

TECHNICAL DOCUMENTATION

SEA-3PO 2026



AUC Aquavaders

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Abstract

The AUC Aquavaders is AUC Robotics' undergraduate remotely operated vehicle team, returning for its second year at the 2026 MATE ROV Competition. Our 26-member multidisciplinary team presents **SEA-3PO**, a complete redesign built on the lessons of our previous season, with a renewed focus on performance, reliability, and mission effectiveness.

SEA-3PO's modular 4040 aluminum extrusion frame supports a six-thruster configuration delivering full six degrees of freedom. Topology-optimized 3D-printed mounts and a sealed acrylic-tube electronics enclosure reflect our emphasis on structural efficiency and watertight integrity. A servo-actuated four-bar linkage gripper handles object manipulation.

A four-board custom PCB architecture manages power delivery and signal routing across propulsion, flight control, and auxiliary systems. On the software side, BlueOS and ArduSub provide reliable vehicle control, complemented by a custom computer vision interface supporting species detection, photogrammetry, and depth measurement. The team additionally developed a standalone vertical profiling float with a syringe-based buoyancy engine and wireless data transmission.



Figure 1. SEA-3PO

SEA-3PO is the result of a team that learned from its first year, challenged its own assumptions, and built something it is proud of.



Figure 2. AUC Aquavaders team members and supervisors



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1. Teamwork

1.1. Team Structure

AUC Aquavaders is made up of a small leadership team and a group of engineers working across three technical domains. Table X outlines what each role is responsible for.

Position	Responsibilities
CEO	Sets the team's overall direction, keeps track of deadlines, and keeps everyone aligned on the big picture.
COO	Manages day-to-day operations, handles external relationships, and makes sure work is moving forward across the team.
CTO	Owens the technical direction of the ROV and connects the work happening across mechanical, electrical, and software.
Technical Chiefs	Run their domain (Mechanical, Electrical, or Software), support their engineers, and send a weekly progress report to leadership each week.
CMO	Handles outreach, sponsorships, and the team's public presence and documentation.
Engineers	Do the hands-on work within their domain and pitch in on other areas when needed, especially during integration.
Mentors	Give advice, review key decisions, and share their professional experience with the team throughout the year.

Figure 3. Team Roles and Responsibilities

1.2. Schedule

The team follows a yearly plan split into five phases, each one building on the last.

Planning (June): At the start of the year, the leadership team meets to reflect on what went well before and set clear goals for the new season.

Training & Recruitment (July – August): New members go through training sessions and a short interview process. This gives everyone a common starting point before technical work begins.

Ideation (October – January): The team digs into the MATE RFP requirements and starts developing concepts. Each domain works on its own ideas, then the team comes together to agree on a single design direction.

Prototyping (February – March): Engineers build and test early versions of their sub-systems. Chiefs stay in close contact with their teams to catch any issues before they become problems during integration.

Integration (March – April): All the pieces come together into one ROV. The team runs in-water tests regularly to make sure everything works as a whole and fixes anything that comes up before the competition.

There is intentional breathing room between phases so the team can adjust if something takes longer than expected without falling behind.

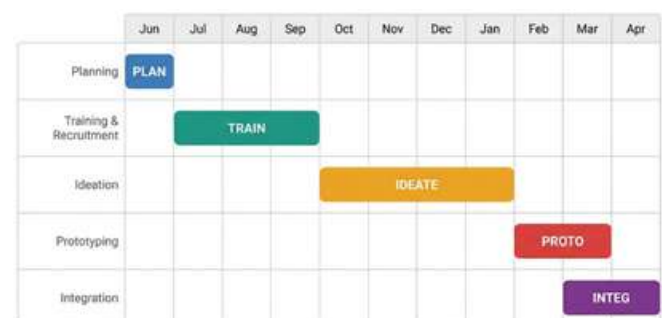


Figure 4. Year-Round Development Schedule



1.3. How We Work

The team works in weekly sprints. Every week starts with a short standup where each person shares what they got done, what they are working on, and anything blocking their progress. The team then talks through any blockers together before getting into the actual work.

At the end of each week, every Technical Chief sends a short report to the CTO and COO. The report covers three things: what was finished, what is still in progress, and what the plan is for next week. These reports help leadership stay on top of how things are going and catch problems early. Every meeting is documented and saved to a shared Google Drive folder, along with sprint reports and any other relevant files. Everything is organised by date and domain, so anyone on the team can look back and see exactly what happened and why.

1.4. Tools We Use

We picked tools that are easy to use together and keep everyone on the same page:

- **Canva** — Used by the marketing team for creating visual content such as posters, social media materials, and presentation slides.
- **Altium Designer (Professional)** — Used by the electrical team for advanced schematic design and PCB layout. It provides powerful design tools, real-time collaboration features, and industry-standard workflows for developing reliable and complex circuits.
- **SolidWorks** — For detailed mechanical parts and assemblies.
- **Fusion 360** — For collaborative CAD design and prototyping.
- **ANSYS Discovery** — Tests designs for stress, flow, and strength.
- **GitHub** — Stores code, designs, and documents, and allows version control and team collaboration.

- **Google Drive** — Our main storage for everything: meeting notes, sprint reports, designs, and documents. It is always up to date and accessible to the whole team.
- **Notion** — Where we plan and track our sprints. Each chief keeps a board for their domain and updates it weekly.
- **Discord** — Our structured communication hub. The server is organised into dedicated channels for each subteam (Mechanical, Electrical, Software), as well as channels for announcements, resources, and cross-team coordination. This helps keep discussions focused, searchable, and accessible, especially for ongoing technical conversations.
- **WhatsApp** — How we communicate day-to-day. We have separate groups for each domain and a shared leadership group for bigger decisions and discussions.



2. Design Rationale

2.1. System Design Process

AUC Aquavaders design philosophy focuses on following MATE's philosophy of student learning. We took into consideration the knowledge, technical skills, and – most importantly – the soft skills, driven by “good for good”.

The design process followed the corporate framework, staying within the constraints of the competition. Inspired by the design thinking process, we aimed to define the problem, constraints, resources, and our capabilities. Split into three phases, the definitions took place first within the experienced members of the team to ensure that the definitions are not only good on paper but are relevant to the real-life problem we are facing. The second phase was presenting the findings to the rest of the team and our advisors to hear feedback, and lastly, we reformed our definitions based on the feedback and repeated.

Design thinking sessions took place within the high board and each sub-team to define the relevant problems. This included reviewing the competition manual, video walkthrough, and the previous team's documentation to learn from their designs and improve on them, focusing on innovation.

Following our problem definition phase, we established system-level constraints by analyzing the MATE mission tasks alongside our physical and manufacturing limitations. To ensure objective decision-making across sub-teams, we utilized tradeoff matrices. For instance, the software team evaluated photogrammetry software for the coral garden task by comparing Meshroom, Agisoft, RTAB-Map, and PolyCam. Based on initial rendering tests, PolyCam was selected for its speed and reliability, with the team accepting the constraint of an internet dependency.

Physical manufacturing constraints also guided our electrical architecture.

