



MARINE XPERTS

BEYOND THE HORIZON,
INTO THE DEPTHS.



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ABSTARCT

MarineXperts is an engineering company founded in 2023 at the Arab Academy for Science, Technology and Maritime Transport Alamein Branch, dedicated to developing practical marine engineering solutions. For the MATE ROV Competition 2026, whose theme focuses on operations in cold and ice-influenced marine environments of the cryosphere, the company presents ORCA, an upgraded evolution of the team’s previous competition ROV. Building on lessons learned from the previous season, ORCA incorporates targeted design improvements to enhance performance, reliability, and mission effectiveness. Inspired by the strength, intelligence, and adaptability of the orca, the vehicle reflects precision, control, and efficiency through a streamlined, mission-driven engineering approach. The result is a robust, competition-ready ROV developed in alignment with professional engineering practices.

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01.Teamwork

1.1 Project Management

- Phase1: Initiation

In the initiation phase, we defined the objectives and features of the ROV based on the needs of underwater engineering and research. The goal was to design a vehicle capable of safely performing inspections, maintenance, and data collection in underwater environments, minimizing the risk to human divers. These objectives guided the selection of components, system functionality, and overall design approach, ensuring the ROV could meet the expected challenges of the competition.

- Phase2: Planning

During the planning phase, a clear organizational structure was established to ensure efficient workflow and accountability across all technical and administrative activities. The Chief Executive Officer (CEO) is responsible for overall leadership, strategic direction, and supervision of all departments. The Chief Financial Officer (CFO) oversees budgeting, cost control, and resource allocation to ensure financial sustainability throughout the project lifecycle. Department heads are responsible for detailed task planning, technical decision-making, and coordination within their respective teams. Team members execute assigned tasks, contribute to subsystem development, participate in testing procedures, and support system integration.

PERSON	ROLE
CEO	Leads the team and oversees all departments.
CFO	Manages the budget and resources.
HEADS	Plan work, supervise their teams, and coordinate with others.
MEMBERS	Do assigned tasks, support testing, and help integrate systems.

Figure1: Team organization table

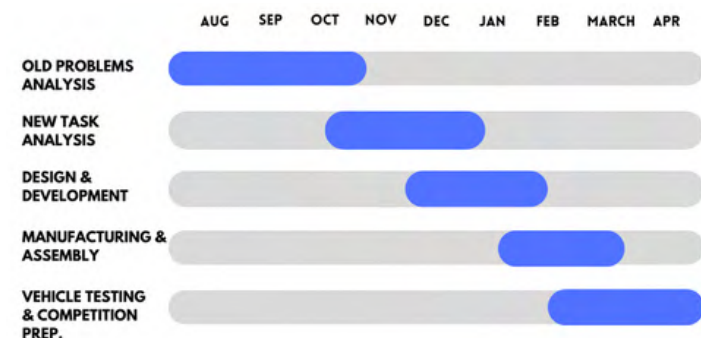


Figure2: Project Timeline

A comprehensive project timeline was developed using a Gantt chart to define task sequencing, dependencies, and deadlines. The schedule covers all major stages, beginning with research and technical review, followed by subsystem design, manufacturing, assembly, integration, testing, and final validation. Key milestones include the completion of subsystem designs, full vehicle assembly, successful dry and wet testing phases, and final competition readiness preparation.

The project budget (explained in details in the accounting section) was structured to prioritize essential materials, components, manufacturing processes, and testing requirements. Financial planning was aligned with the project timeline to ensure that all critical resources were available when needed, minimizing delays and maintaining steady progress toward competition objectives.

- Phase3: Risk Planning

During this phase, potential technical, financial, and operational risks were systematically identified and evaluated. Each risk was analyzed in terms of its possible impact on performance, schedule, and safety. Appropriate mitigation strategies were defined to reduce the likelihood and severity of these risks.

A detailed Risk Mitigation Table outlining identified risks, potential impacts, and corresponding mitigation strategies is provided in Appendix E.

- Phase4:Execution

The execution phase focused on implementing the approved designs while maintaining coordination across all departments. Communication is primarily conducted through in-person meetings on campus to ensure efficient technical discussions and decision-making. In addition, a structured Discord platform is used with dedicated channels for each department, enabling organized communication through both text and voice.

Task allocation and progress tracking are managed through Trello, where responsibilities and deadlines are clearly defined. All technical documents, design files, and shared resources are stored in a centralized cloud drive to maintain accessibility and version control. Resource allocation follows the approved budget and schedule to prevent delays during manufacturing and testing.

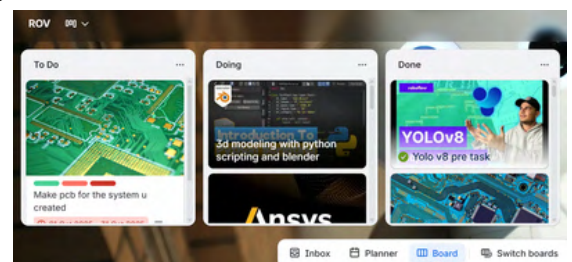


Figure3: MarineXperts Trello Platform

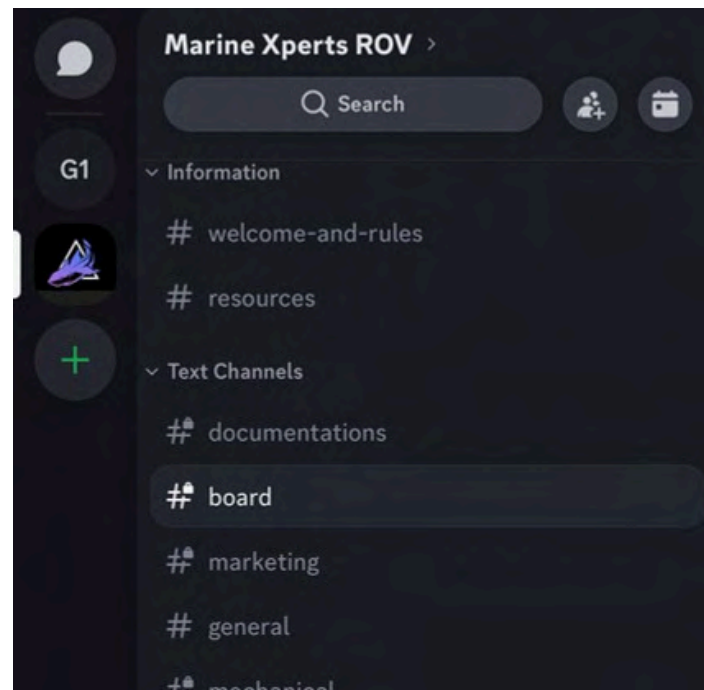


Figure4: MarineXperts Discord Platform

• Phase5:Quality Assurance

The Quality Assurance phase ensures that the vehicle meets all defined technical, operational, and safety requirements prior to final approval. Each subsystem is verified against design specifications, and the integrated system undergoes controlled functional and performance testing. Acceptance criteria assess operational stability, waterproof integrity, electrical safety, and mechanical reliability. Any non-conformities are documented, corrected, and re-tested before approval. Inspections during assembly confirm proper installation of structural, sealing, and electrical components. Dry and controlled wet tests evaluate propulsion, maneuverability, control response, sensor functionality, communication stability, depth tolerance, and operational endurance. Electrical systems are verified for insulation integrity, voltage regulation, current protection, and overall safety. All results are documented to maintain traceability, and deployment is authorized only after full compliance is achieved.

• Phase6:Closing

The Closing phase marks formal project completion following successful validation and approval. A final readiness review confirms compliance with competition and internal engineering requirements. All technical documentation, test records, and configuration data are finalized and archived. The project is formally closed after internal evaluation, team debriefing, and documentation of lessons learned to support continuous improvement in future development cycles.

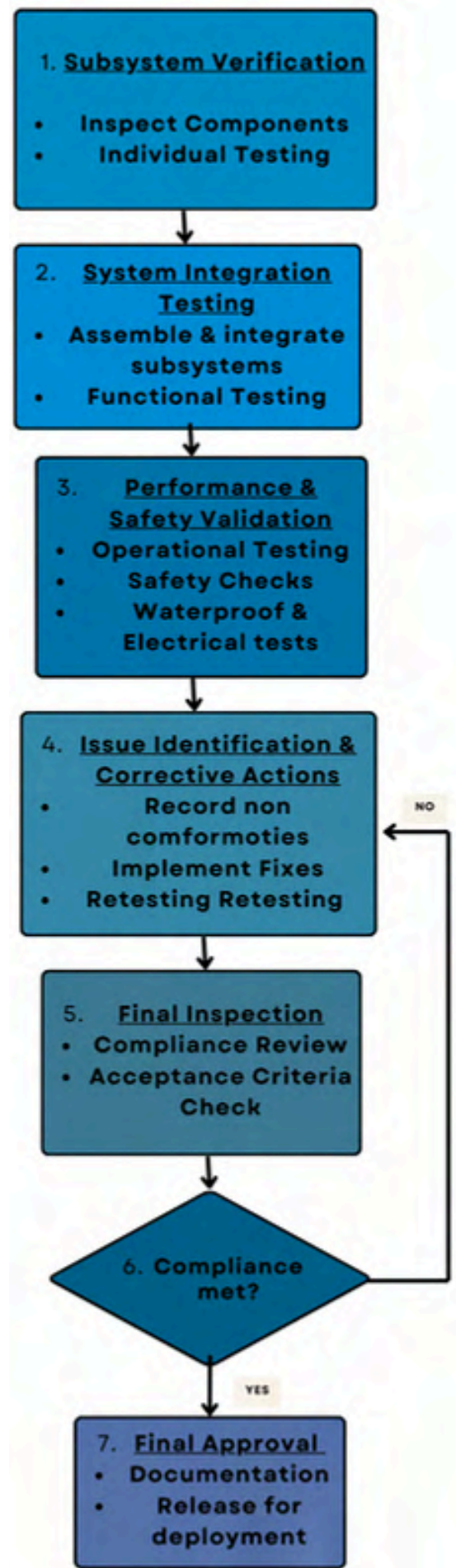


Figure5: Quality Assurance & Closing Flowchart

02.Design Rationale

2.1 Engineering Design

- Design Overview

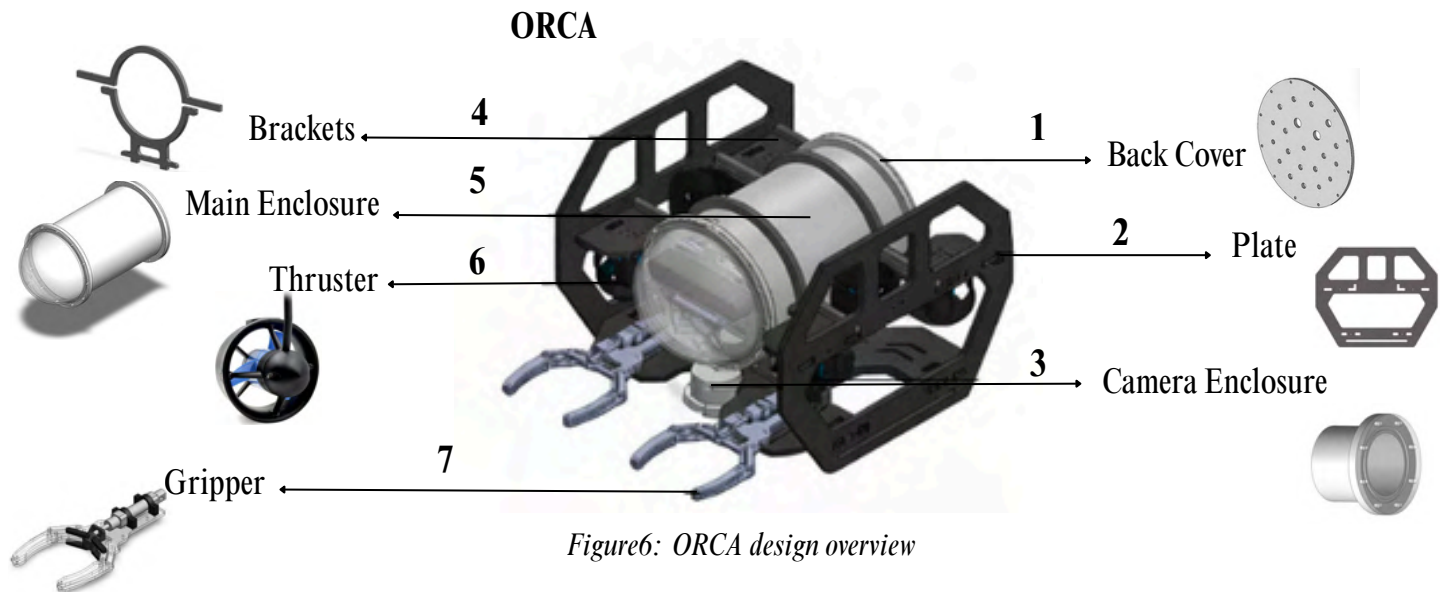


Figure6: ORCA design overview

Orca is a purpose-driven remotely operated vehicle developed by the MarineXperts team to compete in the 2026 MATE ROV Competition, where the focus is on real-world engineering solutions that support exploration, monitoring, and protection of challenging aquatic environments particularly those associated with the cryosphere and harsh, cold-water conditions as emphasized by this season's theme of advancing cryospheric science and technology. Designed with reliability, adaptability, and task effectiveness in mind, Orca embodies a balanced integration of mechanical, electrical, and control systems that allow the team to meet diverse mission requirements with operational precision while showcasing innovation, teamwork, and engineering excellence.

