

ROV Engineers for Environmental Futures(R.E.E.F)

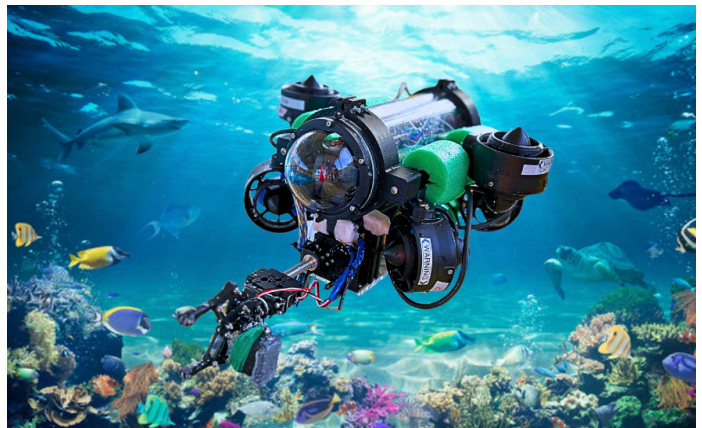
Technical Documentation

Thuwal, Saudi Arabia



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1. ABSTRACT

R.E.E.F. (ROV Engineers for Environmental Futures), based at King Abdullah University of Science and Technology in Thuwal, Saudi Arabia, has been developing ROVs for 2 years. Participating in the 2026 MATE ROV Competition, R.E.E.F. designed and built *Acropora*, an ROV engineered to accept the fragility of ocean ecosystems and to be reliable across diverse environments, whether it be hot or cold, fresh or salt. The ROV *Acropora* was named after a famous coral found commonly in the Red Sea, which is reflected by the company's location and name, R.E.E.F.

To meet the mission requirements, *Acropora* is outfitted with a 3-axis servo arm for manipulation tasks, a vertical profiler, and software features like photogrammetry and pixel-measurement recognition to complete the measurement and observation-intensive tasks for this year. These features and components were designed in Fusion 360 and fabricated via 3D printing or aluminum cutting, ensuring strong parts.

Acropora is engineered to perform tasks in diverse aquatic environments, including oceans, cold-water lakes, and pools. These tasks include modeling a coral reef, observing corals, and replacing coral restoration components underwater. This document explains the engineering in detail to demonstrate our problem-solving and technical skills in building this ROV.

R.E.E.F. prioritizes safety above all. A dedicated safety officer monitors all operations and ensures the team adheres to strict safety protocols. Meanwhile, the CEO and lead engineers plan and schedule tasks to guarantee that every team member works safely and efficiently.



Fig 0: Team Photo

(Sriram Dasari, Hussain Sheikh, Ahmed Alramadhan, Ryoji Kobayashi, Alikhan Dukebayov, Murari Gubba, Ronan Erickson, Ammar Alfelfel, Fahad Alofesani, Shaswat Saxena, Jayaram Dasari, Imaad Rehman)

Credit - Mery Tellez

2. PROJECT MANAGEMENT

A. Company Overview

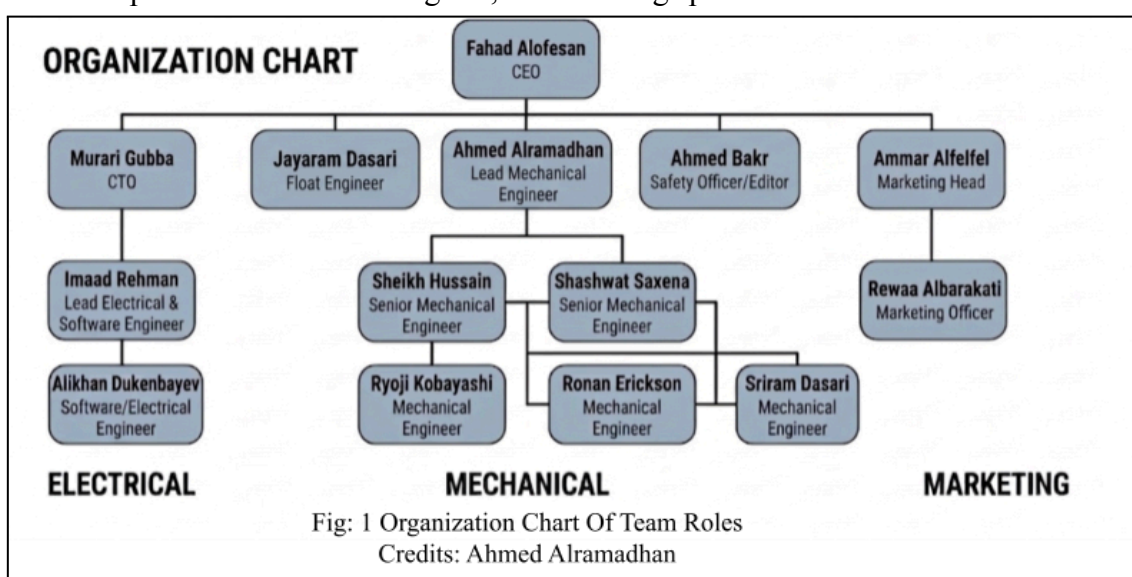
The R.E.E.F. company is a second-year student-run company with a simple goal: *"Serve the Ocean, Explore the Deep, and Keep it Blue."* The team expanded from 10 to 13 members this year, all sharing a passion for engineering, conservation, and exploration of the deep. Returning employees retained their roles, and new members were placed according to their strengths and team interests.

The CEO and CTO start meetings with a company-wide briefing of upcoming tasks and research objectives. At the same time, project progress is tracked in Google Sheets with real-time updates, attendance records, and task priorities to ensure accountability and smooth workflow. Our mentors support the company by resolving technical issues, keeping the team accountable, and improving the team's workflow. R.E.E.F. loves teamwork and promotes a positive, safe, and productive environment.

B. Company Organization

For a company to function correctly, people need to work across all sectors of a project, whether engineering, marketing, documentation, or even task management, and, most important of all, they need to be interested in their work. The R.E.E.F. CEO, Fahad Alofesan, and CTO, Murari Gubba, who have led R.E.E.F. for 1 year and counting, chose their team members after analyzing their strengths and interests, and project managers have the members split off into 3 groups according to their roles:

- The mechanical group, led by Jayaram Dasari and Murari Gubba, ensures the ROV is successfully constructed and tests its props, tools, and equipment. This group ensures that everything works mechanically.
- The electrical group, led by Imaad Rehman, codes the ROV and vertical profiler and ensures the ROV responds to the controls. They code the ROV's interface and help make it easy to control.
- The marketing group, led by Ammar Alfelfel, is responsible for technical documentation, marketing the team on platforms such as Instagram, and securing sponsors to fund the team's endeavors.



C. Procedural Challenges and Company Scheduling

As a company, we value organization, especially in time management and self-accountability. As such, the company met in early October 2025 and reached consensus on a detailed master schedule to guide our team as a whole, as shown in Fig 2. By following this schedule, we ensured we had ample time to troubleshoot if needed and spared us time for modifications, backup plans, and practice runs to help build our piloting skills. The schedule was designed so that each person knew what they were doing, making it easier for us to manage task overlaps, such as building the ROV, preparing the documentation, and getting ready for the marketing display and engineering presentations. The team had a group chat where updates, schedule changes, and progress videos were shared to keep everyone on the same page (Fig 3).

The company met for 4 hours per week, and the engineers sometimes dedicated 6 hours per week to developing Acropora. However, the R.E.E.F. The team faced scheduling conflicts, as most members had other academic/extracurricular commitments, which often limited full team attendance. Additionally, since the company is based in Saudi Arabia, sourcing materials for ROV construction is more difficult than in other countries. Because of this, importing components such as servos, printed circuit boards, and underwater enclosures took about 1 month, resulting in about 16 hours of work lost waiting for them to arrive. To combat these two issues, the company strived to get sponsorships in the first week of MATEROV and ordered components to arrive by November 2025, and by following the timeline very strictly and adding overtime work hours during weekends to allow the whole team to collaborate effectively, we were able to finish the final build of the Acropora ROV on time. This is how R.E.E.F. has solved a day-to-day operational problem with the company.

R.E.E.F. Safety Officer and Lead Engineers were tasked with developing specific protocols for each of the 3 ROV mission tasks and 1 vertical profiler mission task to ensure R.E.E.F. meets mission objectives. These task procedures outlined the pilot and co-pilot roles, tether management roles, and peripheral software management roles and documented step-by-step actions and safety precautions. Before the regionals, each

PROJECT DETAILS					
STATUS	PRIORITY	DEADLINE	TASK NAME	ASSIGNEE	DESCRIPTION
Project Management & Operations					
Complete	High	10/7	Season kickoff + master schedule consensus	Fahad, Murari	Align roles, meeting cadence, and the season timeline for the full MATE ROV cycle.
Complete	High	10/10	Sponsorship outreach + budget planning	Ammar, Fahad	Pursue early funding and budget coverage to offset imported components and travel costs.
Complete	High	10/15	Order critical imported components	Murari, Imaad	Place orders for servos, PCBs, enclosure, and key electronics so parts arrive by November.
In Progress	Medium	10/20	Progress tracking sheet + attendance workflow	Fahad, Ammar	Keep the Google Sheets task tracker, attendance log, and priority updates current each week.
Mechanical Engineering					
Complete	High	10/25	Frame brainstorming + CAD concepts	Jayaram, Murari, Shashwat	Translate lessons learned from the previous ROV into acrylic-based frame concepts and layout options.
Complete	High	11/15	Prototype frame geometry + cardboard checks	Jayaram, Ahmed A., Shashwat	Validate thruster spacing, payload clearance, and frame modularity before final cutting.
Complete	High	12/5	Final acrylic frame fabrication + extrusion assembly	Jayaram, Murari, Ahmed A.	Build the compact acrylic frame with aluminum extrusions and 3D-printed clamps.
Complete	Medium	1/15	Buoyancy balancing + foam placement	Jayaram, Shashwat	Tune trim with pool noodle foam and correct front-heavy behavior for stable operation.
Electrical & Software					

