2024 Technical Documentation

Underwater Remotely Operated Vehicle Team

Seafox Inventive - "ROVIN"

Center of Excellence for Innovation and Design (CEID)

at CETYS University

Mexicali, B.C., Mexico

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'25 Alvaro Trujillo, Electrical
'25 Cesar Ahumada, Electrical
'27 Karime Plasencia, Electrical
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ABSTRACT

The following documentation outlines the development of an innovative Remotely Operated Vehicle (ROV) designed for the 2024 MATE ROV World Competition. This ROV aims to address critical challenges in ocean conservation and sustainable management. Our ROV focuses on enhancing the Global Ocean Observing System, safeguarding ecosystems, and supporting ocean-based climate change mitigation strategies.

The ROV is engineered to perform complex tasks with precision, such as placing SMART repeaters, connecting docking stations, and installing probiotic irrigation systems to treat diseased coral reefs. It features six degrees of freedom for improved maneuverability and is capable of handling various tube diameters with minimal resistance.

Our multidisciplinary team has developed a robust, efficient ROV that advances scientific knowledge, technological capabilities, and conservation efforts, ensuring the long-term resilience and health of global marine ecosystems. Through rigorous testing and optimization, we have addressed key engineering challenges, positioning our ROV as a competitive and reliable tool for ocean exploration and conservation.

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INTRODUCTION

Seafox Inventive proudly presents our latest project: the design, build, and deployment of a versatile underwater robot capable of performing various tasks in marine environments, named "ROVIN". This project is part of the MATE ROV competition, which challenges teams from around the world to apply their engineering, problem-solving, and teamwork skills in a real-world context.

OBJECTIVES

- **Design and Development:** Create an innovative and robust ROV that can operate effectively in underwater conditions.
- **Mission Capability:** Equip ROVIN with the necessary tools and sensors to complete specific missions as outlined by the MATE ROV competition.
- **Cost Efficiency:** Balance the design and functionality with cost-effective solutions, ensuring the project remains within budget constraints.
- **Safety:** Implement comprehensive safety protocols to protect both ROVIN and the operators during construction and operation.

SCOPE

- **Research and Planning:** Conduct thorough research on existing ROV technologies and identify key requirements for the competition missions. Develop a detailed project plan, including timelines, resource allocation, and risk management strategies.
- **Design and Prototyping:** Utilize CAD software to design the ROV structure and systems. Build and test prototypes to refine the design and address any technical challenges.
- **Construction and Integration:** Assemble the final ROV, integrating all mechanical, electrical, and software components. Ensure all systems work cohesively to achieve optimal performance.
- **Testing and Troubleshooting:** Perform rigorous testing in controlled environments to validate the ROV's functionality and reliability. Develop troubleshooting protocols to quickly address any issues that arise during testing or missions.
- **Competition and Evaluation:** Participate in the MATE ROV competition, demonstrating the ROV's capabilities in real-world scenarios. Conduct a post-competition evaluation to assess performance and identify areas for improvement.

This project not only aims to succeed in the MATE ROV competition, but also to contribute to the broader field of marine technology by developing innovative solutions and fostering a deep understanding of underwater robotics.

OVERVIEW OF SEAFOX INVENTIVE

Seafox Inventive is a dynamic and innovative company specializing in the development of advanced underwater robotics. Our mission is to push the boundaries of marine technology by creating cutting-edge solutions that address the unique challenges of underwater exploration and operations. With a commitment to excellence and a passion for innovation, Seafox Inventive combines technical expertise with creative problem-solving to deliver high-performance ROVs designed to excel in various marine environments.

TEAM MEMBERS

Luis Carlos Basaca - Mentor
His extensive background in engineering and project management offers valuable insights and advice to help the team overcome complex challenges.

Chantal Mendoza - Chief Executive Officer
Leads the team with strategic planning and project management skills, ensuring that all project milestones are met on time and within budget.

Anahi Hull - Chief Financial Officer
Oversees the financial aspects of the project, including budget planning, expense tracking, and resource allocation.

Luis Solis - Lead Mechanical Engineer
Responsible for the mechanical design and structural integrity of the ROV.

Kevin Payan - Lead Electrical Engineer
Designs and implements the ROV's electrical systems, including power distribution and sensor integration.

Lorenzo Villalobos - Lead Software Engineer
Develops the control software and user interface for the ROV.

Aide Sandoval - Safety Officer
Ensures that all safety protocols are followed during the design, construction, and operation of the ROV.

Mechanical Engineering Team
Responsible for assisting in the design and assembly of mechanical components.

- **Carolina Flores**
- **Daira Razo**
- **Hermak Banda**
- **Raúl Gallareta**

Electrical Engineering Team
Assist in the wiring, integration, and testing of the ROV's electronic systems.

- **Alvaro Trujillo**
- **Cesar Ahumada**
- **Karime Plasencia**
- **Pedro Inyun**
- **Leonardo Lomeli**
- **Valeria Ibarra**

Software Engineering Team
Focus on coding and integrating new software features.

- **Joshua Ibarra**
- **Brandon Herrera**
- **Mario Alcaraz**
- **Jacobo Rodriguez**

PROJECT MANAGEMENT

Our team, comprised of students from various engineering disciplines, collaborated closely to design and build ROVIN. We began by establishing a clear project timeline, dividing the project into distinct phases: design, prototyping, testing, and final assembly. Each phase had specific milestones and deadlines to ensure steady progress.

Team Division

To streamline our efforts and leverage specific skill sets, our team was divided into five subgroups: mechanical, electrical, software, administration and finances, and research. Each subgroup focused on its respective area while maintaining close communication with the others to ensure integration and overall project cohesion.

Scheduling and Resource Management

A comprehensive schedule was developed to aid in building the vehicle. This schedule included regular meetings, progress check-ins, and deadlines for each project milestone. Additionally, we used project management tools to track our progress and manage our resources efficiently. We held meetings every Saturday, dedicating 3 to 5 hours of focused work to ensure steady progress and address any issues promptly.

Operational Protocols

We described how resources, procedures, and protocols were managed to meet mission objectives and solve day-to-day operational problems. This included the procurement of materials, manufacturing processes, and quality control measures. Safety protocols were also strictly followed to ensure the well-being of team members during the construction and testing phases.

By following these structured project management practices, we ensured that ROVIN development stayed on track and met all competition requirements and deadlines.

							PHASE ONE				PHASE TWO				PHASE THREE					PHASE FOUR			
							FEBRUARY				Y	MARCH			MARCH	APRIL				MAY			
WBS NUMBER	TASK TITLE	TASK OWNER	START DATE	DUE DATE	DURATION (Days)	PCT OF TASK COMPLETE	WEEK 0 (JAN 29 –	WEEK 1 (FEB 5 –	WEEK 2 (FEB 12 –	WEEK 3 (FEB 19 –	WEEK 4 (FEB 26 –	WEEK 5 (MAR 4 –	WEEK 6 (MAR 11 –	WEEK 7 (MAR 18 –	WEEK 8 (MAR 25 –	WEEK 9 (APR 1 –	WEEK 10 (APR 8 –	WEEK 11 (APR	WEEK 11 (APR 22 -	WEEK 12 (APR 29 –	WEEK 13 (MAY 6 –	WEEK 14 (MAY 13 –	WEEK 15 (MAY 20 -
1	**Problem Statement**																						
1.1	First meeting	All	30/01/2024	03/02/2024	1	100%																	
1.2	Work schedule	All	30/01/2024	03/02/2024	4	100%																	
1.3	ROVS investigation	All	30/01/2024	03/02/2024	4	100%																	
1.4	Brainstorm	All	30/01/2024	03/02/2024	4	100%																	
1.5	Design proposal	All	05/02/2024	26/02/2024	21	100%																	
2	**Design**																						
2.1	Design decision	Company	26/02/2024	26/02/2024	1	100%																	
2.2	Material decision	All	19/02/2024	09/03/2024	6	100%																	
2.3	Design development	Carolina Flores/ Chantal Mendoza	26/02/2024	23/03/2024	28	100%																	
3	**Analysis**																						
3.1	Analysis with Patran	Aide Sandoval	25/03/2024	06/04/2024	12	100%																	
3.2	Changes in design	Hermak Banda	25/03/2024	06/04/2024	12	100%																	
4	**/ Monitoring**																						
4.1	1st presentation	All	19/02/2024	26/02/2024	7	100%																	
4.2	2nd presentation	All	01/04/2024	13/04/2024	13	100%																	
4.3	3rd presentation	All	20/05/2024	01/06/2024	13	100%																	