Orca features a streamlined and robust mechanical design that integrates all functional subsystems for underwater operations. At the core of the vehicle is the main enclosure, which houses the electronics, including the ZED camera for stereo vision and two Hikvision cameras for additional visual feedback. To enhance situational awareness, two dedicated camera enclosures are positioned on the ROV: one monitoring the rotating mechanism and the other providing a downward view.

Two pneumatic two-claw grippers, operated via directional control valves, provide additional versatility for handling tasks and interacting with the environment.

Propulsion is provided by six T200 Blue Robotics thrusters, enabling maneuverability in 4 degrees of freedom.

Structural support is provided by three plates two side plates and one lower plate that carry the thrusters and grippers, while custom brackets connect these plates to the main enclosure, ensuring mechanical stability. The aluminum back cover serves both as structural reinforcement and heat dissipation for onboard electronics, with provisions for cable glands and secure tether connections.

This mechanical configuration balances robustness, modularity, and functionality, forming a strong foundation for Orca's operational performance and adaptability in various underwater missions.

All dimensions are in cm

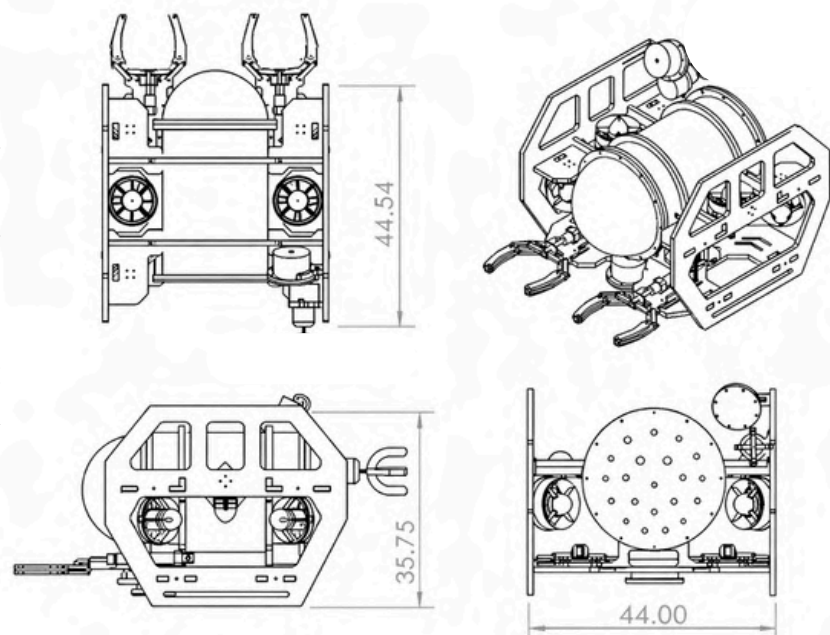


Figure7: Four views and dimensions of ORCA

• Planning & Design Process

ORCA derives lessons from earlier iterations of the ROV, which enables the ROV team to focus on improving related attributes including reliability, maneuverability and task efficiency, while satisfying the MATE mission goals entirely. A concurrent engineering process was instituted; where all aspects of the vehicle's life cycle, including design, prototyping, testing and maintenance, were considered at the same time. This process assures that all the areas of vehicle development (performance, integration and reliability) are balanced during the development process. The design process involves the following critical stages:

1. Identifying the Problems and Constraints

Our team reviewed the MATE RFP, along with information from previous years' competitions, to determine the primary operational challenges involved in the MATE competition today. The following challenges were identified; namely, performing precise maneuvers in cramped spaces; operating effectively and efficiently with respect to the manipulation of objects; structural integrity of the vehicle at depth underwater and situational awareness for the ROV operator. In terms of constraints on the vehicle's design, the limiting factors include the dimensions of the vehicle; the maximum allowable weight; the total budget; the availability of parts or components; and the complexity of the ROV's systems. Also, with respect to this stage of the design process, the team was able to identify the points of failure in the ROV that will require redundancy or an alternative means of control.

2. Develop Ideas

As part of collaborative design sessions, the team has developed and evaluated numerous alternative Propulsion Layout, Frame Geometry, and Manipulation Systems Concepts. Some concepts were evaluated with single/double grippers articulated by manipulators. Trade-off studies were completed using the basic criteria of feasibility, expected performance, hydrodynamic efficiency, ease of integration, and maintainability criteria. The team evaluated structural layouts to establish satisfactory mass distribution, stability, and to protect internal components. Each Concept was critically evaluated against Design Priorities which included the efficiency with which tasks are accomplished, reduction in pilot workload, and modularity.

3. Create a Design and Manufacturing

The team selected Concepts to develop into CAD Models/prototypes. The concept of cost-effectiveness, manufacturability, and performance were analyzed during the design and prototyping processes. The frame of the prototype was optimized for rigidity with as little mass as possible, giving the frame a streamlined shape which decreased drag and increased stability of the vehicle. The positioning of thruster units allowed for translational/rotational motion with as little interference as possible, while still allowing for independent operation. The Dual front-mounted grippers were prototyped and tested for the potential to stable/efficiency grasp a variety of mission objects with stability and precision. The modular nature of component designs facilitated assembly and repair

of components and allow for future upgrades to the vehicle.

Component	Manufacturing Process
Frame	CNC Routing
End Cap	CNC Laser Cutting
Grippers	CNC Laser Cutting
Gripper Connectors	3D Printing
Dome	Vaccum Forming
Enclosure	Lathe Machining

Figure8: Manufacturing Processes

4. Testing and Iteration

Prototypes went through extensive testing in both controlled and realistic underwater environments. Measurements were collected to evaluate the thruster efficiency, vehicle stability and performance of manipulations performed with the vehicle. Based on data collected from tests, modifications to the design of the vehicle were made using trial and error. These modifications included adjusting the orientation of the thruster, improving the mechanics of the gripper and changing the arrangement of the internal components. Latency of Cameras and sensor data, field of view coverage, and usability for the pilot were tested to ensure that the pilot had accurate situational awareness of surroundings. By utilizing an iterative cycle of testing and redesign, risk was reduced, reliability was increased, and performance of the overall tasks were improved.

5. Final Integration

The finalized configuration of ORCA represents the convergence of the design objectives identified throughout the planning and development phases. The vehicle adopts a six-thruster configuration to enable full four-degree-of-freedom motion, ensuring accurate positioning, stable station-keeping, and controlled maneuvering during mission execution. Dual front-mounted grippers were integrated to enhance task versatility and minimize the need for frequent vehicle repositioning. The structural frame was fabricated from German Artillon, selected for its high strength-to-weight ratio and reliability in submerged environments. The overall geometry of the frame was refined to achieve a balanced mass distribution while minimizing hydrodynamic drag, thereby safeguarding internal subsystems and improving vehicle stability. Integrated cameras and sensor systems provide continuous real-time feedback to the operator, enhancing situational awareness and reducing pilot workload during complex operations.

2.2 Innovation & Problem solving

Design 1



MAKO



ORCA



Figure9: The evolution of ORCA

Innovation without problem-solving is creativity without direction, and problem-solving without innovation becomes repetition without progress. Our development journey combined both. The evolution of our ROV began not with success, but with incompatibility. Design 1 was our initial attempt at building a competitive underwater system. While ambitious, it lacked the structural and mechanical maturity required for competition standards. The frame provided limited surface area for mounting manipulators, restricting functional adaptability. Thruster placement was not aligned with the calculated center of gravity, resulting in inefficient thrust vectors and unstable maneuverability. Structural analysis also revealed stress concentration areas, indicating weak load distribution and potential vulnerability under operational forces. This design did not qualify for competition, but it became our first true exercise in engineering problem-solving. Instead of abandoning the concept, we analyzed it. Structural weaknesses, integration flaws, and system inefficiencies were identified and converted into measurable engineering parameters. From this analysis, Mako was developed. Mako represented clear progress. The frame geometry was expanded to increase usable mounting space, enabling the integration of a pneumatic gripper and improved thruster positioning. Structural integrity was significantly enhanced, allowing the system to compete successfully and achieve third place. However, real engineering maturity comes from field validation. During competition, new challenges appeared. A single gripper limited multitasking capability, buoyancy required frequent adjustment due to density inconsistencies, and minor thruster misalignment produced small rotational instabilities. These observations became engineering data. Orca was developed as a direct response to them. The integration of dual pneumatic grippers improved manipulation efficiency, while the use of higher-quality German Artelon enhanced structural consistency and buoyancy stability. Thruster placement was

recalculated to align with the center of mass, minimizing unwanted pitch and roll. Additionally, removing the top weight plate reduced overall mass and hydrodynamic resistance, improving maneuverability and energy efficiency. This progression reflects a continuous engineering cycle: Design 1 exposed structural incompatibilities, Mako demonstrated competitive capability, and Orca transformed operational challenges into engineered solutions.

2.3 Systems Approach

Orca was developed using a capability-driven, model-based systems engineering approach. Mission requirements were translated into functional system capabilities including controlled mobility, vision-based perception, and dual-manipulator task execution. The vehicle achieves four Degrees of Freedom (DOF): surge (forward/backward motion), sway (left/right motion), heave (vertical motion), and yaw (rotational motion about the vertical axis) enabling precise underwater positioning and alignment during mission tasks. A digital twin of Orca was developed to evaluate system performance prior to physical testing. The virtual model was used to analyze thrust vector distribution across the 4 DOF, assess stability through center of gravity and center of buoyancy alignment, and verify maneuverability under simulated mission conditions. Additionally, the digital environment supported validation of camera field-of-view alignment, midpoint estimation accuracy, and manipulator workspace limits. This predictive methodology reduced iterative redesign, minimized operational risk, and ensured performance validation before hardware deployment.

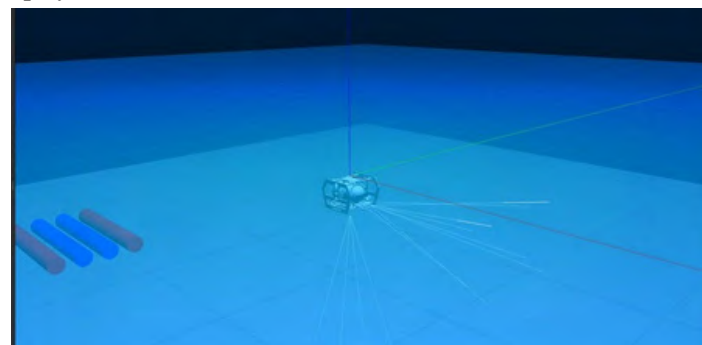


Figure10: ORCA digital twin

2.4 Vehicle Structure

Component	Orca (2026)
Frame	4698 g
	$3426.64 \times 10^{-6} \text{ m}^3$
Grippers	338 g
	$400 \times 10^{-6} \text{ m}^3$
Enclosure	1500 g
	0.0134 m^3
Mini Enclosure	120 g
	$3.18 \times 10^{-4} \text{ m}^3$

Figure11: Weight & Volume Table

Orca's design represents a calculated balance between material volume, mass, and mechanical resilience. By optimizing the frame's specific volume ($3426.64 \times 10^{-6} \text{ m}^3$) through strategic cutouts, the frame mass was minimized to 4.698 kg, directly enhancing the ROV's overall power-to-weight ratio and underwater agility. Crucially, the stress analysis (provided in Appendix F) validates that this aggressive reduction in frame material does not compromise the vehicle's structural integrity; with maximum operational stresses remaining below 10.49 MPa, the design ensures a high safety factor while maintaining the lightweight, low-drag characteristics essential for mission success.

