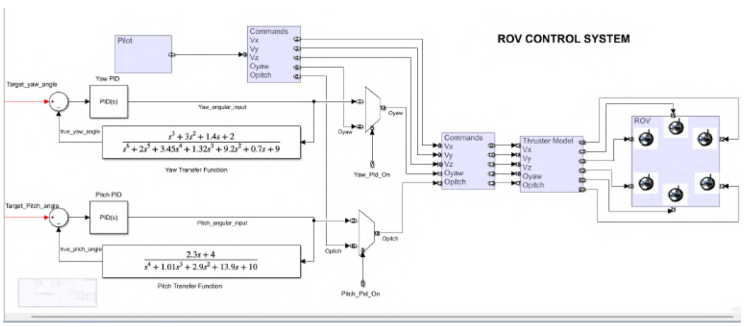

Figure 25: Control System Block Diagram

Firmware

The firmware developed for the AU-ROBOTICS Remotely Operated Vehicle (ROV) system is designed to manage critical low-level operations including sensor data processing, motor control, communication protocols, and safety features. Built on an Arduino-compatible microcontroller, the firmware employs a modular architecture focused on maintainability and reliability, especially in the demanding underwater environment. The main control loop runs at 30Hz, ensuring a balance between responsiveness and computational load. The architecture features a clear separation of concerns through dedicated modules for sensor interfacing, actuator control, communications, and safety monitoring.

The firmware interacts closely with hardware components through a carefully planned pin configuration that supports PWM motor control, I²C communication with an IMU, and safe separation of power-sensitive lines. The BNO055 IMU was selected for its built-in sensor fusion capabilities, which simplify orientation estimation and improve system stability. The IMU's data is processed through a structured pipeline involving coordinate transformation, angle normalization, and validation before being passed to control systems.

For communication, the firmware uses a custom 9-byte serial protocol optimized for low-latency, deterministic behavior, and error detection using an XOR-based checksum. Thruster commands are computed using matrices derived from the ROV's geometry and capabilities, and are constrained to avoid overdriving the motors. Horizontal thrusters use a simple H-bridge control scheme, while vertical thrusters support bidirectional control with safety-enabled operation.

Safety features include a communication watchdog that halts motor activity if control signals are lost, as well as a self-test routine that sequentially verifies motors, valves, lighting, and sensors. Additionally, the firmware includes a JSON-based telemetry system for real-time status monitoring, and a debugging framework that can be selectively activated via compile-time flags to aid development and troubleshooting.

Overall, the firmware showcases strong engineering practices tailored for robust, safe, and efficient control of an underwater ROV. Its modular design and layered architecture ensure ease of maintenance and adaptability for future enhancements.

Mission Algorithms

Photosphere Imaging

Like panoramas, 360 photospheres are a projection of a scene onto a singular image. They can be imported into an appropriate viewer software to allow the user to "scroll" through the image – whether indefinitely and in all directions, as with 360 photospheres, or about one axis, as with normal panoramas.

There are several techniques through which one can project a given three-dimensional scene onto one two-dimensional image, the most ubiquitous of which is the equirectangular projection technique, used to project the globe onto a two-dimensional map.

A lot of research has gone into automatic keypoint detection (e.g. SIFT Algorithm) and stitching images based on overlapping keypoints between the images. Software exist to enable automatic stitching of multiple images based on keypoints (otherwise called "control points" in some applications), while allowing users to have fine-grained control over these keypoints to achieve a seamless 360 photosphere.

The software of choice will be PTGui, as it is the most powerful option. Hugin remains a decent alternative and will be installed in case issues arise with PTGui.

There is no FOV-agnostic algorithm that dictates how a camera on any given type of mount should rotate in order to span a scene without leaving any spot uncaptured. As a general rule, a picture for each of the direct north and south of the capturer, with images of the rest of the environment in increments of *FOV / 2* (i.e., around $(360/\text{FOV}) \times 2$ horizontal) $\times$ $(360/\text{FOV})$ vertical captures of the environment.

The capturing will be done from the GUI Console, which will have a button that captures and saves a shot of the feed from any specific camera mounted on the ROV.

Length Measurement

During the research and development phase, We found many ways to measure the real-life dimensions of objects, all revolving around two main methods, using stereo cameras and getting the depth map to calculate distance in 3D space, or have a reference in the same plane as the object you want to measure.

We decided to base our code on the second method since it can only be done with one camera, saving the cost of a second dedicated camera, since we already know certain lengths of the shipwreck, as seen in figure 26.

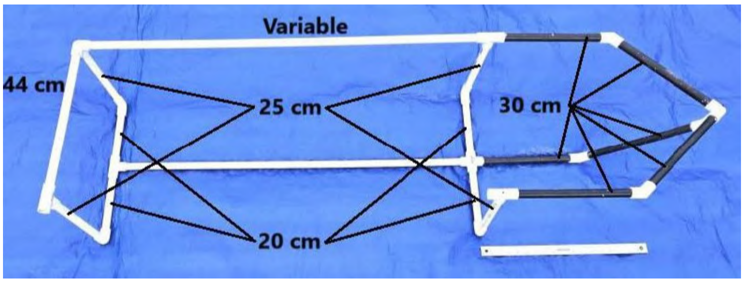

Figure 26: Shipwreck Length Measurements

The idea depends on the proportionality of lines lying in the same plane. An image is captured from the main camera feed, that contains either the top or side views of the shipwreck. The co-pilot selects the endpoints of the reference on that image and enters its real-life length, then selects the endpoints of the shipwreck. The length of the shipwreck is then calculated and displayed on the image to be written down by the co-pilot.