Testing of the power distribution boards indicated that the readily available copper thickness at local manufacturers could not safely handle the current demands of the Electronic Speed Controllers (ESCs). Resulting in the design was modified to mount the ESCs on external screw terminal blocks, prioritizing system safety over an integrated board aesthetic.

Interface management was another focal point of our design process. We applied a separation of concerns principle to the custom two-layer circular Control Board. High-current servo power, low-level PWM drive signals, and serial telemetry were isolated into separate net domains to prevent cross-interference. This hardware supports a software architecture utilizing a Raspberry Pi running BlueOS as a MAVLink router, which passes pilot commands to a Pixhawk flight controller running ArduSub.

During early system load testing, routing computer vision data through the Raspberry Pi overloaded the processor and caused input lag. Based on this feedback, the electrical and software teams iteratively adjusted the design to route the OAK-D camera directly to the top-side control station via Ethernet. This allowed our computer vision algorithms, such as the SIFT and FLANN matchers used for European Green Crab detection, to run at a stable 30 frames per second without affecting vehicle control.

The ROV evolved through continuous prototyping, testing, and pilot feedback. Safety implementations include isolating the 48V power supply using a topside contactor with an emergency stop switch, and protecting the onboard DC-DC buck converters with fuses and filtering capacitors to suppress switching noise. Finally, when pool testing showed that dynamic underwater environments caused noisy readings, the software team updated the custom Tkinter GUI. The addition of "live continuous" and "burst capture" modes provided the pilot with the tools to adapt to visual noise in real-time, demonstrating our iterative approach to interface refinement.



2.2. Mechanical Systems

2.2.1. Frame and Body



Figure 5. ROV Frame

Figure 5 shows the ROV frame and semi-completed assembly for visualization purposes. This section will be discussing frame materials, assembly, and design rationale. Our team opted to use 4040 Aluminum extrusions for the frame of the ROV. While traditionally used for 3D-printers and as support materials in home-made applications, our team realized that the 4040 extrusions are quite abundant, affordable, and durable to be used in an underwater vehicle. More importantly, we recognized that the real importance of such a part is in its modularity. Sliding nuts can be inserted into these frames allowing any sort of equipment with an M5 screw hole to be mounted onto the frame easily. The extrusions themselves can easily be cut using a traditional metal saw which allows them to be constructed into the required length with minimal effort.

The frame extrusions are connected together using a 3-way corner bracket which allows for 2 directional connections between the extrusions. As mentioned earlier, M5 sliding nuts were installed into every face of the extrusions to allow for modular assembly of any required component, such as the thruster mounts, onto the frame with minimal assembly.

2.2.2. Control Box

Figure 6 shows the control box cover design. As shown in figure 6, the control box can be divided into 5 main components. The first component is the acrylic tube, which acts as a transparent housing for all the electronic components needed for the ROV to function. The second component are the 2 aluminum cover plates. These plates have been machined with tight tolerances to be fitted into the acrylic tube with a tight seal. The third component is the o-rings, which have been placed inside grooves that are machined into the aluminum plates. The fourth component are the glands. With 6 IP-68 rated glands placed onto each side of the control box ends, the ROV control box is equipped with 12 total glands to allow for all the wiring to leave the control box safely. The fifth and last component are 4 threaded rods that are placed in a circular pattern around the control box and through the aluminum plate in order to tightly lock and close the plates using a locking nut.



Figure 6. Control Box Cover

2.2.3. Thruster Mounts

Figure 7 shows the initial traditional thruster mount developed by our team. The 2 rectangular cross sections on the right and left side of the mount allow for it to be easily equipped onto the aluminum extrusions. The 2 holes in each side are M5 holes that allow the mount to be secured onto the extrusions and not move or slide at the maximum rated thrust produced by the thrusters. The top of the thruster contains a reversed profile of the T100 thruster bottom.



This allows the thruster to lie flat onto the mount and be secured using the M3 holes found on the mount. This mount is meant to be 3D printed.



Figure 7. Traditional Thruster Mount

Figures 8 and 9 show the same traditional thruster after it went through a topology optimization process using the Ansys Discovery software. Our team opted to apply this optimization process since the part will be produced using additive manufacturing which allows the production of complicated cross sections and to reduce the amount of plastic used in the overall production of the ROV. Figure 9 shows that the part should be safe, with a very high factor of safety, even after removing much of the materials used in its making.

It is important to note that only 3 thruster mounts, the straight sided ones, were optimized. The other 3 mounts have remained the same or very similar to the one shown in figure 7. Our team concluded that it is safer to keep the slightly more complicated geometries on the traditional mount as the impact of the angled forces due to the angle of the thrusters were not fully studied.



Figure 8. Optimized Thruster Mount

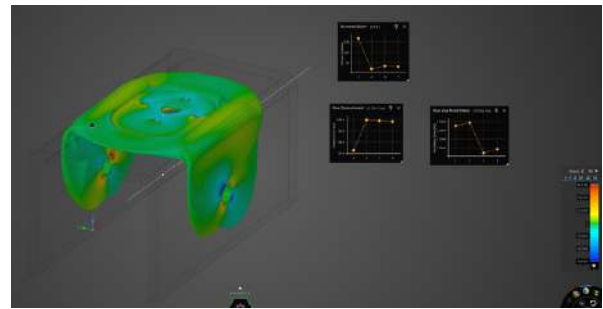


Figure 9. Optimized Thruster Mount Analysis

2.2.4. Camera Control

Figure 10 shows the camera control mechanism, which consists of a custom part that will be mounted onto the camera using mounted holes on the sides and the back. The part will be 3D printed. A servo motor will be used to give the camera a 1 degree of rotation around its axial axis which should give the pilot a wider range of motion than possible with a static camera. The servo motor will control the camera using a gear that fits within the custom mounting part.

The camera and its mechanism are placed in tube that is almost identical to the control box tube shown in figure 6. The difference will be in the number of glands, which will be only 1 for the camera, and the diameter of the tube which will be smaller.

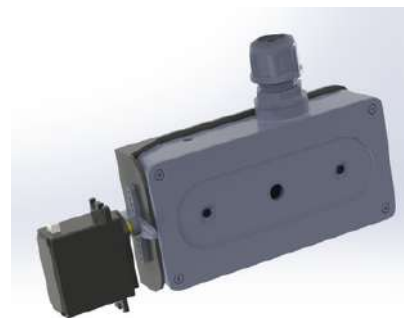


Figure 10. Camera Control Mechanism

2.2.5. Gripper Mechanism

The gripper mechanism is based on a simple four-bar linkage, making it easy to design, prototype, and repair. It is manufactured from ABS to ensure it can withstand exposure to water. Actuation is achieved using a servo motor connected to a small gear, which drives both of the main linkages to produce the gripping motion.



A 2:1 gear ratio from the servo output is used to increase the torque delivered to the gripper. Bearings are incorporated at key joints to ensure smooth motion and reduce friction. The end-effector (gripper) used in this design is intended for prototyping purposes and can be easily replaced or modified depending on the specific object being handled.



