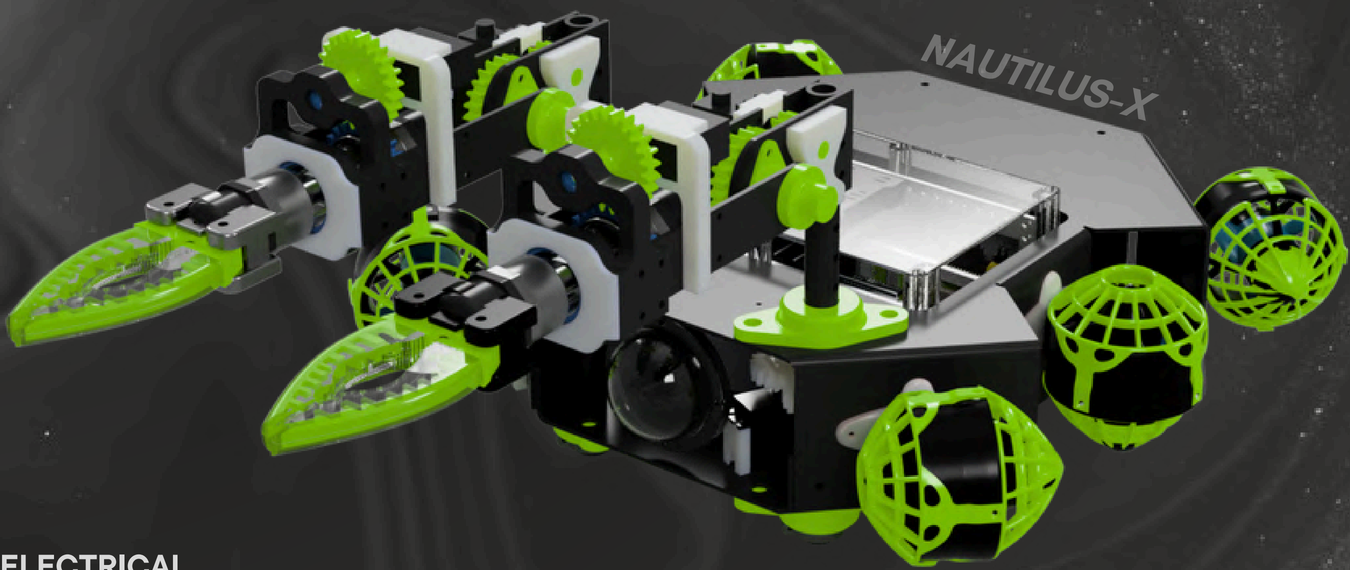
JALPARI

TECHNICAL REPORT

Manipal Academy of Higher Education, Dubai, UAE



ELECTRICAL

MEDWIN SAJAN-Elec Head (Year III-Returning) / **CEO & Pilot**
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MOINUL ISLAM-----------------------------------(Year II - New)
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1| ABSTRACT

Situated in Dubai, a coastal city with rich maritime heritage and growing environmental concerns, Team Jalpari acknowledges the urgent need to protect fragile marine ecosystems in the Arabian Gulf. This region faces threats from climate change, pollution, and unsustainable industry, making underwater robotics a vital tool for conservation and research.

Driven by this purpose, Team Jalpari is returning to the MATE ROV Competition for the second year. Our team consists of fourteen dedicated undergraduate engineers from Manipal Academy of Higher Education, Dubai, supported by five senior mentors whose past successes inspire our efforts. We aim to honor their legacy through continuous innovation and commitment.

Our latest vehicle, Nautilus-X, marks a significant advancement from our previous design. Guided by last year's lessons and specific points noted to us from our MATE ROV Judges, Nautilus-X features enhanced stability, improved maneuverability, two manipulators for delicate tasks, and integrated sensors for real-time environmental monitoring. Constructed from lightweight, corrosion-resistant, and sustainable materials, it embodies our values of eco-conscious engineering and adaptability.
This documentation details the entire process -from design and development to testing and deployment- highlighting our team's collective dedication to creating a reliable, mission-ready ROV. Team Jalpari proudly presents Nautilus-X for MATE ROV 2025, driven by a clear purpose: to explore, protect, and preserve underwater life through innovative technology.

Fig 1 : Jalpari Team members

2| TEAMWORK

2.1 Company Organization

Team Jalpari is a multidisciplinary group of fourteen students from Mechatronics, Electrical Engineering, and Computer Science at Manipal Academy of Higher Education, Dubai. To manage the development of our ROV effectively, Team Jalpari adopts a collaborative and flexible structure. Instead of working in isolated divisions, members from different departments contribute to interdisciplinary focus areas such as mechanical systems, control and navigation, embedded electronics, and software development. These groups operate under the guidance of experienced team leads, who ensure that each component is developed in alignment with the overall design goals. Regular discussions and joint review sessions help maintain smooth coordination, encourage open problem-solving, and keep all team members engaged in the broader progress of the project. This approach not only strengthens technical integration but also builds a strong team culture based on shared learning and mutual respect.

At the helm of our team is the Team Lead, who works closely with department heads to monitor progress, maintain alignment with MATE ROV regulations, and steer the team through key decision-making processes. Our mentors—senior students who have previously competed—play a crucial advisory role, pointing us to learn the right topics and steering us from previous failures at the same time allowing us to fail and learn. New members are onboarded through focused workshops and mentorship sessions led by experienced peers.

Each student is entrusted with responsibility over a specific component or task, allowing them to gain in-depth expertise and ownership over their contribution. This hands-on approach has fostered a strong sense of accountability and technical confidence across the team.

Cross-department collaboration is fundamental to our work culture. Whether integrating hardware and software systems or solving design bottlenecks, we prioritize clear communication and team-wide synergy. This collaborative spirit is what fuels our innovation and allows us to evolve as a cohesive, mission-driven unit—ready to tackle the challenges of MATE ROV 2025.

2.2 Project Management

Team Jalpari structures its project management around a dynamic weekly routine designed to maximize both productivity and transparency. Weekly strategic planning meetings led by team leads help establish priorities, resolve pressing challenges, and initiate discussions around upcoming STEM outreach activities—an essential part of our mission to spread awareness about underwater robotics and inspire the next generation of innovators. To maintain seamless coordination, the team relies on shared Excel sheets that track daily tasks and individual progress, allowing every member to stay updated on ongoing work and avoid unnecessary delays or confusion. Regular team check-ins throughout the week offer space for cross-subsystem collaboration, problem-solving, and timely course corrections. This structured yet flexible workflow ensures steady progress, clear communication, and a shared sense of purpose across the team.

Microsoft Teams	Central hub for meetings, updates, and asynchronous communication
Miro	Visual task management board for tracking daily to-do lists and progress
Notion	Collaborative documentation for engineering logs, research, and brainstorming
Google Workspace	File storage and live collaboration on design documents and reports
Fusion Team Hub	Cloud-based sharing and review of 3D CAD designs and technical drawings
Excel Sheets (Shared)	Real-time project scheduling, member-wise task tracking, and progress monitoring

Table 1 : Project Management Tools

2.3 Project Schedule

Team Jalpari's development cycle is strategically divided into five major phases: **Onboarding, Conceptual Design, Subsystem Development, Integration & Testing, and Mission Readiness.** This staged approach ensures that new recruits are onboarded smoothly, ideas are developed systematically, and all systems are thoroughly tested before final deployment.

- Onboarding Orientation (August -September):

The season began with welcoming new members through structured orientation sessions. Senior members conducted technical workshops and walkthroughs of last year's ROV to transfer domain knowledge and define expectations.

- Conceptual Design (Late September – October):

Brainstorming sessions were held to outline the goals for Nautilus-X. Teams proposed design sketches, simulation workflows, and underwater strategies based on lessons from the previous season.

- Subsystem Development (November – January):

Parallel development began on mechanical structures, electronics, and software algorithms. CAD modeling, custom PCB design, and embedded code were developed simultaneously. Weekly progress was monitored using shared trackers

- Integration & Testing (February – March):

System integration commenced after component validation. Pool tests were conducted regularly, with feedback loops driving iterative refinement. Safety protocols and redundancy measures were introduced during this stage.

- Mission Readiness & Outreach (April – May):

Final touches were made to the ROV, including waterproofing, sensor tuning, and field-testing. Simultaneously, STEM outreach plans were executed to promote underwater robotics in schools and universities through workshops and demos.

