

Penguins Team

MATE ROV'26

📍 ZAGAZIG, EGYPT



TECHNICAL Documentation

Team Members

27 Omar Salama - CEO
27 Ahmed Ibrahim - CTO
26 Marwan Tamer - CFO
27 Abdelrahman Elghandour - CAO / Pilot
27 Ahmed Elsherbiny - COO
26 Ahmed Medhat - ESG
26 Tasnem Sabry - Media Director
26 Ali Abdelaziz - Marketing Director
27 Mohamed Abbas - Software Leader
26 Awwab Khalil - Software Eng
27 Ayman Yasser - Software Eng*
26 Manar Ahmed - Software Eng*
26 Mostafa Elshahat - Software Eng*
27 Nadeen Elhady - Software Eng*
27 Shahd Mahmoud - Software Eng*
27 Sohaila Samy - Software Eng*
27 Abdelrahman Abdellateef - Mechanical Leader
27 Maryam Mohamed - Mechanical Eng / R&D*

29 Aya Seddik - Mechanical Eng / R&D*
27 Abdallah Ahmed - Mechanical Eng*
28 Hassan Emad - Mechanical Eng*
27 Eman Akmal - Mechanical Eng / R&D*
28 Mohamed Akram - Mechanical Eng*
28 Mohamed Elnagar - Mechanical Eng*
29 Mohamed Ghanayem - Mechanical Eng*
26 Mohamed Montser - Mechanical Eng*
29 Yousef Aamer - Mechanical Eng* / Pilot
27 Ziad Hesham - Mechanical Eng*
28 Omar Hekal - Electrical Leader
26 Abdullah Elmasry - Electrical Eng
28 Nada Ahmed - Electrical Eng / R&D*
27 Mohamed Gamal - Electrical Eng / R&D
27 Nadine Haytham - Electrical Eng / R&D*
28 Arwa Bahaa - Electrical Eng*
27 Hamdi Emad - Electrical Eng*
28 Jasmine Ahmed - Electrical Eng*

28 Norhan Yasser - Electrical Eng*
27 Merna Atef - Electrical Eng*
27 Mohamed Shaban - BD*
28 Aida Abdelaziz - BD*

(*): Refers to new members

Advisor

Prof. Dr. Mohammed Lotfi

Mentors
Amr Yasser
Mustafa Mohamed
Hossam Elsherbiny
Aya Mahmoud
Shahd Elbendary

1. Abstract

The Underwater Remotely Operated Vehicles Team **Penguins** is an undergraduate student team established in **2024** at **IEEE Zagazig Student Branch**. This is the 2nd time for participating in **MATE ROV Competition** to build ROV that designs, builds, markets, and competes at the competition. Penguins team is thrilled to present **Skipper 2.0**, designed to complete tasks for the 2026 MATE Request for Proposals (RFP). **Skipper 2.0** is modular, lightweight, and specially designed to be a competitive ROV to complete the MATE RFP tasks. The Development criteria followed a rigorous, iterative prototyping process. From testing mechanical mechanisms to pool tests and interdepartmental meetings. At MATE ROV 2026, our ROV represents more than advanced engineering – it embodies our commitment to conserving the environment. This vehicle proves that adaptive, mission-driven design can address environmental challenges one piece at a time. **Skipper 2.0** is optimized for performance and reliability. Each design decision is based on our company's philosophy, where mechanical efficiency, electrical precision, and ecological responsibility converge. The team's safety policy follows a clear hierarchy: it begins with ensuring personal safety, extends to the safe construction of the ROV, and culminates in maintaining operational safety during deployment and testing. This structured and consistent focus on safety has empowered us to innovate with confidence, knowing that every step of our development process is grounded in **careful planning, situational awareness, and mutual respect**. This document provides an overview of the development and design of **Skipper 2.0**, including timeline, technical features, cost, and more.



Figure (1): Skipper 2.0



Figure (2): Penguins Team Members

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- **Zagazig University:** for providing space, facilities and resources to advance our work.
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- **Altium and MATLAB:** for providing their software for free, enabling us to design our PCBs and run system simulations effectively.
- **Prof. Dr. Mohamed Lotfy:** for continuous follow-up and unwavering support.
- **Our Mentors:** for their guidance and providing us a supportive environment.



4. Design Rationale

4.1. Engineering Design Rationale

Body & frame impact on CFD

The design of the ROV's body and frame critically influences its Computational Fluid Dynamics (CFD) analysis. The body's shape dictates the water flow around the vehicle: a streamlined design minimizes drag and promotes smooth flow, whereas complex shapes and sharp edges generate turbulence and increase resistance. Similarly, the frame structure affects hydrodynamic performance, as its components, like pipes, can disrupt the surrounding water and boost drag forces. Consequently, we prioritized streamlining the ROV by minimizing the number of pipes used. For the structural framework, we selected an appropriate size and an organized configuration to prevent unnecessary increases in resistance.

4.2. Systems Approach

In **Skipper 2.0**, we used a 48V power supply and then converted it to 12V using a buck converter outside the tube, so that the tube receives 12V without any voltage drop in the tether cable.

The power distribution for the system was designed to meet the specific voltage and current requirements of each component. A single **5 V, 12 A buck converter** is used to power the servo motors, providing sufficient current for simultaneous operation. One additional **5 V, 8 A buck converter** is dedicated to the Raspberry Pi 4, ensuring stable operation under peak loads. For the depth sensor, a **24 V boost converter** is employed to supply the required voltage.

Current Rating	Current	Voltage	Maximum Output Power	Quantity
DC-DC Buck Converter 8A	8A	5V	40W	1
DC-DC Buck Converter 12A	12A	5V	60W	1
DC-DC Buck Converter 20A	20A	12V	240W	1
DC-DC Boost Converter 4A	4A	24V	96W	1

Table (1): Converters

The table above summarizes the estimated power consumption of the main electrical components used in the system. The current values for the thruster motors were measured under different operating conditions, including forward and

backward motion in both air and water, in order to obtain a realistic estimation of their electrical load. The average power for each motor was calculated considering the operating voltage of 12 V.

For other components such as servos, cameras, the depth sensor, Raspberry Pi 4, and LEDs, the current consumption values were estimated based on their typical or maximum ratings according to the manufacturer datasheets. The total power consumption of the system is therefore estimated to be approximately **229.47W**, which represents the expected electrical load during operation. This estimation is used to guide the design of the power distribution system and to ensure that the selected power supply and voltage regulators can safely support the required load with adequate reliability, (detailed system power calculations is at [Appendix D](#))

4.3. Vehicle Structure

Our ROV balances priorities of low cost, size, and weight. Small, lightweight ROVs can be made at a lower cost, are more maneuverable, can be safely handled by a single poolside operator, and have no need for a deployment crane. A small size and frame are optimal for navigating without accidental contact. However, a lower weight also reduces the inertia, making the ROV more susceptible to unwanted movement. With the benefits of a small, lightweight frame outweighing the costs. A comparison between **Skipper 1.0** and **Skipper 2.0** is shown in **Table (2)**:

Component	Skipper 1.0 (2025)	Skipper 2.0 (2026)
Frame	4292 grams	2687 grams
	3301 mL	2067 mL
Gripper	438 grams	1829 grams
	432 mL	1070 mL
Electronics bay	1561 grams	1561 grams
	1079 mL	1079 mL

Table (2): Weight & Volume compared to previous ROV

Vehicle specifications such as size and weight play an important role in the design and performance of an ROV. The overall size of the vehicle, including its length, width, and height, affects its ability to move through water. So we made maximum effort to make it the least possible size without losing its performance.

Metric	Value
Length	798 mm
Width	488 mm
Height	302 mm
Weight	14.3 kg

Table (3): Skipper 2.0 Specifications

Weight is another critical factor because it directly influences the vehicle's buoyancy and stability underwater. Proper weight distribution helps maintain balance and ensures that the ROV can remain stable while performing tasks.

4.4. Vehicle Systems

4.4.1. Mechanical

Enclosure

The enclosure consists of a 140mm diameter, 220mm long Artelon tube. Artelon was chosen because it is easy to operate, has a density similar to water, is suitable for underwater operation without problems, and is cheaper than other materials such as aluminum. The enclosure also includes a dome made of transparent acrylic. This material was chosen to improve camera visibility, and the dome shape, rather than a flat plate of the same material, provides a wider field of view, reduces surface water resistance, and allows for smooth water flow around it. The enclosure is sealed using gaskets, insulating materials, and an aluminum plate with connectors, and then mounted horizontally on the ROV.



Figure (3): Enclosure Tube

Thruster orientation

Thruster orientation is the most important factor in ROV movement. It acts as the driving force for the entire system; therefore, any mistake in the alignment will directly cause steering problems and make the ROV unstable. The ROV features four horizontal thrusters mounted at a 45° offset angle to achieve 3-DOF (Surge, Sway, and Yaw). Unlike a vertical alignment, this vectored configuration enables lateral movement (Sway) through thrust vectoring. While slightly reducing peak forward velocity, this orientation provides superior station-keeping and precise positioning essential for underwater navigation.

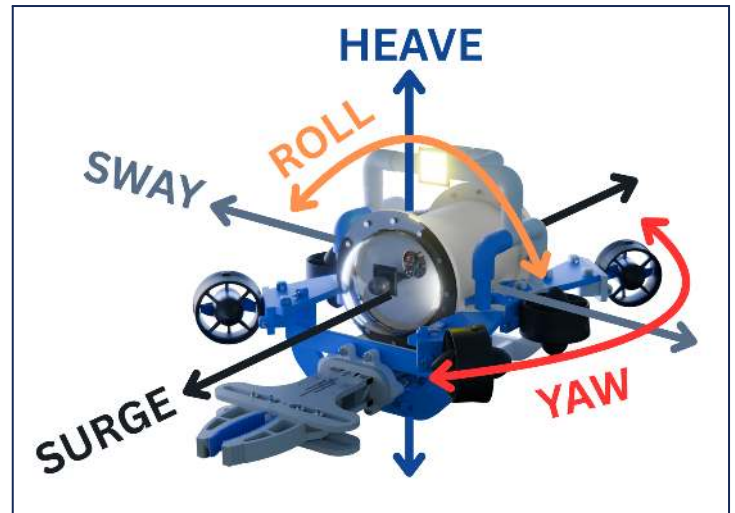


Figure (4): Skipper 2.0 Degrees of Freedom

Gripper

Our team designed a custom 2-D.O.F subsea Gripper for the MateROV competition. The main goal was to build a strong parallel gripping mechanism that can roll **360 degrees** continuously **without tangling any wires**. To do this, we kept all moving electrical parts out of the rotating front section.

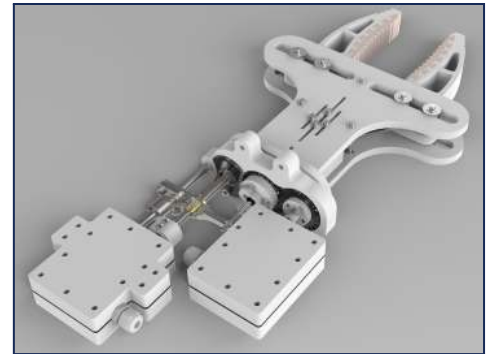


Figure (5): Overall 2-D.O.F Gripper Assembly

Linear Actuation and Toggle Kinematics For the gripping motion, we used an 8mm pitch lead screw driven by a base-mounted MG995 servo. Our power calculations show this setup generates about 299N of linear force. This force pushes a main aluminum slider, which connects to two 90mm toggle linkages. These linkages **multiply the force at the jaw tips**. This setup also acts as a **mechanical self-lock**, meaning the gripper will securely hold its payload even if the ROV loses power.

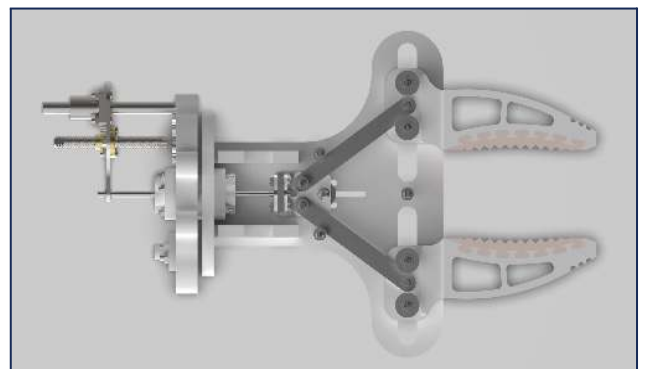


Figure (6): Linear Actuation & Toggle Mechanism

Structural Integrity & Parallel Linear Guide

Pushing with 299 N creates a huge off-center bending moment on the lead screw nut. Without support, the nut would just tilt and jam on the threads. To fix this, we added a parallel guide system. We connected the nut to a custom aluminum sheet metal bracket, and supported the other end of the bracket with a linear bearing sliding on a smooth rod. This balances the load and ensures a perfectly straight, smooth push.