Figure 11. Gripper Mechanism

2.2.6. Thruster Orientation

We conducted a literature review and found a paper [1] comparing different thruster configurations, from which we selected the best configuration. This configuration consists of six thrusters, with three arranged in the XY plane and three in the XZ plane, providing full six degrees of freedom (6-DOF). The thrusters are organized in pairs, as shown in the top figure, with one thruster from each pair positioned in each plane. For our design, several modifications were made to better suit our application. While maintaining the same thrust angles, the thrusters were repositioned such that they are no longer colinear.

This adjustment offers multiple advantages: it increases the lever arm, resulting in higher torque output; it creates additional space at the center of the ROV for mounting components such as the control box; and it places the thrusters in clearer flow paths, minimizing interference and improving overall performance. In the bottom figure, the green arrows/circles represent forward thrust, while the red arrows/circles represent reverse thrust; the reverse thrust is slightly lower in magnitude (indicated by the smaller arrows/circles), although this reduction is not significant and is unlikely to have a noticeable effect on the performance of the ROV.

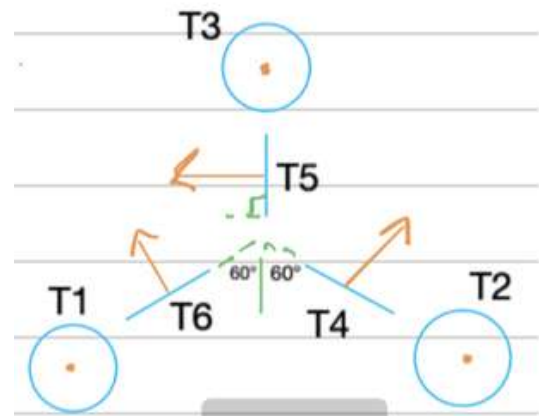


Figure 12. Hand Drafted Thruster Orientation

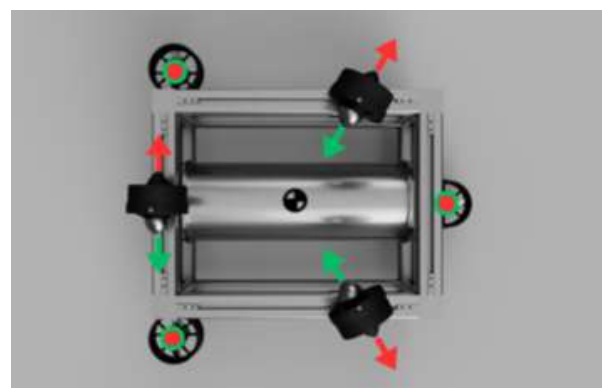


Figure 13. Thruster Orientation in CAD



2.3. Electrical Systems

Sea-3PO's electrical structure consists of four boards in total: one power interface board, two power distribution boards and one control (signals) board.

2.3.1. Power

The ROV system is powered from 48-12V buck converters connected to the power supply. These converters distribute power to 6 electronic speed controllers (ESCs) to power the T100 thrusters, a fan and a flashlight. It is further stepped down by buck converter modules to power a Raspberry Pi 4, a Pixhawk 2.4.8 flight controller and the servo rail used for the arm manipulating the gripper.

Power Interface Board

This board connects the 48V, 30A power supply in parallel to the 4 48-12V buck inputs so that each buck is supplied with 48V and 7.5A.

For one 48-12V buck, the maximum power output is 360W. Utilizing 4 bucks connected in parallel to the power supply, the power distribution is as such:

48-12V Buck	Connections	Total Power Consumption (W)
Buck 1	ESC 1, 12/5V(3A) Buck 1, 12/5V(3A) Buck 2, Switching Circuit (flashlight control)	$138 + 16.3 + 16.3 + 24 = 195$
Buck 2	ESC 2, 12/5V(8A) Buck 3, 12/5V(8A) Buck 4, Fan	$138 + 43.5 + 43.5 + 3.36 = 228.36$
Buck 3	ESC 3, ESC 4	$138 + 138 = 276$
Buck 4	ESC 5, ESC 6	$138 + 138 = 276$
Total		975.36

Figure 14. 48/12V Buck Power Distribution

Power Distribution Boards

The first distribution board is responsible for two main functions within the ROV power architecture:

1. Generating regulated 5V supplies for low-voltage electronics.
2. Providing a GPIO-controlled 12V switching circuit for external components.

The board receives 12 V input from the main power distribution system, which originates from the high-power buck converters supplying the ROV. This 12V rail is then used both for voltage conversion and for controlled switching of external loads.

Two onboard DC-DC buck converters generate regulated 5V, 3A supplies from the incoming 12 V rail. These converters power the Raspberry Pi and the Pixhawk.

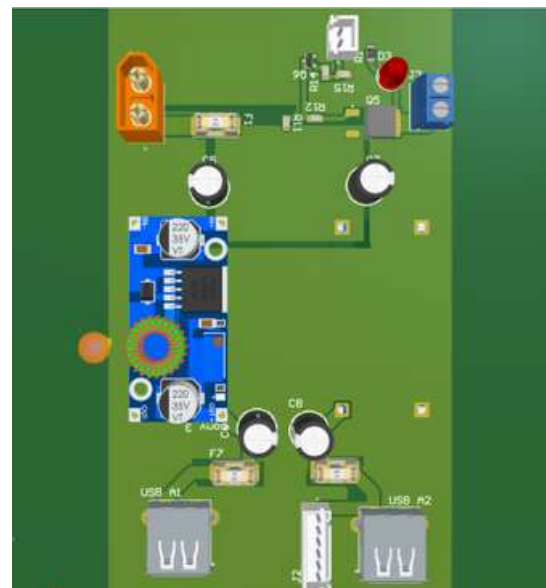


Figure 15: Power Distribution Board 1

The second distribution board follows a close design to the first except that it has DC_DC bucks with higher output current (8A) to meet the demands of the servo motors that it powers. It additionally includes a DC fan to cool down the control box.

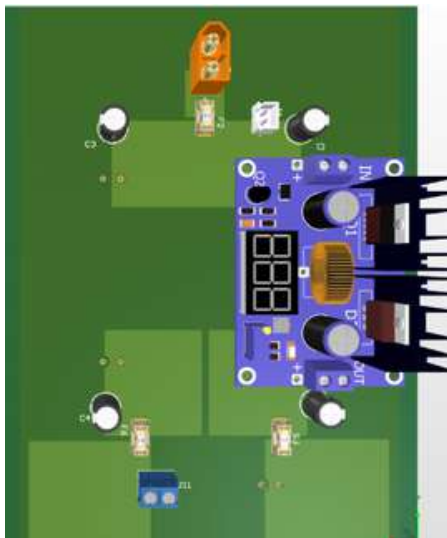


Figure 16: Power Distribution Board 2

In both boards, the outputs of the buck converters pass through fuses. Filtering capacitors are also implemented to ensure safe and stable power delivery. Fuses protect the circuit from overcurrent conditions such as short circuits or current spikes, while capacitors stabilize the voltage supply and reduce ripple from the switching converters.

