VORTEX
UNCHARTED EXCELLENCE

VORTEX ACADEMY
THE ART OF THINKING

THE MEGATRON

Vortex Explorers

TECHNICAL DOCUMENTATION

Vortex Academy

Alexandria, Egypt

COMPANY STRUCTURE

SOFTWARE ENGINEERS

25' Mostafa Hala CEO
25' Ali Mones Control/GUI Lead
25' Ali Ezzeldin ML/CV Lead
25' Mazen Sakr FM/TDR Lead
25' Asmaa Aboushady* Media Lead
25' Mustafa Mohamed
25' Esmael Saleh
25' Abdelraouf Elmaghraby
25' Abdelrhman Essam
25' Mazen Eldeeb*
26' Ahmed Elkhereby*
26' Mohamed Hisham*
26' Ahmed Emad*
26' Seif Taha*
26' Ahmed Hendawy*
26' Mohamed Elsayed*
26' Ammar Elsamman*
27' Youssef Mahmoud*
28' Youssef Taha*

ELECTRICAL ENGINEERS

25' Abdelrahman Aqaby FM
25' Ahmed Fathy
25' Habiba Hatem Float pm
25' Omar Ahmed
25' Rodina Ehab
26' Mahmoud Reda

MECHANICAL ENGINEERS

25' Ahmed Kamel FM
25' Jana Ghassan
26' Ammar Yasser
26' Ahmed Samir
Highschool Grade 12 Retaj Tamer
25' Mariam Hesham
25' Abdelrahman Badawy
25' Mohamed Abdrabo*
25' Ali Mohamed*

MENTORS

Muhammed Salem
Abdelrahman Abouklila
Asmaa Bhaa
Maryam Mohammed
Abdelaziz Yousry

Graduation Year
* Denotes New Members
FM : Functional manager
TDR : Technical Documentation and Reporting

ABSTRACT

In pursuit of uncharted excellence, we embrace Steve Jobs' insight: "If you are working on something that you really care about, you don't have to be pushed. The vision pulls you" and acknowledge Robert Swan's warning: "The greatest threat to our planet is the belief that someone else will save it."
Since 2015, Vortex Robotics has led underwater exploration, leveraging engineering expertise to tackle real-world challenges. Our team of 34 engineers—specializing in electrical, mechanical, and software disciplines—is dedicated to advancing sustainable technology and environmental protection.

Our latest Remotely Operated Vehicle (ROV), Megatron, reflects our commitment to accessibility, reliability, and environmental impact. It's designed to be user-friendly and adaptable, making it a powerful tool for a range of critical underwater tasks.

ROVs like Megatron are already transforming industries and conservation efforts around the world. They're used to inspect offshore wind farms, support marine biology research, assist in underwater construction, monitor pollution levels, and document shipwrecks for historical preservation. Megatron plays an active role in all of these, helping maintain infrastructure, collect scientific data, and reduce human risk in hazardous environments.

Engineered for mission-critical tasks, Megatron excels at underwater shipwreck documentation, spotter buoy maintenance, and water sample collection for analysis. It also supports renewable energy structures maintenance and environmental impact Monitoring. Through this unified platform, Vortex Robotics advances environmental research and conservation, forging a future where innovation and sustainability work hand in hand.

Figure 1. Vortex Company Photo, By Maryam Mohamed

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Company & Project Management

Company Profile

Vortex Explorers is a driven company focused on pushing the boundaries of underwater robotics through the design and deployment of cutting-edge Remotely Operated Vehicles (ROVs).

Figure 2: Vortex Company Structure

The team is led by a CEO who oversees the organization and its departments. The CEO is responsible for setting weekly goals, monitoring the progress of the ROV and float projects, and addressing any challenges the departments face. They analyze these challenges and work towards solutions to ensure smooth operations.

The company is structured into three departments: Software, Mechanical and Electrical, as well as the TDR (Technical Documentation and Reporting) and Media committee. Each department has a specific focus, such as

The Electrical team is responsible for tasks such as circuit wiring, PCB design, and PCB soldering. They manage the electrical connections for the ROV and ensure all components are integrated correctly.

The Mechanical team is responsible for designing the ROV body and the float body. They focus on creating functional and efficient structures to ensure the ROV can perform well in the competition. This includes working on buoyancy, durability, and overall design to meet competition requirements.

The Software team handles the coding and software development for the ROV. They are responsible for writing and optimizing the code that controls the ROV's functions, ensuring smooth and efficient operation during the competition. This involves programming sensors, motor controls, and other key functionalities.

The TDR (Technical Documentation) and media committee is responsible for creating all technical documentation -internal and submitted-. They ensure that all project details, designs, and developments are documented and well-organized and they are responsible for all designs, marketing and media coverage.

Refer to the cover page for individual members and their roles.

Project Schedule

In August, the entire team collaborated on comprehensive project planning. This phase involved defining the overall project scope, setting a timeline, and dividing the project into clear development phases. During this time, we also established Key Performance Indicators (KPIs) to assess progress, evaluate departmental productivity, and identify areas requiring additional support. These KPIs are revisited regularly to ensure alignment with project goals.

Phase 1: **R&D and Recruitment** (September – November 2024)

This phase focused on two parallel efforts:
R&D: Detailed analysis and enhancement of the previous ROV model and float system. Issues identified in past performance were addressed, and new design opportunities were explored.

Training and Recruitment: New team members were onboarded and trained in department-specific fundamentals (e.g., PCB design, SolidWorks, embedded systems). Cross-training sessions promoted interdisciplinary awareness.

Phase 2: **Design and Ideation** (December 2024 – January 2025)

Following the release of the official competition manual, this stage combined R&D findings with new requirements to brainstorm and develop the new vehicle concept. Each subsystem (mechanical, electrical, software) proposed initial designs, which were reviewed and refined collaboratively. This stage also involved the design of mission-specific tools and payloads.

Phase 3: **Manufacturing and Assembly** (February-March 2025)

Subsystems moved into fabrication and assembly. Mechanical components were 3D printed or machined, electrical systems soldered and tested, and software integrated into embedded systems. Interdepartmental collaboration was critical to ensure timely handoffs and efficient integration.

Phase 4: Debugging and Continuous Improvement (April 2025)

A critical and iterative phase where each subsystem underwent rigorous testing. Extensive in-water tests in competition-simulated environments were conducted. Tools and payloads were refined based on performance, and operational reliability was prioritized. Continuous debugging cycles allowed us to improve both system response and operator control.

Milestone 1: MATE Regional Competition (April 24–27, 2025)

A full-system trial under competitive conditions, providing key insights and qualifying the team for the *MATE International Competition.*

Phase 5: Post-Competition Enhancements (May – June 2025)

Based on competition feedback, the ROV's scope and performance were optimized to improve efficiency, fault tolerance, and task automation for international readiness.

Milestone 2: MATE International Competition (June 19–21, 2025)

The ultimate test: competing at the world championship in Alpena, Michigan against top global teams.

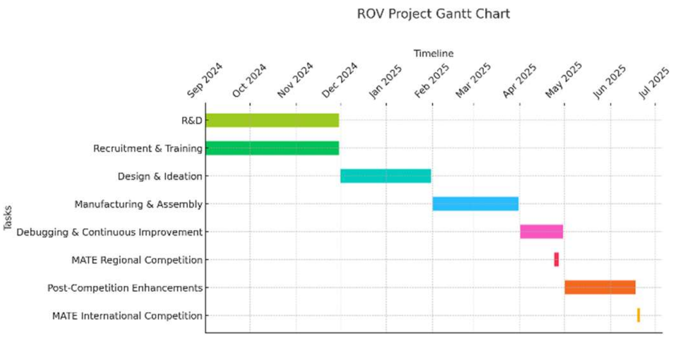

Figure3: Project Gantt Chart

Resource, Procedure, & Protocol Management

During the August planning period, the company defined the resource allocation strategies, standardized procedures, and operational protocols required to meet mission objectives and solve daily operational challenges. These systems were built around agility, collaboration, and accountability, ensuring smooth project execution throughout the development cycle.

Resource Management:

Time: Each team member is expected to contribute a minimum of 20 hours per week. Work is divided and tracked using Notion, which replaced Trello this year. The switch to Notion gave the team a more flexible and powerful workspace, allowing for improved task tracking, centralized documentation, sprint planning, and better organization of team activities.

Budget & Materials: Resource distribution is overseen by the CEO. Departments submit material requests that are evaluated for necessity, cost-effectiveness, and timing. All purchases are logged in a shared financial system, ensuring transparency and accurate budget tracking.

Manpower: Cross-functional collaboration allows teams to support one another during critical phases like debugging and competition prep. Members are assigned based on workload demands and technical strengths to maintain balance and progress across all departments.

Procedures:

The company follows clear and structured procedures to guide its technical operations:

Manufacturing: All parts are built based on detailed CAD drawings and verified by department heads before production. Mechanical builds go through a dry-fit process before final assembly to minimize errors.

Assembly: Subsystem integration follows approved schematics and diagrams. Weekly integration checks ensure that all parts work seamlessly when combined.

Testing: Testing is performed in stages—starting with individual components, then subsystems, and finally full ROV integration. Regular in-water testing during Phase 4 helps simulate real-world conditions and verify overall system reliability.

Protocols:

Safety Protocols: All team members follow lab safety guidelines, including wearing PPE, following ESD precautions, and using proper tools and procedures when handling high-voltage or mechanical systems.