Fig. 1 *Project timeline and time schedule*

DESIGN RATIONALE

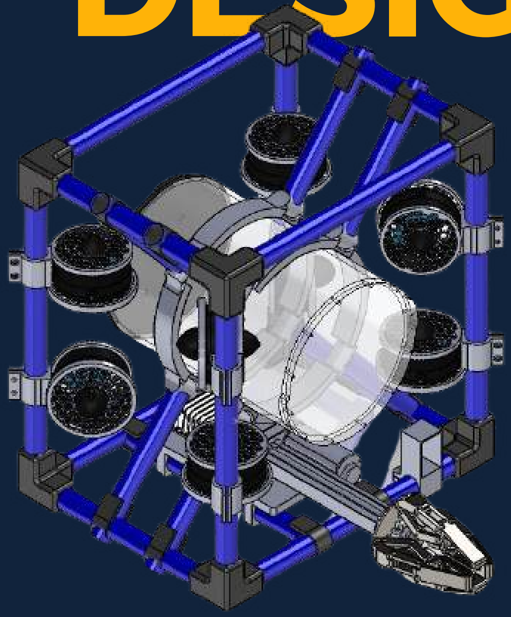


Fig. 2 Isometric view of ROVIN CAD design

OVERVIEW

ROVIN design is based on toys whose center is protected by armor avoiding any harm happening to the centerpiece. The frame protects the 2-in-1 acrylic buoyancy module as well as the electronics bay, the eight thrusters, the linear actuator used for the gripper, and the regulator by being inside of its boundaries. Using a frame also helps ROVIN move through water almost effortlessly. Two cameras are placed strategically to guide the pilot back on the surface in order to help ROVIN complete MATE tasks and missions. The damage to the environment is minimized through features, such as thruster guards and keeping everything but the gripper inside the frame boundaries.

CONCEPTUAL IDEATION AND SELECTION PROCESS

Reviewing the experiences of the previous season, Seafox Inventive team reconsidered the design of the ROV. Considerations such as movement in the water, weight, competition and testing success were paid extra attention when deciding on a design. The company also did market research for a new concept and revisited old concepts that worked really well.

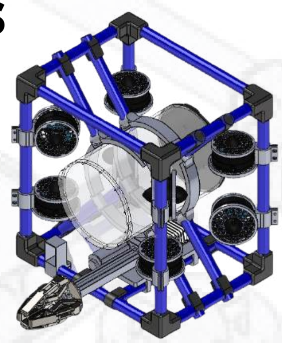


Fig.3 *1st and current design*

The first design decision was determining what needed to change based on the previous design. An agreement was reached, all walls will be removed so that ROVIN could move effortlessly through water. After this decision was made, it was time to determine which parts of the previous design the team wished to keep. The thruster layout and tether components were used on ROVIN. The team doesn't believed these components were perfect, but that they are effective and developing a new component from scratch would take extra time needed for the development of the design.

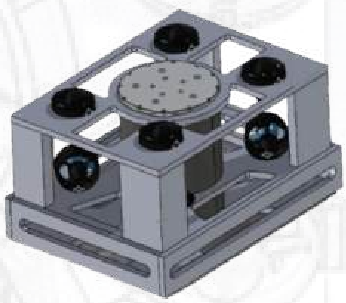


Fig.4 *2nd proposal*

Once the agreements were settled, the team began searching for ideas to design ROVIN. Given that the only thing preserved from previous ROVs were the tether and thruster arrangement, the design could be anything. Seafox members were advised to think out of the box and come up with an innovative design that could complete the tasks and missions given by MATE and be inside the budget established for ROVIN. After 3 proposed designs, the team concluded that the first and current design proposal was the one best suited for Seafox.

Fig.5 *3rd proposal*

BUOYANCY AND BALLAST

The main component that adds buoyancy to this year's ROV is our **air-filled creform tubes**. Paired with the low overall weight (22.6 kg), our ROV presents a positive buoyancy before adding the ballasts. This year's ballast was in the form of metal bars wrapped in waterproof tape. We added a combination of multiple **.20kg and .50kg** weights to achieve **neutral buoyancy**. Due to time constraints, we were not able to calculate exactly how much weight was needed to achieve neutral buoyancy, so a trial-and-error method was employed. Our tether, presenting **negative buoyancy**, has small pieces of foam wrapped around it to achieve neutral buoyancy as well.

VEHICLE STRUCTURE

A structural analysis was conducted to fully support the design of ROVIN and ensure that no significant deformation would occur. To simplify the analysis, a symmetrical cut was made in the structure, allowing us to analyze just one half, as the behavior on one side would mirror the other.

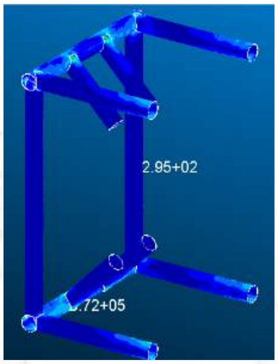


Fig. 6. *Von Misses Stresses in psi*

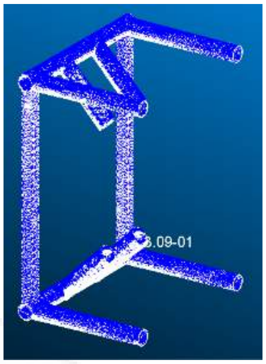


Fig. 7. *Deformation in inches*

Additionally, the motors, gripper, and regulator were removed, and their weight was accounted for in the analysis. This approach maintained the same stimuli experienced by ROVIN while reducing the number of elements, making the analysis more manageable. The results of the analysis confirmed that no significant deformation is present. The safety factor for the full structure, when placed on the floor outside of the water, is 1.4.

FRAME

One of the most relevant decisions for the team was the frame's material, making this one of our main focuses during the design phase. We wanted to focus on optimizing the building process while having a resilient structure and reducing expenses and weight. Therefore, after some evaluation, we determined that a system like Creform could be a wiser option compared to previous material decisions towards previous structures.

ENCLOSURE AND SEALING

Fig. 8 *Watertight enclosure and sealing*

To facilitate the integration of the electronics panel with the ROV's thrusters, sensors, and servo motor, a series of 14 bores were meticulously drilled into the aluminum cap of the enclosure. These bores serve as connection points for the various cables associated with these components. To maintain the integrity of the enclosure and prevent any water ingress, all cables that pass through the enclosure are meticulously sealed using penetrators and marine-grade epoxy. This meticulous sealing process ensures that the electrical connections remain protected from moisture and other external elements that could compromise the functionality and reliability of the ROV's electronics system.

VEHICLE SYSTEMS

In past seasons, one of our main problems was the base material, it was heavy and difficult to manipulate. In consequence, we investigated a possible solution to find a material, which was versatile, durable, and profitable to prioritize the creation of a custom handling ROV. We evaluated the best possible material to compare which was the most effective:

Material	Performance					Ease of development			
	Weight	Strength	Versatility	Modularity	Possible Corrosion	Cost	Already in lab	Tools to work on	Ease of Assembly
Creform	Low	High	High	High	Mid	High	Yes	Yes	Easy
PVC pipe	Low	Low	Low	Mid	Low	Low	Yes	Yes	Easy
Aluminium 6061	High	High	Mid	High	Mid	Mid	Some	No	Mid
High Density Polyethylene	Low	Mid	High	High	Low	Mid	No	Some	Mid

Fig. 9 *Materials Comparative Table*

The investigation led to select Creform, which has the best properties to complete each MATE task efficiently. Luckily, Creform was donated by one of our sponsors, and as a result of this, our main problem was solved. Additionally, 3D-printed PETG and resin components are used to construct various gadgets, including the gripper and base rings for ROVIN. This decision was made to perform specific tasks cost-effectively, because these materials offer a balance of strength, flexibility, durability, and printability, making them suitable for our gadgets.

The image on the right presents an isometric view of the device called ROVIN, offering a three-dimensional perspective that allows a complete visualization of all its components and characteristics. This representation gives us the opportunity to carefully examine each element that makes up this device, from its visible parts to those details that could be hidden in other perspectives.

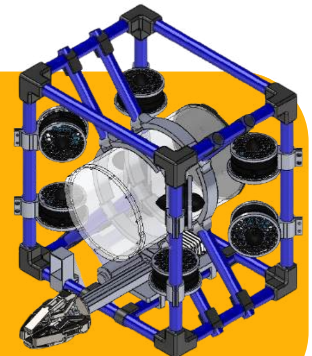


Fig. 10 *Isometric view of ROVIN*

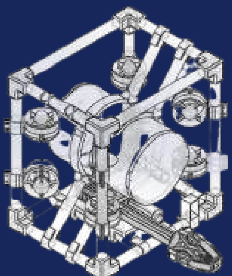


Fig. 11 *3D view of ROVIN CAD design*

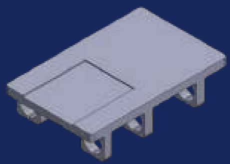


Fig. 12 *Regulator and Actuator platform*

In the 3D view of the device, we can see that the rings and the four cross tubes serve as connectors between the frame and the capsule. The choice to use four bars was made to ensure greater stability for the capsule. In addition, a platform was created to house both

the regulator and the linear actuator of the gripper. This deck is attached to the frame via tubes connected to the base of the ROV.

