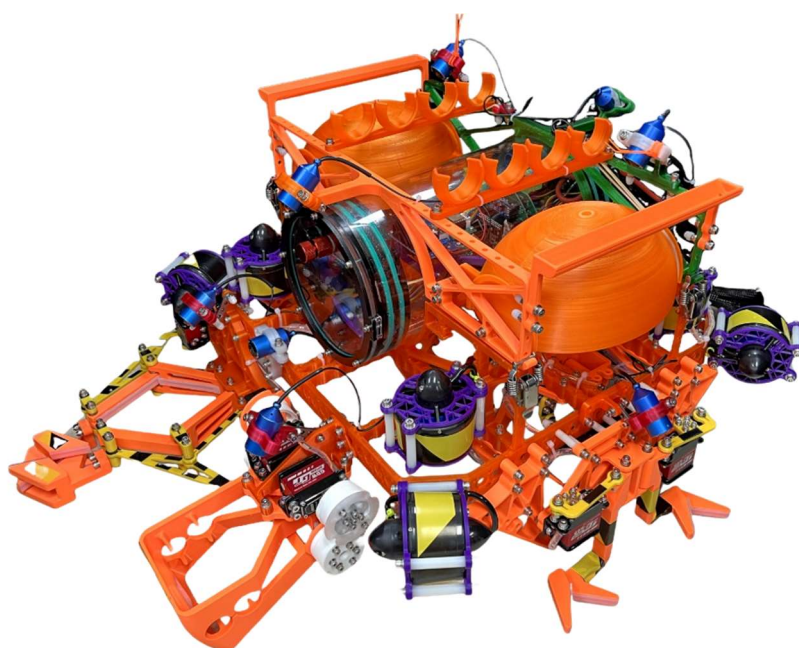


OCTO

Technical Documentation



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CHIEF TECHNOLOGY OFFICER

WU Tsz Wah Grade 11

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1. Abstract

Over-Defined is a company focused on building cutting-edge ROVs to tackle complex challenges and carry out demanding, high-risk underwater missions. After more than 350 hours of engineering work by a team of 25 skilled engineers, we developed our fourth-generation ROV, Octo.

Octo features multitasking capabilities. It is equipped with multiple multifunctional manipulators, a comprehensive control system, and a variable buoyancy system. Octo is designed to complete tasks for the 2026 MATE Request for Proposals (RFP), such as iceberg analysis, monitoring the health of cold-water habitats, and powering an oil platform from a wind turbine. A vertical profiling float was designed along with the ROV to assist in investigating the underwater environment.

Octo is modular, highly repairable, versatile, and specially designed to complete the MATE RFP tasks. This document highlights our development process and the vehicle design of Octo, including the project schedule, technical features, and budget.



Figure 1. Team Photo

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3. Teamwork

A. Company Profile

Established in 2022 and headquartered in Kwun Tong, Hong Kong, Over-Defined is dedicated to protecting and rebuilding global ecosystems. Our company restructured our team to develop professional environmental robotics designed to heal our planet. Today, our company consists of 25 engineers across three departments: Mechanical, Electrical, and Software.

Leadership remains deeply integrated into the technical process. The CEO manages company progress while contributing as a software engineer; the CFO oversees the budget and spending while collaborating with the Mechanical department; and the CTO orchestrates technical workflows and manages documents. Sub team leaders guide engineers on department-specific projects, providing feedback to deliver a safer, higher-quality product. Our company views safety and reliability as our top priority. Guided by a dedicated Safety Officer, we maintain strict safety standards throughout the entire development process.

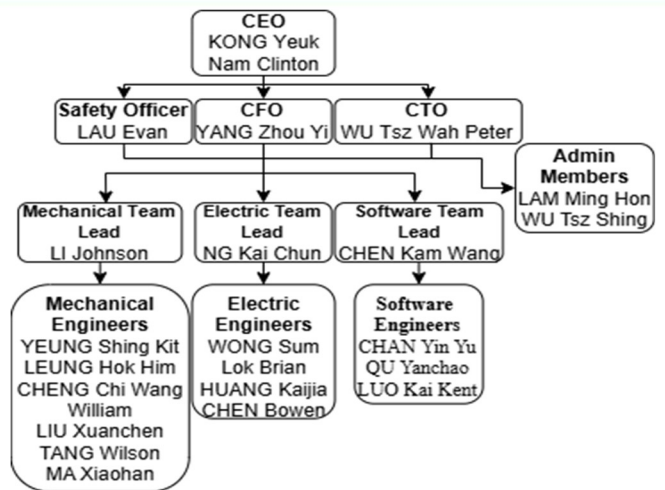


Figure 2. Over-Defined Organisation Structure

To sustain the future of the team, we have recruited Grade 9 engineers who have completed our comprehensive, one-year foundational course. This training allows these engineers to grow professionally based on their individual strengths and solid fundamentals, building a highly skilled team fully committed to our long-term environmental goals.

B. Project Management

Our company tracks workflows and clarifies task ownership through Google Sheets, collaborates on all documentation via Google Docs, and manages media storage through Google Drive. External communication is handled via Gmail, while internal communication relies on WhatsApp groups dedicated to specific departments and projects.

Software is developed in an open-source GitHub repository, while mechanical designs are created in SolidWorks and electrical designs in KiCad. These resources enable online collaboration and communication, accelerating the development process and minimizing miscommunication.

Our company maximizes project efficiency through a strategic departmental structure consisting of Programming, Mechanical, and Electrical teams. This specialization allows for precise resource allocation and enhanced task fluency across all technical stages. Our commitment to progress is reinforced by weekly Wednesday meetings led by sub team leaders, which are dedicated to idea sharing and cross-functional feedback to clarify day-by-day plans for the upcoming week.

To ensure consistent ROV operation, pool tests are conducted weekly. These sessions allow us to detect operational errors and brainstorm solutions to solve the problem after the pool test.

Employee well-being is central to our success. To balance our heavy workload, our company hosts annual team-building events like our company barbecue. Not only does this enhance employees' productivity, but it also fosters a supportive environment.

Month	Sep				Oct				Nov				Dec				Jan				Feb				Mar				Apr			
Week	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Rov Main Frame Design																																
Rov Control System Update																																
Ground Station Update																																
ROV electronic system Update																																
Task Specific Manipulator Design																																
Assembly and Test																																
Pilot Training																																

Figure 3. Project Timeline

4. Design Rationale

A. Design Methodology

Our Engineering Design Process emphasizes planning over adapting. The first step in every project is evaluating failures of similar past projects and analysing new tasks or components. Project teams use an evaluation matrix to decide whether to use an existing tool. If none is suitable, members sketch ideas and capture concepts in a 'Solution Book'. Ideas are scored in weekly peer reviews based on cost, feasibility, efficiency, and manufacturing time. Quality review sessions assess trade-offs to avoid costly changes later. Once a decision is made, a formal action order tasks the design team with manufacture and assembly.

B. Problem-Solving

First, we examine all task details to identify upcoming challenges. We take inspiration from everyday tools to cut brainstorming time and reserve more time for later improvements. We then visualize possible methods and share them with our team. In weekly meetings, we discuss approaches, choose the best method, gather feedback, and refine decisions in later meetings. Once the design is complete, we assign tasks to turn our concepts into reality.

Our company prioritizes a logical approach to problem-solving. Using a trade study, we first define project goals and constraints. Different ideas are suggested during brainstorming. The optimal design is selected based on criteria such as cost, performance, weight, and risk.

C. Vehicle Structure

Octo's framework was manufactured using 3D printing for its cost-effectiveness and design flexibility, maintains its original 420mm x 420mm dimensions just like last year's, but features increased thickness and four reinforced support structures to accommodate heavier loads. This allows the Octo to carry more manipulators and mission payloads, enabling it to complete multiple objectives in a single dive, thus reducing the times returning to shore.

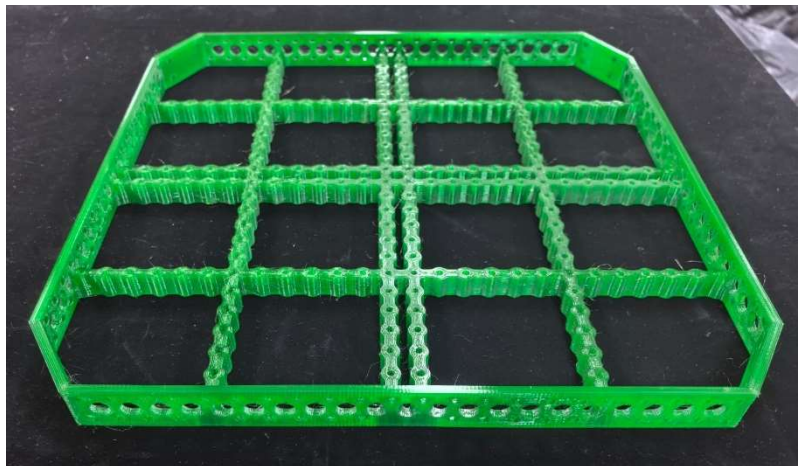


Figure 4. ROV Frame

To minimize travel time between targets and improve positioning precision, we recalibrated the thruster angles to prioritise longitudinal speed. The 16-mm-spaced holes on the frame ensure modular compatibility with LEGO and Makeblock components, increasing design flexibility. We design manipulators that fit the modular holes, ensuring the ROV is always equipped for the task at hand. Thruster placement has been optimised for effortless maintenance and rapid servicing. The slope angles of the weight mounts have been adjusted to prevent tether entanglement during operation. For customer convenience, we incorporated quick-release snap-fit mechanisms for the watertight compartment enclosures.

Our company considered four types of 3D printing materials: PETG, PLA, ABS and TPU. Our ROV's structure was originally made from PLA, yet the PLA frame broke easily and needed replacement. After searching alternative materials, PETG and ABS are found as potential options because of their high durability and resilience. However, scientific studies show that ABS emit more toxic gases during printing. Therefore, PETG is selected. TPU is used for the CRAMS (Compliant rolling-contact architected materials), as it has greater flexibility and higher durability compared to other 3D printing materials.

D. Propulsion

The Octo features four horizontal and four vertical thrusters on an octagonal frame, with a setup enabling six degrees of freedom (6 DOF). Although this increases control and stabilization complexity, it raises the performance ceiling, making the trade-off worthwhile. To prioritize forward and backward speed, horizontal thrusters are angled at 33° to the Y-axis, balancing fast transit with precise lateral manoeuvres.