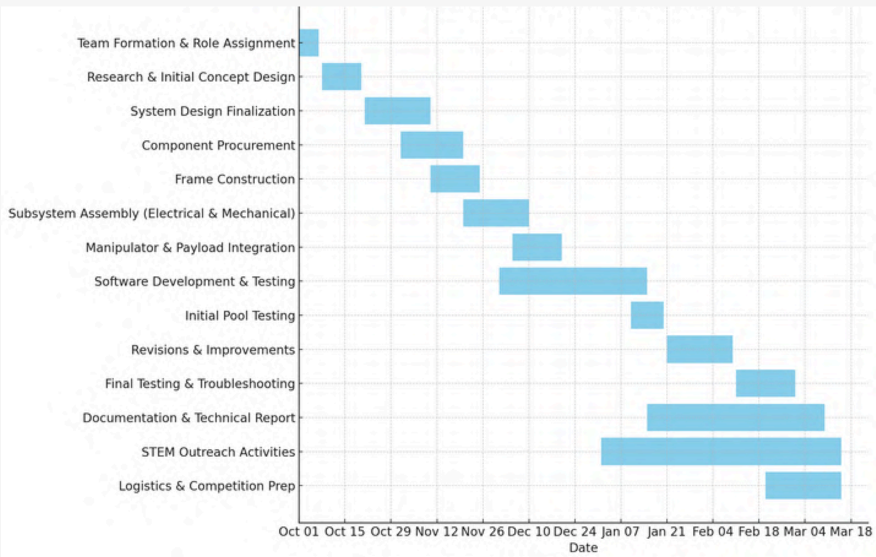


Fig 2 : Gantt chart showing Team Jalpari project timeline .

3| DESIGN RATIONALE

3.1 Vehicle Overview

Team Jalpari's 2025 ROV is a high-performance, mission-centric underwater vehicle designed to execute complex MATE ROV Competition tasks with precision, reliability, and efficiency. The vehicle integrates interdisciplinary engineering with sustainability and innovation, refined through iterative prototyping, pool testing, and field deployments.

Structural Design and Buoyancy:
The frame is built from sheet metal aluminum for corrosion resistance and lightweight strength. Replacing last year's T-slot profiles, the new design uses CNC-cut, bent aluminum sheets to meet strength and modularity requirements while reducing the ROV's overall size to 40x40x25 cm (7 kg, without the manipulator). Custom 3D-printed brackets and mounts allow compact placement of components, reducing hydrodynamic drag. Buoyancy is tuned using syntactic foam and fish weights, maintaining a low center of gravity and high center of buoyancy aligned with the vertical thrusters to ensure stability and slight positive buoyancy for effective underwater performance.

Propulsion and Mobility:
The ROV is powered by six T200 brushless thrusters in a vectored configuration, enabling 5-degree-of-freedom control: vertical lift, yaw, lateral strafing, and roll stabilization. Each thruster is managed by ESCs through a Pixhawk microcontroller, linked to a surface control station. PID tuning and deadband elimination provide smooth, precise handling.

Mission Tooling and Payload Systems:
Equipped with two custom four-function manipulator arms, each featuring:

- Three servo motors for articulated motion.
- Piston-actuated jaw for secure gripping and object manipulation.

The arms include a "learn and preset" feature that records motion sequences for quick, repeatable execution enhancing precision and reducing pilot workload during time-sensitive tasks.

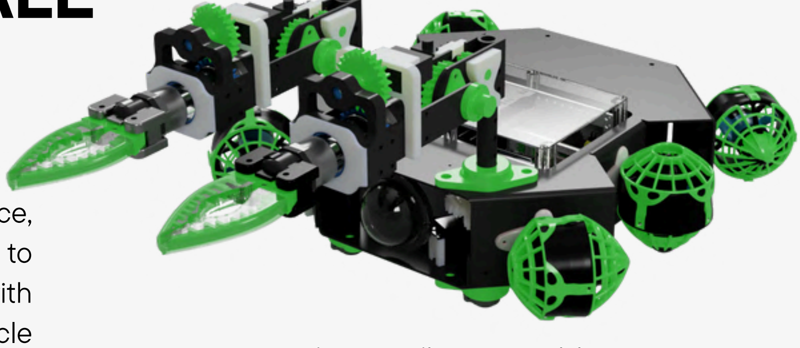


Fig 3 : Nautilux-X 3D Model

Camera and Vision Systems:
The ROV is equipped with 5 cameras: 4 analog cameras via an AHD DVR PCB subsea system and 1 Blue Robotics camera as a backup. All feeds are transmitted via network-based communication, offering multi-angle views (front, down, both manipulators, rear) for enhanced pilot awareness. Video latency is ~30 ms, ensuring near real-time feedback.
Real-time sensor data—including depth, temperature, leak detection, and IMU orientation—is processed onboard to improve situational awareness and mission reliability.

Electronics and Software Architecture:
The electronics are housed in a custom waterproof enclosure, with SP connectors resin-potted for durability under pressure. The design supports modular sensor and payload swapping, enabling mission adaptability.
A Pixhawk flight controller manages thruster control, stabilization, and mission execution, offering robust sensor fusion and failsafe systems.
Auxiliary systems (manipulators, lights) operate independently from navigation and propulsion to enhance fault tolerance.
Custom PCBs optimize space, simplify wiring, and improve internal layout for easier troubleshooting.

Sustainability and Innovation:
In line with SDG 14 (Life Below Water), the ROV uses recycled PET-G 3D prints, reduced acrylic use, and modular reuse of past components. Weight optimization and eco-friendly packaging highlight the team's commitment to sustainable engineering. The modular manipulator was co-developed with marine biologist feedback for coral reef restoration relevance.

4| SYSTEM DESIGN

Team Jalpari's ROV has significantly evolved over the past year, reflecting our focus on improving performance, stability, and mission execution. Last year's top-heavy rectangular frame, though functional, struggled with maneuverability, buoyancy control, and system integration.

The new design features a compact, hydrodynamic aluminum frame with a lower center of gravity for better stability. Improved thruster placement ensures smoother navigation, while reinforced payload tools enhance task execution. A key upgrade is the refined buoyancy system using precision-balanced weights and streamlined floats to reduce drag and improve vertical control.

Cable management has been optimized with a carabiner-mounted tether, minimizing movement interference. The ROV has matured from a basic prototype into a competition-ready vehicle capable of handling complex underwater missions more efficiently.

4.1 Mechanical Design

Materials

Section	Material	Purpose
Main Body	Aluminium sheets	Primary chassis structure; corrosion-resistant and lightweight
	Aluminium Rods	Frame support and component mounting
	Stainless Steel	High-stress joints and fixtures; used for durability and strength
	3D Printed ABS	Custom brackets, housings, and support mounts; designed for precision
Electronics Pod	Polycarbonate (PC) Sheet	Transparent, impact-resistant housing for internal electronics
	Silicone Gasket Seal	Ensures watertight enclosure; provides compression sealing for e-pod lid

Table 2 : List of Materials used

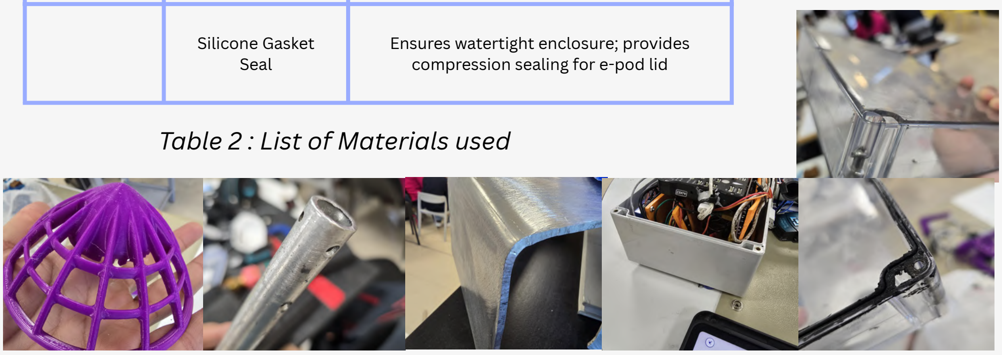


Fig 5: Pictures of important materials used for ROV

Frame Structure

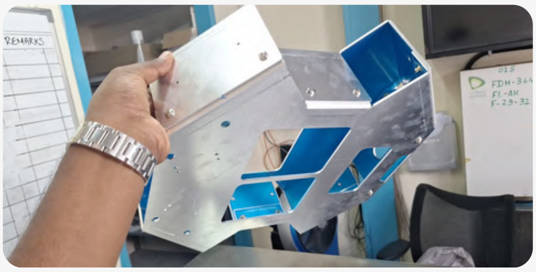


Fig 4 : Picture Of Frame

- Frame Material: Built from 2.8mm aluminum sheets for high strength and corrosion resistance—ideal for underwater use.
- Structural Integrity: CNC-cut and bent sheets ensure a rigid, durable chassis.
- Modular Design: Allows easy upgrades, repairs, or component swaps during testing and development.
- Strain Relief System: Uses a carabiner to manage tether load, reducing connector stress and enhancing durability.