Invasive Carp Migration Modeling

For the invasive carp movement modeling mission, the co-pilot enters the data in the given table into the software, by checking the check-boxes where the data says that the invasive carp has been found. After all the data is entered appropriately, the software overlays the regions where the invasive carp has been found in each year.

3 Safety

At AUR, safety is not just a checklist or a set of rules, It's a culture and a mindset embedded into every aspect of our work. From the early training sessions, Team members are introduced to safety principles and practices that protect both individuals and equipment. These principles are then applied during the designing, building, and testing phases of the ROV.

3.1 Safety Features

One of our top priorities is to keep our ROV safe-to-use throughout various development phases. Electrical and mechanical components are developed with multiple protective layers to prevent accidents and ensure durability in underwater conditions:

- **Fused Electrical System:** Appropriately rated fuses are used across all major circuits to safeguard and protect sensitive components from over-current damage. A 30A fuse is placed 30 cm from the Anderson Power-pole connectors as MATE's specifications.
- **Waterproof Enclosures:** All electrical parts are enclosed in protective housing to prevent water from entering, even under high pressure conditions.
- **Strain Relief:** To prevent the tether from pulling or damaging connectors during operation, both ends are supported using stress relief techniques. This helps keep connections stable and minimizes the risk of accidental disconnection during movement.
- **Shrouded Thrusters:** All thrusters' propellers are fully covered with shrouds to prevent accidental contact during testing and operation, making testing and handling significantly safer.
- **Smoothed Frame Edges:** The frame is carefully burred and polished to eliminate sharp edges that could harm team members or damage sensitive surfaces.
- **Warning Labels:** Clear visual warnings are placed on hazardous or high-voltage areas such as the thrusters and main power unit.

These features collectively enhance the safety of our ROV and ensure efficiency during testing and deployment, as well as simplify maintenance.

3.2 Safety Procedures

We follow strict operational procedures to ensure the safety of every member at all times. These include:

- **Safety Training:**
  All new members are given a guided introduction to the workspace safety rules and are required to work under close supervision of mentors until they prove a solid understanding of safety measures.
- **Personal Protective Equipment (PPE):**
  Members, especially in the mechanical subteam, are required to wear appropriate safety gear, including goggles, gloves, and face masks when working with high-speed tools, soldering stations, or heavy equipment as shown in figure 27.
- **Workshop Clean-Up:**
  At the end of each session, there's a cleanup conducted to maintain an organized and hazard-free work area, where members are expected to organize tools and return equipment to its proper place. In addition,

Every month the entire team participates in a cleanup day, where the entire workshop undergoes a full deep clean up to keep the work area efficient and safe for everyone.

- **Safety Checklist:**
A comprehensive safety checklist is followed before any testing or deployment step, available in the Appendix 7.1. It confirms that all systems are functioning properly and all risks are accounted for. It includes connections and power checks, tether inspections, and leak prevention measures.

By applying these procedures consistently, the team maintains a safe environment where everyone can work confidently and efficiently.

Figure 27: Applying Safety Procedures

4 Testing & Troubleshooting

4.1 Testing Methodology

Our Electrical system went through a multi-leveled testing process that began with testing each component's functionality on an individual level, then testing each PCB individually, which includes multiple stages such as short circuit testing, testing track to pad connectivity, making sure every component receives its power efficiently , and testing the PCB's functionality as a whole, a further detailed illustration of our PCB testing process is shown in figure 28, and finally testing the whole system with every component connected.

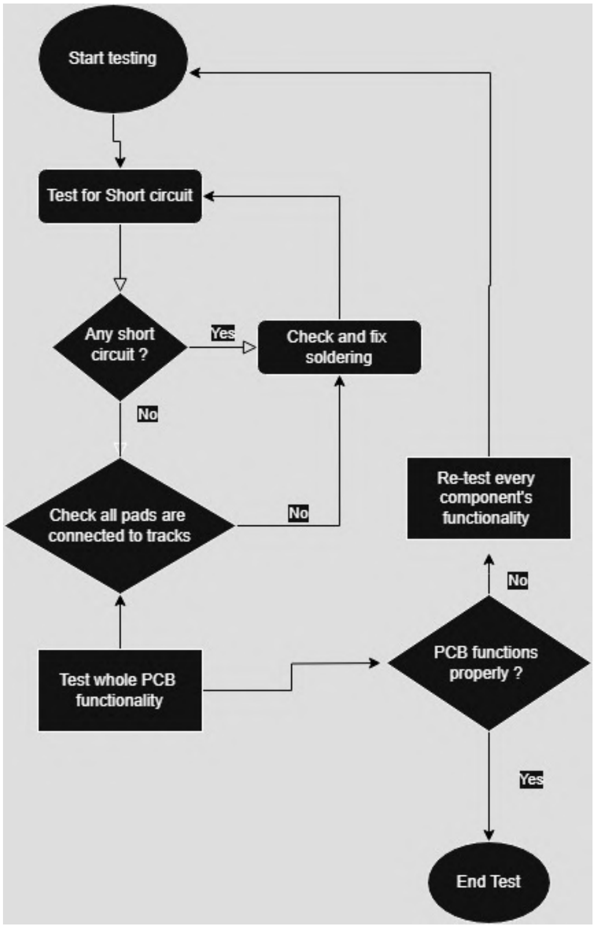

Figure 28: PCB Testing Flow Chart

After this entire process was over, we held multiple underwater tests to ensure every part of our system worked efficiently under real life conditions. mechanical part

Before putting Giulietta in the water, we needed to make sure all our enclosures were really waterproof - we definitely didn't want any water getting to our electronics! We came up with a pretty simple but effective way to test this.

