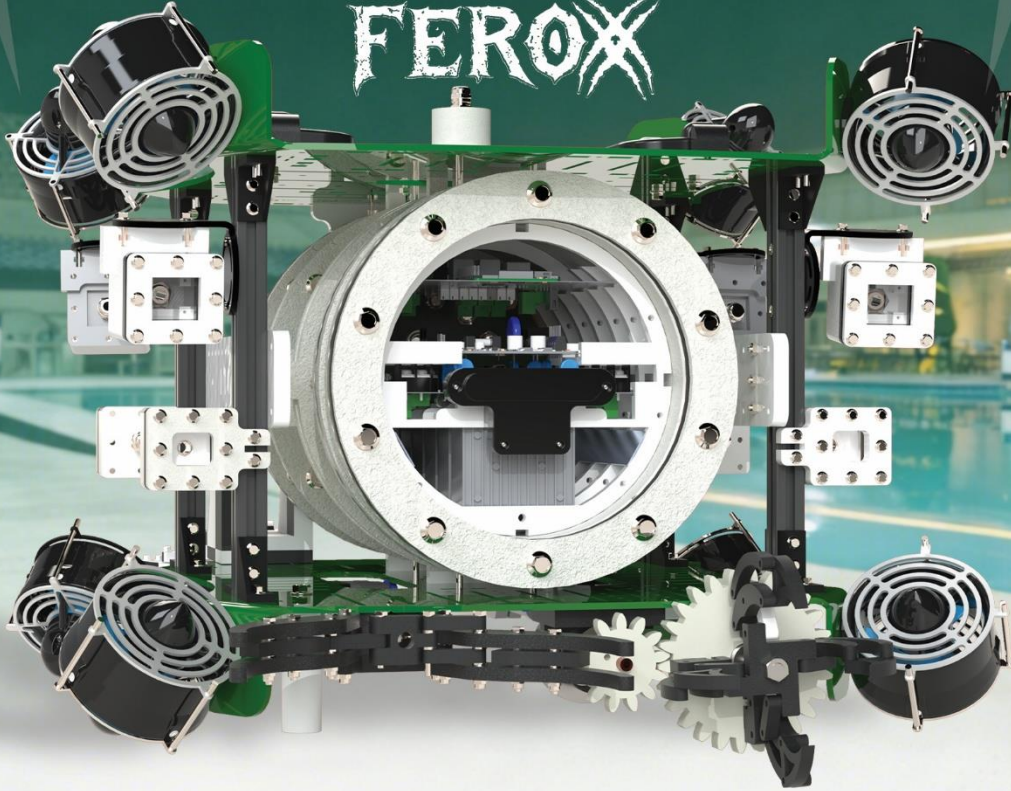


CROCOMARINE

Alexandria University - Egypt

FEROX



TECHNICAL REPORT

MATE ROV'26

Company Members :

28' Youssef Elmaghraby CEO
27' Mohamed Khaled CFO
27' Abobakr Safwat Pilot
27' Abdelrhman Ihab Software Leader
28' Ahmed Amr Mechanical Leader
28' Badr Hassan Hardware Leader
25' Ziad AlAwady Media Designer
26' Abdelrhman Wael Software Engineer*
27' Ahmed Roshdy.....Software Engineer
27' Ahmed Sherif Hardware Engineer*
27' Mahmoud Nader Public Relations*
27' Mazen Azhary Software Engineer
27' Yahia Ahmed Mechanical Engineer
28' Ahmed Abdallah Software Engineer*
28' Amr Khaled Mechanical Engineer*
28' Belal Ahmed Mechanical Engineer*
28' Khaled Abdelmageed Software Engineer
28' Loay Mohamed Hardware Engineer*
28' Mostafa Abdelbasset Hardware Engineer*
28' Omar Abdelmoneim Mechanical Engineer*
28' Omar Sallam Hardware Engineer*
28' YoussefMagdy Mechanical Engineer*

[*] For New Members

Mentors :

Abdelrahman Hosny
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Nour Eldin
Moaaz Mahmoud
Mohamed Sami

Under The Supervision of
Dr. Abdelrahman Farghly

Abstract

We are Crocomarine. A technical team from Alexandria university founded in 2016, driven by a passion for Engineering and developing underwater solutions to environmental challenges facing the Mediterranean, the Red Sea, and the River Nile. Over the years our team has cultivated a decade of deep technical expertise from participating in ROV competitions and industrial manufacturing. This journey cultivated in the creation of Ferox, a vehicle that represents the peak of our collective engineering knowledge.

Ferox is a modular, lightweight ROV specifically engineered to tackle dynamic subsea missions. Designed for agile maneuverability in various subaquatic harsh environments, while being non-disruptive and safe to marine life. The vehicle features an expanded field of view, modular actuators to take on underwater tasks, and six degrees of freedom supported by a custom control system for motion stability. Tested and designed with the collaboration of our mechanical, hardware, and software departments, resulting in a friendly pilot interface and high-precision control.

Engineered for precision and impact Ferox is capable of performing critical tasks to assist in ocean research, infrastructure deployment, and marine ecosystem monitoring. This document provides a comprehensive overview of the vehicle's development timeline, technical specifications, and cost.



Figure I-1 Crocomarine Team

ACKNOWLEDGEMENT

Crocmarine Team extends its sincere gratitude to the organizations, sponsors, mentors, and individuals whose invaluable support, guidance, and resources were instrumental to our success in the 2026 MATE ROV season. We are deeply appreciative of the following partners who provided the momentum and expertise needed to achieve our engineering goals:

- **Alexandria University:** For foundational backing and continuous competitive support.
- **Innovators Support Fund (ISF):** For critical financial sponsorship and project sustainment.
- **Arab Academy (AASTMT):** For exceptional regional organization and team assistance.
- **The MATE Center:** For inspiring innovation and fostering a global engineering community.
- **Dr. Ahmed El-Shenawy:** For dedicated coordination of the Egypt Regional competition.
- **Dr. Abdelrahman Farghaly:** For invaluable technical mentorship and logistical oversight.
- **Eng. Mohamed Seddik:** For essential hands-on assistance and day-to-day support.
- **SolidWorks:** For sponsoring premium software licenses and certification exams.
- **JLCPCB:** For sponsoring the reliable fabrication of our custom PCBs.
- **Makers Electronics:** For supplying high-quality electrical components at a discount.
- **Blue Robotics:** For providing specialized marine components crucial to our ROV.
- **ANSYS, Altium & Festo:** For the industry-leading software vital to our engineering phases.
- **Families, Friends & Alumni:** For your unwavering encouragement, sage advice, and resilience.



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1 Teamwork

1.1 Company Organization

Crocomarine is made up of 21 members which are divided into three technical sub teams along with non-technical departments. Each sub-team has a corresponding head who acts as a team leader - monitoring, assigning and delegating tasks, whilst actively participating hands-on alongside the team. These heads, along with the CEO and CFO, form the board of directors of the company.

When it calls for, once the ROV's design is final and realized our company goes through a restructuring process to operate the ROV safely on site. These positions are a pilot team consisting of a pilot and a co-pilot, a tether-man and a maintenance crew.

1.2 Project Management

At the start of the year there are board meetings where milestones are set and protocols are established such as warnings, daily feedback, task submissions, training for new members, etc.

To make sure that the sub teams' goals are aligned we monitor our progress using ClickUp which allows us to avoid deadline delays.

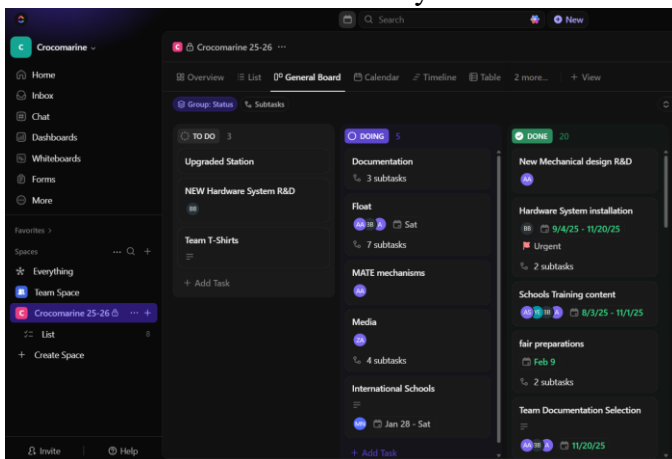


Figure 1-2 ClickUp Project Management Board

version control: To manage collaborative [software](#) development, we utilize GitHub for strict version control. The GitHub community we have set up provides a central platform where all team members can work on their own branches simultaneously, only after thorough testing are changes merged into the main branch.

1.3 Project Schedule

Crocomarine adheres to a structured bi-weekly development cycle, commencing with a leadership planning board meeting every Thursday. During this meeting, the leadership team establishes

weekly objectives and evaluates each team's adherence to the project timeline. Whenever deemed necessary the whole team is called for a general meeting to discuss progress, collaborate on working through project setbacks and brainstorm new ideas and solutions.

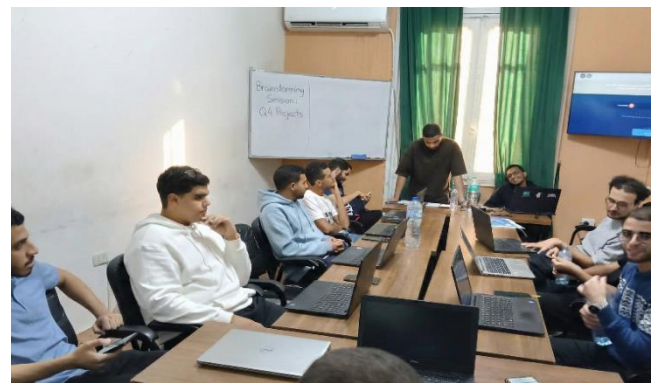


Figure 1-3 General meeting

1.4 Intercommunication

To have effective communication we have decided to implement a wide variety of communication tools, such as discord for online meetings, WhatsApp community which contains sub team group chats as well as a general daily feedback group chat where it is discussed what we did that day. As for formal meetings with external entities such as partnerships and sponsorship deals, we rely on google meet