Fig 2: Master Plan
Credits: Fahad Alofesan

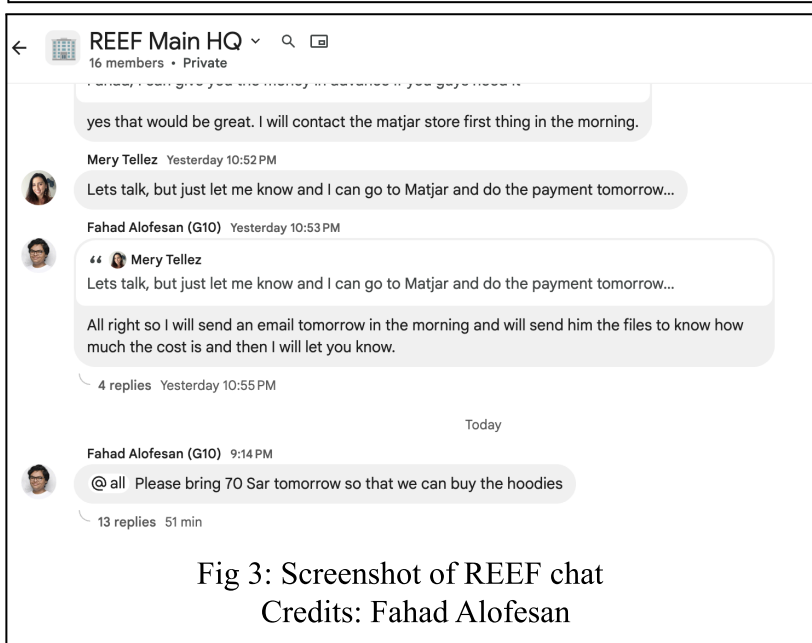


Fig 3: Screenshot of REEF chat
Credits: Fahad Alofesan

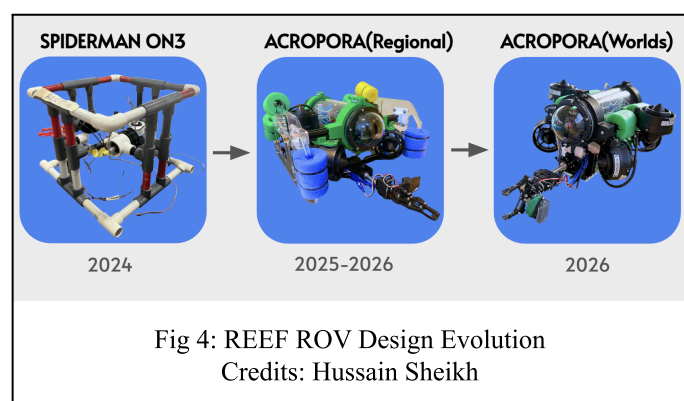
protocol was tested during pool tests to determine whether the ROV performed as predicted, whether employees worked as a team, and whether mission goals were effectively achieved.

3. DESIGN RATIONALE

As stated before, Acropora is a reliable, easily usable Remotely Operated Vehicle (ROV) designed to meet mission requirements from the 2026 MATEROV competition, thanks to its many engineered and customized features. R.E.E.F ensures that Acropora executes tasks efficiently while also aligning with the requirements of the MATEROV competition and will help fulfill the company's mission: "Serve the Ocean, Explore the Deep, Keep it Blue."

A. Design Evolution

Over the 2 years of the R.E.E.F. company's existence, the company has developed 2 ROVs: Spiderman ON3 and its successor, Acropora 1. Acropora, the second-generation ROV, reflects the company's knowledge and understanding of ROV technology and demonstrates how hands-on experience and iterative design help improve a



product (Fig 4). The first ROV, Spiderman ON3, used a PVC frame due to its price effectiveness and ease of use during the learning stages. While this ROV was quite effective at teaching us how ROV mechanics work, it fell short in the regional competition, unable to correctly perform the tasks due to a lack of speed, precision, and long-term use. Following this, the company's biggest goal was to transform the ROV control system from analog to digital, enabling easier modularity and faster access to the ROV.

Additionally, from 2025-2026, the team applied their learnings from previous years and shifted from PVC to acrylic plates for the frame. After careful planning, prototyping, and construction of the new ROV frame, the ROV's strength, modularity, and underwater performance have significantly improved during pool testing (Fig 4). Currently, Acropora has again been changed to replace the acrylic side panels with aluminum extrusions horizontally to attach the thrusters. After evolving the frame design, the engineers moved on to the underwater manipulator and made it 3-axis, unlike the 1-axis grabber arm from last year that barely functioned. Waterproofing and testing the servo manipulator underwater showed that the ROV's reach had significantly improved, allowing it to perform more complex tasks, demonstrating proper evolution in the ROV design over the company's 2 years of competition. This allowed the company to make an ROV that is reliable, maintainable, and ready for the demanding conditions of most marine environments.

With the performance of the ROV from the regional competition, we had identified limitations of the frame of the ROV, this is because the acrylic panels were bulky and caused drag when the ROV was moving in any direction, limiting the both the accuracy and speed of the movement, not only that, the acrylic panels did limit the water flow since the thruster were partially blocked by the panels intercepting the flow. We decided to completely structure the out of aluminum extrusions maximizing the water flow produced from the thrusters which would allow us to use less thrust for a balanced speed. We have demonstrated proper evolution in the ROV design over the company's 2 years of competition. This allowed the company to make an ROV that is reliable, maintainable, and ready for the demanding conditions of most marine environments.

B. Innovation

Innovation is the pinnacle of scientific or technological progress, and this rule applies to our company as well. REEF has limited resources readily available. The innovation of a high-performance ROV design that uses readily available, low-cost components was crucial. Innovation on the AcroPora was driven by 3D printing and by adapting cost-effective parts into systems capable of operation in a subsea environment. As a result, the vast majority of components on the AcroPora are replaceable and low-cost, giving it a cost-effective, serviceable design.

The company's most significant innovations include the creation of the grabber arm by adapting a cheap, mass-produced, DIY model and the utilization of Lego in the Vertical Profilers gear systems. The grabber arm carries great responsibility on an ROV, as it picks up, moves, and rotates parts and PVC pipes to complete the necessary tasks. To perform well, this required the grabber arm to contain multiple axes of freedom. However, achieving this would mean purchasing several expensive waterproofed servos, designing and 3D-printing custom



Fig 5: Acropora's Grabber arm
Credits: Ahmed Bakr

parts for the grabber arm, and finally assembling it. The company estimated around \$200 in material costs and several dozen hours of production time to complete this. This is when REEF innovated by adapting a mass-produced, pre-existing 3-axis DIY grabber arm. The team decided to purchase one of these, disassemble it, individually and carefully waterproof each servo, and then reassemble it in a way that better met the needs of the tasks. With these adaptations, the company was able to produce a waterproofed, length-fitted grabber arm and mount it on the front of the Acropora (Fig 5). This 3-axis grabber arm gives the Acropora a significant upper hand. Because of this innovative approach, the Acropora did not just achieve high

performance but also cost just 80\$ (less than half the 200\$ initial estimate) while saving dozens of work hours. This showcases how innovation resulted in a cost-effective, time-effective, and high-performance arm.

R.E.E.F. also incorporated innovation into the profiling float, particularly the use of LEGO gears to operate the syringe of the vertical profiler (Fig. 6). This was done when the company was deciding how to create the buoyancy of the vertical profiler. The company was in a cornered situation, with only 2 choices: either purchase high-quality gears or CNC-custom gears. 3D printing was an option, but it was not considered a potential solution as the company had a poor experience with it last year due to its unreliable strength, especially in a high-tension gear system. The company innovated through this by deciding to use LEGOs. They are widely used, modular, and strong, making them an ideal solution. The school had large holdings of old LEGO parts that the R.E.E.F was able to utilize. This makes this solution not only extremely cost-effective, but also demonstrates the resourcefulness of R.E.E.F.

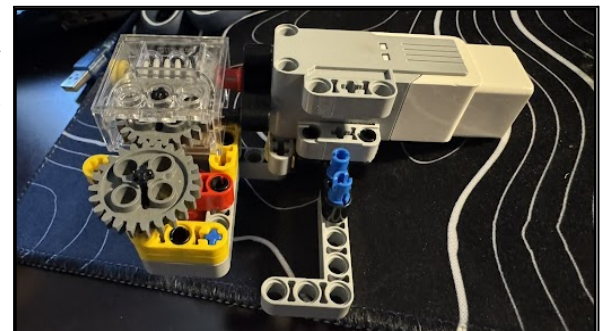


Fig 6: Usage of Lego in Buoyancy Engine
Credits: Jayaram Dasari

C. Problem Solving and Brainstorming

R.E.E.F. employs a systematic engineering design process to create solutions for mission requirements. Whenever the team faced a design challenge, we did not immediately jump to building. Instead, we began with expansive brainstorming sessions utilizing digital collaboration software. These digital brainstorm drawings allowed us to map out mission tasks by priority, consider which design features are needed for each, sketch early geometries (see Fig 7), and finally put it all together. Once we finished brainstorming, we started modeling in CAD to visualize our concepts, which helped us identify spatial constraints and test the feasibility of our ideas digitally.

We also created a decision matrix to evaluate how many axes we need on the grabber arm, considering each task and whether a second or third axis would help (Fig 8). This allowed us to safely brainstorm and edit the grabber arm design before actually bringing it into the real world, and really allowed R.E.E.F. to fine-tune the manipulator to the mission tasks. This shows how the company brainstormed ideas for the ROV build and some of its payloads.