We used compressed air to pressurize each enclosure - the main electronics box, camera housings, and the box for our pneumatic valves. It's actually pretty straightforward - we'd seal everything up, pump some air in, and then just watch to see if the pressure held. If the pressure dropped, we knew we had a leak somewhere.

This was really helpful because we could find and fix any problems without risking our electronics getting wet. Plus, it let us check if all our cable glands were sealed properly and if our acrylic end plates were fitting right. Sometimes we'd find tiny leaks, fix them up, and test again until everything was perfect.

It might not be the fanciest testing method, but it worked great for us. We knew if an enclosure could hold air pressure, it would definitely keep the water out when Giulietta was underwater. Better to find problems on the workbench than in the pool!

4.2 Troubleshooting Strategies

Electrical Troubleshooting

We followed a multi-staged strategy that included :

1. Visually inspect the system for obvious signs of damage, such as burnt components, loose connections, or tripped breakers.
2. Use diagnostic tools like multimeters, clamp meters, or insulation testers to measure voltage, current, and resistance, comparing readings against expected values.
3. Isolate sections of the circuit to narrow down the fault, checking switches, relays, and sensors for proper operation
4. Review wiring diagrams and control logic to ensure proper sequencing.

Once the faulty component is identified, repair or replace it, then verify the fix by retesting the system .

Mechanical Troubleshooting

When something goes wrong with Giulietta's mechanical parts, we've got some go-to fixes we usually try first. For leaks, we start with our air pressure test - it's pretty simple but works great for finding where water might be getting in. Usually, it's just a loose cable gland or maybe we need to tighten up some seals.

Frame issues are pretty straightforward - we keep an eye out for cracks in the PVC, especially where we glued things together. Sometimes the weights inside the pipes shift around, so we check those too. With the thrusters, it's usually just debris getting stuck in the nozzles or making sure our 3D printed mounts aren't cracking.

The manipulator can be tricky - if it's not working right, we spray some soapy water on the pneumatic lines to check for air leaks. That usually shows us where the problem is pretty quick.

We've learned to keep spare parts for the stuff that breaks most often. It's not rocket science - most of the time it's just about checking the obvious stuff first and fixing things before they become bigger problems!

5 Logistics

5.1 Company

5.1.1 History

Founded in **May 2021** by a group of ambitious engineering students from various departments at **Alexandria University**, **AUR** emerged from a shared passion for robotics and a desire to create opportunities for hands-on learning, creativity, and technical exploration.

From the very beginning, AUR has been fully dedicated to the field of robotics. Through intensive training, collaborative projects, and national and international competitions, we have empowered students to become not only skilled engineers but also confident problem-solvers and innovators.

In just a few short years, our initiative has reached remarkable milestones. To date, we have trained more than **250 students**, equipping them with strong foundations in **mechanical design, electronics, and programming**. Many of these students have gone on to lead and contribute to competitive robotics teams, research projects, and engineering initiatives.

- **Entering the World of ROVs**
  In **2025**, AUR proudly took on a new challenge — building our **first-ever Remotely Operated Vehicle (ROV)** and participating in the **MATE ROV Competition**. While our past experience had been centered around land-based robotics, this leap into underwater robotics opened new doors for innovation and learning.
- **Competition Achievements**
  1. **All Egypt Micromouse 2021** – Dominated the podium, earning **1st, 2nd, and 3rd place** at **E-JUST University**.
  2. **ORCE Innovation Challenge** – Secured **3rd place** with an original project competing against top teams across Egypt.
  3. **IEEE Victoris 1.0 (2022)** – Finished in the **Top 10** in the **Micromouse category** at **Mansoura University**.
  4. **IEEE Victoris 2.0 (2023)** – Returned with stronger designs and teamwork, taking **1st place**.
  5. **Minesweepers 2023 (Alamein University)** – Competed for the first time in minefield navigation, gaining key insights and experience.

6. **IEEE Mutex Summit (2024)** – Earned the award for **Best Mechanical Design** in the **Firefighting Robot Challenge** held at **Zagazig University**.
7. **ANNMMC'24 (Hungary)** – Reached the **final round** of the international **All Nations Micromouse Competition**, competing among the world's best.
8. **IEEE Victoris 3.0 (2024)** – With stronger designs and teamwork, taking **1st place** again.

At AUR, every robot we build and every competition we enter is a step toward our greater mission: to inspire the next generation of engineers, creators, and change-makers. We take pride in our journey so far and look forward to continuing to push the boundaries of student-led innovation.