The power distribution between the DC-DC bucks is as follows:

Onboard 12-5V Buck	Connections	Maximum Power Consumption (W)
Buck 1	Pixhawk	10
Buck 2	Raspberry Pi	15
Buck 3	Wrist Servo 1(waterproof), Gripper Servo(waterproof)	40
Buck 4	Wrist Servo 2(waterproof), Servo 3(for linear left-right movement) (waterproof), Camera Rotation Servo	40

Figure 17. 12/5V Buck Power Distribution

It is important to note that in Buck 4 for instance, the maximum power consumption is 40W although the components connected would require more than that due to the presence of a 3rd servo. This is because the servo motors are distributed amongst bucks 3 and 4 with the assumption that no more than two servos connected to a single power input can work simultaneously. Logically, that is valid as both wrists in addition to the linear servo will be moved simultaneously by the motion planning algorithm while the rest of the servos can wait until these 3 servos are no longer working to start execution.

In this design, the electronic speed controllers (ESCs) that operate the thrusters are placed on screw terminal blocks outside the PCBs. This is to comply with the current manufacturer's fabrication constraints, namely the copper thickness available to make the traces. The thin copper trace increases the need for wider traces, making it more efficient to wire the ESCs externally.

2.3.2. Control

The Signals Board is a two-layer, circular PCB designed as the central signals-distribution hub of Sea-3PO. It consolidates all signal paths between the on-board computer (Raspberry Pi), the flight controller (Pixhawk), six Electronic Speed Controllers (ESCs), three RC servos, and an external switching circuit into a single, compact board. The board also carries a dedicated servo power rail (SERVO_VCC) complete with bulk and high-frequency decoupling.

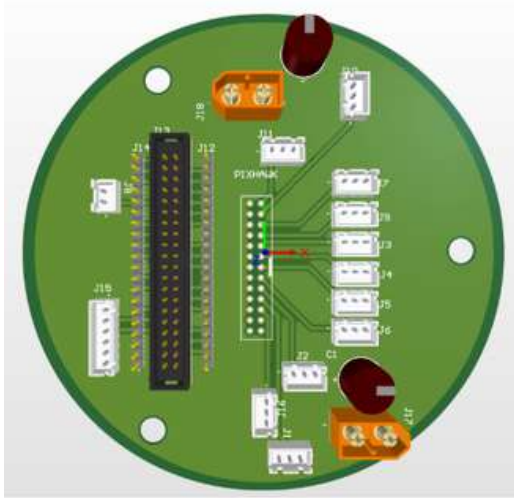


Figure 18: Signals Board

The fundamental design philosophy is separation of concerns: high-current servo power, low-level PWM drive signals, GPIO logic, and serial telemetry are each given their own connector blocks and net domains, reducing cross-interference and simplifying harness assembly during integration.

Servo Power Rail and Decoupling

Two dedicated servo power rails supply all servo connectors. Two bulk electrolytic capacitors are connected between the power polygon and ground to handle the large transient current demands generated by servos during sudden movements or stall conditions. Distributing the bulk capacitance between two physically separate sites reduces equivalent series inductance (ESL) on the rail. Four local ceramic capacitors are placed in close proximity to each servo connector to suppress high-frequency switching noise.

Raspberry Pi ↔ Pixhawk Interface and Raspberry Pi → Switching Circuit

The board houses the interface between the Raspberry Pi and the Pixhawk through the telemetry pin in addition to a GPIO output delivered to one of the power distribution boards for switching the flashlight.

The Raspberry Pi is connected to the board through a 40-pin IDC while the Pixhawk is connected with a 36-pin IDC.

The 36-pin IDC was specifically chosen for the Pixhawk to match the needed number of pins from the main and auxiliary PWM output, reducing the need for custom connectors and making space utilization on the board more efficient. It is important to note that the Pixhawk is not powered from this board. So, the VDD rail in the PWM input was ignored.

Pixhawk → ESC Outputs

Six 3-pin JST XH connectors provide PWM signal and ground to each ESC. The ESCs are externally powered and incorporate their own input conditioning; therefore, no pull-down resistors or signal-side filtering components are added to the PWM lines on this board. This keeps the board lean and avoids loading effects on the Pixhawk's output drivers.

Pixhawk → Servo Outputs

Three standard 3-pin servo connectors implement the RC servo interface. Each connector provides a PWM control signal from the Pixhawk, the SERVO_VCC power rail, and a common ground.

2.3.3. Top Side Control Station

As seen in the “Control Station SID” in the appendix, our control station includes buttons to control the power supply to the ROV in addition to providing ethernet communication by incorporating the POE switch. The contactor is the central switching element of the system. It is a 3-pole electromechanical switch that is controlled by 220VAC and controls the 48VDC supply to the ROV. Its coils are connected to a normally closed E-stop button and a normally open start button, and thus the coils are energized when the start button is pressed, closing the switches and powering the ROV. Note that T2 and T3 of the contactor are bridged together to double the current handling capacity between the contact and reduce contact wear.

As for the power over ethernet (POE) station, it is energized by the power strip within the station and supplies power to connected devices and/or receives data from the connected devices.



2.4. Software Systems

2.4.1. Control System

Our software system consists of three components: our station computer, the ROV's onboard Raspberry Pi 5, and the Pixhawk flight controller alongside it. We run our control functions through BlueOS, an open-source operating system for the Raspberry Pi designed for ROVs of any terrain. The flight controller runs through ArduSub for basic control loops and communication with the Pi. We chose these frameworks primarily for their reliability and ease-of-use, compared to other options like building an ROS system from scratch.

The pilot controls the ROV through Cockpit, an open-source control interface compatible with BlueOS and ArduSub. The ROV communicates with the station computer via Ethernet, specifically the MAVLink protocol.

For basic control of the ROV, we use a simple joystick connected via USB to the computer.

The Raspberry Pi acts as an intermediary between the other components; a MAVLink Router. It receives input commands from the station computer via Ethernet and repackages them to be sent to the Pixhawk via a UART serial connection.

The Pixhawk controls most peripherals in our ROV. It translates joystick inputs to PWM signals to be sent to the motors.

Sensor data such as depth and acceleration are sent upstream through the same process.

The flight controller also maintains a control loop that uses the built-in MPU 6000 IMU sensor to stabilize the ROV, either for all degrees of freedom or just depth for the transect task. The control loop is powered by ArduSub depth-hold mode.

The ROV's camera, the OAK-D, is connected directly to the station computer via Ethernet. With multiple tasks focusing on computer vision, we decided that it would be more efficient to capture the video feeds directly from the source, rather than potentially overloading the Raspberry Pi and risking lag.

2.4.2. Computer Vision

Computer vision tasks were built using Python. Alongside Cockpit, we designed a custom GUI using OpenCV and Tkinter that offers quick switching between our tasks: European Green crab counting, coral garden photogrammetry, iceberg keel depth measurement, and percentage frequency and threat level calculation. The interface brings a live feed of the camera and buttons on the side each for a specific task.