2.5 Vehicle Systems

Vehicle systems were built using materials and components chosen for performance, reliability, and cost. Corrosion resistance, strength, weight, and underwater suitability guided material selection, while components were selected for function and compatibility. Reused parts reduced costs, and new parts added necessary capabilities.

Part	material	Price (per sheet)	Density	Thermal conductivity
Main frame	Artelon	18200 EGP	1.12 g/cm ³	Extremely low
Enclosure	Artelon	18200 EGP	1.12 g/cm ³	Extremely low
Rear enclosure panel	Aluminum	1360 EGP	2.7 g/cm ³	High
Front enclosure panel	Acrylic	4500 EGP	1.18 g/cm ³	Extremely low
Front enclosure panel	Artelon	4500 EGP	1.18 g/cm ³	Extremely low

Figure12: Material Selection

Component	Used for	Status	Selection Rationale	Quantity
ARDUINO NANO	dcv and cytron signals	reused	enough for simple signals (dcv, cytron)	1
BUCK(48-12)	power under water	reused	12V system design good for our components selection	4
BUCK(48-19)	Jetson orinn power	new	needed cause jetson use 19V to handle our system	1
BLUEROBOTICS ESCS	Motors control	reused	good compatible with our thruster	6
T200 THURSTER	Motors (motion)	reused	provide good thrust for power provided	6
jetson orinn super developer	compoter board for all algorithms	new	lacing the jetson nano because it couldn't handle zed cam	1
zed 2i	camera for vision and 3d	reused	powerful camera for 3d models and scans	1
DCV	Gripper control	reused + new(1)	added one because of new gripper for competition	2
CCTV	blind points vision	reused+new(1)	added one for more vision in the pool	4
pixhawk	escs control	reused	powerful board for control no need to replace	1

Figure13: Component Selection

2.6 Propulsion

The propulsion system consists of six T200 thrusters, selected for their proven reliability and high thrust efficiency. Two horizontal thrusters are integrated directly into the side plates of the frame. This placement is intentionally close to the vehicle's center of gravity (CG), a critical design decision that significantly enhances stability and maneuverability by minimizing unwanted rotational moments. Embedding the thrusters within the frame profile maintains a compact design, reducing hydrodynamic drag and improving the overall efficiency of the vehicle's movement through the water.

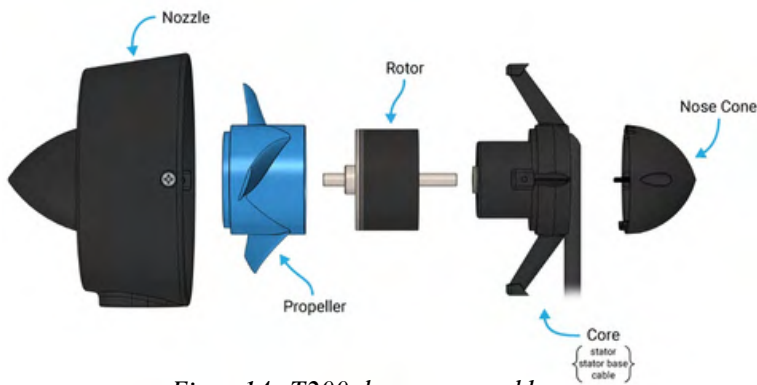


Figure14: T200 thruster assembly

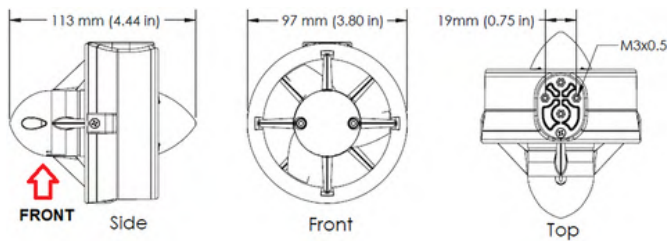


Figure15: T200 Thruster Dimensions

The propulsion configuration of ORCA is designed to provide four controlled degrees of freedom (4-DOF), enabling precise maneuverability in underwater environments. The six T200 thrusters are strategically positioned to generate controlled force vectors that allow the ROV to move forward and backward (surge), translate right and left (lateral motion), ascend and descend (heave), and rotate about its vertical axis for yaw left and yaw right. Forward and backward motion is achieved through synchronized thrust of the horizontal thrusters in the same direction, while differential thrust between opposing horizontal thrusters produces yaw rotation. Lateral movement is generated by vector-based thrust distribution across the angled horizontal thrusters, allowing smooth side translation without changing heading. Vertical motion is controlled by dedicated vertical thrusters that provide stable ascent and descent by producing upward or downward thrust. This configuration ensures high stability, efficient force distribution, and precise positioning capability during mission tasks, which is critical for navigation, object manipulation, and station keeping in competition scenarios.

• Power consumption

Each T200 thruster in the ROV consumes about 453.6W during normal operation, which is below its maximum rated power of 645W. This ensures efficient performance while keeping the thrusters within safe limits.

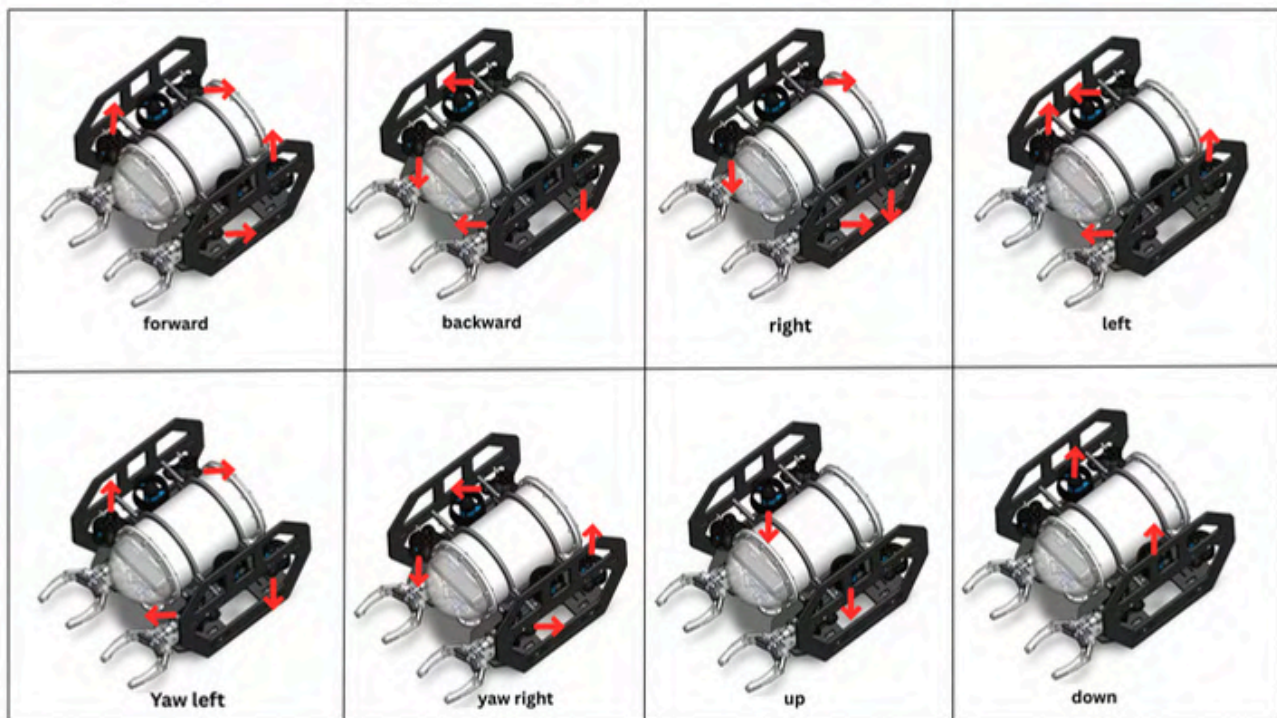


Figure16: Thruster Configuration

2.7 Buoyancy & Ballast

The buoyancy and ballast system of ORCA was designed to achieve near-neutral buoyancy, allowing the vehicle to remain stable in the water column while minimizing the thrust required for vertical motion. Maintaining this condition improves maneuverability, reduces energy consumption, and allows the propulsion system to focus on horizontal movement and precise positioning during mission tasks. The buoyant behavior of the vehicle follows Archimedes' Principle, which states that a submerged body experiences an upward force equal to the weight of the fluid it displaces. This buoyant force can be expressed as $F_b = \rho g V$, where F_b represents the buoyant force, ρ is the density of water, g is gravitational acceleration, and V is the volume of displaced water. The downward force acting on the vehicle is its weight, given by $W = mg$, where m is the total mass of the ROV. Neutral buoyancy occurs when the buoyant force equals the weight of the vehicle ($F_b = W$), allowing the ROV to remain suspended underwater with minimal vertical thrust. As illustrated in the buoyancy force diagram below, an underwater vehicle may exhibit positive buoyancy (rising), negative buoyancy (sinking), or neutral buoyancy (balanced forces).

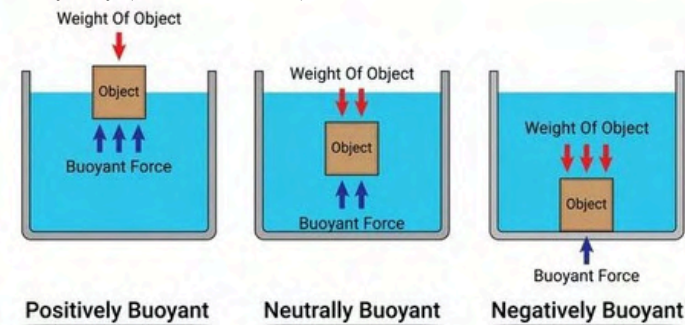


Figure17: Bouoyncy Explanation Diagram

For optimal operational performance, our design targets a near-neutral buoyancy condition. To achieve this balance, we integrated approximately 5 kg of ballast mass into the vehicle structure. This ballast compensates for the buoyant force generated by the ROV's displacement and allows the system to maintain stable depth during operation. The structural materials used in the vehicle including acrylic, Ortoloon, and aluminum contribute to the overall volume and displacement of the ROV, which directly influence its buoyancy characteristics. Additionally, stability was enhanced through careful mass distribution within the frame: heavier components were positioned lower in the structure to maintain a lower center of gravity relative to the center of buoyancy, helping the ROV maintain a stable orientation while operating underwater.

2.8 Payload & Tools

Main Pilot Camera (ZED 2i Stereo Camera)

ORCA's primary visual perception system is the ZED 2i Stereo Camera, serving as the main pilot camera. This stereo vision system captures high-resolution paired images that provide real-time depth perception and three-dimensional modeling of the underwater environment. Its capabilities include calculating distances and midpoints between objects, allowing operators to navigate precisely and execute manipulation tasks with accuracy. The ZED camera not only enhances situational awareness but also forms the backbone of ORCA's advanced computer vision capabilities.



Figure18: ZED 2i Camera

Dimensions are in mm

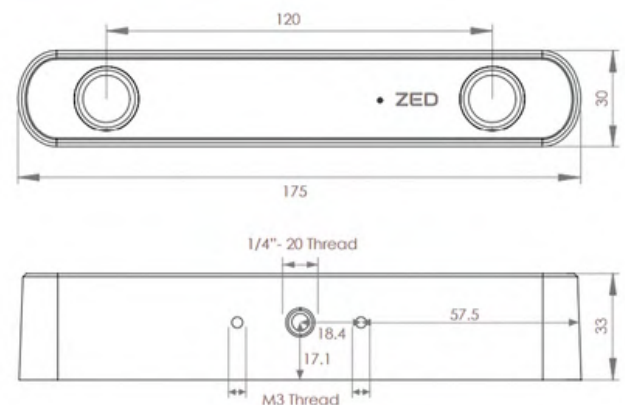


Figure19: ZED camera dimensions

Auxiliary Observation Cameras (Hikvision)

To support detailed observation and task monitoring, ORCA integrates three Hikvision auxiliary cameras. Two are dedicated to monitoring the pneumatic grippers, providing the operator with clear views of object interaction, while the third camera looks downward, offering a comprehensive view of the area beneath the vehicle. These additional perspectives enable precise positioning, improved environmental awareness, and more effective execution of complex underwater operations.