The horizontal thrusters are placed on the outer perimeter to maximize the yaw moment arm. Despite increasing the risk of tether entanglement, this placement ensures responsive heading changes for yaw, which is our most frequent rotation. Meanwhile, the four vertical thrusters are located at the inner corners to maximize stability and actively control pitch, roll, and depth.

We chose the ROVMaker 2216 thruster because it is lightweight, cost-effective, and gives enough propulsion. Also, it comes with a built-in motor driver, so the wiring is much simpler.

The ROV is supplied with 12V, which drops to 8V after the tether, with each thruster drawing up to 5A. The system features three adjustable power modes managed by software capping: Horizontal mode limits vertical power and prioritizes horizontal thrusters to speed up transit between tasks, consuming 240W under full load; Vertical mode limits horizontal power and prioritizes vertical thrusters for fast diving and surfacing, consuming 240W; and Balanced mode offers high precision for complex operations, consuming 280W.

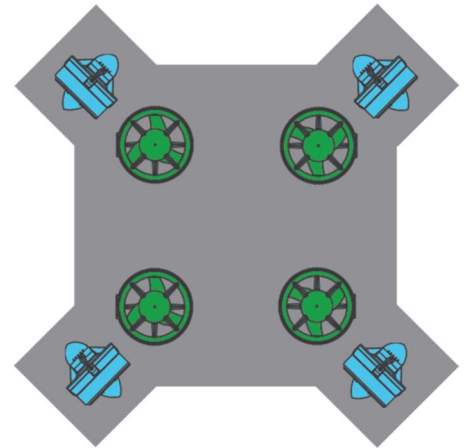


Figure 5. Octo's Thrusters Placement

E. Buoyancy

i. Ping Pong Holder

This year, Octo's new multi-claw design has resulted in an increase in its weight, and extra buoyancy is required instead of weights. To address this need, our company designed the quick-set ping-pong ball holders as part of the Variable Buoyancy System.

Two ping-pong ball holders are installed on both sides of the top surface of the ROV, each with 4 slots for ping-pong balls. Each ping-pong ball provides 0.328 N of buoyancy.



Figure 6. Ping Pong Holder

The ping-pong ball holders allow our engineers to freely adjust the number and position of the ping-pong balls and thereby manage uneven weight distribution of the ROV.

ii. Weight Mount

Our company installed weight mounts on both sides of the Octo's frame to allow for fine-tuning with various weights. However, subsequent testing indicated that no additional weight is required.

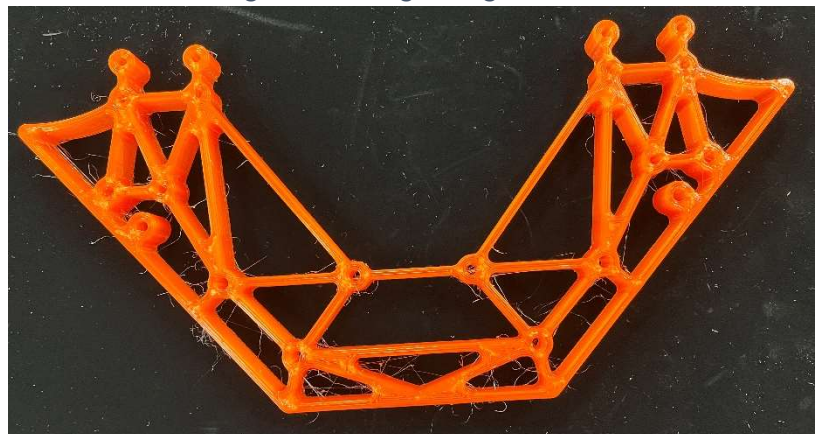


Figure 7. Weight Mount

iii. The “Rugby Balls”

For payload-specific tasks such as lifting the lobster pot, Octo requires a variable ballast to alter its buoyancy underwater. Therefore, our company designed a pair of 3D-printed air chambers, the “rugby balls”, as part of the Variable Buoyancy System.

We determined the volume of each air chamber to be 1.02 L by calculating based on the gravity of the payload. Therefore, two air chambers can provide 20 N of net buoyancy, which counteracts exactly the gravity of the lobster pot. We selected a semi-oval shape for these air chambers, which could concentrate the contained air to maintain a stable buoyancy distribution.

To concisely adjust the buoyancy of the ROV, a mechanism composed of servos, rubber bands, and linkages was designed. It can roll the air chambers underwater, and therefore change the volume of contained air.

When Octo captures the lobster pots, air is supplied from an onshore manual pump through two hoses. The air is injected beneath the air chambers, where it rises to be captured by the chambers. Then, the buoyancy of the ROV increases. After the lobster pot is unloaded, the chambers roll 90° and release the contained air, eliminating the extra buoyancy.

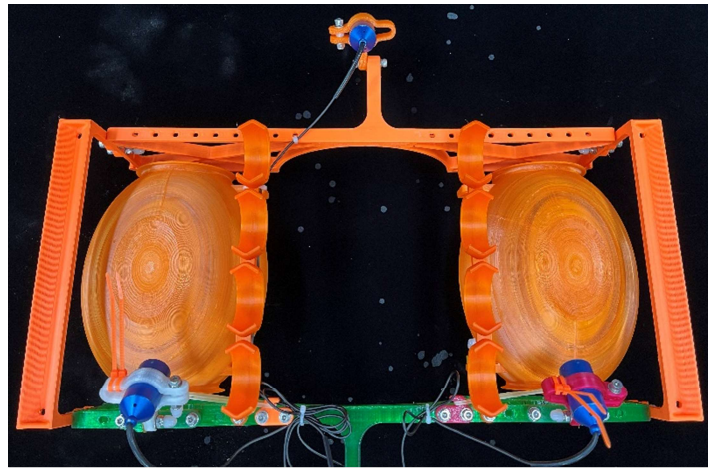


Figure 8. The “Rugby Ball”

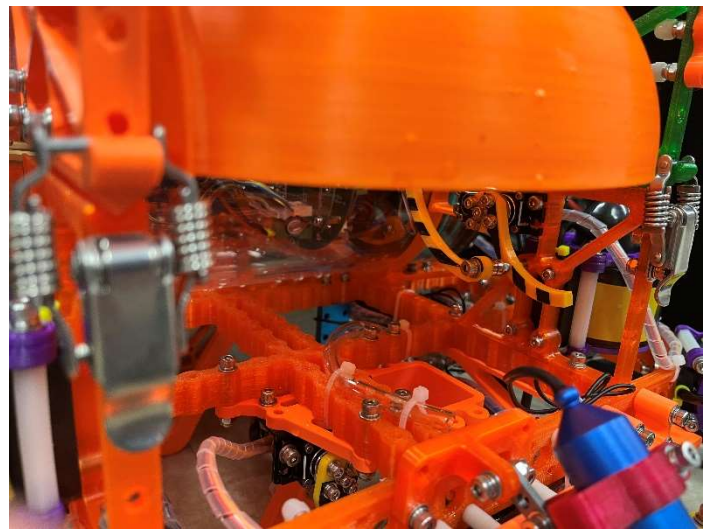


Figure 9. Supply Air Outlet

F. Control and Electric System

i. Electronic Design and Cabling

1. ROV Side

The underwater circuit serves as the core electronic structure of the ROV, collecting sensor data, providing stable power, driving thrusters, and controlling servos. To ensure stable operation, the system utilizes an Arduino Mega 2560 Pro to process data and execute commands, while converting a 12V input into a stable 5V supply and establishing an anti-interference communication channel. It features sensors to monitor depth and attitude, while reserving sufficient interfaces for the propulsion and actuation systems.

This underwater system is split across two stacked, double-layer PCBs. The back side of the control board houses the Arduino Mega 2560 Pro, a step-down voltage module, anti-interference RS485 modules, a gyroscope, and a depth sensor to handle stable signal transmission and environmental monitoring. Meanwhile, the front power distribution board manages power across the vehicle, utilizing input capacitors to suppress voltage fluctuations and protect the circuitry. This board also features 12 dedicated interfaces for thrusters and servos to seamlessly adapt to different modular configurations.

Our ROV-side electrical design delivers two core advantages: the stacked, two-PCB layout saves critical internal space, while the use of interconnecting metal pin headers simplifies assembly and disassembly for easier maintenance. However, this stacked configuration introduces unavoidable engineering trade-offs. The concentrated layout increases localized weight, requiring the addition of balancing components to properly adjust the ROV's buoyancy.

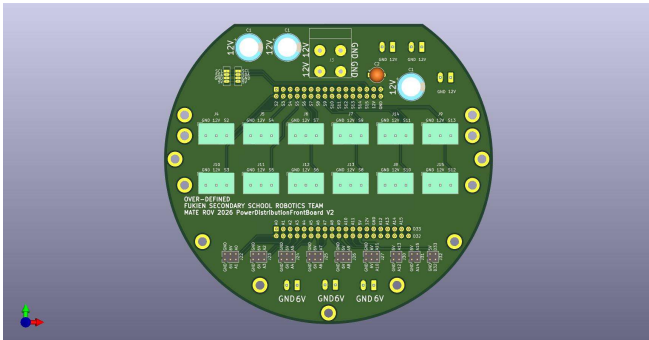


Figure 10. Front Side Of PCB

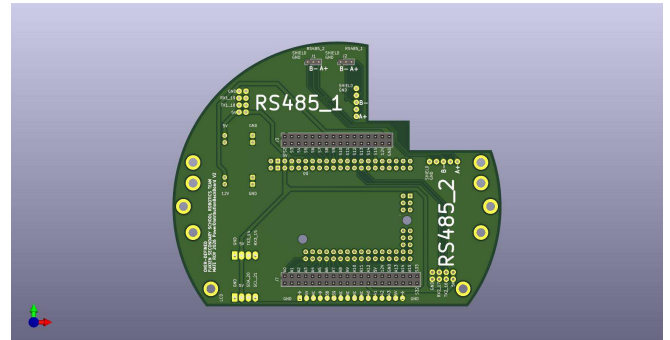


Figure 11. Back Side Of PCB

2. Controller Side

The shore-side controller serves as the primary hub for human-computer interaction. Utilizing an Arduino Mega 2560 as the main control board, the system accurately processes component signals to achieve low-latency, real-time control. Integrated RS485 modules transmit signals to the ROV, ensuring reliable two-way communication. To optimize operator performance, this hardware layout incorporates LED indicators, buttons, mode switches, and dual-axis joysticks that simplify manual commands and display system status in real time.

To ensure stability during competition, the controller features optimized, neat wiring to minimize failure rates. The custom PCB also incorporates a redundant backup design, providing immediate hardware failover in the event of a malfunction to drastically reduce downtime. Furthermore, the physical layout of the user interface components is ergonomically arranged, allowing operators to execute precise manoeuvres comfortably during extended operations.