In the image on the right, we can see the 3D prints designed specifically to support the thrusters. These prints are secured in position by screws. Additionally, you can see the 3D printed protective covers for the thrusters, which completely surround it and the surrounding area to ensure that they do not pose any risk to humans or the environment.

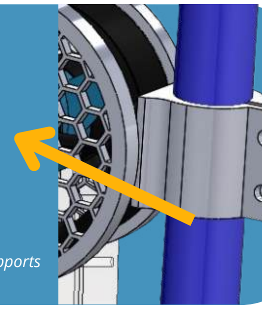
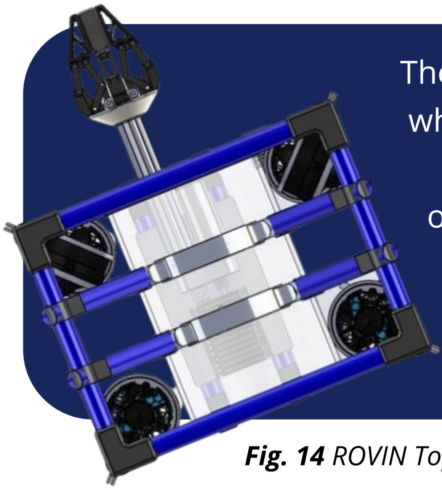


Fig. 13 *Thruster supports CAD design*

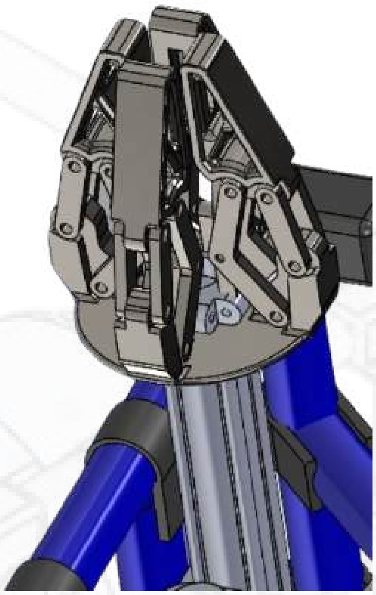


The visual representation shown on the left presents a top view of the ROVIN, in which it can be seen that all of its elements are confined within the main frame, with the exception of the gripper. The latter has been deliberately positioned outside the frame, adopting a placement strategy that seeks to provide a clear visualization of its movements. This tactical design aims to optimize the gripper's ability to hold objects more efficiently and precisely, while ensuring clear observation of its actions and functionality from a higher perspective.

Fig. 14 *ROVIN Top View CAD design*

The gripper is crucial for our ROV as grabbing props is our main priority. Previously, we used servo motors to open and close the gripper, but their IP67 rating made them water-resistant, not waterproof, resulting in inadequate seals for underwater use. We adapted our old designs to work with a Progressive Automations IP68 rated linear actuator with a 4-inch stroke. The gripper is mounted on this actuator, which provides proper movement. The design allows for it to grip objects horizontally or vertically, and an elastic material connects the actuator to the gripper for handling different sizes, relying on a mechanical rather than electrical solution.

Fig. 15 *GRIPPER CAD design*



The gripper is made from UV-curing resin, offering higher hardness and a completely sealed, airtight print with a layer height of 0.05mm, preventing water entry. This design meets competition requirements, and we aim to improve it annually to ensure a functional and reliable gripper.

BUILD VS BUY/ NEW VS USED

Unlike previous years, this year's ROV is made almost entirely of new components. This is mostly because this year's design is vastly different from previous years which makes it impossible to use components that were made to accommodate other designs, such as ROV supports and mainframe. Last year, we focused on upgrading and improving our ROV, which is why we could reuse some components. This year, we are focusing on creating an entirely new ROV with different capabilities than its predecessors. Not everything is new. We made sure to incorporate previously used components to minimize costs and increase reliability (by using previously tested and qualified equipment). Some of the components we reused are thrusters, electronic components and the tether.

FLOAT DESIGN

This year the team embarked on the creation of its first float for the competition. The focus was on researching and learning the most effective way to build a buoyancy engine that would fit inside already used parts from past competitions and that would be able to fulfill the competitions requirements. A buoyancy engine using a 250ml syringe and a 3D printed set of fittings to fix the syringe in position while a stepper motor pulled and pushed in order to increase or decrease the floats weight.

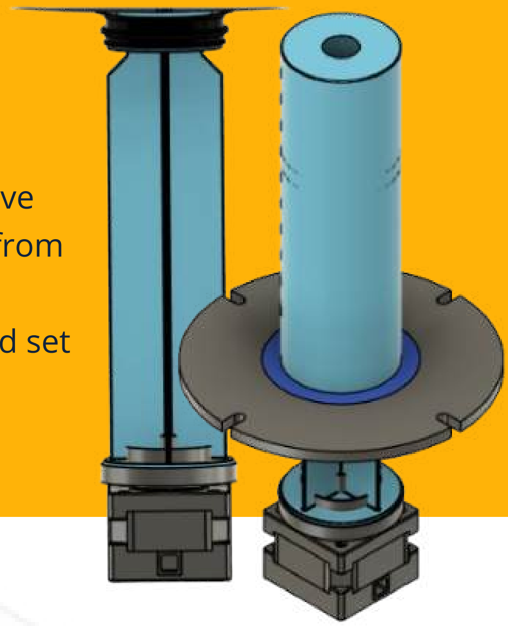
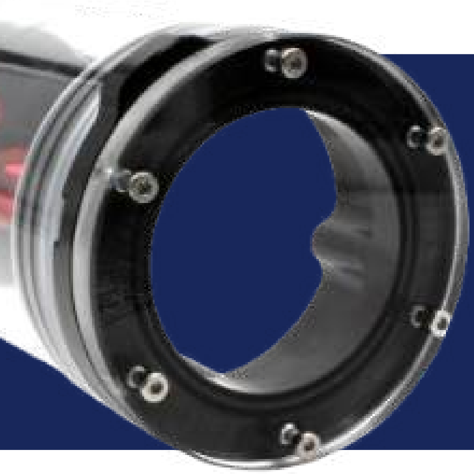


Fig. 16 *Bouyancy Engine*



The float is designed to submerge for a set period of time and to return to the near surface of the body of water, maintaining itself in this cycle until cycle time ends at an estimate of the competitions duration. The main enclosure for the float is a used 4" blue robotics watertight enclosure, with its included O-ring being used for the buoyancy engine's input for water.

Fig. 17 *4" Blue Robotics Watertight Enclousure*

A nema 14 stepper motor was used for the buoyancy engine, as well as a 250ml syringe that would allow for the displacement of 75 ml of water in and out of the float enclosure.

- The plunger was refitted from a electric actuators packaging capsule attached with 3d printed bases to hold the syringes plunger and to adapt for the motors output shaft.
- 3D parts were joined using M3 screws and riser inserts for the electronics and battery assembly to fit properly in the allocated space.
- The battery holder was designed with the idea to have the batteries surrounding the syringe to have a better approach to the batteries.
- Computation is made by an ESP32 microcontroller, that controls the stepper motor driver, and reads a Depth/Pressure sensor and transmits data back to ROVIN.

Fig. 18 *CAD design of battery holder*

SYSTEM APPROACH

The design and integration of the utilized components were carried out under a "**black box**" methodology, where each system is designed assuming that the other systems on which it depends, or controls, function perfectly.

Physically, the ROV's design was divided into two main systems: the exterior and interior of the watertight enclosure. The exterior system refers to the components that interact with the environment. On the other hand, the interior system refers to the components necessary for the exterior system to function. The main consideration that facilitated integration was that the junction point of both main systems would be the rear part of the watertight enclosure.

To facilitate the independent development of physical systems, CAD models were created to visually show which parts were used, how many, and their exact location on the vehicle. Consequently, it was easier to make decisions about rearrangements, notice possible failure points, and apply the necessary design considerations to optimize the vehicle's performance. All of this led to a generally better organization of ROVIN.

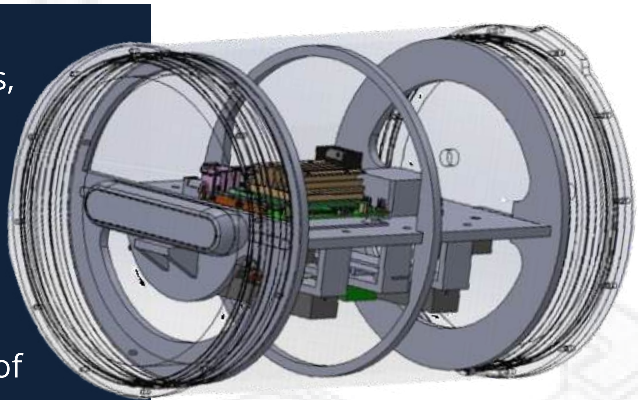


Fig. 19 *Watertight enclosure 8" (WTE8) isometric Interior View CAD*

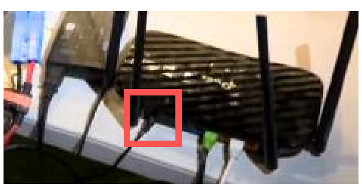


Fig. 20 *Ethernet communication cable*

The tether used in this ROV includes a power supply cable and an Ethernet communication cable. Wire gauge charts were consulted to determine the most appropriate power cable for the required 30A current.