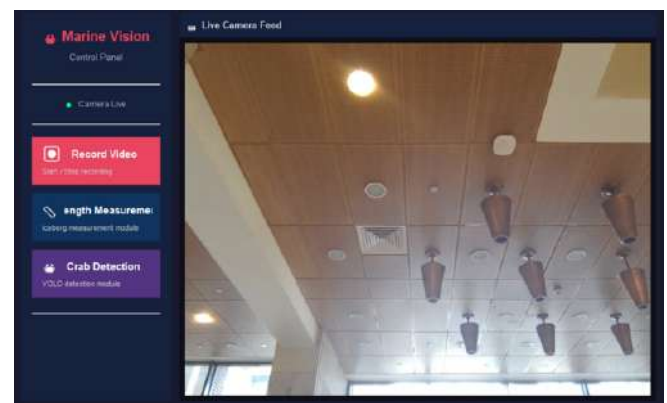


Figure 19: Custom GUI

For European Green Crab counting, we developed a real-time detection system using the DepthAI SDK for the OAK-D. We implement SIFT (Scale-Invariant Feature Transform) to find keypoints on a reference image of the European Green Crab. Then, we compare descriptors from the reference image to each live camera frame using a FLANN matcher. Descriptor matching uses a FLANN-based KNN matcher with Lowe's ratio test to filter ambiguous matches. When more than 10 good matches are found, a homography is computed via RANSAC to project a perspective-correct bounding polygon around the detected crab. The system runs at approximately 30 fps at 480p resolution on the OAK-D.



For our photogrammetry task, we have considered and tested multiple options, their benefits and setbacks. From our research, we narrowed it down to Meshroom, Agisoft MetaShape, RTAB-Map, and PolyCam. We prioritized speed and reliability above all. Since some of these programs used RGB data exclusively, we also considered depth integration as an addition, but not a necessity.

Software	Speed	Quality	Reliability
Meshroom	Medium	Medium	Low
PolyCam	High	Medium	Medium
Agisoft Metashape	Low	High	High
RTAB-Map	High (real-time)	High	Low

Figure 20: Photogrammetry Software Tradeoff Matrix

We decided to use PolyCam for their speed and accurate results during testing, even considering the internet dependency it brings.

DepthAI was used again for iceberg keel depth measurement. The program runs in two modes, a **live continuous mode**, where the pilot clicks on two points from the live feed to measure the euclidean distance, and a **burst capture mode** where the pilot takes multiple images and measures distance there instead of a live feed. We did the two modes simultaneously to bring flexibility for the pilot. If the live feed produces unnatural results, they can switch to burst capture mode. For live continuous mode, we also add in average distance over time between the same two points to decrease error.



2.5. Vertical Profiling Float (Non-ROV Device)

2.5.1. Device Overview & Mechanical Design

The float features two vertically stacked sections: a lower hull housing the pressure sensor and battery to lower the center of gravity, and an upper hull containing the buoyancy engine and control PCB. The 55cm (3mm thick) acrylic main body balances cost and weight, while the end caps are machined from high-fatigue Aluminum 7075. Waterproofing relies on dual 6mm NBR O-rings, designed with a 15.1% squeeze and silicone lubrication, sealing the caps to the tube. To comply with safety rules, a 2.5cm diameter tapered rubber stopper is press-fit into the top cap, acting as an emergency pressure relief valve against internal pressure buildup.

2.5.2. Propulsion & Buoyancy Engine

The buoyancy engine utilizes seven 60mL medical syringes (420mL total capacity) driven by a stepper motor and lead screw assembly. For safety, a calibrated physical top plate prevents plunger overextension. If the software attempts to overextend, this hard stop forces the motor to stall safely, which is instantly mitigated by the motor driver's built-in stall detection and sensorless homing.

2.5.3. Electrical & Power Systems

Power is supplied by an NPP 12V-9Ah AGM VRLA battery securely mounted in the lower hull. To comply with the 5A competition limit, a single 3A fuse is installed within 5 cm of the positive battery terminal, configured to shut down all power sources if blown. This fuse was appropriately sized based on measured Full Load Amperage (FLA) calculations:

- **Waiting/Standby Mode:** 0.2A
- **Buoyancy Change Mode (Active load):** 2.54A

The 3A fuse safely accommodates the 2.0A peak draw while providing enough headroom to prevent nuisance blowing.

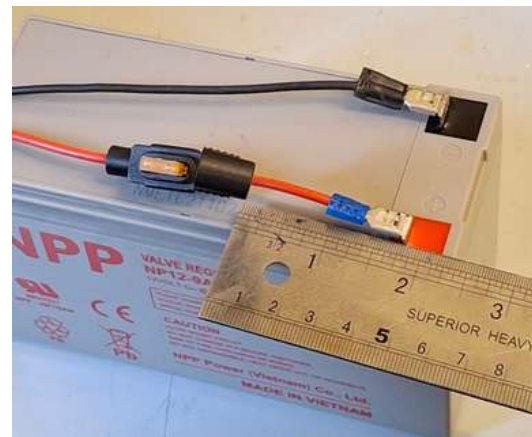


Figure 21: 3A Fuse

Component	Consumption
ESP32	2.50 W
Stepper Motor Driver	24.0 W
Pressure Sensor	0.014W
DC-DC Buck Converter	4.0 W
Total:	30.514 W

Figure 22: Power Consumption Breakdown

Using the values in Table 1, the total current draw was calculated by dividing the power consumption (30.51 W) by the battery voltage (12V) to obtain approximately 2.54A.

2.5.4. Sensors, Software, & Control Systems

An onboard ESP microcontroller manages all logic, reading real-time depth data from a DFRobot Gravity water pressure sensor. A custom PID control loop calculates depth errors and commands the stepper motor to adjust water displacement accordingly. Upon completing its profile and resurfacing, the float uses the *ESPNow* protocol to establish a fast, connectionless link with a secondary ESP at the surface control station, wirelessly transmitting the gathered data for analysis.



3. Safety

3.1. Personnel Safety

Before any team members use the workshop or its equipment, they undergo a mandatory safety orientation. This covers proper use of hand tools, locations of all safety equipment (first aid kit and fire extinguisher), accident reporting procedures, and the use of the required PPE, including safety glasses and close-toe shoes, and information on the emergency contacts. The first aid kit and fire extinguisher are accessible at all times in the workshop and at the pool during testing.

For specialized equipment, members complete live training with an experienced lead before independent use. For example, electrical team members were trained on soldering iron operation and safe wiring practices before working on the RO electronics. This training requirement applies to all power tools used during fabrication.

During all pool testing, strict poolside safety procedures are enforced. Aunty personnel at the pool's edge must wear a properly fitted flotation device (PFD) at all times. Close-toed shoes and safety glasses are required on the pool deck. The pool area is kept clear of loose debris and tripping hazards, and the power supply and control station are positioned away from the pool edge to prevent electrical hazards from water contact. There is a lifeguard available at all times, and those close to the pool, including the pilot, tether tenders, and safety officers, have to go through a mandatory test to ensure they can swim in case of emergencies.

3.2. Equipment Safety

All propellers are enclosed by custom 3D-printed thruster shrouds that fully encircle each propeller, extending protection both in front of and behind the blade plane. The shrouds meet IP-20 standards (mesh opening <12.5 mm), ensuring that fingers or foreign objects cannot contact the spinning propellers. Guards are applied to all thruster faces on all sides of the ROV.