However, this design presents certain engineering limitations. The integration of numerous control components and indicators increases the complexity of power distribution, requiring precise voltage and power management to prevent signal noise. Additionally, the integrated joysticks and switches inevitably expand the PCB footprint, which slightly reduces the controller's overall portability.

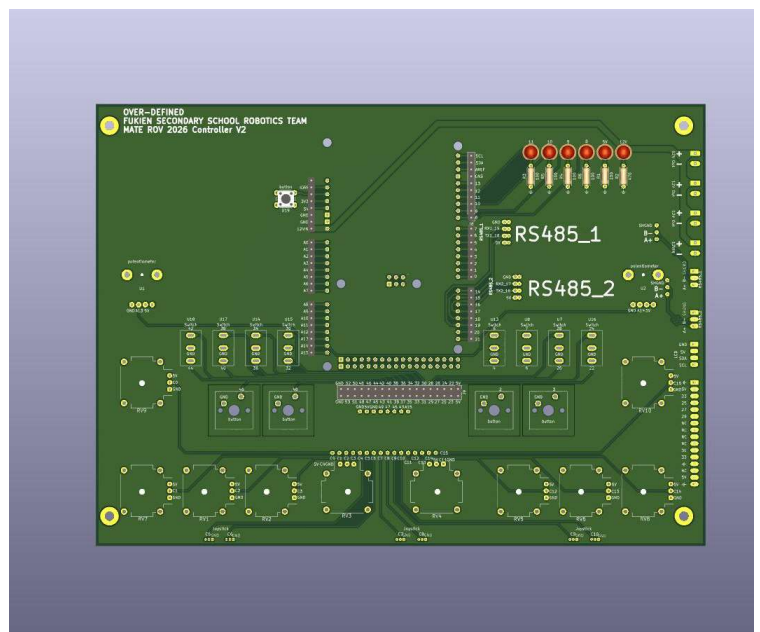


Figure 12. Controller Side PCB

G. Control Station

To meet this year's safety requirements and reduce transport damage, we now mount the motherboard horizontally inside the box instead of lifting it during setup. Hinges on both sides and a bottom board secure the motherboard, saving setup time and reducing repair costs by providing a robust, durable mounting. We added rubber grommets to the controller covers to protect the wiring, and we installed bottom partition boards alongside a black-and-yellow, 3D-printed warning cover to separate the AC and DC areas. The PCB is supported by side frames that comply with IP-30 dustproof requirements.

A video capture card is linked to a laptop to capture real-time video signals for computer-based tasks.

This design ensures intentionally simple, efficient, and reliable processes for setup and teardown during mission runs.



Figure 13. Control Station of Octo

H. Control Software System

Our software is built on the Arduino platform using C++ to provide seamless, unrestricted underwater control. Unlike previous iterations limited by a single microcontroller and a 3-meter range, this design uses two Arduino Mega boards—one on the surface and one on the ROV. This dual-microcontroller setup optimizes performance and enhances modularity, allowing for the integration of additional sensors and payloads.

The surface and ROV nodes communicate via the Universal Asynchronous Receiver-Transmitter (UART) protocol [1] over an RS485 transceiver and a Shielded Twisted Pair Cable. This configuration provides a lightweight, point-to-point link that handles thruster, manipulator, and sensor data with minimal hardware overhead. Through precise mathematical modelling, joystick inputs are translated into pulse-width modulation (PWM) values and transmitted down the tether.

Because the RS485 link is half-duplex, simultaneous two-way communication is restricted. However, a custom software protocol manages this by utilizing handshakes, error-correction algorithms, and structured data packets to safely alternate between transmitting and receiving. Ultimately, the resulting stability and system expandability far outweigh this communication limitation.

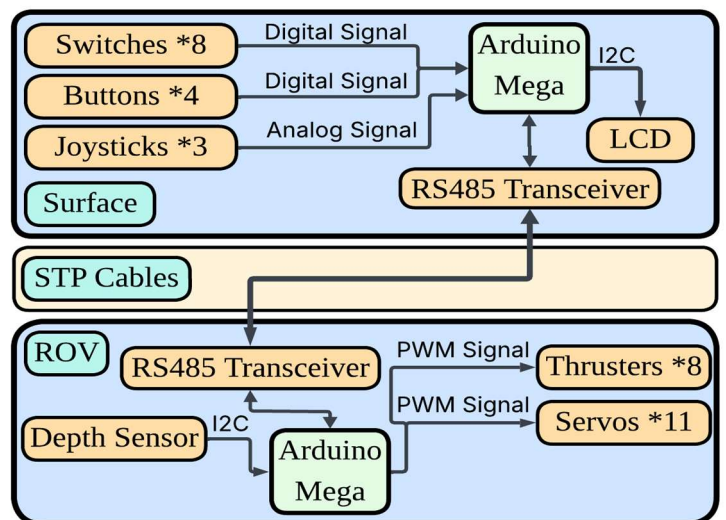


Figure 14. Architecture of ROV Software System

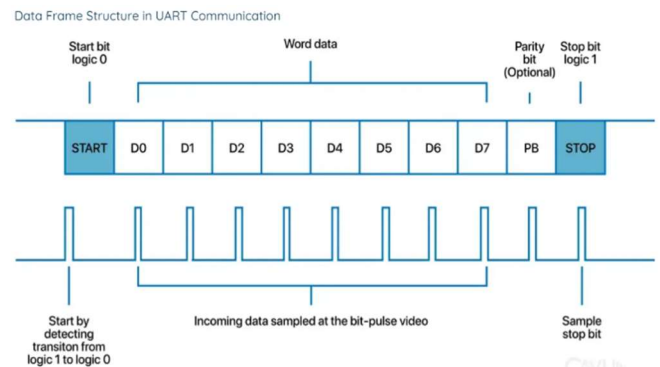


Figure 15. UART Protocol

For our error correction algorithm, we tested several methods and found that while CRC16 was more robust, Fletcher-16 gave us quicker response times with enough reliability for our needs. Choosing Fletcher-16 improved efficiency, though it does mean slightly less error detection compared to CRC16.

For our software innovation, the ROV features two key switches that enhance operational performance:

- Power Optimization Switch: Dynamically regulates thruster output to maximize power efficiency, maintaining a current cap of 25A.
- Roll/Pitch Switch: Allows the ROV to tilt up to 90° in either direction (left/right or up/down), improving manoeuvrability and stability in varying underwater currents.

These enhancements collectively minimize task completion time and substantially increase operational efficiency.

Additionally, a Liquid Crystal Display (LCD) provides real-time feedback of control parameters and depth sensor data for iceberg measurement, reducing debugging time and enabling rapid troubleshooting during field operations.

We used GitHub for version control, which let us track changes, manage branches, and work together more effectively. This made integration smoother and reduced conflicts.

Algorithms	Reliability	Response Time
CRC-16 (bit to bit)	Highest	~ 250 μ s
CRC-16 (Table-driven)	Highest	~ 142 μ s
Checksum	Medium	~18 μ s
Parity check	Low	~ 5 μ s
Fletcher-16	High	~ 45 μ s

Table 1. Error Checking Algorithms Comparison

I. Camera System

The Octo integrates last year's Analog High-Definition (AHD) camera system to support up to 12 fisheye cameras (195° FOV). To support this year's multi-gripper tasks, at least eight simultaneous video feeds must be managed by the control system to provide sufficient situational awareness.

A major limitation of alternative digital systems (like USB or IP cameras) is that encoding and streaming eight channels would require an additional heavy onboard computer, introducing significant control lag and power overhead. The primary advantage of our AHD design is that video data is processed directly via hardware converters, completely bypassing our primary microcontrollers. This serves as a key feature to improve system and operator performance: it eliminates video latency and ensures zero control lag, allowing the pilot to perform high-precision manoeuvres in real-time while keeping the main control loop stable and unburdened. Although AHD provides lower resolution than IP cameras, this trade-off is highly cost-effective and perfectly meets our mission specifications.

J. Tether

The tether provides power, data, and a secure link between the ROV and the surface. It is built from: two shielded twisted cables (0.2mm²), two power cables (6.0mm²), twelve camera cables (two configured as backups), three flexible foam buoyancy strips (10mm dia.), two pneumatic hoses (8mm dia., 1.2 MPa), and a paracord (6mm dia.).

Functionally, the shielded cables carry control commands and telemetry, the power cables supply the ROV, the camera cables deliver video (with redundancy), the foam strips add positive buoyancy and help prevent entanglement, and the plastic tubes are used to fill air into the “rugby balls”.

For safety and durability, the tether includes strain relief at both ends and is routed inside abrasion-resistant cable sleeves. The strain-relief connections—three to the control box and one to the ROV—prevent excess tension on the wires and improve system reliability.

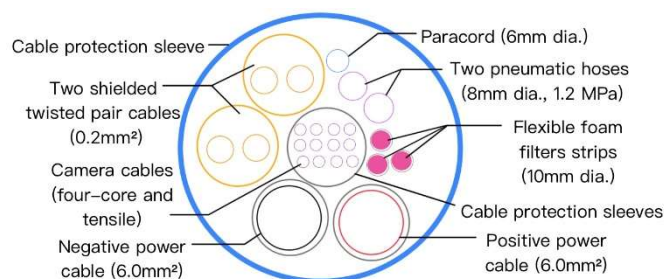


Figure 16. Cross Section Diagram of Tether

K. Payload Tools

i. Horizontal Claw

The Octo's parallel-translation horizontal claw streamlines object retrieval by maintaining a constant parallel profile, eliminating the need for precise alignment with the target's centre point. This movement is executed via a Chebyshev Lambda Linkage [2] that converts rotational servo input into straight-line horizontal motion [3]. Featuring a 14cm stroke length, the claw utilizes dual 270° servos (providing a 3.33 Nm combined torque) to easily adapt to diverse object widths. Its 3.8cm height and rigid, 3-layered design ensure high structural strength, preventing the gripper blade from twisting under heavy loads. Furthermore, embedded thrust bearings absorb payload-induced axial loads at the joints, reducing mechanical wear and extending the tool's operational lifespan.