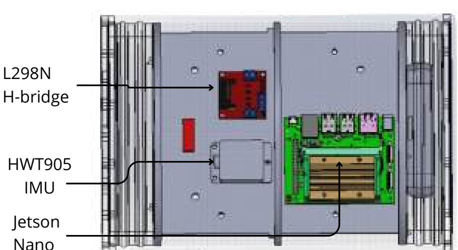


Fig. 21 *WTE8 Interior Top View CAD*

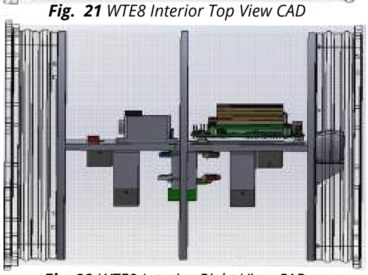


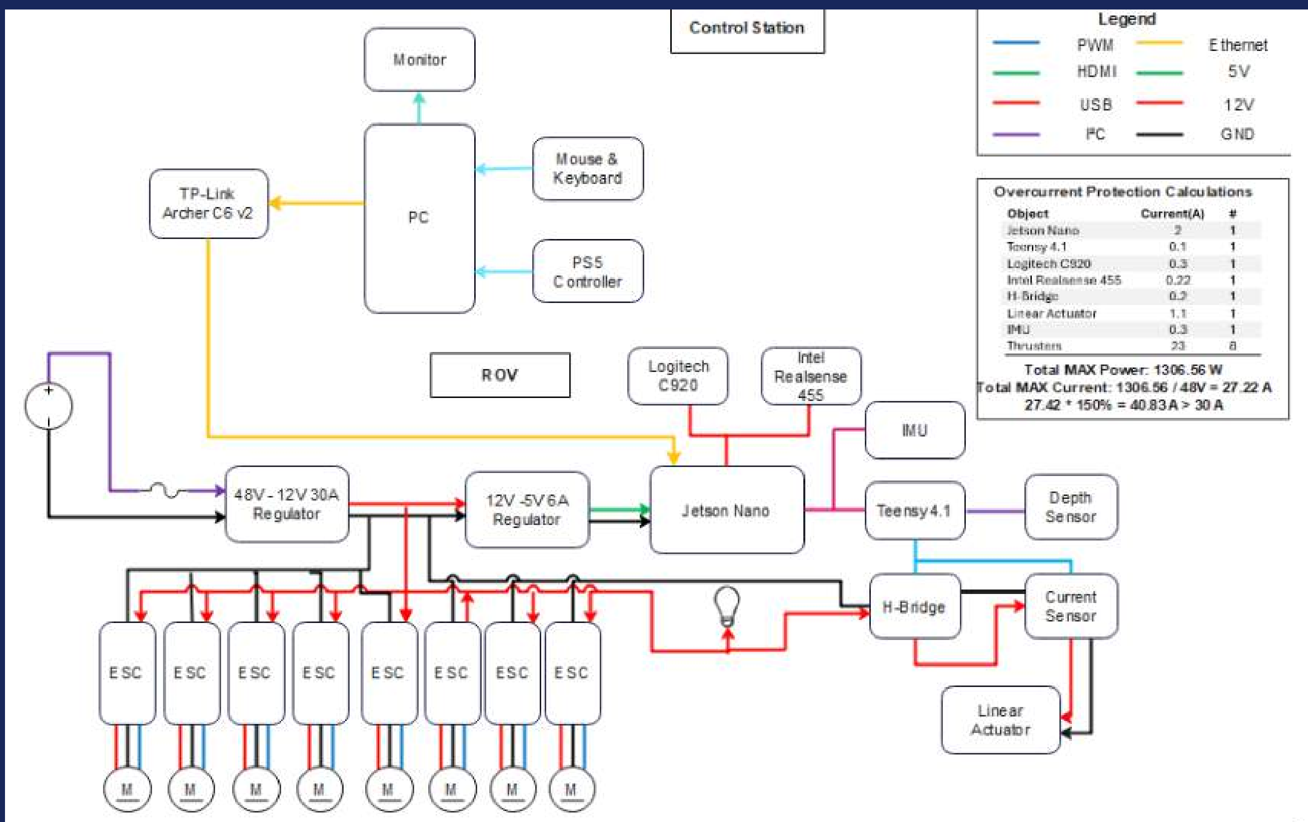
Fig. 22 *WTE8 Interior Right View CAD*

CONTROL AND ELECTRICAL SYSTEMS

- ROVIN is composed of a **Jetson Nano** connected to a **Teensy 4.1**, interfaced with a *TP-Link Archer C6 V2* for communication with the PC, a *Logitech C920 camera*, and an **Intel RealSense D455**.
- The Teensy is interfaced with a *L298N H-bridge*, and a *Bar30 High-Resolution 300m Depth/Pressure Sensor*.
- The entire system is powered by regulated power supplies converting 48V to 12V and 12V to 5V.
- The thrusters are controlled by electronic speed controllers (*ESCs*).
- ROVIN is operated using a *DualSense PlayStation 5 controller*, with camera outputs displayed on a monitor connected to the PC via the *TP-Link Archer C6 V2.*
- The H-bridge is crucial for controlling the linear actuator. This combination was chosen to create a balanced, efficient and robust system for the ROV's underwater operations.

ROVIN consumes 1206.6W in total, most of it coming from the thrusters with 276W, and are powered by the 48V-12V regulator along with the linear actuator which consumes 13.2W.

This is done in order to prevent damage from voltage spikes with delicate components. ***(Fig. 23)***



Object	Current(A)	#
Jetson Nano	2	1
Teensy 4.1	0.1	1
Logitech C920	0.3	1
Intel Realsense 455	0.22	1
H-Bridge	0.2	1
Linear Actuator	1.1	1
IMU	0.3	1
Thrusters	23	8

Fig. 23 *Electrical diagram of the ROV including Overcurrent Protection chart.*

CONTROL SYSTEM SOFTWARE

The control system software for ROVIN operates on **ROS Melodic** using a Jetson Nano onboard computer and a Teensy 4.1 microcontroller with ROSSerial. The architecture is designed to ensure precise and stable operations through the effective integration of user inputs, sensor data, and control commands. The system is divided into three primary layers: surface components, the onboard computer, and the base controller, each providing a level of abstraction for the next.

Our design approach emphasizes **modularity and reliability**, facilitating maintenance and upgrades. The control system is constructed with distinct, interchangeable components, allowing easy updates and repairs. For instance, the Motion Controller, PID controllers, and sensor interfaces are designed as separate modules. This modularity ensures that any component can be updated or replaced without affecting the entire system.