Standard Operating Procedures (SOPs): Each department has developed SOPs for common tasks such as soldering PCBs, deploying the ROV, and flashing software. These ensure consistency, quality control, and a smoother learning curve for new members.

Troubleshooting: When technical problems arise, they are first handled within the subteam. If not resolved, the issue is presented to the department head and then to the CEO if needed. All issues are logged and tracked in Notion to ensure organisation and follow-up.

Operational Schedule

To maintain structure and stay on schedule, the company follows a consistent weekly and monthly meeting routine:

- **Fridays:** CEO-Department Head Meeting: Review weekly KPIs, track project milestones, and discuss cross-department concerns.
- **Department Head – Subteam Leader Meeting:** Review current progress, assign tasks for the upcoming sprint.
- **Departmental/Subteam Meetings:** Plan weekly work, review completed tasks, and assign new ones based on sprint objectives.
- **Monthly General Meeting**: All team members gather to review overall progress, raise major issues, and plan for upcoming project phases.

Daily Communication: The team stays in touch every day using **Slack**, where members share quick updates, ask questions, and report any issues. This keeps communication smooth and helps solve problems quickly between scheduled meetings.

Safety & Risk Management

Philosophy

At Vortex, safety is not an afterthought—it is a core value embedded in every aspect of our work. We believe that innovation and safety must go hand in hand to achieve sustainable excellence. Our team adheres to industry best practices, international safety standards, and MATE ROV competition regulations, with a strong emphasis on proactive risk management and continuous preventive measures. Every team member is empowered and expected to take ownership of safety by identifying hazards, proposing mitigations, and maintaining compliance across all activities. We foster a culture of accountability through regular assessments, collaborative reviews, and open communication. This approach ensures that our work environment remains secure, efficient, and conducive to high-performance engineering.

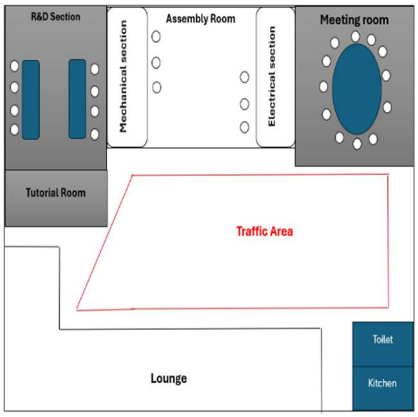

Figure 4: Vortex Workshop

Standards

Lab Protocols

Strict lab protocols are enforced to maintain a hazard-free workspace. Key elements include:

Job Safety Analysis (JSA): Conducted before each task to assess potential risks and define mitigation strategies.
Mandatory PPE: Use of safety goggles, gloves, anti-static gear, and protective clothing when handling tools or equipment.
Tool Inspections and Maintenance: All tools and test setups undergo scheduled checks to ensure functionality and safety compliance.
Clean Bench Policies: Workstations must remain uncluttered and organized to reduce accident risks and improve workflow.

By strictly adhering to these procedures, we reduce the likelihood of injury, equipment damage, or system failure during both lab work and field testing.

Training

To ensure a uniformly high level of safety awareness and operational readiness, all Vortex team members complete a structured safety training program. This includes:

Initial Safety Inductions: Covering lab rules, risk assessments, emergency protocols, and proper use of Personal Protective Equipment (PPE).
Hands-On Supervised Sessions: Members practice safe handling of electrical, mechanical, and pneumatic systems under mentor supervision.
Refresher Workshops: Periodically conducted to review procedures, introduce updated safety protocols, and address any past incidents.
Safety Drills and Peer Reviews: Simulating emergency scenarios to reinforce preparedness and encourage mutual oversight.

This comprehensive program ensures every member is capable of contributing to a safe work environment and responding effectively to potential hazards.

Features.

To ensure a high level of safety in Megatron, we have implemented several key electrical precautions. A 30A fuse is strategically placed within 30cm of the Anderson connector to safeguard the system from excessive current flow. Another 30A fuse is installed after the buck converter, adding an extra layer of protection against overheating and potential damage. To prevent wiring errors, power and signal cables are distinctly color-coded and arranged separately, minimizing the risk of reversed connections. Additionally, AC and DC wiring systems are kept independent to eliminate electrical interference and enhance the safety of both operators and equipment.

Figure 5: Thruster Guard

The ROV's design prioritizes user safety by incorporating smooth, rounded edges and eliminating sharp corners. To further reduce injury risks, exposed bolt threads are fitted with cap nuts. Protective aluminum meshes are integrated around moving components, such as thrusters, to prevent unintended contact with rotating parts and the intrusion of foreign objects. These meshes comply with the **IP20 standard**, ensuring that objects larger than 12.5 mm in diameter cannot enter while maintaining proper airflow. For waterproofing and electrical safety, O-ring face seals and agro gland are utilized to keep electronic components dry and secure from damp conditions. The pressure regulator plays a crucial role in maintaining optimal air pressure within the pneumatic system, preventing damage and ensuring smooth operation. Additionally, regular maintenance and inspections are conducted to identify and mitigate potential safety risks before they escalate.

To enhance safety awareness, warning labels are placed on critical components of the ROV. These labels are applied to thrusters and moving parts, high-pressure areas, fragile PMMA sections, and electrical components. They serve as clear reminders of potential hazards, ensuring that anyone interacting with the ROV is informed of the associated risks and follows proper safety protocols.

Design Rationale:

Core Vehicle Design

Design Methodology

Megatron was developed using a systems-based design approach, ensuring seamless integration between mechanical, electrical, and software subsystems. Guided by functional decomposition, we broke down mission objectives into specific design requirements, ensuring every component served a distinct role.

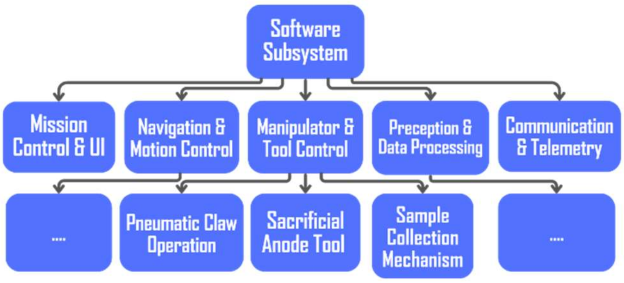

Figure 6: Functional decomposition diagram

To make informed design decisions, we conducted trade studies, evaluating options based on cost, efficiency, manufacturability, and reliability. Researching previous ROV designs, competitor approaches, and industry standards allowed us to implement proven solutions while introducing novel improvements, such as a 7 IP camera network and a dual-PCB system to mitigate EMI interference.

A collaborative, interdisciplinary approach ensured seamless integration across subsystems, reducing compatibility challenges and improving reliability. Redundancy and failure mitigation were prioritized, informed by industry practices and our own past experiences.

We embraced an iterative design process, using simulations, prototyping, and systematic testing to refine Megatron's performance. By continuously validating our design through real-world trials, we ensured that every decision was data-driven and mission-optimized.

This structured, research-driven methodology enabled Megatron to be a high-performance, adaptable, and reliable ROV, ready to tackle any challenges.

Vehicle Overview

Figure 7: Megatron

Megatron is composed of several integrated systems, each playing a crucial role in its functionality and mission success.
The structure provides a durable yet modular frame, ensuring robustness and customizability. Buoyancy and stability systems maintain balance and control underwater, allowing for smooth maneuverability. The propulsion system consists of strategically placed thrusters that enable precise movement in all directions.
The control system processes real-time data for navigation and automation, while the electrical system ensures efficient power distribution and vehicle operation. The tether serves as the vehicle's lifeline, carrying power, data, and pneumatic lines.
Finally, Megatron's payload and tools include manipulators, sensors, and cameras, allowing it to complete mission tasks such as object retrieval, environmental monitoring, and underwater inspections.

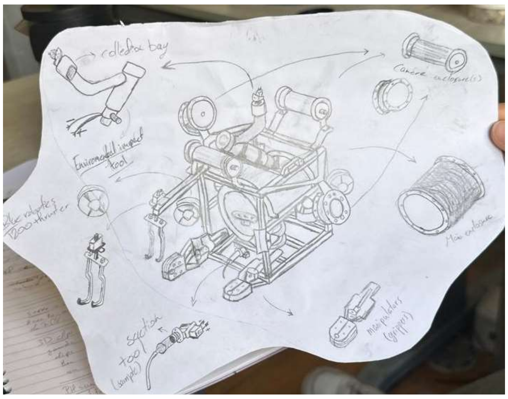

Figure 8: Megatron's Hand Sketch

Vehicle Systems

a. Structure

Manufacturing Processes

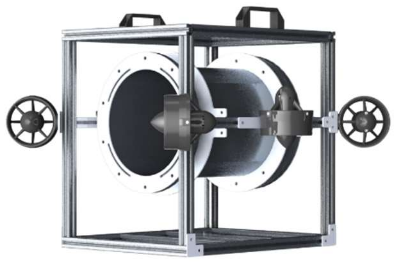

Figure 9: Megatron's Structure

Megatron' design is completely unconventional. We simulated water flow through the vehicle by CFD using ANSYS fluent. Therefore, we tested our design before production to ensure success after manufacturing. The mechanical design team put in excessive effort to bring this together, but the main issue was getting our vehicle to move smoothly. We decided that the best solution was to try to make our ROV as smooth and streamlined as possible, which was achieved by using thin but durable supports like the aluminum extrusions and making sure that in a frontal plane view of the ROV there would be many empty spaces for the water to pass through to reduce drag.