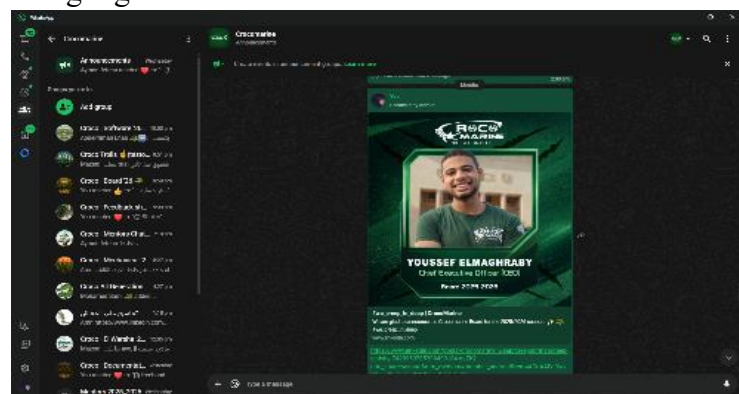


Figure 1-4 WhatsApp group community

GANTT CHART CROCOMARINE 2025-2026

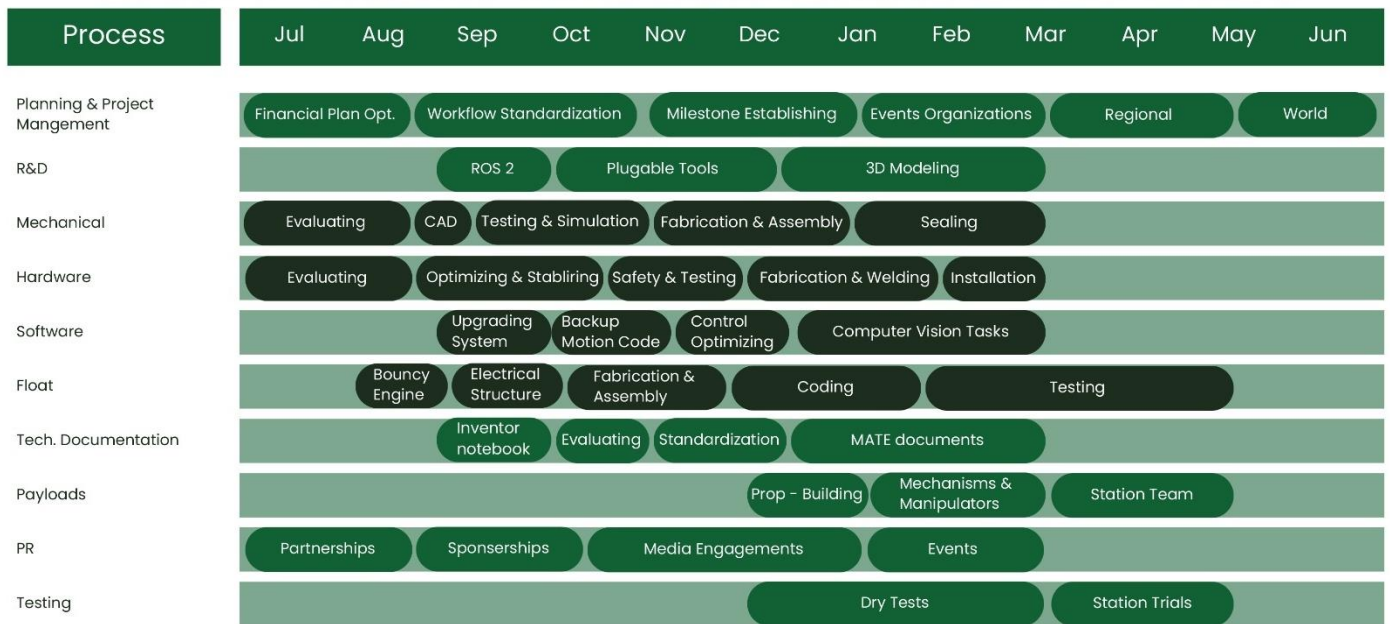


Figure 1-5 Gantt Chart 2025-2026

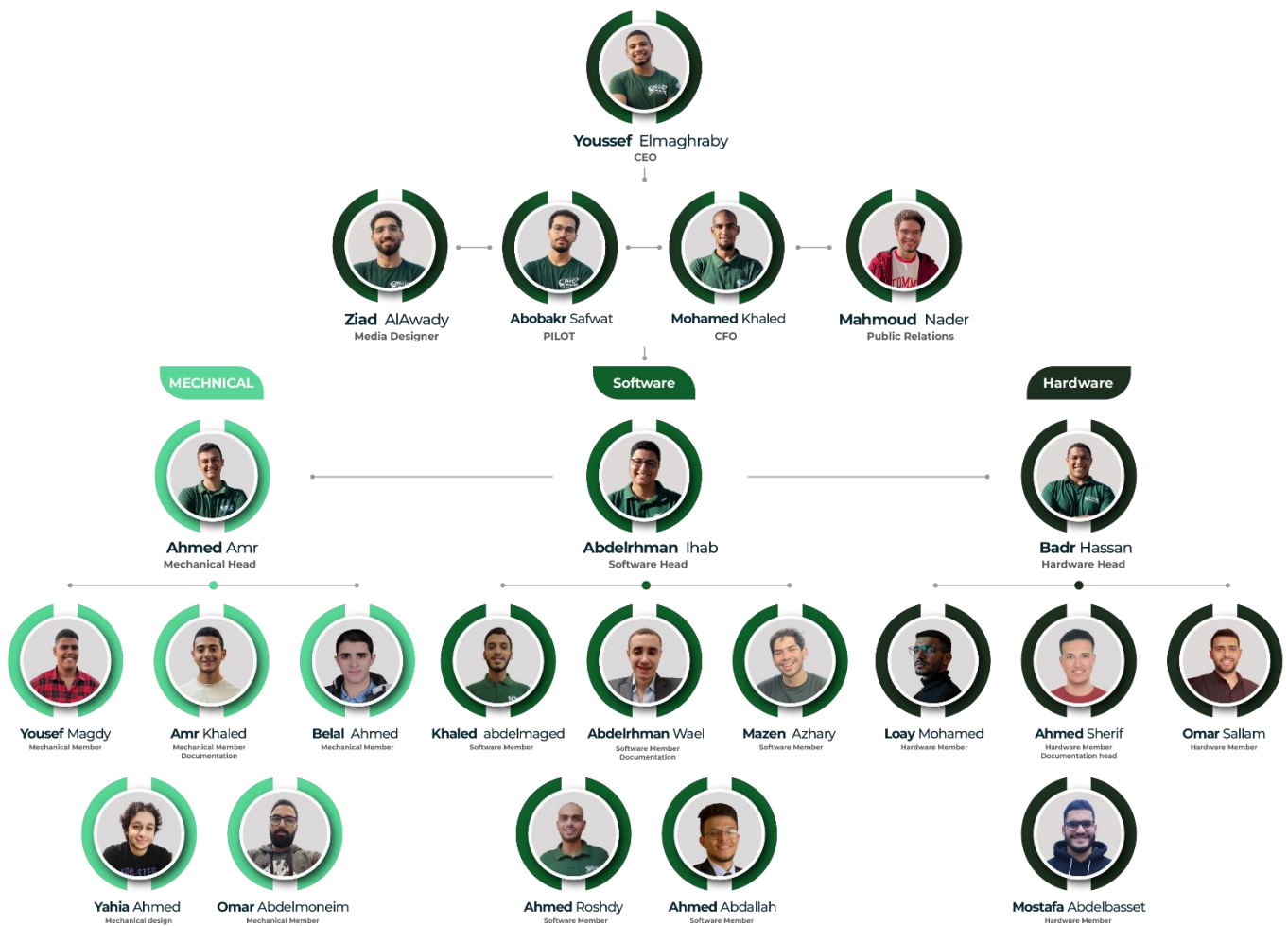


Figure 1-6 hierarchical structure

2 Design Rationale

2.1 Vehicle Overview

Ferox is our innovative ROV that is an evolution of last year's design **Exodia**, with a focus on stable and reliable performance. It features six degrees of freedom, providing high maneuverability and precise control in all directions. The frame is designed to be just wide enough to support the system layout yet kept light to allow easy handling and deployment. The design prioritizes predictable operation and accessibility, so components can be adjusted or serviced. This balance of stability, maneuverability, and simplicity allows the team to complete tasks efficiently while minimizing operational complexity. Overall, the vehicle serves as a practical and versatile platform for tackling a wide range of challenges.

Also, **Ferox**, with **mass of 25kg**, has a modular payload system that enables it to perform a wide range of underwater tasks without requiring major structural modifications.

Common payloads such as cameras, manipulators, sensors, and measurement instruments can be easily installed or replaced depending on mission requirements. This flexibility makes the payload system highly efficient, allowing the same ROV platform to be used for inspection, exploration, maintenance, and data collection while minimizing time and operational costs.

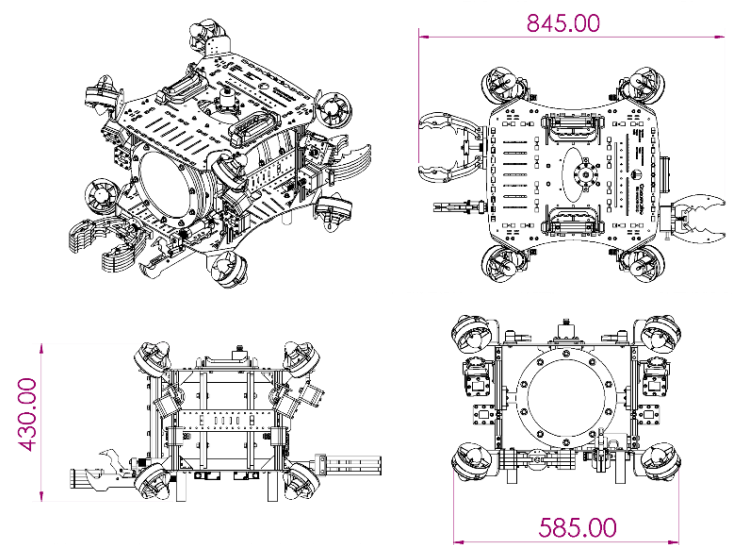


Figure 2-1 ROV CAD Drawing

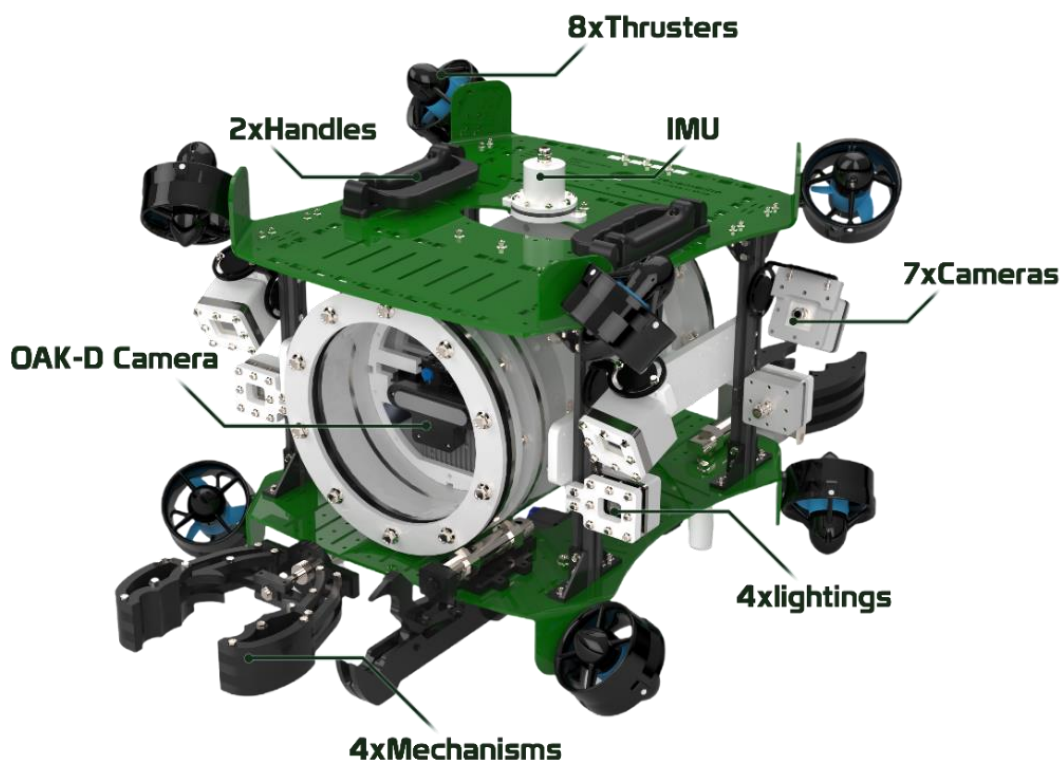


Figure 2-2 Ferox Render

2.2 Mechanical System

Frame

The frame is engineered to provide strong mounting, straightforward assembly and maintenance, and reduced weight through a **two-plate** configuration that improves flexibility. Both plates are designed to accommodate eight thrusters. The plates feature slots that allow the installation of manipulators, grippers, and cameras. They are joined using **aluminum profiles**.