Electronic enclosure

The electronic enclosure is a NEMA 6P-rated Polycarbonate box that houses the following components to ensure environmental protection and reliable operation:

- PCB
- Buck converter
- ESC (Electronic Speed Controller)
- Arduino Mega
- Relay
- Pixhawk
- Camera
- Depth sensor
- Raspberry Pi

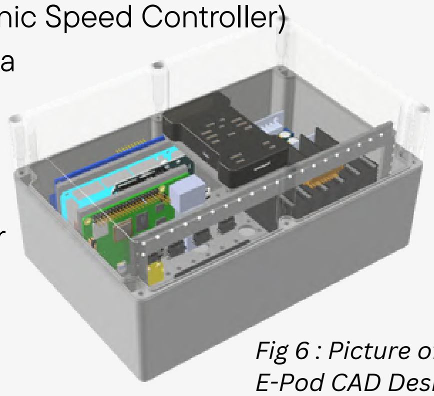


Fig 6 : Picture of E-Pod CAD Design

Fig 7 : Picture of E-Pod

Propulsion

Last year, NIMO used eight 3D-printed thrusters (4 mounted on top, 4 mounted underneath) This configuration enabled motion in all directions but had limitations in control complexity and efficiency. This year, we upgraded to six Blue Robotics T200 thrusters. This thruster arrangement is designed to provide balanced thrust across five degrees of motion: heave, sway, surge, yaw, and roll. Pitch motion is excluded in this configuration.

Benefits of the new setup include:

- Enhanced stability and precision
- More thrust per thruster compared to A2217 BLDC Motors
- Improved propellers from previously 3D printed ones
- Greater effectiveness for delicate underwater maneuvers

This six-thruster arrangement was finalized after iterative pool trials and pilot feedback, confirming it as the optimal balance between thrust power, control simplicity, and operational efficiency. These inputs are translated into precise PWM signals, allowing for smooth and responsive thruster actuation through dedicated ESCs. The T200 thrusters were chosen for their high performance in underwater environments, offering strong thrust-to-weight ratios, corrosion resistance, and modular maintainability, key traits for prolonged field operations.

Overall, the system ensures that the ROV remains stable under load, can hover with minimal drift, and responds quickly to operator commands, even in complex mission scenarios. Incorporating redundancy and distributed thrust, the system also enhances fail-safe capabilities; a single thruster failure does not compromise core navigational functionality, ensuring mission resilience.

FIG 8 : T200 Thruster Placement and ROV Movement/DOF.

Thruster configuration

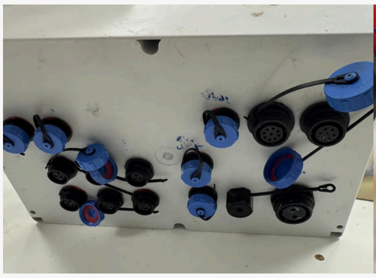
The system comprises 4 lateral thrusters mounted diagonally and 2 vertical thrusters positioned near the center of mass on the left and right sides. This arrangement enables the ROV to maintain precise stability and orientation in all directions, including fine yaw rotations and hovering maneuvers. The use of angled lateral thrusters also improves compactness and efficiency, minimizing drag and simplifying thruster layout. The configuration allows for robust performance during delicate tasks such as manipulation, inspection, and station keeping. Each thruster was tuned in the parameters of the QGround control such as direction as well as thrust to access straight direction maneuverability.

Movement	Controlled By
Surge	Thrusters 1 & 2 (front) + 3 & 4 (rear)
Sway	Thrusters 5 & 6 (side-facing center)
Heave	Vertical thrust from angled 1–4 + 5 & 6
Yaw	Differential between 1–2 and 3–4
Roll	Minor control via side counter-thrust

Table 3 : Thruster Configuration

Water proofing

To ensure maximum protection of onboard electronics, NEMA 6P and IP68-rated enclosures are used, offering excellent resistance to water ingress even under prolonged submersion. All external electrical connections, such as those for actuators and servos, are sealed using waterproof resin to prevent compromise due to exposure. A dedicated junction box is employed to safely separate and distribute servo power in a controlled, dry environment. Additionally, critical components like the e-pod, DVR unit, and junctions are resin-sealed around their connectors, further reducing the risk of leakage and ensuring long-term reliability during underwater missions.



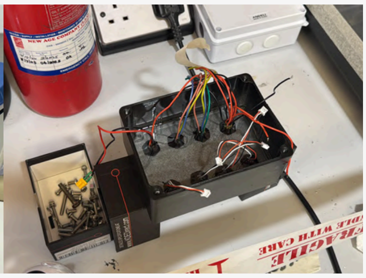


Fig 9 : Waterproof Connectors *Fig 10 : Resin for 2nd Layer of Security*

Camera Casing

The camera is a 88mm diameter hemisphere housed within a durable acrylic hemisphere, chosen for its excellent optical clarity and impact resistance underwater. To ensure waterproofing, a silicone ring is precisely fitted between the hemisphere and the mounting plate, creating a reliable seal that prevents water ingress. The mounting plate itself is made from aluminum, selected for its rigidity and minimal flex, which protects the silicone seal from deformation and exposure to water. Additionally, the aluminum plate aids in heat dissipation, helping to keep the camera cool during extended underwater operations.

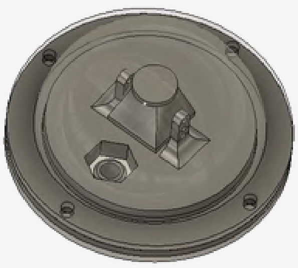
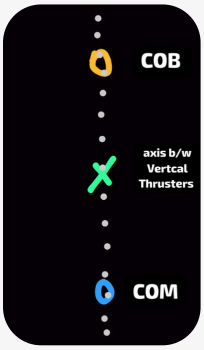


Fig 11 : Camera Enclosure (Left), Caddx Camera (Right)

Bouyancy

Achieving neutral buoyancy and stable orientation was central to Nautilus-X's design. To ensure the Center of Buoyancy (CoB) sits significantly above the Center of Mass (CoM) - enabling passive self-righting -we addressed the front-heavy load from dual manipulators by relocating the junction box, pump, and electronics housing toward the rear for better balance. For buoyancy, Team Jalpari repurposed rejected offshore work vests from a local marine store, the vest filled with closed-cell polypropylene foam, offering durability, compressive strength, and suitability for deep-water use. These were mounted symmetrically on the top and frame to reduce waste and enhance stability. Fine-tuning was achieved by combining these vests with modular buoyancy blocks and ballast weights, allowing dynamic CoM/CoB adjustments during testing. This mix of repositioning, recycled materials, and industrial-grade foam ensures excellent buoyant stability and precise control in demanding underwater missions.

Fig. 12: Buoyancy Solutions. Work Vest (Left), Foam Cube(Center) and Fish Weight(Right)



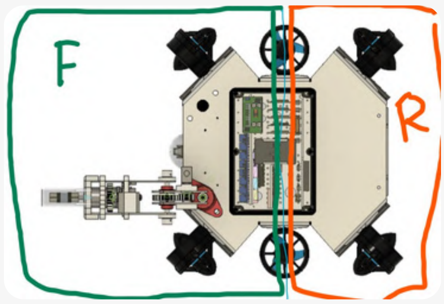


Fig 13: COM vs COB Mapping as well as weight placement

4.2 - Electrical Design & Controls

ELECTRONIC OVERVIEW SYSTEM

Jalpari's electronic system is centered around a custom PCB designed using Autodesk Fusion featuring a buck converter (BMR491) that steps down 48V to 12V at 1300W max power, powering the ESCs and various peripherals including the Raspberry Pi, Pixhawk, Relay, and Arduino Mega. The small size of the Flex Power Module (Buck) is a major improvement in space and the isolation it features for the 12V output protects each component from erratic surface power surges. The ESCs control the thruster motors, while the Raspberry Pi acts as the communication bridge between the Pixhawk and the surface station via Ethernet. The relay manages actuator functions for the gripper and controls the pump used for tasks such as collecting water samples for pH analysis. The Arduino Mega handles servo control for the manipulator arm, processes readings from the pH sensor, monitors water and humidity sensors within the E-Pod for leak detection, and activates the relay as needed. Additionally, a secondary buck converter steps down 48V to 7.4V specifically to power the servos.
All of this is enclosed in a Polycarbonate NEMA 6P rated box ensuring safety and water proofing

Power Consumption

Sl	Item	# Quantity	# Voltage	Current	Tota
1	T200 BLDC Thruster+ESC	6	12	15	1080
2	Servo	6	7.4	4	177.6
3	Actuator	2	12	0.5	12
4	FPV Camera	4	12	0.2	9.6
5	USB Camera	1	5	0.25	1.25
6	Pixhawk	1	5	0.5	2.5
7	DVR	1	12	3	36
8	Raspberry Pi 4	1	5	3.5	17.5
9	Arduino Mega	1	12	0.05	0.6
10	Pump	1	12	2	24
				Power(W)	1361.05
			Theoretical Peak Load(A)		28.35520 A
			Practical Peak Load(A)		26.6 A
			Fuse Chosen		30 A

Table 4: Power Consumption Table of N-Xs Electrical Stack

The ROV consumes 1361.05 W while at full load.
Theoretical Peak Load Amp(A) = 1361.05/48=28.35A
Practical Full Load Amp(A) = 26.6 A
Fuse Chosen = 30 A

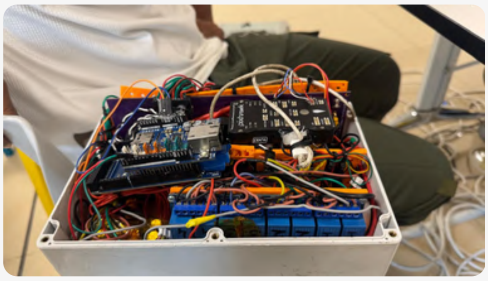


Fig 14 : Electrical Box

Tether

Our Nautilus-X ROV utilizes a 20-meter deployment tether for reliable communication and power delivery. The tether enters the vehicle through a secure, moisture-protected port and consists of a rubber-coated 12AWG power cable for reliable power delivery and a double shielded CAT6 Ethernet cable for high-fidelity, low-latency video and sensor data transmission. To reduce drag and maintain neutral buoyancy, foam floats are attached at intervals along its length. A custom strain relief mechanism using a carabiner absorbs mechanical stress at the connection point, preventing wear while allowing safe detachment and easy transport. The ROV can be completed deployed and recovered by holding the tether.