Mechanical Materials:

	HPDE	Acrylic (PMMA)	Aluminium	PLA	Stainless Steel 304
Density (g/Cm^3)	1	1.2	2.7	1.24	8
Impact Strength (J/m)	260	74	294	96.1	325
Flexibility (MPa)	24	71	90	80	540
Cost	Moderate	Moderate	Moderate	High	Moderate

We selected the best materials for our frame structure based on the nature of each component and the properties of each material, such as density, impact strength, flexibility, and cost. The frame of our ROV is meticulously constructed from aluminum extrusions of varying lengths, specially manufactured for this purpose. When assembled, these components create a streamlined and accessible design that accommodates numerous attachable and detachable tools. Furthermore, the frame is lightweight yet exceptionally durable. Additionally, one of our team members created a CAD model for a 3D printable clip that makes these aluminum extrusions even more accessible. This clip attaches onto any aluminum extrusion and includes an additional part for sticking or screwing tools or materials into it, which can then be clipped into the initial piece.

·**HDPE:** Created using a CNC (Computer Numerical Control) routing machine. (Used in manipulators, & Electronics housing)

·**Acrylic:** Cut with a CNC laser machine. (Used in the Housing's face)

·**Aluminum and Stainless Steel:** Processed using wire CNC machines. (Used in links and extrusion connectors)

·**PLA:** 3D printed material. (Used mostly in payloads and internal structure fixations)

Electronics Housing:

We designed our electronics housing as an HDPE cylinder with two face plates on each side. HDPE was chosen for its ability to withstand the level of pressure we need. One face plate was made of Acrylic to ensure transparency for our vision system. The other face plate was composed of stainless steel and featured multiple holes for glands. The reason we chose HDPE for the enclosure was for its ability to withstand the level of pressure we need. We encountered several issues, including limited space inside the enclosure, which required manufacturing a housing extension to accommodate our internal structure and enlarge the housing. Additionally, we faced problems with the acrylic front face affecting our sealing. The gaps between the bolts filled with water, and further tightening of the bolts would crack the face, leading to additional sealing challenges and material wastage. We resolved this issue by making a face plate that distributed the bolts' pressure, improving sealing and protecting the acrylic face. The enclosure was sealed with face seals for the main face-housing contact, while external cables passing into the enclosure were secured with cable glands.

Figure 10: Megatron's Main Enclosure

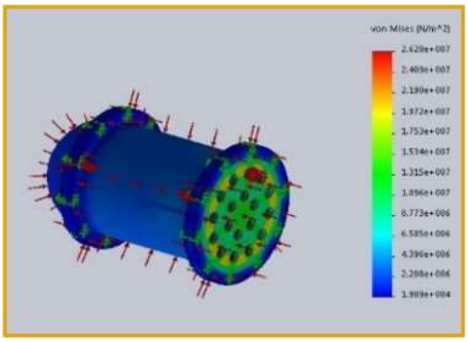

Figure 11: FEA stress analysis of Megatron's main enclosure

Electric enclosure and sealing:

The main enclosure is sealed using a method called "face sealing," which utilize O-rings placed in a groove that is compressed between the face and housing. Other housings are sealed using both a face seal and another method called "Piston Seal", which also utilizes O-rings but in a different way, where we manufacture a cap with O-rings in its base/thread and push it inside a cylindrical enclosure until it's secured inside. The O-rings, made of Nitrile, serve as a reliable sealant between the enclosure and the faces and were selected based on Parker's Sealing Handbook specifications. No chemical sealant was applied in the enclosures. Cable glands were used to seal any cables entering the enclosures, thereby isolating the external environment from the interior space of the enclosure. Additionally, stress analysis conducted with SolidWorks static analysis confirmed that the enclosure can withstand pressures up to 10 meters underwater.

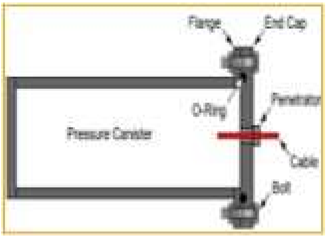

Figure 12: O-Ring Face Sealing method

b. Buoyancy and Stability

Megatron exhibits significant stability due to the strategic placement of weights at the base, which lowers the center of gravity (CG). This stability is further enhanced by the addition of foam, making the ROV slightly positively buoyant. However, this buoyancy can be easily neutralized by the vertical thrusters when needed.

The enclosure on Megatron is designed to displace the highest volume of water, measuring 9923.5 cubic centimeters, which shifts the center of buoyancy (CB) effectively counterbalancing the weight of the ROV and any payloads it may carry.

c. Propulsion:

Direction	Maximum thrust
Upward	2*3.55 = 7.1 Kgf
Downward	2*3.0 = 6 Kgf
Forward	4*3.55*sin (45) = 12.0 Kgf
Backward	4*3.0*cos (45) = 10.2 Kgf
Lateral	(2*3.0*cos (45)) + (2*3.55*sin (45)) = 9.19 Kgf

In Megatron, we aimed to utilize an optimal number of thrusters and appropriate types to maintain all necessary degrees of freedom for smooth maneuvering. A six-thruster configuration was chosen to meet these objectives. The selected thrusters were Blue Robotics T-200 models, known for their high performance and ability to withstand pressures at depths of thousands of meters. This selection was made based on their ease of control, cost-effectiveness, various mounting options, accessibility, and enhanced flow capabilities.

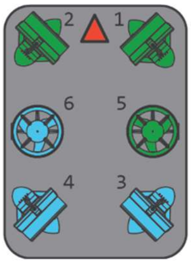

Figure 13: Megatron's Thruster Configuration

The four horizontal thrusters enable the vehicle to move laterally, a movement known as "Crabwalk", along with other maneuvers without necessitating any central thrusters. The

two vertical thrusters facilitate vertical movement. Additionally, the 45° angled horizontal thrusters allow movements along the x and z axes, such as forward, backward, left, right, and rotational motions.

Thruster fixation:
In Megatron, the thruster mounts are crafted from bent aluminum sheet metal and are securely attached to four aluminum profiles, positioned at each vertex of the ROV at a 45-degree angle. After evaluating options of 30-degrees, 60-degrees, and 45-degrees through flow simulations, the selection of the 45-degree angle was determined to be the most effective. We preferred bent stainless steel over 3D printed parts due to its superior strength and rigidity, whereas PLA was considered too fragile for this application, HDPE was too fragile when thin and an unstable fixation, PMMA could not be bent and would be very fragile.

Feature	NVIDIA Jetson	Intel NUC	Raspberry Pi 5
Processing Power	High	Very High	High
Power consumption	Moderate	Very High	High
4K Video Streaming	Yes	Yes	Yes
Integrated AI Capabilities	Yes	Yes	No
Hardware I/O	Good	Moderate	Extensive
Cost	Moderate	High	Low

Figure 14: Main Computer Decision matrix

d. Control System

Control System Selection

In designing the control system, we conducted a comparative analysis of potential main computing units based on power efficiency, processing capability, features, and cost.

The decision matrix above highlights why we selected **Raspberry pi 5** as the ROV's main computer

Based on this comparison, we chose the Raspberry pi 5 as the ROV's main computing unit. It serves as a proxy between the Pixhawk and the top-side laptop, handling real-time data processing and communication. Additionally, it plays a crucial role in streaming video from the blue robotics camera, ensuring high-quality visual feedback for the operator.


Figure 15: Raspberry pi 5

Pixhawk for Navigation and Control
We integrated Pixhawk as the controller for the ROV due to its built-in PID controller, which ensures precise thruster control for stable movement. Another key factor in choosing Pixhawk is its support for various flight modes, making it easier for the pilot to execute mission tasks efficiently.

Figure 16: Pixhawk 1.4

Control Modes and Mission Applications
To ensure precise maneuverability and stability during mission tasks, our ROV utilizes multiple control modes tailored to specific operational requirements. Each mode enhances the ROV's ability to execute competition tasks efficiently and precisely.

Stabilize Mode allows manual control while automatically correcting roll and pitch angles, preventing sudden tilts and ensuring smooth navigation. This is particularly useful for cargo inspection and manipulation, sacrificial anode replacement, jellyfish and fish specimen collection, hydrophone placement, and shipwreck documentation.

Depth Hold Mode locks the ROV at a fixed depth, ensuring consistent positioning while allowing free horizontal movement, which is essential for water sampling, eDNA analysis, and hydrophone deployment.

By leveraging these advanced control modes, the ROV achieves superior stability, efficiency, and precision, ensuring optimal performance in executing mission-critical tasks during the MATE ROV Competition.

The internal IMU provides real-time orientation data, while **the external Bar30 pressure sensor** accurately measures depth. This combination enhances navigation accuracy by ensuring precise depth control and stable maneuvering during mission tasks.

Unified and Customizable GUI – VORTEX UI

In previous years, the GUI was divided into separate interfaces for different components, including the pilot, copilot, and float. This year, we aimed to create a **standardized, user-friendly, and modular** GUI. To achieve this, we developed **VORTEX UI**, a **unified and customizable** application that integrates all functionalities into a single interface.

Figure 17: Main tab

Key Features of VORTEX UI:

- **Fully modular** – Users can configure and customize interface elements based on mission needs.
- **Multi-device support** – While designed for a single laptop interface, camera feeds and controls can be extended across multiple laptops.
- **Integrated mission tabs:**
  - **Photosphere Tab** – Displays 360-degree camera feeds.
  - **Float Tab** – Manages float communication and data visualization.
  - **Settings Tab** – Allows interface customization based on pilot strategy.
  - **Measurements Tab** – Displays tools for integrated object measurement approaches.
  - **Map Tab** – Provides tools for autonomous invasive carp map creation.