360-Degree Continuous Roll & Motion Decoupling

For the roll axis, a base-mounted servo drives a 1:1 acrylic gear train, spinning a hollow tube that rotates the front frame. To isolate this rotation from the linear grip, a stationary push-pin runs through the tube and presses against a bearing inside the main slider. This allows the slider to spin freely around the pin without affecting the jaws, ensuring continuous rotation with no tangling.

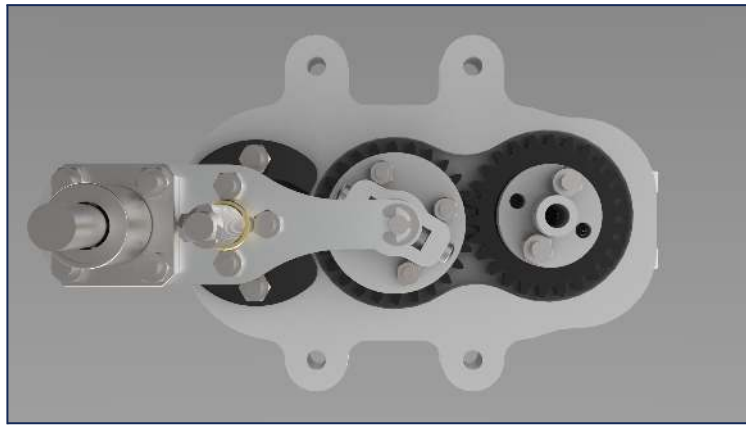


Figure (7): 1:1 Gear Transmission System

Materials and Manufacturing We machined the main body and jaws from Artelon for its impact toughness and zero water absorption. High-stress parts, like the main slider and brackets, are machined from Aluminum. The gears are laser-cut 6mm Acrylic to act as a mechanical fuse. Finally, all load-bearing pins and the lead screw are stainless steel to prevent rust underwater.

Sealing Materials

The main enclosure of the ROV is made out of an Artelon tube that houses the internal electronics. One side of the tube is sealed using an acrylic dome with a rubber and foam gasket ring covered in silicone seal placed between the dome, the tube and an aluminum ring is installed above the dome to distribute the clamping force evenly when bolts are tightened creating a compression seal as shown in Figure (8). The other side of the tube is closed using an aluminum plate that holds the external connectors; a gasket ring covered in silicon is placed between the plate and the tube to maintain sealing at the joints. For external

components exposed directly to water, a couple layers of epoxy are applied to insulate and protect any components water exposed during operation while wire joints are encapsulated in epoxy.

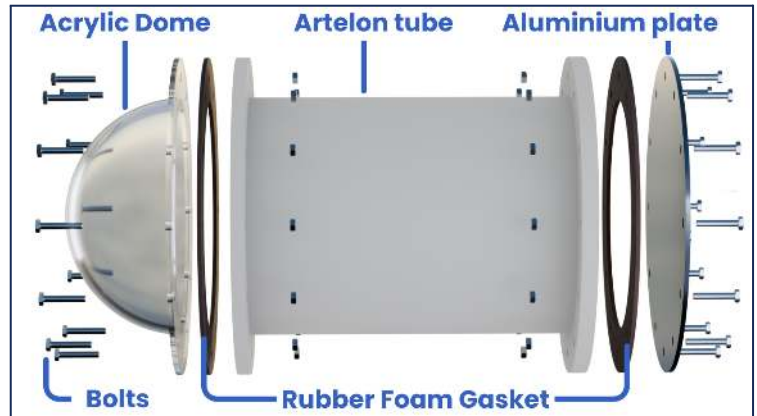


Figure (8): Tube Sealing Layers

4.4.2. Electrical ESP32

We chose ESP32 instead of Arduino because it provides higher performance, larger memory, more GPIO pins, and built-in Wi-Fi and Bluetooth communication. It is used in the ROV to control Motors, Sensors, ESCs, and Servos. The sensors are connected using sleeves, and the ESP32 communicates with the Raspberry Pi to send and receive data.

Raspberry pi 4

Raspberry Pi 4 was selected for its high-speed performance, robust support for ROS2, and integrated I/O, including Gigabit Ethernet, USB 2.0, and a PCIe x1 lane. The PCIe lane is used to connect a USB 3.0 controller card, enabling four high-speed USB connections for onboard peripherals.

Power Converters

We used waterproof buck converter to step down the provided 48 V to 12V-20A. From this 12 V output, two additional buck converters provide first one 5 V at 12 A powering the servos and the second one 5V at 8A is powering the Raspberry Pi. Additionally, a boost converter is used to step up 12 V to 24 V to supply the depth sensor and the LEDs.

MPU-6050 sensor

It combines a 3-axis accelerometer and 3-axis gyroscope in a single module. This makes it lightweight, cost-effective, and easy to integrate into the ROV, while providing accurate motion and orientation data for stabilisation and control.

Thrusters

The Blue Robotics T100 thrusters were selected because of their lower power consumption and sufficient thrust compared to the Bilge Pump.

making them more energy-efficient and better suited for longer ROV operation

Depth Sensor

We chose the Pressure-Level Depth Sensor over the BMP280 because it is more accurate for underwater measurements, giving precise depth readings for the ROV.

4.4.3. Software

Topside Control System

1. Control Panel

It is the **primary operational interface** for monitoring controller inputs, sensor telemetry, and communication status between the GUI and the ROV. It ensures that commands are correctly detected and sensor data is reliably received in real time.

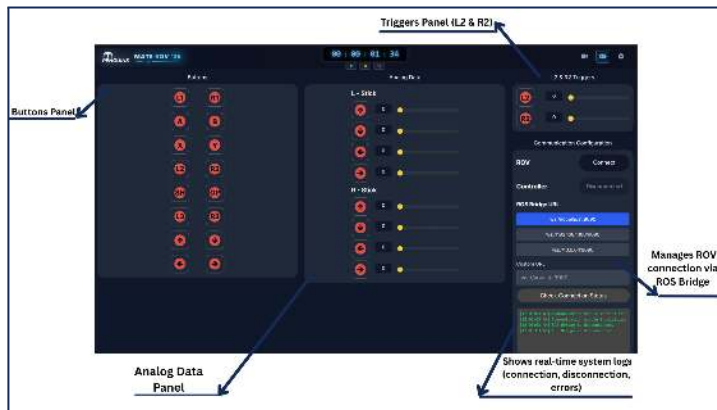


Figure (9): Control Panel Page

2. Configurations Page

The Configurations Page provides an interface for **system setup and calibration** before or during operation. It ensures proper hardware behavior and stable communication.

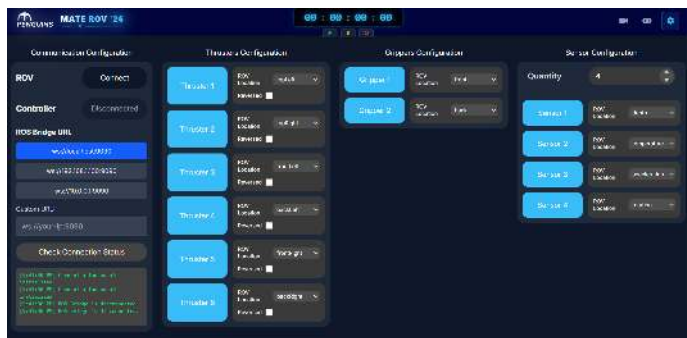


Figure (10): Configurations Page

3. Web-based GUI & Tasks Integration

The GUI enhances the ROV's operational capability by allowing the pilot to control the system while monitoring live camera feeds and sensor telemetry in real time. This year, the interface brings together three camera streams, depth measurements, MPU spatial data, and a mission checklist within a single unified workspace. Rather than relying on a fixed dashboard layout, the system introduces

context-aware mission panels that adjust according to the current task. The interface also supports a distraction-free viewing mode by allowing non-essential elements to be hidden when required. This design keeps the interface organized and easy to navigate while providing additional functionality without overcrowding the screen.



Figure (11): Top Side GUI Task Integration

4. Camera Measurement Calibration

To enable single-camera 2D measurements, the GUI features an interactive Calibration Mode where the co-pilot selects two reference points on a frozen video frame to establish a pixel-to-centimeter ratio. This baseline ratio is then automatically applied to instantly calculate and display the real-world dimensions of mission targets.

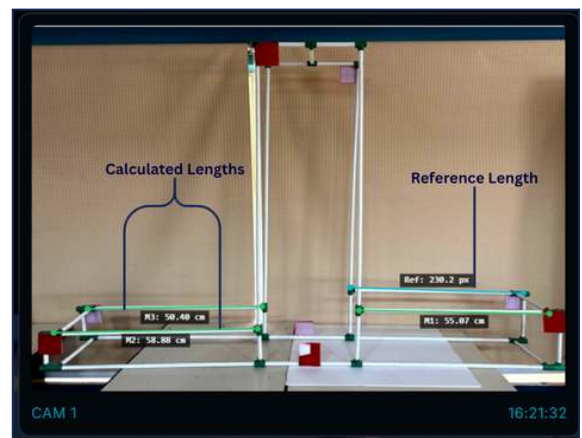


Figure (12): Single-Camera Measurement Calibration.

5. Laptop Communication with ROV

The Topside laptop serves as the centralized command hub over the peer-to-peer tether. Because web browsers cannot natively speak the ROS 2 DDS protocol, a Node.js gateway and rosbridge_suite establish a WebSocket connection on port 9090. As the pilot interacts with the GUI, JSON control events are transmitted via WebSockets and translated by the rosbridge_server into native ROS 2 messages.

Bottom Side ROS2 System

1. Network Configuration on the Raspberry Pi

To guarantee deterministic routing over the **Cat6** Ethernet tether, the Bottomside Raspberry Pi uses a **static IP** configured via Ubuntu Netplan. Additionally, the ROS 2 Data Distribution Service (DDS) is isolated using a specific ROS_DOMAIN_ID. This prevents network interference and confines topic traffic to the ROV's internal network, ensuring high-frequency control loops operate with minimal packet loss.

2. Video Feed Server & Cameras Config

To optimize underwater bandwidth, the ROV utilizes **web_video_server** and **v4l2_camera** nodes to compress raw frames into lightweight MJPEG streams broadcasted over HTTP. To manage identical budget USB cameras that swap kernel designations upon reboot, custom **udev** rules were written to map cameras directly to their **physical USB port** paths (e.g., `/dev/cam_front`). This hardware-level lockdown ensures persistent ROS 2 namespaces, preventing swapped camera feeds mid-mission.

3. ROS Bridge communication and Micro ROS

To connect the Topside GUI and Bottomside Raspberry Pi, **rosbridge_suite** acts as a WebSocket server, translating native ROS 2 messages into JSON payloads for the NodeJS backend via **roslibjs**. Symmetrically, the **micro_ros_agent** bridges the Pi to the ESP32. Running Micro XRCE-DDS, the ESP32 operates as a native ROS 2 node, replacing raw serial with a standardized DDS framework. This enables critical connection monitoring: if the serial link fails, the agent broadcasts a **LIVELINESS_LOST** event to trigger an automated emergency ascent (Detailed data flow in [Appendix B](#)).

4. PID Integration with the system

To reduce pilot cognitive load during horizontal maneuvers, an automated Depth Hold feature was implemented. A custom ROS 2 "**Gatekeeper**" node intercepts movement commands before hardware execution. If the pilot's vertical (Z-axis) input is non-zero, manual control overrides the system. When the Z-axis input returns to zero, the node locks the current pressure sensor reading as the new target setpoint. It then continuously executes a Proportional-Integral-Derivative (**PID**) algorithm to calculate the necessary vertical correction thrust, seamlessly merging it with the pilot's horizontal vectors. The control algorithm and PID constants were pre-tuned and validated using a virtual underwater **Gazebo simulation**.

AI & 3d Modeling

1. YOLO Model Green Crab Detection Process

To ensure we can accurately identify Green Crabs underwater, we followed a 3-step process:

A. Dataset Collection & Curation:

To minimize false positives, the model was explicitly trained to distinguish European Green Crabs from native species by including Jonah, Helmet, and Rock crabs as **negative samples**. The dataset aggregated imagery from MATE ROV competition resources, web scraping, and open-source **Roboflow** databases. Inconsistent labels across these disparate sources were manually unified to establish a standardized training pipeline.

B. Data Integration & Augmentation:

Using **Roboflow**, we merged our custom collected images with the existing data to create a robust training set. We performed manual bounding box labeling, focusing on the limbs to provide precise localization. To simulate real mission conditions, we applied **Augmentations** (blur, brightness adjustments, and grayscale). This helped the model handle murky water and light attenuation at various depths. The dataset included crabs in various orientations, depths, and levels of partial burial in the seabed to ensure detection even in camouflaged scenarios.

C. Iterative Development (Versions & Training):

The development was a series of iterations aimed at maximizing performance. We developed multiple versions of the model using **Google Colab's** GPUs, testing different hyperparameters and dataset balances. We analyzed Edge Cases where the model struggled and refined the dataset to address these gaps. We continued tuning the model until we achieved a Stable Version ensuring real-time feedback for the ROV.