Figure20: Hikvision camera used in ORCA

Pneumatic Manipulation System

ORCA's interaction with mission elements is facilitated by two pneumatic grippers, each featuring two claws for secure grasping. The grippers are actuated using a pneumatic system that delivers strong and consistent force while maintaining a lightweight and reliable design suitable for underwater conditions. This mechanism allows ORCA to perform tasks such as retrieving objects, operating mechanisms, and manipulating mission-specific equipment, ensuring versatility and precision in diverse underwater scenarios. The gripper's pneumatic system is explained in Appendix B

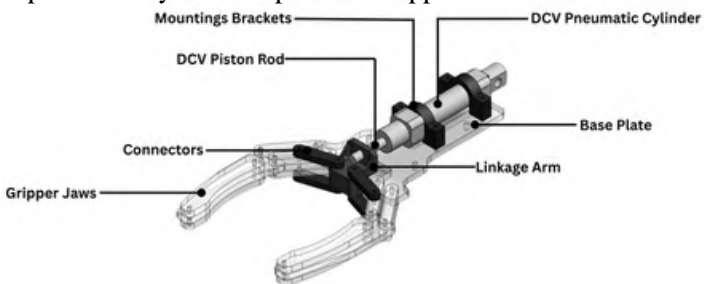


Figure21: Gripper Assembly

2.9 New vs Old Bought vs Built

Newly Integrated Components

Component	Justification	Built/Bought
Pixhawk Hub	Fully functional and compatible.	Bought
T200 Thrusters	Proven efficiency and reliability.	Bought
Buck Converters (48V → 12V)	Continue providing stable power.	Bought
ESCs	Compatible with propulsion system.	Bought
ZED Camera	Provides reliable stereo vision.	Bought

Hikvision Cameras	Provides pilot visual feedback.	Bought
Aluminum Back Cover	Structurally strong and reusable.	Built
Compressor	Fully operational for pneumatic system.	Bought

Figure22: New components table

Reused Components from previous design

Component	Justification	Built/Bought
Acrylic Sheet	Transparent & Waterproof for camera dome	Bought
Artelon Sheet	Higher material quality and durability.	Bought
DCV	Enables pneumatic gripper control.	Bought
Pneumatic Cylinder	Provides gripping actuation force. Bought	Bought
O-Ring	Improves sealing against water ingress.	Bought
Arduino Nano	Supports additional control tasks.	Bought
Controller	Improves pilot control accuracy.	Bought
PCB	Supports updated electrical layout.	Built
Buck Converter (12V → 5V)	Supplies stable 5V power.	Bought

Figure23: Reused components table

2.6 Electrical System

The electrical architecture of ORCA has been developed to support the updated mechanical design in a simplified, structured, and robust manner. The system follows a modular philosophy to facilitate maintenance, fault isolation, and future scalability, while maximizing efficiency and operational safety.

Lessons learned from previous iterations of the ROV informed the design, leading to standardized cabling, connector selection, and custom PCB layouts that ensure clarity, reliability, and safe operation for both the operators and the vehicle.

• Power System Design

The ROV is powered by a surface DC supply delivered through the tether. Onboard DC-DC converters regulate and step down the voltage to meet subsystem requirements.

• Power Budget and Justification

A power budget was developed to ensure reliable operation, incorporating a 20–30% safety margin for transient loads and inefficiencies. High-efficiency (>85%) DC-DC converters were selected to minimize power loss and heat generation.

• Protection, Safety, and System Integrity

To ensure safe and reliable operation, the system includes overcurrent and short-circuit protection using fuses, reverse polarity protection, and an emergency kill switch for rapid shutdown. Thermal management is addressed through proper component placement.

Waterproofing is achieved using sealed enclosures, waterproof connectors, and insulated cables. A common grounding system is implemented to maintain stability and reduce noise, while separation of power and signal lines, along with shielded and twisted-pair cables, minimizes electromagnetic interference and ensures reliable communication.

• Tether System

The tether serves as the primary link between the control station and the ROV, transmitting power, data, and pneumatic signals. A 48V DC line, with an 8 mm² cross-sectional area, ensures stable voltage and adequate current capacity under all operating conditions.

High-speed Ethernet cables handle command, control, and real-time video transmission, while pneumatic lines supply pressurized air to onboard systems. This integrated design enables reliable communication, efficient power delivery, and safe operation.

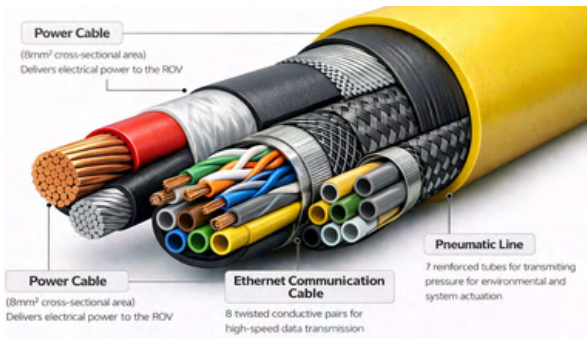


Figure24: Tether Construction

• Tether Management Protocol

Phase	Procedure	Purpose
Pre-Dive	- Inspect insulation, connectors, and strain relief - Perform continuity check - Coil using figure-8 method	- Ensure electrical and mechanical integrity - Prevent power/signal failure - Eliminate torsional stress
Launch	- Maintain slight slack during deployment - Keep tether aligned with vehicle axis	- Prevent tension loading - Reduce drag
Operation	- Dedicated tether manager monitors slack - Avoid loops near mission props	- Prevent entanglement - Maintain maneuverability
Recovery	Retrieve gradually, no sharp pulling	Protect internal conductors
Post-Dive	Inspect, dry, and store properly	Extend cable lifespan

Figure25: Tether mangement protocol table

• Control Station

The control station is designed to support piloting, monitoring, and system supervision in an integrated manner. It includes a primary laptop for vehicle control, a secondary laptop for monitoring video and telemetry, and an external display for real-time visualization.

Video signals from the ROV cameras are transmitted via Ethernet to a video balun, then processed by a Digital Video Recorder (DVR), which distributes the feed to the copilot laptop and external display, ensuring continuous situational awareness.

Pneumatic lines from the air compressor are connected to Directional Control Valves (DCVs) in the control station, enabling precise actuation while maintaining safe separation from electrical systems.

This architecture allows efficient control of propulsion, real-time monitoring of subsystems, and reliable environmental observation.



Figure26: Control Box

• Inside ROV System

Within the ROV, the 48V DC supply from the surface is distributed and regulated by five dedicated DC-DC buck converters, each assigned to specific subsystems to maintain voltage stability and electrical isolation. Three converters step the voltage down to 12V for the propulsion system, powering six thrusters via ESCs controlled by the Pixhawk flight controller through PWM signals. This setup provides balanced load distribution and precise maneuvering across all degrees of freedom. A fourth converter steps the voltage down to 19V to power the Jetson Orin, which functions as the main onboard processor and communication hub.

The Pixhawk and Arduino Nano interface with the Jetson Orin via USB connections to facilitate reliable control and data exchange, including real-time depth feedback from the pressure sensor. The fifth converter provides 12V power to auxiliary systems, including the DCVs, CCTV cameras, and the Cytron motor driver for the bilge pump. MOSFET switching circuits control the DCVs from the Arduino Nano, ensuring safe operation while isolating high-current loads. CCTV signals are transmitted to the control station using video baluns for monitoring and navigation.

All electrical components are integrated via custom-designed PCBs, using XT60 connectors for high-current lines and JST connectors for signal connections. Terminal blocks distribute power efficiently across subsystems, while color-coded cabling enhances system readability, reduces integration errors, and simplifies maintenance. The modular, standardized architecture of ORKA 2.0 ensures reliable operation, efficient power management, and easy scalability, forming a robust foundation for both current and future missions.

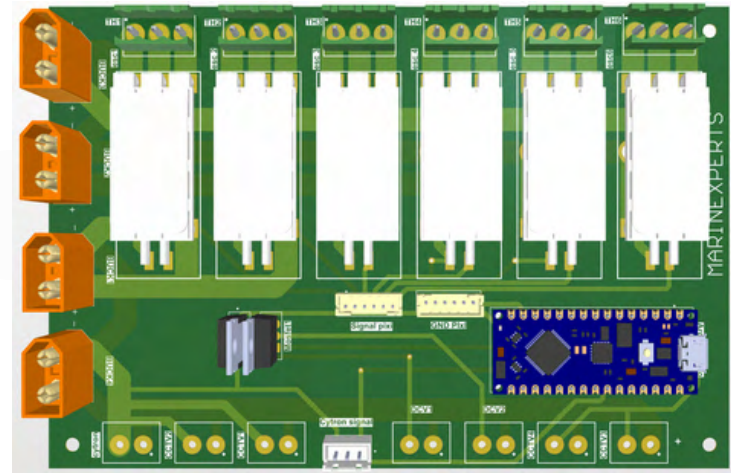


Figure28: 3D PCB (Printed circuit board) design

An electrical SID is provided in Appendix C

2.7 Sofyware Systems

1) Control System

The control system of the ROV is responsible for translating pilot commands into electrical signals that drive the vehicle's hardware components. It establishes a link between the surface control station and the onboard computing and flight control units, ensuring accurate and real-time operation of thrusters and mission actuators.

At the surface, the control laptop runs Ubuntu 22.04 and utilizes ROS 2 (Robot Operating System 2) as the system's communication framework. Sensor data, including image streams and depth information, are published as ROS 2 topics, allowing them to be accessed by different nodes for visualization and processing. CUDA acceleration is used to efficiently handle depth computation without affecting overall control performance. Compared to the previous season, where a Jetson Nano running Ubuntu 18.04 with ROS 1 required Docker for dependency management, the current system benefits from a more streamlined and native integration.

Communication between the surface station and the ROV is achieved through a wired Ethernet connection, providing high bandwidth, low latency, and reliable real-time data transmission. Onboard the vehicle, the NVIDIA Jetson Orin Nano Super Developer Kit serves as the primary embedded computer, running Ubuntu 22.04 with native ROS 2 support. It receives control commands from the surface laptop and interfaces with the Pixhawk flight controller via MAVROS.

MAVROS acts as a communication bridge between ROS 2 and the Pixhawk autopilot by converting ROS 2 messages into MAVLink protocol commands that the Pixhawk can interpret.

The Pixhawk handles low-level control tasks, including thruster signal output and stabilization.

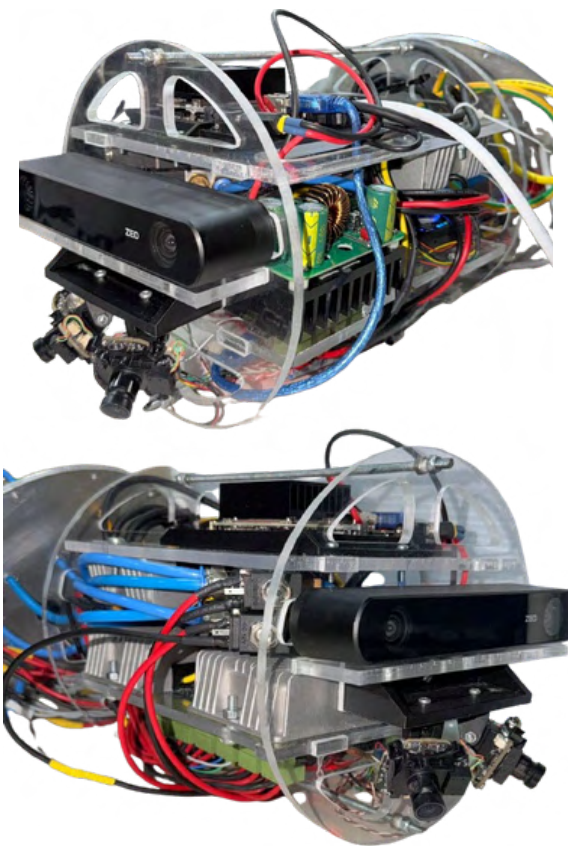


Figure27: Electronics Housing

This architecture separates high-level processing (Jetson and surface laptop) from low-level actuation (Pixhawk), improving system reliability and control consistency. Additionally, the Jetson manages the stereo vision system using the ZED SDK. The ZED ROS 2 wrapper is used to publish camera data as ROS 2 topics, enabling seamless integration with the rest of the system. The upgrade to the Jetson Orin Nano, with native ROS 2

support, eliminates the need for Docker, simplifies integration with MAVROS and the ZED ROS 2 wrapper, and enhances overall system responsiveness. Through the integration of ROS 2, MAVROS, Pixhawk, and Ethernet communication, the control system ensures that pilot inputs are efficiently processed, transmitted, and executed, enabling stable propulsion control and precise actuator operation during underwater missions.