4. SYSTEMS APPROACH and ENGINEERING DESIGN RATIONALE

R.E.E.F. approaches every engineering decision with a focus on holistic system integration. To meet the demanding mission requirements of the 2026 product demonstration, our team balanced critical trade-offs across systems, including electrical, software, buoyancy, and payload. Each system was designed to integrate with the ROV's frame and software, ensuring that tools like the grabber arm operate efficiently without interfering with our camera visibility or thruster wash. The following outlines our approach to the ROV and the step-by-step rationale for each component's planning and decision-making.

A. Vehicle Frame and Structure

As specified in the design evolution section, the current ROV frame consists entirely of a modular aluminum extrusion matrix and custom 3D-printed clamps for assembly. This finalized design represents the culmination of multiple prototyping iterations, balancing cost, material availability, underwater adaptability, and structural reliability to ensure peak efficiency for the final competition.

The final chassis design is the result of addressing distinct limitations across three structural generations:

Last Year's Design: The previous year's ROV frame was completely inefficient from a hydrodynamic standpoint. It was highly rigid, making it nearly impossible to

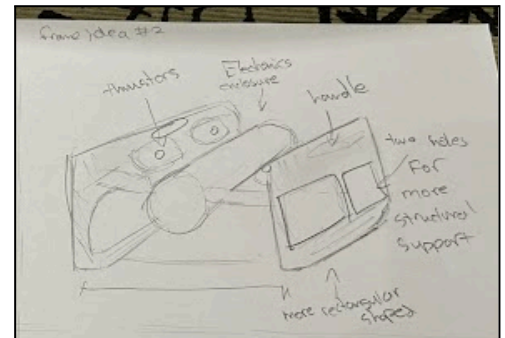


Fig 7: Brainstorming Sketches of ROV
Credits: Imaad Rehman

Task No	Task	1 Axis	2 Axis	3 Axis
1	Basket star recovery	+10	+10	+10
2	Cord by substrate	+10	+15	+15
3	Turn release handle	+5	+10	+15
4	Recover lobster pot	+10	+15	+15
5	Attach line to U-bolt	+5	+10	+15
6	Recover old eDNA sensor	+10	+10	+15
7	Place new sensor upright	+5	+15	+15
8	Connect new sensor	+5	+10	+20
9	Rotate biofouling disk	+5	+10	+20
10	Retrieve power connector	+10	+10	+15
11	Lay cable in waypoint	+5	+10	+10
12	Remove platform port cover	+10	+10	+15
13	Install power connector	+5	+10	+20
TOTAL		+95	+145	+204

Fig 8: Table comparison of points with the different grabber arm options
Credits: Jayaram Dasari



Fig 9: Regional Frame Iterations and Tests
Credits: Sriram Dasari

modularly attach payloads and tools during operations, rendering it highly impractical during competitive trials.

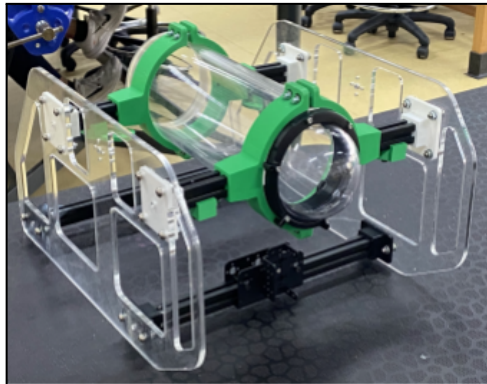


Fig 9.5: Regional ROV Frame Design
Credit: Alikhan Dukenbayev

The Regional Prototype: To resolve the initial modularity issues, the team collaborated with the RISC labs at KAUST. Research pointed toward using either High-Density Polyethylene (HDPE), density of 0.93 g/cm^3 or Acrylic 1.15 g/cm^3 due to their densities being close to that of water 1.00 g/cm^3 . (Fig 9) While HDPE was preferred for its positive buoyancy, local availability constraints in Saudi Arabia and tight budget limits forced the team to select acrylic. The negative buoyancy of the acrylic was easily offset using foam supplements. In this phase, aluminum extrusions were clamped between flat acrylic panels to allow basic tool integration. (Fig 9.5)

The Current Final Framework (Post-Regionals): While the regional frame improved the integration of the components, the flat acrylic panel walls proved to be too bulky and non-hydrodynamic during regional match runs. Following the competition, the team stripped the acrylic panels away entirely. This left a completely open-chassis system made solely of T-slot aluminum extrusions and 3D-printed mounts, which heavily reduced water resistance while maximizing structural accessibility, through mounting the thrusters on the aluminum extrusions on the sides, we proceeded to attach an acrylic base under the electronics enclosure to support the grabber arm and also structurally integrate the ROV and not make it rest on any payload. (Fig 10)

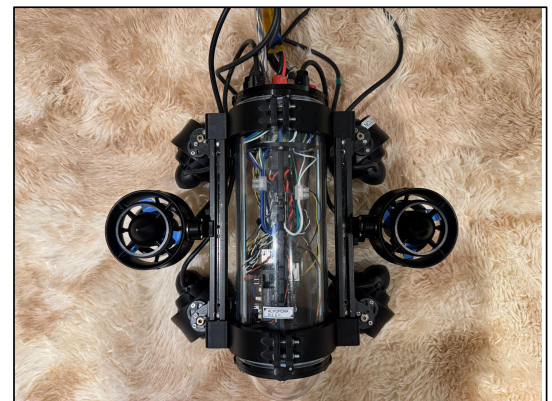


Fig 10: Final Frame
Credit: Jayaram Dasari

Additionally, aluminum extrusions clamped with 3D-printed attachments were chosen to form the entire open frame structure. This ensures that adding tools and payloads can be done easily, as the T-slot aluminum extrusions can be effortlessly repositioned along the rails to add more features, reflecting modular systems that are used in industrial environments. This was also much cheaper than using other systems, such as flat aluminum or HDPE plates, as we could reuse extrusions from 3D printers, demonstrating resourcefulness that R.E.E.F. seeks to uphold and our ability to weigh the key trade-offs in our design choices.

The frame's dimensions were closely monitored to keep it as compact as possible, while putting as much as we could in it, such as a grabber arm, the central electronics enclosure, and a good thrust configuration, so that it could have good maneuverability underwater with it being 35 cm in length (with arm down), 32 cm in width, and 22 cm in height. Additionally, the construction uses ultra-lightweight materials, which avoids the heavy acrylic entirely to rely strictly on PLA filament and aluminum extrusions. This open layout maintains a high strength-to-weight ratio, ensuring that Acropora is well under 15 kg, at a light 6.8 kg, aligning perfectly with the MATE ROV competition mission rules and proposal.

B. Vehicle Systems

I. ROV Electrical Systems

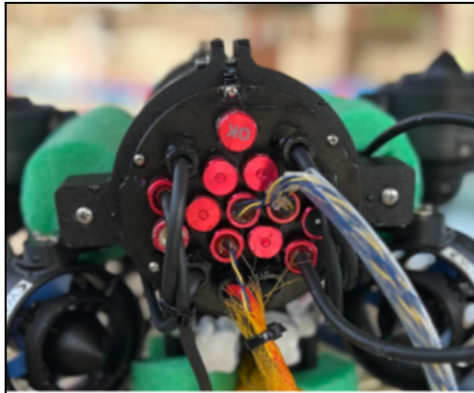


Fig 11: End Cap of Electronics Enclosure
Credits: Jayaram Dasari

The electrical system of Acropora is built around a 12 V DC power architecture and is housed within a clear acrylic waterproof enclosure, secured by dual O-rings and bulkhead penetrators that allow cables to come safely from the wet side to the dry side (Fig 11). To ensure efficient power delivery over the 18-meter tether, originally, a 10 AWG wire was chosen to minimize resistance. However after the regional competition, we noticed that using two 10 AWG wires would be much more amplified for the current(amperes) to be maintained. Using paired wires for both power and ground is equivalent to 7 AWG, which also remains thin enough to fit in the tether. Inside the enclosure, power distribution is handled by a main barrier block for high-power electronic speed controllers(ESCs) and a secondary barrier block for smaller peripheral devices, isolated via a buck converter that steps the voltage down from 12 to 5 V (See Appendix B for SID).

Inside the core of the vehicle's control system lies a Raspberry Pi paired with the Blue Robotics Navigator board (Fig 12). This specific flight controller was selected over cheaper options like Pixhawk or no flight controller at all

due to its ease of connectivity and software modularity, complemented by recently updated ArduSub functionality. The Navigator board also comes with onboard telemetry such as heading, leak, depth, and heat sensors. These sensors help make troubleshooting easier and provide the pilot with data that would be inaccessible during a dive.

The electrical system also includes ROV-to-topside communication, which is managed through a high-speed Ethernet-to-twisted-pair bridge, utilizing a Blue Robotics Fathom X board on the ROV and an OpenROV homeplug on the topside. This allows the ROV to maintain high-bandwidth data over a single twisted pair, reducing the tether diameter. Additionally, this method has been proven to be faster than an Ethernet cable for streaming digital cameras and control interfaces, which is why this connection method was chosen.



Fig 12: Internal Electronics
Credit: Murari Gubba

II. Topside Control System (Software-Based)

The MATEROV competition requires a setup that takes less than 5 minutes, which means the control system on the surface must be efficient and work without hurdles. This is exactly what our topside control system attempts to do. It consists of a pelican and a laptop with a briefcase handle, providing the amazing portability of the ROV control system. Reasoning for the choices is also discussed.

The Pelican case consists of the following components:

- Laptop and Laptop Tray:** This design choice was made as having a single computer that works on everything is much easier than having a monitor, another keyboard, and other computer peripherals. The Laptop tray holds the laptop at an optimal



Fig 13: Controller Configuration on Cockpit

position for the pilot to see the cameras and is similar to the plastic trigger fish control box.