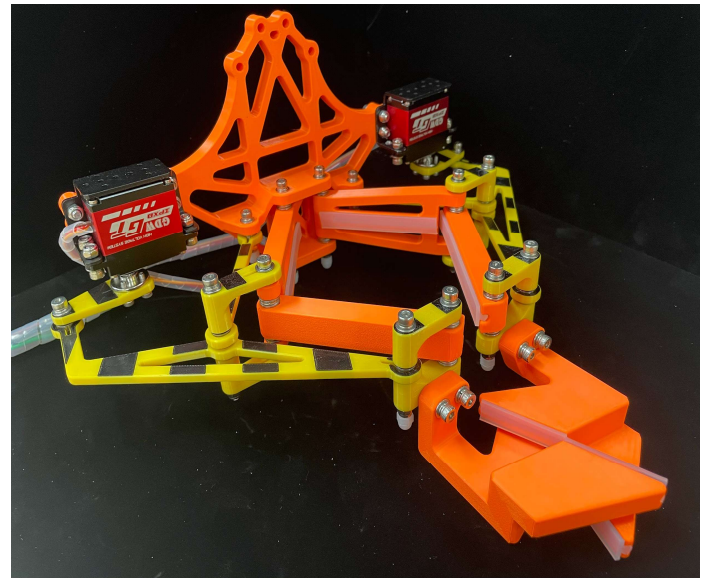


Figure 17. Horizontal Claw

ii. Vertical Claw

To interface with the 2026 MATE eDNA sensor and its 45° angled sockets, a specialized vertical claw was developed, building upon last year's compliant rolling-contact architected materials (CRAM) platform [4]. While the previous design targeted fixed-angle entry for the pCO₂ sensor, this year's iteration implements a controlled forward and backward swinging motion. This structural upgrade prevents the claw from hitting the fixed frame sockets on the PVC framework before full installation. Furthermore, this adjustment provides a flexible angle of approach, allowing the pilot to transition smoothly into a straight vertical grip for high-precision deployment.

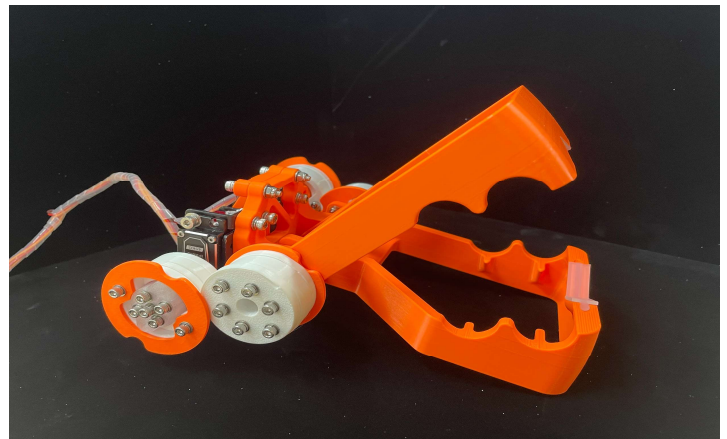


Figure 18. Vertical Claw

iii. Side Claw

To optimize operational efficiency for multi-object recovery tasks, an auxiliary side claw is integrated on the vehicle's port (left) side, increasing the volume of items collected per dive. The claw connects to its servos through a pair of custom stress-reducing linkages. This mechanical configuration buffers heavy impact loads before they reach the servo gears, effectively protecting the internal motor structure from failure and minimizing long-term maintenance costs.



Figure 19. Side Claw

iv. 360° Rotary Gripper

To execute biofouling removal on the Holyrood subsea observatory camera, an efficient 360° rotary gripper was developed to meet this year's mission specifications. Upgrading last year's direct-drive setup—which coupled a servo motor directly to a rotating ring—the current design integrates a custom 3D-printed cross roller bearing into the disc assembly. This separate structural layout protects the servo motor shaft from external side forces and heavy bending loads. It also significantly reduces rotational friction to ensure smooth, high-torque operation.

v. Hooks

To safely transport the lobster pot from the seabed to the surface, relying solely on the primary robotic claws presents significant operational risks. This approach could damage the lobster pot and shift the ROV's centre of gravity too far forward, making the vehicle unstable during transportation. To mitigate this, a pair of dedicated lifting hooks is installed directly underneath the centre of the ROV's frame, preventing any adverse centre of gravity migration. These hooks are connected to servo motors via custom stress-reducing links, enabling precise forward and backward pivoting. This mechanical configuration ensures that the loaded lobster pot remains secure and balanced below the vehicle's centre of buoyancy during underwater transport, greatly enhancing overall stability.

vi. Buoy Anchor Connector

To recover the buoy anchor, a custom carabiner-style mechanism was engineered, featuring an enlarged profile, interlocking hooks, and a guiding pin for rapid underwater alignment. This connector functions as a modular accessory to the horizontal claw, utilizing matching rhombic grips to ensure a secure, slip-free hold.

Concurrently, a tether spool containing the recovery cable is secured to the 360° rotary gripper via a quick-release pin, allowing the multifunctional gripper to actively roll out and wind up the line through controlled rotation. A thick, high-gauge line was specifically selected to prevent underwater tangling. To counteract the trade-off of increased line weight, extra buoyancy using hollow polymer spheres (ping-pong balls) was integrated directly onto the spool assembly. This weight optimization eliminates adverse centre of gravity shifts, preserving the vehicle's balance and stability.

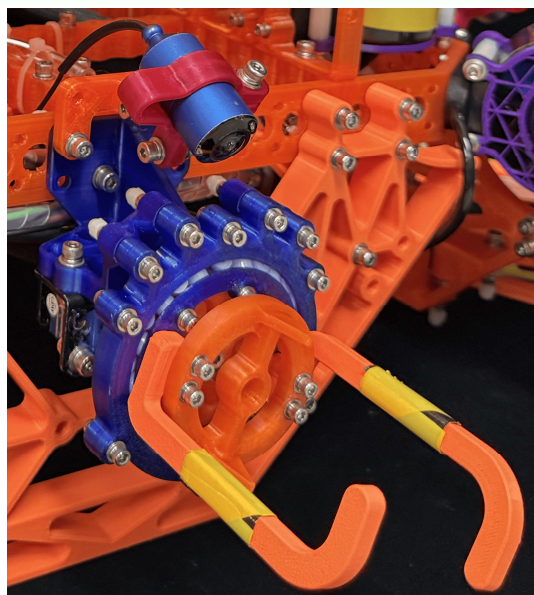


Figure 20. 360° Rotary Gripper

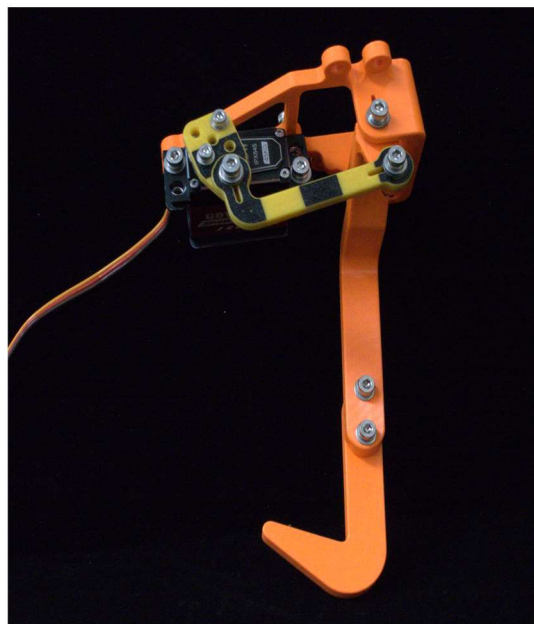


Figure 21. Hook



Figure 22. Buoy Anchor Connector

vii. Vertical Profiling Float

Structure

Considering that the task does not change for this year, we decided to only make modifications based on the previous float design, as: It completed the vertical profiles perfectly last year.

No leakage occurred throughout the testing and operation process, proving its waterproof performance.

The large size of the waterproof enclosure ($\varnothing 16 \times 32$ cm) allows integration of new modules in the future.

As the upgrade of Submerger, we incorporated a high-brightness LED strip inside the waterproof enclosure and two handles on the stand. They facilitate quicker locating and alignment by the ROV.

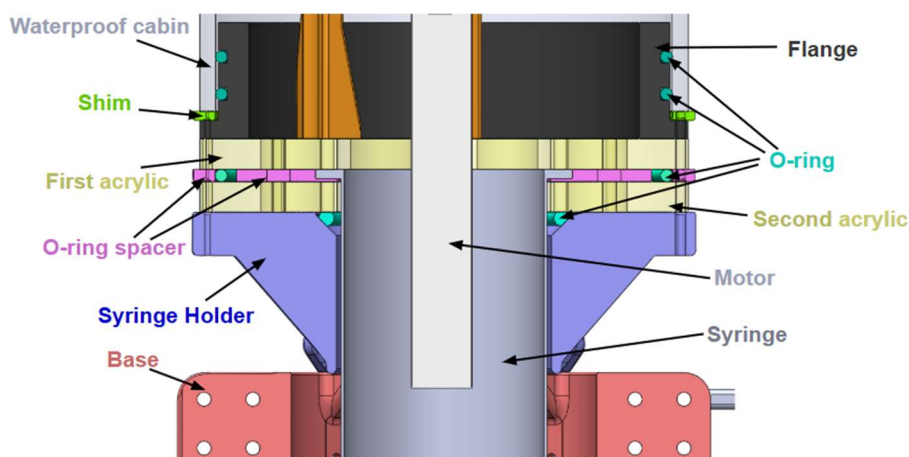


Figure 24. Cross Section Diagram of Submerger

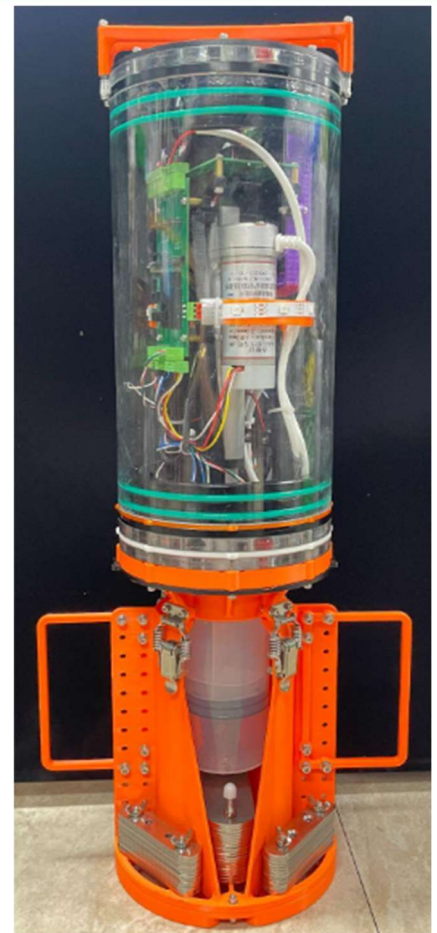


Figure 23. The Submerger

Electric system

The electrical system of the VPF is composed of a double-layer PCB and several peripheral devices, managing power distribution and connections of components. Based on last year's version, our company focused on improving the reliability of the electrical system.