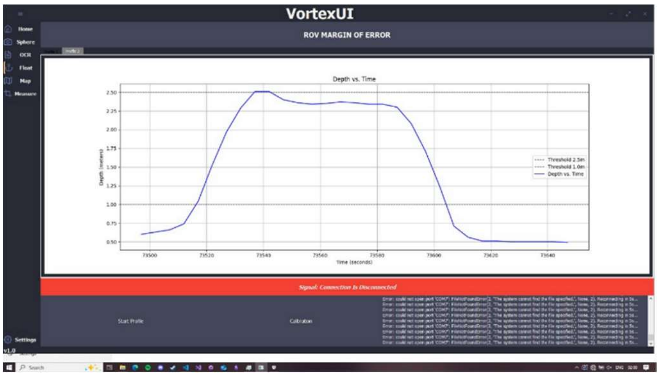

Figure 11: Float Mission Tab

This transformation ensures a more efficient **user experience** while maintaining flexibility and adaptability for different operational conditions.

This UI is integrated into an **executable** with all its dependencies included. The executable can run on any **windows** device and is intended to be run on multiple laptops in the station to achieve mission tasks.

Figure 19: Settings tab

e. Electrical System

Our vehicle's electrical system has undergone significant improvements by strategically dividing functionality into two specialized printed circuit boards (PCBs): a dedicated **Power PCB** and a separate **Control PCB**. This separation effectively minimizes electromagnetic interference (EMI) between the high-current circuits (such as thrusters) and sensitive control components. Moreover, this design significantly reduces complexity, resulting in smaller-sized PCBs that are lighter, more cost-effective, easier to integrate, and better optimized for specific functions.

Enhanced Power Distribution

In previous designs, a single 60A buck converter (48V to 12V) was utilized to power all six T200 thrusters, accompanied by one 15A converter for auxiliary systems. This setup caused performance constraints due to voltage instability and potential current limitations during peak loads. Recognizing these limitations, this year's design significantly improves power management by employing:

Two dedicated 60A buck converters (48V to 12V) exclusively powering the six T200 thrusters, effectively eliminating voltage instability, reducing wiring complexity, and substantially improving thruster responsiveness and overall system speed. This configuration fully leverages the advanced thruster stabilization capabilities provided by the Pixhawk flight controller.

Two auxiliary 15A buck converters (48V to 12V) providing isolated and stable power for critical subsystems and tools, including the servo motor used in the sacrificial anode tool, two Directional Control Valves (DCVs) for operating the grippers, bilge pump, auxiliary pumps, sensors, and other system components. The isolated auxiliary supply ensures that these critical components receive uninterrupted and noise-free power, significantly enhancing operational reliability and component lifespan.

Modular ESC Design and Connectivity

An important enhancement retained from last year's system is the modular Electronic Speed Controller (ESC) arrangement. Each ESC is individually mounted on compact, removable PCB modules and connects directly to the Power PCB using robust, polarized MT-30 connectors. This modular approach simplifies maintenance, significantly reduces downtime, and prevents potential damage associated with traditional soldered ESC connections. Furthermore, these ESC modules are now easily reusable, adaptable for future systems or vehicle platforms, further improving overall cost efficiency and flexibility.

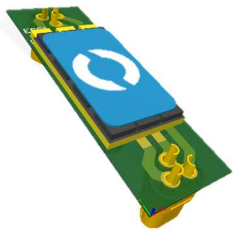

Figure 20: ESC Module

Advanced PCB Fabrication and Performance Enhancement

Surface-mount device (SMD) components, including resistors, capacitors, diodes, and LEDs, continue to be extensively utilized.

The provided PCB schematics clearly illustrate the improved circuit design, optimized component placement, and specialized functionalities within each PCB:

Power PCB

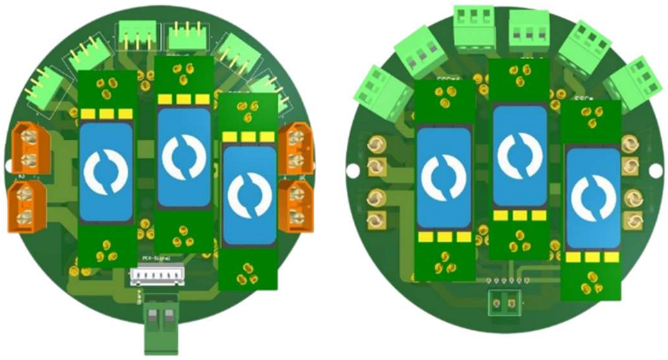

Figure 21: power pcb

- Incorporates modular ESC interfaces using polarized MT-30 connectors.
- Clearly defined power pathways and separate circuits supplied by dual 60A buck converters dedicated to thrusters.
- Auxiliary outputs powered by two independent 15A buck converters.

Control PCB

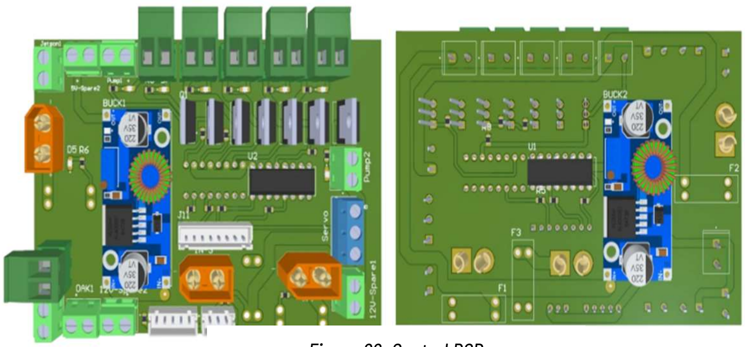

Figure 22: Control PCB

The MOSFETs are controlled using optocoupler-based gate drive circuits, which act as the interface between the Pixhawk and the power electronics. Since the Pixhawk's output signals are not sufficient to directly drive the MOSFETs, the optocouplers provide both electrical isolation and signal amplification. These MOSFET-based circuits function as the switching circuits for controlling essential auxiliary equipment such as two DCVs for gripper operation, the servo motor, the bilge pump, an auxiliary pump. This solution was first tested and implemented in last year's system to overcome the limitations of direct Pixhawk control. After

proving to be reliable and effective in real-world conditions, the same gate driving and switching circuit design was reused in this year's system without modification.

Features dedicated two 5V buck converters providing stable power separately to critical computational hardware, including the Raspberry Pi and the other dedicated to Pixhawk flight controller, thus addressing previous overcurrent concerns.

Employs polarized connectors (e.g., XT60, MT-30, and JST) for secure and error-free connections, enhancing reliability and ease of integration.

To ensure safety and prevent damage to the components, fuses were added to protect the circuit after each buck converter and also for most of the valuable components. Additionally, all wiring was properly insulated using heat shrink tubing to minimize the risk of short circuits and enhance overall system durability.

f. Tether

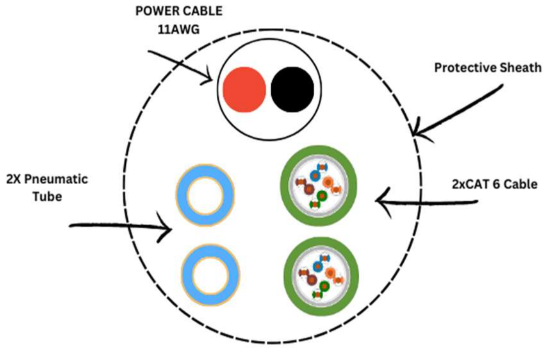

Figure 23: Tether

The tether serves as the ROV's critical lifeline, enabling power delivery, high-speed data transmission, and pneumatic control while maintaining the flexibility, buoyancy, and robustness required for effective

underwater operation. Its design was developed to meet MATE's RFP specifications while ensuring safe, efficient, and streamlined operation under competition conditions.
The tether consists of the following components:

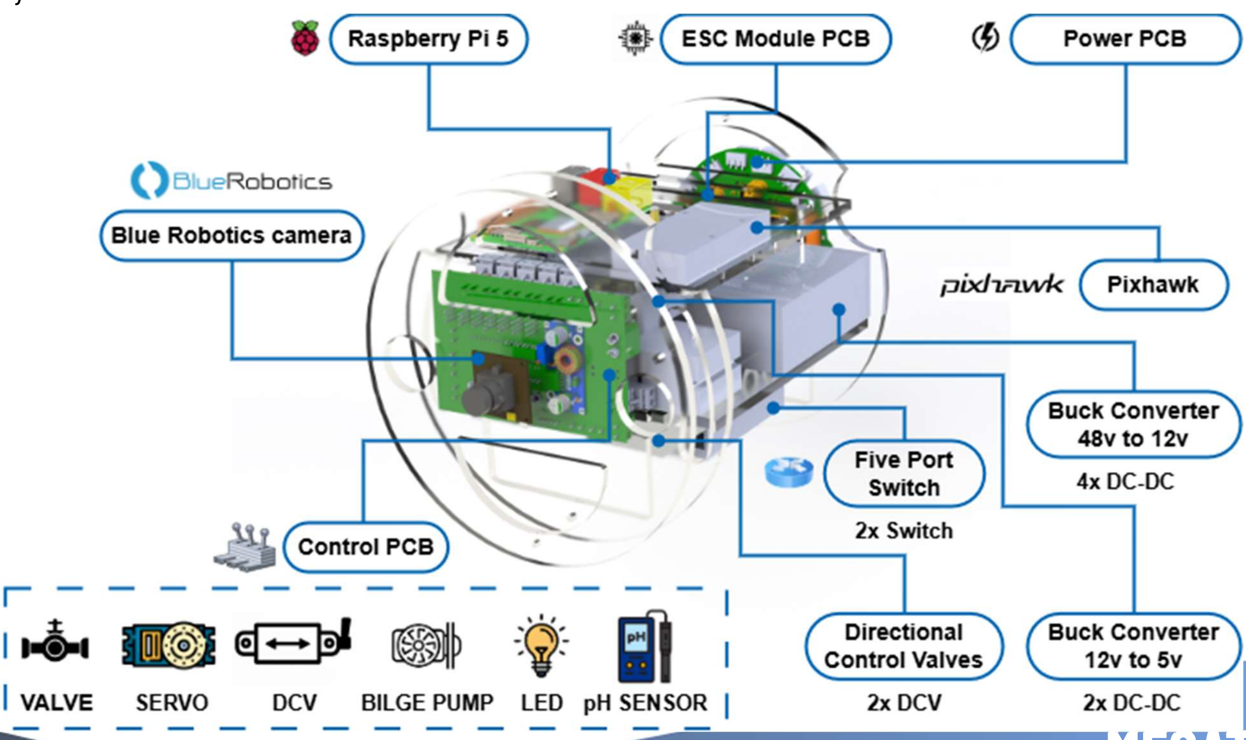

Figure 24: Electrical System Diagram

1. Power Cable: An 11 AWG two-core power cable ($4mm^2$ in diameter) delivers 48V DC to the ROV. This choice is based on the current carrying capacity of the cable (up to 45A) and minimal voltage drop (approximately 0.4% over 25 meters), ensuring stable power delivery throughout the mission.
2. Data Cables: Two Cat6 Ethernet cables (23 AWG) are used for high-speed communication. One handles data from the IP cameras, and the other transmits data between the Raspberry Pi and control systems. These cables support up to 10 Gbps, making them suitable for real-time video streaming and control.
3. Pneumatic Tubes: Two 6mm polyurethane tubes, rated for 10 bar, deliver air to the pneumatic grippers. This ensures that the system operates safely at the 2.75 bar required for the grippers while preventing overpressure or failure.

The tether is 25 meters long, chosen to meet the 5.5-meter pool depth and the 10-meter horizontal distance from the poolside specified by MATE. The additional length provides extra slack, allowing the ROV to move freely without risk of entanglement or excessive tension.

All cables are organized and protected within a braided cable sleeve to prevent abrasion and mechanical damage. The sleeve maintains flexibility and reduces tangling, ensuring the tether remains organized and secure during operation.

A strain relief mechanism is implemented at the ROV side to absorb movement cable damage.

This strain relief system minimize mechanical stress, ensuring the tether's integrity and reducing the risk of operational failure.

To maintain neutral buoyancy, sections of the tether are covered with closed-cell foam at strategic intervals along its length. This ensures that it remains manageable during ROV operations, reducing drag and minimizing potential entanglement or tension-related issues.

Tether Management System

The **Tether Management System** is designed to ensure efficient and safe handling of the Tether during deployment, operation, and retrieval.

Pre-Deployment: The tether is carefully inspected for wear or damage. It is coiled and stored in a manner that minimizes tangling, ensuring a smooth deployment process.

During Operation: A tether manager actively monitors the tether, ensuring that it remains untangled and has adequate slack for unrestricted ROV movement. The manager adjusts the length as needed to prevent the tether from becoming taut or tangled, reducing the risk of snagging or damage.

Post-Operation: After mission completion, the tether is carefully retrieved, inspected for any signs of wear, and stored in a clean, dry environment to preserve its longevity. Proper storage ensures the tether's durability for future missions.

Payload & Tools

Our Mechanical team developed a method to make our payloads completely independent from our ROV. This ensures that our tools are not permanently attached to the ROV, thereby saving time, reducing weight, improving accessibility to our station, and simplifying the collection of points.

1. Manipulators

Our manipulators are engineered for optimal functionality.

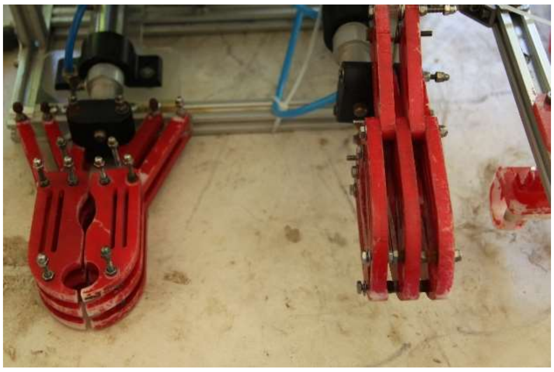

Figure 25: The manipulators

After three prototypes, we finally found success with our current design. The first prototype made with PMMA (Acrylic) broke easily, necessitating a switch to a polyethylene type supported by fiberglass in the second prototype, which was still too weak to depend on. Finally, the third prototype, made with HDPE (high-density polyethylene), proved to be durable and effective. The vertical (longitudinal) gripper is specifically designed for missions such as Shipwrecks 1.1, where it is required to remove container covers to identify the cargo of a ship. The horizontal (axial) gripper is designed to provide greater accessibility, enabling the simultaneous handling of multiple objects to enhance efficiency and save time.

2. Sacrificial Anode Replacement

One of our team members patented this tool, which is attached to a servo motor designed to twist the handle of a lid open and then lift it. In detail, we made two HDPE handles to hook onto the lid and release it. Initially, we placed the tool at the bottom of the ROV, which caused difficulties for the pilot during manoeuvring and operation. We then relocated the tool to the front of the ROV, improving visibility and manoeuvrability.

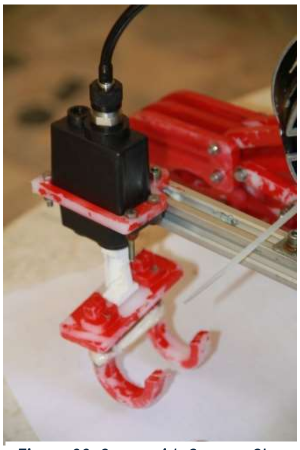

Figure 26: Servo with Custom Claw

3. Marine Species Collection

This tool stands out as one of our best ideas. We attached a pipe to the top of the ROV. This pipe has three openings: one connects to a bilge pump, another serves as the collection bay for ping pong balls that serve as fish, and the last opening suctions water and said fish into the tool. We divided these pathways by inserting wires in the middle of the pipe's path, redirecting fish into the collection bay and water to the bilge pump for expulsion.

Figure 27: Bilge Pump Powered Suction Collector

4. Water Sample Analysis

Our suction tool underwent two main prototypes. The first prototype involved a self-sealed water pump connected to a water line leading to a removable enclosure. However, we faced challenges as the pump only worked when submerged in water, lacking the torque to suction liquid below it. The second and final prototype, suggested by a team member, involved using a solenoid valve on a syringe to function as a pump, effectively suctioning water while expelling air through another pump.

Figure 28: Water Analysis Tool

Our PH sensor is integrated with the sample retrieving tool. The sample is automatically inserted into a small enclosure connected via pipes, where the PH level is then measured.

Vision System

Clear, accurate, and reliable visual data is essential for the success of our ROV. To achieve full 360-degree coverage, our system integrates eight cameras, one Blue Robotics camera and seven IP cameras. Each camera is strategically placed to provide multiple perspectives, ensuring seamless maneuvering**,** monitoring, and mission-specific tasks. With advanced depth-sensing and high-resolution imaging, our setup guarantees optimal navigation and interaction within the underwater environment.

Cameras Rationale

Figure 29: IP camera enclosures

Blue Robotics Camera

At the heart of our underwater exploration system lies the Blue Robotics camera, a powerhouse of performance featuring a 1/2.9" Sony IMX322 sensor and onboard H.264 compression chip. Its wide-angle, low distortion lens makes it indispensable for underwater inspection, exploration, and photogrammetry tasks. With excellent low-light performance and the ability to capture 1080p video, it delivers high-quality visuals even in dark or turbid waters. We control all the features of the Blue Robotics camera by using its software, ArduSub

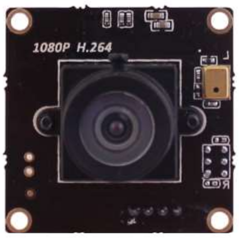

Figure 320: Bluerobotics

For the **IP cameras**,

Feature	IP Camera	CCTV Camera	USB Camera
Signal Type	Digital	Analog	Digital
Resolution	High 1080p	Low 720p or lower	Varies (Limited by bandwidth)
Installment	Easy (POE support, network-based)	Complex	Limited
Scalability	Highly Scalable	Limited (requires DVR)	Limited(USB constraints)
Latency	Low (<=200ms)	Higher (<=400ms)	Higher (<=400ms)
Integration	Seamless with modern systems	Requires additional hardware	Limited to direct connections
Cost	Moderate to high	Low to moderate	Low

we chose IP cameras because, although they are expensive, their features allow us to perform tasks better, such as measurement tasks,360 photosphere tasks, and manoeuvring, helping the pilot see a full high-quality view underwater.