- **Xbox Controller:** An Xbox controller with two joysticks and 12 buttons allows us to control the grabber arm, thrusters, and camera servos, with an optimal layout that makes it easier for the pilot to control the ROV and ROV tools simultaneously. Additionally, the Xbox controller provides greater precision in thruster commands due to its engineering.
 - It should be recognized that R.E.E.F. purposefully chose each button for a specific function to make it easy for the pilot to control the ROV and its tools. For example, our grabber controls are optimized in such a way that it is easy to remember, as it is the left and right triggers, and such that the pilot does not need to lift their fingers off the joysticks.

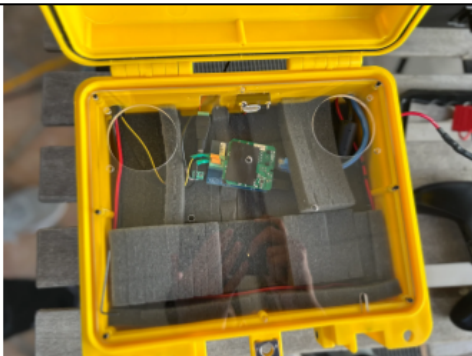


Fig 14: Image of Tether Box
Credit: Murari Gubba

- **ROV Surface Homeplug:** A Fathom X equivalent is seated in the topside box (Fig 14), allowing twisted-pair communication from the ROV to be translated back to Ethernet, improving ROV communication speed. As stated before, without the Fathom X communication system, the camera communication would be too slow, and control would not be fast enough.

- **Safety Components:** Safety components, such as the fuse between the power source and the topside control system, and foam padding on the inside, ensure the components and ROV pilots remain safe without damaging the ROV in case of power problems.

a. ROV Software Control System

To start off, the control system requirements were determined by analyzing the primary mission tasks, which required precise yet speedy maneuvering in all 3 dimensions, fast control of the grabber arm, and a high-quality camera to observe specific points underwater. We documented these requirements through initial logic flowcharts that mapped human input to physical thrust. By connecting to the already onboard "mavlink" system on the Navigator, we were able to isolate the motor drivers and thrusters (see Fig 15) and ensure our software accurately linked the operator Interface to the hardware systems, such as the propulsion subsystem, the manipulator subsystem, and the vision subsystem.

The ROV's control system operates as a continuous software feedback loop written in Python, running on a Raspberry Pi. The software uses the PyGame library to ask the Xbox controller for real-time input data, with almost no latency (See Appendix A for software flowchart). The joysticks output a raw digital value, from -1.0 to 1.0, and when our script captures this data, it applies a mathematical scaling algorithm, specifically for the thruster outputs. The thrusters operate on pulse-width modulation signals from the ESCs, and our code takes the raw

```
ROV_IP = "192.168.2.2"
MAVLINK_PORT = 14551
CAMERA_URL = f"rtsp://{ROV_IP}:8554/video_udp_stream_0"

# --- SETTINGS ---
PWM_RANGE = 400
JOYSTICK_DEADZONE = 0.15
SEND_INTERVAL = 0.1 # 10Hz is standard for MAVLink RC Override

# POWER SCALING
FWD_SURGE_POWER = 0.90
REV_SURGE_POWER = 0.40
GENERAL_POWER = 0.80

# SERVO CONFIG
SERVO_PINS = {'rotate': 12, 'updown': 13, 'claw': 14, 'camera': 16}
LIMITS = {
    'updown': (1950, 2185),
    'rotate': (847, 2177),
    'claw': (1795, 2185),
    'camera': (1100, 1900)
}
```

Fig 15: Snippet of Motor Isolation Code
Credit - Murari Gubba



Fig 16: Photo of GUI in action,
Credit - Murari Gubba

value from the Xbox controller and converts it to PWM percent (0 to 100%). Similarly, our grabber arm servos also operate using PWM signals, and our code tells them exactly how much voltage and movement to apply to a servo on specific GPIO pins of the Raspberry Pi board, allowing singular control of each servo with buttons on the Xbox controller.

Alongside the whole control loop, the software captures video from the onboard camera. This video data is compressed and streamed back up the tether via GStreamer from an RTSP link, and, due to the tether's single twisted-pair design, it provides the pilot with a low-latency, real-time view of the ROV's environment. The primary advantage of this software design is the freedom it gives us over the ROV's controls. Blue Robotics recommends using their services to control the navigator board, but we faced many hurdles when adding our servos and properly controlling the thrusters with the Xbox controller. With this code, telemetry, grabber actuation, and the video feed are handled by the Pi and are easily transmitted over a single connection. However, streaming high-resolution video while processing the control loops requires software optimization to prevent input lag and video stuttering. Python library OpenCV was used to make the dashboard-style window (see Fig 16), with progress bars to show the arm servo movement, the video stream, and the arm/disarm notification.

This part of the ROV had the most iterations during prototyping and testing different snippets of code for each subsystem. We developed standalone scripts for each script and added each one to the next in an iterative process, which allowed us to efficiently identify mistakes without having to struggle through 100's of lines of code. After verifying that each script worked individually, we tried to merge them into the master script. Moreover, our code included many failsafes that completely shut down the ROV from the software side, for example, when the connection drops or the controller disconnects, to ensure that the ROV does not become uncontrollable in water by any means. Additionally, the team always kept a copy of each script for each part, a sort of version control, so that if something goes wrong, R.E.E.F. has something to fall back on.

III. Tether and Tether Management

The tether is arguably the most important part of an ROV system, and R.E.E.F. understands the importance of good tether management during operation. The tether connects the surface box to the ROV. Acropora has a 18-meter tether that is neutrally buoyant and consists of two 10 AWG power wires and 1 twisted pair for data, as stated before (see Fig 17). 10 AWG wire (two for power and two for ground) was chosen because it offers the perfect balance between thickness and amperage rating. For example, a 12 AWG wire would mean that the voltage drop would be significantly higher, meaning the ROV would have to operate at lower power, whilst an 8 AWG wire would have a lower voltage drop but a significantly higher thickness, which would make the tether more expensive and harder to put through the mesh. This was one of the decisions that R.E.E.F. deliberately made.

The power wires are already insulated with rubber, while the R.E.E.F. team decided to add plastic tubing atop the twisted pair to prevent water from contacting the signal wire, even though it is already insulated. A self-tightening protective mesh covers all the wires and prevents entanglement and potential damage. Additionally, a tether relief system is employed at the end and start of the tether, allowing for pulling forces to be transferred away from breaking the tether (See Fig 18). The tether's neutral buoyancy is achieved by attaching pool noodle bits at half-meter increments, and they are attached with string to prevent tangles when the ROV is moving, which was an issue we saw with zip ties the year before. This allows the ROV to swim free without the tether weighing it down.

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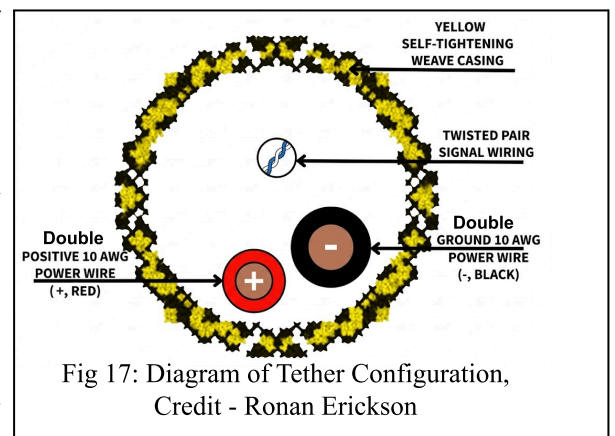


Fig 17: Diagram of Tether Configuration,
Credit - Ronan Erickson

The assigned tetherman must follow a protocol set by the safety officer and the pilot. This protocol consists of communication guides with the pilot, always monitoring how much tether remains on deck and observing the ROV's movements so the tetherman can quickly adjust. Other safety precautions within the tether management include clearing the area where the tether is to be used to ensure no obstructions or damage to the tether, and to limit tripping hazards and entanglements, even on deck.

IV. Propulsion

The ROV uses 6 Blue Robotics T200 thrusters that have an electrical range from 12 to 24V. R.E.E.F. chose these thrusters due to their accessibility, as these thrusters were passed down from an older team. Ordering other thrusters would take longer and would cost significantly more than just using the thrusters we have readily available in the school resources. Additionally, these thrusters were chosen over the previously used bilge pump motors (triggerfish kit) because they deliver almost 2 times the thrust at a lower power rating and lower weight. Moreover, the bilge pump motors were analog, whereas the proposed T200 thrusters are digital, enabling easier integration with flight controllers such as the Raspberry Pi or the Navigator Board.

Additionally, the team was able to upgrade from 4 thrusters to 6 thrusters this year, allowing for the whole 6 degrees of freedom (Surge, Sway, Heave, Roll, Pitch, Yaw), creating the maneuverability that the mission tasks require this year. The thrusters are shrouded with a ring

shroud that goes atop the thruster vents and follows the competition rules of no fingers fitting in it (see Fig 19). The ROV employs one of the most famous 6 thruster configurations, the vectored format (see Fig 20), such that two front and two rear thrusters are mounted at 45 degree angles, which allows for maximum water flow through the frame, and two vertical mounted thrusters in the center of the ROV, for degrees such as lift and tilt. This configuration provides a good balance of maneuverability and speed while maximizing the efficiency of the voltage from the MATEROV power source and the amperage delivered to the ROV via the tether.

One major downside of using T200 thrusters is the high power consumption they require. For example, with the current tether and the MATEROV power supply, the thrusters cannot operate at 100 percent efficiency; otherwise, the whole system shuts down and blows the fuse. However, even at 20% power, the thrusters are already much faster than the ROV's from the past year and make it extremely maneuverable. Additionally, the navigator software and our Python code allow for specific control over the percentage of power allocated to the thrusters and the max amp request of the ROV, enabling smooth

operations without random ROV shut-downs.