2. Video Feed Scraping and Publishing

This module implements a low-latency pipeline that acquires the ROV's video feed and processes it through a custom-trained **YOLOv8** model to detect and count **European Green Crabs**. The resulting analytical telemetry, including base64-encoded annotated frames and real-time target counts, is continuously published back into the **ROS ecosystem** via WebSocket bridges to facilitate ground control monitoring.

3. Comparison Between YOLO & Color Detection

We initially developed a detection using **Color Based Detection** (HSV Thresholding). However,

field testing revealed several critical challenges that hindered our ROV's performance, leading us to adopt the Deep Learning approach using **YOLO**.

Challenges with Color Based Detection:

- **Underwater Lighting Distortion:** We observed that the water column absorbs light wavelengths unevenly. As the ROV's depth changed, the "Green" in the crabs shifted significantly, making our static HSV thresholds completely unreliable.
- **Environmental Noise:** Our use of Erosion & Dilation failed to isolate the crabs from the complex seabed. It either removed the crab's distinct features like legs or failed to filter out the high frequency noise from the rocky seabed, leading to constant false detections.
- **Camouflage & Low Contrast:** Because the Green Crab is naturally evolved to blend into its environment, the lack of a distinct color contrast resulted in a high rate of False Negatives, where the system simply couldn't see the target against the background.

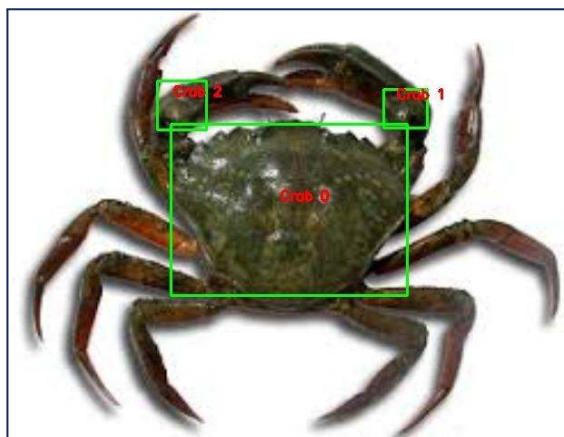


Figure (13): Struggling to identify the crab as a single object

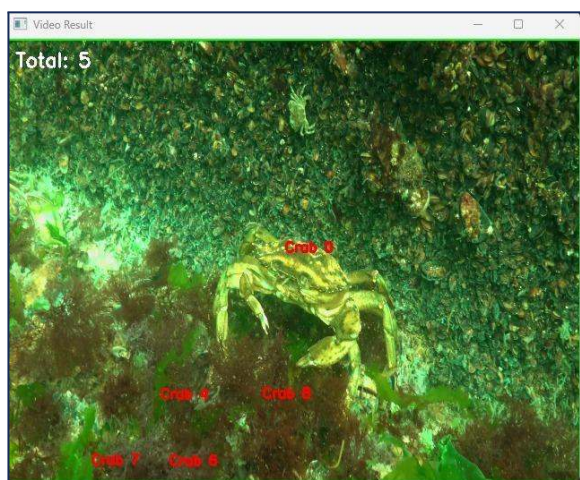


Figure (14): High background noise and false positives in murky water

Why We Switched to YOLO:

To ensure mission success, we replaced the color-dependent logic with YOLO for the following reasons:

- **Feature Recognition:** Instead of chasing colors, YOLO recognizes the crab's geometric structure and shell patterns. This made our detection immune to lighting changes.
- **Superior Filtering:** YOLO's deep learning layers naturally filter out background noise, accurately distinguishing the crab even in highly cluttered or turbid environments.
- **Multi Object Accuracy:** It successfully detects and counts multiple crabs in real-time, even when they are overlapping a task where traditional CV failed.

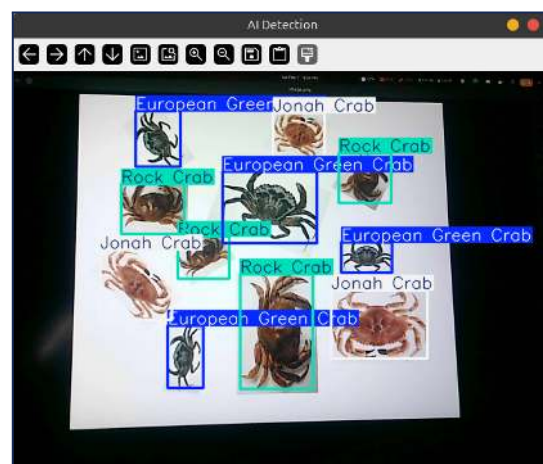


Figure (15): YOLO Model Result

4. 3D Construction

The primary challenges in this phase are **strict time limitations** and **computational constraints**. Traditional 3D reconstruction often requires long processing windows that are incompatible with our requirement for rapid, near-real-time results during ROV operations. We evaluated Photogrammetry (Zephyr, Meshroom) against Neural Radiance Fields (NeRF). While photogrammetry offers high geometric precision, **Instant NGP** was selected as the optimal solution due to its revolutionary processing speed and efficiency in handling resource-heavy underwater data.

Rank	Quality	Speed	Usability	Reliability
1	3DF Zephyr	Instant NGP	3DF Zephyr	3DF Zephyr
2	Instant NGP	NeRF	Instant NGP	Instant NGP
3	Meshroom	3DF Zephyr	NeRF	NeRF
4	NeRF	Meshroom	Meshroom	Meshroom

Table (4): 3D Construction Application Comparison Matrix

Technical Workflow

Our developed pipeline maximizes speed through an integrated two-step process:

- **Spatial Mapping (COLMAP):** We utilize COLMAP to perform Structure-from-Motion (SfM). This stage identifies key visual features to calculate exact camera trajectories and spatial orientation, providing the necessary geometric foundation.
- **Volumetric Training (Instant NGP):** The spatial data is fed into Instant NGP, which leverages neural graphics primitives to "learn" the environment. This allows us to generate a navigable 3D volume in seconds, bypassing the heavy computational overhead of traditional mesh generation.

4.5. Control and Electrical System

4.5.1. Electrical

The pilot controls **Skipper 2.0** using a joystick connected to a laptop. The control commands are sent from the laptop to the Raspberry Pi 4 through an Ethernet connection. The Raspberry Pi communicates with the ESP microcontroller using Micro-ROS, which allows the ESP to receive the control signals and manage the hardware components of the system. The Raspberry Pi 4 Controls 3 Cameras: two of them are outside the tube for external monitoring and one camera inside the tube. From the ESP, PWM signals are sent to the ESCs to control the thruster. The ESP also controls four servo motors where two of these servos are located outside the tube and two are inside the tube as part of the mechanical system. In addition, the depth sensor is connected to the ESP through an ADC to convert the analog signal into a digital value that the controller can read. The MPU sensor communicates with the ESP using the I2C protocol to provide orientation and motion data. The system also includes a leak detection circuit. The leak system consists of two pins: one connected to the 3.3V supply and the other connected to a digital input pin on the ESP.

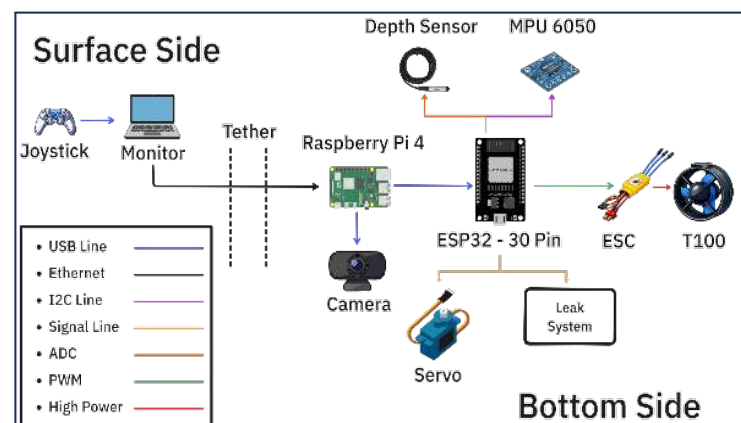


Figure (16): System Diagram

Tower

To ensure organized circuit and wiring, the tower is installed inside the ROV's frame. The components are mounted in an ordered manner on each plate to keep wiring clean and easily mounted inside the frame.

1. Lower level (power layer)

This level of the tower contains three plates containing the power related components and power distribution elements as ESCs, Buck converters, Boost converters and connectors, to ensure secured wiring between components. Between the two levels there are aluminum plates to reduce electrical interference and noise that can affect the upper level plates components.

2. Upper level (processing layer)

The upper level has control and processing components, including PCB, Raspberry Pi and the camera hub which is responsible for system control, communication and processing. This layout allows the cable routing to be organized and easy to troubleshoot.

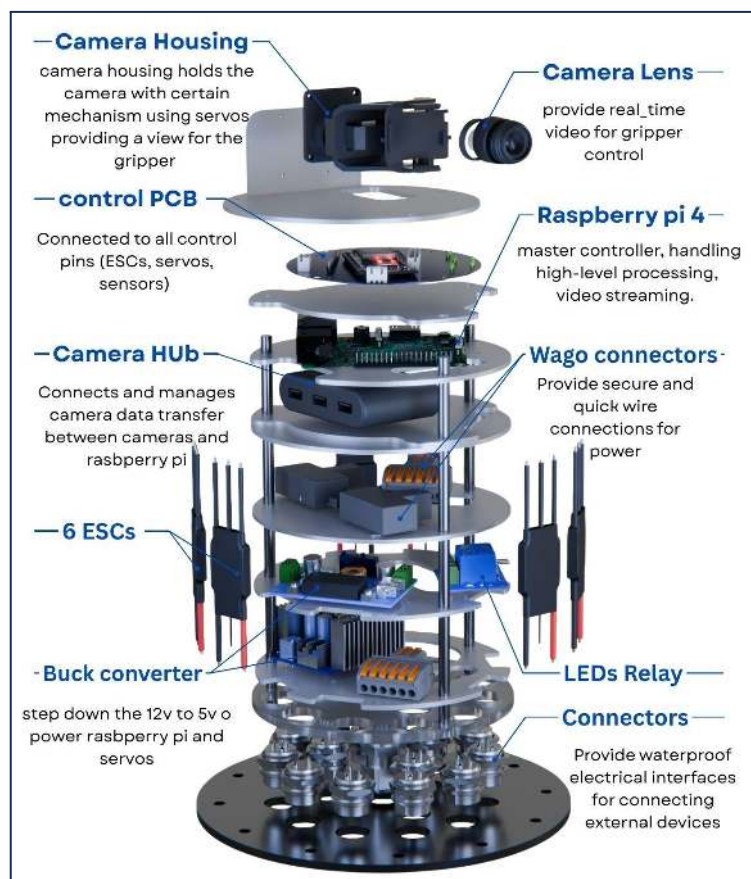


Figure (17): Tower Levels

Tether

The tether in skipper 2.0 provides a physical connection between the ROV and the surface station. The importance of the tether cable comes from its two main parts: the power cable and an ethernet cable. The power cable transmits 48V from the surface to supply the ROV with the

energy it needs. The ethernet cable is a **CAT6** line, with high speed up to **1 Gbps**. It establishes a reliable communication link between the surface station and the ROV's **Raspberry Pi 4**, so that the ROV can receive all control commands sent from the surface and transmit data and video feedback in real time.

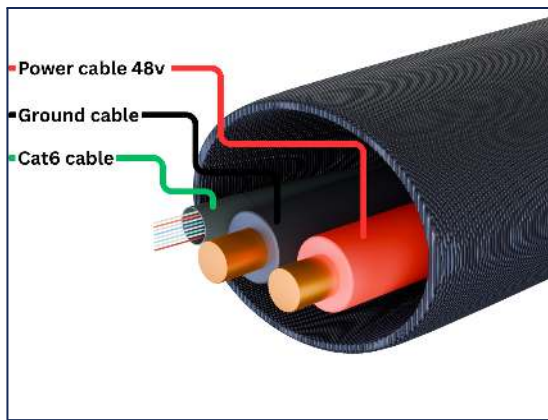


Figure (18): Cross Section of the Tether

4.5.2. Station

Topside Control Station is designed as a modular command center. The core processing is handled by a high-performance laptop equipped with a dedicated NVIDIA GPU, which is strictly required for running real-time AI object detection (YOLO) and the Graphical User Interface (GUI). A USB Hub to manage connectivity of needed inputs to the Main Laptop. The primary pilot input is handled by a standard gamepad controller. Additionally, a secondary external monitor is integrated into the station, exclusively dedicated to displaying the multi-camera video feeds, allowing the primary laptop screen to focus entirely on telemetry data, AI detection, and task-specific widgets.