Tether Voltage Drop

As the ROV consumes about 1361.05 Watts of power, the 12 AWG wire, at the length of 20 meters, is more than enough for the operation purposes.

Cable	Voltage (V)	Current (A)	Length (m)	Voltage Drop (Vd)	Power (After Vd)
8 AWG	48	30	20	2.41 V	1367.7 W
10 AWG	48	30	20	3.83 V	1325 W
12 AWG	48	30	20	6.09 V	1257.2 W

Table 5: Tether Voltage Drop (According to Blue Robotics Calculations)

Tether Weight Consideration

Choosing the 12 AWG wire as Nautilus-X's primary power cable has the advantage of being lightweight over a 20-meter span. The reduced weight eases the load on Nautilus-X, enhancing its maneuverability and task performance. Moreover, the 12 AWG wire's ability to efficiently transmit power without notable voltage drop or power loss over this distance contributes to Nautilus-X's operational effectiveness.

Cable	Weight (km/kg)	Total Weight (kg)
8 AWG (10 sq.mm)	552	13.8
10 AWG (6 sq.mm)	316	7.9
12 AWG (4 sq.mm)	240	6

Table 6: Tether Weight Consideration

4.3 - Software System

Communication System

The communication infrastructure of Nautilus-X is designed to ensure reliable and efficient data transmission between the ROV and the topside control station. The system features two network switches that manage Ethernet connections throughout the ROV and the surface station. One switch is located inside the ROV, while the other is positioned at the surface station, providing a direct communication link. CAT6 double shielded outdoor cables are used to communicate between different systems.
The Pixhawk flight controller inside Nautilus-X is connected via ARDUSUB firmware running on a Raspberry Pi 4. This setup allows the Pixhawk to communicate with the surface station through the network. The BlueOS firmware on the Raspberry Pi 4 facilitates the transmission of control commands and sensor data between the ROV and the topside operators. Arduino Mega is being used for controlling the manipulators with servos and relays acting as the actuators.

Control Systems

This controller was chosen for its capability to manage complex underwater navigation tasks and seamless integration with ARDUSUB firmware, which is tailored specifically for underwater vehicles. The firmware offers multiple advanced flight modes including Stabilize Mode, which maintains stable attitude using onboard sensors to keep the ROV level; Depth Hold Mode, which leverages the Bar30 pressure sensor to keep the vehicle at a precise depth for task accuracy; and Manual Mode, granting operators direct control via joystick for flexible maneuvering. The integrated Bar30 sensor also provides accurate depth and temperature data, essential for reliable underwater navigation and environmental monitoring.

Fig 15: Pixhawk

E-POD

The E-POD is the electronic box that handles the 48V Power supply coming from the surface via the tether and distributes it to all the components. It comprises of multiple PCB's and JST connectors to handle efficient modularity with the E-POD. Swapping out PCB's increases efficiency and reduces downtime in case of equipment or component failure. The first PCB holds the buck and the crown edge connectors for the ESC's, this PCB acting like a backplate. The 12V is then supplied to the ESC's and other peripherals (XT power connectors) with the help of PCB traces. There are fuses present in each positive trace of the connection for each component as it helps isolate the components causing issue from other working components.

The power for peripherals are parallel to the ESC power so that the voltage pull by the peripherals does not affect the power to the thrusters. The peripherals include Relay, Arduino Mega, DVR, Network switch. The Network switch allows for the communication from the surface to the different peripherals in the ROV like the DVR, Arduino Mega, Raspberry Pi 4. Pixhawk present in the E-POD is what allows smooth ROV movement.

DVR POD

The DVR POD is connected to the E-POD via 12V power as well as ethernet. It is mainly used to handle the connections between the DVR to the 4 FPV cameras via waterproof connectors. This feed is then relayed to the network switch present in the E-POD.

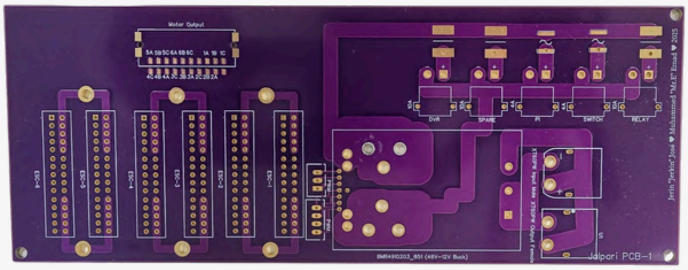


Fig 16 : Electrical Communication Pipeline to Control Thrusters

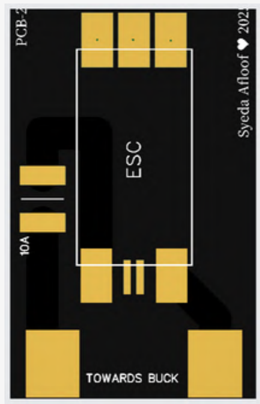


Fig 17: ESC PCB

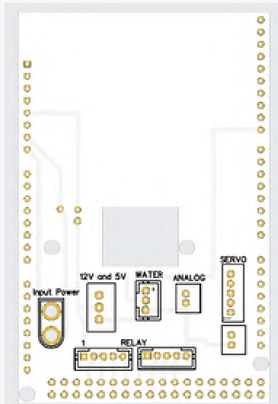


Fig 18: Arduino PCB

Fig 19: DVR PCB

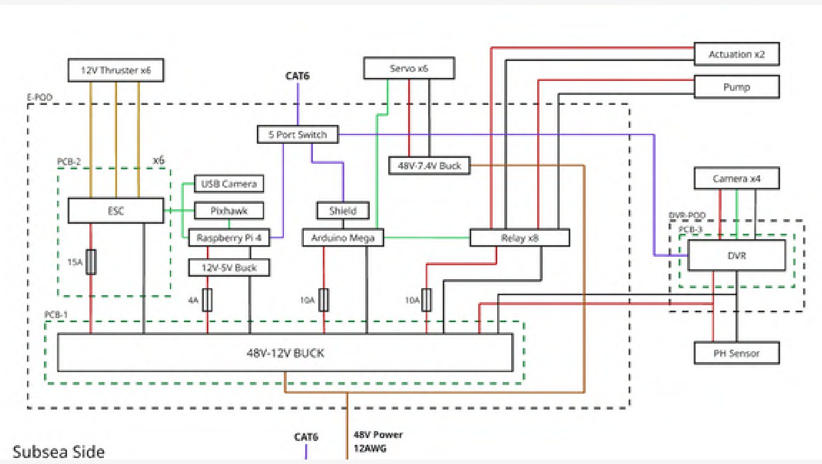


Fig 20: EPOD and DVR SID

SURFACE CONTROL STATION

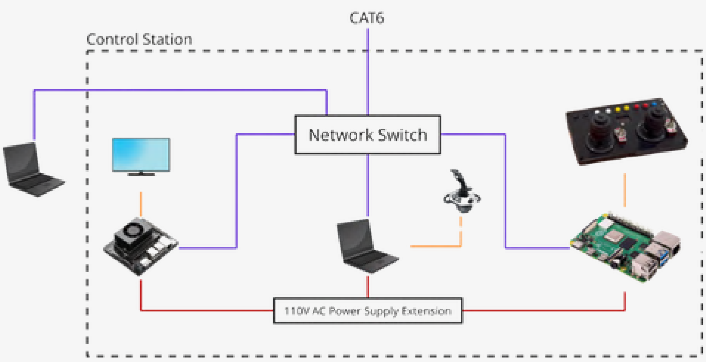


Fig 21: Surface Station SID

Previously, the ROV consisted of a surface station that comprised of the DVR, Switch, Actuator Control with Keyboard, Kill Switch and the Joystick. This year we have improved it by adding certain improvements by removing the DVR from the surface to subsea. At the same time, we have added joystick integration to allow precise movements to the arms.

Now, the topside control station is the command center for Nautilus-X., equipped with essential components for effective operation:

- Monitor: Displays video feeds and other relevant data, offering a clear view of the ROV's environment.
- Network Switch: Manages Ethernet connections between the ROV and the surface station, ensuring flawless communication.
- Actuator Control Raspberry Pi 4: This device allows the communication between the ROV to the surface with the help of joystick as well as buttons. This enables movement as well as actuator control.
- Kill Switch: A safety feature that allows operators to quickly disconnect or connect power to the ROV, ensuring immediate response in case of emergencies.
- Logitech Extreme 3D Joystick: Used for navigating the ROV, this joystick provides intuitive control over its six degrees of freedom, allowing for precise maneuvering.
- Manipulator Control- A 4 Freedom joystick has been integrated to allow the control of each arm, so there are a total of 2 joysticks for each arm.