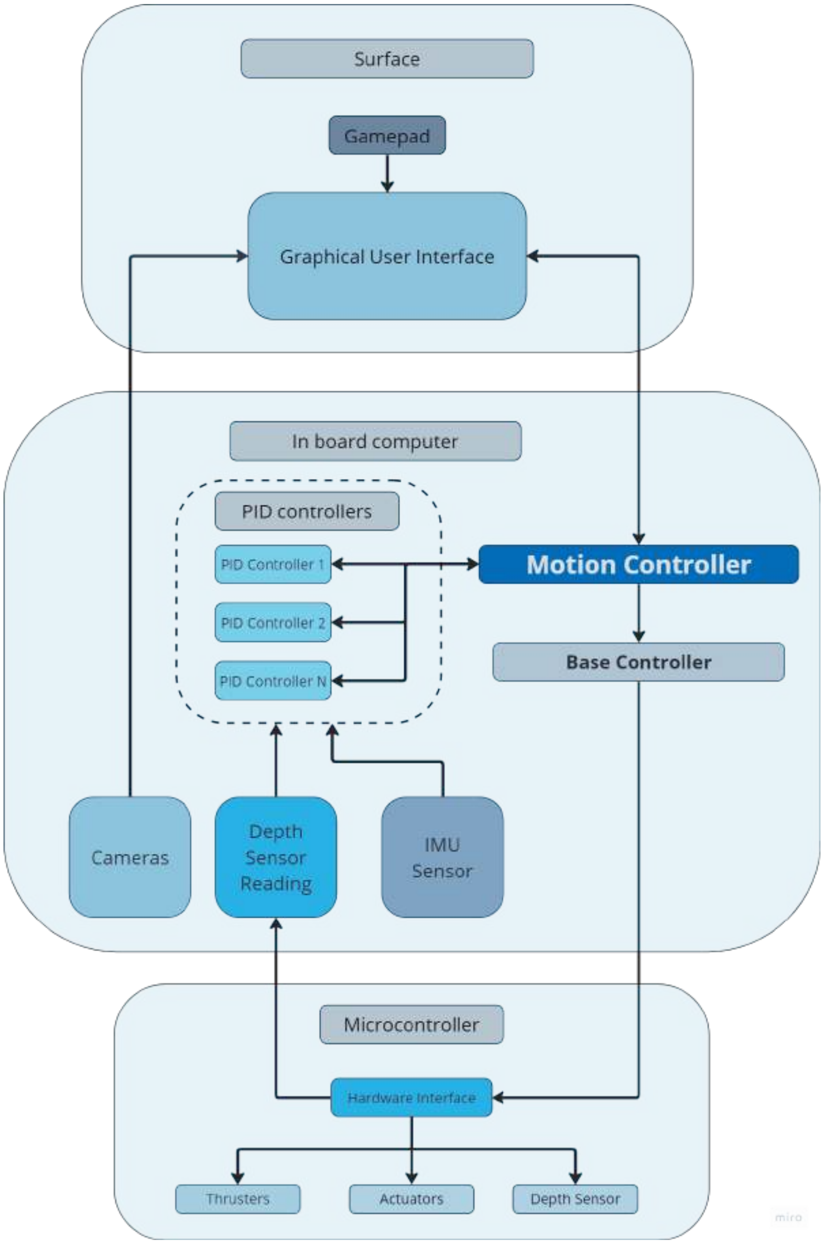


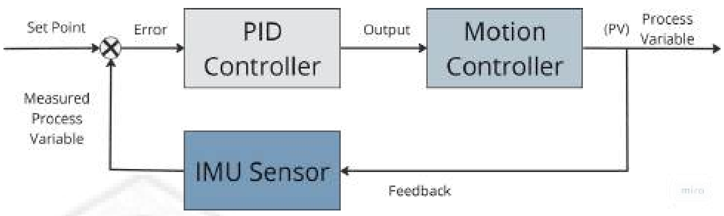
Fig. 24 *Software arquitecture diagram*

This year, the software supports **six degrees of freedom (6DOF)**, enhancing the ROV's maneuverability. Motion Controller and Base Controller utilize these additional axes. The onboard computer houses the Motion Controller, which integrates sensor inputs, processes commands from the GUI, and sends processed data to the PID controllers. The Motion Controller determines the ROV's overall linear and angular movements and sends these commands to the Base Controller. The Base Controller is responsible for the **equations of motion** that account for the 6DOF. It calculates the required velocity for each thruster based on the movement commands from the Motion Controller and ROVIN's thruster configuration and other parameters. It then sends these velocity commands to the hardware interface managed by the microcontroller.

The microcontroller interfaces directly with the ROV's hardware components, including thrusters, actuators, and sensors. It receives desired velocity commands and translates them into PWM signals for the motors and hardware. Additionally, it reads sensor data and transmits these values back to the onboard computer, ensuring real-time feedback and precise control.

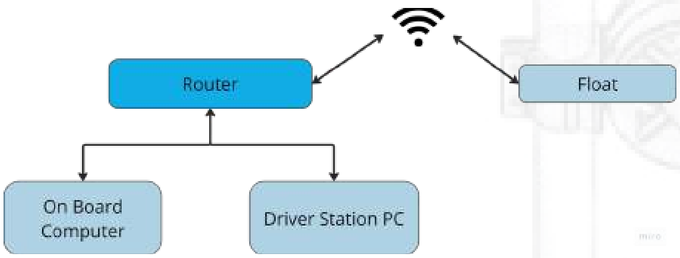
The ROV's control system utilizes **Proportional-Integral-Derivative (PID) controllers** to maintain stability and accuracy in its movements. Our approach to designing the PID controllers is centered around the integration of the Witmotion IMU HWT905 sensor and the Motion Controller. We selected the Witmotion HWT905 IMU due to its high precision and built-in Kalman filter, which effectively reduces noise in sensor readings.

Fig. 25 *Axis Controller diagram*



Each PID controller processes these inputs to correct ROVIN's angular and linear velocities, with separate PID controllers for each degree of freedom, allowing for **precise tuning and control**. This modular design means we can adjust the parameters of each PID independently to optimize performance. The output from the PID controllers is sent to the Motion Controller, which integrates these corrections into the overall movement commands for the ROV.

Fig. 26 *Network topology diagram*



The system integrates the float using an ESP32 microcontroller with Wi-Fi capabilities. When the float surfaces, it connects to a Wi-Fi network provided by the TP-Link Archer C6 router. This router not only supports the float's connection but also provides Ethernet connectivity for both the onboard computer and the driver's station computer, ensuring stable signal reception.

The ESP32 on the float runs **ROSSerial TCP**, allowing it to send data and commands through the router to ROVIN's control systems. Upon surfacing, the float transmits sensor data and status updates via Wi-Fi to the router, which then routes this information to the onboard and driver's station computers.

Fig. 27 *Driver Station GUI*

Our driver station software GUI is built using **React and packaged with Tauri**, providing a lightweight and efficient user interface that can run on multiple platforms. This software leverages **ROSbridge** to facilitate communication with both ROVIN and the float, enabling seamless data exchange and control. The GUI also supports the connection of a DualShock controller, which is read using the Gamepad API, making it compatible with most modern gamepads. With its cross-platform capabilities and versatile input support, the driver station software can be run on virtually any computer, ensuring flexibility and ease of use in various operational environments.

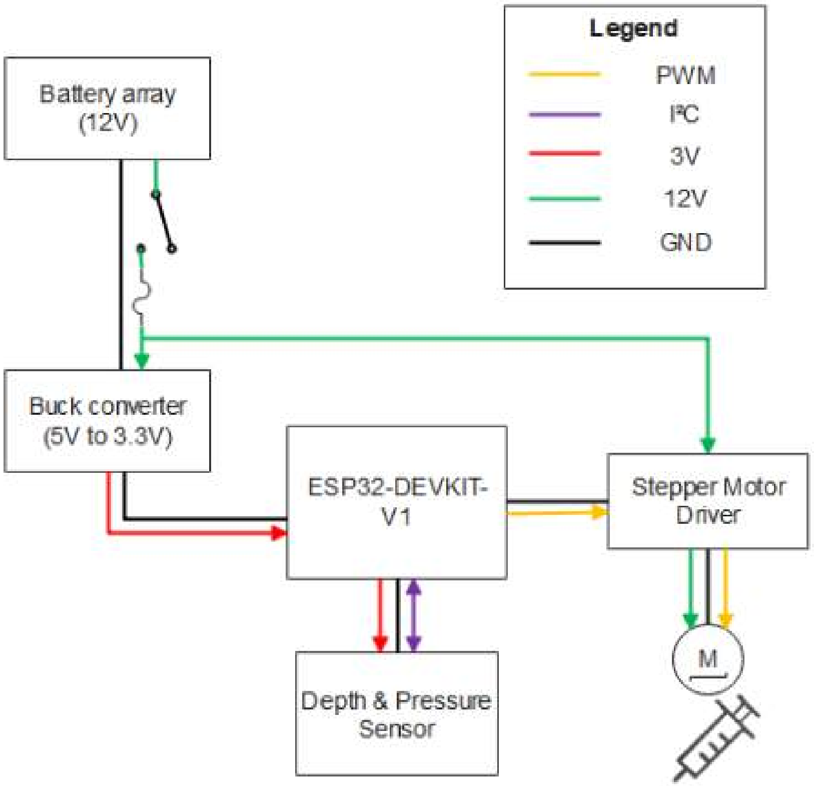
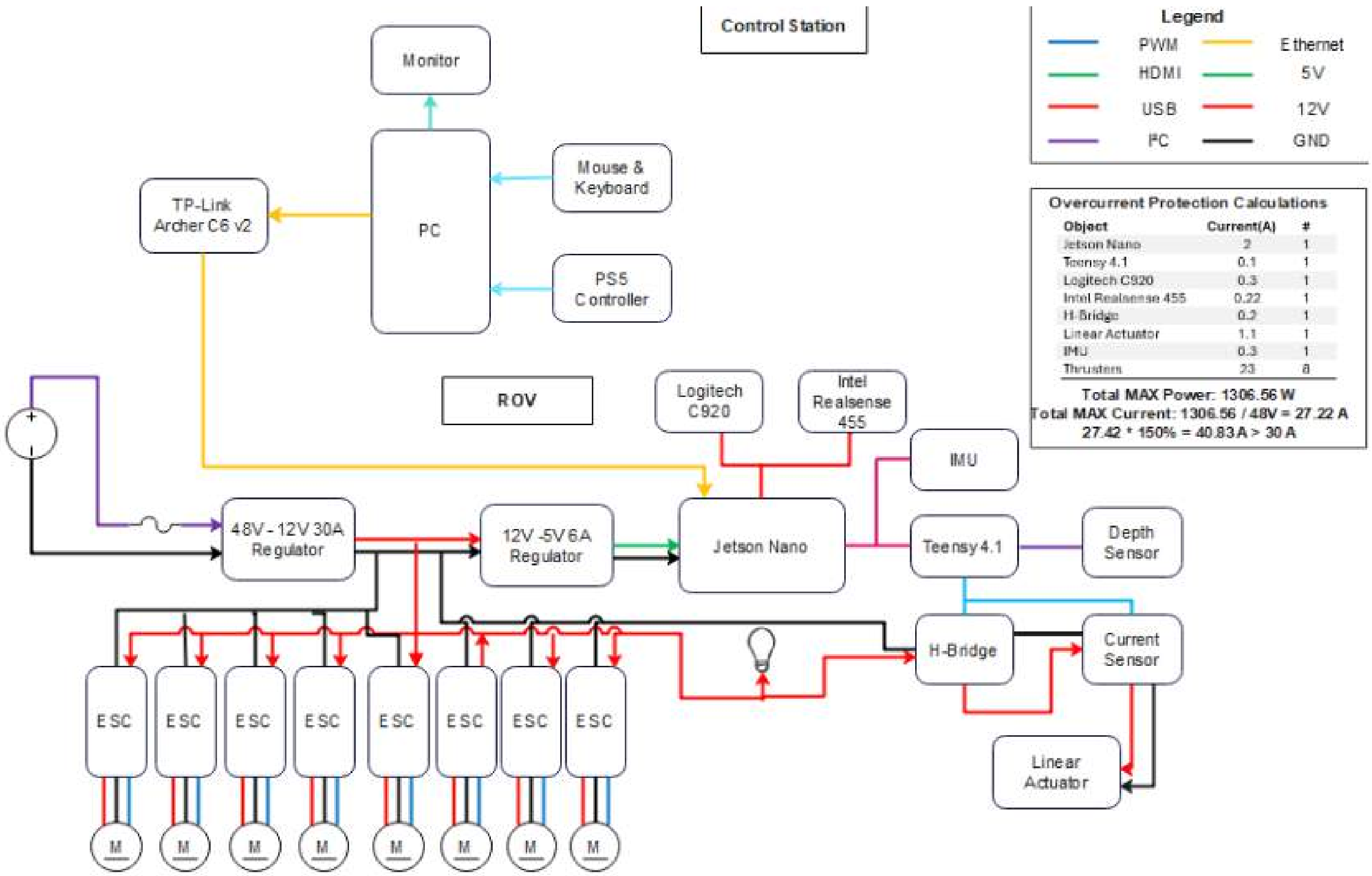