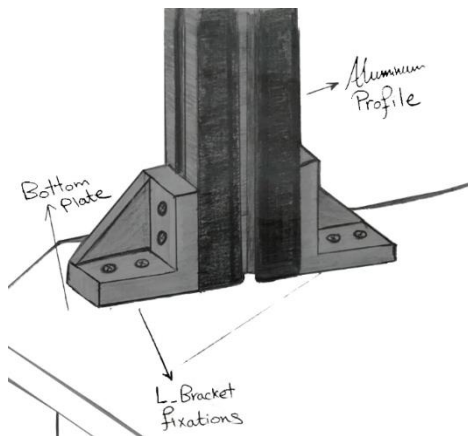


Figure 2-3 Aluminum Profile Fixation

while the enclosure is secured using **two horizontal HDPE plates** connected through **ring fixation**. These plates are mounted onto the **aluminum profiles**. This arrangement ensures stability by preventing rotation of the electrical enclosure and limiting its motion in the longitudinal direction.

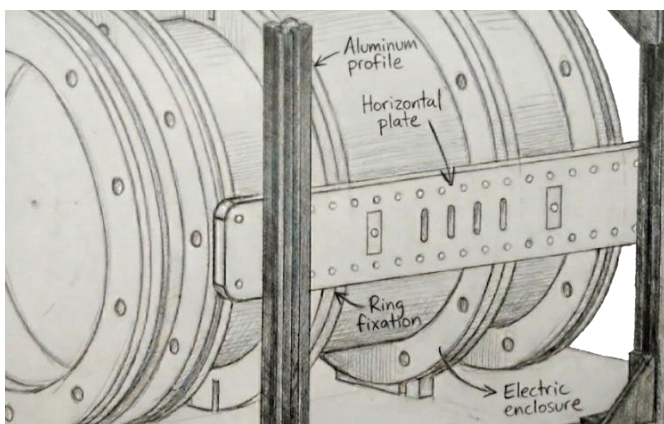


Figure 2-4 Electrical Enclosure Fixation

Building on the previous design, where the ROV relied on its thrusters for support while resting on the ground, an improved support concept was developed to eliminate the load on the thrusters entirely. As part of this enhancement, a set of **four support legs** was designed to carry the full weight of the ROV instead of the thrusters. Each leg is capable of withstanding up to **350 N**, with a factor of safety **5.5**, ensuring high structural integrity and reliable performance.

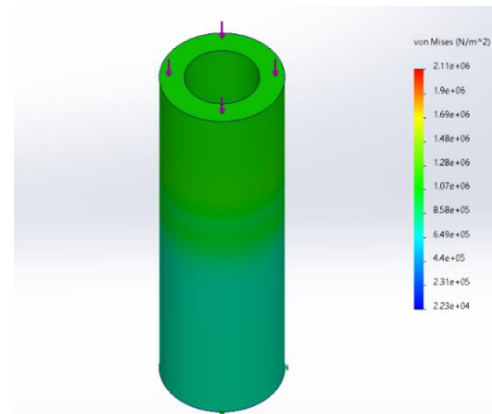


Figure 2-5 Stress Analysis-Support Leg

Electrical Enclosure

Compared to last year's design, which was cuboid shape of **2mm 304 stainless steel**, the cuboid shape has been **cylindrical** to reduce the drag force and improve the maneuverability and **HDPE** was selected to reduce the weight and for its ease of manufacturing, this enables a seamless single piece cylinder structure without any welds, which improved strength and sealing.

Table 1 Electrical Enclosure Comparison

Parameter	Last year Enclosure	New Enclosure
Density	Higher	Decreased by 73%
Drag force	Higher	Decreased by 24%
Maneuvering	Lower	Higher
Manufacturability	More difficult	Easier
Cost	Higher	Decreased by 68%

The **transparent acrylic face** allowed visual access inside the enclosure, enabling the installation of the OAK camera within the enclosure (no additional camera sealing is required). The rear plate of the enclosure is made from **4 mm thick 1050 aluminum**, chosen for its good thermal and mechanical properties. Aluminum efficiently dissipates heat from internal electronic components, helping prevent overheating during operation. It is also easier to manufacture than stainless steel, allowing for simpler machining and reduced production time, while providing greater durability and strength than **HDPE** without adding significant weight.



Figure 2-6 Electrical Enclosure Exploded view

Sealing & Pressure

After conducting research and development, it was decided that all critical electronic components and connections should be integrated within a unified electrical enclosure to facilitate sealing and simplify maintenance. Gasket face sealing was evaluated and selected as the preferred method for sealing the enclosures, including both the electrical enclosure and the camera and lighting casing, due to its reliability under underwater pressure conditions.

For cable sealing, PG-standard glands were used, with a total of 33 cables secured using PG-7 and PG-9 types according to cable diameter requirements. These glands provide reliable protection against water ingress and organized cable arrangement within the system. This sealing approach allows the ROV to operate safely at depths of 25 meters, as confirmed through theoretical calculations and experimental testing.

Propulsion

Ferox is equipped with eight reused **T200 Blue Robotics** thrusters, each subjected to rigorous evaluation to ensure reliability and performance. This assessment confirmed that all selected thrusters remain as effective and dependable as in the previous operational cycle.

The T200 thrusters exhibit high efficiency, delivering strong thrust output and high speed. Their primary drawback is elevated power consumption, which becomes a concern only at high speeds due to the relationship between speed and drag force in the drag equation.

$$F_d = \frac{1}{2} C_d \cdot A \cdot V^2 \cdot \rho$$

Where:

F_d : Drag force

ρ : Fluid density

V : Velocity

C_d : Drag coefficient

A = Projected area

Following extensive research, the team opted to maintain the current thruster configuration due to its demonstrated efficiency in enabling six degrees of freedom, even in the event of up to four thrusters failures. The eight-thruster arrangement generates greater thrust than a traditional four-thruster setup and ensures a symmetrical thrust profile, improving stability, weight distribution, and maneuverability.



Figure 2-7 Thruster Configuration

Camera & Lighting Mounting

To ensure optimal vision angles for both the pilot and the image processing team, the mechanical sub-team has designed a mounting system that offers multiple degrees of freedom for camera adjustment, allowing rotation about the Z-axis and Y-axis, thereby improving visibility and enabling precise camera alignment to adapt to different underwater tasks, environments, and mission requirements during operation.

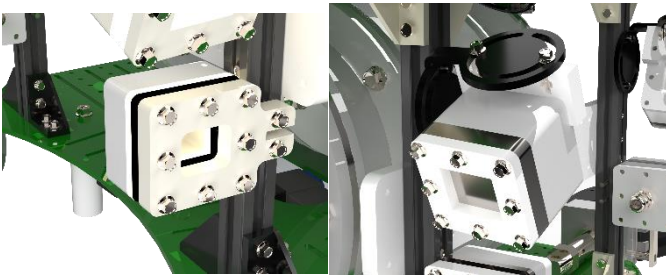


Figure 2-8 Camera and Lightning Mounting

CFD

A Computational Fluid Dynamics (CFD) study was performed on **Ferox** in SolidWorks to investigate its response to different pressure conditions and to determine the drag force acting on it. The results revealed smooth water flow around the vehicle, suggesting effective hydrodynamic performance. With this design, **Ferox** can reach a velocity of **0.85 m/s** while subjected to a drag force of **18.09 N**. The analysis offered practical insights, confirming that the ROV's shape reduces resistance and supports efficient operation underwater.

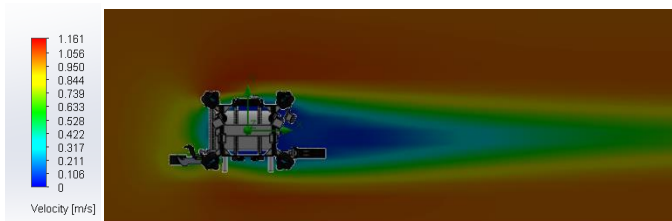


Figure 2-9 Ferox Flow simulation

Buoyancy & Stability

The mechanical team undertook extensive efforts to ensure the stability of the configuration and achieve slightly neutral buoyancy by precisely positioning the center of mass and center of buoyancy. Material selection plays a crucial role in maintaining the vehicle's neutral buoyancy as the table.

A **symmetric structure** was strongly emphasized during the design phase, as it helps ensure that the **center of volume** is closely aligned with the **center of mass**, thereby enhancing the stability of the ROV and minimizing the need for additional ballast weights or buoyant foam.

Table 2 Buoyancy analysis

Item	Quantity	Weight (N)	Buoyant force (N)	Buoyancy Resultant (N)
Top plate	1	18.25	6.77	-11.48
Bottom plate	1	17.17	6.36	-10.80
Horizontal plate	2	3.63	3.83	0.21
Electrical enclosure	1	77.50	111.05	33.55
Electrical enclosure flange	4	3.81	4.01	0.21
Thruster	8	27.47	15.30	-12.16
Aluminum profile	4	6.83	1.73	-5.10
Profile fixation	16	3.14	1.21	-1.93
camera box	7	10.68	9.69	-0.99
Lighting box	4	4.98	3.91	-1.07
IMU box	1	0.63	0.62	0.00
Grippers	4	31.10	69.65	38.55
Screws & nuts		40.0186	13.24	-16.78
Total		245.19	247.38	2.20

2.3 Hardware

System Architecture

It was decided to revert to a two-year-old **dual-board setup** with one board responsible for efficient **Power** distribution while the other one simply hosted the rest of the electrical components (primarily the raspberry pi and cameras) that was colloquially and (then later formally named) the **Control** board.

This decision was made in contrast with last year's **single-board** setup as it saved wasted space inside of the electrical enclosure, eased trouble shooting and enabled modularity.

The decision to go with a dual-board setup did not fully address the flaws relating to single-board design but it still managed to result in a noticeable improvement, making a **multi-board** setup a definite future consideration.

Physical Layout & Design

To facilitate easy access, the mechanical sub-team was tasked with designing a custom-made enclosure that allows for easy removal of the electrical sub-system. This significantly improved the practicality of hardware maintenance and overall system evolution.