In addition to these components, the control station includes ***two*** laptops:

Pixhawk Communication Laptop: Runs QGround Control software, providing a comprehensive interface for monitoring and controlling the Pixhawk.

Software Laptop: Gets Camera feed from network switch and runs software required to do tasks.

PILOTING INTERFACE

Fig 22: QGround Interface

Fig 23: Control Box Open With Tether Disconnected

4.4 - COMPUTER VISION

CAMERA VIEWS

For vision, we have a 5 camera set up. It includes 4 FPV Cameras, 1 for Each manipulator as well as 2 for both Front view and gripper POV for better perspective to the object.
The Blue Robotics camera present inside the E-Pod will help the ROV get a Rear View which gives direct access to the tether in case of any tether turns, knots or any safety concerns.

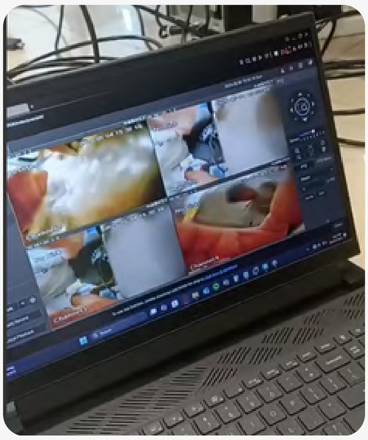


Fig. 24: ROV Frame and Camera positions

Color Correction

To achieve accurate mapping of objects under water, the camera frame goes through color correction. This helps us in the shipwreck task as the dimension of the ship can be analyzed better with the help of this color correction as no parts of the shipwreck could be lost under water.

CAMERA CALIBRATION

Since we are using FPV cameras with an extreme FOV, they utilize fish eye lenses to achieve this. To avoid distortion caused by this, the software utilizes a checkerboard pattern to avoid this distortion and make the camera more usable in its FOV. It also crops the utilizable part of the image to achieve precise outputs.

RECTANGLE DETECTION

To detect the length of the ship, we have used color correction as well as camera calibration into the software. After this part is done, the code displays a frame of the camera and allows the user to plot a known measurement of the ship and waits for a second input from the user which allows the user to plot the unknown measurement of the ship. Both these measurements are compared and then the length of the unknown measurement is determined. All these features combined together enables us to give out this accurate output.

Seamless Fish DNA Detection

This Python program identifies fish species based on DNA sequence patterns by searching for specific genetic markers. It checks for known marker pairs corresponding to four species: Bigheaded, Silver, Grass, and Black. If a match is found, the species name is displayed along with the matching regions.

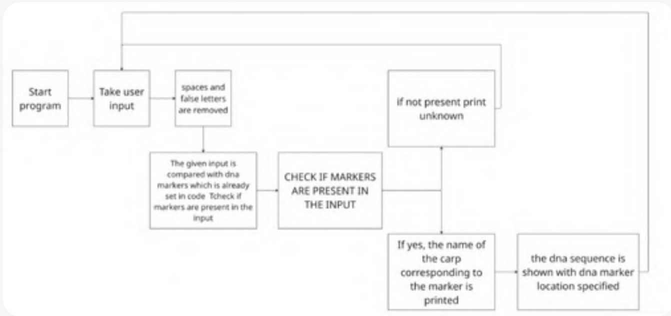


Fig 25: Flow Chart for DNA

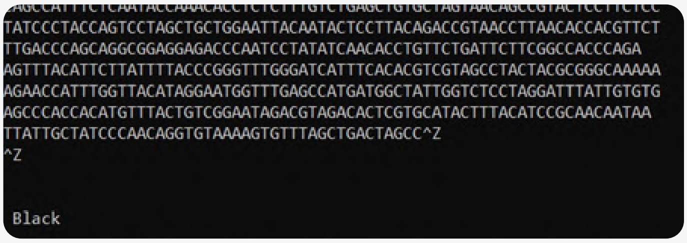


Fig 26: DNA Output

4.5 - Build vs Buy & New vs Used

In-house Build vs Outsourced

Although the materials that we had sourced for the ROV had been from past competitions, for the CNC as well as tasks that involved external involvement, we outsourced it to workshops as well as manufacturers.

ROV Body	Designed with the help of Fusion, given for CNC and bending have been outsourced
PCB	Designed with the help of EasyEDA online software, given in production via JLCPCB

Table 7: Outsourced Items

We have minimized outsourced parts to the maximum as all our connections inside the E-POD as well as all the major mechanical work have been done by us. Only things such as bending, CNC as well as PCB Manufacturing has been done outside as we lack the physical materials and equipments to do so.

New vs Reused

Compared to last year, we felt that we had to do a complete overturn in our mindsets as we faced a good critical review from the judges which helped us gain a lot of experience. So that is why we made a completely new design, but at the same time we tried our best to utilize best out of waste.

ITEM	USED FROM
Power Supply	MATE 2024
200W Buck	MATE 2024
ESP32 (LORA)	MATE 2024
Aluminum Sheet	Malta 2024
Bearings	Malta 2024

Table 8: Outsourced Items

4.6 - SPECIALIZATIONS

Manipulator System Overview

The ROV's manipulator subsystem consists of a dual-arm setup, featuring four function each—slew, shoulder, jaw rotate, and jaw open/close. These arms are mounted symmetrically on either side of the ROV chassis to maintain hydrodynamic balance and reduce undesired torque during underwater operation. This dual-arm arrangement enables co-operative task execution such as stabilizing objects with one arm while performing manipulation tasks with the other, increasing precision and versatility during mission-critical actions.

The system also features programmable presets, allowing specific arm positions to be stored and recalled via dedicated buttons. A "learn mode" is implemented for operators to save new arm positions during the mission, streamlining repetitive tasks like cap-turning or probe placement and task progress.

The entire assembly is optimized for neutral buoyancy, with attention given to placement and mass balancing. All joints are sealed and lubricated with aqualube, and electronic components are protected with conformal coatings. Together, these ensure durability, precision, and reliability in underwater conditions.

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Fig 27: Working prototype of the manipulator

Motor/Servo Mechanism

Each arm is controlled via a topside joystick interface using velocity-based control logic, where servo movement is directly proportional to joystick displacement. This allows smooth, continuous motion rather than jumpy position-based commands, granting the operator real-time, analog-style responsiveness while interacting with underwater props. A dedicated buck powers the system to prevent brownouts. Gear reduction (1:2 for shoulder) is used to improve torque.

Fig 28:70KG Servo

Pump Use for PH

The pump is used for the retrieval of liquid from the soft water bottle present under water. The pump is powered via the relay and is taken in from underwater with the help of needle. This is then taken into a soft water bottle that is present with the ROV and then when it comes on surface, it is retrieved by the team present handling the tether.

Fig 29: Soft Water Bottle

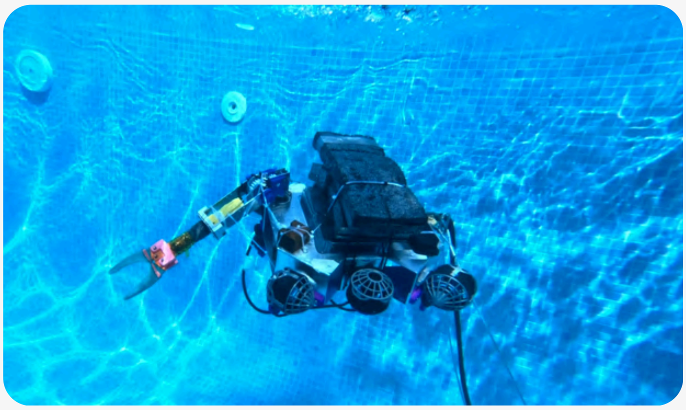

Fig 30 A: Nautilus-X Undewater -Pool Testing

Design Process

The manipulator system was designed based on MATE mission task needs, focusing on cap turning, object retrieval, and precise placement. A dual-arm, 4 Function layout was selected for its balance of control and simplicity. Initial designs were created in Fusion 360 and 3D printed in PLA, then upgraded to ABS for strength. Simulations guided improvements in load handling and arm positioning. Buoyancy and frame balance were key considerations, with foam and mass placement optimized to keep the ROV stable. The final design is modular, balanced, and task-ready—built for reliability and quick servicing during mission operations.