4.6. Propulsion

The **T100 thrusters** were chosen over bilge pumps because of their superior performance, since bilge pumps draw more current and provide less thrust force. T100 is more costly, but ensures the performance we're looking for in Skipper 2.0.

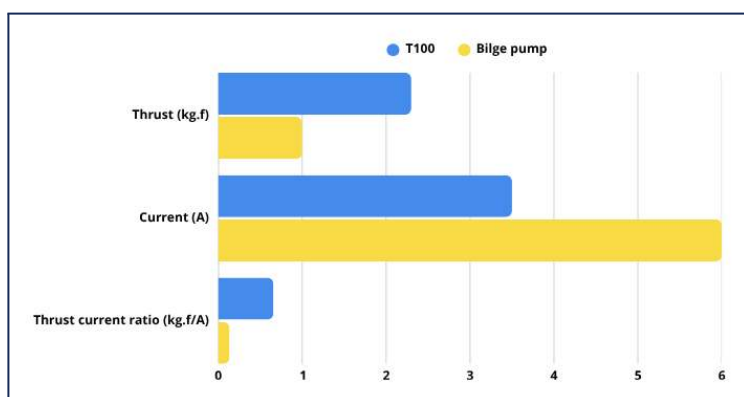


Figure (19): Performance Comparison

Thrust Force

The vehicle uses **Six Blue Robotics T100 Thruster**. Four thrusters are mounted at **45°** to enable **3-DOF motion (surge, sway, and yaw)** in the horizontal plane, while two thrusters provide **2-DOF motion (heave, roll)**. Each thruster can generate about approximately
Maximum Forward Thrust: 2.36 kgf (≈ 23 N)
Maximum Reverse Thrust: 1.85 kgf (≈ 18.14 N)
under standard conditions.



Figure (20): Forward Thrust



Figure (21): Reverse Thrust

4.7. Buoyancy and Ballast

Buoyancy

In order to achieve a fully controlled ROV that depends only on the motor thrust,

We need to achieve the following condition: **The buoyancy force is equal to the weight force.**

Calculations:

With max mass = between 12-15kg

Weight = $m \cdot g$

Weight (max) = $15 \cdot 9.8 = 147.6$ N

Weight (min) = $12 \cdot 9.8 = 117.6$ N

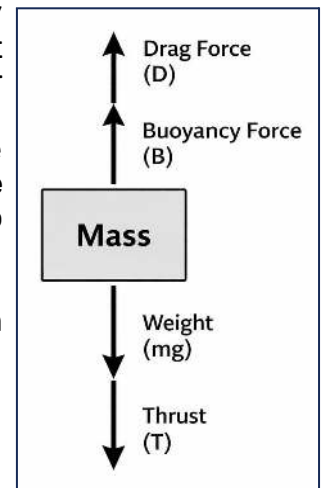


Figure (22): FBD of a mass

To achieve the condition :

We have three factors that affect the buoyancy: the contact surface, pipes and an external buoyant material (if we need it).

Try & Error Approach to Achieve Buoyancy Balance

Achieving buoyancy balance was a critical challenge in the ROV development, as it directly affects stability, maneuverability, and energy efficiency underwater. To address this, the team followed a structured testing roadmap based on iterative experimentation and validation.

Testing Roadmap

The trial-and-error phase was not the initial step. Early **CAD modeling and CFD simulations** were conducted to predict hydrodynamic behavior and analyze the forces acting on the vehicle. These simulations helped estimate buoyant forces, drag, and optimal component placement. However, simulations cannot fully replicate real

conditions. Factors such as material tolerances, assembly variations, and environmental effects can cause deviations from theoretical predictions. Therefore, physical testing was required to refine the buoyancy balance.

Parallel Development Strategy

To maintain progress, the team used a rotating workflow dividing members into **design, assembly, and testing groups**. This allowed experiments to run in parallel with final design improvements and documentation.

Based on feedback from previous competitions, teams performing **more than 15 hours of pool testing** achieved better results. Therefore, our team conducted **over 20 hours of water trials**, including buoyancy balancing, subsystem testing, and full mission rehearsals.

Testing Environment

Due to limited access to specialized facilities, regular system tests were conducted in a **nearby swimming pool**, providing realistic underwater conditions for evaluating stability and system performance.

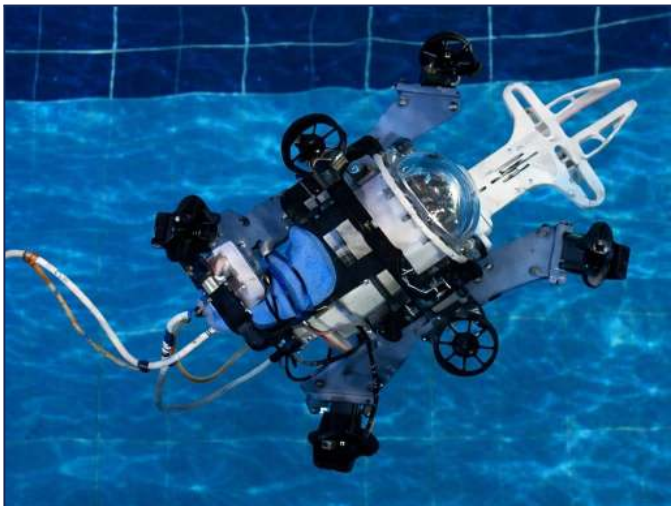


Figure (23): Clarification of the testing in swimming pool

For buoyancy balance, the ROV needed to reach the **neutral buoyancy point**, where the buoyant force equals the vehicle weight. Buoyant materials (**Swimming Noodles**) were gradually added and adjusted through trial-and-error testing until the vehicle achieved stable neutral buoyancy.



Figure (24): Swimming Noodles

4.8. Payload and Tools

Skipper 2.0 uses three main sensors: depth (Figure (25)), MPU sensor, and leak sensor to enhance the performance of the ROV and complete the required missions with high precision.

Depth sensor

The pressure level depth sensor provides accurate readings for the ROV depth from the surface that reaches $\pm 2\text{mm}$ precision that helps the pilot achieve the missions smoothly, it communicates through **analog digital converter (ADS1115)** 16-bit resolution that is connected with the I2C interface with the ESP32. It's used in various tasks such as: (**Task 1.2** Coral garden ridge modelling), (**Task 2.2** Iceberg tracking). We can use it in these tasks to get the readings for the height needed to be measured autonomously and the depth of the iceberg.



Figure (25): Depth Sensor

MPU sensor

The IMU 6-axis which has accelerometer and gyroscope that communicate with the ESP32 through I2C interface provides the orientation of the ROV. To improve readings inaccuracy **Kalman filter** is used, now the pilots can have the ROV orientation that appears in the GUI where the data is delivered through Ethernet cable from the Raspberry pi to the station. It provides the ROV's orientation, which pilots use to adjust and stabilize the vehicle during operation.

4.9. Build vs. Buy, New vs. Used

Build vs. Buy

We chose to build our frame which gave us the ability to custom the structure to meet the specifications needed. This helped to reduce drag force and the frame is lightweight and small which makes its movement easier and more precise. Also this gives us the ability to control the alignment of the motors to maximize thrust efficiency.

New vs. Used

1. Frame

We made a decision to use old PVC Sheets which were in a good state instead of buying new material. We first modeled the structure of the frame then we cut the material and assembled the frame. Reusing PVC Sheets was not only a sustainable and cost-effective choice, but it also supported our underwater performance.



Figure (26): Manufacturing

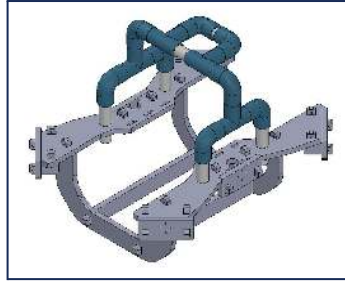


Figure (27):Structure

2. Thrusters

In the earlier stages we used Bilge Pumps because they were cheap. However, they had a lot of problems with control and efficiency. Switching to T100 has made a huge difference in how the ROV moves. The new thrusters outperform the old setup across three key areas:

- **Better Thrust:** Bilge pumps are made to push water through pipes, not for moving a vehicle. These new thrusters have a 97mm nozzle and a 76mm propeller designed specifically for speed and power, giving us a solid 2.36 kgf of thrust.
- **Strong Reverse Power:** Bilge pumps are very weak when moving backward. The new motors give us 1.82 kgf in reverse, which means the ROV can move backward easily as it moves forward.
- **Smoother Control:** Since we use ESCs, these motors respond much better to our commands. This gives us better control when we need to do precise movements, unlike the unstable movement we had with the old pumps.

3. Old vs. New camera

The transition from old cameras to modern USB Webcams made our work much easier. Instead of the old units that relied on DVRs and had poor image quality. The new cameras provide high definition output with easy USB connectivity.

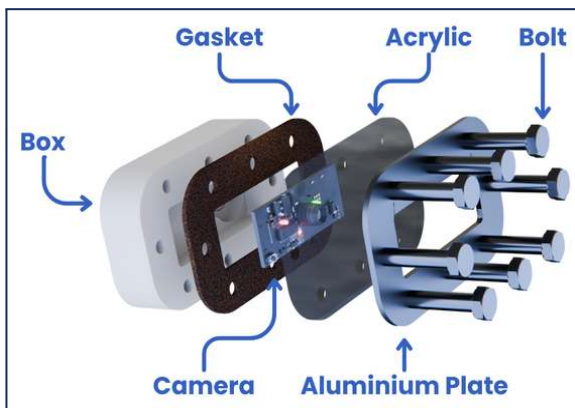


Figure (28): New Camera Housing

Also the camera orientation and sealing process are now much more intuitive. The improved sealing design allows for repeated access to the

internals for maintenance while maintaining a secure, waterproof housing which was a major problem in the older models.

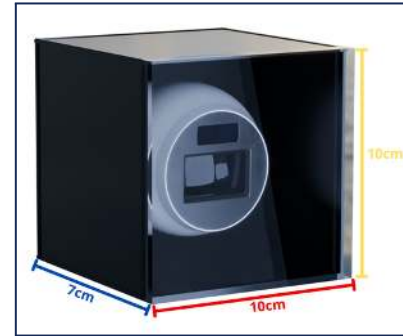


Figure (29): Old Camera Housing

4.10. Problem Solving

4.10.1. Connectors

One of the **challenges** in the ROV electrical system was the routing of external wires through the enclosure while maintaining reliability and ease of maintenance. Initially cables were passed through glands (pg7) and sealed using multiple layers of epoxy while this method provided sealing it significantly **increased assembly and disassembly time and difficulty during electrical/ mechanical maintenance** the seal had to be broken damaging the gland and the sealing process had to be done from the start introduced potential **leakage risks**.



Figure (30): Gland (pg7)

To solve this issue the **connector system** (Chassis Connector (Male-Female) GX16) needed to **allow quick assembly and disassembly** for the **ease of maintenance** and ensuring not to **damage** any components while providing a reliable sealing method. As mentioned in the innovation section (4.11.2)

4.10.2. Sealing

Ensuring reliable sealing of the ROV enclosure was a major challenge. The vehicle contains sensitive electronics that must be fully protected from water while allowing the enclosure to be assembled and disassembled for maintenance. Improper sealing or uneven bolt pressure could lead to leakage or cracks in the acrylic dome.

The sealing system was designed using compression-based sealing combined with sealing materials Gasket rings were placed between structural interfaces to create a tight seal when compressed, while O-ring were used on bolts to prevent leakage through mounting holes.

To improve sealing reliability, aluminum rings were added to distribute the clamping force evenly across the acrylic dome, reducing stress and minimizing the risk of cracking. Silicone is added in the threaded interfaces to close small gaps, while epoxy resin was applied to encapsulate external wiring joints and cover electrical components exposed directly to water. The combination of the **compression sealing**, O-ring, silicone and epoxy provides a reliable waterproof system that protects the internal electronics while maintaining the structural integrity of the enclosure.

4.11. Innovation

4.11.1. Servo Sealing

Regular servos burn out underwater. We had to build a custom waterproof enclosure to protect our servos at depth.

Static Sealing We machined a housing out of two Artelon blocks. The servo goes inside. We put a rubber gasket between the two Artelon halves and bolted them closed. To route the wires out, we used a cable gland and added silicone around it. This completely seals the static parts of the housing.



Figure (31): Artelon housing

Dynamic Sealing For the spinning part, we made a custom metal shaft and connected it to the servo hub using a custom coupling. Where the shaft exits the Artelon box, we installed a bearing first. This bearing takes the load and keeps the shaft spinning perfectly straight and smooth. Right after the bearing, we put two oil seals. This combination seals the rotating shaft and keeps the water out.