5.1.2 Structure

AUR's executive board consists of:

- **CEO - Chief Executive Officer:** Responsible for all high-level decision-making to ensure that the goals and vision are realized with established timelines.
- **CTO - Chief Technology Officer:** Supports the CEO and oversees all technical divisions.
- **CFO - Chief Financial Officer:** Manages the financial planning and strategy.

The organizational structure is divided into three primary departments: **Mechanical**, **Hardware**, and **Software**. Each department is led by a **department head** and supported by a **vice head** to ensure efficient management and coordination. A full hierarchical structure diagram is shown in the Appendix 7.2.

Additionally, we have a dedicated **Media Team** that manages social media, creates visual content, and collaborates with sponsors to ensure consistent branding and promotional outreach.

5.1.3 Management

At AUR, we believe that teamwork, innovation, and structured knowledge-sharing are key to our success. Our goal is to ensure that every team member, whether new or experienced, has the tools and support needed to contribute effectively. With a well-organized project management approach, we keep things running smoothly and make sure every idea gets the attention it deserves.

- **How We Stay On Track**
  We break our season into four major phases, each one helping us build toward our final goal:
  1. **Training & Research Phase**: This is where new members get up to speed, and we explore ways to improve our designs.
  2. **Design & Prototyping Phase**: Using what we've learned, we start building the ROV, testing different ideas, and refining our approach.
  3. **Mission Planning & Development Phase**: Once competition details are released, we make sure our ROV is perfectly suited to meet the mission requirements.
  4. **Testing & Optimization Phase**: We put our ROV through intense testing to make sure it's reliable, efficient, and competition-ready.
- **How We Manage Our Resources & Workflow**
  To keep everything organized, we use digital tools like **Trello** and **Notion** to track tasks and deadlines. Regular meetings help us stay aligned, solve challenges, and make sure we're on schedule. Here's how we keep things running smoothly:
  - **Task Management**: Every team member knows what they're responsible for, thanks to Discord and Notion (in addition to GitHub for software tasks) as shown in figure 29.
  - **Checkpoints & Reviews**: Weekly team meetings help us review progress and adjust plans if needed.
  - **Budgeting & Procurement**: Our finance team works closely with technical leads to make sure we have the materials we need without overspending.
  - **Quality Control & Safety**: We follow strict testing protocols to ensure our ROV is both safe and high-performing.

Status	Aa Task	Category	Date	Priority	Project	Assigned to
Done	New Frame Assembly	Mechanical	March 8, 2025	High	ROV	S Salah Khaled
Done	Fix Vertical Thrusters Mount	Mechanical	March 6, 2025	High	ROV	Mohamed Ab
Done	Implement Pneumatic Syste OPEN	Mechanical	March 10, 2025	High	ROV	A Ahmed Husse
Done	Implement Actuators	Mechanical	March 10, 2025	High	ROV	M Mohamed Sa
Done	Attach Boxes for the PI and DCVs	Mechanical	March 11, 2025	Medium	ROV	S Salah Khaled
Done	Board Holders Inside Main Box	Mechanical	March 8, 2025	High	ROV	Mohamed Ab
In progress	Computer Vision Tasks	Software	March 14, 2025	High	ROV	Sama Ahmed
In progress	Finalize GUI	Software	March 11, 2025	High	ROV	B batoul E e
Done	Interface with IMU & Pressure Sensor	Software	March 8, 2025	High	ROV	ahmed elmas
In progress	Implement PID	Software	March 6, 2025	High	ROV	Yusuf Ahmad
In progress	Finalize Motion	Software	March 6, 2025	High	ROV	Yusuf Ahmad
Done	Fix the 12V_A Buck	Hardware	March 8, 2025	High	ROV	M Mohamed Na
Done	Implement Over-voltage Protection	Hardware	March 8, 2025	Medium	ROV	M Mohamed Na

Figure 29: Sample of AUR's task distribution on Notion

- **Learning, Growing & Passing It On**

At AUR, we're not just building robots, we're building skills, knowledge, and lasting connections. Our experienced members mentor newer recruits, ensuring that valuable expertise is passed down. We also maintain detailed documentation, storing design files, meeting notes, and technical specifications on **Google Drive** and **Notion** for easy reference.
With a structured yet flexible approach, AUR ensures that we stay efficient, innovative, and ready to tackle any challenge. By working together, we create something greater than just a robot—we build a community of passionate problem-solvers.

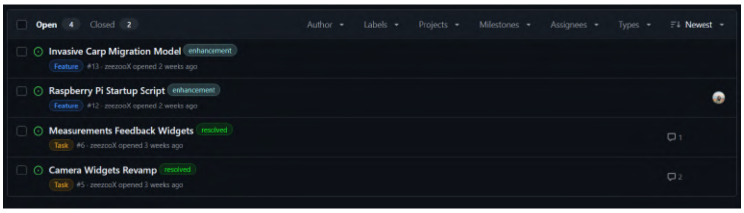

Figure 30: Sample of AUR's software task managament on GitHub

5.2 Accounting

5.2.1 Budget

The project budget outlines the financial plan for Giulietta, detailing the anticipated costs for each category necessary to successfully design, develop, and participate in the competition. The breakdown of the planned budget categories is as follows:

Category	%	Description
Mechanical System	30%	Costs related to the ROV frame.
Electrical System	25%	Costs for controllers, drivers, PCBs, power supply, wiring, and sensors.
Registration & Fees	25%	Fees for registering for the competition.
Workshop & Tools	7.5%	Hand tools, soldering stations, drill bits, and consumables such as wires and heat shrink tubing.
Contingency Fund	5%	Set aside for unexpected costs, emergency repairs, or last-minute purchases.
R&D and Testing	5%	Costs for prototyping, material trials, iterative upgrades, testing pools, and spare parts.
Branding & Media	2.5%	Costs for merchandise, banners, stickers, and media equipment for promotion and representation.