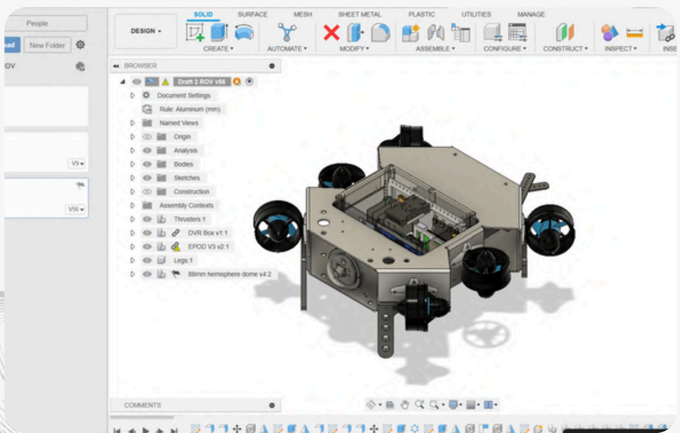

Fig 30 B: CAD file of the ROV

Sensors

Depth Senor: A Bar30 Sensor has been placed on the E-Pod for the ROV to determine the depth of it with respect to the ocean floor. This helps the ROV navigate better, at the same time, helps it hold current depth. This enables the ease of task as well as ease of maneuvarability.

Temperature and water level Measurement :The humidity as well as temperature sensor has been placed inside the E-Pod for the sake of protection. This is one of the key safety features which enables the Pilot to understand in case of any water breach and accordingly pull the kill switch if required. The temperature sensor enables the pilot to understand the current situation of the inside of the E-Pod which could get a bit warm inside due to the presence of an intensive buck as well as other equipments.

Fig 31: Bar30 Depth Sensor

Fig 32: PH Sensor

5| CRITICAL ANALYSIS

Testing Methodology

We designed and built our own pressure chamber to test small components under simulated underwater pressure conditions. Throughout the design and development process, Team Jalpari employed a thorough testing strategy to ensure durability and reliability. Critical mechanical parts were subjected to detailed finite element analysis (FEA) before manufacturing, aiming for a minimum factor of safety (FoS) of 2.0 on pressure-sensitive and costly components such as the electronics housing. Less critical parts were designed with a FoS of at least 1.5 in their final versions, while initial prototypes were tested less rigorously to speed up development. Components vulnerable to water ingress underwent pressure testing at up to 15 psi in our chamber prior to integration. Custom tools and attachments were validated using a practical one-meter extension test, confirming their functionality and strength when deployed at distance. This comprehensive approach enabled us to identify and separate issues caused by submersion from purely mechanical failures.

Fig 33: Pressure Chamber

Troubleshooting

One of the first things we learned as a team was that problems rarely wait for ideal lab conditions to appear—they show up during pool tests, transport, or even just by holding a part wrong. So our troubleshooting approach prioritized easy on-the-spot fixes and design-for-repair. From the start, all major modules—arms, electronics, and end-effectors—were designed with quick access and modularity in mind. This meant damaged parts could be swapped or patched without dismantling the whole system.

When performance issues arose, we didn't just rely on simulations. Instead, we would run physical stress trials under mission-like conditions, observe failure behavior, and then tune designs accordingly. If geometry flaws were suspected, we validated them using FEA—primarily to confirm real-world weaknesses, not just to predict them. In many cases, we adjusted print parameters such as infill pattern, material choice (switching between PLA, PETG, and carbon fiber nylon), or added gussets and structural ribs to improve durability without redoing the entire design.

To avoid design bottlenecks, we developed multiple prototypes in parallel for high-risk parts. This not only accelerated troubleshooting but also helped the team cross-validate ideas and choose the most effective solutions. Rapid prototyping with 3D printing and scrap material was encouraged, especially in early-stage concepts where size or motion range had to be felt physically before finalizing on CAD. And whenever a part failed, we treated it as a data point—not a setback—which helped build a stronger, field-tested design culture across the team.

6| SAFETY

PHILOSOPHY

Team Jalpari approaches safety as a core element of engineering—not a checklist item. From early design decisions to final deployment, safety is prioritized through foresight, risk reduction, and shared team responsibility. Our philosophy is to design systems that are intuitive to handle, minimize hazard exposure, and prevent accidents before they occur. Every team member is involved in identifying and mitigating risks, whether electrical, mechanical, or operational.

STANDARDS

The ROV complies with MATE ROV 2025 safety standards, using Anderson Powerpole connectors as the main power input and a fuse within 30 cm of the connection point. Fuses are sized based on current draw, and the system includes Miniature Circuit Breakers (MCBs) for added protection. The ROV operates on low-voltage DC only, with no AC or fluid power systems used.

The control box features organized, insulated, and labeled wiring, with separate routing for signal and power lines. All external wiring includes strain reliefs to prevent damage at connection points. Watertight housings are pressure-rated beyond 4 meters, and all thrusters are partially shrouded and mounted internally to reduce contact risk. All sharp edges have been removed or padded.

FEATURES

The ROV includes an easily accessible emergency stop switch at the control station, as well as physical safeguards such as shrouded thrusters, rounded frame edges, and shock-absorbing mounts. All wiring is routed cleanly within the control box with no exposed conductors, using insulated and labeled cables. Fuses are placed near the main power input, and power distribution is done through dedicated, tested lines. The power line (AC) uses Miniature Circuit Breakers to prevent the breakage of power in our testing environment.

(Non-ROV devices—FLOAT and Photosphere—are fully sealed, passive, and have no external moving parts. FLOAT includes a pressure release valve for added safety, and its acrylic housing allows for easy visual checks of internal components, including fuses and wiring.

6.1 Awarness Training

Team Jalpari completed a water safety awareness session with Blue Guard Middle East DMCC, covering throw-rescue techniques, floatation use, and seizure response in shallow water. Swimmers practiced victim retrievals, including recovering weighted dummies from the pool floor. Beyond water safety, the team gained hands-on experience by inspecting and repairing the SeaTrekker ROV, reinforcing our understanding of real-world faults and operational hazards. Throughout the season, we stayed in contact with mentors—most notably Jerin from Horizon Geosciences, an ROV pilot technician —who advised us on deployment methods, risk reduction, and industry-standard procedures.

Fig 34: Safe working practices demonstrated by employee.

Tether and the Management

The ROV tether is a neutrally buoyant cable that carries power and communication between the vehicle and topside control. A strain relief system at the ROV connection prevents stress-related damage during handling. Before each mission, the tether is inspected for damage, continuity is tested, and the last two meters are marked for recovery. During deployment, a dedicated handler maintains light tension, responds to pilot commands, and monitors for snags. After recovery, the tether is cleaned, dried, reinspected, and stored coiled in a safe, shaded area. Any wear or faults are logged for maintenance. Check Company Safety Review for an extensive explanation.

7| ACCOUNTING

7.1- Budget

Our team has created a detailed and well-balanced budget to support our participation in the MATE ROV competition. The primary focus of the budget is on acquiring the materials and components necessary to build a high-functioning underwater remotely operated vehicle (ROV). This includes costs for thrusters, motors, structural materials, control systems, waterproof cameras, and lighting. We have also accounted for tools and equipment required during the construction and testing phases, such as soldering tools, 3D printing supplies, and multimeters. Every item has been selected with both performance and cost-efficiency in mind to ensure the ROV is capable of completing mission tasks while staying within financial limits.

In addition to construction costs, the budget covers expenses related to travel, competition registration, documentation, and team branding. This includes transportation, lodging, and meals for team members if the event is held out of town. Registration fees, along with printing and presentation costs for the technical report and display materials, are also included. We've reserved a portion of the budget for a contingency fund to cover unexpected costs, such as emergency repairs or last-minute purchases. To support this budget, we are actively seeking sponsorships, school funding, and organizing fundraising activities. Our team is committed to careful financial management and transparency, maintaining clear records of all expenses. This budget not only supports the technical success of our ROV but also reflects our planning, teamwork, and commitment to delivering a strong performance at the competition.

	A	B	C	D	E
1	**School Name :**	Manipal Academy Of Higher Education , Dubai Campus			**From : 14/10/2024**
2					**To : 22/03/2025**
3					
4	**Income Source**		**Buy ins**		**Amount**
5	Team Members	14	$272.26		$3811.66
6					
7	**Expenses**				
8	**Category**	**Type**	**Description**	**Projected Cost**	**Budgeted Value**
9	Hardware	Purchased	PCV Pipe & Fitting	$250	$200
10		Donation	Aluminium Extrusions	$330	$0.00
11		Donation	3D Printing Filament	$50.00	$0.00
12		Purchased	Screw/Nuts/Bolts	$20.00	$20.00
13		Purchased	Silicon Sealant	$15.00	$10.00
14		Purchased	Epoxy Resin	$50.00	$40.00
15		Purchased	Insulation Liquid	$15.00	$10.00
16		Purchased	Waterproof Glands	$10.00	$5.00
17		Purchased	Valves	$120.00	$100.00
18		Donation	Control Station Box	$30.00	$0.00
19		Purchased	Stress Relief	$10.00	$10.00
20					
21	Electronics	Purchased	Power Supply	$100.00	$90.00
22		Purchased	2 Core Rubber Flexible Cable	$110.00	$100.00
23		Purchased	Microcontrollers	$80.00	$60.00
24		Purchased	Fuse & Fuse Holder	$45.00	$40.00
25		Purchased	Anderson Connector	$100.00	$90.00
26		Purchased	Thrusters with ESC's	$300.00	$250.00
27		Purchased	Linear Actuators	$60.00	$50.00
28		Purchased	Buck Converters	$45.00	$40.00
29		Purchased	Bus Bar	$10.00	$8.00
30		Purchased	2 Channel Relay	$10.00	$10.00
31		Purchased	Connecting Wire	$200.00	$150.00
32		Donation	Monitors	$50.00	$0.00
33					
34	Sensors	Purchased	Camera	$90.00	$80.00
35		Purchased	Pressure & Depth Sensor	$60.00	$50.00
36					
37	Travel	Purchased	Round Trip to Michigan, USA	$13,000.00	$14,000.00
38		Purchased	Visa	$2,000.00	$2,000.00
39		Purchased	Accomodations	$6,000.00	$5,500.00
40					
41	General	Purchased	Transportation	$40.00	$60.00
42		Donation	Swimming Pool Rent	$100.00	$50.00
43		Purchased	Registration Fee	$465.00	$465.00
44					
45				Total Income	$3811.66
46				Total Expenses	$23,185.00
47				Total Expenses Re-use/Donations	$23,288.00
48				Total Funding Needed	$2500

Fig 35: Expense sheet detailing components and their respective costs.