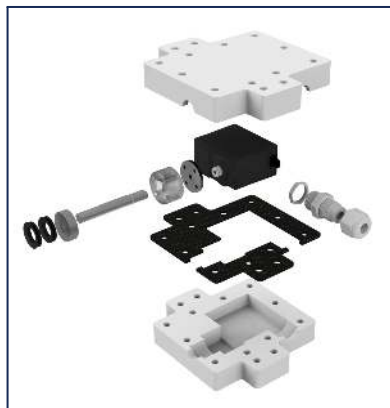


Figure (32): Internal sealing parts

4.11.2. Connectors

A major design goal for the ROV electrical system was improving reliability while simplifying maintenance. **Initial methods** use **glands** sealed with silicone or epoxy; **which makes maintenance difficult** because cables cannot be removed without breaking the seal and reinstalling the seal. To address this limitation the

design uses **panel mounted connectors fixed to the ROV enclosure**. This approach allows cables to be **easily connected and disconnected** without disturbing the enclosure seal **reducing maintenance time**, allows the separation between power and signal lines and provides strong mechanical fixation through threaded mounting.



Figure (33): Connector GX16

4.11.3. Functional Gripper

The Engineering Challenge In ROV competitions, making a gripper roll 360 degrees is tricky. If you put the rotation motor on the moving jaws, the wires twist and eventually break. Slip rings can fix this, but they are hard to seal underwater and make the electronics complex. Also, when you try to combine this continuous rotation with a linear lead screw mechanism, the off-center pushing forces usually cause the whole system to bind and get stuck.

Stationary Actuation & Hydrodynamic Stability To completely avoid wire tangling, we decided to fix both servos to the back frame of the gripper. We send the rotation to the front jaws using a hollow tube. Because the motors stay still, the wires never move, giving us a true infinite 360-degree roll. As a bonus, keeping the heavy servos at the back shifts the ROV's center of gravity backward, which actually helps balance the vehicle in the water.

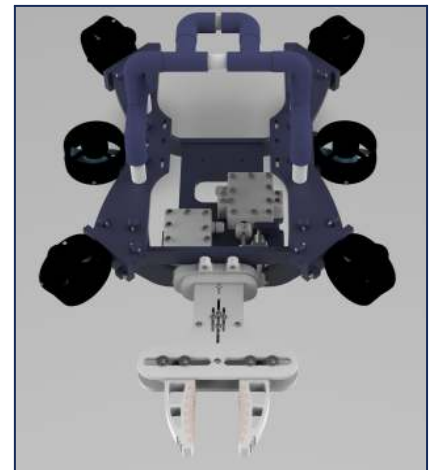


Figure (34): Base-Mounted Actuation Setup

Decoupled Kinematics The hardest part of the design was pushing the jaws open and closed while they are spinning. If we attached the lead screw nut straight to the rotating slider, the spinning motion would twist the nut and force the jaws to move. To get around this, we ran a stationary central pin right through the middle of the rotating hollow tube. This pin pushes against a bearing that sits inside the main slider. When the gripper rolls, the slider just spins freely around the pin. This separates the two motions

completely, so the jaws stay locked exactly where they are while rotating.

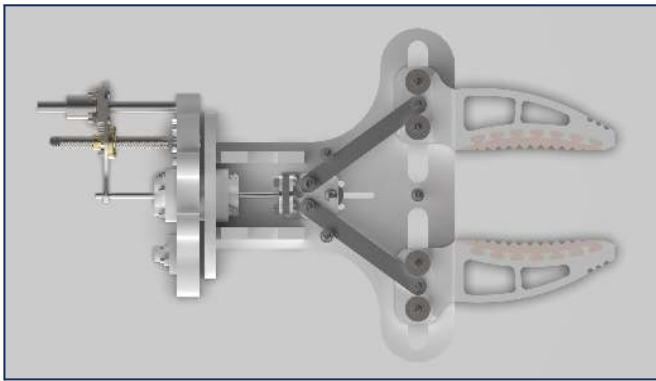


Figure (35): Decoupled Motion Interface

Interlocking Silicone Grip Bare plastic jaws easily drop wet objects. We avoided gluing rubber pads because adhesives fail fast underwater. To solve this permanently, we designed a dovetail interlocking pattern directly into the inner jaw faces and poured liquid silicone into the grooves. When the silicone cures, it gets locked inside the plastic grooves. This way, the rubber won't peel off when we grab an object.

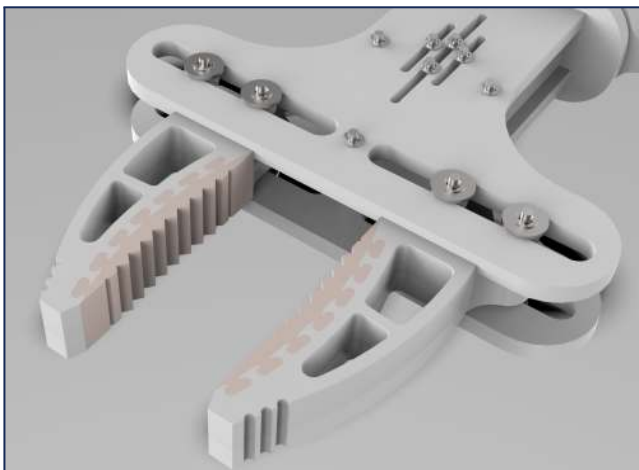


Figure (36): Dovetail interlocking pattern and the molded silicone grip

4.11.4. 2-DOF Camera

One of the key innovations in our ROV design is the integration of a camera with a pan-and-tilt mechanism, enabling controlled movement in both horizontal and vertical directions. This allows for a wider field of view and enhances real-time underwater inspection without requiring repositioning of the entire vehicle.



Figure (37): Pan & Tilt mechanism

4.12. Non-ROV Device (Float)

The float is made around a tube that is 70 cm long and made of PVC. This tube is closed at both ends with HDPE caps. It has special O-rings to keep the water out. The float works because it weighs the same as the water it pushes away. We can control the vertical motion by adding or removing water from inside the float. This way you can control how deep the float goes in the water.

To control buoyancy, the system uses a syringe-based mechanism driven by a lead screw and stepper motor, allowing water to be injected or removed in fine increments. An ESP32 microcontroller manages motor control, sensor readings (pressure for depth and leak detection), and wireless data transmission. Powered by a 12V battery pack 10x AA-1.2V - Ni-Mh Set Of 2400mAh with protective circuits, the float continuously sends depth data to a surface server, where it is logged and visualized real time in the GUI.



Figure (38): Buoyancy Engine



Figure (39): Float

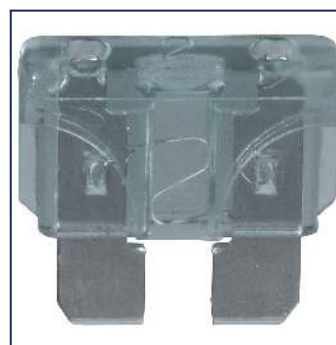


Figure (40): 2A Fuse



Figure (41): Battery Pack

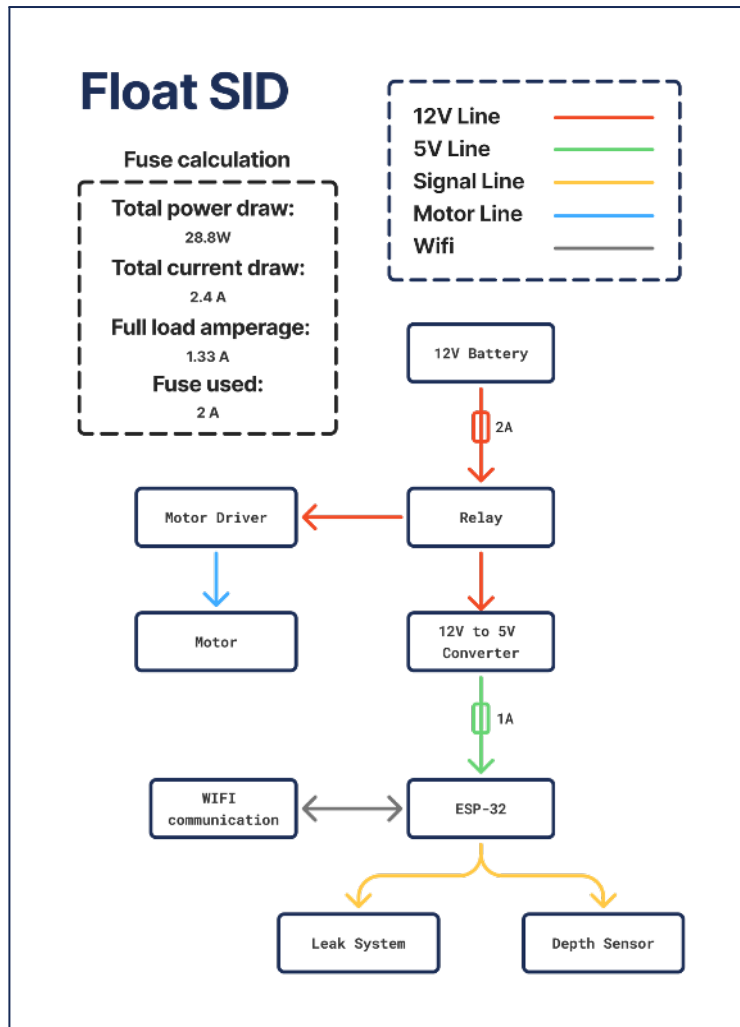


Figure (42): Float SID

5. Safety

At the Penguins team, we prioritize our members' well being with safety as our core value. Our safety philosophy is to stop risks long before unsafe situations occur. Personnel and equipment safety are highly prioritized due to new members joining with little to no experience with engineering equipment (Detailed **Safety Checklist** is at [Appendix D](#)).

5.1. Personnel Safety

All engineers must review and acknowledge the lab safety guidelines before entering the lab. These guidelines outline the proper use of equipment, required protective gear, and emergency procedures, reinforcing awareness of associated risks and responsibilities.

5.2. Equipment Safety

Personal Protective Equipment (PPE) is mandatory when working with soldering and sealing materials such as epoxy and silicone. We provide all necessary gear to every team member and keep it easily accessible at all times.



Figure (43): Safety Procedures

5.3. Operational Safety

Fire extinguishers are located in both the electronics and assembly zones, allowing for instant responses in emergencies. We keep the workspace clean and make sure emergency exits and fire escape routes are always clear, which helps prevent accidents and allows quick and safe evacuation.



Figure (44): Fire extinguishers in workspace

5.4. Safety Features

Kill switch

We installed a kill switch in the station so that the pilot can completely cut off power to the ROV in case of any issue with a single press.

Leakage system

We implemented a leak detection system that displays a warning message to the pilot on the GUI if any water leakage occurs inside the enclosure.

Strain Relief

To prevent the tether from pulling or damaging connectors during operation, both ends are supported using stress relief techniques. This helps keep connections stable and minimizes the risk of incidental disconnection during movement.

Shrouded Thrusters

All thrusters' propellers are fully-covered with shrouds to prevent accidental contact during testing and operation, making testing and handling significantly safer.

Smoothed Frame Edges

The frame is carefully buried and polished to eliminate sharp edges that could harm team members or damage sensitive surfaces.

6. Critical Analysis

6.1. Testing Mechanical

Connectors Testing

Ensuring proper insulation of the electrical connectors is essential for reliable operation, especially in environments where water exposure may occur. Therefore, a sealing test was conducted to verify that the connectors prevent water ingress and maintain proper insulation.



Figure (45): Connectors

The section of the tube containing the connectors was submerged in water while connected to an electrical circuit with a lamp indicator. If water leaked into the connectors, a short circuit would occur and the lamp would illuminate, indicating insulation failure. The absence of illumination confirmed proper sealing of the connectors.

Electrical

Our testing methodology involved evaluating each electrical component individually before integrating them into the complete system. In addition, prototypes were developed for each part to verify functionality and performance.

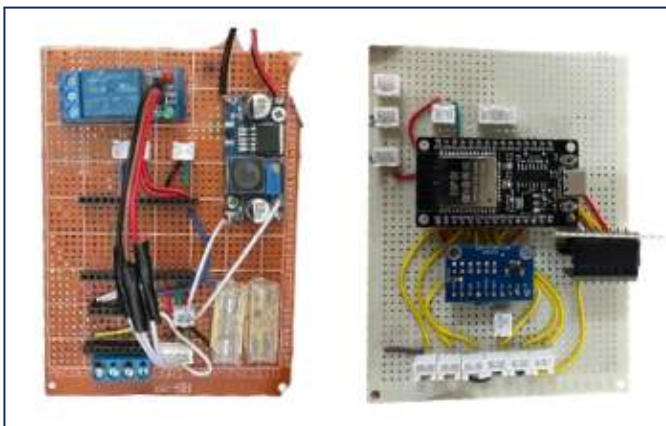


Figure (46): ROV & Float Prototypes

Software

Testing the Network communication:

To guarantee reliable tethered communication, baseline ICMP pings were used to validate static IP configurations and ensure the system accepted traffic from the 192.168.1.0/24 subnet. Additionally, bandwidth saturation testing via **iperf** simulated heavy video and telemetry loads, enabling the team to optimize MJPEG compression ratios and prevent critical control packet loss.