Last year, while Submerger completed the vertical profiles, intermittent communication outages occurred due to poor signal reception at the water surface. To improve the signal quality, we have replaced the home WI-FI antenna (a collinear antenna array with a gain of 10 dBi) with an FPV antenna (a half-wave dipole antenna with a gain of 3 dBi), and the antenna has been relocated from the centre to the top of the waterproof enclosure. The lower gain makes the antenna's radiation range more balanced in both the horizontal and vertical dimensions, allowing the signal to travel over the water surface and reach the poolside receiver, instead of being limited primarily to travelling horizontally underwater. Furthermore, Capacitors (0.47F & 22 μ F) are added to prevent accidental voltage drops when the actuator launches.

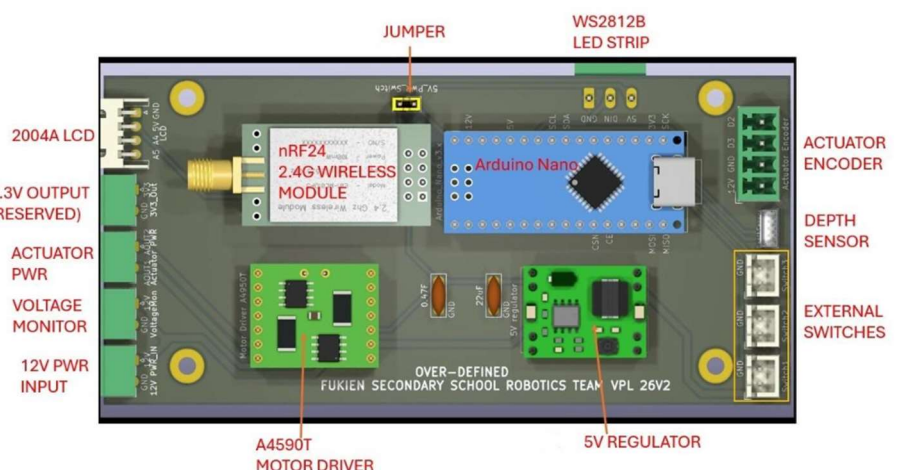


Figure 25. PCB of Submerger

Control System

Submerger has a syringe with a plunger inside controlled by an actuator. The actuator moves based on the depth detected by the pressure sensor to change the air volume inside the float and hence the buoyancy. An nRF24 module is used for data transmission.

The previous version of the float uses a Bang-Bang control system, which causes the float to perform oscillatory motion with a decreasing amplitude up to 0.2m. This takes a long time to reach the target. This year, we used two PID control systems for the plunger. The first system controls the plunger's position using encoder readings. The second system controls the float's depth using pressure sensor readings.

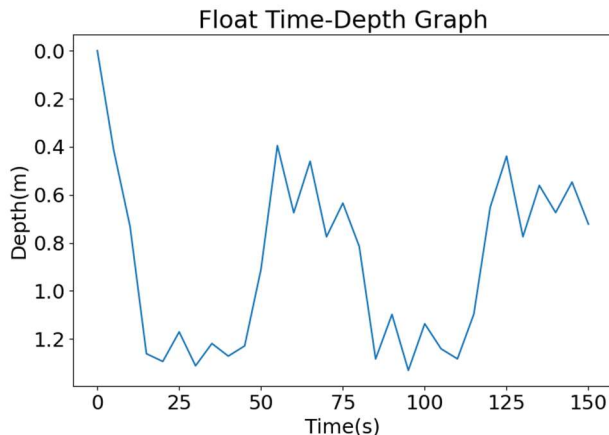


Figure 26. Float Time-Depth Graph Using Bang-Bang Control

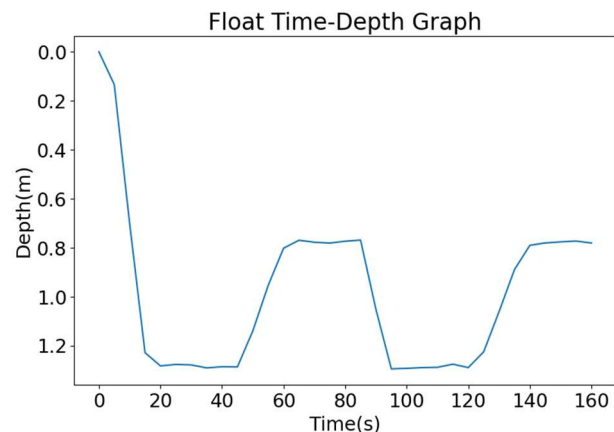


Figure 27. Float Time-Depth Graph Using PID Control

The new system reduced the position error to 0.01m within 5 seconds. Testing showed that the float can still maintain its depth with a ± 200 g payload tolerance, without breaking the ice surface. The efficiency and stability are greatly increased.

To avoid data loss in the entire process, we've designed several checks in the 'first transmit' session before diving. After the vertical profiles, the Submerger continuously transmits data packets to the control station using the nRF24 module. Then, our program at the station would filter out the invalid data and choose the most accurate data to plot a depth-time graph.

For testing, we have designed 'Editor mode', which allows us to change parameters. This greatly enhances testing efficiency.

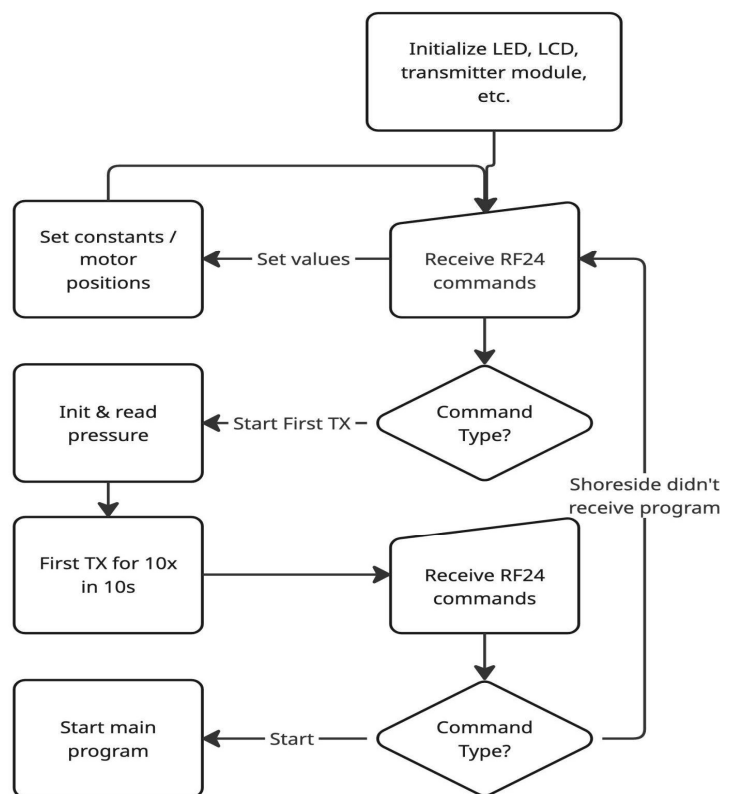


Figure 28. Program Flow of Submerger

L. Software Tools

i. Threat Identification of Iceberg

To calculate the distance between the iceberg and the surface platforms, our company developed a threat identification program using C++.

First, it converts the coordinates from longitude and latitude to nautical miles. Then it multiplies the horizontal component at the equator by the cosine of the latitude. The resulting value using Trigonometric Theorems gives the shortest distance between the iceberg and the surface platforms.

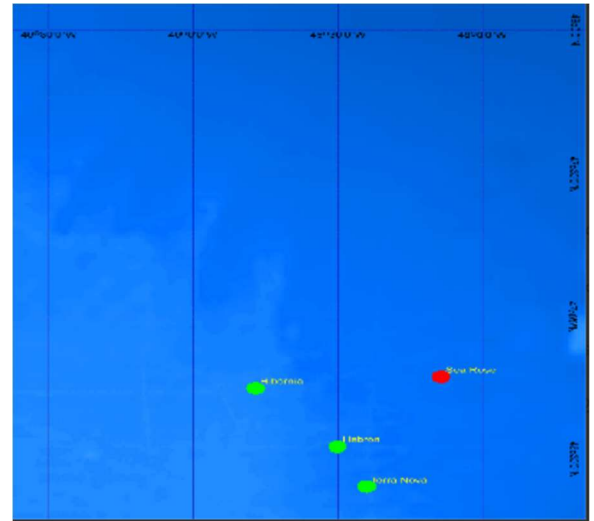


Figure 29. Iceberg Tracking

ii. Invasive Crab Recognition

To recognize European Green Crab, our company uses a custom dataset that was collected underwater to train a YOLOv26 model to detect invasive crabs. This approach is more efficient compared to traditional methods such as Faster R-CNN, as YOLO uses a single backbone network, adopts end-to-end inference, and does not involve a regional proposal network and anchor generation. We also created a program for live detection using the image input from the camera we installed in the ROV, and it can display real-time bounding boxes.

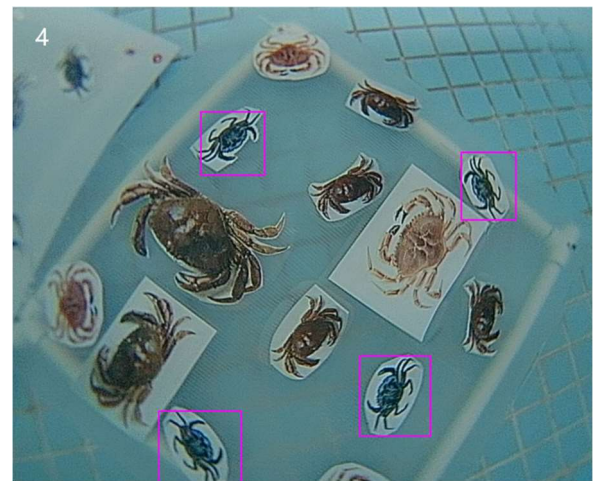


Figure 30. Example of Crab Image Recognition

iii. Coral Garden 3D photogrammetry

For precise scaling of the model and measuring the length of the coral garden. We firstly use COLMAP, a specialized software for 3D reconstruction to get the camera parameters, including the feature of distortion. Then, we built an OpenCV program to distort the fisheye images captured by the camera using camera parameters so that the error of the measurements can be controlled within 5cm. Using these precise data, we use SolidWorks to create a 3D representation of coral gardens manually.