Strategic Camera Placement:

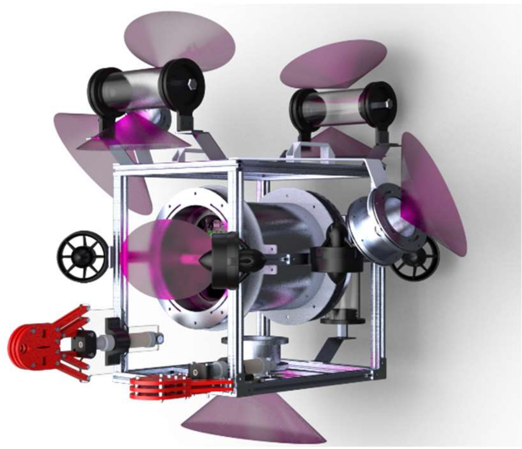

Figure 31: Camera View Cones

- **Front:** Two cameras—one facing up, one facing down—to enhance forward visibility.
- **Back:** Two cameras—mirroring the front setup—to provide full rear coverage.
- **Bottom Center:** A downward-facing camera for precise positioning and interaction with the seabed.
- **Right & Left**: One camera on each side to complete a full 360-degree field of view.

All cameras are connected through **two** Power-over-Ethernet (PoE) switches, optimizing tether efficiency and reducing cable clutter, ensuring a stable and reliable connection. Thw two switches are daisy chained to minimise the number of required cat 6 cables in the tether.

Figure 32: Gigabit PoE switch

Streaming and Calibration

For streaming, GStreamer pipelines are used for real-time video streaming, ensuring low latency and high-quality feeds for the pilot. RTSP streaming for IP cameras is enabled for customizability and be able to work on multiple laptops, ensuring uninterrupted video feeds, while TCP streaming is used for the Blue Robotics camera.

For calibration, ChArUco marker-based calibration board is applied to correct fisheye distortion from the wide-angle IP cameras, ensuring precise image mapping and navigation accuracy. Calibration data is pre-stored and applied in real-time to maintain consistency and reliability throughout the mission.

Figure 33: Before Calibration

Figure 34: After Calibration

Photosphere 360° Image Construction

A360-degree photosphere is essential for shipwreck documentation and marine biodiversity monitoring. We employ two cutting-edge approaches

Figure 35: 360 photoshpere

to achieve this:
The PTGui method excels in producing high-detail panoramas, ideal for shipwreck analysis, while the SuperPoint & SuperGlue approach is optimized for real-**time applications**, such as biodiversity monitoring.

Figure 36: Underwater Photoshpere

Ultimately we decided to use PTGui for it's high quality and reliability.

Feature	PTGui-Based Stitching	SuperPoint & SuperGlue-Based Stitching
Processing Speed	Slower, requires manual adjustments	Faster, fully automated with AI
Automation Level	Low, user-guided	High, deep-learning-driven
Robustness to Noise	Moderate, sensitive to misalignment	High, adapts to underwater conditions
Computational Cost	High, CPU-intensive	Moderate, GPU-optimized
Output Quality	85% accuracy by our testing	Adaptive, resilient to distortions

Depth Measurement Approach

Our measurement approach achieves high precision and reliability by integrating multiple reference points with advanced depth estimation techniques. We use the MiDaS v3.1 DPT_Hybrid model to generate high-precision depth maps from single images, renowned for its robustness and accuracy in monocular depth estimation, making it ideal for environments with varying lighting conditions. To enhance accuracy, we employ a multi-reference calibration technique, placing reference objects with known dimensions in the scene. These references serve as anchors for calibrating the depth map, and by manually selecting corresponding points on these objects, we establish a relationship between depth values and real-world distances, ensuring accurate calibration across different regions of the image. The depth map is further refined through post-processing steps, including median filtering to remove noise and outliers, and Gaussian filtering to smooth depth values, improving the overall quality of the depth map. To convert the depth map into metric units, we calculate a scale factor based on the distance between reference points in the depth map and their actual distances, allowing us to measure distances between any two points in the image by projecting them into 3D space using the camera's intrinsic parameters and the calibrated depth map. Our approach also includes a weighted scale factor calculation, combining depth estimates from multiple references and giving more weight to closer, high-confidence references, ensuring accurate and reliable depth estimation, especially in complex scenes. By integrating multiple references with advanced depth estimation and post-processing techniques, our system provides high-precision, consistent, and reliable measurements suitable for various applications.

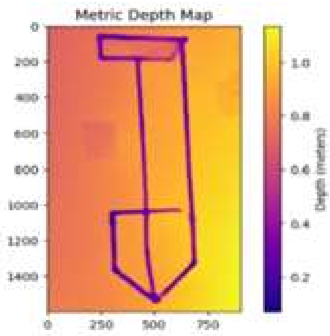

Figure 37: Model generated Depth

Vertical Profiling Float

Figure 38: Floatilla actual

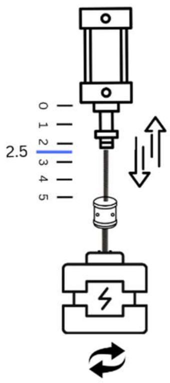

Figure 39: Floatilla diagram

At the start of this phase, we re-evaluated the design approaches from previous versions of our float system, leveraging our experiences from past competitions and thorough technical analysis. Rather than starting from scratch, we carefully assessed what worked, what didn't, and why. This involved comparing mechanical stability, control accuracy, and component efficiency across iterations. By identifying design flaws and performance bottlenecks, we developed a clear improvement roadmap. Each decision in the new system—from motor selection to sensor integration—was informed by these insights, ensuring a more robust, efficient, and reliable float system for real-world deployment

The float's core mechanical structure is built on a single aluminum extrusion rod, which supports all major components—stepper motor, battery, pneumatic cylinder, and PCB. This unified design simplifies both assembly and maintenance, allowing the system to be accessed or removed as a single unit. The pneumatic cylinder is mechanically linked to the stepper motor through a screw mechanism. As the motor rotates, the cylinder moves downward, gradually filling with water until it reaches neutral buoyancy. After a 45-second pause, the motor reverses direction, expelling the water and causing the float to rise. Internal weights maintain the float's volume, eliminating the need for external adjustments and ensuring consistent buoyancy.

To withstand underwater conditions, the float includes a piston-sealed enclosure that safeguards internal electronics from environmental damage. It also features a built-in pressure relief mechanism to prevent over-pressurization. The float is hydrodynamically designed for stability, with a durable enclosure that ensures long-term performance in submerged conditions.

Our initial design used a DC motor, but it failed to deliver the necessary precision for controlled depth adjustments. We then adopted a stepper motor, which proved superior in terms of motion accuracy and reliability. Through comparative testing, the stepper motor demonstrated better performance and became the final choice for our actuation mechanism.

To measure depth, we first employed a linear potentiometer, but it produced inconsistent readings due to movement-induced noise. To address this issue, we integrated an infrared (IR) sensor, which significantly enhanced depth accuracy and overall system stability during operation.

The ESP32 microcontroller was chosen for its robust communication capabilities and support for multiple protocols including UART, SPI, and I2C. These allowed seamless integration with the IR sensor, motor driver, and pressure modules. A standout feature was its Over-the-Air (OTA) firmware update capability, which enabled remote updates without breaking the float's waterproof seal—saving time during deployment and testing. Its built-in Wi-Fi and Bluetooth also allowed real-time monitoring and diagnostics, making it essential for system reliability.

To power the system and contribute to internal ballast, we used a 12V 7Ah lead-acid battery positioned at the float's base. Its high energy capacity allowed for extended operation without frequent recharging, offering better endurance than previously tested Nickel Metal Hydride (NiMH) batteries. This made the lead acid battery a more stable and dependable choice for long-term underwater use.

Critical Analysis

The Megatron ROV requires rigorous testing and troubleshooting to ensure reliability and operational efficiency. Our approach incorporates mechanical, electrical, and software testing methods, alongside a systematic troubleshooting protocol to identify and resolve issues quickly. This ensures that the ROV performs optimally under real-world conditions, with minimal risk of failure during competitions or missions.

Testing Methodology

Testing is conducted at several levels, from individual component assessments to full system validation, ensuring the Megatron ROV meets all performance, safety, and competition requirements.

1. Mechanical Testing:

- **Structural Integrity Assessment**: Finite Element Analysis (FEA) simulations are conducted to predict stress distribution, helping identify potential failure points under operational loads. Physical load testing is also done to validate structural durability, especially in underwater environments.

- **Hydrostatic Pressure Testing**: To ensure the ROV's electronic components can withstand deep-water conditions, the system undergoes a hydrostatic pressure test simulating depths of up to 0.5 bar. A differential pressure test, combined with bubble observation, is used to detect micro-leaks.

- **Buoyancy and Stability Verification**: The ROV undergoes controlled buoyancy tests to verify optimal weight distribution and achieve neutral buoyancy. Moment of inertia calculations ensure the system's stability under various hydrodynamic conditions.

Sealing & Pneumatics: The enclosure is exposed to water to check for leaks, while pneumatic parts are tested for proper airflow, actuator function, and pressure control.

2. Electrical System Testing:

- **Power Distribution Analysis**: The electrical subsystems are tested for voltage regulation and current draw using oscilloscopes and multimeters to ensure proper operation under peak loads.
- **Component Verification**: Individual electrical components undergo meticulous testing to confirm their functionality. Prototypes, such as double-layer PCBs, are used to verify the system design.

System Integration Testing: Once individual components pass testing, they are integrated into the full electrical system, and power flow, data transmission, and response times are verified under real-world conditions.

3. Software Testing:

- **System Integration Testing**

The ROV's software and control algorithms undergo hardware-in-the-loop (HIL) simulation to validate real-time performance. Ensures seamless sensor-actuator synchronization and system responsiveness before deployment.