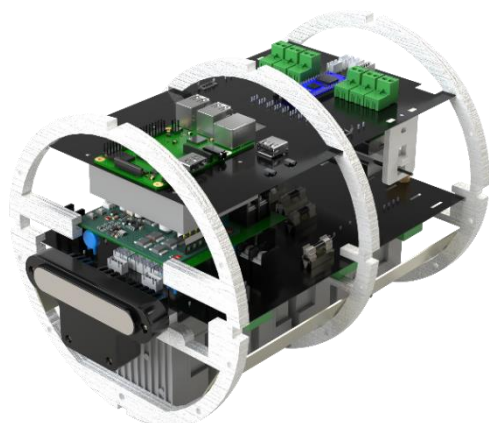


Figure 2-10 Quick-release Structure

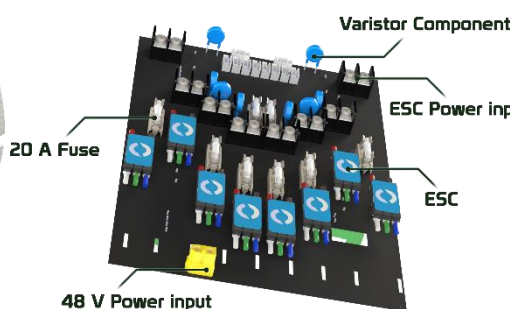


Figure 2-11 Power Board

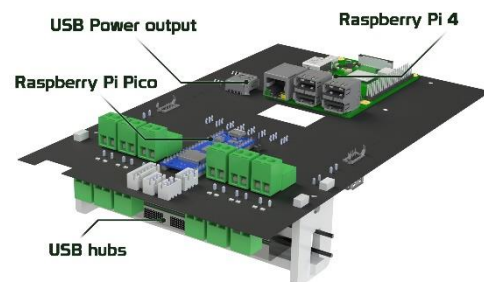


Figure 2-12 Control Board

2.4 Tether And Power Distribution

Tether Management Protocol: Our poolside tether man actively manages slack and prevents tangles, aided by a single outer cover that consolidates all internal wires and a buoyant foam tube that minimizes drag. Additionally, a robust strain relief securely anchors the tether to the ROV, protecting internal connections from operational tension.

A specialized 30-meter tether is the lifeline of the ROV, incorporating **three** key conduits:

Conductor: An AWG 10 cable that supplies 48 V up to 30 A, protected by a 30 A fuse to ensure both system and power supply safety.

Ethernet Link: A Cat6a Ethernet cable provides a 10 Gbit/s high-speed connection between the control station and the onboard Raspberry Pi.

Pneumatic Line: This channel delivers pressurized air required for actuating grippers and other payload mechanisms.

Vent Line: Used to release air from the DCV outside the water, ensuring that water cannot enter and damage the DCV.

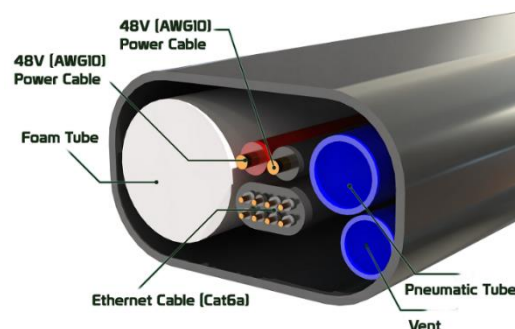


Figure 2-13 Tether Cross-section

Power System

Through a single XTAX-90 connector, the **Power** board receives 48V up to 30A connection. This 48 Volt line is then shared between **Six** 48-13.4 V buck converters inputs.

The ROV's Power board then uses an OR power delivery system where **Five of the Six** converters outputs are merged into a single 12-volt rail to power the main load of the electrical subsystem. The **Eight T200 Blue Robotics Thrusters**.

The Shared OR system was chosen to allow for flexible power demands as well as to share the current production across as many bucks as possible by decreasing the maximum continuous temperature that each individual buck experiences, increasing their lifespan and spreading the heat intense regulation process as wide of surface area as possible through the buck's mounted heatsinks.

$$P_{losses} \propto I^2 R$$

To overcome the drawbacks of an OR Powering System:

- A Diode was placed at each of the buck output's as to prevent two bucks with unmatched voltages for driving current into one another.
- Each Motor was connected in series with a 20-amp fuse
- Software team was instructed to code in a hard limit on the maximum amount of power that an ESC controller can draw.

As for powering the Control part of the system an isolated **Sixth** 48-12V buck powers the Control board completely, with two specially mounted 12V to 5V buck converters Powering the Raspberry Pi and USB hubs **separately**.

Control & Communication

As mentioned above, our ROV communicates with the station using a **Cat6a** Ethernet cable as it was found to have satisfactory upstream and downstream transmission rates as well as adhering to well-known documented industry standards.

As for inner communication, inside of the ROV enclosure USB communication and connectors

were settled on as they provided adequate power to the Raspberry Pico and cameras whilst providing steady and reliable data paths.

Modular Design and Innovations

The ROV's PCB design took modularity into consideration by having **extra signal and power ports available**, this modularity allowed for the construction and connecting of a third board which was used to power and control a MDD10A Cytron dual channel motor driver and a spare ESC power port if needed.

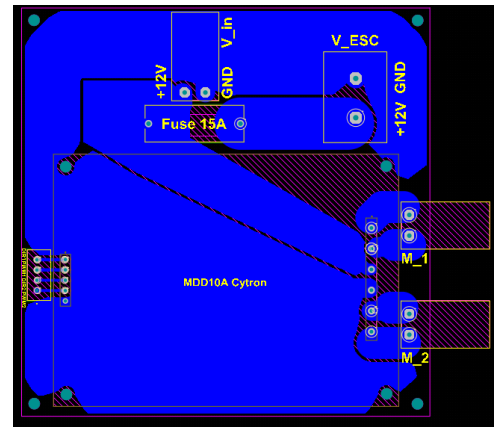


Figure 2-14 Modular Cytron Board Design

Last year's design suffered from an interesting problem, the magnetic field emanating from the buck converters affected the IMU sensor's reading. The solution: placing the buck converters on their side and in pairs of alternating directions causing the magnetic fields to cancel out in the Z axis. The IMU was then placed in line of sight of magnetic field dead zone in an outside enclosure to increase the distance from the magnetic field source, minimizing electromagnetic field interference.



Figure 2-15 Buck Pair Setup

2.5 Software

Communication

A real-time responsive communication system is a critical part of the ROV's success, that's why this year our top priority was to enhance it. We selected the **Robot Operating System (ROS 2)** as our primary communication framework; ROS is an open-source framework built for seamless information exchange between different components of our software system. Upgrading to the newest version of **ROS 2** not only allowed us to utilize the newest ROS features but also significantly reduced communication latency.

To bridge the gap between hardware and software, we integrated a Raspberry Pi Pico as a low-level controller responsible for generating the proper actuator control signals. Data is transmitted from ROS nodes to the Pico on a **need-to-send** basis using **serial communication**. This architecture proved to be the most efficient system.

Motion and Control

Precise thruster control signals are required for enabling smooth maneuverability of the ROV across all **six degrees of freedom**. We can accomplish this using a two-step process; first we use the axes from the joystick input to calculate the proper motor speeds; second, the motor speeds and **IMU feedback** are fed into a **PID control system** that is designed to enhance stability and to aid the pilot in compensating for dynamic changes such as variations in load when holding heavy objects.

Our system continuously monitors the ROV orientation using the **Adafruit BNO055 IMU** sensor, which provides real-time data. This process involves three key steps:

- Sensor fusion algorithms can convert raw IMU data into yaw, pitch and roll angles.
- The system calculates the error by comparing the actual orientation with the desired orientation.
- This error is fed into the PID control system, which works to minimize the error by adjusting the motor speeds.

To achieve this responsive and stable system, we utilized the **Ziegler-Nichols method** for tuning the PID controller. This efficient technique allows our engineers to manually adjust the proportional, integral, and derivative gains, optimizing system stability and performance.

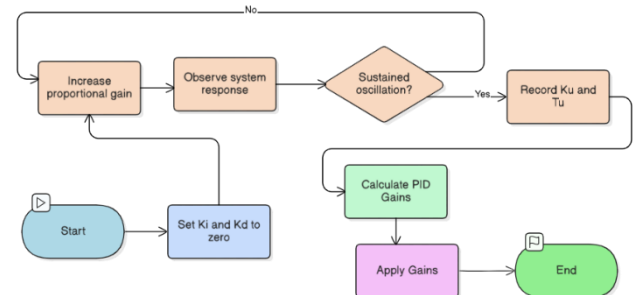


Figure 2-16 Ziegler-Nichols PID tuning procedure

Station Setup

Crocmarine's control station prioritizes efficiency, portability and operator comfort. Our team adopted a **multi laptop setup** to avoid processing bottlenecks and delays, maintaining optimal workload distribution across dedicated systems.

- A primary laptop operates the GUI for pilot-ROV interaction, enabling **real-time control and status monitoring**.
- A second laptop is dedicated to computer vision tasks, handling the heavy **image processing and AI** tasks without interfering with real-time piloting.
- Additionally, a separate third laptop manages **camera streaming** to provide real-time, uninterrupted video feeds.

A high-resolution **LCD screen** connects to the streaming laptop to deliver high quality camera feedback, offering a clear and expansive underwater view.



Figure 2-17 Control Station

Control Station Interface

The **graphical user interface (GUI)** is a key component of the control station, providing vital monitoring of underwater activities. We developed two user interfaces to split the workload between both co-pilots. First the main GUI made using **PyQt5** due to its ease of development and seamless integration with the rest of our software stack. The GUI provides real-time task management with detailed step tracking, 3D orientation visualization, dynamic PID parameter tuning, individual thruster monitoring, and status indicators for gripper and motion states.