Gazebo Simulation:

The finalized SolidWorks design was converted into a URDF model for Gazebo. By integrating Buoyancy, Hydrodynamics, and Thruster plugins, the team created a physics-accurate virtual ROV driven by native ROS 2 messages. This environment allowed for safe, early validation of movement and the pre-tuning of PID control loops. Because the simulation perfectly mirrored the physical hardware's topic architecture, the validated control nodes were deployed directly to the onboard Raspberry Pi, significantly reducing physical pool testing time and mitigating hardware risk.

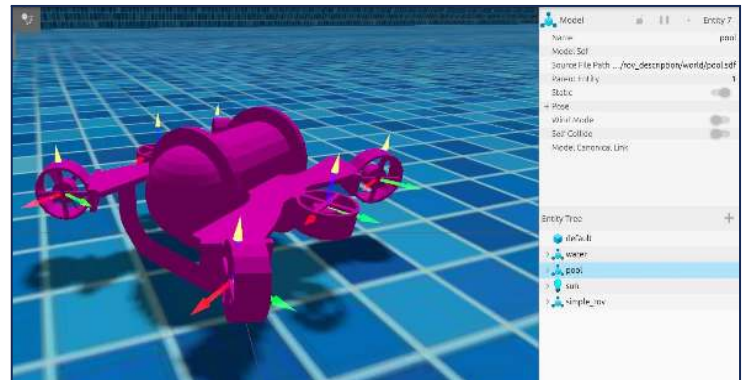


Figure (47): Gazebo real world Simulation

6.2. Troubleshooting Mechanical

ROV Buoyancy

Smooth underwater operation also requires a neutral buoyancy ROV which is achieved with PVC pipes. Such material has high impact resistance and can be easily machined. It also provides protection for the inner tube. Meanwhile, it has great corrosion resistance. PVC top frame also provides ease of grip and transport of the ROV safely. It is attached to the top of our ROV. This strategic placement protects the hardware components beneath the buoyancy block while providing a restoring torque using its buoyancy, further enhancing body stability underwater.

Electrical

Voltage Drop in the tether

Our system initially operated using a 12-volt power supply; however, a voltage drop of up to 5 volts occurred in the tether cable. To overcome this issue, we adopted a 48-volt power system and implemented power conversion underwater.

Thruster Failure and Phase Repair

During operation, one of the thrusters stopped working. We disassembled it, resolved its three phases, and then insulated the connections.

Noise Overcome

Our sensor readings were severely impacted by electromagnetic interference (EMI) originating from the power distribution system. To resolve this, we implemented a **Faraday cage** to shield the sensitive electronics and eliminate the noise.

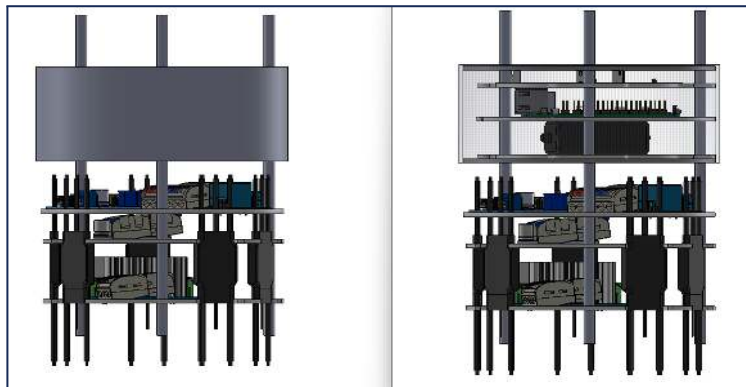


Figure (48): Faraday Cage

7. Teamwork

7.1. Company Overview

Penguins Team is a dynamic team from **Zagazig University** that includes 40 members from all over Alsharqia that is divided to 15 Old members and 25 New members. We are dedicated to advancing ROV technology to support marine conservation and address climate change. Our mission is to develop an advanced, eco-friendly ROV equipped with high-resolution sensors, capable of monitoring marine ecosystems and supporting ocean protection initiatives. **Penguins Team** drives innovation to enhance biodiversity preservation and reduce environmental impact. **The team** consists of four sub-teams: **Mechanical, Electrical, Software and Business Development**. The team is led by the **CEO** who is responsible for the entire team, providing strategic oversight and hosting follow-up meetings with board and members. **CFO** manages all the financials and budgeting, while **CTO** monitors the technical progress over the three technical teams and oversees the technical integration between them. **CAO**

handles administrative processes and team coordination. **COO** is responsible for managing the team's daily operations, making sure the tasks and milestones are executed with our timeline. The mission of **ESG** is to implement the strategies to improve team performance, risk management, and ethical practices, the detailed company structure is at [Appendix \(C\)](#).

7.2. Project Schedule

In alignment with our cohesive organizational structure, the project schedule has been systematically divided into six key phases:

1. Research & Development (Aug 15 - Nov 30):

We focused on researching about fixing our problems that we have faced in the previous ROV competitions, how to upgrade our ROV systems as much as possible and what features we can add to our ROV.

2. Recruitment and Training (Oct 8 - Nov 30):

We started the recruitment process for the new members. After the filtration phase we held technical workshops by giving them sessions about ROV subsystems and performing tasks.

3. Missions Brainstorming (Nov 10 - Dec 15):

Our members in each team started brainstorming and analyzing the competition missions. Each team focused on understanding how the tasks could be accomplished, discussing possible mechanisms, control methods, and design ideas that would help the ROV perform the required missions efficiently.

4. Prototyping (Nov 25 - Feb 5):

The team started building initial prototypes and testing different components to ensure their reliability and performance.

5. ROV Manufacturing (Jan 15 - Mar 15)

The team focused on manufacturing and assembling the final ROV structure. During this phase, all mechanical parts were fabricated, electronic systems were integrated, and the complete system was assembled to ensure that the ROV was ready for testing and mission operations.

6. ROV testing & Pilot training (Mar 15 - Apr 22):

The team conducted extensive testing to evaluate the ROV's performance, ensure system reliability, and verify that all subsystems operated correctly and the Pilot tried how to control the ROV. We also made a simulation of this year's MATE tasks to provide a replica environment of the tasks the pilot will face in the competition.



Figure (49): Timeline for MATE ROV 2026

7.3. Resources

Resources:

To ensure timely project execution and foster interdepartmental collaboration, Penguins conducts weekly meetings on Thursdays. Each department leader shares their respective progress updates and raises challenges faced, enhancing transparency and teamwork. Also to enhance the communication & Planning methodology, we used Discord, ClickUp and Github.

Discord is for real-time communication features, bot automation, and voice/video call services, facilitates our weekly meetings and ensures live updates to all team members, enhancing communication and innovation.

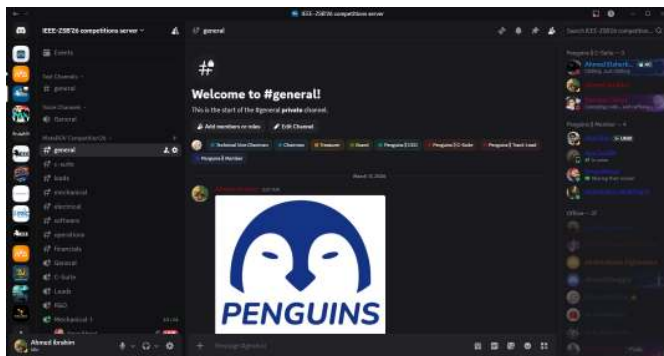


Figure (50): Penguins' Discord Server

ClickUp is for project management capabilities and task organization features, helps the team plan, track, and manage all project activities in one place.

GitHub is for managing and sharing the project's code. It allows team members to track changes, and review updates easily.

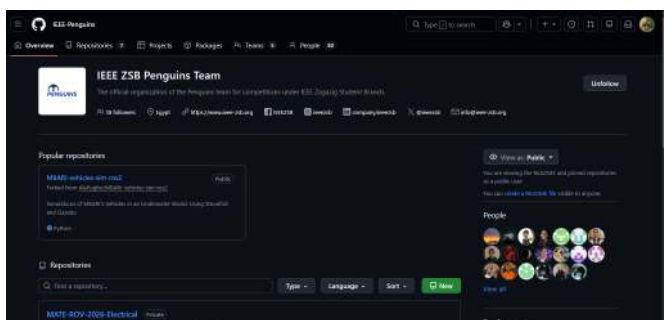


Figure (51): Penguins' Github Organization

7.4. Procedures & Protocols

Penguins team implements Agile development methodology. Team Board holds a weekly meeting to track the progress of the team, setting the upcoming week's goals and looking for opportunities we can go on. Alongside we hold another weekly meeting with sub-teams to track progress of each sub-team, problems they faced at the past phase, how to overcome them and what solutions could be made. Each sub-team leader manages the day-to-day updates at clickup to ensure all details are documented, all the deadlines are met and replanning their future goals alongside with the CTO's vision. At each sub-team meeting, all team members share their progress to the rest of the members, challenges they faced, solutions they implemented and resources. This approach enhances the collaboration of the team, encourages members to ask and discuss their thoughts and brainstorm ideas.

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9. Accounting

Penguins Underwater Robotics Team operates on a strict philosophy of financial efficiency and sustainable engineering. For the 2026 season, the true market value of our project—including the ROV, travel, and competition logistics—is evaluated at 150,000.00 EGP. However, through aggressive reclamation of legacy components and strategic manufacturing, our actual out-of-pocket expenditure has been limited to 19,265.57 EGP. By reusing high-value assets such as T100 thrusters, double-direction ESCs, and our core HDPE structural tubes, we offset over 40,000 EGP in potential structural and electrical costs. Our current operational spending is heavily focused on critical upgrades and logistics, allocating 9,000.00 EGP to power electronics, 10,000.00 EGP to structure and sealing, and 11,000.00 EGP toward local competition registration fees. The team's liquidity relies on a hybrid funding model, bolstered by 2,856.55 EGP in IEEE sponsorships and sustained by out-of-pocket contributions from dedicated team members, ensuring continuous development leading up to the competition. The detailed cost and projection are at [Appendix \(F\)](#) & [Appendix \(G\)](#).

Category	Name	Amount (EGP)	Amount (USD)
Sponsorship	IEEE Sponsored	2,856.55	54.51
Sponsorship	Student Care	21,000.00	400.76
Personal Contribution	Individual Payments (Team Members)	10,520.00	200.76
	Total Available:	34,376.55	656.04
Remaining Components	Total Budget	83,623.45	1,595.87
	Total Project Budget	118,000.00	2,251.91

Table (5): Available Funds

Budget Category	Example Items	Budgeted (USD)	Total Value* (USD)	2026 Spending (USD)
ROV Power Electronics	Thrusters, PCA9685, Connectors, Development Board, Webcams, Video Capture, Tether Cable	690.84	1,282.82	194.57
ROV Structure	CNC Parts, Manufacturing, Float Components, Bearings, Rods, Sealing Materials, Epoxy	190.84	572.52	136.26
Tooling & Equipment	Screws, Screwdriver, Clips, Drill Bits	19.08	15.27	3.82
Travel Expenses	Lodging and Transportation	591.60	887.40	0.00
Media and Marketing	Brochures, Marketing Display, Banners	47.71	47.71	47.71
Float	Tube, Motor, Buoyancy Engine, Battery, End Caps	95.42	108.02	96.37
Competition Fees	Pioneers Class Registration Fees	538.17	538.17	209.92
Total:		2,173.66	3,451.91	688.66

Table (6): Expenses

Budget Category	Example Item(s)	Total Est. Value (EGP)	Total Est. Value (USD)
Structure	Manufacturing, Tube, Screws, Bearings	2800	53
Electrical	Depth Sensor, ESP32, Stepper Motor, Buck Converter, Battery	2250	43
Total:		5050	96