- **Fault Injection Testing**

Simulated failures, such as sensor disconnections and data corruption, assess software resilience. Evaluates fault detection, isolation, and recovery mechanisms. Communication protocols (RTSP & TCP) are tested for secure and stable data exchange.

- **Component Validation and Simulation**

Components undergo test bench validation before integration to verify functionality and reliability under controlled conditions. Critical hardware, including the Raspberry Pi and Pixhawk, is subjected to performance tests to ensure compliance with system requirements. We utilized QGroundControl for Pixhawk simulation, enabling early issue detection and ensuring optimal system performance before hardware deployment.

- **Structured Testing Approach**

1. Test Package Design

Custom test modules are developed at the design stage to align with system requirements.
Ensures each component meets defined functional and performance criteria.

2. Module Integration Testing

Validated components are integrated and tested collectively to confirm seamless subsystem interaction.

3. Full System Integration

The complete ROV undergoes end-to-end validation to assess coordination, functionality, and efficiency.

4. System Stress Testing

The ROV is tested under maximum load conditions to ensure operational reliability in extreme environments. Confirms system robustness and ability to complete mission tasks under peak performance demands

Troubleshooting

When issues arise, a structured troubleshooting methodology is followed, ensuring efficient diagnosis and resolution without reintroducing problems to unaffected areas.

1. Issue Identification

System logs and performance metrics are monitored to detect deviations from normal operation. Using baseline data, anomalies are quickly identified, allowing the team to focus efforts on the affected subsystems.

2. Fault Isolation and Diagnosis

Issues are categorized by mechanical, electrical, or software subsystem to streamline troubleshooting efforts. Diagnostic tools like oscilloscopes are used for electrical faults, while software debuggers are employed for control system issues. A logical, step-by-step approach isolates the affected module or component.

3. Corrective Actions and Verification

Once the root cause is identified, targeted fixes are implemented, whether it's replacing faulty components or updating software. The repaired subsystem is independently revalidated to ensure the problem is resolved without impacting other system areas. Comprehensive documentation of each case, including the symptoms, faults, and corrective actions, helps refine future diagnostic efforts

Accounting

Our accounting system is designed to ensure transparency, accuracy, and efficiency in tracking project expenditures. All departments submit purchase requests, which are reviewed for necessity and cost-effectiveness before approval. Approved expenses are logged in a centralized financial tracking sheet shared across the company, allowing real-time budget monitoring. Costs are categorized into project components, with a clear distinction between purchased and re-used items. This system not only ensures financial accountability but also supports informed decision-making and sustainable resource management throughout the ROV development cycle.

	Income Source		Amount (USD)		
	Self-Funds From Company Members		3600$		
Project	**Type**	**Description**	**Projected Cost**	**Budgeted Value**	**Expenses**
Tether	Purchased	12AWG Power Cable 25m	70$	70$	60$
	Purchased	Pneumatic Cable 25m	10$	10$	8$
	Re-used	Pneumatic Cable 25m	70$		
	Re-used	Cat 6 Cable 25m x2	80$		
	Re-used	Tether Sheath	5$		
Floatilla	Purchased	Materials and Fabrication	145$	150$	117.75$
	Purchased	Esp32	8.5$	10$	8.5$
	Purchased	TOF050C IR Sensor	4$	4$	4$
	Purchased	TMC2209 Motor Driver	8$	10$	5$
	Purchased	40X50 Pneumatic Piston	20$	20$	20$
	Purchased	2-layer PCB	28$	30$	29$
	Purchased	MTM LP7-12 Lead Acid AGM Battery	25$	30$	21.5$
	Re-used	Nema 17 Stepper Motor	12$		
	Re-used	DS3231 RTC Module	3$		
	Re-used	Bar30 Pressure Sensor	85$		
	Re-used	I2C level Converter	25$		
	Re-used	Underwater Switch	10$		
TCU	Purchased	5 Port Gigabit Switch	7$	10$	7$
	Purchased	Esp32	8.5$	10$	8.5$
	Re-used	Xbox Joystick	72$		

Megatron	Purchased	Camera Boxes (Face Seal)	60$	70$	76$
	Purchased	Grippers Material and Fabrication	56$	65$	60$
	Purchased	Aluminium Extrusion	40$	55$	45$
	Purchased	O-Rings	5.6$	5.6$	5.6$
	Purchased	3D Printed Parts	30$	35$	23.5$
	Purchased	Thruster Guards X12	20$	30$	24$
	Purchased	Cameras and Tools Fixations	28$	30$	24$
Megatron	Purchased	Control PCB	68$	70$	62$
	Purchased	Power PCB	73$	80$	65$
	Purchased	8A DC-DC Buck Converter	6$	6$	6$
	Purchased	Hikvision DS1123 IP Camera X 7	200$	200$	179.5$
	Purchased	Hikvision Gigabit PoE Switch X2	15$	15$	9$
	Purchased	DFRobot pH Sensor	3$	3$	3$
	Purchased	12V Submersible Pump	4$	5$	3.5$
	Purchased	1100GHP Bilge Pump	10$	10$	7$
	Re-used	T200 Thruster X6	1200$	1250$	1200$
	Re-used	48V 30A Power Supply	20$		
	Re-used	Bar30 Pressure Sensor	85$		
	Re-used	BlueRobotics ESC X6	228$		
	Re-used	ESC Module PCB X6	33$		
	Re-used	Blue Robotics Low Light Camera	250$		
	Re-used	Pixhawk 1.4	193$		
	Re-used	60A DC-DC Buck Converter X2	90$		
	Re-used	15A DC-DC Buck Converter X2	25.75$		
	Re-used	Camera Boxes (Piston Seal)	35$		
	Re-used	Underwater Servo Motor	58$		
	Re-used	Raspberry Pi 5	40$		
	Re-used	AGRO Glands X 40	177$		
	Re-used	DCV X2	45$		
	Re-used	Pneumatic Piston X2	88$		
	Re-used	Main Enclosure Material (HDPE & PMMA)	200$		
	Re-used	Compressor	135$		
Customs and Shipping	Purchased	Customs and Shipping for all imported items	450$	500$	450$
Travel Expenses	Purchased	ROV Shipping	1000$	1000$	1000$
Total Income			3600$		
Total Expenses			5597.1$		
Total Re-used			2332.75$		
Total Expenses - Reused			3264.35$		
Final Balance			335.65$		

Acknowledgements & References

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We acknowledge the pivotal contributions of **the following companies and platforms:**

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GitHub, Ansys, VS Code, **Altium and SolidWorks, for advancing our software development and engineering capabilities.**

HackerRank, Clockify, Slack, and Notion, for streamlining collaboration and project **management.**

We are also **grateful to Makers Electronics, Afeez Maker Space, Victoria College School, and E.G.C for their invaluable resources, facilities and support.**

Finally, we extend our heartfelt thanks to our families, friends, and company employees for their steadfast encouragement, and to the competition sponsors—Innovators Support Fund, NTRA, Fugro, MTS, and NSF—as well as the volunteers and judges, whose dedication has been integral to the success of this event.