Table 2: Project Budget Breakdown

While planning the budget, the team faced several challenges, most notably the economic instability in Egypt, which caused frequent fluctuations in the prices of components and materials. This made it difficult to make accurate cost projections, especially for imported items affected by currency exchange rates and customs fees. Furthermore, availability issues and shipping delays often required us to consider alternative suppliers or more expensive local options.

A detailed list of all budget items and their estimated values can be found in Appendix 7.3.

5.2.2 Costing

While the budget section outlines the projected financial plan, this section documents the actual expenses incurred during the development and execution of the Giulietta project. This includes real payments made for each of the categories listed previously.

To ensure transparency and accuracy, the team used a shared Google Sheet to record every purchase and track the total expenditure in real time. Additionally, all related invoices and receipts were uploaded to an associated Google Drive folder organized by category and date.

A comprehensive breakdown of all expenditures is included in Appendix 7.4.

6 Conclusion

6.1 Future Improvements

6-DOF Motion

The ROV is currently limited to 5 DOF motion, which restricts its ability to navigate complex underwater environments. By implementing a 6 DOF motion system, the ROV can move freely in all directions, allowing for more versatile exploration and manipulation tasks.

The 6 DOF motion system will also require an updated control algorithm to ensure smooth and accurate movement in all directions.

Variable Buoyancy System

The ROV currently relies on a fixed buoyancy system, which limits its ability to adjust its depth and position in the water. By implementing a variable buoyancy system, the ROV can adjust its buoyancy to achieve neutral buoyancy at different depths, allowing for more precise control over its position in the water.

The variable buoyancy system will also require additional sensors to provide feedback on the ROV's depth and buoyancy. This can include pressure sensors to measure depth and accelerometers to measure the ROV's orientation in the water.

Full Autonomous Motion in All Axis

One of the main goals of the ROV project is to achieve full autonomous motion in all axis. This will allow the ROV to navigate complex underwater environments without human intervention, making it more efficient and effective for exploration and data collection tasks. This can be achieved by implementing a more advanced control algorithm that uses machine learning or artificial intelligence to adapt to changing conditions in the water.

2-DOF Manipulators

The ROV currently relies on a two manipulator arms, which limits its ability to perform complex tasks underwater. By implementing a 2 DOF manipulator system, the ROV can perform more complex tasks, such as picking up and manipulating objects in the water. This can be achieved by adding additional servos or motors to the manipulator arms, allowing for more precise control over their movement.

The 2 DOF manipulator system will also require additional sensors to provide feedback on the position and orientation of the manipulator arms. This can include encoders or potentiometers to measure the position of the servos or motors, other sensors to provide feedback on the ROV's environment.

Cameras' Servos

The ROV currently relies on a fixed camera system, which limits its ability to capture high-quality images and video underwater. By implementing a camera system mounted on servo motors, the ROV can adjust the position and orientation of the cameras in real-time, allowing for more precise and detailed imaging of the underwater environment

Using Separate MCUs

Currently we are using a single MCU to control the ROV and all of its systems. This can lead to performance issues and limitations in the ROV's capabilities. By using separate MCUs for control and other systems, we can improve the performance and reliability of the ROV.

6.2 References

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7 Appendices

7.1 Safety Checklist

Operational Safety Checklist				Workshop Construction Safety Checklist
Preparations Pre-operation	**Powering Up**	**Launching & In-Water Operations**	**Retrieval & Post-Mission Checks**	☐ The work area is clean and free from clutter before starting any task area
☐ Clearing any obstacles at the pool side area	☐ Ensure ROV's LEDs are on	☐ Unit testing before full integration	☐ Pilot surfaces the ROV then powers off all thrusters	☐ Only assigned team members are present in the workshop during operations
☐ Tether is untangled & securely attached to both the Station and ROV	☐ Dry test of thrusters, manipulators, and payloads	☐ Tether man maintains firm control of the tether at all times	☐ Assigned team members retrieve the ROV	☐ Hazardous tools are handled only by trained members
☐ Proper safety measures are followed, including wearing PPE	☐ All video feeds and sensor data are checked	☐ Only assigned team members handle the ROV	☐ ROV is safely placed on poolside	☐ PPE Must be worn when working with tools, soldering, or handling chemicals
☐ Ensure fuses are rated and installed correctly	**Loss of Communication**	☐ Visual inspection for leaks and air bubbles	☐ Power off the ROV completely	☐ Power is turned OFF before working on any electrical component
☐ Inspect for exposed wiring or unsecured electrical connections	☐ Power off the ROV completely	☐ Regular checks for ROV communication responsiveness	☐ Full inspection for leaks, loose connections, & tether integrity	☐ All tools and materials are stored safely after use
☐ All electronic components are properly sealed	☐ Inspect the ROV for damage, loose connections, or leaks	☐ Confirm task objectives are completed through GUI checklist	☐ All tools, and equipment used must be collected from station	☐ Monthly deep cleaning is conducted to maintain an organized and hazard-free workspace
☐ Station computer and necessary software are running an operating	☐ Perform troubleshoot procedures		☐ Tether coiled and stored to prevent damage	☐ Sharp edges on fabricated parts are filed down or labeled before handling