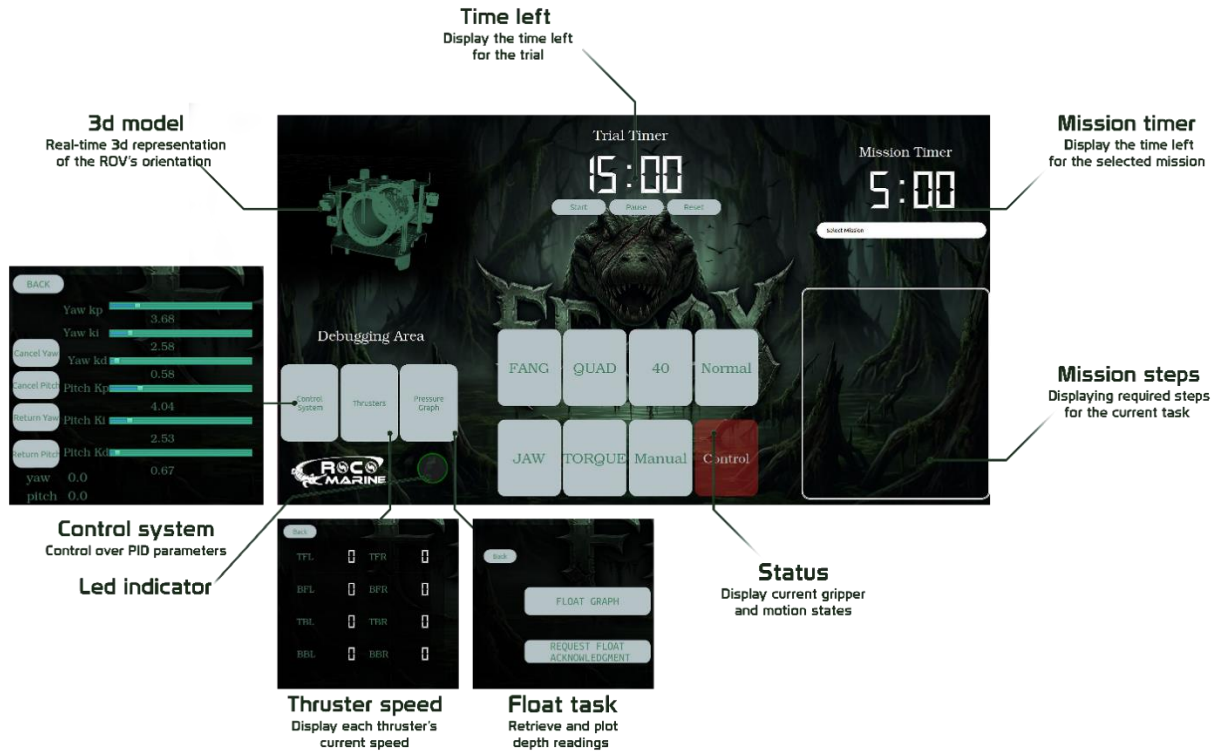


Figure 2-18 Main GUI

Additionally, we have a **web-based GUI** designed to aid in computer vision tasks like object detection and tracking, 3d modelling, autonomous motion and monitoring of subsea assets, to enable those capabilities it provides real-time access to all the **camera streams** including the **OAK-D depth camera** for depth calculations. The GUI also integrates a **graphical processing unit (GPU)** that substantially accelerates processing speed for computer vision applications.

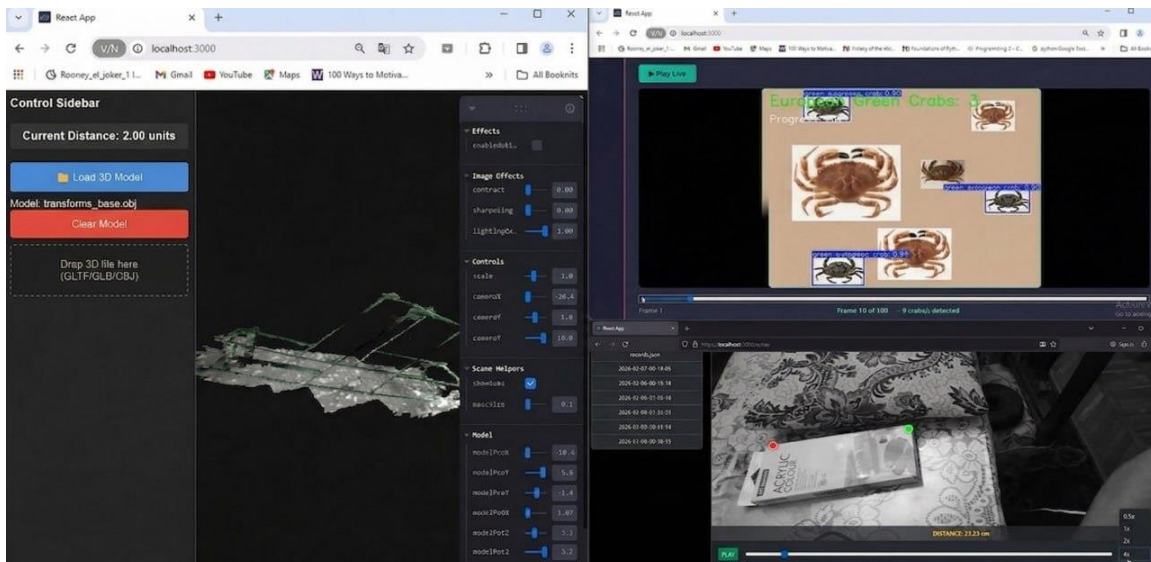


Figure 2-19 Computer Vision GUI

2.6 Vision

Oak-D Stereo Camera

We selected the Oak-D stereo camera as the main camera for our system due to its combination of high-resolution imaging and precise depth sensing capabilities. It is set up to allow us to perform accurate measurements of objects and distances, which is exactly what we need for our tasks. Additionally, the camera features an on-board Myriad X VPU, enabling real-time processing of AI applications directly on the device, reducing latency and offloading computation from the main system. This makes the Oak-D an ideal choice as both the primary camera and the measurement sensor in our setup.

Table 3 Camera Comparison

Camera Model	Depth Accuracy	Processing	Price
Oak-D	High precision	Powerful built-in processor	Moderate
Intel RealSense D455	Good, but lower at long range	Requires external processing	Low
ZED 2i	Excellent, long-range capable	Some built-in capabilities	High

Image Preprocessing

Underwater images often suffer from poor visibility and reduced contrast making it difficult for computer vision algorithms to work as intended; to address this issue multiple filters are applied to the image to increase contrast and highlight subtle, one of the techniques used is the **CLAHE filter** used to enhance the visibility of features in images.

3D Construction

Generating accurate 3d models of real-life objects is a complex task, but we have achieved it by first capturing **360°** video using the **OAK camera** then we employ **COLMAP** to solve a 3D point cloud to build a highly accurate digital **skeleton** of the reef.

We then leverage **Instant NGP** to create a **high-quality** model in record time. Instant NGP is an elite, state-of-the-art, **open-source** artificial

intelligence system. After a final **meshing** step that adds a realistic ‘skin’, we have a **3D digital model** that we can then scale and accurately measure details like coral reef growth.

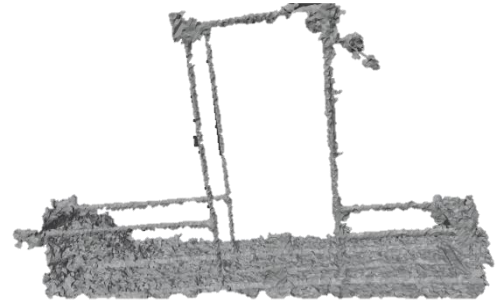


Figure 2-20 3D Model Of The Coral Garden

Multi-Object Detection

Effective detection in real-world environments requires the ability to handle multiple objects within a single scene, using the latest version of YOLO has allowed our system to accurately detect multiple objects simultaneously with a high level of accuracy.



Figure 2-21 Crab Species Detection

Camera Angles and streaming

Our ROV is equipped with a **multi-camera vision system** that has seven digital cameras strategically positioned around the ROV as shown in **Figure X**. Additionally, the stereo camera also serves as the primary camera; this arrangement allows the pilot to clearly see all around the ROV and monitor all its payloads. Each of these cameras connects to a **Raspberry Pi** (gateway + streaming server) that sends video frames via **HTTP**. Using this setup, the streaming GUI can present video in real time with little time delay.

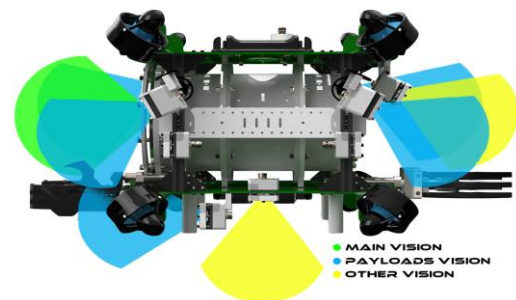


Figure 2-22 Camera View Angles

2.7 Payloads & Tools

Quadraginta:

The mechanism features two degrees of freedom and is actuated by two pneumatic pistons. one of them enables rotational motion of 45 degrees “**Quadraginta** = forty-five in Latin”. The second piston actuates the movement of end effector, which is designed to securely connect the **eDNA** sensor in **Task 2.5**.

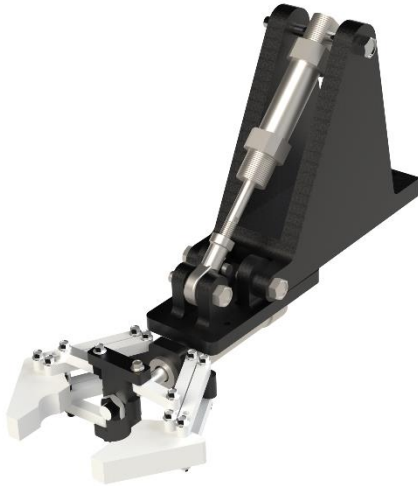


Figure 2-23 Quadraginta mechanism

Torque Bite:

The payload is a two-degree-of-freedom mechanism capable of rotating up to 360 degrees, driven by a gear mechanism actuated by a bilge pump. The end effector, powered by a pneumatic piston, is specifically designed to rotate the disc in **Task 2.5**.



Figure 2-25 Torque Bite mechanism

Fang:

Ferox's Fang is designed with three interlocking prongs that provide enhanced stability. The increased grabbing surface area allows for improved grip on horizontally positioned objects, facilitating secure and efficient handling. Ferox's Fang is responsible for collecting the basket stars in **Task 1.1**.

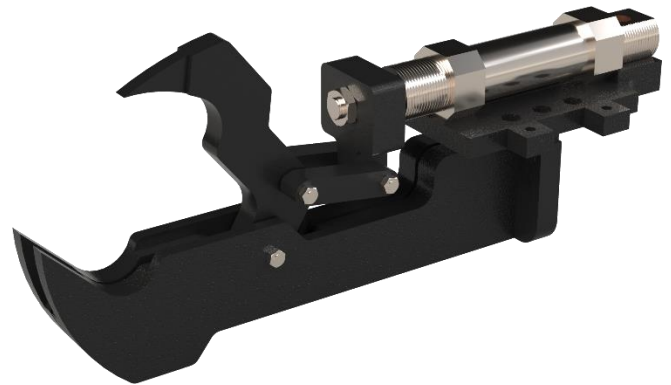


Figure 2-24 Fang mechanism

Jaw:

The **jaw** payload is engineered to provide a strong and reliable grip, enabling it to execute a variety of general tasks with high efficiency. Its design is intentionally versatile rather than tailored for a specific function, allowing the mechanism to perform a broad range of operations effectively without necessitating multiple specialized payloads.

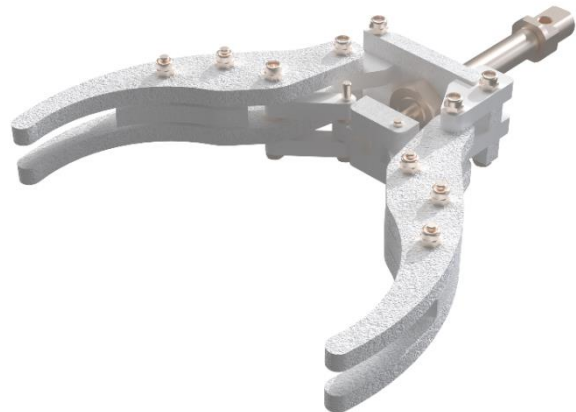


Figure 2-26 Jaw mechanism

3 Allivator Float

3.1 Mechanical System

The Allivator is equipped with four syringes, each having a capacity of **50 mL**. These syringes are fitted with PG-standard sealing glands, while the end caps are sealed to the **HDPE** body using **piston O-ring** seals to ensure complete watertightness and prevent leakage during operation. The **HDPE** body also functions as a protective housing for the electrical components, shielding them from potential water exposure. The syringes are driven simultaneously by a precision lead screw mechanism powered by a **12-V DC** motor.