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VORTEX UNCHARTED EXCELLENCE

Appendix

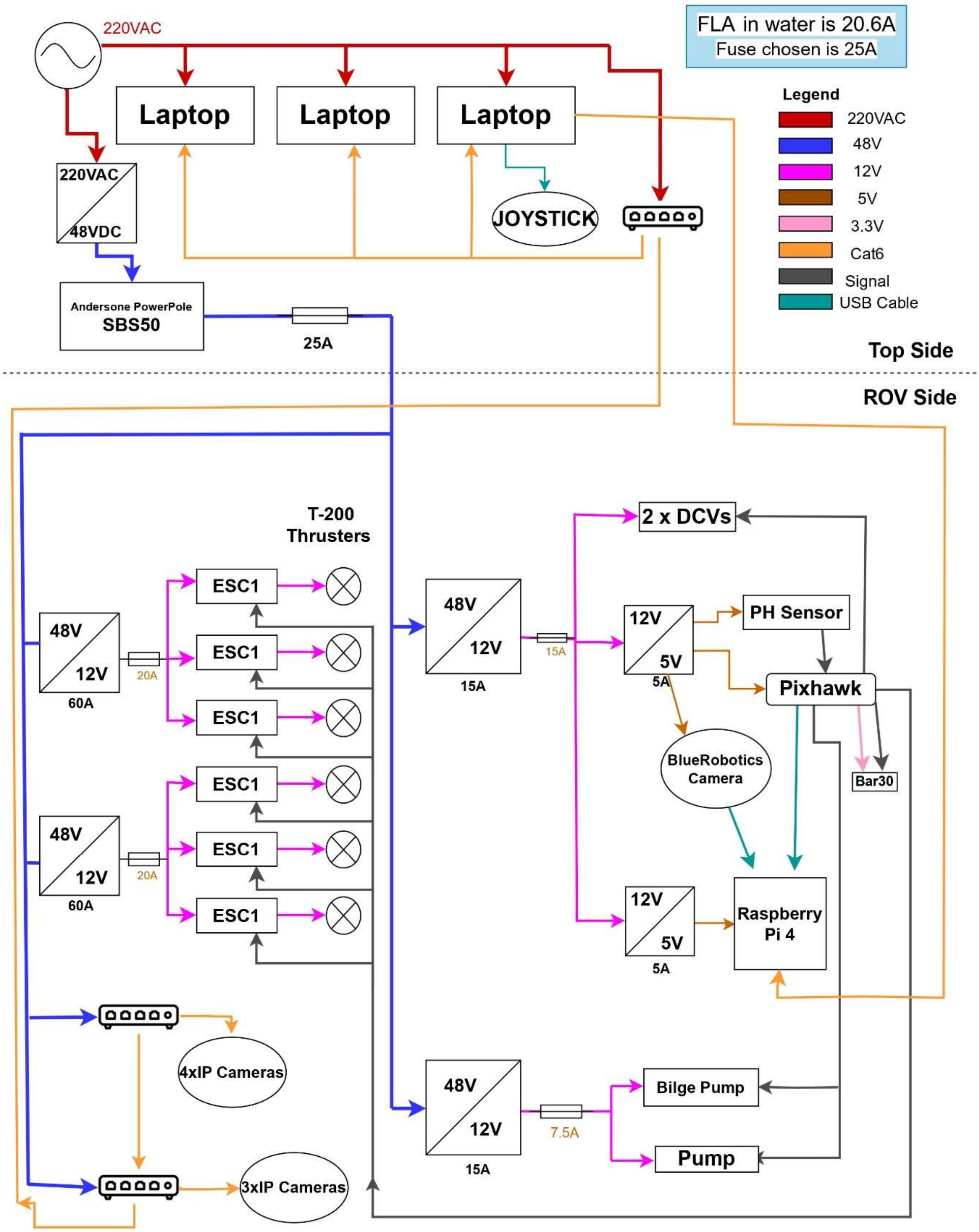

Figure40:ROV SID

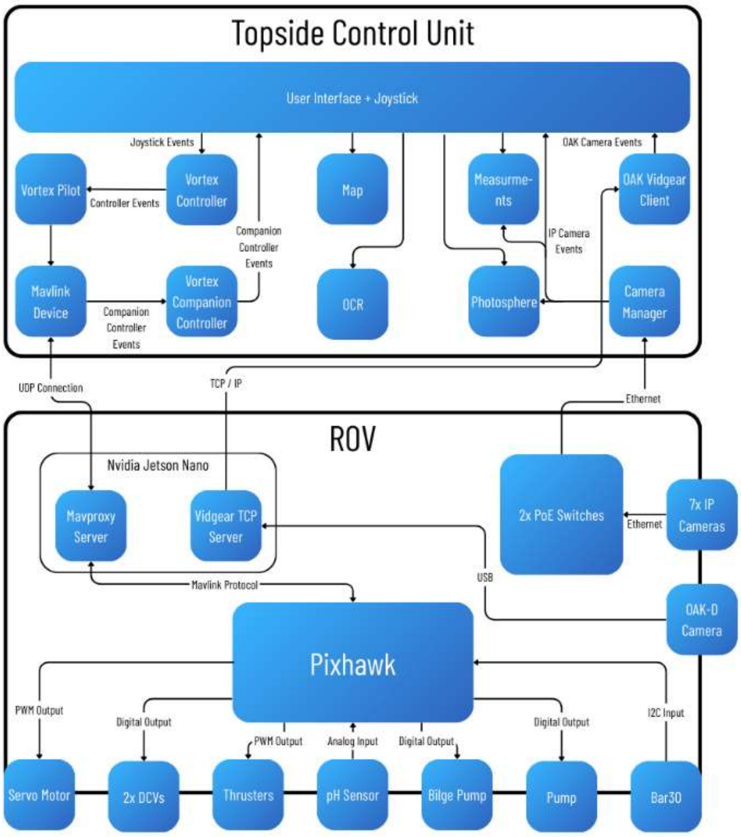

Figure 41: Software SID

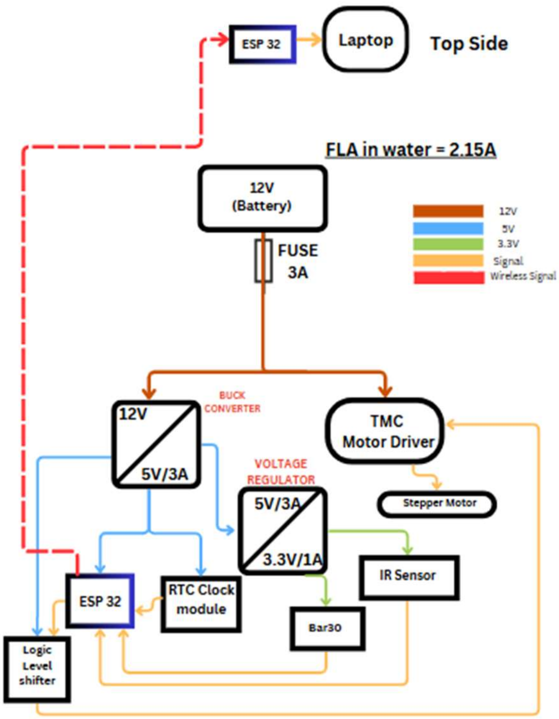

Figure 42: Float SID

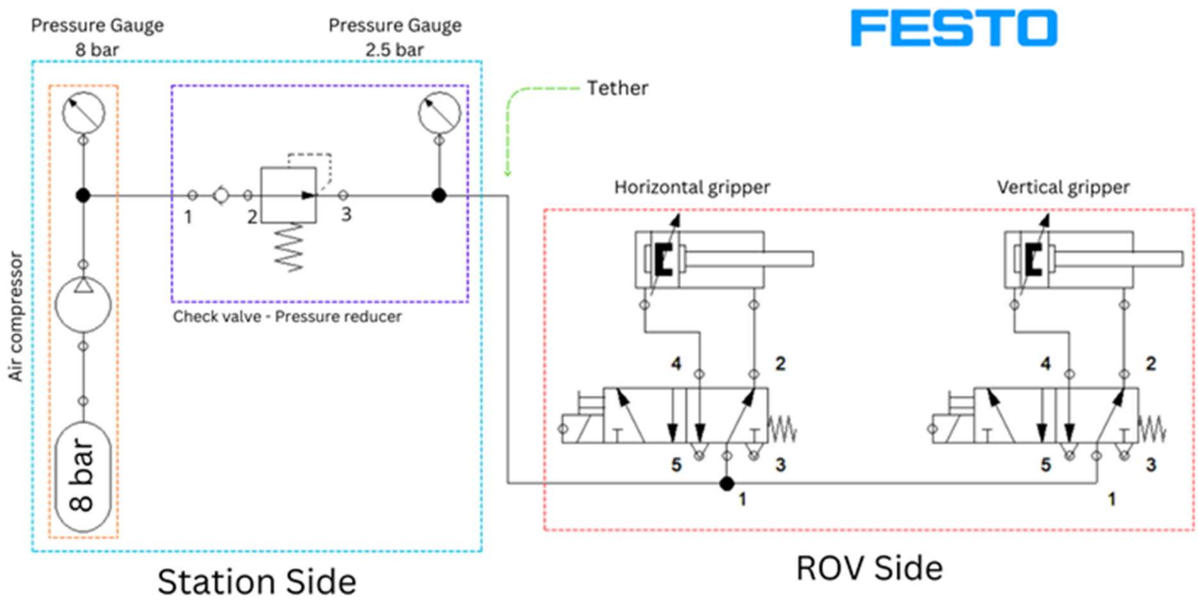

Figure 43:Pnuematic SID

ROV Operations Safety Checklist

VORTEX
UNCHARTED EXCELLENCE

Pre-Operational Safety Checklist

1. **General Workspace Safety**
   - ☐ Confirm a secure and clutter-free workspace.
   - ☐ Ensure no obstacles or trip hazards.
   - ☐ Verify no personnel running around the pool area.
2. **Equipment Inspection**
   - ☐ Check the sealing of electronics housings.
   - ☐ Verify unobstructed thrusters.
   - ☐ Confirm power source is securely connected to ROV.
   - ☐ Ensure cables are secured and leak-proof.
   - ☐ Check for protective gear availability.
3. **Communication**
   - ☐ Establish clear and audible communication protocols.
   - ☐ Test all communication devices.
4. **Power Verification**
   - ☐ Ensure the ROV is receiving the correct nominal voltage.
   - ☐ Test power systems for proper operation.
5. **Thruster Testing**
   - ☐ Test all thrusters for proper operation.
   - ☐ Confirm controller movements correspond with thruster activity.
6. **Camera and Sensor Checks**
   - ☐ Verify functionality of all cameras and sensors.
   - ☐ Test camera positioning and video feeds.
7. **Leak Tests**
   - ☐ Perform leak tests on the pressure hull.
8. **Pre-Dive Preparations**
   - ☐ Prepare the dive site, including clearing any hazards.

Pre-Water Safety Checklist

- ☐ Power up the system by connecting the tether cable to the control station.
- ☐ Set electronics enclosures' pressure to the rated depth.
- ☐ Test camera functionality and sensor readings.
- ☐ Confirm thrusters operate correctly with controller inputs.
- ☐ Announce "Water Ready" after confirming system readiness.
- ☐ Lower ROV into pool with tether handler and team.

During Operation Safety Checklist

1. **Operation Monitoring**
   - ☐ Continuously monitor systems and operations.
2. **Tether Management**
   - ☐ Ensure proper tether management to avoid entanglement.
3. **Communication Continuity**
   - ☐ Maintain clear communication with surface team.
4. **Tool Deployment**
   - ☐ Follow protocols for tool deployment and retrieval.

Post-Operation Safety Checklist

1. **ROV Retrieval**
   - ☐ Safely retrieve ROV from water.
2. **System Power Down**
   - ☐ Power down system and announce "Crew in Command."