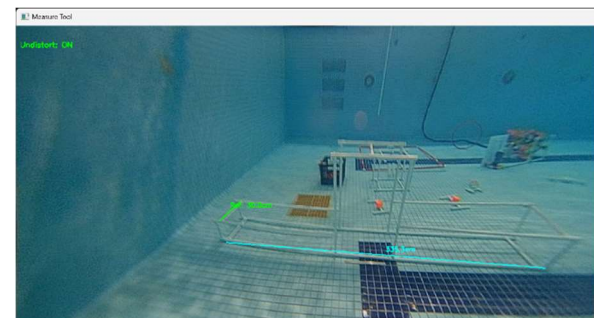


Figure 31. Manual Measurement of the length of Coral Garden

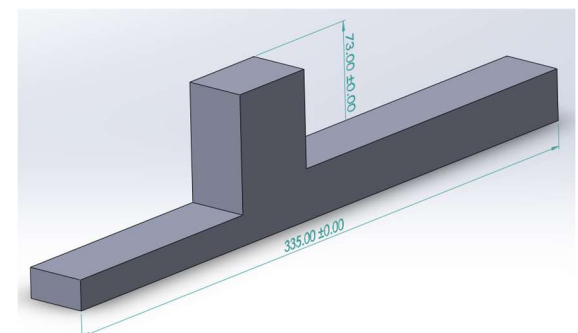


Figure 32. 3D CAD Model

5. Safety

i. Safety philosophy

Our company values safety as our top priority in both the development and testing processes. This is the reason we have implemented strict safety rules and protocols to align with our goals.

ii. Workshop safety

Employees must handle all tools and equipment with professional care. This includes conducting pre-use inspections, wearing required Personal Protective Equipment (PPE) like safety goggles, and properly cleaning and storing equipment after use.

In addition, Junior members must have a senior member present when testing newly designed components to ensure compliance with all safety and testing protocols.

iii. Mechanical Safety Features

To ensure user safety, all 3D-printed components are manufactured with rounded edges. Thruster protection complies with the IP20 standard. Improving upon last year's design, high-visibility safety warnings are 3D-printed directly onto moving components to ensure they remain permanently attached. Handles were installed to ensure safety during ROV launch and recovery, and screw caps were used to cover the sharp tips of screws to prevent injury and damage.

To ensure environmental safety, the ROV's size is minimized. Additionally, the tether and controller now feature integrated strain relief systems, preventing controller dislodgement and protecting the ROV from tension-related cable damage.



Figure 33. Company Members Assembling Octo

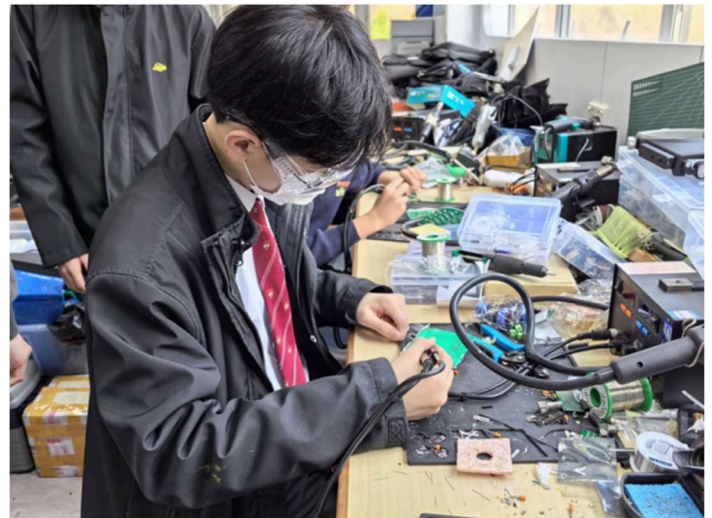


Figure 34. Company Members Soldering PCB



Figure 35. Thruster Guard

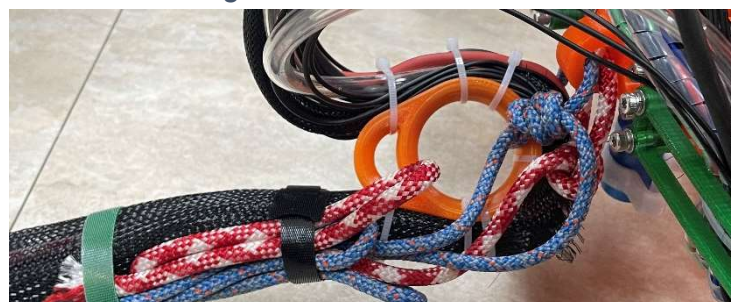


Figure 36. Strain Relief on Octo

iv. Electrical safety features

The controller integrates a 25A fuse and an emergency stop button to provide immediate power isolation.

The vehicle features a transparent, waterproof pressure chamber that protects internal electronics from water ingress and physical damage, while allowing visual inspections to detect debris or component fatigue. Silicone-Waterproofed Connectors were used to prevent water from entering the waterproof compartment and coming into contact with internal electronic components.

The monitoring system reuses the same SDI camera multiplexer and power configuration as last year to maintain reliability and safety. The camera monitor operates via a 220/110V AC connection to an SDI camera multiplexer, which is equipped with a 220/110V AC to 12V DC power converter. The AC and DC power supplies remain distinctly separated and labelled to ensure safety and mitigate potential wiring errors.

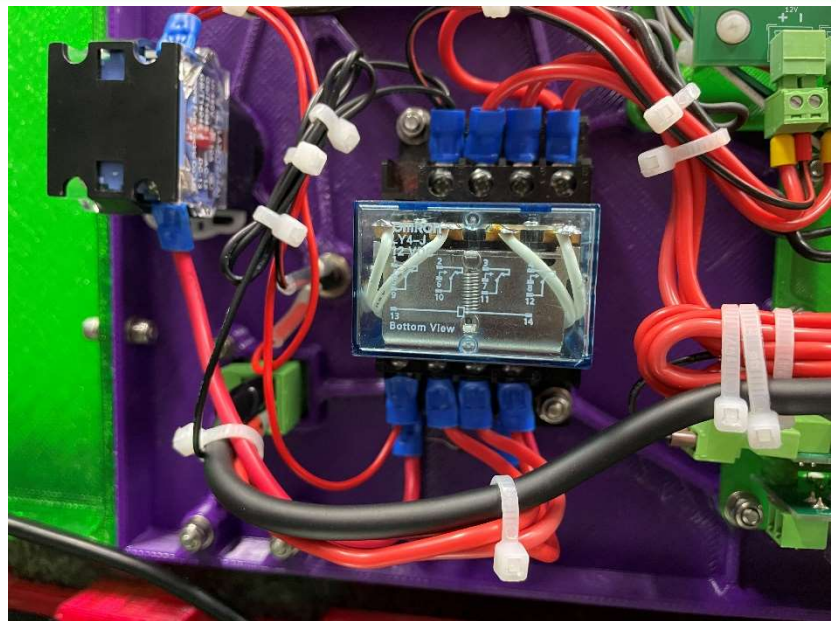


Figure 37. Emergency Stop Circuit

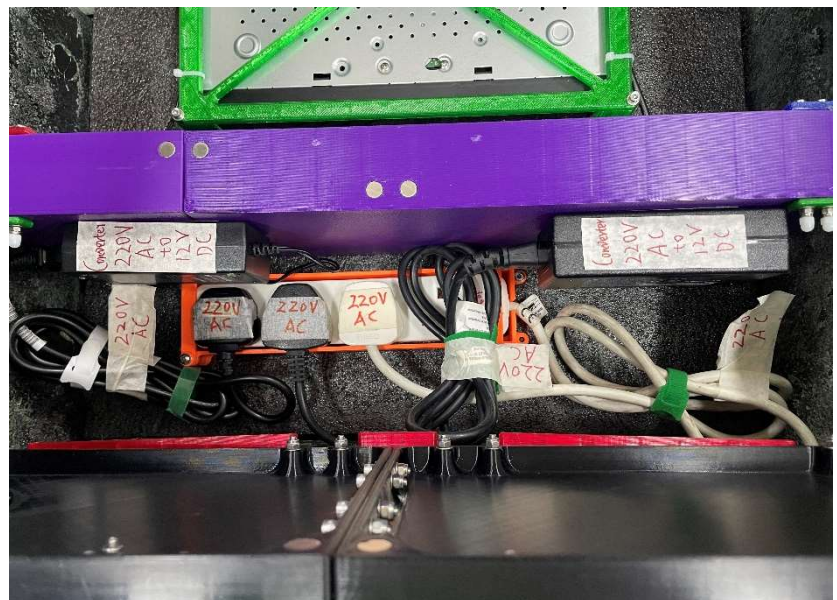


Figure 38. Compartment For 220V AC

6. Testing and Troubleshooting

Our team tested each component and the complete ROV throughout development to ensure safety, functionality, and operational effectiveness. We implemented a comprehensive Safety and Calibration methodology. In the Safety phase, components are verified against thermal and electrical safety requirements to ensure runtime safety. In the Calibration phase, thrusters and servos are adjusted for optimal performance and synchronized initialization, ensuring consistency and stability before in-pool use.

We apply a Dry and Wet prototyping protocol for new designs and payloads: prototypes must function in simulated dry conditions and then be verified underwater. The dry phase reveals initial design flaws; the wet phase confirms real-world performance and informs pilot feedback on tool function and placement.

For example, the RS485 anti-interference communication module underwent Safety and Calibration checks for thermal and electrical safety and communication calibration, followed by dry testing of long-distance transmission and noise rejection and underwater verification to ensure tether signal stability.

When problems arise, we initiate root-cause analysis using a quick-response diagnostic protocol that breaks issues into software, tether signal, and mechanical domains and inspects each to identify and resolve the fault.

7. Build vs Buy, New vs Used

We chose to reuse components whenever they could meet our needs and requirements. Reusing components allows us to reduce development costs, increase reliability by utilizing previously qualified systems, and focus our efforts on developing new manipulators for new tasks.

We decided to build our own components for design flexibility, ensuring they perform the required tasks perfectly. When it comes to purchasing products, available market options are compared to find the most cost-effective and suitable choices."