7.2 Cost Accounting

	A	B	C	D	E	F	G	H	I	J
1	EXPENSE REPORT				EXPENSE REPORT					
2	Time Stamp	Paid Amount	Paid By	Paid To	Category	ipt	Comments	Type	Amount	Running Balance
3	18/12/2024	$73.78	Medwin	Ali Express	Electrical	//driv	bought, FPV,	Purchased	$73.78	$73.78
4	10/1/2025	$256.99	Medwin	DigiKey	Electrical	//driv	Medwin's	Purchased	$256.99	$330.77
5	12/1/2025	$20.44	Medwin	Ali Express	Mechanical	//driv	RS485 Dongle	Purchased	$20.44	$351.21
6	17/01/2025	$24.62	Medwin	Shop And Ship	Electrical	//driv	import and	Purchased	$24.62	$375.83
7	26/01/2025	$33.22	Medwin	Ali Express	Mechanical	//driv	and servo, the	Purchased	$33.22	$409.05
8	28/01/2025	$106.45	Medwin	Ali Express	Electrical	//driv	photosphere	Purchased	$106.45	$515.50
9	6/2/2025	$63.03	Medwin	Ali Express	Mechanical	//driv	soft bottle and	Purchased	$63.03	$578.53
10	10/2/2025	$55.81	Medwin	Ali Express	Mechanical	//driv	Sensor,	Purchased	$55.81	$634.34
11	13/02/2025	$5.04	Medwin	iMile	Electrical	//driv	for Photosphere	Purchased	$5.04	$639.38
12	19/02/2025	$195.76	Medwin	JLCPcb	Electrical	//driv	10 PCB-2	Purchased	$195.76	$835.14
13	19/02/2025	$19.06	Medwin	Ali Express	Mechanical	//driv	Conversions for	Purchased	$19.06	$854.20
14	26/02/2025	$6.81	Medwin	Ali Express	Mechanical	//driv	Connectors	Purchased	$6.81	$861.01
15	3/3/2025	$13.61	Medwin	FedEx	Electrical	//driv	Import Tax	Purchased	$13.61	$874.62
16	3/3/2025	$11.71	Medwin	Ali Express	Electrical	//driv	XT30 and XT60	Purchased	$11.71	$886.33
17	4/3/2025	$95.29	Medwin	DigiKey	Electrical	//driv	PCB, All PCBS	Purchased	$95.29	$981.62
18	5/3/2025	$10.01	Medwin	Amazon	Electrical	//driv	PCB	Purchased	$10.01	$991.63
19	8/3/2025	$14.70	Medwin	Ali Express	Electrical	//driv	and Junction	Purchased	$14.70	$1,006.33
20	15/03/2025	$6.40	Medwin	Shop and Ship	Electrical	//driv	Connectors	Purchased	$6.40	$1,012.73
21	15/03/2025	$44.11	Medwin	Ali Express	Electrical	//driv	Outside	Purchased	$44.11	$1,056.84
22	23/03/2025	$18.08	Medwin	Shop and Ship	Electrical	//driv	import tax for	Purchased	$18.08	$1,074.92
23	23/03/2025	$34.04	Medwin	Amazon	Electrical	//driv	for Photosphere	Purchased	$34.04	$1,108.96
24	24/03/2025	$42.20	Medwin	Ali Express	Electrical	//driv	pneumatic	Purchased	$42.20	$1,151.16
25	29/03/2025	$669.76	Medwin	MateROV	Other (mention below)	//driv	Registration	Purchased	$669.76	$1,820.92
26	7/4/2025	$111.63	Medwin	Ali Express	Electrical	//driv	flange bearing	Purchased	$111.63	$1,932.55
27	14/04/2025	$62.62	Medwin	Devices	Electrical	//driv	Cat6 Cable	Purchased	$62.62	$1,995.17
28	15/04/2025	$32.13	Medwin	JLCPCB	Electrical	//driv	and Mega	Purchased	$32.13	$2,027.30
29	18/04/2025	$244.49	Medwin	Ali Express	Mechanical	//driv	for DVR, Gland	Purchased	$244.49	$2,271.79
30	21/04/2025	$7.23	Medwin	Amazon	Mechanical	//driv	Gasket	Purchased	$7.23	$2,279.02
31	23/04/2025	$121.70	Medwin Sajan	DigiKey	Electrical	//driv	Connectors for	Purchased	$121.70	$2,400.72
32	23/04/2025	$466.38	Medwin	Blue Robotics	Mechanical	//driv	ESC's	Purchased	$466.38	$2,867.10
33	2/5/2025	$257.29	Medwin	Ali Express	Electrical	//driv	Connector Pair,	Purchased	$257.29	$3,124.39
34	2/5/2025	$5.45	Medwin	Building Materials	Electrical	//driv	Sleeve, Steel	Purchased	$5.45	$3,129.84
35	2/5/2025	$98.01	Medwin	Mouser	Electrical	//driv	for EPOD and	Purchased	$98.01	$3,227.85
36	2/5/2025	$5.17	Medwin	FedEx	Electrical	//driv	PCB Import	Purchased	$5.17	$3,233.02
37	7/5/2025	$28.32	Medwin	Aramex	Electrical	//driv	Thrusters import	Purchased	$28.32	$3,261.34
38	7/5/2025	$5.17	Medwin	Building Materials	Mechanical	//driv	Nylon Sleeve,	Purchased	$5.17	$3,266.51
39	7/5/2025	$5.72	Medwin	Transco Spacers	Mechanical	//driv	for Float,	Purchased	$5.72	$3,272.23
40	7/5/2025	$0.82	Medwin	Pharmacy	Mechanical	//driv	Gripper	Re-used	$0.00	$3,272.23
41	7/5/2025	$2.72	Medwin	Transco Spacers	Mechanical	//driv	For Float, more	Purchased	$2.72	$3,274.95
42	7/5/2025	$1.63	Medwin	Transco Spacers	Mechanical	//driv	Connectors	Re-used	$0.00	$3,274.95
43		$3.27	Medwin	Besomi Electronics	Electrical			Purchased	$3.27	$3,278.22
44		$9.80	Medwin	Transco Spacers	Mechanical			Purchased	$9.80	$3,288.02
45		$59.90	Medwin	Const. Ind. LLC	Mechanical			Purchased	$59.90	$3,347.92
46		$1.91	Medwin	Transco Spacers	Mechanical			Re-used	$0.00	$3,347.92
47		$12.25	Medwin	Amazon	Electrical		Tape	Purchased	$12.25	$3,360.17
48		$4.08	Medwin	bab Al Yemen Hard	Mechanical			Purchased	$4.08	$3,364.25
49		$8.44	Medwin	Capcut	Software			Purchased	$8.44	$3,372.69
50		$34.85	Medwin	Aramex	Mechanical			Purchased	$34.85	$3,407.54
51		$7.08	Medwin	Aramex	Mechanical			Purchased	$7.08	$3,414.62
52		$5.99	Medwin	Supermarket	Mechanical		Extension	Purchased	$5.99	$3,420.61
53		$1.63	Medwin	Supermarket	Mechanical		Water	Purchased	$1.63	$3,422.24
54		$24.50	Medwin	JLCPCB	Electrical			Purchased	$24.50	$3,446.74
55		$187.04	Medwin	Ali Express	Mechanical			Purchased	$187.04	$3,633.78
56		$25.86	Medwin	Rolla DVR	Electrical		DVR	Purchased	$25.86	$3,659.64
57		$13.61	Medwin	Security	-		Security	Purchased	$13.61	$3,673.25
58										
59									Total Raised	$3,811.66
60									Total Spent	$3,673.25
61									Final Balance	$138.41

Fig 36: Documentation of cost analysis and tracking

8| ACKNOWLEDGEMENTS & REFERENCES

Our Sponsors

Team Jalpari Thanks

Manipal University Dubai for their continuous academic and logistical support throughout the project | Our faculty advisor for their guidance, technical advice, and encouragement | Parents and family for their advice, motivation, and unwavering support | MATE Center for providing us this opportunity to explore marine technology and robotics | Volunteers and judges at the MATE competition for their time, feedback, and commitment | SolidWorks for sponsoring us with essential CAD tools used throughout our design process | Blue Robotics for their reliable components and open-source documentation | Company alumni for their support, insight, and mentorship throughout the year | All our team members for their dedication, collaboration, and hard work | IEEE Student Chapter at Manipal University Dubai for being a great parent organization | University staff and lab technicians for access to facilities and technical assistance | Local venues and pools that supported our underwater testing sessions | All supporters, sponsors, and mentors who contributed to making this project a success

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Appendix A : Safety Checklist

Procedure

Check Mark

1. Pre-Power Checks

- Everyone on the team is wearing safety gear.
- Before conducting the safety check, power is turned off. Make sure the fuse isn't blown.
- Clear obstructions from propellers, shafts, and manipulators. "Safe" should be shouted.