Figure29: Joystick Layout

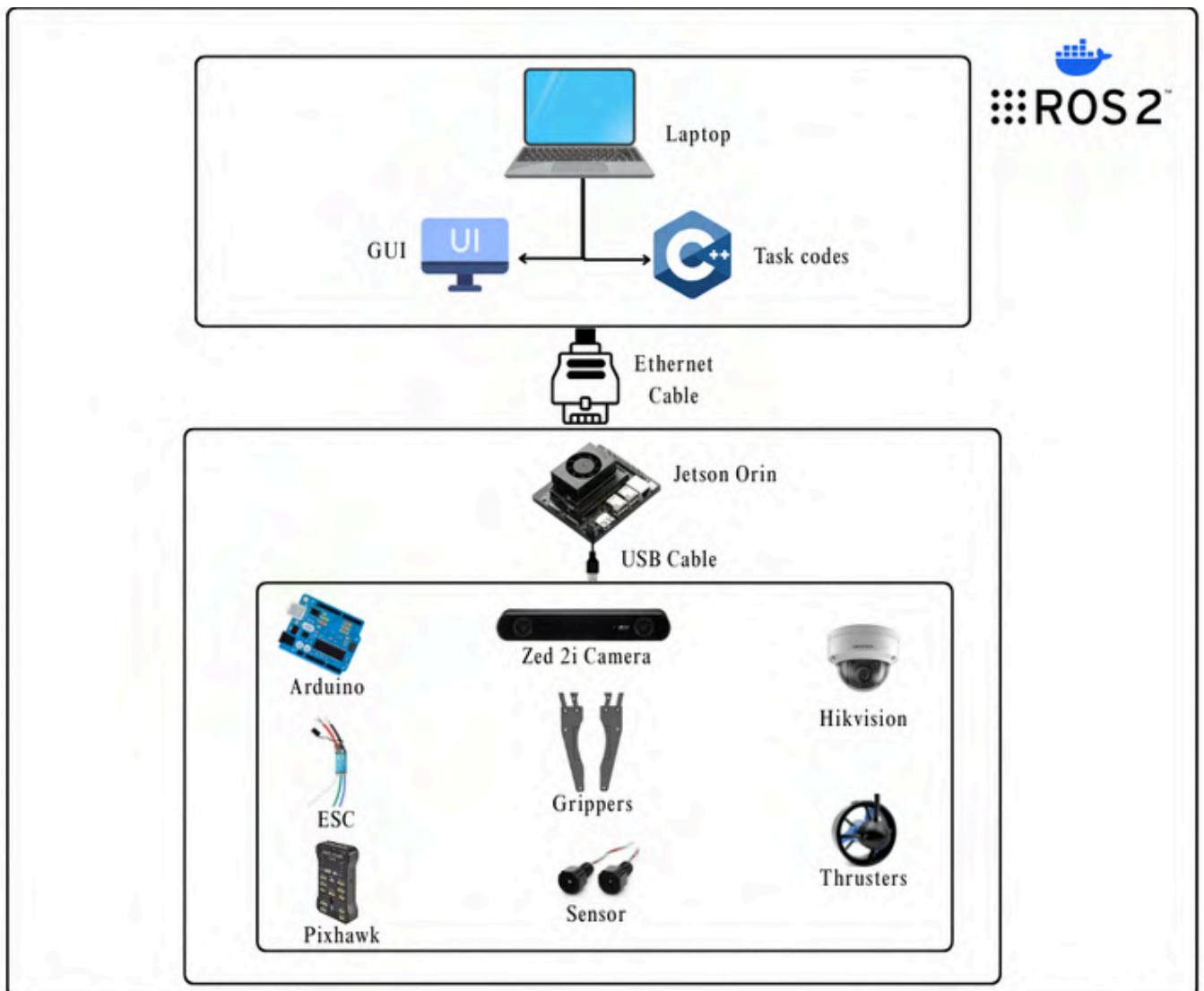


Figure30: Control System Diagram

2) Computer Vision System

The computer vision system functions as the visual perception unit of the ROV, enabling detection, recognition, and measurement of mission-relevant underwater objects. It supports both manual piloting and semi-autonomous behaviors. The primary perception device is the ZED stereo camera, which captures high-resolution stereo images streamed through ROS 2 using the ZED ROS 2 wrapper. Four auxiliary cameras—two forward-facing, one downward-facing, and one monitoring the rotating mechanism—provide expanded visual coverage and improved situational awareness. For invasive species mitigation (Task 2.1), the system uses a YOLOv8 (You Only Look Once, Version 8) model trained on annotated datasets to detect European green crabs. The model generates bounding boxes with associated confidence scores. A confidence threshold of 0.8 is applied to minimize false positives and improve reliability. OpenCV is used for image preprocessing, segmentation, and visualization, while Matplotlib supports development-phase analysis and debugging. Dataset preparation and management are conducted using platforms such as Kaggle.

Color detection is implemented for tasks requiring identification of colored pipeline sections or markers. Using OpenCV, RGB thresholding isolates target colors, after which geometric properties such as centroids are extracted. These values are used to compute spatial relationships and enable vision-guided alignment. The midpoint of detected regions is calculated using pixel coordinates, and the offset from the image center provides corrective feedback to the control system for stable alignment during transect navigation or object positioning. For Iceberg Tracking (Task 2.2), depth estimation is required to determine keel depth within scoring constraints. The system integrates data from an IMU (Inertial Measurement Unit), which provides acceleration and angular velocity measurements. A processing algorithm estimates motion state and relative depth, contributing quantitative data for keel depth evaluation.

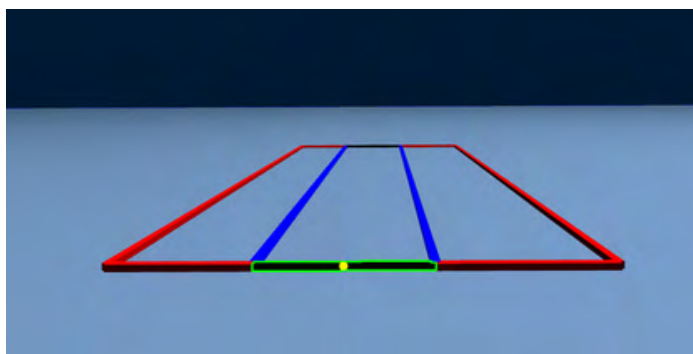


Figure32: Fly Transect & Midpoint calculations

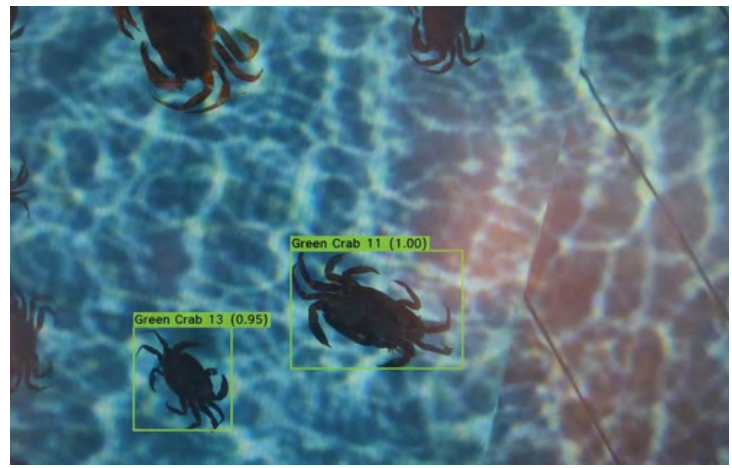


Figure31: Crab Detection

3) Graphical User Interface (GUI)

Our team developed a custom Graphical User Interface (GUI) to serve as the primary control and monitoring platform for Mako during mission operations. The GUI provides a centralized, real-time interface that integrates live video streaming, vehicle telemetry, and system status indicators into a clear and professional layout. The central display presents high-resolution live footage from the onboard camera system to support navigation and task execution, while orientation data including yaw, pitch, roll, and pressure readings are continuously streamed from the Pixhawk flight controller for stability and depth monitoring. A dedicated mission control panel enables start, stop, and reset functions alongside a visible mission timer, ensuring accurate time management during competition tasks. Additionally, system state information such as connection status, operational mode, and arm/disarm condition enhances safety and operational awareness. Designed with clarity, responsiveness, and modular expandability in mind, the GUI ensures efficient human-machine interaction and reliable control of the ROV throughout mission deployment.

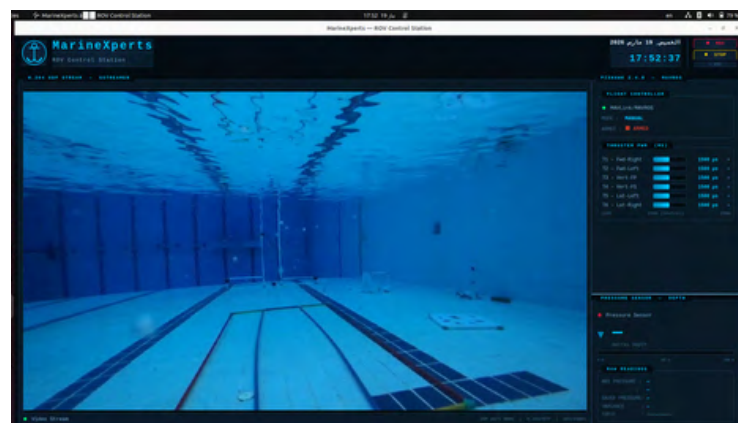


Figure33: MarineXperts GUI

A software flowchart is provided in Appendix A, explaining the software system

03.Safety

“No task, mission, or deadline justifies compromising safety in a marine engineering environment.”

3.1 Safety Philosophy

The MarineXperts team operates under a safety-first philosophy, where safety is the essential condition that enables all operations. In marine engineering and subsea exploration, safety is integrated into every design decision, operational procedure, and mission objective. This approach ensures that all activities are conducted responsibly, systematically, and with full awareness of the potential hazards inherent to underwater environments.

3.2 Safety Rationale

Safety considerations are addressed across three interrelated domains: personnel, ROV system, and marine environment.

1. Human Safety

- Personnel safety is the highest priority. Operating near water and handling equipment presents physical risks. To reduce these risks, team members use personal protective equipment (PPE), follow clear operational roles and communication procedures during launch and recovery, and receive training in emergency response, tether management, and safe deployment.



Figure34: Our team member wearing safety gloves

2. Environmental Safety

Operations are conducted responsibly to minimize environmental impact. Deployment areas are evaluated for water conditions and ecological sensitivity. The ROV is constructed from marine-safe materials (Artelon, acrylic, and aluminum), and high-quality cameras with controlled maneuvering help prevent accidental contact with marine ecosystems.

3. ROV System Safety

The ROV includes multiple safety features to prevent operational hazards. Electrical and mechanical safety measures are detailed in the Company Safety Review document. All systems operate within defined safety limits to ensure reliable and secure missions.