Table (7): Float Cost

10. Appendices

A. Electrical SID

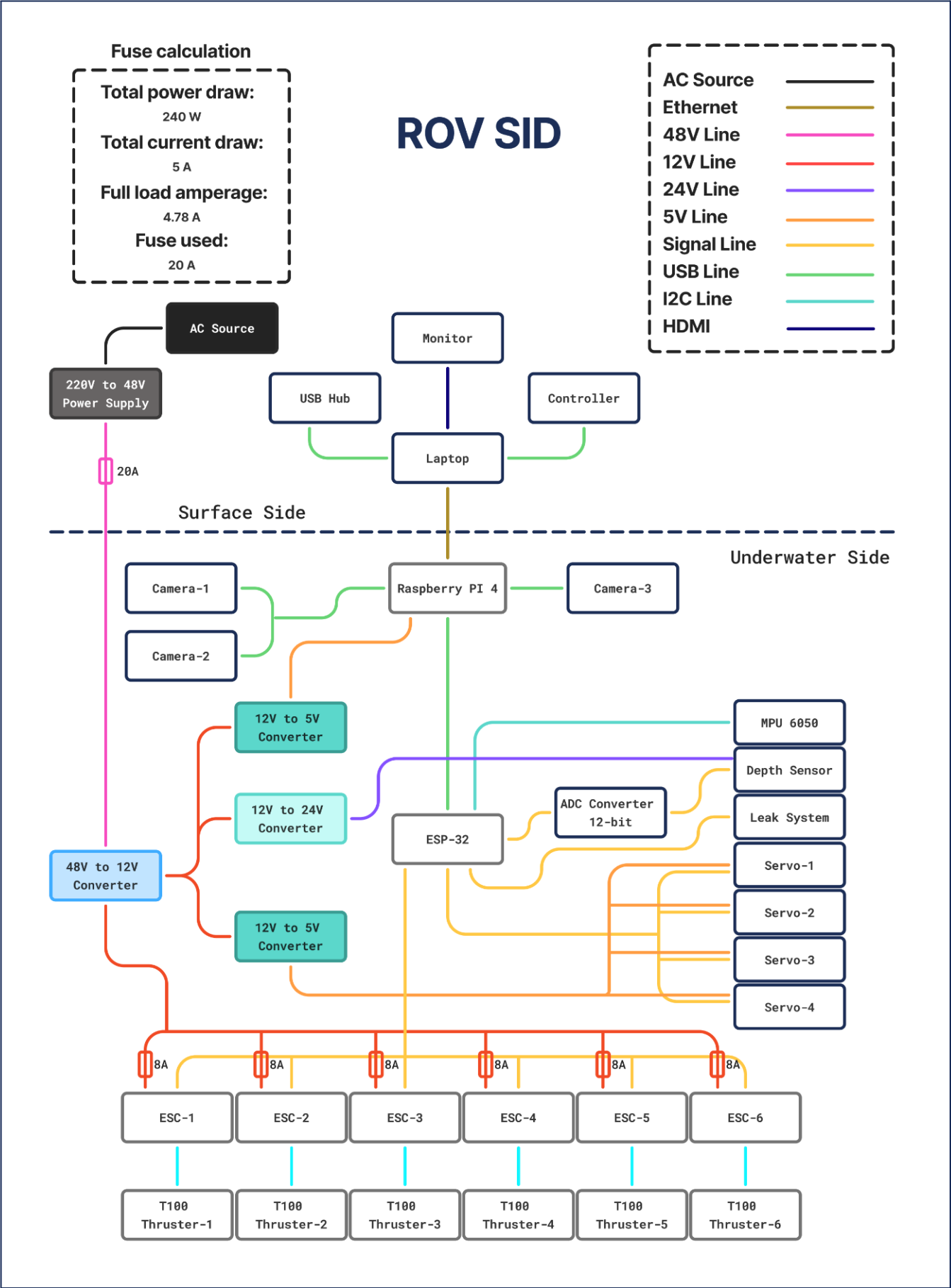


Figure (52): Electrical SID for Skipper 2.0

B. Software Data Flow

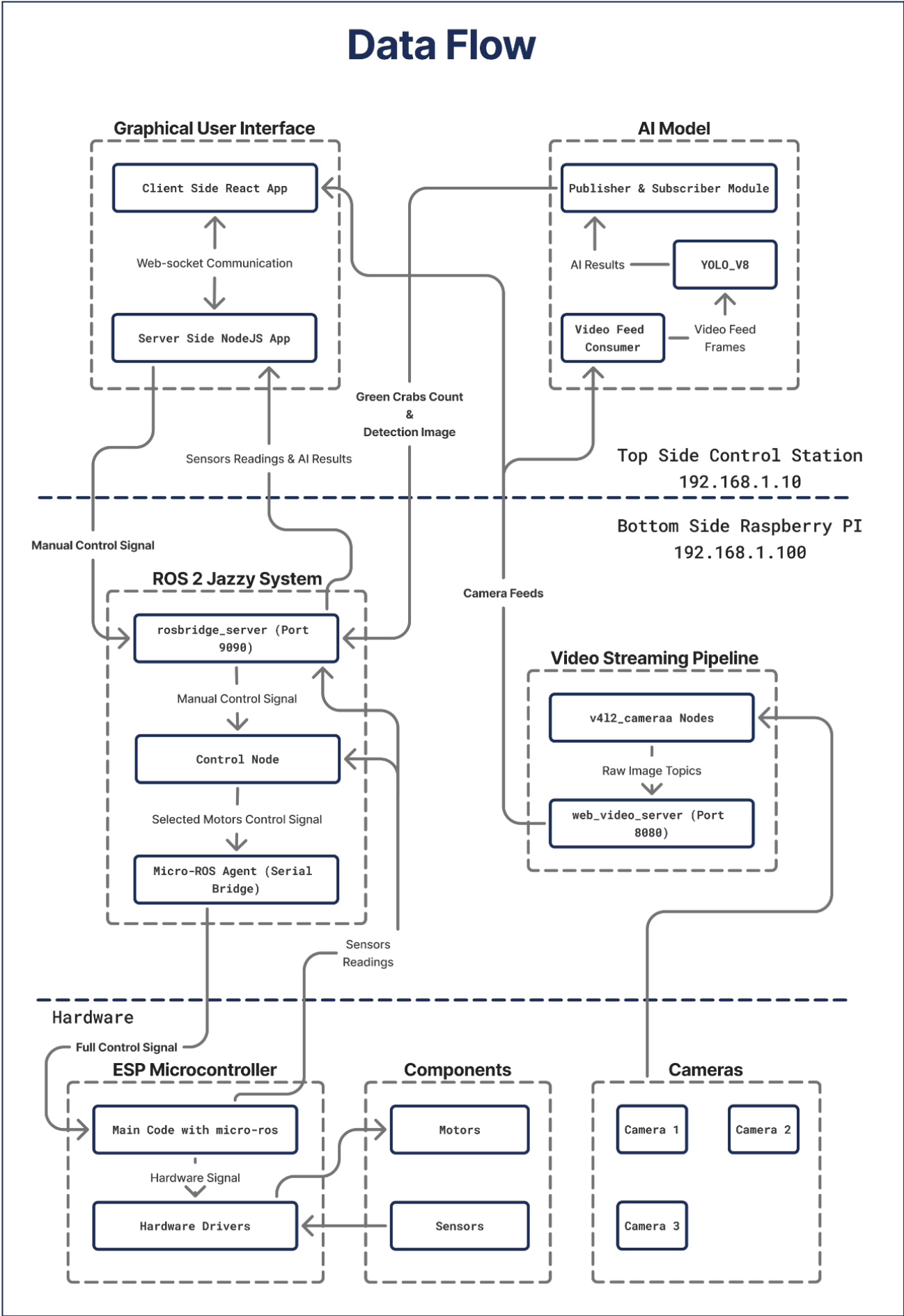


Figure (53): Data Flow Diagram

C. Company Structure

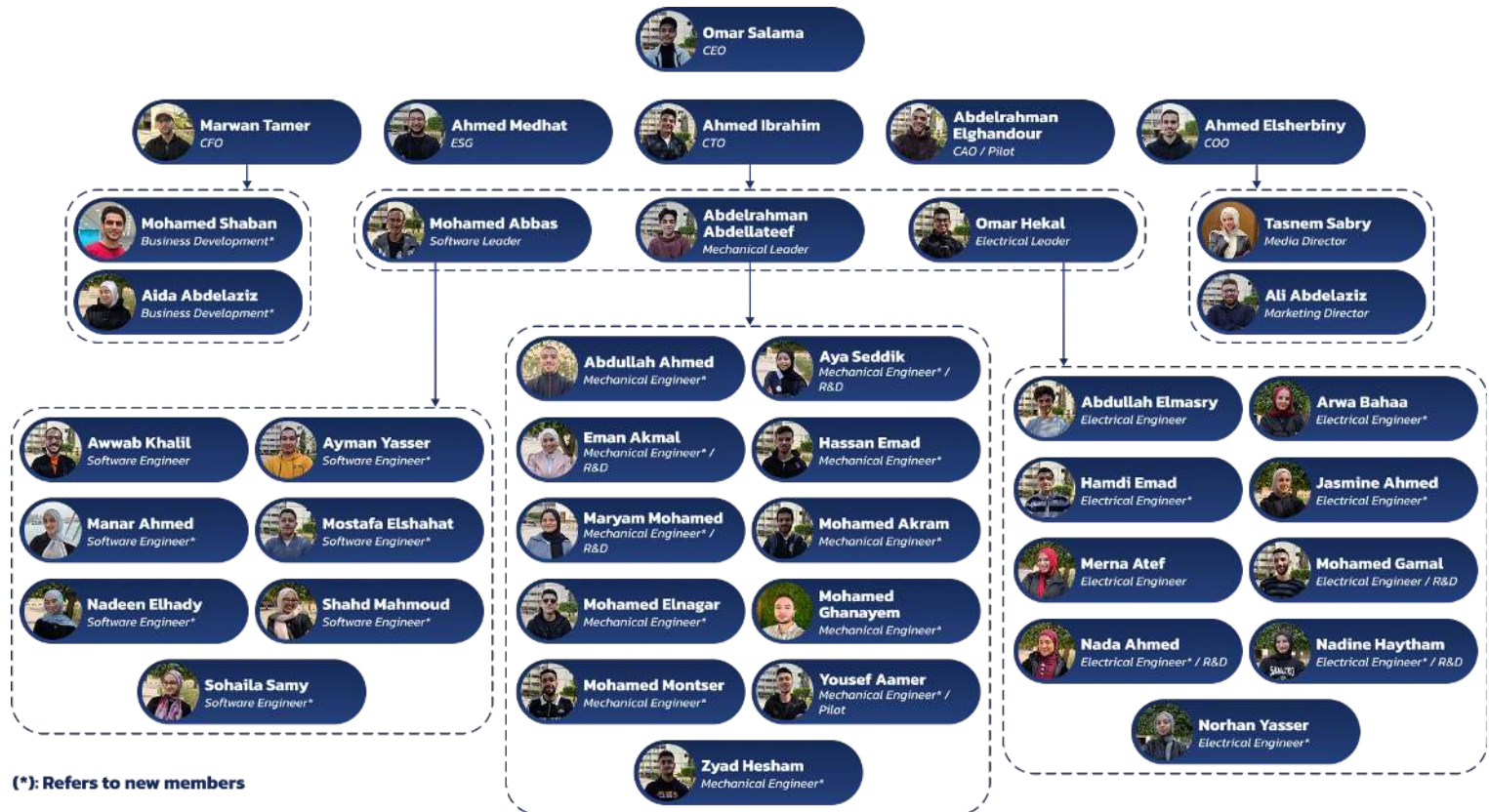


Figure (54): Company Structure

D. System Power Calculation

	Backward Ampere (A)		Forward Ampere (A)		Operating Voltage (V)	Average Power (W)
	Air	Water	Air	Water		
Motor 1	1.6	2.48	1.95	2.66	12	32
Motor 2	1.6	2.5	2.02	2.2	12	30
Motor 3	1.37	2.5	2.36	2.6	12	31.2
Motor 4	1.9	1.95	2.4	2.7	12	32.4
Motor 5	2.65	2.72	1.96	2.17	12	32.64
Motor 6	1.2	1.7	1.2	2.09	12	25.08
Servo sg 90	500 mA				5	0.5 A * 5 V * 2 (no. of servo) = 5
Servo mg 996r	2				5	2 A * 5 V * 2 (no. of servo) = 20
Depth Sensor	100 mA				24	0.1 A * 24 V = 2.4
Camera	250 mA				5	0.25 A * 5 V * 3 (no. of camera) = 3.75
Raspberry Pi 4	3				5	5 A * 3 V = 15
Total Power						229.47

Table (8): Power Calculations

E. Safety Checklist

Construction:

Workspace & Personal Safety

- ☐ Personal Protective Equipment (PPE): Wear safety goggles/face shields when cutting/grinding and use appropriate gloves.
- ☐ Ventilation: Perform soldering or practices involving toxic gases in well-ventilated areas.
- ☐ Tool Maintenance: Ensure all machinery and tools are inspected and are in good condition.
- ☐ Tool Checkout : Ensure all shared tools (soldering irons, drills) are properly powered down and logged back into the tool kit after the build session.
- ☐ Clean Environment: Keep the workspace clear
- ☐ Confirm all personnel are wearing correct attire (close-toed shoes, no loose clothing, and long hair tied back).

Electrical & Mechanical Assembly

- ☐ Battery Storage: Store batteries in designated fireproof containers.
- ☐ Pressure Tube Sealing:
- ☐ O-rings and grooves are clean, lubricated, and free of hair/debris.
- ☐ Pressure hold has no clouding or cracks.
- ☐ Wiring Integrity: Check that no wires are loose, disconnected, or exposed
- ☐ Energy Isolation: Ensure all power sources are isolated or de-energized before servicing.
- ☐ Microelectronics: Isolate low-voltage logic circuits (microcontrollers, sensors) from high-power thruster lines to prevent electrical surges.