Any gear assemblies used in manipulators are fully enclosed to IP-20 standards to eliminate pinch-point hazards. No sharp edges or points exist on the ROV frame or attached systems. All cut cable ties are flush-cut, and shrinks are used at all times to ensure the wires are fully enclosed from water. Frame edges are filed or covered, and no glass components are used on the vehicle or at the pool deck.

3.3. Pressure Housing & Sealing

The electronics control box uses a clear acrylic enclosure, allowing full visual inspection of the internal components without opening the housing. Wastertight integrity is maintained through four complementary measures.

- Aluminum end plates provide rigid, corrosion-resistant closure at both ends of the housing.
- Dual O-rings on each endplate create a redundant seal, preventing water ingress.
- Custom-fit cable glands to fit the exact diameter of each wire bundle, maintaining a complete seal while allowing tether and signal cables to pass through the housing wall.
- Critical penetration points are additionally secured with marine-grade epoxy, providing a final barrier against leakage.

Before any electronics are installed, the sealed control box undergoes a two-stage leak verification protocol. First, a bubble test is performed: the sealed housing is fully submerged, and each gland and seam is inspected for escaping air bubbles. Any bubbles indicate a seal failure requiring correction before proceeding. Second, the sealed, empty housing is mounted to the ROV frame, and a preliminary buoyancy check is conducted in water to confirm structural integrity and correct displacement prior to electronics installation. Only after both tests pass are the electrical components installed and a full system test performed.



3.4. Electrical Safety

The ROV electrical safety is designed to comply fully with MATE Pioneer class specifications. The correct Anderson power connector is used as the main point of connection to the MATE supply. No onboard batteries are present on the ROV. All power is supplied via the tether from the surface. The ROV is confirmed to cease all operations within 5 seconds of power disconnection.

Full load amperage was measured with all motors running at full load in water:

ROV Full Load Amps (FLA) in water = 23.5A

Fuse size selected upon FLA = 25A

The selected fuse is located 30 cm from the Anderson power connector. The surface control station is wired neatly with no exposed connections, and tether strain relief is installed at both the surface station and ROV-side tether entry points.

4. Critical Analysis

4.1. Buoyancy Test

Buoyancy is the force that pushes the ROV upwards when it gets inside the water. It is calculated as the displaced volume of water multiplied by the specific weight of water or 9180. Our primary concern was regarding the buoyancy of the ROV since CAD software wasn't extremely accurate when it comes to calculating the weight and volume of the ROV. Our team decided to conduct a buoyancy test at the AUC pool where the empty frame of the ROV was placed inside the water to test the effect of large and empty volumes such as the control box and the camera box. The test proved successful and the ROV could be controlled with the vertical positioned thrusters alone without the need for extra weight or buoyancy adjustments.

4.2. Servo Motor Waterproofing Test

Our team waterproofed the servo motors to be used in the water manually. In order to test the quality of the seal, its corrosion resistance, electrical shorting risks, shaft seal leakage with time, and lubricant washout, the servo was placed in shallow water for around an hour. The test results showed that the servo continued running for the entire duration of the test. A side effect of the test is that the oil placed inside the servo to counteract the water pressure leaked into the servo enclosure. Our team hypothesized that the intense water pressure at the 2 meter depth would fix this issue, but we tightened the sealed enclosure and slightly reduced the amount of oil in the servo to make sure this problem does not repeat.

4.3. Sealing Test

The two most important items to be sealed are the control box and the camera box. These components were sealed tightly and then an actual depth test was conducted at a 2 meter depth in the AUC pool. This test also allowed us to test the seal compression, the acrylic deformation, the cable glands, and long term leakage. The test was proven successful as no water entered the ROV.

4.4. Electrical Testing and Troubleshooting Framework

Step 1: Visual Inspection

- Check for solder bridges/short circuits
- Check for cold solder joints
- Verify component orientation and polarity
- Inspect PCB for damage such as scratched masks or overlapping reliefs

Step 2: Continuity testing

- Check there are no short circuits with a multimeter
- Check ground plane continuity
- Check for open circuits

Step 3: Functional Testing

- Check each subsystem/component independently
- Increase the load incrementally after testing each subsystem



Step 5: Stress Testing

- Run the system at full load for an extended period of time
- Check for overheating
- Verify behavior during power cycling

Symptom	Likely Cause	How to Test
Board draws no current	Open circuit on power rail	Continuity test from supply to board
Board draws excessive current	Short circuit or wrong component value	Check power-to-ground resistance, inspect for bridges
Module gets hot immediately	Module installed backwards / short on output	Visual check, continuity on pins
Signal missing on output	Missing power to module, failed component	Probe power pins of module, then signal pins
Intermittent faults	Cold solder joint, loose connector	Flex board gently while monitoring, reflow suspect joints

Figure 23. Common Faults and How to Spot Them

5. Accounting

At the beginning of the season, our team secured an initial grant of \$3,400 USD from the university's primary student activities fund. During the early design and component research phase it became evident that, according to the projected budget we had developed, this allocation alone would be insufficient to field a competitive ROV at both the regional and international levels. The team responded by preparing a detailed engineering and cost proposal and presenting it to the CCC (Campus Clubs & Competitions) Committee at our university. After a thorough review, the committee approved a supplementary grant of \$6,600 USD, bringing total institutional funding to \$10,000 USD.

This two-phase funding process demonstrated that financial and engineering planning are inseparable: early cost modelling directly shaped the funding proposal, and the approved budget in turn guided every major procurement decision throughout the build season.

Source	Amount (USD)	Type
University Student Activities Fund (Initial Allocation)	\$3,400.00	Cash grant
CCC Committee Supplementary Grant	\$6,600.00	Cash grant
TOTAL INCOME	\$10,000.00	

Figure 24. Income Sources

Before any procurement took place, the team developed a projected budget to guide spending decisions and inform the CCC funding proposal. Each category was estimated based on supplier quotes, competition guidelines, and travel research. As shown in Table 2, this initial plan projected a total season cost of \$12,380, as shown in Appendix E.

The most significant financial outcome of the season was the discovery and refurbishment of five BlueRobotics T100 thrusters found in university storage after eight years of disuse. The team disassembled, inspected, cleaned, re-greased, and bench-tested all five units, restoring them to full operational condition at zero parts cost. With a T200 retailing at \$480, purchasing six new units would have cost \$2,880. Instead, the team bought only one T200 and refurbished five T100s (fair market value: \$120 each), bringing actual propulsion spend to just \$480 — a saving of \$2,400 against the propulsion budget.



6. Acknowledgements

We would like to express our sincere gratitude to all those who supported and contributed to the success of our journey in developing AUC Robotics' Underwater Remotely Operated Vehicle.

We extend our heartfelt thanks to the American University in Cairo, our home institution, for its continued unwavering support and funding throughout every phase of this project. We are also grateful to the MATE Center for sponsoring this year's competition and to the Arab Academy for Science and Technology (AAST) for hosting and organizing the regional event.

A special thanks goes to Eng. Ahmed Maged, whose technical guidance and mentorship were instrumental in shaping our engineering decisions and driving our progress throughout the development process. We also extend our appreciation to Mr. Abdelmoneim Ibrahim of the Office of Student Life, whose support was invaluable in managing the logistical and administrative aspects of our participation, including travel coordination and university liaison.