Table 3: Safety Checklist

7.2 Company Structure & Job Description

Figure 31: AUR's Team Structure

7.3 Project Budget

Alexandria University / Faculty of Engineering		AU-Robotics Project Budget		
	Sub-Category	Item	Status	Cost(USD)
Mechanical	Frame	PVC pipes	Purchased	9.2
		Adhesive	Purchased	5.8
	Thrust System	6* Bilge Pump	Purchased	139.36
		6* T100 Propellers	Purchased	45.21
		6* T100 Kort Nozzle	Purchased	25.43
		Connecting Part	Purchased	8.4
	Pneumatic System	Pistons	Purchased	20.73
		Soleniod Valve	Purchased	40.63
		Hose	Purchased	13.83
		Flow Control Valve	Purchased	0.87
		Compressor	Purchased	86.91
		Service unit with pressure control valve	Purchased	10.4
		Safety Valve	Purchased	0.26
		Non return valve	Purchased	1.73
		Fittings	Purchased	19.54
	Enclosure	Electronics Enclosure	Purchased	79.12
		Pneumatic Enclosure for soleniod valves	Purchased	35.25
		Camera Enclosure	Purchased	35.63
		Total(USD)		578.3
		Contingency (5%)		28.915
		Total with contingency		607.215
Electrical	Control System	Raspberry Pi 4 (4 GB RAM)	Purchased	98.4
		ESP32 Dev Board	Purchased	8.4
		3*Cytron 10A Motor Driver	Purchased	63.2
		2*BTS7960 Motor Driver	Purchased	18.6
	Power System	2*Waterproof 48/12VConverters	Purchased	52.6
		6*12V Power Supply	Purchased	121.3
		12/5V Buck Converter	Purchased	0.68
	Wiring	68m Power cable	Purchased	28.2
		30m CAT6 Ethernet	Purchased	12.5
		20*XT60 Connectors (Male, Female)	Purchased	10.6
		18* Pluggable Rosetta	Purchased	1.5
		6* Transistors	Purchased	1.5
		10*Diodes	Purchased	0.83
		40*Male Headers	Purchased	0.085
		40* Female Headers	Purchased	0.085
	Sensors	3* Aukey camera	Purchased	32.8
		BNO055	Purchased	5.25
		BMP280	Purchased	1
	PCB Fabrication	Main Board Fabrication	Donated	17.79
		Power Board Fabrication	Donated	17.79
		Total(USD)		493.11
		Contingency (5%)		24.6555
		Total		517.7655
Workshop Costs	Rent	Workshop Rent	Donated	174.86
	Tools	Soldering Irons	Purchased	4.1
		Solder Wire	Purchased	2.6
		Multimeter	Donated	10.87
		Wire Stripper And Cutter Pliers	Purchased	1.6
		Screwdriver Set	Purchased	3.24
		Drill & Drill Bits	Purchased	5.25
	Supplies	Electric Wires	Purchased	2.8
		Heat Shrink Tubing Pack	Purchased	0.89
		Total(USD)		206.21
General Costs	Registration Fees	Regional Registration	Purchased	217.46
		Global Registration	Purchased	330
	Transportation Costs	Fuel	Donated	18.56
	Merchandise	T-shirts	Purchased	76.54
		Banner	Purchased	6.45
		Stickers	Purchased	2.56
		Total(USD)		651.57
R&D Costs	Mechanical R&D	3D Printed Mockups	Purchased	5.42
		Waterproofing Experiments	Purchased	4.23
	Electrical R&D	ESP32 Dev Board	Purchased	8.95
		Breadboard and Jumper wires	Purchased	3.5
		Sensor Test Modules (BMI, BNO555)	Purchased	7.89
		Total(USD)		29.99
		Total Budget(USD)		1959.18