Operation:

Pre-Deployment Test

- ☐ Poolside Safety: Clear the area of tripping hazards and ensure no personnel are running around the pool area.
- ☐ Tether Management: Ensure the tether is laid out neatly without knots or tangles
- ☐ Seal Verification: Perform a final visual inspection for leaks or loose parts and ensure the electronics housing is fully sealed.
- ☐ Site Transport: Secure the ROV frame, tether, and surface station electronics safely in transport cases before moving them to the competition site or pool deck.
- ☐ Kill Switch Test : Physically test the emergency "Kill Switch" on the surface control station to verify it immediately cuts power to the thrusters.

Power-Up & Systems Test

- ☐ Voltage Check: Confirm the system is receiving the correct nominal voltage
- ☐ Communication: Establish clear and audible communication protocols
- ☐ Functional Tests:
- ☐ Test camera functionality and sensor readings.
- ☐ Verify thruster movements correspond correctly with controller inputs.

In-Water

- ☐ Submergence Watch: Immediately check for bubbles; if large bubbles appear, pull the ROV to the surface immediately.
- ☐ Active Monitoring: Continuously monitor the tether to prevent entanglement with thrusters or external obstacles.
- ☐ The "Hands On/Off" Protocol: Pilot announces "READY FOR HANDS ON" before the handler touches the ROV.
- ☐ Poolside Tether Manager must follow designated tether management protocols to avoid entanglement.
- ☐ To minimize the risk of tripping, DO NOT run near the pool.

Post-Operation

- ☐ Loss of Communication: If signal is lost, power down the ROV/TCU immediately.
- ☐ Power Down: Announce "Crew in Command" once the system is fully powered down.
- ☐ Incident Logging : Document any safety violations, near-misses, or damaged components immediately to review for future team disciplinary actions

Table (9): Safety Checklist

F. ROV Total Cost

Type	Item / Description	Est. Value (EGP)	Est. Value (USD)
Frame & Structure			
Frame Components			
Reused	140 inner Diameter Artelon tube	3,000.00	\$57.25
Reused	Hard PVC Sheets Frame	1,000.00	\$19.08
Frame Components Subtotal		4,000.00	\$76.34
Raw Materials			
Purchased	4Kg HDPE (Artelon) Sheets	500	\$9.54
Purchased	1m Stainless steel Rods	99	\$1.81
Purchased	2Kg Acrylic Sheets	400	\$7.63
Raw Materials Subtotal		999	\$18.99
Structural Hardware			
Reused	1/2 Inch Metal Clamp kit	14	\$2.69
Reused	Big Metal Zipties	60	\$1.15
Purchased	Lead Screw Size 8mm	123.75	\$2.36
Purchased	Micro Pan/Tilt Servo Bracket SG90	22.5	\$0.43
Reused	PG7 Gland	70	\$1.34
Purchased	Bolts & Nuts	500	\$9.54
Structural Hardware Subtotal		917.25	\$17.50
Frame & Structure Total		5,912.25	\$112.83
Waterproofing & Sealing Total			
Adhesives & Epoxy			
Purchased	Epoxy	637.5	\$12.17
Purchased	Black Paste	330	\$6.30
Purchased	Silicon	237.5	\$4.53
Waterproofing & Sealing Total		1,205.00	\$23.00
Manufacturing Services			
CNC Machining			
Manufactured	Gripper Manufacturing	1600	\$30.53
Manufactured	Acrylic Parts Manufacturing	1000	\$19.08
Manufactured	Camera Sealing Box	750	\$14.31
Manufactured	Artelon Manufacturing	400	\$7.63
CNC Machining Subtotal		3350	\$63.93
Manufacturing Services Total		3,750.00	\$71.56
Propulsion System			
Thrusters			
Reused	T100 Thruster	30,000.00	\$572.52
Reused	Double Direction ESC	5,700.00	\$108.78
Thrusters Subtotal		30,000.00	\$572.52
Propulsion System Total		35,700.00	\$681.30
Electronics & Control			
Cameras & Vision			
Purchased	AUKEY FHD 1080p Webcam (x2)	1,625.64	\$31.02
Purchased	Raspberry Pi 4 Camera	500.00	\$9.54
Cameras & Vision Subtotal		2,125.64	\$40.57
Connectors & Wiring			
Reused	25m Power Cable	1,200.00	\$22.90
Purchased	30m CAT6 Tether cable	750	\$14.31
Purchased	GX16 Chassis Connectors (Male-Female)	270	\$5.15
Purchased	Connectors, Data Headers and Cables	158.75	\$3.03
Purchased	Wire, Heat shrink 5mm, Fuses, Capacitors	62.5	\$1.19
Connectors & Wiring Subtotal		2,441.25	\$46.59
Microcontrollers & Computers			
Reused	ESP32 Microcontroller 30pins	300	\$5.73
Purchased	Raspberry Pi 4 + kit	6500	\$124.05
Microcontrollers & Computers Subtotal		6800	\$129.77
Electrical & Power Components			
Reused	Power supply 12v 30A x4	1600	\$30.53
Purchased	SG90s servo motor 180deg x2	210	\$4.01
Purchased	MG996R servo motor 360deg x2	420	\$8.02
Purchased	XL4016 DC-DC Buck Converter 8A	165	\$3.15
Reused	DC-DC Converter (48V to 12V)	1800	\$34.35
Reused	DC-DC Converter (48V to 5V) x2	130	\$2.48
Purchased	Boost Converter x2	100	\$1.91
Reused	30Watt LEDs	70	\$1.34
Reused	1-Channel Relay Module	60	\$1.15
Electrical & Power Systems Subtotal		4555	\$86.93
Sensors			
Purchased	ADS1115 - 16 Bit I2C ADC	275	\$5.25
Reused	MPU-6050	135	\$2.58
Reused	Depth Sensor	1,300.00	\$24.81
Sensors Subtotal		1,710.00	\$32.63
Electronics & Control Total		17,631.89	\$336.49
Research & Prototyping			
Testing Equipment			
Rental	Pool	4000	\$76.34
Testing Equipment Subtotal		4000	\$76.34
Research & Prototyping Total		4000	\$76.34
TOTAL PROJECT COST		68,199.14	\$1,301.51

Table (10): ROV Total Cost

G. Cost Projection

Item Name	Projected (USD)	Projected (EGP)	Actual Paid (USD)	Actual Paid (EGP)	Status
Income					
IEEE Sponsored	51.03	2673.972	51.03	2673.972	Received
Individual Payments (Team Members)	194.58	10195.992	194.58	10195.992	Received
Student Care	687.5	36000	400.7	21000	Partially Received
Total income	933.11	48894.964	646.31	33866.644	
Production Expenses (Detailed)					
Actuation - Servos & Manipulators					
MG90s Servo, Mg996R Servo 180deg, and Servo motor MG996R 360deg	29.77	1559.948	0	0	Not Purchased
Servo Extenders	6.3	330.12	0	0	Not Purchased
Actuation - Servos & Manipulators Subtotal	36.07	1890.068	0	0	
Buoyancy - Floatation System					
Float Components	27.18	1424.232	27.18	1424.232	Purchased
Buoyancy - Floatation System Subtotal	27.18	1424.232	27.18	1424.232	
Electronics - Components & PCB					
LED Indicator Lights	1.43	74.932	0	0	Not Purchased
Push Button Switches	1.14	59.736	0	0	Not Purchased
Relay Module 5V	2.67	139.908	0	0	Not Purchased
PCB Components and Fabrication	64.84	3398.664	0	0	Not Purchased
Electronics - Components & PCB Subtotal	70.08	3673.24	0	0	
Electronics - Connectors & Wiring					
GX16-2 Connector (x2)	0.95	49.78	0.54	28.296	Purchased
GX16-3 Connector (x10)	5.15	269.86	0.54	28.296	Purchased
JST Connectors (Various)	0.04	2.096	0.03	1.572	Purchased
GX16-8 Connector (x2)	1.45	75.98	0	0	Not Purchased
Soldered Cables, Insulated Wires, and Heat Shrink	27.95	1464.58	0	0	Not Purchased
Terminal Block Connectors	1.62	84.888	0	0	Not Purchased
Cables (Micro HDMI and Generic), Cable sleeves, and Ethernet Cable CAT6 50m	77.17	4043.708	14.31	749.844	Purchased
Electronics - Connectors & Wiring Subtotal	114.33	5990.892	15.42	808.008	
Electronics - Microcontrollers & Sensors					
ADS1115 16-Bit ADC (x2)	10.49	549.676	3.93	205.932	Purchased
PCA9685 16-Channel Driver	8.01	419.724	3	157.2	Purchased
MPU 9265 Gyroscope	14.31	749.844	0	0	Not Purchased
Raspberry Pi 4 and Heatsink Kit	120.85	6332.54	0	0	Not Purchased
ESP32 38 Pins (x3)	20.03	1049.572	0	0	Not Purchased
Bluetooth Module HC-05	3.82	200.168	0	0	Not Purchased
MPU 9265 (Float)	14.31	749.844	0	0	Not Purchased
Depth Sensor	25.75	1349.3	0	0	Not Purchased
Electronics - Microcontrollers & Sensors Subtotal	217.57	11400.668	6.93	363.132	
Electronics - Power Systems					
Buck Converter 8A (x2), Buck Converter 12v-5v, and Waterproof Converter 48v to 12v 20A	45.02	2359.048	0	0	Not Purchased
220v AC to 12v DC Supply and Power Supply 12v 10A	18.12	949.488	0	0	Not Purchased
Voltage Regulator 12V to 5V	3.43	179.732	0	0	Not Purchased
12v 6A Battery	10.49	549.676	0	0	Not Purchased
Electronics - Power Systems Subtotal	77.06	4037.944	0	0	
Electronics - Video & Communication					
HDMI Adapter	0.57	29.868	0.43	22.532	Purchased
4K Video Capture Card	4.96	259.904	6.47	339.028	Purchased
AUKEY Webcam (x2), Generic Webcam, and USB Hub	116.86	6123.464	31.01	1624.924	Purchased
Camera Sealing box (manufacturing + material)	76.31	3998.644	0	0	Not Purchased
Electronics - Video & Communication Subtotal	198.7	10411.88	37.91	1986.484	
Mechanical - Fasteners & Hardware					
Stainless Steel Bolts M4	2.29	119.992	0	0	Not Purchased
Nylon Washers Kit	0.86	45.064	0	0	Not Purchased
Sealing tools (Epoxy, Silicon, Screws, Nuts)	57.23	2998.852	12.3	644.52	Purchased
Mechanical - Fasteners & Hardware Subtotal	60.38	3163.912	12.3	644.52	
Mechanical - Frame & Structure					
Acrylic Sheets Clear 3mm and Aluminum Profile Extrusion	17.74	929.576	0	0	Not Purchased
Frame Manufacturing and optimization	19.08	999.792	0	0	Not Purchased
HDPE (Rtlone) Material and Manufacturing	58.09	3043.916	6.3	330.12	Purchased
Acrylic Tube	133.54	6997.496	3.43	179.732	Purchased
Manufacturing (General)	57.23	2998.852	0	0	Not Purchased
Mechanical - Frame & Structure Subtotal	285.68	14969.632	9.73	509.852	
Mechanical - Sealing & Waterproofing					
O-Ring Seal Kit	7.25	379.3	4.67	244.708	Purchased
Grippers (servo sealing, mechanism)	114.44	5997.704	0	0	Not Purchased
Mechanical - Sealing & Waterproofing Subtotal	121.71	6377.604	4.67	244.708	
Other Components					
Electrical Components	1.34	70.216	1.34	70.216	Purchased
EMI Noise Filters (3/5/7mm)	1.24	64.974	0	0	Not Purchased
Other Components Subtotal	2.58	135.192	1.34	70.216	
Pneumatics - Air System					
Air Components (Hoses, Valves)	38.15	1999.04	0	0	Not Purchased
Pneumatics - Air System Subtotal	38.15	1999.04	0	0	
Propulsion - Thrusters & ESC					
T200 Thruster (x2) and ESC Bi-Directional	906.15	47482.26	0	0	Not Purchased
Propulsion - Thrusters & ESC Subtotal	906.15	47482.26	0	0	
Sensors - Mission Specific					
PH Sensor	32.43	1699.332	0	0	Not Purchased
Sensors - Mission Specific Subtotal	32.43	1699.332	0	0	
Tools & Consumables					
Desoldering Wick	3.15	165.06	3.15	165.06	Purchased
CNC Machined Parts	5.72	299.728	5.72	299.728	Purchased
Soldering Flux 250ML	6.68	350.032	0	0	Not Purchased
Tools & Consumables Subtotal	15.55	814.82	8.87	464.788	
Total production expense	2,203.64	115,470.74	124.35	6515.94	
Financial Summary					
Total Income Available	933.11	48894.964			
Total Projected Expenses	2,203.64	115,470.74			
Total Actual Paid	124.35	6515.94			
Remaining Budget Needed	1,270.53	66,575.77			

Table (11): Cost Projection