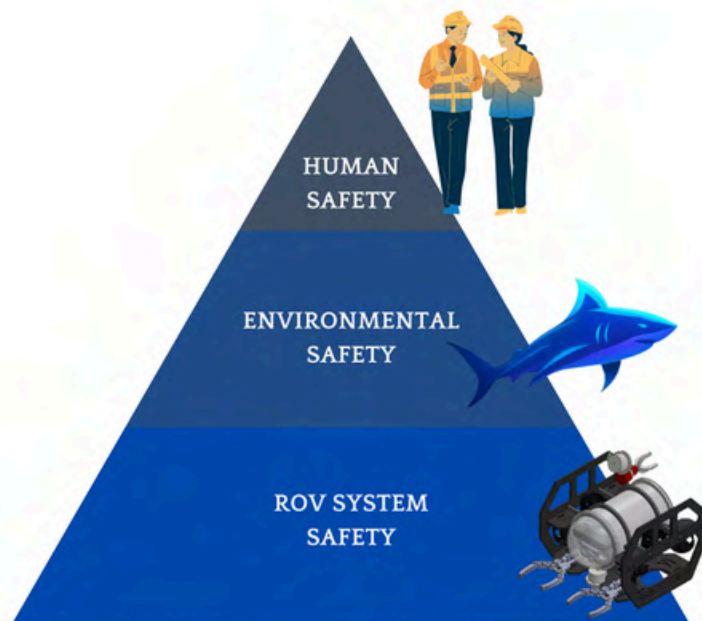


Figure35: Safety Chart

3.3 Operational Safety

Operational safety is the result of combining rigorous safety principles with structured operational procedures, creating a framework where ROV activities can be conducted efficiently, reliably, and responsibly. It ensures that all team members work in a disciplined, coordinated manner, remaining aware of potential hazards while following clear operational protocols. This integrated approach allows the team to maintain full control over the mission, respond proactively to unexpected challenges, and make immediate decisions to pause or abort tasks if conditions become unsafe. By balancing operational objectives with safety considerations, operational safety protects personnel, preserves the environment, and upholds professional marine engineering standards. All specific steps, checks, and guidelines that support this approach are provided in the Job Safety and Environmental Analysis, ensuring that every phase of the mission from preparation to execution and recovery is guided by both safety and operational efficiency.

3.4 Safety Precautions

Standardized safety procedures are followed for all ROV operations to ensure consistent and controlled execution. These procedures are implemented through structured safety checklists covering pre-operation, operational, and post-operation phases. The checklists are used by the team to verify readiness, monitor safe conduct during missions, and ensure proper recovery and shutdown activities. A detailed safety checklist is provided in Appendix D for reference and verification.

04.Critical Analysis

4.1 Testing & Troubleshooting

• Testing

To ensure the reliability and performance of our ROV, we conduct a comprehensive testing program across all subsystems. For the mechanical and overall vehicle functionality, we perform in-water testing, placing the ROV in controlled environments to evaluate maneuverability, stability, and operation of tools and manipulators. In addition, we use interactive virtual simulations, where the ROV is modeled in a 3D digital environment and can be remotely operated on screen. This allows us to test vehicle controls, navigation, and task execution safely before physical trials. We also perform computer-based analyses such as stress analysis and hydrodynamics modeling to predict structural performance and optimize design. For the electrical and electronic systems, individual components and circuits are tested to verify proper operation, power distribution, and signal integrity. By combining in-water testing, virtual simulations, and analytical studies, we can detect issues early, improve system robustness, and ensure the ROV performs effectively under real-world conditions.

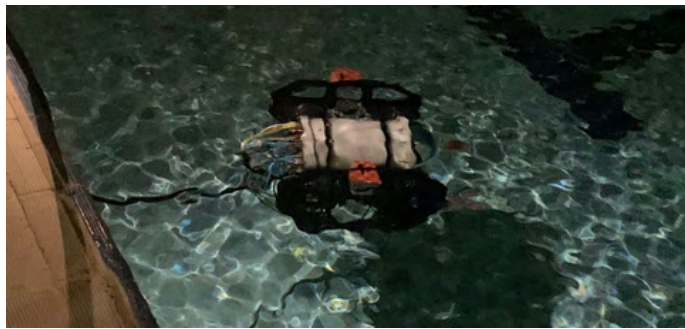


Figure36: Underwater testing

• Troubleshooting

Troubleshooting is a systematic process used to identify, analyze, and resolve issues that occur during the operation of the ROV. It involves investigating abnormal behavior, determining the root cause of a problem, and applying corrective actions to restore the system to proper functionality. This process ensures that faults are addressed efficiently without causing further damage to the system.

Troubleshooting is performed whenever the ROV does not behave as expected. This includes situations such as device or component failure, unexpected operation, loss of functionality, performance degradation, or the appearance of unusual or unexplained behavior. Any anomaly observed during testing or operation is treated as a trigger to initiate the troubleshooting process.



Figure37: When to troubleshoot diagram

To make the troubleshooting process clear and organized, we break it down into logical phases. Each phase ensures a systematic approach, allowing us to identify and resolve problems efficiently.

Phase 1: Problem Identification

The first step is to recognize that an issue exists. We carefully observe the ROV's behavior and determine the specific problem that needs to be addressed.

Phase 2: Information Collection

Once the problem is identified, we gather all relevant data about the issue. This can include logs, sensor readings, observations from tests, or reports from operators.

Phase 3: Data Analysis

The collected information is analyzed to identify the possible causes of the problem. If the data is insufficient to find a solution, we return to Phase 2 to collect additional information.

Phase 4: Solution Implementation and Testing

After determining a potential solution, we apply it to the system and test the ROV to see if the problem has been resolved.

Phase 5: Verification and Iteration

If the problem persists, we return to Phase 3 and refine our analysis. If the issue is resolved, the troubleshooting process is complete, and the ROV is confirmed to be fully operational.

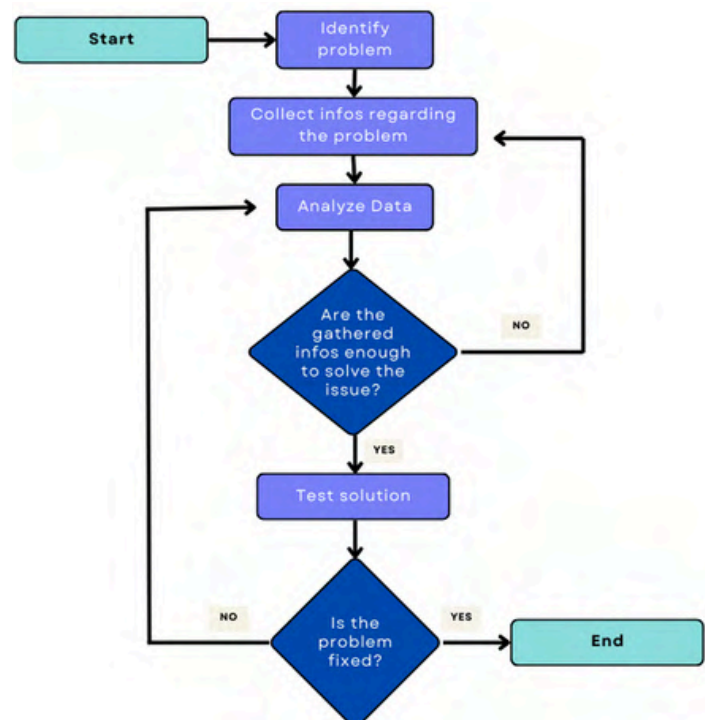


Figure38: Troubleshooting Flowchart

05. Float

Our float system integrates mechanical, electrical, and control components to manage water intake and discharge safely and efficiently. Its design ensures precise operation, robust protection, and reliable performance in underwater conditions.

• Mechanical Design

The system is built around two diaphragm water pumps connected through a Y-connector to a flexible bladder, allowing them to operate in a coordinated manner. Pump 1 draws water from the surrounding environment and passes it into the bladder through a normally closed solenoid valve, which prevents unintended flow when the pump is inactive. Pump 2 draws water from the bladder and discharges it back into the environment through its own solenoid valve. The float itself is constructed from durable acrylic, with aluminum end caps on both sides. These end caps are sealed using a two-stage O-ring system, ensuring a secure, leak-proof assembly capable of withstanding repeated operation.

• Electrical Design

The float system operates on a 12 V, 5 A battery pack, with circuit protection provided by a 5 A fuse positioned directly after the power input. This configuration safeguards the system against overcurrent and potential short circuits.

Power is distributed to both high-demand components, such as the pumps, and low-power electronics through a regulated supply line. A linear from the motor driver 5v line the input voltage from 12 V to a stable 5 V output, which powers the ESP32 microcontroller along with its associated control circuitry. The ESP32 serves as the system’s control hub, managing pump operation and enabling wireless communication with the surface station via its built-in antenna,

• Pump Driver and Protection

Each pump is controlled through a H-bridge motor driver to ensure safety from the draw back current while handling the switching modes of the float

Operational current measurements indicate that each pump draws approximately 0.9 A, while the ESP32 consumes around 0.31 A, resulting in a total system current of about 1.933A. To ensure safe operation under transient conditions such as startup surges, a safety factor of 125% was applied when selecting the fuse rating.

As a result, a 5 A fuse was chosen, providing adequate headroom for peak loads while maintaining effective protection against electrical faults. This approach enhances both the reliability and safety of the system during underwater operation.



Figure39: MarineXperts Float

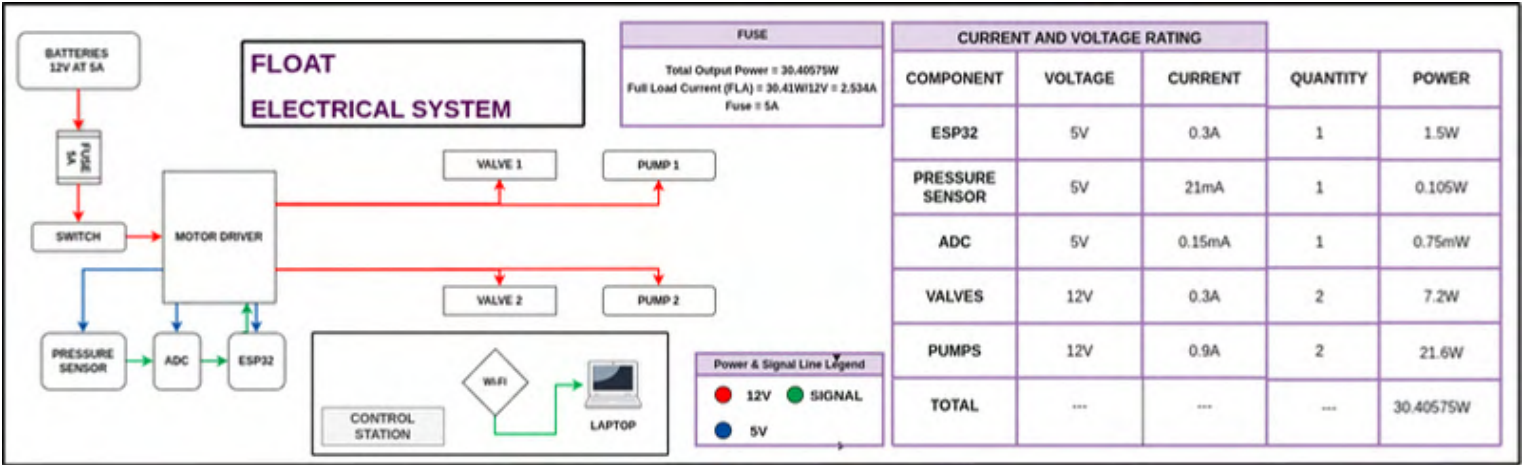


Figure40: Float SID

06.Accounting

• Budget

The total project budget for Mako was planned and managed through Orca.com, where all expected and actual expenses were recorded and monitored. The budget covered major subsystems including propulsion, mechanical structure, electronics, control hardware, pneumatic components, manufacturing, and testing materials. During the planning phase, projected costs were estimated based on supplier quotations and market research, allowing the team to allocate funds strategically according to subsystem priority and mission requirements. Financial decisions were guided by performance-to-cost evaluation to ensure optimal technical capability within available resources. A detailed itemized budget table is provided in Appendix H.

• Cost Analysis

A structured cost analysis system was implemented to ensure transparency, traceability, and financial control throughout the project lifecycle. Every purchase was documented with supplier details, unit price, quantity, and subsystem classification. This allowed continuous comparison between estimated and actual costs, helping the team identify variances and adjust spending where necessary. Sponsorships, in-kind contributions, and donated components were also recorded to reflect the true economic value of the project. Full documentation and financial records are included in the appendices for verification and review. More cost analysis details in Appendix G

07.Acknowledgements Acknowledgements & References

The MarineXperts team sincerely thanks everyone who supported the development of ORCA.

We are grateful to the MATE Center for organizing this competition and inspiring innovation in marine technology.

We also appreciate the Arab Academy for Science, Technology & Maritime Transport and the College of Engineering & Technology for their continuous academic support and provision of resources.

We extend our thanks to our mentors for their guidance and to our dedicated team members for their commitment and teamwork. We are equally thankful to our families and friends for their encouragement throughout this journey.