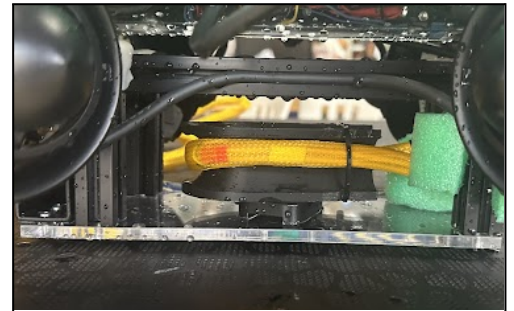


Fig 18: Tether Strain Relief
Credit - Ryoji Kobayashi

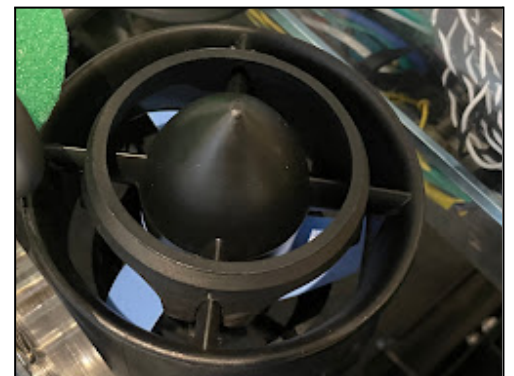


Fig 19: T200 Thruster Shroud
Credit - Ammar Alfelfel

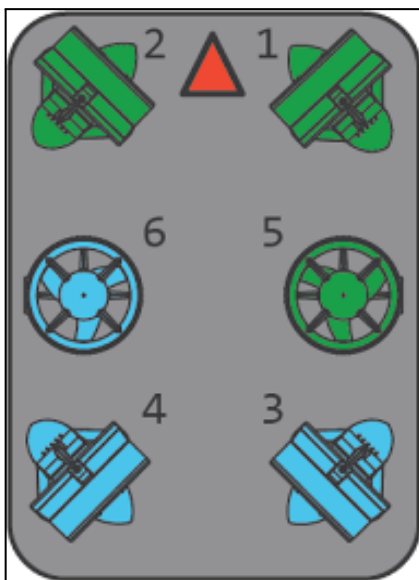


Fig 20: Motor placement
Credit - Ahmed Alramadhan

V. Buoyancy

The R.E.E.F. The team conducted research into buoyancy strategies used in professional ocean ROVs and found that they are typically designed to be slightly positively buoyant. This approach ensures that when the ROV carries or manipulates objects, which can increase its weight and make it negatively buoyant, it remains balanced during operation. Additionally, in the event of a system failure, slight positive buoyancy allows the ROV to slowly rise to the surface instead of remaining submerged, reducing the need to manually retrieve it using the tether.

$$1. F_b = \rho g V \Rightarrow$$

$$2. V = 0.38 * 0.114 * 0.114 = 0.00494 m^3 \Rightarrow 3. F^+ = 1000 * 9.81 * 0.00494 = 48.45 N \Rightarrow$$

$$4. F^- = 2.25 * 9.81 = 22.07 N \Rightarrow$$

$$5. F^T = F^+ - F^- = 48.45 - 22.07 = 26.37 N$$

Calculations show us that our 380mm * 114mm watertight enclosure had a mass of 2.25kg, which, when put into the buoyant force formula, shows us that the ROV has an upward force of 48.45 N, a downward force of 22.07 N, totaling to a net buoyancy of positive 26.37 N. This means that we can add approximately 3 kg of tools and frame weight to make it perfectly neutrally buoyant, which balances the positive buoyancy. Furthermore, pool noodle foam was added to the edges of the ROV to balance how the ROV sits in the pool (see Fig 21). For example, the back of the ROV was heavier than the front, hence it was tipping over. To combat this, we added more noodle foam to the base at the back to balance the back-heavy ROV. This is how applying buoyancy principles can help the ROV be better for the mission tasks, as a stable ROV allows for good maneuverability.

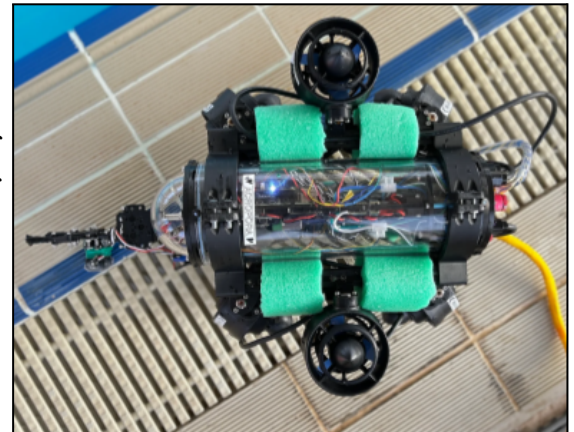


Fig 21: Pool noodles on Frame
Credit - Shashwat Saxena

C. Vehicle Payload

The payload of an ROV enables it to carry out mission-specific tasks while improving the pilot's control and operational efficiency. These payloads can also be used to transmit additional data or support specialized functions depending on the mission requirements. Each choice for the ROV payload was planned and made deliberately to ensure efficiency and simplicity when operating the ROV.

I. Camera

The vision sub-system on the ROV is the most important payload, as without a view of the pool, the pilot would not know the position of the ROV. The team carefully considered the rationale of the camera to ensure that we meet mission requirements. We equipped the ROV with a singular USB camera rather than having multiple cameras. Even though multiple cameras would provide better peripheral awareness, streaming several live video feeds at the same time demands a lot of bandwidth and would overheat the Raspberry Pi, which can induce severe control latency. Additionally, using analog cameras would introduce another complexity, which is the need for an analog-to-digital translator, and would also make the tether significantly thicker, which is one of the things R.E.E.F. wanted to avoid when building the ROV. By choosing a single, plug-and-play USB camera, we effectively



Fig 22: Camera
Credit - Fahad Alofesan

balanced the trade-off between spatial awareness and system performance (see Fig 22). This decision ensured that the pilot receives a smooth, low-latency video feed that seamlessly integrates into our OpenCV GUI. Additionally, the camera has a quality of 720p at 30 fps, which is fast and clean enough to operate the ROV at pool speeds and even in harsher environments.

To mitigate the limited field of view that is obvious in a single camera setup, the team strategically decided to mount the camera on a micro servo positioned centrally in front of the water-tight enclosure, above the grabber arm. This placement allows the pilot to look straight ahead for transits across the pool and then physically tilt the camera down when approaching a target, to easily see the manipulator. Additionally, the pilot can also tilt up to see other details for the specific mission tasks, such as the iceberg observation or the coral transect. This allows the placement to meet our mission requirements, which guarantees precision with the grabber arm and improves operational efficiency and overall maneuverability.

II. 3-Axis Manipulator

R.E.E.F. prides itself and its engineers on developing an arm that goes beyond basic functionality and provides versatility and reliability during operation. To meet the complex requirements of this year's mission tasks, the team designed a custom 3-axis manipulator arm(see Fig 23). Rather than relying on a single claw design, our manipulator uses three independent servo motors to control vertical pitch,

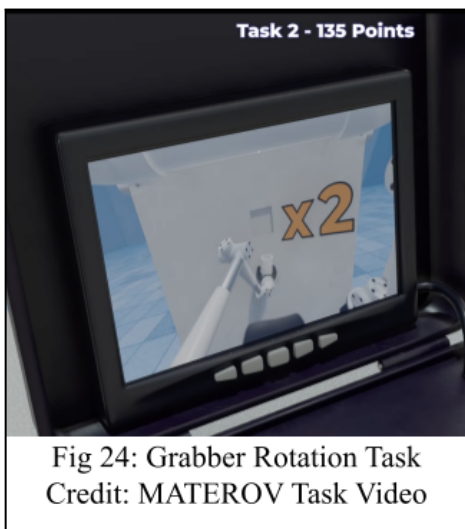


Fig 24: Grabber Rotation Task
Credit: MATEROV Task Video

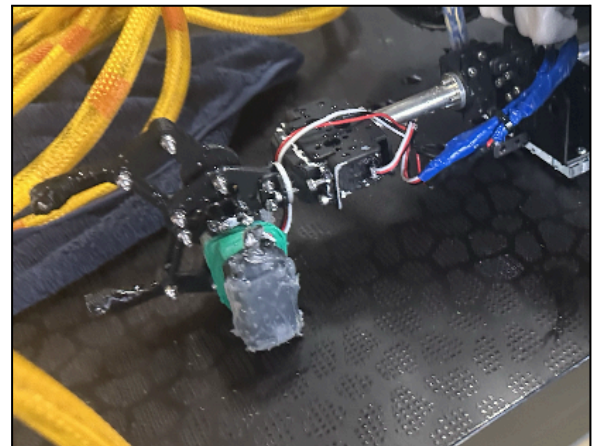


Fig 23: Grabber Arm
Credit - Jayaram Dasari

wrist rotation, and primary claw actuation. This design allows the ROV to grasp, lift, and manipulate underwater props in multiple orientations without requiring the pilot to constantly reposition the entire vehicle.

For example, we see that there is a mission task that requires rotation of a disk on a flat plane, and the rotation in the grabber arm can hold and do the task independently of the ROV tilt (see Fig 24 for the task), allowing for more efficient task completion. Additionally, some tasks involve bringing small objects to the surface, and the pitch function can really help when it comes to lifting up parts to give to the people on deck. Thus, it is seen that the decision to implement a 3-axis system was directly driven by mission requirements. Before building, the manipulator was carefully planned in Fusion 360 (see Fig. 25), and thorough research was conducted on whether servos can actually be made waterproof, and only then did we move on to buying anything. The servos are filled with mineral oil and coated in waterproof epoxy around the seams, then double-coated in a leak seal that forms a rubber/plastic surface on the servos, ensuring that they are sealed. Additionally, there is an O-ring on the servo hat and a layer of silicone grease, completing the waterproofing process. Repeated testing showed that the servos worked perfectly underwater, if we correctly maintained them, i.e., applying silicone grease regularly and washing the chlorine off.