Fig. 28 Electrical diagram of the float



Overcurrent Protection Calculations

Object	Current(A)	#
Jetson Nano	2	1
Teensy 4.1	0.1	1
Logitech C920	0.3	1
Intel Realsense 455	0.22	1
H-Bridge	0.2	1
Linear Actuator	1.1	1
IMU	0.3	1
Thrusters	23	8

Total MAX Power: 1306.56 W
Total MAX Current: 1306.56 / 48V = 27.22 A
27.42 * 150% = 40.83 A > 30 A

Fig. 29 Electrical diagram of the ROV including Overcurrent Protection chart.

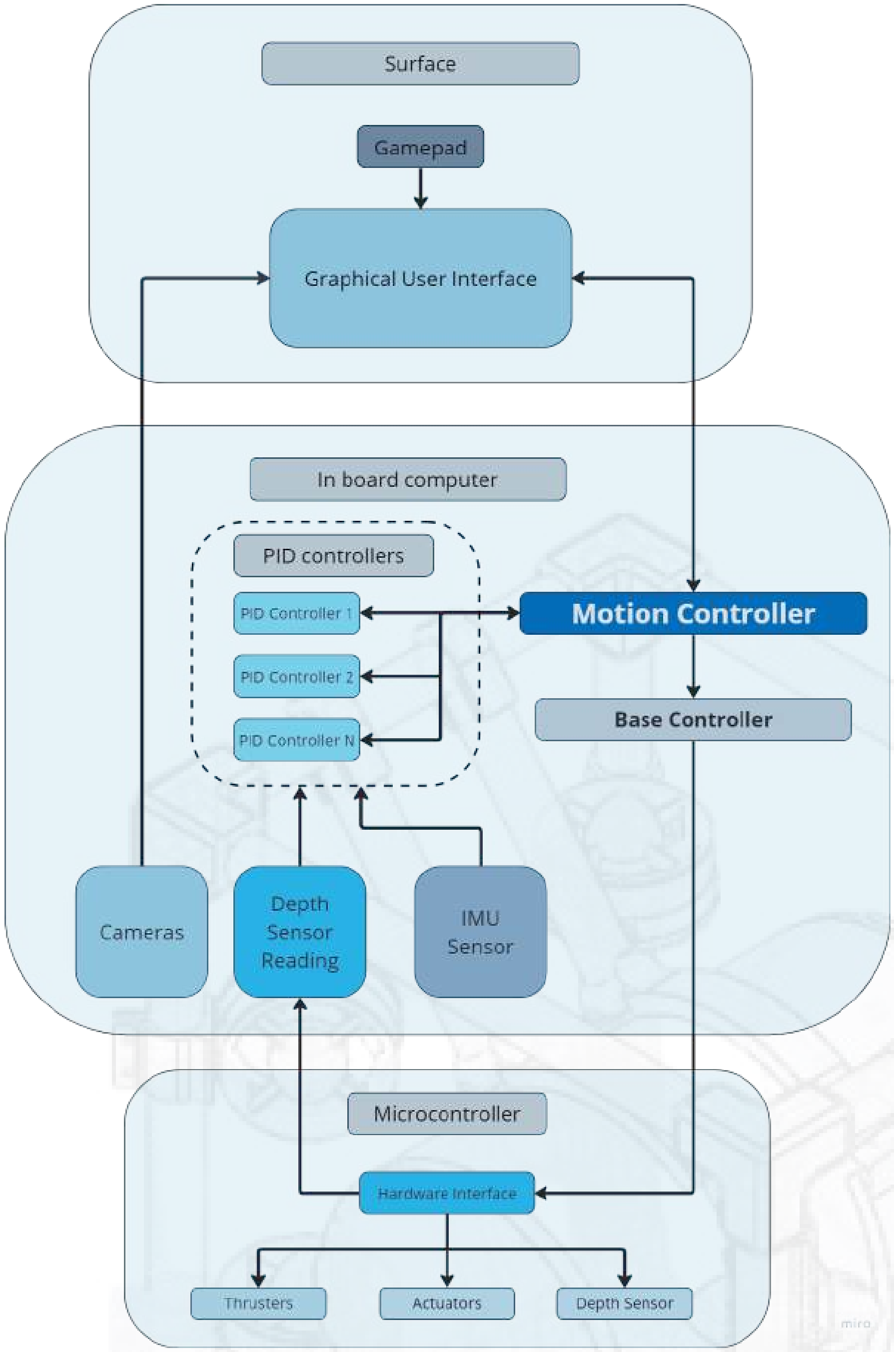


Fig. 30 *Software arquitecture diagram*

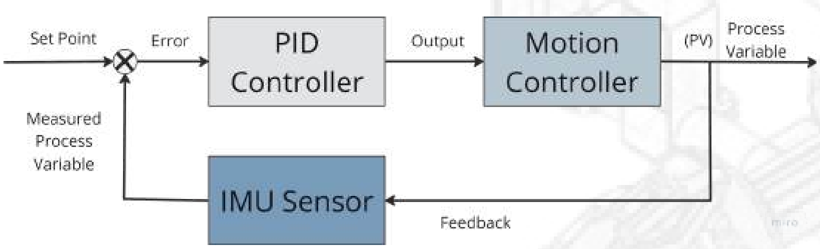


Fig. 31 *Axis controller diagram*

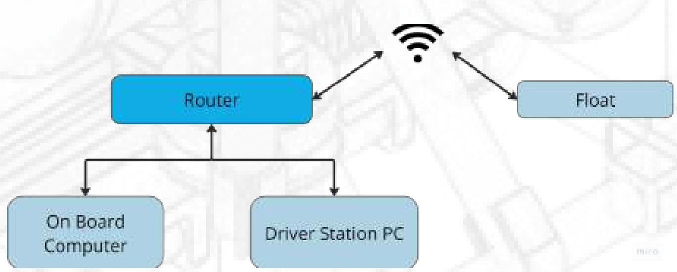


Fig. 32 *Network topology diagram*

SAFETY

***Fig. 33** Operational safety checklists in use by a SEAFOX members.*

To ensure the well-being of team members and the safe operation of ROVIN, we have implemented a number of **safety measures and protocols** at the start of the season. Recognizing the natural risks associated with using various equipment in ROV development, we have established protocols and equipped our lab with essential safety tools to maintain a secure working environment. Our commitment to safety is crucial, with personnel and equipment protection being top priorities. A dedicated team member has been appointed as the **Safety Officer**, responsible for overseeing and verifying safety throughout the entire ROV development process.