Reused Purchased	Justification
2216 Thrusters	Meets requirements: Sufficient thrust and stable to perform MATE missions
Arduino Mega 2560	Meets requirements: Sufficient computation power

Table 2. Reused Purchased Components

Newly Purchased	Justification
Arduino Mega 2560 PRO	Fulfill the limited space in the waterproof enclosure
RS485 isolated module	Enhance Dual-MCU communication stability over long distances
Monitor	To fulfill the new control box size and increase maximum brightness
Control Box	To fulfill IP30 standard ratings
Cameras	Legacy version discontinued, new model satisfies the previous system.
Power Converter	To prevent Arduino's onboard regulator from overloading

Table 3. Newly Purchased Components

Newly Custom-built	Justification
Tether	Increasing safety, two STP wires for communication and an air tube for this year's mission.
3D print components	High design flexibility and excellent weather resistance
PCB	Fulfill the new Dual-MCU communication structure
Thruster Guards	Improved the design to ensure it can firmly attach on the thruster

Table 4. Newly Custom-built Components

8. Accounting

At the beginning of the year, Over-Defined established an agile accounting protocol and a centralized Google Sheet budget-tracking system to manage funding efficiently. A key feature is the “To Buy Wish List,” where engineers submit component requests; these are reviewed and approved weekly only after a clear use case is verified. All expenses are tracked in our team's Google Sheet, ensuring transparency and allowing all members to monitor financial activity. The travel expenses of 44,695.70 USD will be paid by the team members, including flight tickets, living expenses, and daily expenses. For more details, the budget and costing data sheets are available in Appendix IV.

9. Acknowledgements

Over-Defined is incredibly grateful for the support of the following organizations and individuals who have contributed to the development of Octo:

- Fukien Secondary School — for the continuous support, sponsorship, and resources
- HUNG Kam Fai, LEE Ka Wai — our supervisor, for his consistent guidance in all aspects
- HUI Shek Hin, CHAN Kam Pui — our mentors, for their guidance and technical help throughout the development of Octo
- MATE Center — for organizing the 2026 MATE World Championship, providing a platform for the community to learn about marine technology, and promoting STEM education around the world by solving real-life problems
- The Institution of Engineering and Technology, Hong Kong (IET HK) — for organizing the 21st IET/MATE Hong Kong Regional of the MATE ROV Competition and educating the Hong Kong public on marine technology
- Beltron International Limited — for their kind sponsorship of a bottle of O-ring grease



福建中學
FUKIEN SECONDARY SCHOOL

**Beltron
International
Limited**

10. References

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11. Appendics

i. Safety Checklist

While Constructing ROV

Checklist Item	Details/Instructions	Progress
Wear appropriate personal protective equipment (PPE)	Use safety goggles, gloves, and closed-toe shoes to protect against sharp edges, electrical hazards, and chemical exposures.	✓
Ensure workspace is clean and organized	Clear the area of clutter to prevent trips and falls; keep tools in designated places.	✓
Verify all electrical connections are insulated	Use heat-shrink tubing or electrical tape on wires to avoid short circuits or shocks.	✓
Handle batteries with care	Check for damage, use correct chargers, and avoid overcharging to prevent fires or explosions.	✓
Secure mechanical components properly	Tighten all screws and bolts to manufacturer specifications to avoid loose parts during operation.	✓
Test sub-assemblies in isolation	Verify functionality of motors, sensors, and cameras before full integration to identify issues early.	✓
Follow manufacturer's guidelines for materials	Use waterproof seals and corrosion-resistant materials for underwater components.	✓
Avoid working alone if possible	Have a colleague present for assistance in case of accidents.	✓
Inspect overall build for defects	Check for cracks, loose wires, or improper seals that could lead to failures.	✓
Perform a dry-run power test	Power on the ROV on land to ensure all systems activate without issues like overheating.	✓
Calibrate sensors and controls	Adjust thrusters, cameras, and depth sensors for accurate readings and responses.	✓
Document all modifications	Record changes made during construction for future reference and troubleshooting.	✓
Store in a safe, dry location	Keep away from moisture, direct sunlight, and extreme temperatures to preserve integrity.	✓
Label all cables and ports	Use clear labels to prevent incorrect connections during setup.	✓
Charge batteries fully	Ensure all power sources are at full capacity before storage or use.	✓

After Constructing ROV

Checklist Item	Details/Instructions	Progress
Inspect overall build for defects	Check for cracks, loose wires, or improper seals that could lead to failures.	✓
Perform a dry-run power test	Power on the ROV on land to ensure all systems activate without issues like overheating.	✓
Calibrate sensors and controls	Adjust thrusters, cameras, and depth sensors for accurate readings and responses.	✓
Document all modifications	Record changes made during construction for future reference and troubleshooting.	✓
Store in a safe, dry location	Keep away from moisture, direct sunlight, and extreme temperatures to preserve integrity.	✓
Label all cables and ports	Use clear labels to prevent incorrect connections during setup.	✓
Charge batteries fully	Ensure all power sources are at full capacity before storage or use.	✓

While Testing ROV

Checklist Item	Details/Instructions	Progress
Select a suitable testing environment	Use a controlled pool or tank with clear water, no strong currents, and adequate depth.	✓
Have emergency stop procedures in place	Know how to quickly cut power or retrieve the ROV if malfunctions occur.	✓
Monitor tether for tangles	Ensure the umbilical cable remains straight and free from knots to avoid pulling or damage.	✓
Check water seals before submersion	Inspect O-rings and gaskets for proper placement and condition.	✓
Start with shallow depths	Gradually increase depth while monitoring for leaks or performance issues.	✓
Record test data and observations	Note battery life, maneuverability, and any anomalies for post-test analysis.	✓
Ensure operator is trained	Confirm the person controlling the ROV understands controls and safety protocols.	✓
Use flotation devices if needed	Attach buoys to the ROV for easy recovery in case of power loss.	✓
Limit test duration initially	Avoid prolonged sessions to prevent overheating or fatigue of components.	✓

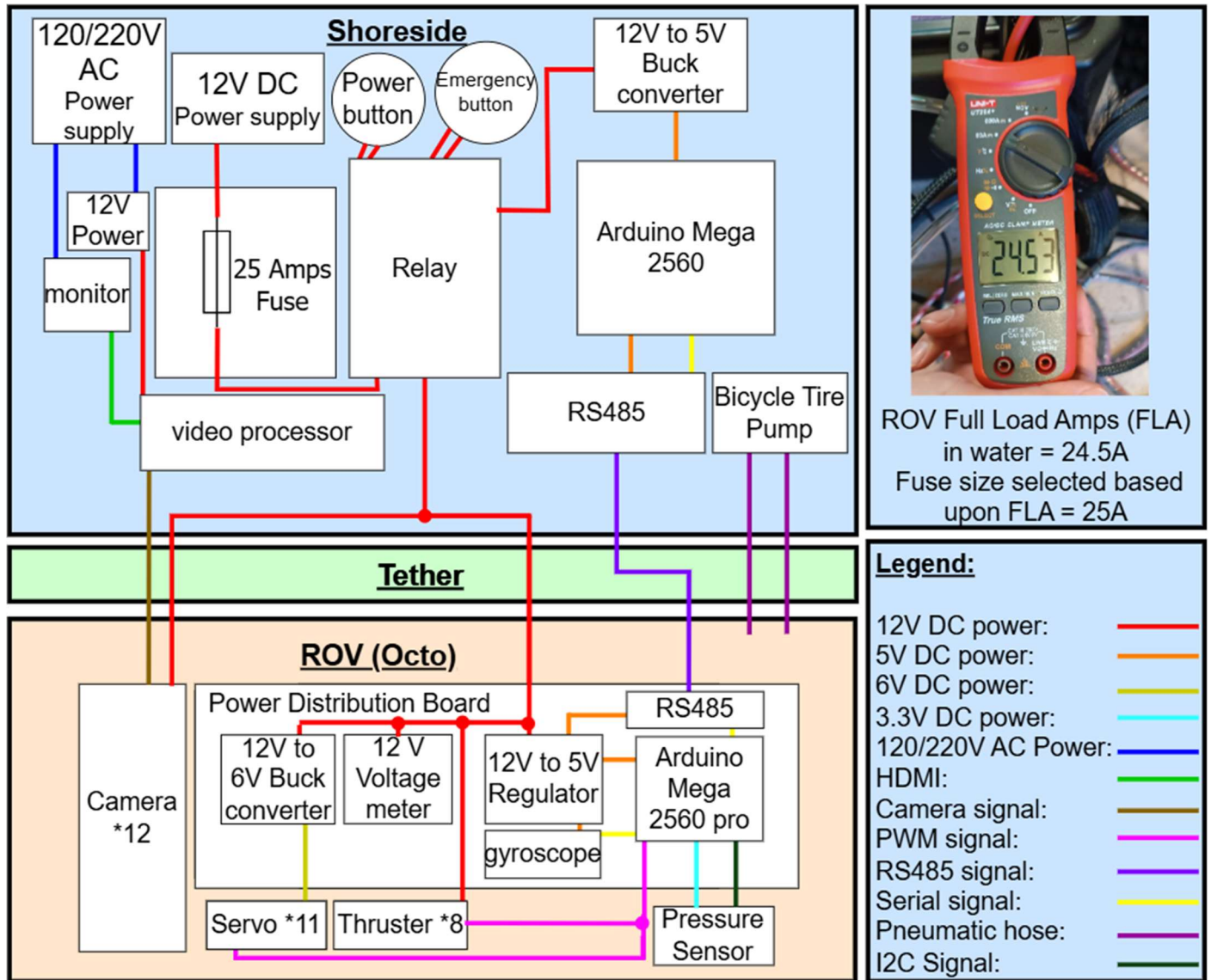
After Testing ROV

Checklist Item	Details/Instructions	Progress
Rinse with fresh water	Remove any chlorine, salt, or debris to prevent corrosion.	✓
Dry thoroughly	Use compressed air or towels to dry all parts, especially electronics.	✓
Inspect for damage	Look for scratches, dents, or water ingress post-test.	✓
Recharge or replace batteries	Assess power levels and recharge as necessary.	✓
Clean and store equipment	Wipe down controls, tether, and ROV; store in protective cases.	✓
Review test footage and logs	Analyze data for improvements or issues.	✓
Update maintenance records	Log the test date, duration, and any findings.	✓

Emergency Situations (e.g., Water Leakage)

Checklist Item	Details/Instructions	Progress
Detect signs of leakage early	Watch for bubbles, unusual sounds, or erratic behavior during operation.	✓
Immediately power off the ROV	Cut all electrical supply to prevent short circuits or shocks.	✓
Retrieve the ROV safely	Use the tether or a retrieval tool without entering the water if hazardous.	✓
Isolate affected components	Disconnect wet parts from dry ones to limit damage.	✓
Dry and assess damage	Remove water, dry with absorbent materials, and test components individually.	✓
Replace damaged seals or parts	Identify failed O-rings or gaskets and install new ones.	✓
Document the incident	Record what happened, causes, and corrective actions for future prevention.	✓
Notify relevant personnel	Inform team members or supervisors if the issue affects operations.	✓
Perform a full system check before reuse	Re-test in a controlled environment after repairs.	✓

ii. ROV SID & Pneumatic SID



ROV Full Load Amps (FLA)
in water = 24.5A
Fuse size selected based
upon FLA = 25A