Figure 32: Project Budget

7.4 Project Costing

Alexandria University		AU-Robotics Project Costing		
Faculty of Engineering		Currency conversion was done according to the currency exchange rate on 8/4/2025 1USD = 51.24 EGP		
	Sub-Category	Item	Status	Cost(USD)
Mechanical	Frame	PVC pipes	Purchased	5.9
		Adhesive	Purchased	2.71
	Thrust System	6* Bilge Pump	Purchased	111.04
		6* T100 Propellers	Purchased	58.06
		6* T100 Kort Nozzle	Purchased	23.22
		Connecting Part	Purchased	6.97
	Pneumatic System	Pistons	Purchased	23.22
		Solenoid Valve	Purchased	45.48
		Hose	Purchased	15.48
		Flow Control Valve	Purchased	0.97
		Compressor	Purchased	81.28
		Service unit with pressure control valve	Purchased	11.61
		Safety Valve	Purchased	0.29
		Non return valve	Purchased	1.94
		Fittings	Purchased	19.35
	Enclosure	Electronics Enclosure	Purchased	88.05
		Pneumatic Enclosure for solenoid valves	Purchased	39.23
		Camera Enclosure	Purchased	21.29
		Total		556.09
Electrical	Control System	Raspberry Pi 4 (4 GB RAM)	Purchased	115.65
		ESP32 Dev Board	Purchased	9.88
		2*Cytron 10A Motor Driver	Purchased	49.42
		2*BTS7960 Motor Driver	Purchased	21.75
	Power System	4*Waterproof 48/12VConverters	Purchased	61.68
		48/5VBuckConverter	Purchased	1.56
		12/5V Buck Converter	Purchased	0.8
	Wiring	68m Power cable	Purchased	33.61
		30m CAT6 Ethernet	Purchased	14.83
		20*XT60 Connectors (Male, Female)	Purchased	12.65
		18* Pluggable Rosetta	Purchased	1.78
		6* Transistors	Purchased	1.78
		10*Diodes	Purchased	0.97
		40*Male Headers	Purchased	0.099
		40* Female Headers	Purchased	0.099
	Sensors	3* Aukey camera	Purchased	38.55
		BNO055	Purchased	6.275
		BMP280	Purchased	1.19
	PCB Fabrication	Main Board Fabrication	Donated	12.79
		Power Board Fabrication	Donated	12.79
		Total		398.153
		Giulietta manufacturing cost		954.243
Workshop Costs	Rent	Workshop Rent	Donated	296.5
	Tools	Soldering Irons	Purchased	9.58
		Solder Wire	Purchased	5.8
		Multimeter	Donated	11.62
		Wire Stripper And Cutter Pliers	Purchased	3.58
		Screwdriver Set	Purchased	7.26
		Drill & Drill Bits	Purchased	11.85
	Supplies	Electric Wires	Purchased	4.65
		6*12V Power Supply	Purchased	140.27
		Heat Shrink Tubing Pack	Purchased	2.32
		Total		493.43
General Costs	Registration Fees	Regional Registration	Purchased	217.46
		Global Registration	Purchased	330
	Transportation Costs	Fuel	Donated	18.56
	Merchandise	T-shirts	Purchased	91.33
		Banner	Purchased	5.14
		Stickers	Purchased	2.37
		Total		664.86
R&D Costs	Mechanical R&D	3D Printed Mockups	Purchased	5.42
		Waterproofing Experiments	Purchased	4.23
	Electrical R&D	ESP32 Dev Board	Purchased	8.95
		Breadboard and Jumper wires	Purchased	3.5
		Motor Drivers (BTS7960, Cytron)	Purchased	34.45
		Sensor Test Modules (BMI160, BNO555)	Purchased	7.89
		Total		64.44
		Total Cost		2176.973
		Income		2189.7
		Remaining Balance(USD)		12.727

Figure 33: Project Costing

Income	Competition Prizes	IEEE Victoris 3.0	179.23
		IEEE Mutex	38.96
	Self Funding	Employees Dues	1718.26
	Sponsors	Nori Solutions	155.85
		Makers Electronics	97.4
		Total balance	2189.7