We are grateful for the industry-standard tools provided by SolidWorks, Altium, and Raspberry Pi, which continue to empower us with powerful design and development platforms.

Finally, we owe immense appreciation to our families and friends, whose constant encouragement and patience kept us grounded and motivated. This project would not have been possible without the collective efforts and support of this incredible network, thank you for believing in us.

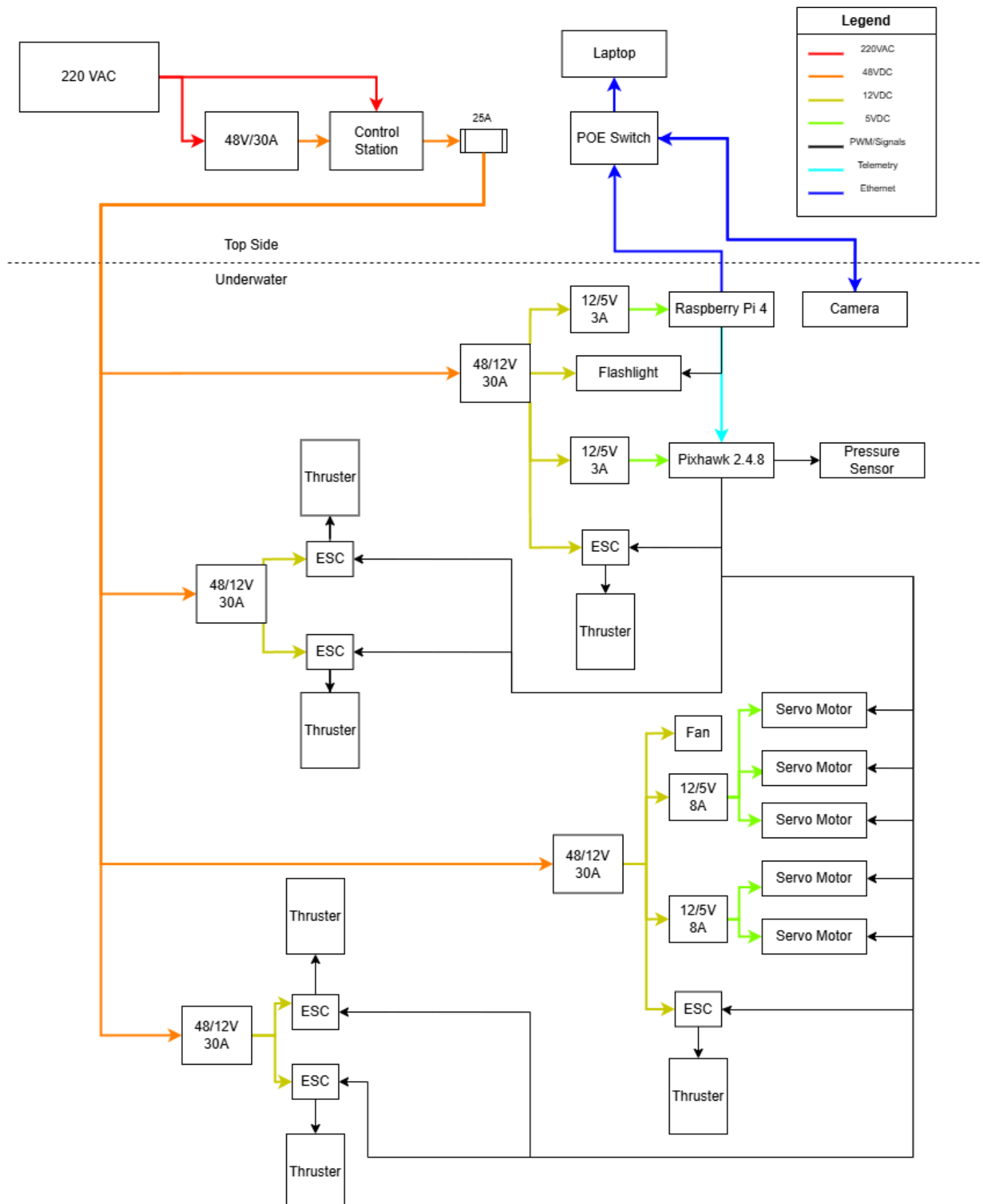
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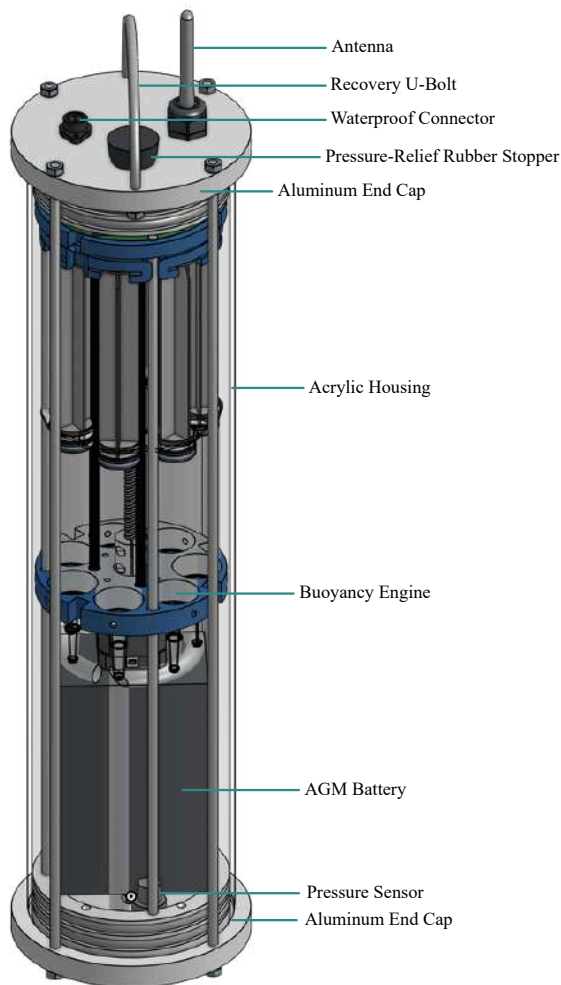
8. Appendices