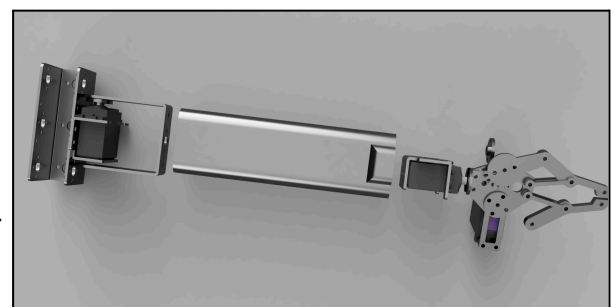


Fig 25: Grabber Arm CAD Model
Credit - Jayaram Dasari

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To ensure the manipulator was highly capable and cost-effective, the team selected standard high-torque water-resistant servos, as these servos already come with features to stop water ingress. These servos use 5V and are directly connected to the Raspberry Pi inside the enclosure, which allows our software to easily control everything with one computer. To optimize pilot ergonomics, the claw's open/close is mapped to the triggers on the Xbox controller, while the rotation and pitch are mapped to the D-pad. This system-based approach ensures that the pilot can maneuver the ROV and operate each of the 3 axes while keeping their visual focus on the live camera feed.

III. Vertical Profiling Float

The REEFLOAT was designed to perform a very specific task following this order: initially communicate with the mission station on the surface before descending, then complete two vertical profiles using a buoyancy engine where it must hold a depth of 2.5 m for 30 seconds, rise to the surface where it holds 40 cm for 30 seconds while not breaking the surface, and transmit all stored data after being recovered autonomously.

To achieve this, the company broke down the primary components needed into 3 parts: the buoyancy engine, an onboard computer, and a depth sensor, which can transmit this data to the mission station. The buoyancy engine was created by using a 100 cc syringe operated by an EV3 Lego servo motor and Lego gears. This was done because of the versatility of Lego. Lego gears also saved a lot of time as they are easily interchangeable, and they facilitated the 24:1 speed-to-power ratio the buoyancy gear system uses. For the on-board computer system, a Raspberry Pi 0 WH is being used because of its high performance to low power draw ratio, along with its integrated WIFI module, creating ease when transmitting data to the mission

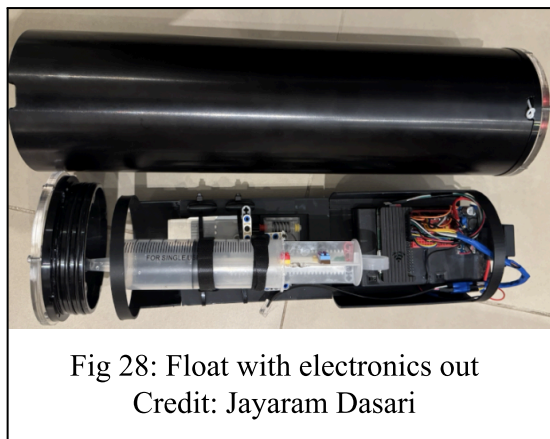


Fig 28: Float with electronics out
Credit: Jayaram Dasari

station. A buck converter was implemented to regulate the power for the Raspberry Pi. To control the Lego EV3 motor with the Raspberry Pi, a TB6612 FNG motor driver was used. All

of these electronics can be seen in Fig 26. Finally, the depth sensor the Float uses is from Blue Robotics, ensuring that it is accurate and reliable. Once all the parts were decided, the team calculated voltage requirements to find the ideal power supply: 8 NiMh AA batteries, which needed to be paired with a 2 A fuse for safety purposes.

After constructing the floats' electronics and buoyancy mechanism using the parts stated above, the team CAD modeled a housing for these components in Fusion 360 (Fig 27). This housing was 3D printed, as seen on the bottom of Fig 28 (the base of the electronics and syringe), it essentially organizes and holds all these parts. But most importantly, it allows the parts to easily slide out of the outer, black, aluminum enclosure. This is crucial since it makes access to the components extremely easy.

All of these components came together cohesively, creating a functional float that meets the mission requirements.

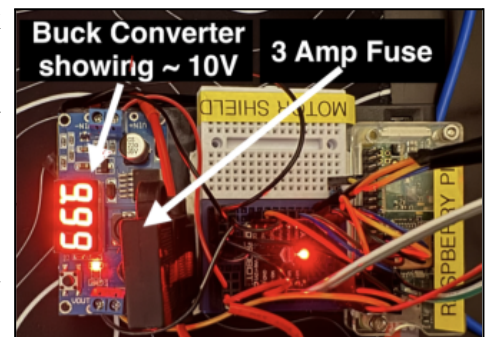


Fig 26: Float's Electronics
Credit: Jayaram Dasari

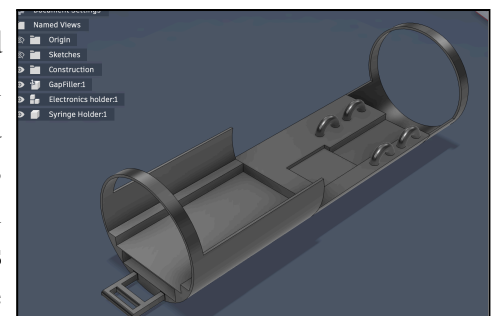


Fig 27: CAD model of floats base
Credit: Murari Gubba

D. Build vs. Buy, New vs. Used

R.E.E.F. prioritized a highly sustainable and cost-conscious approach to Acropora's design. By evaluating exactly what we needed and setting our priorities straight, we were able to decide which components to buy, which to repurpose, and which to build ourselves, helping the team maximize their budget while minimizing our costs as much as possible. The team heavily leaned on reusing proven components from previous years, such as the acrylic for the base, aluminum extrusions for the frame, and the doubled 10 AWG tether power wires. The team even reused old LEGO motors and LEGO parts for the construction of the vertical profiler, to try to minimize buying, and instead design and innovate. Such reused parts often were chosen only because they fit mission requirements, such as being able to pull a syringe cap to use the buoyancy engine, or being able to transmit power correctly and efficiently.

However, to meet this year's demanding mission tasks, the team deliberately chose to purchase several critical upgrades rather than attempting to reuse/build them, simply because our resources lacked this equipment. We purchased the acrylic enclosure for the electronics, and the main computers, such as Blue Robotics Navigator Board, Raspberry Pi 4, Fathom X, and thruster control boards. School resources did not have these things, and so we had to make the decision to buy them, as these improvements drastically changed how efficiently the ROV works.

Where commercial options were too expensive or not specialized enough, we wanted to manufacture components in-house. For example, rather than buying a generic commercial gripper, we designed an aluminum grabber arm that is 3-axis from reused servos, to meet the specific mission requirements. Ultimately, whether reused, built, or purchased, every component on Acropora was selected to balance cost, operational efficiency, and in-house innovation. Table 1 shows the parts that were reused, built, or purchased.

Inherited/Reused (Main Parts)	Built Inhouse	Purchased
- Grabber Arm Servos - Metal Alloy Servo Brackets 6 T200 Thrusters - Lego Motors and Gears(Float) - OpenROV homeplug adapter	- Tether Wire - Tether Reliefs - Enclosure Clamps - Frame (from reused aluminum extrusions)	- Fathom X Interface 6 ESCS - Navigator + Raspberry Pi 4 14-5 Stepdown Buck - Power Barriers - Acrylic Enclosure/Tube

Table 1: Inherited vs. Built vs. Purchased Equipment for ROV Build

5. SAFETY

A. Safety Rationale and Checklists

Any company or team that handles lab equipment and fabrication machinery must view safety as the cornerstone of its philosophy. As such, R.E.E.F. views safety as one of the main pillars of the engineering cycle, ensuring that protocols created by the safety office cover employees, equipment, and operational safety.

- Employee Safety:** Protecting our engineers is our topmost priority.

When building, all team members working are required to wear

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The KAUST School, 303858, King Abdullah University of Science and Technology, King Abdullah University Of Science And Techno
MATE ROV – Ranger Class



Fig 29: Safety Protection

Credit: Freepik

proper PPE, such as safety glasses, aprons, or lab coats, when cutting aluminum extrusions or operating machinery (Fig 30). Additionally, due to the lack of fume extractors in the lab, engineers are required to wear N95 face masks when using the soldering iron and are advised to keep their noses away from the fumes. Our construction checklist strictly mandates verifying PPE (Fig 29) and workspace ventilation before any work begins. The checklist also includes situations where an aerosol is being used, in which case, it must be done in proper ventilation, most likely outside. Lab requirements state that closed-toed shoes, long hair tied up, and no loose clothing are mandatory in a lab setting.

- **Equipment Safety:** To protect the ROV's electrical subsystems and mechanical integrity from failure,



Fig 30: Servo Waterproofing Process with appropriate PPE
Credit: Ronan Erickson

certain safety standards must be met before working with the ROV. The ROV must lie atop a thermocol sheet to provide some padding and prevent it from scratching the table or itself. Moreover, when working with the ROV, all exposed metal must be easily visible or covered with insulation material, specifically when using power sources and alligator clips. Our construction checklist also states that the power source must be plugged into a GFCI before plugging it into a socket, so that current leaks and backflow can be detected and stopped immediately. Of course, there are more, but these are the key

protocols to maintain equipment safety.

- **Operational Safety:** Poolside operations are often the riskiest because water is so close to electrical equipment. Our operational checklist created by the safety officer mandates that the water and the power source must be at least 3 metres away from each other, and that the GFCI is attached to the power source, to mitigate any short circuiting (Fig. 31). Additionally, when people are working on the ROV next to the pool side, the ROV must be disarmed (thruster disengage) and at least 1 metre away from the poolside, so that no employees risk falling in. The pilot can only arm again once the "Clear!" signal comes from our tetherman, ensuring that the operation process is smooth but safe.

Safety Checklist

Precaution

- All Employees are wearing Personal Protection Equipment
- Shoes with proper grip for non-poolside operators and closed-toed proper grip for poolside operations.
 - Ensure all team members have no loose clothing or hair that can get in the way of the ROV.