Figure 34: Income

7.5 SIDs

7.5.1 Pneumatic

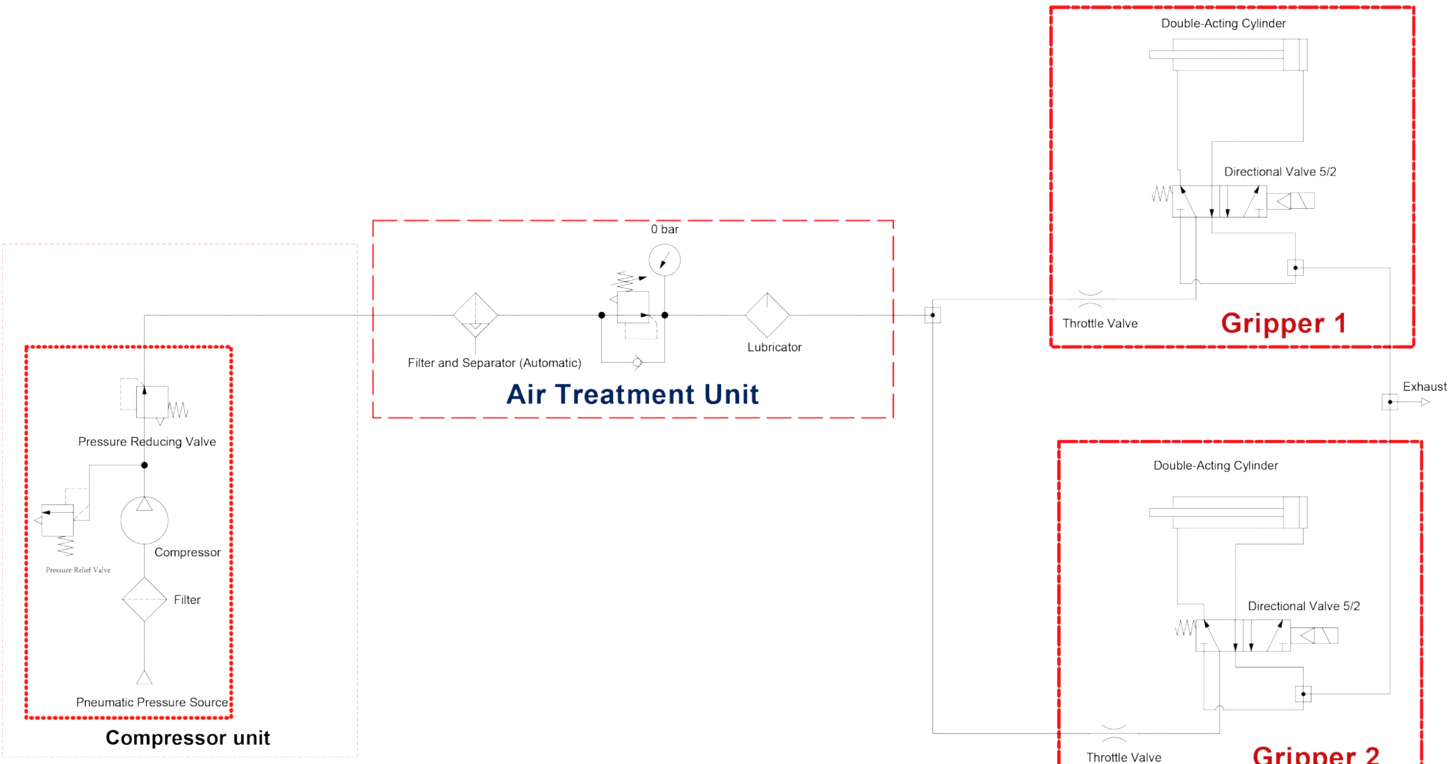

Figure 35: Pneumatic System Interface Diagram (SID).

7.5.2 Electrical

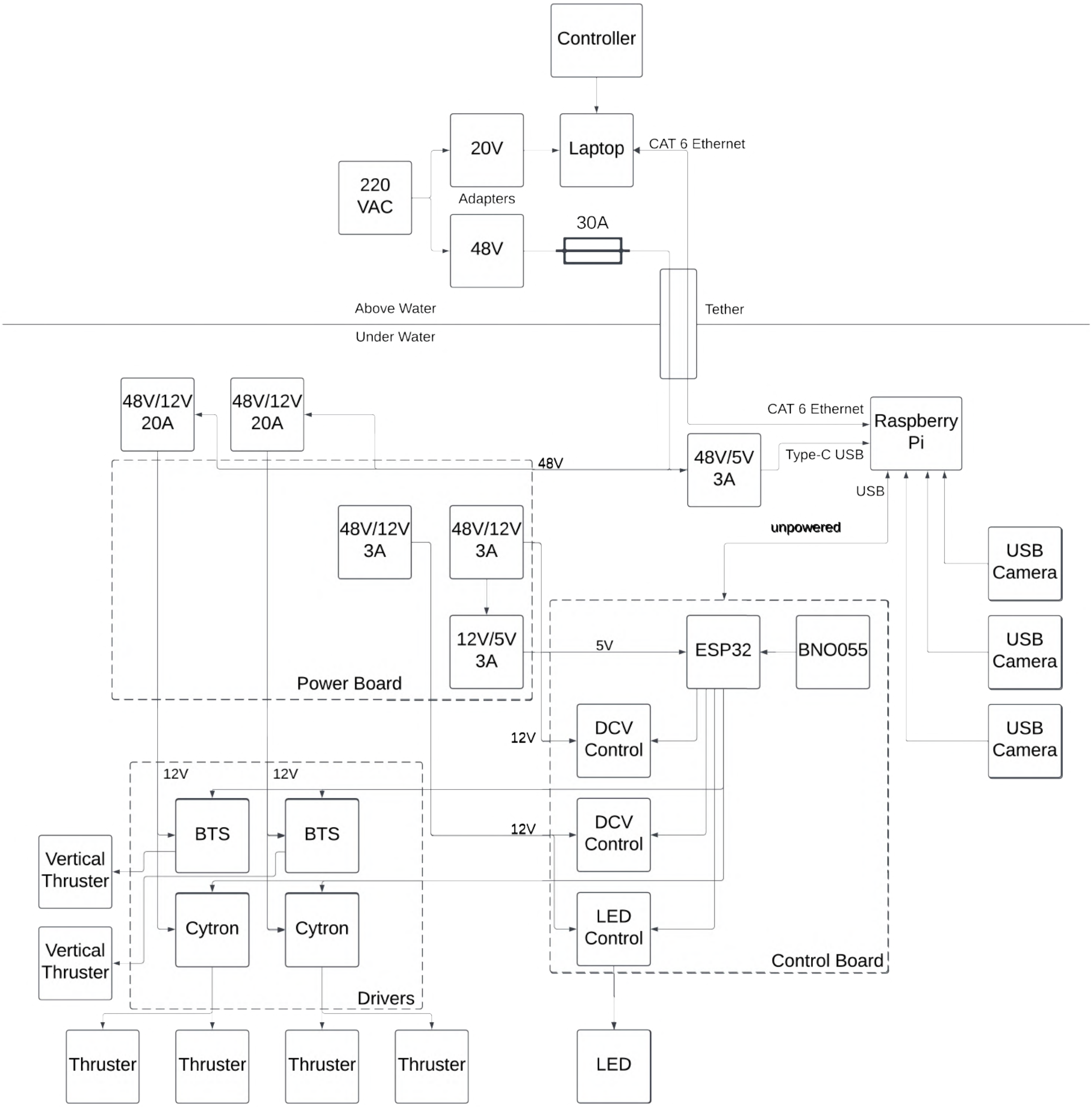

Figure 36: Electric System Interface Diagram (SID).