The motor was selected to ensure sufficient torque to overcome operational resistance, based on the lead screw torque equation:

$$T = \left(\frac{\text{Force} * D_M}{2} \right) * \frac{\pi * D_M * f + L}{\pi * D_M - f * L}$$

To enhance buoyancy control and overall stability, a heavy **lead disk** is positioned underneath the system. By adjusting the volume of water displaced from the syringes, the device can modulate its buoyancy: increasing the displaced volume creates positive buoyancy for ascent; while reducing it induces negative buoyancy for descent, in line with the buoyancy force formula:

$$F_b = \rho V g$$

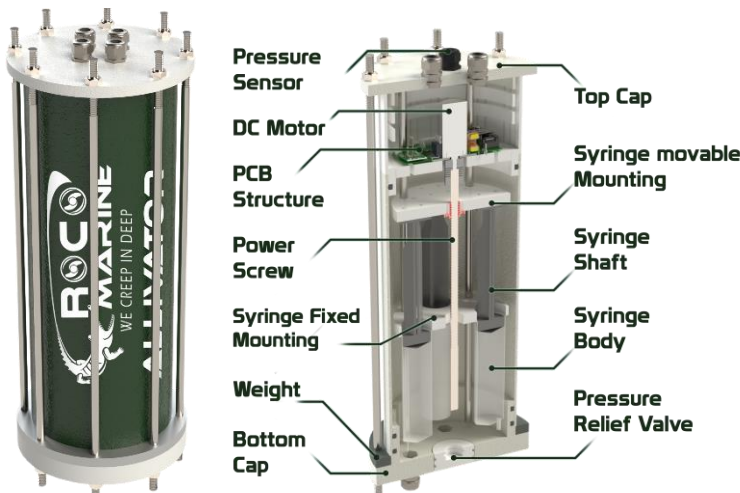


Figure 3-1 External & Internal Structure

3.2 Electrical System

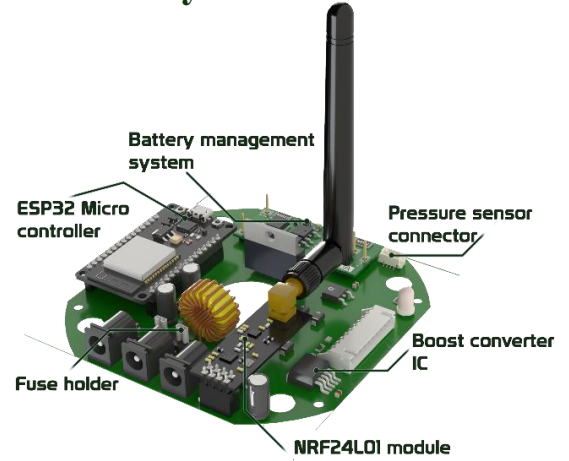


Figure 3-2 Electrical System layout

The Allivator's electrical system is powered by six series-connected NiMH cells (7.2 V). Protection is ensured via a Schottky diode and a 5 A Mini blade fuse, with a BMS managing charge and discharge.

The ESP32 is powered directly from the battery. A PCB-mounted boost converter supplies 12 V to a motor driver IC, while two regulators provide 3.3 V and 5 V for the NRF24L01 module and Bar02 pressure sensor.

Depth data is taken from Bar02 and processed by the ESP32 to control motor movement. The system is designed to hold float movement at any target depth. Wireless communication is handled by NRF24L01 with an external antenna for enhanced range.

Table 4 Allivator's Power Budget

Component	Voltage (V)	Current (A)	Power (W)	Notes
ESP32 (Modem Sleep)	7.2	~0.02	~0.14	Supplied directly from battery, modem-sleep mode
NRF24L01P + PA + LNA	3.3	~0.045 – 0.115	~0.15 – 0.38	Peak during TX (115 mA), idle ≈ 45 mA
Bar02 Pressure Sensor	5	~0.01	~0.05	Low constant draw, via L7805
L298N + Motor (Loaded)	12	~0.15 – 1.2	~1.8 – 14.4	Power varies from light load near surface to stall current at max load
XL6019E1 Boost Converter Loss	—	—	~1.6	XL6019E1, assumed 90% efficiency → ~16.36 W input for 14.4 W output
Total Estimated Power	—	—	~2.14 – 16.57	Varies with TX activity and motor load

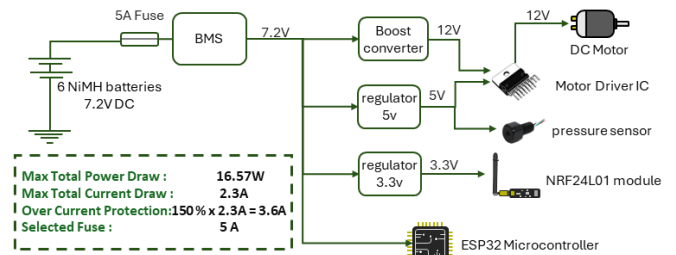


Figure 3-3 Allivator's Electrical SID

4 Testing & Troubleshooting

4.1 Initial steps

The philosophy of troubleshooting emphasizes that the first and most important step in resolving a problem is to clearly define it and understand its underlying cause. After that, through collaborative decision-making, an effective and implementable solution can be developed.

4.2 Mechanical

Before fabrication, all critical components must undergo analytical simulations to verify their performance under expected operating conditions. Structural analyses such as Finite Element Analysis (FEA) are conducted to ensure that components possess sufficient strength and structural integrity. Additionally, Computational Fluid Dynamics (CFD) simulations are performed to evaluate hydrodynamic behavior and minimize drag forces, thereby enhancing the ROV's maneuverability and overall operational efficiency.

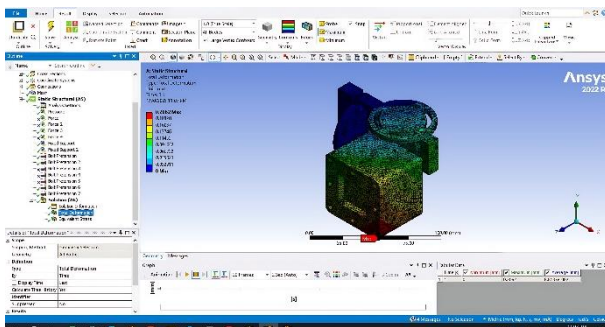


Figure 4-1 Simulation on ANSYS

When the functionality of a design is uncertain, developing a **prototype** becomes an essential step. Prototyping allows the concept to be tested and evaluated to verify that it performs as intended. Once the design's functionality and performance are confirmed through prototyping, the complete design can then proceed to full-scale fabrication.

4.3 Hardware

Whenever a new electrical component is connected, a continuity test is done to check for proper electrical connections and to ensure there are no short circuits or breaks in the circuit.

When a hardware issue arises, our team subdivides the problem recursively to pinpoint the critical point(made easier by PCB Built in Design test points) and if it calls for, electrical components are isolated and individually tested.

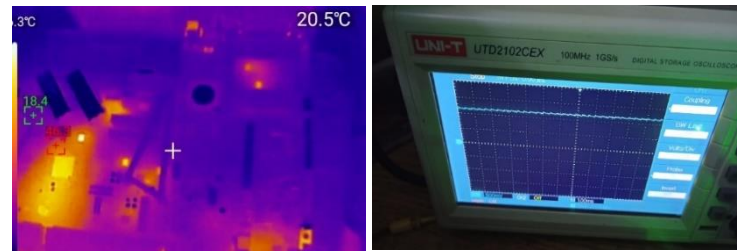


Figure 4-2 Detecting by thermal camera & oscilloscope testing of ESC output

4.4 Software

System tests happen regularly at every step of operation. The test includes starting the system in debug mode, where feedback is sent from every component of the software system (**very useful for troubleshooting**), and performing a check on all actuators and sensors to guarantee connectivity.

Additionally, to avoid future problems, a software test is required after every session. This is done using testing software designed specifically for ease of use by non-software members; the test is initiated simply by running a command on the Raspberry Pi.

Before heading to a trial, a stability test ensures that the control system is properly tuned. Settling time, rise time, overshoot, and steady-state error are evaluated using a graphing tool to visualize the error over time.

If a problem arises a debugging session involves checking sensors, actuators, communication systems, and software components using logs, and test scripts. Once issues are resolved, system checks are repeated to confirm proper functionality, and records are kept preventing similar problems in the future.

5 Safety

5.1 Philosophy

At Crocomarine, safety is of upmost priority to ensure a safe, comfortable, and secure environment for our employees. Strict adherence to local and international safety guidelines and regulations are maintained during manufacturing, maintenance and testing

5.2 Standards

Newcomers into our mechanical and electrical sub-teams are given a safety lecture as part of their training. These guidelines are then enforced throughout all teams and building processes.

Each sub-team head also acts as a safety lead and is responsible for the safety and wellbeing of their employees.

We also employ a buddy system where any given task is shared between two to three team members, making them wary of each other's potential mishaps and ensuring their work is safe and reliable.



Figure 5-1 PPE-Equipped Tether Men

5.3 Features

Ferox has built in mechanical and electrical safety features to ensure that it is safe to operate, build and maintain.

To mitigate sharp-edge related injuries, the primary frame and all modular enclosures were designed with rounded corners and smooth edge profiles. Additionally, each **thruster propeller is fitted with a protective shroud**. This shroud serves a dual purpose: it minimizes the risk of finger injury during handling and prevents electrical cables or other loose components from being drawn into the propeller flow during operation.



Figure 5-2 Shrouded Thruster

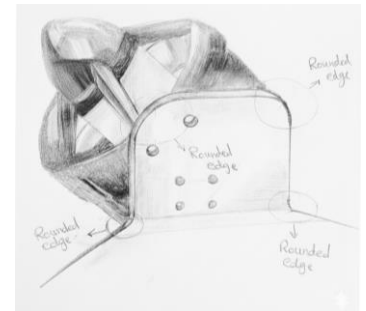


Figure 5-3 Rounded edge free-hand sketch

For electrical safety, PPE equipment is worn by onsite hardware members for their own safety, and all exposed sections of the wiring were insulated using heat-shrink tubing to prevent accidental contact and short circuits.



Figure 5-4 PPE-Equipped Members



Figure 5-6 Heat-Shrink Protection

6 Accounting

At the beginning of the year there was a board meeting where company goals were set, and each sub team was inquired about their respective budget needs. During this meeting each sub team was tasked with auditing themselves, the auditing process consisted of counting inventory and comprehensive testing of existing components to assess for depreciation.

Last year we had relatively high expenditure as a (cash donated) fund was available which allowed us to buy a lot of necessary equipment and supplies with their respective spares.

We expected this year to have sufficient funding allowing us to upgrade our more expensive components, primarily the ROV's thrusters, as they are nearing their end-of-life cycle, as well as buying a brand-new stereo camera.

However, due to unforeseen circumstances, no external funding was secured, forcing us to go with an alternative strategy. This plan mainly consisted of us depending on the previous year's supplies and spares.