PERSONAL AND EQUIPMENT SAFETY

The safety information provided at the start of the season include locations of a first aid kit, a fire extinguisher, an eye wash station, and visual aids about the requirements for PPE, such as safety glasses, gloves, earplugs, and safety boots, depending on the activity being performed. Each tool used in the work area requires a different PPE. The person in charge of safety provides instructions on what is necessary for each tool, whether it is for cutting, welding, etc.

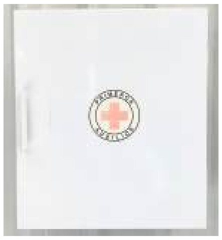


Fig. 34

First Aid Kit: Accessible for immediate medical assistance in case of minor injuries.

Fig. 35

Fire Extinguisher: Strategically placed to address fire emergencies promptly.

Fig. 36

Eye Wash Station: Available for immediate use to flush out contaminants from the eyes.

Fig. 37

Visual Aids: Detailed posters and signs outlining PPE requirements for various tasks.

PPE REQUIREMENTS

- **Safety Glasses:** For eye protection against debris and sparks.
- **Gloves:** Varieties such as cut resistant or heat resistant gloves, depending on the task.
- **Earplugs:** For hearing protection in high-noise environments.
- **Safety Boots:** To protect feet from heavy objects and sharp materials.

OPERATIONAL SAFETY

According to the specifications outlined in the ***MECH-006*** protocol, the design of the thruster guards is meticulously crafted to ensure comprehensive coverage of all apertures present on the thruster apparatus. The primary objective of these guards is to establish a robust barrier, effectively mitigating potential ingress of foreign matter into the thruster assembly.

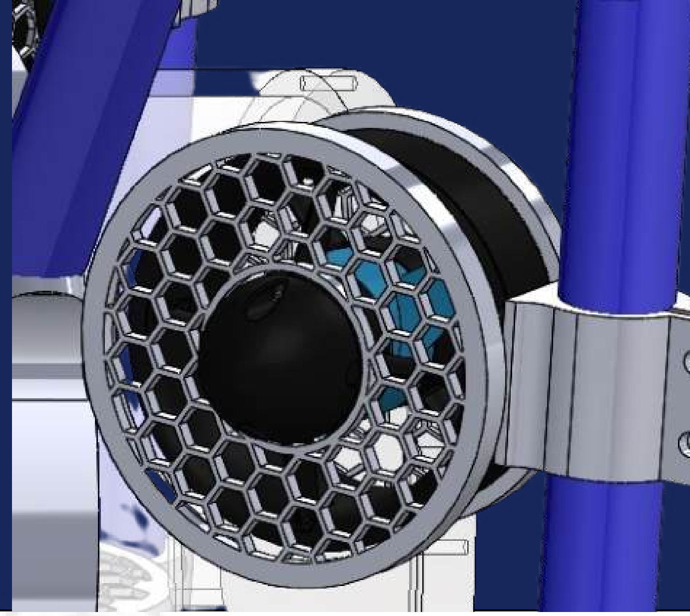


Fig. 38 *Thruster guards*

__Fig. 39__ Front and Back Thruster guards

The construction of the guard structure is engineered to meet the stringent **IP-20 standards**, specifically targeting the delineated criteria for solid particulate protection at level 2. This designation denotes a degree of safeguarding against solid particles larger than 12.5 millimeters in diameter, providing a formidable defense against ingress that could compromise the operational integrity of the thruster system. Manufacturing the guard using 3D printing technology, ensures compliance with motor protection requirements while also providing safety for the team members and others in contact with the ROV.

WARNING LABELS ON THRUSTERS

Signal Word Panel	Used for ANSI Z535.2	Used for ANSI Z535.4	Used for ANSI Z535.5	Used for ANSI Z535.6	Classification
⚠WARNING	Yes	Yes	Yes	Yes	Indicates a hazardous situation that, if not avoided, could result in death or serious injury. Usually used outside of a spatial or mechanical barrier separating the viewer from the hazard.

Fig. 40 *Warning label design for thrusters: ISO 7010 – Standard for safety symbols used in ISO 3864. ANSI Z535 – Corresponding American standard for safety signage, product warning labels and product instructions.*

All electronics are safely contained within a **waterproof enclosure** to shield them from water damage. To ensure safety, external systems and mechanisms undergo design or treatment to remove any sharp edges. Additionally, safety guards are meticulously installed to safeguard the eight thruster motors. The tether is supported by a **strain relief mechanism**, effectively preventing damage to the watertight enclosure penetrators. Furthermore, the ROV tether is equipped with the requisite fuse as mandated by competition requirements, ensuring operational reliability and adherence to safety standards.

Fig. 41 *Strain Relief SYSTEM*

SAFETY PROCEDURES

We employ a set of safety protocols during the assembly and deployment of the ROV to mitigate potential risks to both personnel and the equipment itself **(refer to Appendix A and Appendix B).**

CRITICAL ANALYSIS: TESTING AND TROUBLESHOOTING

During the testing phase of each system, it was noticed that everything was in order. Upon conducting a comprehensive test of the entire ROV, which was already assembled and ready to enter the water, concerns arose regarding the different mechanisms that would be used.

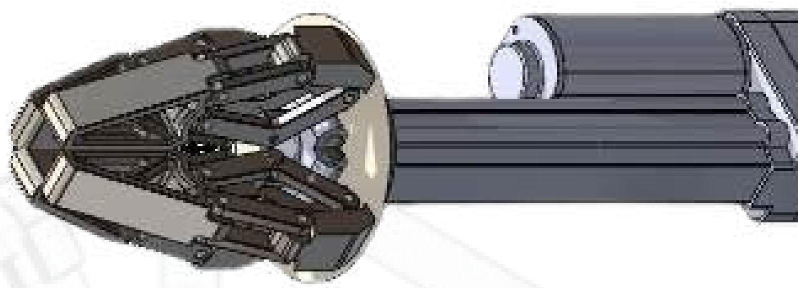


Fig. 42 *ROV Gripper CAD*

Fig. 43 *Gripper linear actuator mechanism*

One of our major concerns was the performance of the linear actuator in the gripper, as this was our first time incorporating one into an ROV. Initially, we attempted to use a current sensor to detect current spikes and identify when the gripper was encountering resistance, thereby detecting objects. However, this approach proved inadequate, as the force required to trigger the sensor was enough to damage the gripper. To address this, we implemented a solution that involved setting maximum and minimum actuation times, corresponding to the full opening and closing of the gripper. Additionally, the system continuously saves the actuator's position in seconds, allowing it to remember its last state even if the actuation is interrupted or course is changed mid-operation, ensuring reliable and safe performance.

Furthermore, our software includes mechanisms to handle rapid shifts in demand from the ESCs, preventing overvoltage shutdowns. By measuring the jerk, or the rate of change of acceleration, in each thruster over time, we can dynamically adjust the power distribution to the thrusters. This proactive monitoring and management of sudden changes in power demand help maintain optimal performance and prevent potential power shutdowns due to overvoltage conditions. These comprehensive testing and troubleshooting measures ensure that ROVIN performs reliably under diverse operational scenarios.

BUDGET

The budget was meticulously planned to ensure all resources are allocated effectively and the project remains financially viable. This section provides a detailed breakdown of the expenses and funding sources, ensuring transparency and accountability in our financial management. The budget planning process involved identifying all necessary expenses, estimating costs, and securing funding from various sources. The primary categories of expenses include materials, equipment, travel, and miscellaneous costs.

Expenses Breakdown

Category	Description	Cost
Materials and Components	○ Mechanical Components: ▪ Structural materials, fasteners, and custom parts. ○ Electrical Components: ▪ Sensors, wiring, connectors, and control systems.	$1800
Equipment	○ Testing Equipment: ▪ Instruments and tools for prototyping and testing. ○ Safety Gear: ▪ Protective equipment and safety supplies for team members.	$450
Travel Expenses	○ Competition Travel: ▪ Transportation, accommodation, and meals for the team during the competition.	$10,400
Miscellaneous Costs	○ Marketing and Presentation Materials: ▪ Printing, display boards, and promotional materials. ○ Contingency Fund: ▪ Reserve for unexpected expenses.	$700
Total		**$13,350**

Fig. 44 *General Budget Table*

Funding Sources

Category	Description	Amount
Company Contributions	◦ Initial fund	$300
Sponsorship and Donations	◦ CETYS University ◦ Intuitive Foundation ◦ Spark Technologies	$7,520
Fundraising Activities	◦ Movie nights ◦ Raffles ◦ Krispy Kreme donuts sale ◦ Valentine's Day photobooth ◦ Homemade bread sale	$5,800
Total		**$13,620**

Fig. 45 *Funding Sources Table*

Cost Accounting

Our cost accounting system tracks all expenditures against the planned budget, ensuring all funds are used effectively. Regular audits are performed to ensure compliance with financial policies and to identify any discrepancies. *

Effective Use of Funds

Seafox Inventive is committed to using funds efficiently, prioritizing cost-effective solutions without compromising on quality. We aim to maximize the impact of our budget by negotiating discounts with suppliers, reusing components where feasible, and leveraging in-kind donations.