2. Pre-Water Checks

- Connect the tether cable to the control stationand turn on the power of the system. Test the video system.
- Compress the electronics enclosure to the called dive's rated depth. Turn off the system and say, "Water Ready."

Lower the ROV into the pool by two team members and the tether man ."In Water," say it loudly.

In-Water Checks

- Check the warning lights after turning on the system.
- Verify that the internal pressure is steady at the surface. Check for air bubbles and look for leaks visually.
- "Pilot in Command," say it loudly.

Communication breakdown

- Restart the ROV
- Send another test package.
- If there is no communication, turn off the ROV.
- Bring the ROV to the surface with the tether and inspect it for damage or leakage.

Recovery Checks

- Make sure the ROV is at the surface and looking away from the pool wall. Turn off the system and say, "Crew in Command."
- Lift the ROV from the pool onto land by two crew members and a tether guy.

Safety officer signature:

- Entering the Lab or Workshop
- Wear the facemask and PPE provided by the company.

Operating Power tools

- Wear all PPE necessary for the tools.
- Always keep your hands away from the tool's head.
- Keep long hair tied back and spinning sections free of strings, ropes ,and flexible fabrics/materials.

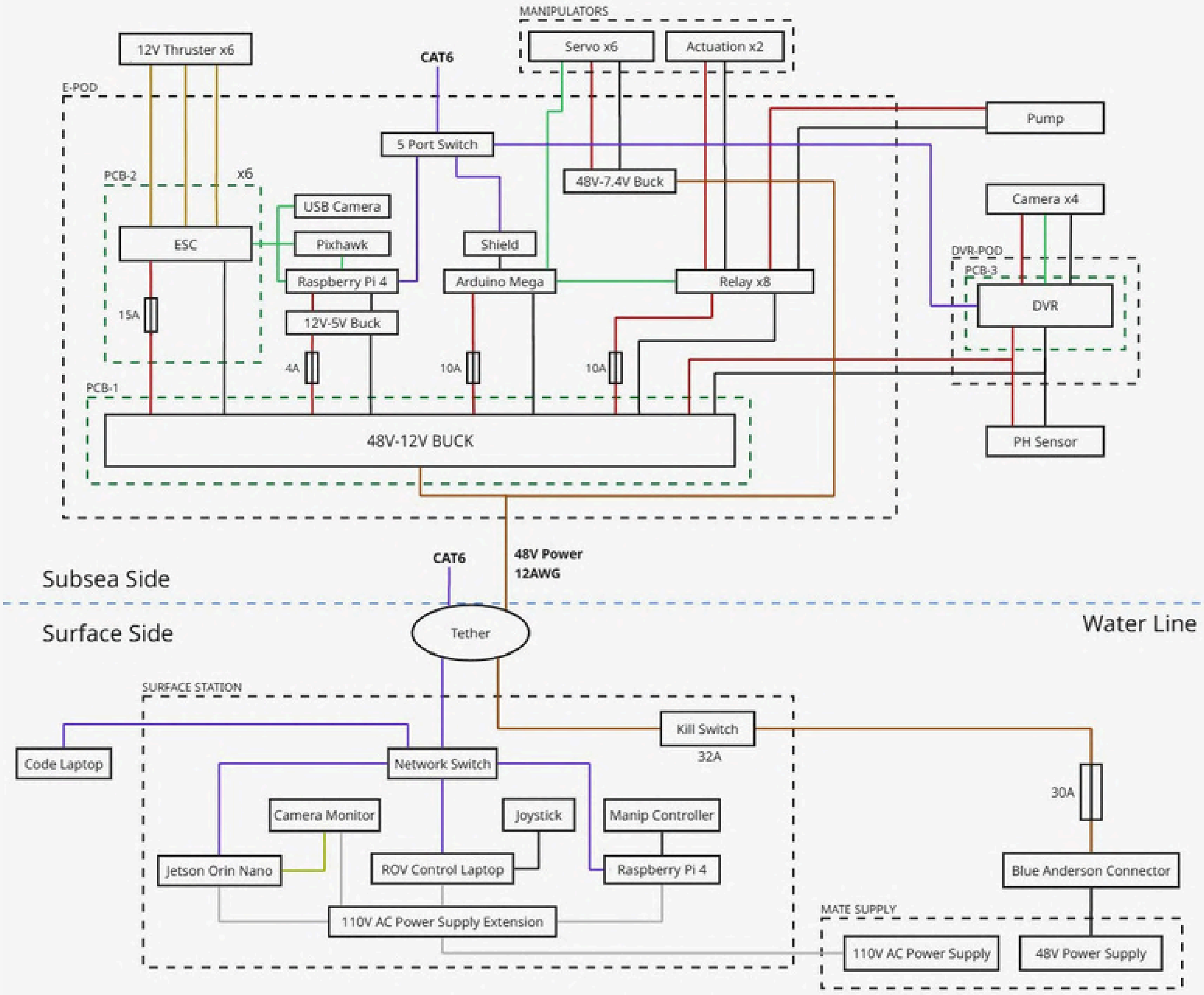
Working with Electrical Components and Soldering

- Use a solder fume extractor
- keep the soldering iron or hot air hand tool in its holder ,When not in use.

Check all electrical connections to ensure they are not in contact with liquids. Employee Signature

APPENDIX B: SID

ROV SID



Guide

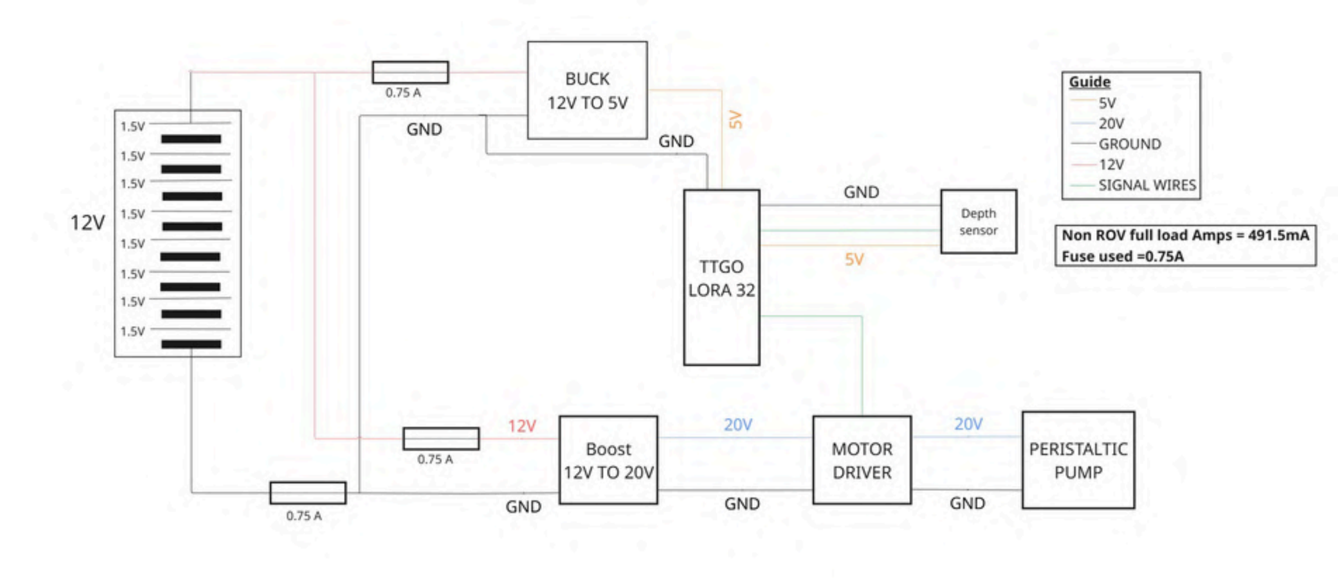
- 12VDC
- 0VDC / Ground
- Ethernet
- Data Signal
- HDMI
- Thruster Commands
- 48VDC
- 110VAC

Fuse Selection

ROV Full Load Amps (FLA) in water = 26.9A

Fuse size selected based upon FLA = 30A

NON-ROV DEVICE - FLOAT SID



NON-ROV DEVICE - PHOTOSPHERE SID