Despite these budget constraints, we were able to sufficiently realize this year's design with minimal expenditure as well as investing in our Research and Development.

For more detailed analysis, data sheets are available in [accounting table](#) and [project cost table](#)

Table 5 details the estimated travel budget for ten team members. This projection comprehensively covers flights, visas, hotel accommodations, local van transportation, and shipping the ROV.

Table 5 Estimated Travel Expenses

Travel Financial Plan (for 10 Members) (in USD)			
Item	Description	price (per member)	total Price
Flight	Plane Tickets and Visas	920	9200
Accommodation	Hotel Rental	195	1950
Transportation	Van Rental	35	350
Transportation for ROV			2300
Total Travel Expenses			13800

7 Conclusion

7.1 Future Plans

In the coming few years, we hope to deploy autonomous technologies using real-time artificial intelligence and sensor technologies to identify floating objects underwater. Efficient and cost-effective system maintenance is made easier through the integration of a quick release watertight lock and a cable gland. These technologies are useful in collecting sophisticated data on soils and chemicals in deep water, thus directly contributing to **UN SDG 9** on Industry, Innovation, and Infrastructure, and **SDG 12** on Responsible Consumption. In essence, the goal is reducing the involvement of humans in hazardous areas, thus supporting **UN SDG 3** on Good Health and Well-being and **SDG 14** on Life Below Water.

7.2 Lesson learned

The Crocomarine team discovered that switching to a modular **dual-board setup** significantly simplified troubleshooting and freed up internal space, improving upon the single-board designs. To resolve sensor interference, the orientation of the **buck converters** was flipped, allowing the magnetic fields to cancel out, keeping **the IMU accurate**. Transitioning to **ROS 2** was also a gamechanger; it minimized communication lag and aligned their platform with industrial standards. When outside funding fell through, the team audited their inventory and reused components, proving adaptability during tough financial times.

7.3 References

- IP Rating Standards: IEC 60529
- O-Ring Sealing: Parker: [O-Ring Handbook](#)
- [PyQt5 Documentation library for GUI](#)
- [2026 MATE Competition Manual](#)
- [ROS2 Documentation](#)
- [OpenCV Documentation](#)
- [T200 Thruster, Blue Robotics](#)
- **Material Selection:** [ALPOLIC Composite Materials](#)
- **Drag Force Calculations:** "Hydrodynamic Drag and Lift Forces on Underwater Vehicles" by **M. Triantafyllou and G. Weymouth.**

8 Appendix

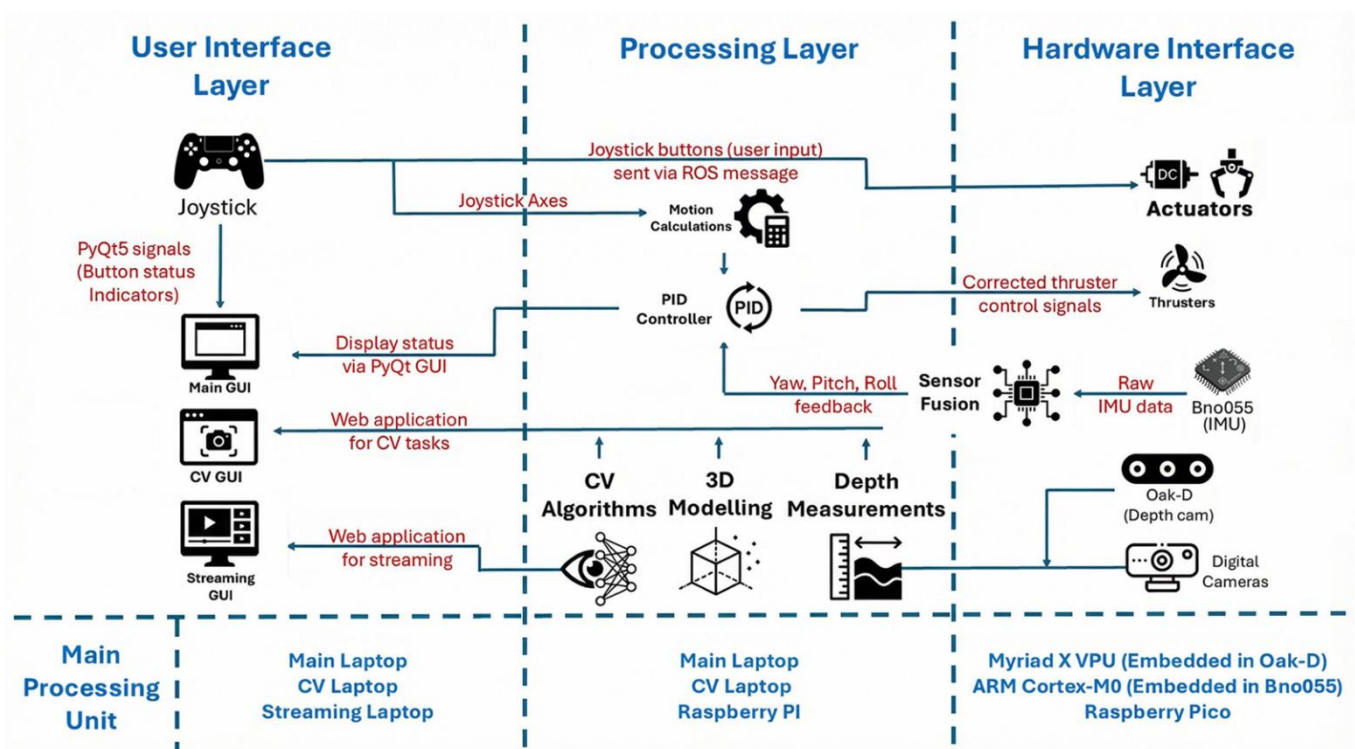
A- Power Budget

Table 6 Power Budget

Component	Voltage (V)	Nominal Current (A)	Max Current (A)	Nominal Power (W)	Max Power (W)	Qty	Total Nominal (W)	Total Max (W)
Raspberry Pi 4	5.0	1.5	3.0	7.5	15.0	1	7.5	15.0
Raspberry Pi Pico	5.0	0.1	0.3	0.5	1.5	1	0.5	1.5
USB 2.0 Cameras	5.0	0.2	0.3	1.0	1.5	7	7.0	10.5
Oak-D Camera	5.0	1.0	2.0	5.0	10.0	1	5.0	10.0
Sensors and Peripherals	5.0	0.1	0.1	0.5	0.5	1	0.5	0.5
Lighting Systems	12.0	0.5	0.8	6.0	9.6	4	24.0	38.4
DCV Solenoids	12.0	0.3	0.5	3.6	6.0	5	18.0	30.0
DC Motors	12.0	1.0	5.0	12.0	60.0	1	12.0	60.0
T200 Thrusters	12.0	4.6	6.9	55.2	82.8	8	441.6	662.4
Totals							516.1	828.3
Final totals after power transmission and conversion losses (90% Efficiency)							573.44	920.33
Current Draw Nominal (48V)							11.95	
Current Draw Max (48V)							19.17	
Fuse Rating (150% Safety Factor)							28.76	