Appendix A: Electrical SID

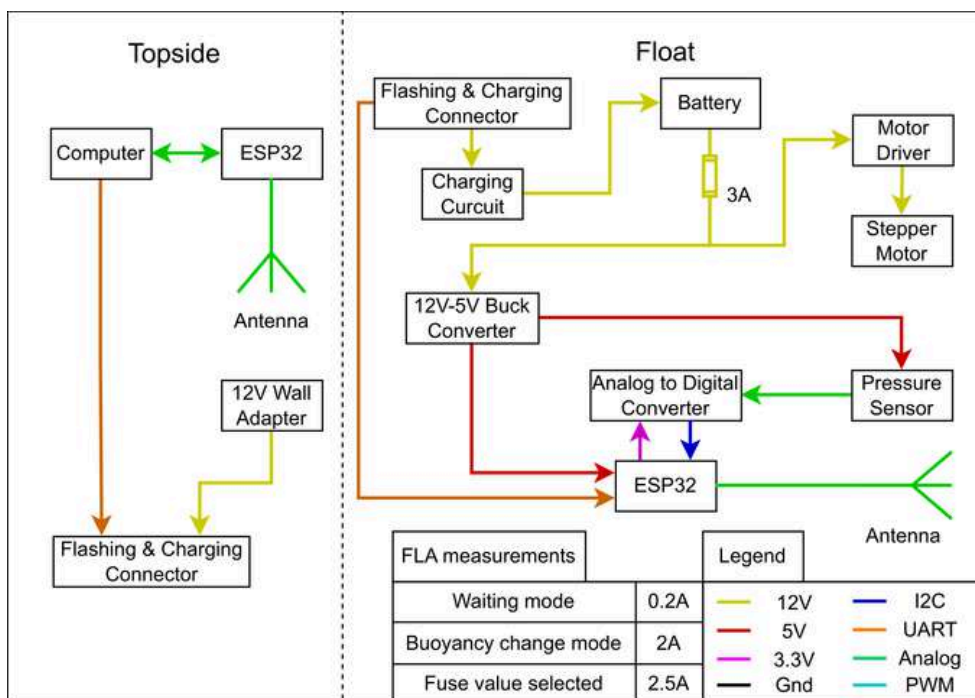




Appendix B: CAD Model of the Float



Appendix C: Float SID





Appendix D: Safety Checklist

Safety Checklists for ROV Construction / Pre-Assembly

Before closing the housing:

- Work surface and outside of ROV are completely dry and free from debris, metal shavings, or loose materials.
- All wiring inside the housing is connected and secure; no exposed conductors present.
- The acrylic housing shows no cloudiness or cracks. The interior is fully dry.
- O-rings and grooves are clean, undamaged, and free from hair, dirt, or debris.
- No wires are pinched between the endplate and the house wall.

While Closing

- Both endplates are flush with the cylinder; no gaps are visible.
- Visually confirm O-rings for a complete, unbroken seal on both ends
- Perform bubble test: Submerge housing and inspect all glands and seams for escaping air bubbles.
- Perform buoyancy check: mount the sealed, empty housing on the frame and verify the correct displacement in water.

Pre-Deployment (Before Entering Water)

- Minimum required personnel present: Pilot, Tether Tender(s), and Safety Officer.
- No damage observed on ROV frame or housing (check for cracks, cloudiness, or bent frames).
- All propeller guards are securely attached on all sides; no guard is loose or missing.
- All ROV attachments are mechanically secured.
- Power supply and surface station are positioned away from the pool edge and are completely dry.
- Surface station tether strain relief is attached to a rigid, fixed structure.
- Surface station laptop is powered on, and communication with the ROV is confirmed.
- All poolside personnel are wearing PFDs, closed-toe shoes, and safety glasses.
- Recovery equipment (pole, net) is accessible at the poolside.
- The control station and tether staging area are clear of clutter and tripping hazards.

During Operation

- Tether tender(s) are actively managing tether slack in the tether management protocol.
- Pilots avoid 360-degree spins and maneuvers that could wrap the tether around obstacles.
- Do not run near the pool, walk at all times on the pool deck.
- Safety office monitors poolside conditions and communicates with the pilot as needed.

Post-Deployment

- Pilot navigates ROV to the launch zone, ROV handler picks up the ROV by the frame (never by the tether)
- Tether tender disconnects power, then ethernet/data, then removes the strain relief from the surface station.
- Inspect the housing, frame, and all connections for any damage or signs of water ingress.
- Coil tether in a figure-eight for storage.



Appendix E: Lab Safety Policy

All team members must read, acknowledge, and follow the rules at all times when in the workshop or working on the ROV.

- NEVER work in the workshop or the ROV without a qualified lead present and supervising.
- Wear required PPE at all times in the workshop: safety glasses, closed-toe non-slip shoes, no loose clothing, jewelry, or rings. Watches, or loose long hair (tie back).
- All injuries or accidents, no matter how minor, must be reported immediately to the team safety officer and/or lead.
- If you are uncertain about a process or procedure, stop working immediately and ask for guidance before continuing.
- Report any unsafe conditions, damaged tools, or potential hazards as soon as they are identified.
- Eating and drinking are prohibited in all workshops and building spaces.
- Be thoroughly familiar with any equipment you operate. Never use a tool you have not been trained on.
- Use all tools only for their intended purpose. Do not improvise with tools in ways not covered by taig.
- Never use fingers or hands to remove chips, debris, or cuttings from machinery, whether moving or stationary.
- Never adjust, modify, or repair moving or rotating machinery. Allow all machines to come to a complete stop before making adjustments.
- Never leave powered or running machinery unattended, unless the equipment is specifically designed to operate unattended.
- Never attempt to slow or stop rotating equipment with hands, clothing, or tools.
- Always properly clamp or secure workpieces before machining or cutting.
- File or sandpaper all machined parts to remove sharp edges before handling.
- Use appropriate respiratory protection when working with dusts, fumes, solvents, adhesives, or resins. Read the SDS for all chemicals before use.
- Use proper lifting techniques and request assistance when moving heavy or awkward loads.
- Keeps walkways and exits clear at all times. Do not place tools, materials, or cables in the way.
- Know the location of all fire extinguishers, first aid kits, emergency exits, and eye wash stations before beginning work.
- Soldering must be performed in a vented area or with a fume extractor. Never solder without safety glasses.



Appendix F: Cost Projection

Category	Budgeted (USD)
ROV Structure	\$750.00
Electrical Systems	\$1,500.00
Propulsion (worst-case: 6× T200 new)	\$2,880.00
ROV Surface Station	\$250.00
Float System	\$350.00
Lab Safety	\$300.00
Competition Fees	\$550.00
Regional Travel & Accommodation	\$2,500.00
International Travel & Accommodation	\$3,000.00
Marketing	\$300.00
Total Projected Cost	\$12,380.00



Appendix G: Total Costs

Category	Key Components	Cost
ROV Structure	Aluminium extrusions frame; aluminium alloy end-caps; acrylic tubes; tether cable; etc.	\$1,000.00
Electrical Systems	DC power supply; custom PCBs; microcontrollers; sensors; converters; OAK-D stereo depth camera; etc.	\$1,750.00
Propulsion	1× T200 Thruster, new — purchased (\$480); 5× T100 Thruster, reused (\$0 cash outlay, fair market value \$120 each = \$600)	\$480.00
ROV Surface Station	Managed Ethernet network switch; 2× USB game controllers; etc.	\$200.00
Float System	Sealed acrylic tube & aluminium end-caps; onboard microcontroller; Battery; etc.	\$550.00
Lab Safety	6× personal flotation devices (life jackets); 2× first aid kits; 8× safety glasses; etc.	\$250.00
Competition Fees	Regional competition registration: \$220; MATE International registration: \$330	\$550.00
Regional Travel & Accommodation		\$2,000.00
International Travel & Accommodation	(Estimate — to be updated once bookings confirmed)	\$3,000.00
Marketing	Team T-shirts; Poster; Stickers; etc.	\$200.00
ROV Hardware Cost	Structure + Electrical + Propulsion + Surface Station + Float	\$3,980.00
TOTAL COST	All categories combined	\$9,980.00