We also acknowledge Makers Electronics and Synthesis 3D for their valuable technical support, and we recognize SOLIDWORKS for providing the design tools that enabled accurate modeling, simulation, and development of our ROV.



• References

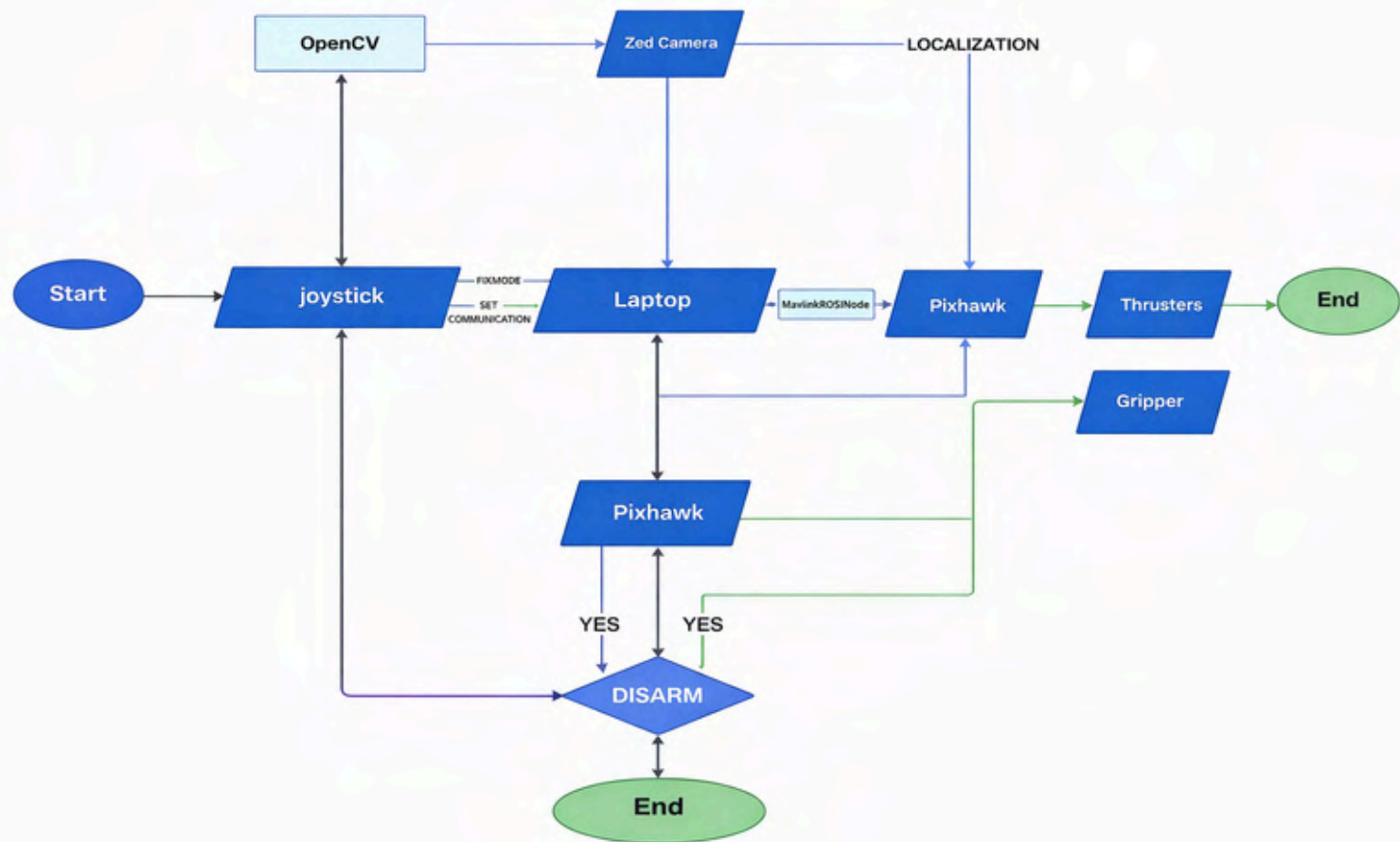
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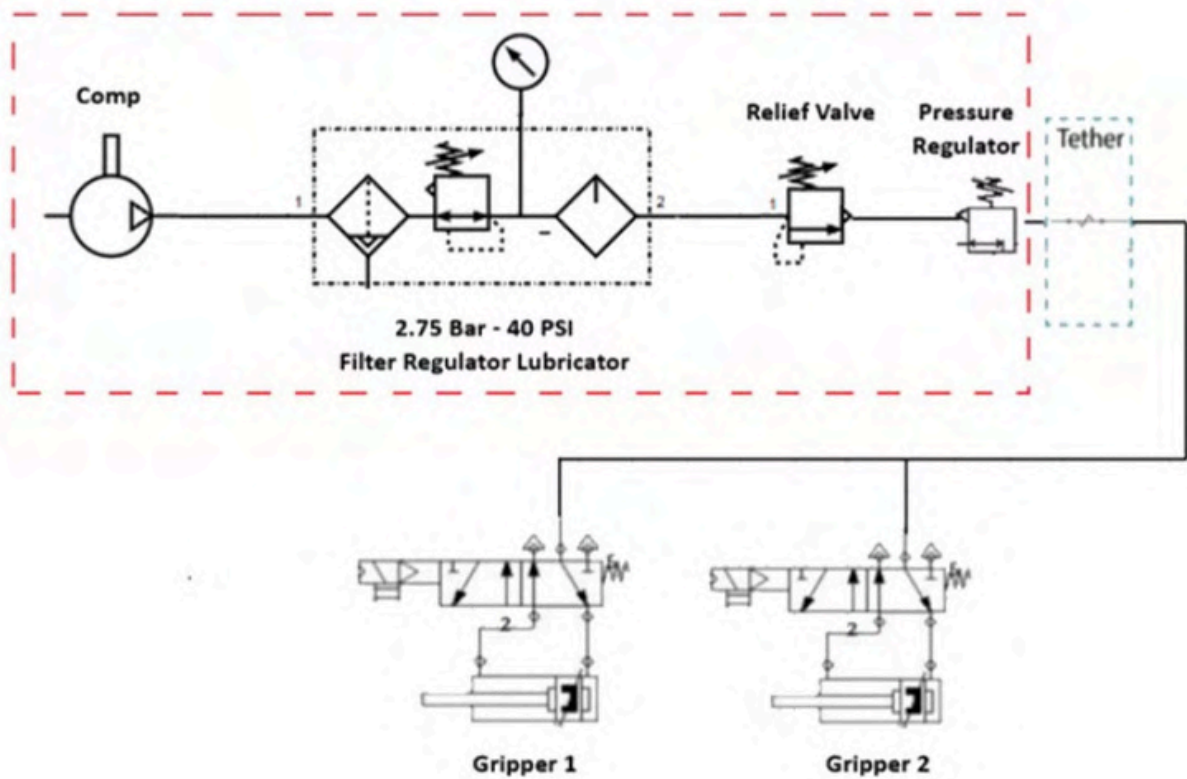
Figure.41: Our Team MarineXperts

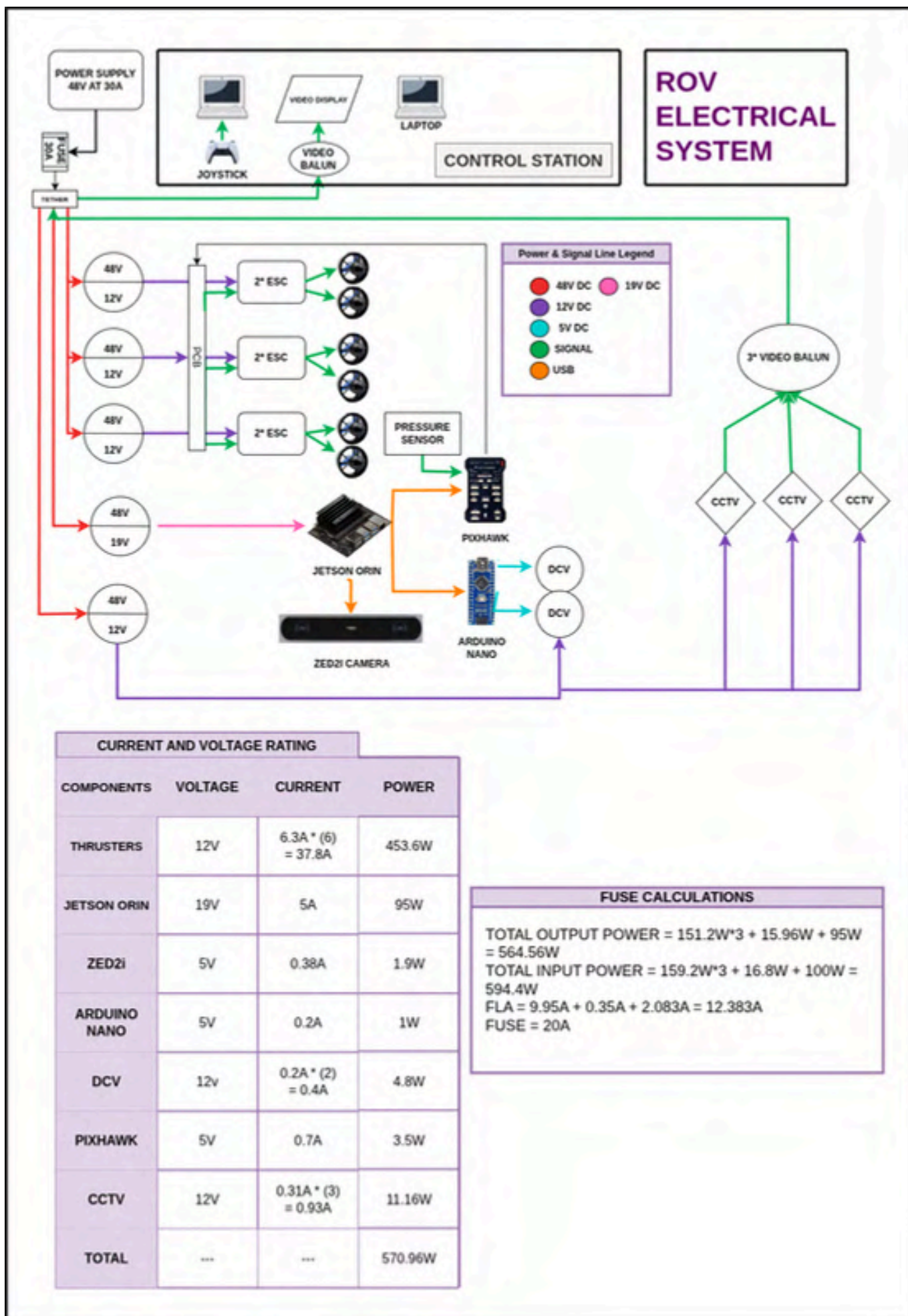
08. Appendices

Appendix A: Software Flowchart



Appendix B: Pneumatic System SID





Appendix D: Safety Checklist

A.1 Pre-Run Safety Checklist

- ☐ All personnel wearing appropriate PPE (closed-toe shoes, no loose clothing, hair secured)
- ☐ ROV frame structurally intact with no sharp edges
- ☐ Thrusters and thruster guards securely mounted
- ☐ Tether free of damage, properly strain-relieved, and routed safely
- ☐ Pressure housing free of cracks or clouding
- ☐ O-rings clean, lubricated, and properly seated
- ☐ Vent plug removed before sealing and secured after closure
- ☐ Leak or vacuum test completed successfully
- ☐ No exposed electrical conductors or loose wiring
- ☐ Correct fuse ratings installed and polarity verified
- ☐ Battery voltage within safe operating limits and batteries secured
- ☐ Emergency power cut-off tested and accessible
- ☐ Control station, software, and camera feed verified
- ☐ Mission tools secured and tested at low power
- ☐ Operational roles assigned (Pilot, Station Leader, Tether Manager)
- ☐ Pre-run safety briefing completed

A.2 In-Run Safety Checklist

- ☐ Tether actively managed to prevent entanglement
- ☐ Clear communication maintained between all team members
- ☐ ROV remains within designated operational area
- ☐ No abnormal thruster noise, vibration, or behavior observed
- ☐ No signs of water ingress or electrical malfunction
- ☐ Immediate shutdown initiated if unsafe conditions arise