***A detailed list of all expenses is included in Appendix C for further reference and transparency.**

ACKNOWLEDGMENTS

Seafox Inventive extends our deepest gratitude to the individuals and organizations that have supported our ROV project. Their contributions have been invaluable to our success and have enabled us to push the boundaries of underwater robotics.

Corporate Sponsors
CETYS University.
Spark Technologies.
Intuitive Foundation.

Individual Donors
Special thanks to our generous individual donors who have provided financial support and resources.

Advisors and Mentors
Luis Carlos Basaca, Ph.D. for his invaluable insights and advice, significantly contributing to the success of our project.

Community Support
We are grateful to our local community for participating in our fundraising activities.

REFERENCES

Our project has been informed and supported by a variety of resources, including academic publications, industry standards, and previous research in the field of underwater robotics. Below is a list of references that have been instrumental in our project development

Blue Robotics. (2021). About Us. https://bluerobotics.com/about/

Blue Robotics Community. (2022). User Discussions and Technical Support. https://community.bluerobotics.com/

Bruno, F., Muzzupappa, M., Lagudi, A., Gallo, A., Spadafora, F., Ritacco, G., ... Di Stefano, G. (2015). A ROV for supporting the planned maintenance in underwater archaeological sites. OCEANS 2015 - Genova. doi:10.1109/oceans-genova.2015.7271602

Caccia, M., Bono, R., Bruzzone, G., & Veruggio, G. (2000). Unmanned Underwater Vehicles for Scientific Applications and Robotics Research: The ROMEO Project. Marine Technology Society Journal, 34(2), 3–17. doi:10.4031/mtsj.34.2.1

Creform. (n.d.). Catalog. Retrieved from Creform: https://creform.com/catalog/#page=1

Evers, J., Editing, E., & Editing, E. (2024). Great Pacific Garbage Patch. Retrieved from National Geographic Education: https://education.nationalgeographic.org/resource/great-pacific-garbage-patch/

Harish, A. (2023, December 8). Finite element method – what is it? FEM and FEA explained. SimScale. https://www.simscale.com/blog/what-is-finite-element-method/

Kuentz, L., Salem, A., Singh, M., Salem, J., & Halbig, M. (n.d.). Additive Manufacturing and Characterization of Polylactic Acid (PLA) Composites Containing Metal Reinforcements. Retrieved from National Aeronautics and Space Administration: https://ntrs.nasa.gov/api/citations/20160010284/downloads/20160010284.pdf

APPENDIX A

SeaFox Inventive: Maintenance and Operation Protocol

Pre-power verification

1. Check that the inside of the ROV is clean and all wires are connected properly.
2. Verify cable connections for any damage or looseness.
3. Ensure proper sealing of the electronic systems enclosure.
4. Clear the area around the ROV and ensure the tether is free from obstructions and tangles.
5. Connect the manual vacuum pump to the vent penetrator.
6. Pump until reaching 10 in Hg, then set a 15- minute time. After 15 minutes, if the pressure remains above 10 in Hg, remove the pump and tighten the vent plug.
7. Battery/power supply is completely dry and away from the side of the water.
8. Surface station computer, router, and monitors are plugged in, powered on, and connected. All personnel have close-toed shoes, safety glasses, no loose clothing, and long hair tied back.

Power-up verification

1. Connect the tether to the power source
2. Confirm connection to the Graphical User Interface
3. Check the cameras for proper operation.
4. Establish a secure control-thruster connection
5. Confirm the sound of thrusters turning on

Water immersion check:

1. Ensure all seals, gaskets, and penetrators are intact and in good condition.
2. Submerge the ROV cautiously, preferably with assistance from two team members.
3. Verify the presence of normal bubble levels
4. Regularly inspect the leak detector.
5. Conduct a functionality test to ensure all systems are functioning properly post-immersion.
6. Document any issues or anomalies observed during the water immersion check for further assessment and action.
7. Lost communication procedure:
8. Disconnect the ROV from the power source and surface it via the tether.
9. Initiate the reboot process to attempt restoration of communication and system functionality.
10. Coordinate with the surface control station team to troubleshoot and resolve communication issues.
11. Document the communication loss incident, including any troubleshooting steps taken and outcomes, for future reference and analysis

APPENDIX B

Seafox Inventive Lab Safety Policy

1. Appropriate Lab Attire: Wear safety glasses or side-shields, close-toed, non-slip shoes, and appropriate gloves. Avoid loose clothing and secure long hair. Remove rings, watches, and bracelets.
2. Clean Workspace: Maintain cleanliness after each use. This entails ensuring that all equipment, tools, and surfaces are properly cleaned and tidied up.
3. Report Incidents: Immediately report all injuries or accidents to the Lab Supervisor.
4. Seek Guidance: If unsure about a procedure, stop and ask for help to the Chiefs or CEO.
5. Address Hazards: Report any unsafe conditions and correct them if possible.
6. Know Your Equipment: Be fully knowledgeable about the equipment you are using.
7. Proper Tool Use: Only use tools for their intended purposes.
8. Adjust Safely: Only adjust machines when they are stopped, unless movement is necessary for the adjustment.
9. Monitor Machines: Never leave a running machine unattended unless it is designed for continuous operation.
10. Stop Equipment Safely: Do not use hands or tools to stop moving equipment.
11. Handle Sharp Edges: File all machined parts or stock with sharp edges.
12. Secure Workpieces: Always clamp or secure the workpiece properly before working.
13. Respiratory Protection: Use appropriate respiratory protection when dealing with dusts, mists, fumes, or vapors.
14. Chemical Safety: Read Safety Data Sheets (SDS) for all lubricants, resins, adhesives, or other chemicals used.
15. Focus on Tasks: Stay focused on your task and avoid distractions while operating equipment.
16. Safe Lifting Techniques: Use proper techniques and get assistance for lifting, moving, or carrying heavy loads.
17. Prevent Tripping: Keep materials and objects out of walkways to prevent tripping hazards.
18. Emergency Preparedness: Know the locations of fire extinguishers, fire exits, and first aid kits.

APPENDIX C

Category	Item/Part Description	Quantity	Unit Cost	Total Cost
Float	150mm Lead Screw with T8 Brass Nut	1	$8.99	$8.99
Float	250ml Large Syringe with Cap (5 pcs)	1	$3.40	$16.99
Prop Building / ROV Accessories	9" Galvanized Steel Pin (30 pcs)	1	$0.33	$9.95
Prop Building	Red Velcro Hooks	1	$6.99	$6.99
Prop Building	3" Knockout Caps, Rope, #310 U-bolt, 1" PVC Cross, Black Milk Crate, Brass Gate Valve, Brass Barb Tee, Bowl, Carabiner	N/A	N/A	$38.27
Prop Building	Example: PVC ½" Tee, PVC ½" Tube, #6 Screw Hooks, PVC ½" End caps, Black Velcro Hooks, Corrugated Plastic	N/A	N/A	$93.22
Prop Building	Waterproof Temperature Sensor (5 pcs)	1	$2.32	$11.58
Prop Building	2 Pack Aquarium Thermometer	1	$4.35	$8.69
ROV Electronics	Stepper Motor Bipolar 1.5A	1	$25.99	$25.99
ROV Electronics	100 Pcs Standard Blade Fuse	1	$15.99	$15.99
ROV Electronics	Breakout Board Module with Pin Board for Teensy	1	$13.99	$13.99
ROV Electronics	Regulator 48V Step Down to 12V 30A 360W	1	$29.00	$29.00
ROV Electronics	5V 6A Power Supply	1	$25.00	$25.00
ROV Electronics	IMU Sensor With Temperature Sensor	1	$106.90	$106.90
ROV Electronics	Teensy 4.1	1	$56.00	$56.00
ROV Electronics	Depth Sensor	2	$85.00	$170.00
ROV Electronics	Underwater Switch	1	$25.00	$25.[illegible]
ROV Electronics	Linear Actuator 12V	1	$29.00	$29.00
ROV Electronics	H-Bridge	1	$2.5	$10.00
ROV Electronics	Current Sensor	1	$3.33	$10.00
ROV Electronics	TP-Link Archer C6 v2	1	DONATED	
ROV Electronics	Logitech C920	1	DONATED	
ROV Frame	Watertight Enclosure for ROV/AUV (8" Series)	1	$461.00	$461.00
ROV Frame	8" Acrylic Dome	1	$28.99	$28.99
Supplies & Equipment	Flexible Couplings 5mm to 8mm (5 pcs)	1	$1.998	$9.99
Supplies & Equipment	H6 PRO Lithium Battery Charger	1	$170.00	$170.00
Supplies & Equipment	TAP Acrylic Cement	1	$24.95	$24.95
Supplies & Equipment	Hypo-Type Solvent Cement Applicators	1	$4.95	$4.95
Supplies & Equipment	6Arm Soldering Station Solder	1	$18.00	$18.00
Supplies & Equipment	ToolBox Plastic Organizer	1	$30.00	$30.00
			Total	**$1,789.00**