Emergency Procedures:

- Ensure that first aid kits are present and an evacuation route is identified in case of an emergency.
- A lifeguard must be nearby to assist with emergency procedures.

ROV Emergency Procedures:

- When ROV is being picked up, everyone, especially the pilot, must ensure that all electricity is turned off during contact.
- If the ROV is stuck in the water, it must be pulled using the tether.

Fig 31: Excerpt of Safety Checklist

Credit: Ahmed Bakr

B. Vehicle Specific Safety Features

The ROV itself contains many specific safety features, both in Hardware and Software sectors. R.E.E.F. prides itself on creating a smooth experience for the pilot, but also a safe one, just in case anything goes wrong. A summary of all the safety features can be found in Table 2

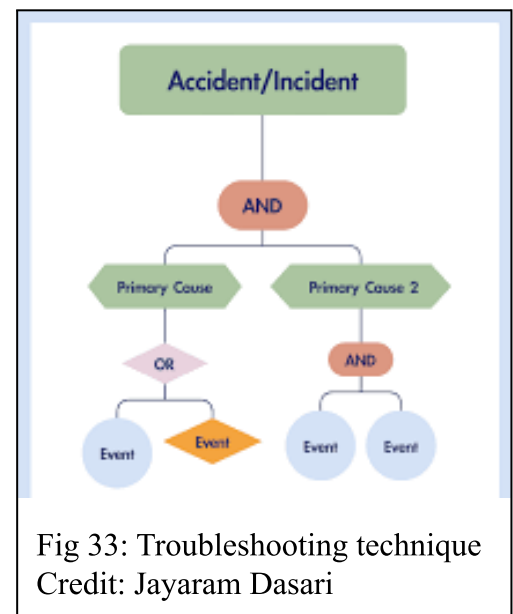
Safety Features	Description
Power Supply Fuse	20A fuse within 30 cm of the positive side of the power supply.
Watertight	All critical electronics are housed within a completely watertight enclosure sealed with

Enclosure	O-rings.
Thruster Shrouds	Every thruster on the vehicle is fitted with a physical shroud, which does not let fingers in.
Caution Labeling	High visibility caution labels are applied directly to the ROV's chassis and thrusters,, to warn observers and crew and to indicate safe lifting points to prevent physical injury.
Tether Strain Reliefs	Robust mechanical strain reliefs are secured at the end and the start of the tether, which physically transfers pulling forces away from the internal wire.
Rounded Edges	The custom 3D printed components, the aluminum extrusions, and the acrylic feature intentionally filled, rounded, or capped edges. Reduce the risk of damage to people or sea life.
Software Failsafes	The Python script acts as an active safety net and features a strict arming protocol, where thrusters do not spin unless the pilot activates the arm command. Additionally, the code can sense whether the controller/ROV is connected, and if not, shuts off the electrical system to protect the ROV (Fig. 32).  ROV SAFETY FEATURES INLINE FUSE PROTECTION TETHER FAIRING & STRAIN RELIEF THRUSTER ASSEMBLY WITH FENDER Fig 32: Safety features Credit: Murari Gubba
Table 2: Safety Features of ROV	

6. TESTING AND TROUBLESHOOTING

A. Troubleshooting

To efficiently troubleshoot issues during both the build and operational phases, R.E.E.F. engineers use a famous diagnostic strategy called the "Fault Tree Analysis" (Fig. 33). This strategy was adopted by the lead engineers when a professional from one of the labs in King Abdullah University of Science and Technology recommended it. Rather than guessing the source of an issue, the team can logically find the root cause by using this branching tree structure. If a sub-system fails, (e.g. a thruster does not spin), the tree guides the team through a checklist: first verifying software outputs (checking the GUI for PWM values), then testing the communication layer (checking tether continuity), verifying power distribution (checking voltage drops across motors), and finally inspecting mechanical hardware (checking for jammed propellers). This



top-down diagnostic strategy dramatically reduces downtime and prevents unnecessary spending when it comes to replacement.

R.E.E.F. also believes that troubleshooting must be approached with a clear mind, so that every possibility is considered without room for crucial mistakes. This can be done by increasing communication and collaboration among company engineers to help identify issues and help resolve them too.

B. Testing Methodology

R.E.E.F. uses a strict, phased testing method to make sure that subsystems are reliable before they are fully integrated. We conduct the initial tests on a dry workbench to separate software and electrical variables. After each part has been checked, subsystems undergo specific wet tests, such as isolated-bucket testing. Finally, the fully assembled Acropora undergoes full-system pool tests. This progressive method enables the team to collect quantitative performance data, ensuring the vehicle can consistently meet mission requirements. The following sections explain the testing procedures used to ensure the ROV's functionality.

I. Frame and Propulsion Testing

Because maneuverability depends on how the thrusters interact with the physical structure, our team tested the frame and propulsion system together. We started by operating motors on dry land to verify electrical and software integration, and by checking the direction of airflow, we could accurately test that the Xbox controls were translating correctly. Once cleared, we mounted the thrusters to our newly designed world championship frame for the first in-water trials (see Fig. 34). This test immediately demonstrated improved water maneuverability compared to the regional frame design, with more controlled movement and the advantages of an open thruster configuration.

With a stable frame established. We conducted a series of pool trials to assess propulsion. R.E.E.F. did a linear transect velocity test, where the ROV moved forward for 5 meters, and that velocity was calculated by timing the transect, which allowed us to see if the thruster configuration was efficient or not. We ran three trials of this to ensure we had reliable data and to allow engineers to estimate underwater distances without relying on external measurement tools.

II. Manipulator Testing

Using 3 servos that are not inherently waterproofed is a fairly new concept, so, of course, without testing, we would never be able to ensure whether it actually worked (see Fig. 35 for the servo). Our team began testing the manipulator with a series of dry runs to evaluate the actuator's range of motion and to verify correct electrical integration with our main controller system. We attached an early prototype of a claw to test the opening and closing mechanism and its responsiveness. Once the basic functionality was confirmed, we mounted the manipulator assembly to the front of our newly designed frame. Before moving to the water, we conducted dry-land sweeps, moving the arm through its full range of motion to ensure it did not obstruct the camera view or accidentally hit the ROV structure.

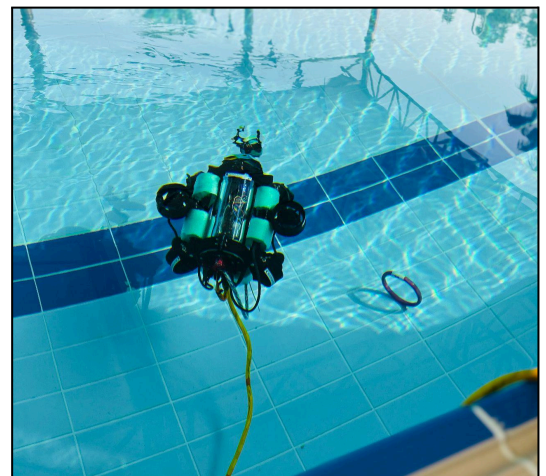


Fig 34: First Water Test
Credit: Murari Gubba

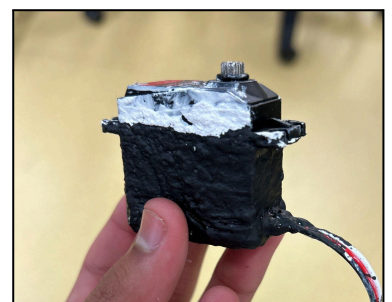


Fig 35: Waterproof servo
Credit: Imaad Rehman

Before even thinking about going into the pool, we conducted a rigorous endurance test. For five consecutive days, we operated the manipulator servos continuously underwater in a small bucket for 30 minutes each day. During these daily sessions, the servos were repositioned in various positions. Our test showed no signs of leakage or breakage within the servos, verifying that the arm's actuators would not drown but would instead work perfectly under continuous workload, and proving that we could use it for prolonged repetitive motion.

After this, when R.E.E.F. started testing in the pool, we noticed that while the pilot could successfully navigate the ROV and arm it into the correct position, the hard plastic of the prototype gripper jaws caused smooth objects to slip easily. To resolve this, we iterated on the claw design and considered adding various claw grips. We ended up with a rubber grip on each side of the claw, providing higher friction to consistently hold the object. This showed our team that rigorous testing enables future changes that can make the ROV better at performing its missions.

III. Vertical Profiler Testing



Fig 36: Vacuum test
Credit: Jayaram Dasari

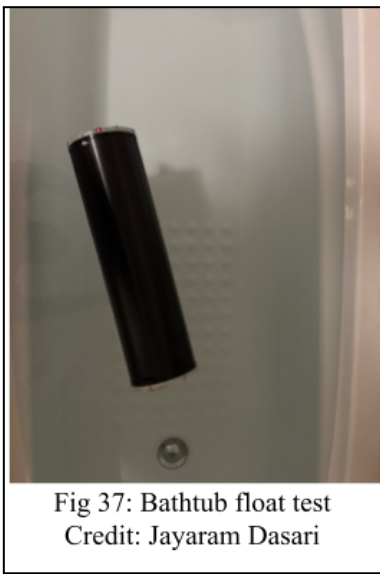


Fig 37: Bathtub float test
Credit: Jayaram Dasari

To test the float, the company used a specific methodology before dropping it into the pool. The first step was to check the electronics by turning them on and establishing a stable connection with a computer. Then, the buoyancy engine would be tested through this connection. A team member would manually move the buoyancy engine using their computer via the Raspberry Pi. This tests the limits of the buoyancy engine, ensuring that the LEGO EV3 servo motor does not exceed the maximum or minimum of the syringe. Once the electronics and buoyancy engine are working properly, the float will be closed and the end caps sealed. This is when the float is put through a vacuum test using the "OK" valve on the endcap (Fig 36). A pressure gun is used to pull a vacuum of 50 inHg, and then the float is

left for 30 min. If, after 30 min, the pressure decreases less than 5 inHg, the float will proceed to the bathtub test (Fig 37). Here, the float is instructed to run a program that operates the buoyancy engine, so it sinks to the bottom of the bathtub, rises to the top, and repeats this five times. If this is successful, the team can be assured that the buoyancy engine is working as planned, the depth sensor is responding, the Raspberry Pi is communicating with the computer, and the float is completely waterproof. As a result, the team is now reassured that the float can safely be placed in the pool for full run-times. Following this methodology also helps pinpoint any issues if they arise, making it significantly easier to overcome them. For example, there was a time when the float sank to the bottom of the bathtub even though it passed the buoyancy engine and electronics tests on land. This made me confident that the issue was in the code, and so without having to open the float again, I just re-uploaded new code, fixing the issue.