A.3 Post-Run Safety Checklist

- ☐ Main power disconnected before handling ROV
- ☐ Batteries safely disconnected and inspected
- ☐ ROV rinsed with fresh water if operated in salt or chlorinated water
- ☐ Pressure housing inspected for leaks or condensation
- ☐ Thrusters checked and cleared of debris
- ☐ Tether properly coiled and stored
- ☐ Operational issues documented in maintenance log

Safety Sign-Off Section

Pilot Name: _____

Station Leader: _____

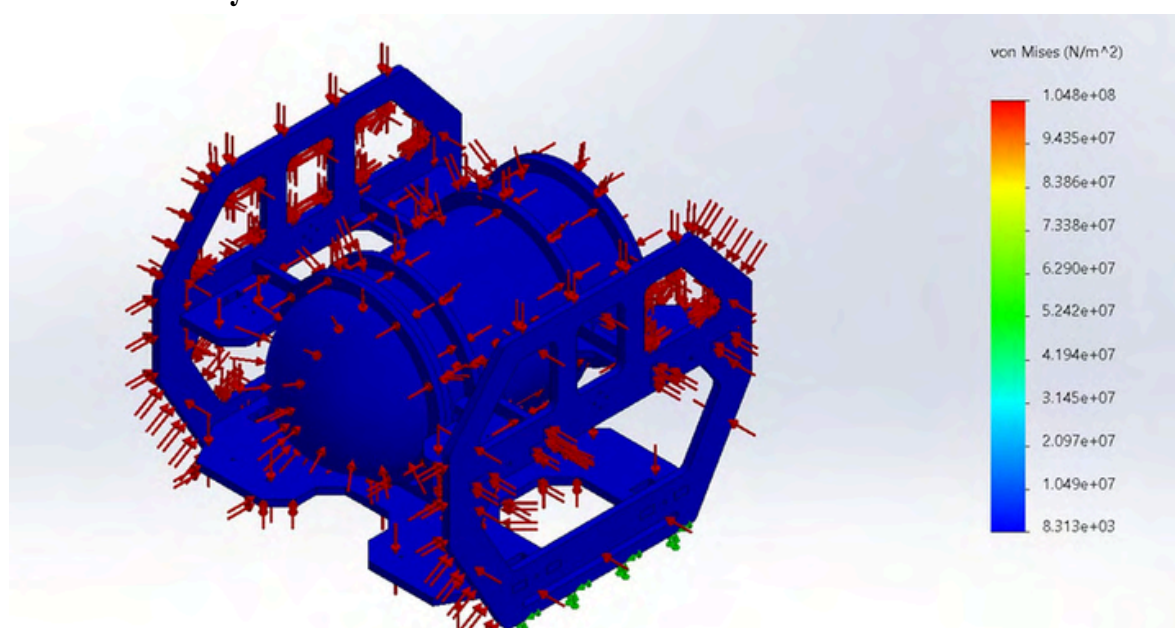
Date: _____

Trial No: _____

Appendix E: Risk Mitigation Table

Identified Risk	Potential Impact	Mitigation Strategy
Water ingress into pressure housing	Electrical short, system failure	O-ring inspection, lubrication, leak/vacuum testing before deployment
Exposed electrical wiring	Electrical shock or fire hazard	Enclosed connectors, insulation checks, pre-run inspection
Thruster contact with personnel	Injury to operators	Thruster guards installed and hands-off protocol enforced
Tether entanglement	Loss of control or tripping hazard	Dedicated tether manager and controlled routing
Battery overcurrent or short circuit	Fire or component damage	Proper fuse ratings and emergency power cut-off
Loss of communication or control	Uncontrolled ROV movement	Immediate shutdown procedure and pilot training

Appendix F: Stress Analysis



Appendix G: Cost Analysis

Type	Expenses	Description	Amount	Project Cost	Running Balance
Cash Donated	Funds from AASTMT University	-	\$ 660.00	\$ -	\$ 660.00
Purchased	Artelon Sheet	Frame Material	\$ 289.00	\$ 289.00	\$ 371.00
Re-used	Artelone Cylinder	For Enclosure	\$ 58.00	\$ 347.00	\$ 371.00
Purchased	Acrylic Sheet	For Gripper	\$ 48.00	\$ 395.00	\$ 323.00
Re-used	Aluminium Sheets	For Backcover and Thruster Shrouds	\$ 85.00	\$ 480.00	\$ 323.00
Raised	Self-Funds from Team Members	-	\$ 750.00	\$ -	\$ 1,073.00
Purchased	Manufacturing	Turning,Router Cutting,Laser Cutting and 3D Printing	\$ 63.85	\$ 543.85	\$ 1,009.15
Re-used	Compressor	For Pneumatic System	\$ 80.15	\$ 624.00	\$ 1,009.15
Purchased	Pneumatic Cylinders	For Gripper	\$ 18.75	\$ 642.75	\$ 990.40
Purchased	DCVs	For Gripper	\$ 7.20	\$ 649.95	\$ 983.20
Purchased	Bolts and Nuts	For Assembly	\$ 11.35	\$ 661.30	\$ 971.85
Purchased	O-rings	For Sealing	\$ 8.25	\$ 669.55	\$ 963.60
Purchased	Wire Glands	For Sealing	\$ 10.45	\$ 680.00	\$ 953.15
Purchased	Tools	For Assembly	\$ 17.55	\$ 697.55	\$ 935.60
Purchased	Epoxy	For Sealing	\$ 1.42	\$ 698.97	\$ 934.18
Purchased	Weights	For ROV Bouyancy	\$ 9.20	\$ 708.17	\$ 924.98
Re-used	Zed 2i Camera	For Vision	\$ 499.00	\$ 1,207.17	\$ 924.98
Re-used	CCTV Cameras	For Vision	\$ 45.95	\$ 1,253.12	\$ 924.98
Re-used	Pdxhawk 2.4.8	For Control	\$ 132.66	\$ 1,385.78	\$ 924.98
Purchased	Jetson Orin Nano	Companion Computer	\$ 532.33	\$ 1,918.11	\$ 392.65
Re-used	T-200 Thrusters	For ROV	\$ 1,428.00	\$ 3,346.11	\$ 392.65
Purchased	Arduino Nano	For Gripper Control	\$ 4.75	\$ 3,350.86	\$ 387.90
Re-used	ESCs	For Control	\$ 303.99	\$ 3,654.85	\$ 387.90
Purchased	PCB	For Electric Structure	\$ 50.25	\$ 3,705.10	\$ 337.65
Re-used	Buck Convertors 48V to 12V	For Power Conversion	\$ 212.05	\$ 3,917.15	\$ 337.65
Purchased	Buck Converter 12V to 5V	For Power Conversion	\$ 11.20	\$ 3,928.35	\$ 326.45
Purchased	Fuses,Wires,etc...	For PCB	\$ 18.30	\$ 3,946.65	\$ 308.15
Purchased	Power Cable	For Tether	\$ 120.00	\$ 4,066.65	\$ 188.15
Purchased	Pneumatic Cable	For Tether	\$ 14.50	\$ 4,081.15	\$ 173.65
Purchased	Cat6 Ethernet cable	For Tether	\$ 20.86	\$ 4,102.01	\$ 152.79
Re-used	Teather Mesh Cover	For Tether	\$ 24.00	\$ 4,126.01	\$ 152.79
Re-used	Monitor	For Control Panel	\$ 20.45	\$ 4,146.46	\$ 152.79
Purchased	Controller	For Controlling Rov	\$ 60.00	\$ 4,206.46	\$ 92.79
Re-used	DVR	For Control Panel	\$ 45.16	\$ 4,251.62	\$ 92.79
Re-used	Control Panel Box	For Control Panel	\$ 83.00	\$ 4,334.62	\$ 92.79
Purchased	ESP-32	For Float	\$ 5.65	\$ 4,340.27	\$ 87.14
Purchased	Antenna	For Float	\$ 2.30	\$ 4,342.57	\$ 84.84
Re-used	Switch	For Float	\$ 50.00	\$ 4,392.57	\$ 84.84
Re-used	Rechargeable Batteries	For Float	\$ 94.67	\$ 4,487.24	\$ 84.84
Purchased	Pumps	For Float	\$ 8.25	\$ 4,495.49	\$ 76.59
Purchased	Bladder	For Float	\$ 1.00	\$ 4,496.49	\$ 75.59
Re-used	Acrylic Cylinder	For Float	\$ 75.00	\$ 4,571.49	\$ 75.59
Re-used	Artelone Covers	For Float	\$ 63.00	\$ 4,634.49	\$ 75.59
Purchased	Solenoid Valves	For Float	\$ 7.40	\$ 4,641.89	\$ 68.19
Purchased	Pneumatic Connectors and Cables	For Float	\$ 4.33	\$ 4,646.22	\$ 63.86
Purchased	PCB	For Float	\$ 7.50	\$ 4,653.72	\$ 56.36
Purchased	Regulators,Fuses,etc...	For Float	\$ 3.40	\$ 4,657.12	\$ 52.96
Project Cost			\$		4,657.12
Project Cost - Re-used			\$		1,357.04
Total Income			\$		1,410.00
Total Raised			\$		750.00
Final Balance			\$		52.96

Appendix H: Budget Sheet

INCOME	Description			Amount (USD)	
	AASTMT			\$	660.00
	Description	Type	Value(USD)	Category Total	Budget
	Raw Material				
Mechanical	Artelon Sheet	Purchased	\$ 289.00		
	Artelon Cylinder	Re-used	\$ 58.00		
	Acrylic Sheet	Purchased	\$ 48.00		
	Aluminium Sheet	Re-used	\$ 85.00		
	Manufacturing Services				
	Turning	Purchased	\$ 10.00		
	Laser Cutting	Purchased	\$ 15.75		
	3D Printing	Purchased	\$ 18.00		
	Router Cutting	Purchased	\$ 16.10		
	Pneumatic Components			\$ 696.41	\$ 473.26
	Compressor	Re-used	\$ 80.15		
	Pneumatic Cylinders	Purchased	\$ 15.69		
	DCVs	Purchased	\$ 7.20		
	Other				
	Bolts and Nuts	Purchased	\$ 11.35		
	O-rings	Purchased	\$ 8.25		
	Wire Glands	Purchased	\$ 10.45		
	Tools	Purchased	\$ 12.85		
	Epoxy	Purchased	\$ 1.42		
	Weights	Purchased	\$ 9.20		
Electrical	Vision System				
	Zed 2i Camera	Re-used	\$ 499.00		
	CCTV Cameras	Re-used	\$ 45.95		
	Components				
	Pxhawk 2.4.8	Re-used	\$ 132.66		
	Jetson Orin Nano	Purchased	\$ 532.33		
	T-200 Thrusters	Re-used	\$ 1,428.00		
	Arduino Nano	Purchased	\$ 4.75		
	ESCs	Re-used	\$ 303.99	\$ 3,397.33	\$ 751.68
	PCB	Purchased	\$ 50.25		
	Buck Convertors 48V to 12V	Re-used	\$ 212.05		
	Buck Converter 12V to 5V	Purchased	\$ 11.20		
	Tether				
	Power Cable	Purchased	\$ 120.00		
	Pneumatic Cable	Purchased	\$ 14.50		
	Cat6 Ethernet cable	Purchased	\$ 18.65		
	Teather Mesh Cover	Re-used	\$ 24.00		
Station					
	Monitor	Re-used	\$ 20.45		
	Controller	Purchased	\$ 50.00	\$ 198.61	\$ 50.00
	DVR	Re-used	\$ 45.16		
	Control Panel	Re-used	\$ 83.00		
Float					
	ESP-32	Purchased	\$ 5.65		
	Antenna	Purchased	\$ 2.30		
	Switch	Re-used	\$ 50.00		
	Rechargeable Batteries	Re-used	\$ 94.67		
	Pumps	Purchased	\$ 8.25		
	Bladder	Purchased	\$ 1.00		
	Acrylic Cylinder	Re-used	\$ 75.00		
	Artelone Covers	Re-used	\$ 63.00		
	Solenoid Valves	Purchased	\$ 7.40		
	Pneumatic Connectors and Cables	Purchased	\$ 4.33		
	PCB	Purchased	\$ 7.50		
Total Cost		\$	4,611.45		
Total Reused and Donated Items		\$	3,300.08		
Total Budget Allocated		\$	1,311.37		
Cash Income		\$	660.00		
Funds Needed		\$	651.37		