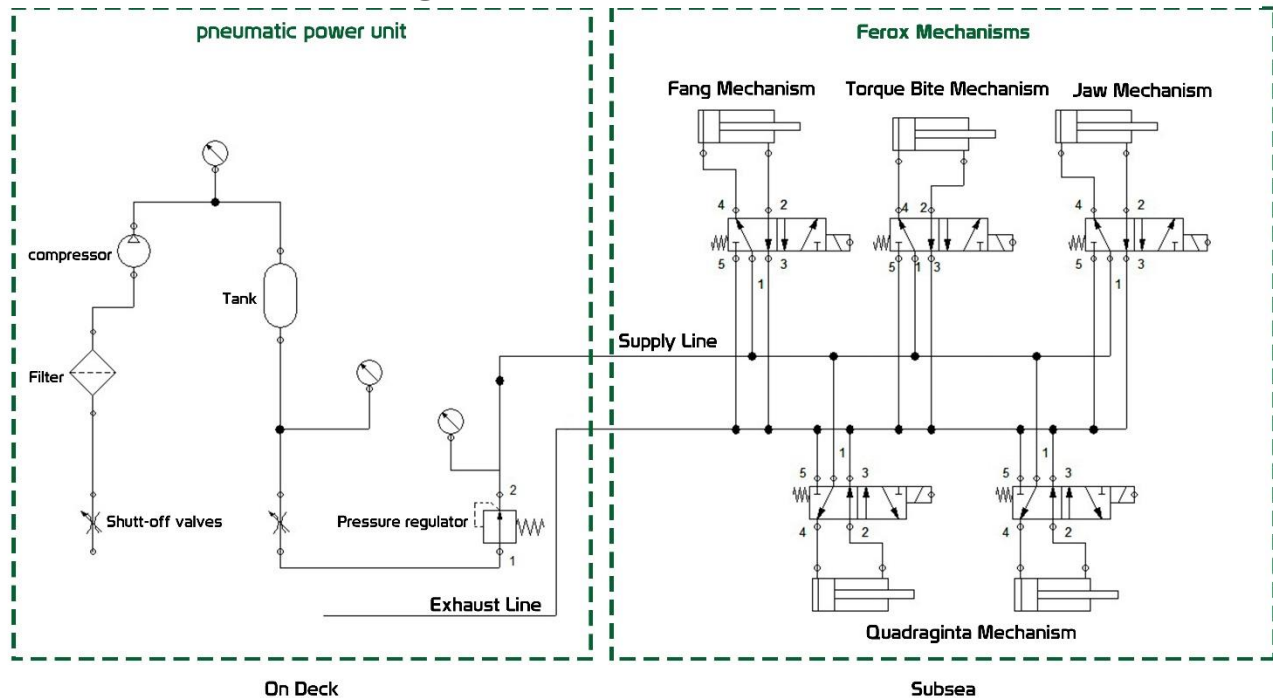
B- Software SID

Figure 8-1 Ferox Software SID



C- Pneumatic SID

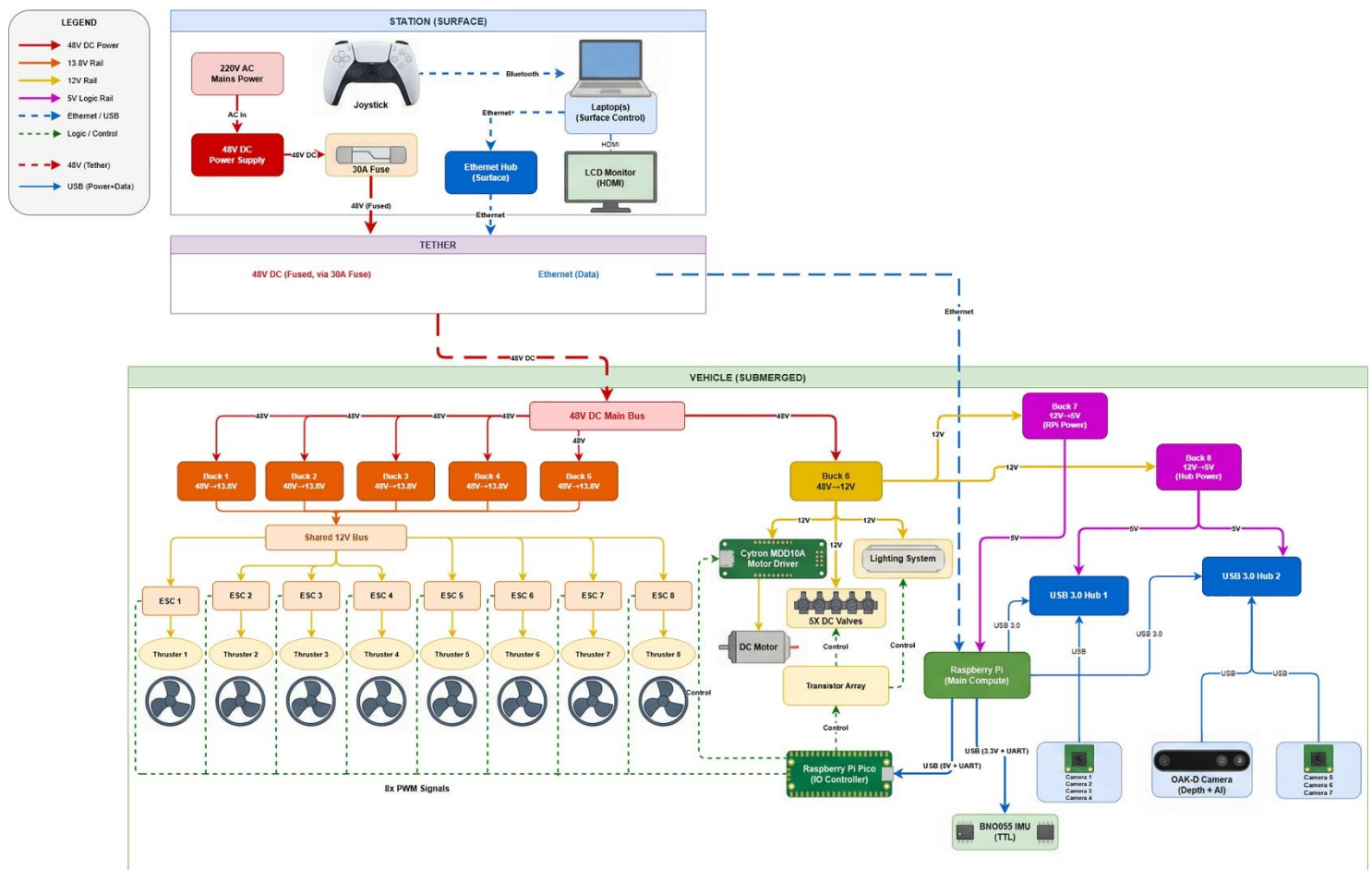
Figure 8-2 Ferox Pneumatic SID



D- Electrical SID

Figure 8-3 Ferox Electrical SID

Underwater ROV — System Interconnect Diagram



E- Accounting budget

Table 7 Estimated season budget

Item	Budget (in USD)	Type	Description
Incomes			
Team Membership Fees	1950.00	Income	Monthly membership fees paid by each team member
Alexandria University	250.00	Income	Funding for MATE Egypt ROV registration fees (Regional Competition)
Funds From Last Year	115.4	Saving	
Total Income	2315.40		
Technical			
Raw Materials	211.54	Reused	Aluminum (1050 Alloy),Acrylic Sheet, HDPE,Silicon,Aluminum L Brackets
	230.77	Purchased	Aluminum Profile,Fasteners ,HDPE,Acrylic Sheet,3D Printing Material,Silicon
Mechanical Components	167.31	Reused	Air Compressor,Solenoids,Pistons,Pneumatic Hose and Fittings
	234.61	Purchased	Fasteners,Epoxy Chemical,O-Rings,Metal Glands,Bearings
Sensors	140.40	Reused	BNO055 Sensor,Bar02 Pressure Sensor
Electrical Components	173.08	Purchased	Raspberry Pi 4, Usb Hubs(3X),Cables &Connectors
	34.60	Reused	Cytron Mdd 10 A, Cables &Connectors,
Fabrication	211.54	Purchased	CNC Router,Fiber Laser, Turning, 3D Printing
Thrusters & ESCs	2620.00	Reused	Blue Robotics T200 Thrusters (10X), Blue Robotics ESCs(8X)
Tools	73.08	Purchased	Grinder,Hot Glue Gun,Soldering Iron
	30.77	Reused	Electric Drill
Vision System	346.16	Donated from alumni member	Oak-D Stereo Camera
	188.50	Reused	Digital Cameras (10X)
Top Side Control Unit and Tether	161.56	Reused	Station Box, Monitor , PS5 Controller,Power Supply,Switch Connector
	24.50	Reused	Fuse Holder, 30A-Fuses,Anderson Connector
Total Technical Expenses Budget	923.08		
Operations & Logistics			
MATE ROV Competition	250	Purchased	MATE Egypt Rov Registration Fees (Regional Competition)
	390	Purchased	MATE Rov Registration Fees (International Competition)
	25	Purchased	Fluid Power Quiz Fees
Propbuilding	86.53	Purchased	PVC,Connectors,Mission Tools
	23.8	Reused	PVC
Safety	44.23	Reused	Life Jackets(2X), Non-Slip Gloves,Water Resistant Shoes
Marketing Purposes	265.35	Purchased	Flag,Poster,Flyers,Banners,T-Shirts
ROV Testing Logistics	576.93	Purchased	Villa Rent,Transportation
Total Operations & Logistics Expenses Budget	1593.81		

F- Project Cost

Table 8 Actual Project Cost

Item	Project Cost (in USD)	Type	Description
Incomes			
Team Membership Fees	1950.00	Income	Monthly membership fees paid by each team member
Alexandria University	250.00	Income	Funding for MATE Egypt ROV registration fees (Regional Competition)
Funds From Last Year	115.40	Saving	
Total Income	2315.40		
Expenses (July 2025 to April 2026)			
Technical			
Raw Materials	211.54	Reused	Aluminum (1050 Alloy),Acrylic Sheet, HDPE,Silicon,Aluminum L Brackets
	198.08	Purchased	Aluminum Profile,Fasteners ,HDPE,Acrylic Sheet,3D Printing Material,Silicon
Mechanical Components	167.31	Reused	Air Compressor,Solenoids,Pistons,Pneumatic Hose and Fittings
	223.08	Purchased	Fasteners,Epoxy Chemical,O-Rings,Metal Glands,Bearings
Sensors	140.40	Reused	BNO055 Sensor,Bar02 Pressure Sensor
Electrical Components	184.62	Purchased	Raspberry Pi 4 ,Usb Hubs(3X),Cables &Connectors
	34.60	Reused	Cytron Mdd 10 A , Cables &Connectors,
Fabrication	182.69	Purchased	CNC Router,Fiber Laser, Turning , 3D Printing
Thrusters & ESCs	2620.00	Reused	Blue Robotics T200 Thrusters (10X),Blue Robotics Escs(8X)
Tools	61.57	Purchased	Grinder,Hot Glue Gun,Soldering Iron
	30.77	Reused	Electric Drill
Vision System	346.16	Donated	Oak-D Stereo Camera
	188.50	Reused	Digital Cameras (10X)
Top Side Control Unit and Tether	161.56	Reused	Station Box, Monitor , PS5 Controller,Power Supply,Switch Connector
	24.50	Reused	Fuse Holder, 30A-Fuses,Anderson Connector
Total Technical Actual Expenses	850.04		
Total Technical Actual Reused	3925.34		
Operations & Logistics			
MATE ROV Competition	250.00	Purchased	MATE Egypt Rov Registration Fees (Regional Competition)
	390.00	Purchased	MATE Rov Registration Fees (International Competition)
	25.00	Purchased	Fluid Power Quiz Fees
Propbuilding	79.80	Purchased	PVC,Connectors,Mission Tools
	23.80	Reused	PVC
Safety	44.23	Reused	Life Jackets(2X), Non-Slip Gloves,Water Resistant Shoes
Marketing Purposes	201.91	Purchased	Flag,Poster,Flyers,Banners,T-Shirts
ROV Testing Logistics	538.46	Purchased	Villa Rent,Transportation
Total Operations & Logistics Actual Expenses	1405.37		
Total Operations & Logistics Reused	68.03		

G- Operational Checklists

Mechanical Checklist

Dry Test

- ☐ Tighten all enclosure screws
- ☐ Check cables (no stretch/bend)
- ☐ Tighten cable glands by hand
- ☐ Set regulator to 1 bar; open air
- ☐ Confirm no air leakage

Underwater Test

- ☐ Fasten motor wires along sides
- ☐ Submerge the ROV and verify that all 10 screws and cable glands are effectively sealed
- ☐ Disconnect the ROV from the air supply and bend the air hose inside the enclosure multiple times to retain the compressed air
- ☐ Adjust buoyancy and stability

System Checklist

Pre-deployment

- ☐ Perform Electrical checklist
- ☐ Perform Dry Motor Test
- ☐ Perform Visualization Test
- ☐ Seal ROV Enclosure
- ☐ Perform Mechanical Dry Test

Arrival / Operation

- ☐ Check off Equipment check-off sheet
- ☐ Perform Mechanical Dry Test
- ☐ Perform Mechanical Underwater Test
- ☐ Turn System on
- ☐ Establish station Communication
- ☐ Perform Visualization Test
- ☐ Perform Control Test

Electrical Checklist

Setup Checklist

- ☐ Turn System OFF
- ☐ Take Structure out of the ROV
- ☐ Disconnect Control board power
- ☐ Disconnect Raspberry and Hubs

Power Board Checklist

- ☐ Continuity 48 V & 12 V (OPEN)
- ☐ System ON
- ☐ Check 48 V input (48–50 V)
- ☐ Check 12 V motor (12–12.5 V)
- ☐ Check 12 V Rosetta (12–12.5 V)
- ☐ System OFF

Control Board Checklist

Control Board Checklist

- ☐ Continuity 12 V input (OPEN)
- ☐ Connect power to Control board from the Power board using the 12 V Rosetta — System ON
- ☐ Check +5 V (Hubs) Test Point and any ground (5–5.5 V)
- ☐ Check +5 V (Pi) Test Jumper Wire, any ground (5–5.5 V)
- ☐ Connect Everything Else

H- Build Vs buy, New Vs used

Items	Built/Bought	New/Used	Justifications
Thrusters	Bought	Used	Undergone operational testing, still functional eligible for reuse
Oak-D	Donated	Used	High-level spatial AI and depth perception were integrated without impacting the procurement budget.
Top plate	Built	New	Custom CNC or laser-cut geometry is needed to make room for certain internal mounting points.
Aluminum Profile	Bought	New	To guarantee a stiff, balanced, and precisely sized chassis, structural framing is cut to exact lengths.
Sensors	Bought	Used	Calibrated units from earlier versions that continue to offer reliable signal stability and accurate telemetry.
Gripper	Built	New	Peak torque performance is guaranteed by new hardware, which also reduces the possibility of slipping or mechanical fatigue.
PCBs	Bought	Used	Reusing circuit designs that have been tested and shown to be stable in terms of heat and electricity.

Table 3 Build Vs Buy/ New Vs Used Table Comparison