7. BUDGET AND COST ACCOUNTING

R.E.E.F. established a strict financial plan early in the season to ensure Acropora could be built efficiently and sponsors could be acquired, all without exceeding our available funds. To continuously track our spending and

evaluate our budget, the team used a shared, real-time financial tracking spreadsheet. This document had every component, its specifications, vendor, cost in USD, and current status.

Because our team operated with a limited out-of-pocket budget, our primary strategy was to maximize the resources available in our school lab. As reflected in our tracking sheet, we borrowed/reused legacy components, such as the OpenROV homeplug adapter (almost 6 years old) and the water resistant servos (2 years old), rather than buying new ones. When purchases were absolutely necessary, team members carefully sourced them from cost-effective vendors such as AliExpress, with a combination of team funding and sponsorships.

A major element of the budget included securing sponsorships, as stated before, to cover high-cost items. For example, the bluerobotics components bought, such as ESCS, Navigator Pi Hat, Barrier Blocks, and Acrylic Enclosure, all cost upwards of 4,234.9 USD. Our sponsors generously provided a budget for these expensive parts through the school management system, thereby reducing our budget. Additionally, we planned a travel budget for the worldwide competition, showcased below.

A. Cost Accounting

Our accounting framework makes a clear distinction between three types of procurement and one estimate for travel expenses to the world championships, reflecting our effective use of funds and accounting processes (see Tables 3 & 4):

- Purchased: Items bought directly using team-raised funds or team contributions.
- Reused: Items sourced from our school lab's inventory. We have recorded the fair market value to accurately show the true cost.
- Donated: High-value components donated by an outside organization or the school.
- **International Travel Expenses:**
 - **Flight Travel (JED to YYT): 12000 USD for 10 people**
 - **Canadian Visitor Visa: 2000 USD for 10 people**

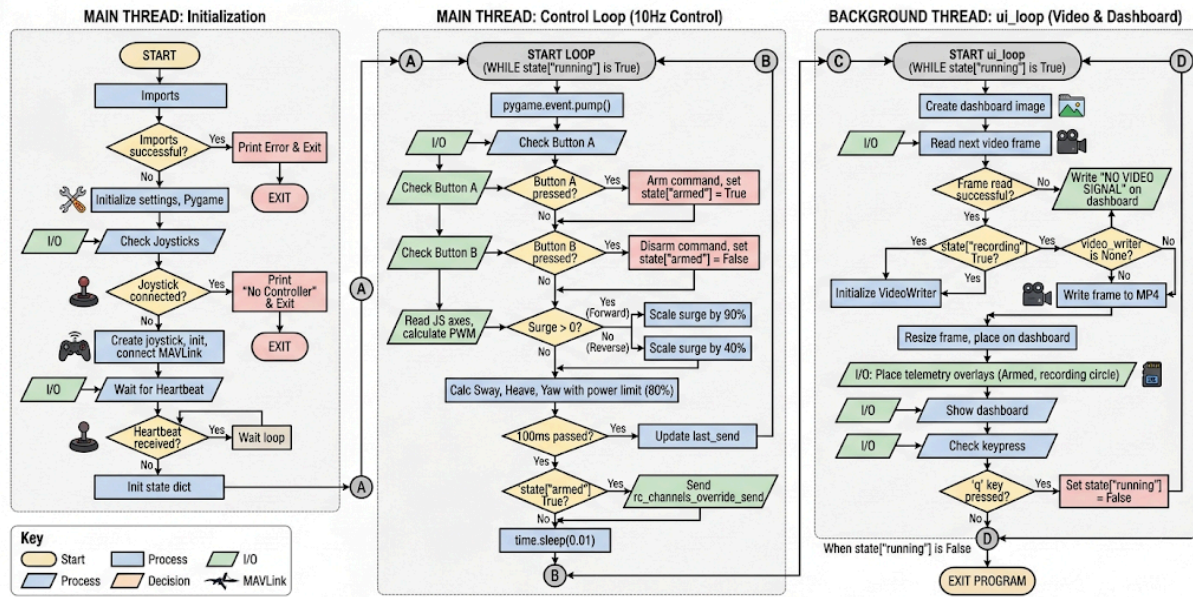
Category	Description	Quantity	Fund Type	Market Value (USD)
Hardware	4" Series Tube	1	Purchased	180
Hardware	4" Series O-Ring Flanges	1	Purchased	50.0
	4" Series Dome End Cap	1	Purchased	42.0
Hardware	4" Series Aluminum 18-Hole End Cap	1	Purchased	69.8
Hardware	4" Series Electronics Tray	1	Purchased	127.0
Hardware	Camera Tilt System (with Mount for USB Camera)	1	Purchased	66.0
Hardware	Penetrators (Includes both Blank Penetrators and M10 7.5 HC version)	18	Donated	306.0
Hardware	Water Resistance 25kg Servo	3	Reused	240.0

Hardware	Aluminum Arm Extensions and Brackets	8	Purchased	500.0
Hardware	Aluminum Extrusions(for frame)	8	Reused	42.4
Hardware	Acrylic Sheet (1.5 cm thick)	1	Reused	22.1
Hardware	Sheath, 18 M Tether	1	Donated	415.2
Electronics	Raspberry Pi 4B	1	Purchased	154.1
Electronics	Navigator Flight Control	1	Purchased	220.0
Electronics	Low Light USB CAMERA	1	Purchased	120.0
Electronics	Fathom X Interface Board	1	Purchased	140.0
Electronics	OpenROV Home Plug	1	Reused	120.0
Electronics	Basic ESC	6	Reused	240.0
Electronics	10 AWG Wire(150m)	1	Purchased	133.4
Electronics	Dell Computer	1	Donated	400.0
Electronics	Xbox Controller	1	Donated	77.0
Consumables	O rings	10	Donated	50.0
Consumables	Leak Spray	1	Purchased	6.5
Consumables	Silicone Grease	1	Purchased	10.7
Merchandise	Team Hoodies	13	Purchased	502.7
Total:				4,234.9
Table 3: ROV Accounting, Use of Budget and Type of Funding				

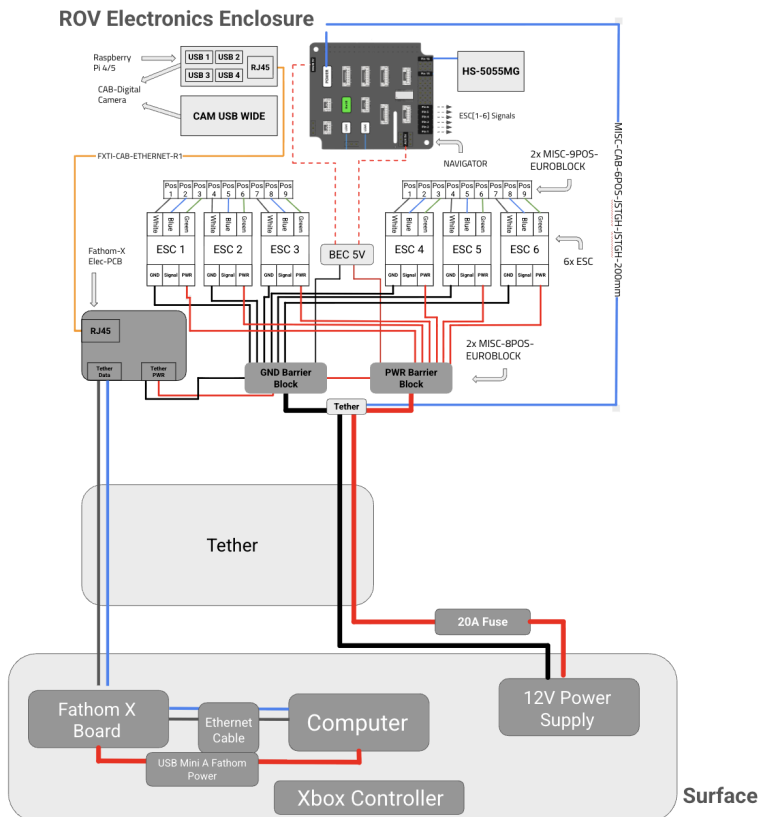
Fund Type	Money (USD)
Donated	1,248.2
Reused	664.5
Purchased	2,322.2
Total	4,234.9
Table 4: Fund Division between categories : Donated, Reused, Purchased	

APPENDICES

Acropora ROV Control Software: System Logic Flowchart



Appendix A: Software Flowchart



Appendix B: ROV SID

ACKNOWLEDGEMENTS

The R.E.E.F. The team expresses its sincere gratitude for the opportunity to participate in the MATE ROV competition. This experience has provided significant growth for our team, and we are grateful to everyone who contributed to making this project a reality.

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We would like to specifically thank Mr. Clements and Ms. Tellez for their unwavering support over the past two years, as their commitment has been fundamental to the team's long-term progress. We also thank Mr. Roulet for his vital contributions and support since joining the project this year.

Finally, the team extends a special thank you to Ms. Tellez as she completes her final year with us. Her leadership and dedication have been instrumental in making this project possible, and her contributions have left a lasting impact on the R.E.E.F. team.

Thank you to everyone who supported our journey and assisted in the development of this ROV.

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