Figure 39. ROV SID

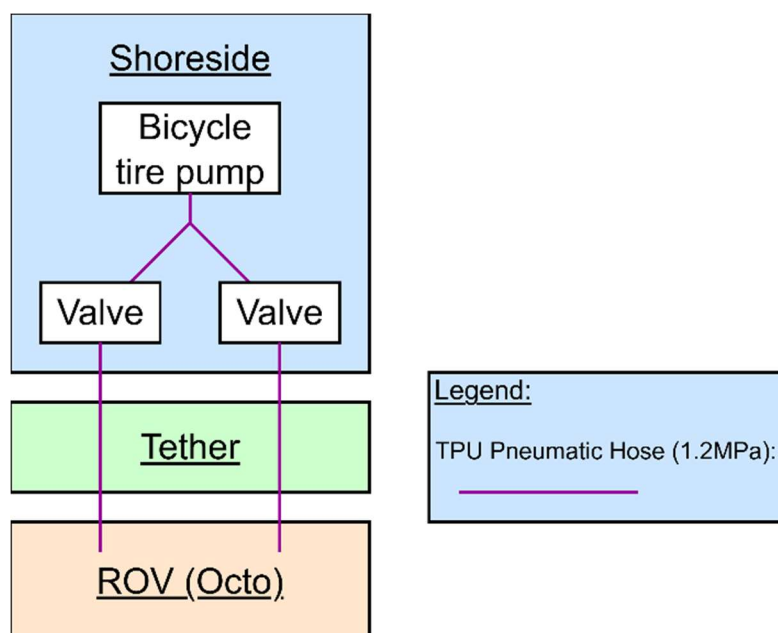
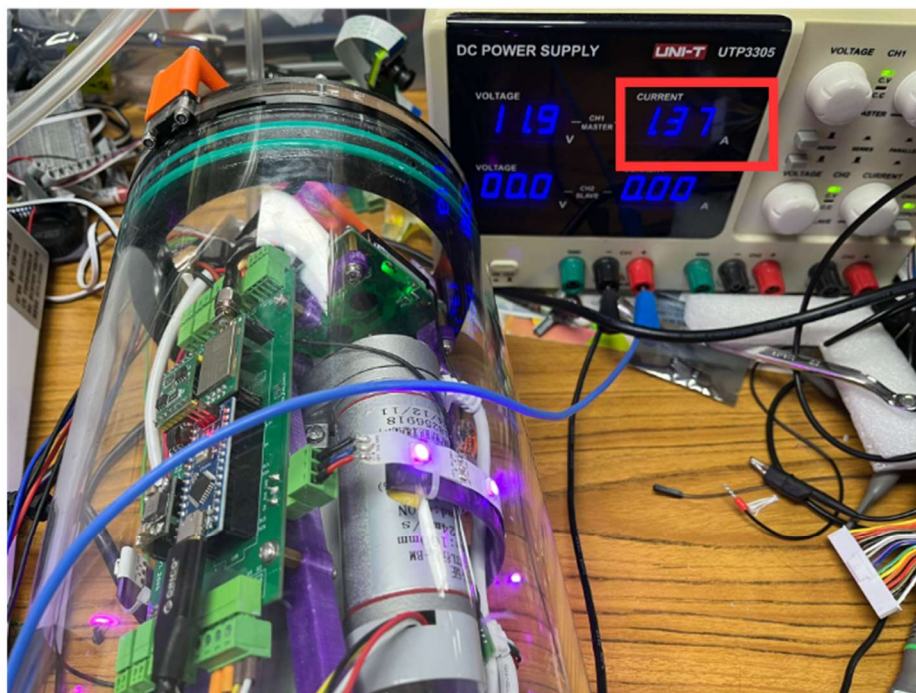
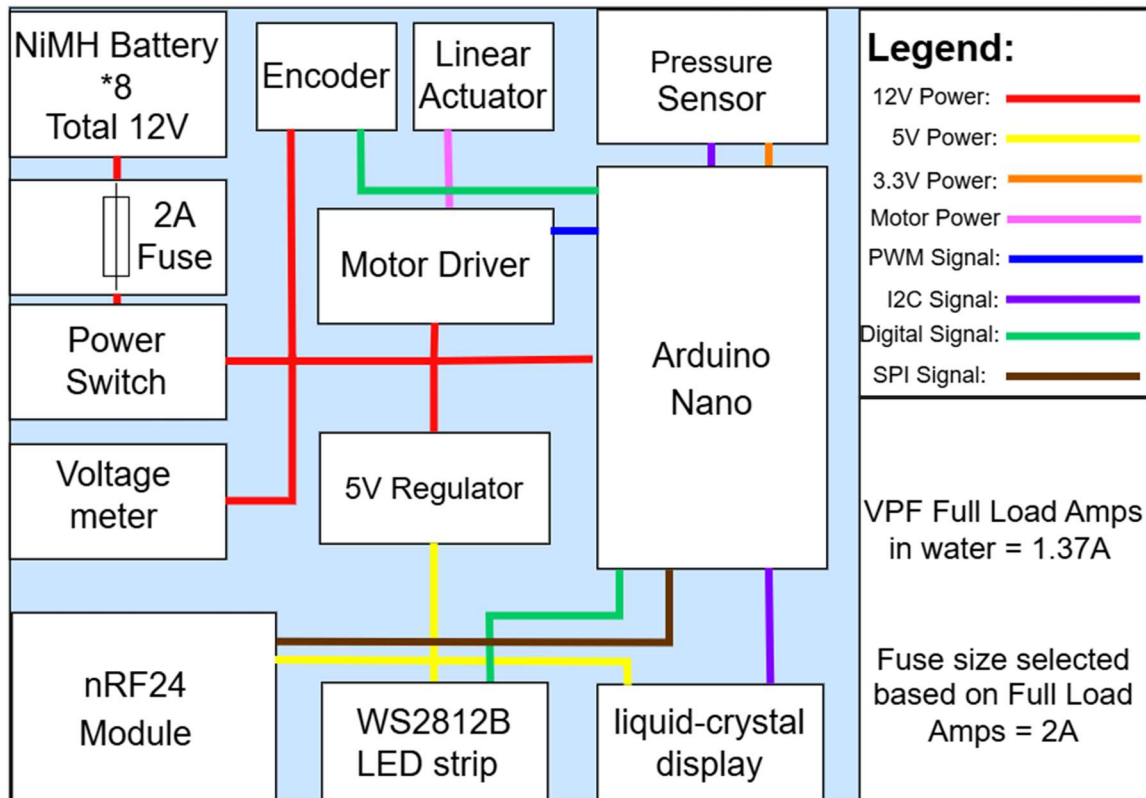


Figure 40. ROV Fluid SID

iii. Non-ROV Device SID



The above figure shows the full load amps in a simulated environment. A vacuum pump is used to simulate the water pressure at a depth of 9 m.

Figure 41. Non-ROV Device SID

iv. Cost Accounting

Total Income:

Category	Name	Amount (USD)
Grant	Funding from Fukien Secondary School	\$15,324.24
Donation	Funding from team members	\$44,695.70
Sponsorship	Beltron International Limited for their kind sponsorship of a bottle of O-ring grease	\$15.38
	Total:	\$60,035.32

ROV Budget:

Budget Category	Type	Item(s)	Quantity	Est. Value (USD)
Surface Station	Re-used	Joystick	3	\$2.19
Surface Station	Re-used	Power button	1	\$18.40
Surface Station	Purchased	DVR monitoring host	1	\$39.60
Surface Station	Re-used	Controller protection box	1	\$117.78
Surface Station	Purchased	27-inch monitor	1	\$184.04
Power Electronics	Re-used	Arduino Mega	2	\$14.72
Power Electronics	Re-used	Arduino Nano	1	\$4.61
Power Electronics	Re-used	Wire connecting terminals	60	\$17.40
Power Electronics	Re-used	Emergency button	1	\$4.24
Power Electronics	Re-used	Wires	1	\$73.61
Power Electronics	Re-used	Wire connecting plugs	30	\$13.20
Power Electronics	Purchased	Camera	11	\$304.48
Power Electronics	Purchased	Thruster	8	\$305.04
Power Electronics	Purchased	Servo	11	\$453.42
Power Electronics	Purchased	Printed circuit board (Non-ROV device)	10	\$14.70
Power Electronics	Purchased	Depth sensor	2	\$64.48
Power Electronics	Purchased	Printed circuit board (ROV)	10	\$14.70
Power Electronics	Purchased	Serial peripheral interface (SPI)	1	\$4.71
Power Electronics	Re-used	Tether foam float	1	\$5.01
Power Electronics	Re-used	Detachable tether plug	15	\$44.10
Power Electronics	Purchased	Tether	1	\$90.40
Structure	Re-used	Piston	2	\$44.16
Structure	Purchased	Other expenses (Tools/Machineries)	1	\$235.57
Structure	Purchased	Waterproof cabin	2	\$132.50
Structure	Manufactured	3D printed frame (ROV)	1	\$22.08
Structure	Manufactured	3D printed frame (Non-ROV devices)	1	\$29.45
Structure	Donated	O-ring grease	1	\$15.38
		Total:		\$1,843.64

Travel Budget:

Travel Budget				
Category	Description	Cost (USD)	Quantity	Subtotal
Airfare	Travel between Hong Kong and St. John's	\$3,000.00	14	\$42,000.00
Lodging	Hotel (Sandman Signature St. John's Hotel)	\$2,300.00	4	\$9,200.00
Coach	Travel between the hotel and the airport	\$1,150.00	2	\$2,300.00
			Total:	\$53,500.00

Expenses:

Budget Category	Example Items	Budgeted	Total Value (USD)	2026 Spending
Research & Development	Prototype hardware, electronics and software	\$312.89	\$574.68	\$574.68
ROV Surface Station	ROV Controller	\$306.50	\$383.12	\$383.12
ROV Structure	ROV & Non-ROV Frame, Waterproof cabin	\$210.72	\$268.19	\$268.19
ROV Power Electronics	Thrusters, Cameras, Sensors, Other electronics	\$702.40	\$708.79	\$708.79
Team Operations	Marketing materials	\$153.25	\$191.56	\$191.56
Competition Travel	Airfare, Hotel and other travel expenses	\$55,680.08	\$55,680.08	\$55,680.08
Total:		\$57,365.84	\$57,806.42	\$57,806.42