Mana Robotics

Technical Documentation

Ka Ulua — Flagship ROV

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Conor Cavens (11th) — Founder, Chief Executive Officer, Lead Designer

Gavin Rhodes (11th) — Chief Operating Officer, Prototype Designer

Rosalisha Barrett (11th) — Chief Financial Officer, Frame Engineer

Fred Collins (12th) — Network Systems Manager, Lead Tether Engineer

Finlay Mulcahy (10th) — Electrical Engineer

Robert Macintosh (10th) — Manipulator Engineer

Carson Hoover (10th) — Buoyancy Technician

Dylan Vincent (11th) — Buoyancy Technician

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1. Abstract

Mana Robotics is a student-led robotics team from Hawaii Preparatory Academy competing in the 2025 MATE ROV Competition. Our ROV, named Ulua, was designed and built to complete complex underwater mission tasks with efficiency and precision. Ulua reflects months of design iteration, teamwork, and testing. Inspired by real-world marine engineering challenges, our goal is to develop a diverse, agile, and modular ROV that can address tasks including but not limited to search and rescue, object retrieval, and environmental sampling.

We aimed to create a modular, cost-effective, and safe robot. Ulua is built using Blue Robotics components and student-designed 3D-printed parts, with an integrated Pixhawk controller and real-time camera system. This report documents the design process, testing challenges, and collaborative effort behind the creation of Ulua.

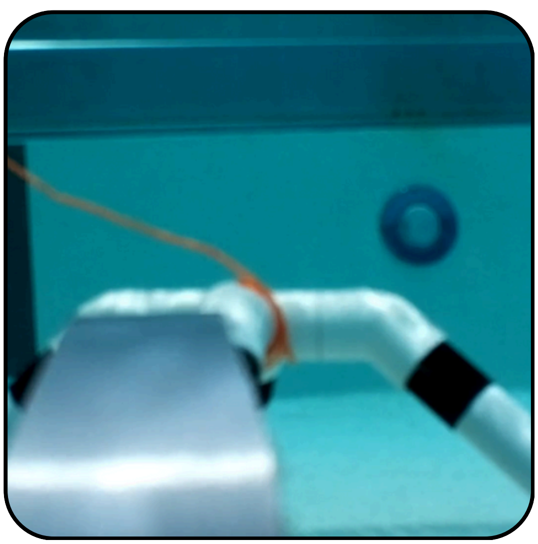

Figure 1. Onboard Video from Ulua

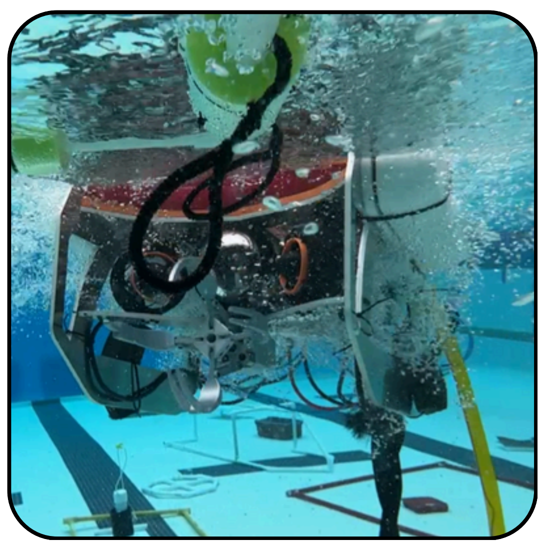

Figure 2. Ulua During a Recent Training Run

2. Project Management

2.1 Company Overview

Mana Robotics is a robotics group focused on designing and constructing underwater ROVs for competition and research. Based at Hawaii Preparatory Academy, our team consists of eight specialized engineers, each contributing to different aspects of the project while collaborating across specialties to ensure overall success.

Figure 3. Engineers Working on Prototype Enclosure Design. From Left to Right, Gavin R. (11th), Fred C. (12th), Carson H. (10th)

2.2 Team Composition and Roles

Our team consists of eight students, each with clearly defined roles and cross-functional responsibilities. Conor Cavens (11th) is the Founder, CEO, and Lead Designer, overseeing the project from concept to completion. Gavin Rhodes (11th), COO and Prototype Designer, manages daily operations and contributes to mechanical planning. Rosalisha Barrett (11th), CFO and Frame Engineer, handles budgeting and resource management while working on the structural design. Fred Collins (12th) manages communication systems and tether development as Network Systems Manager and Lead Tether Engineer. Finlay Mulcahy (10th) focuses on circuit design and power integration as the Electrical Engineer. Robert Macintosh (10th) designs and refines the robot's manipulator arm. Carson Hoover (10th) and Dylan Vincent (11th) ensure underwater stability as Buoyancy Technicians. All members assist with documentation and testing, and leadership is collaboratively managed by the CEO, COO, and CFO to ensure cohesive progress.

2.3 Development Schedule

Our team follows a consistent and structured workflow. We conduct weekly progress checks and meet for approximately 70 minutes every other weekday, totaling two or three sessions per week. When necessary, additional weekend work sessions are scheduled to meet key deadlines or resolve major design challenges. To manage task distribution, communication, and accountability, we use a shared Slack workspace as our central hub for coordination. Within Slack, we assign tasks, share updates, and organize work sessions.

This system enables us to track dependencies, monitor timelines, and communicate effectively throughout the development cycle. As the project evolves, this structured yet adaptable workflow allows us to adjust plans in real time.

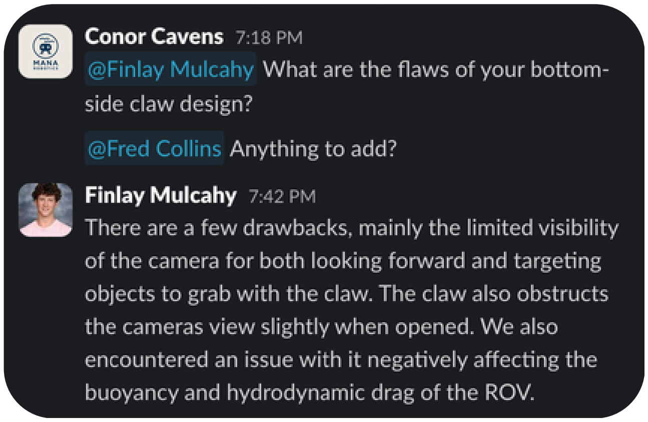

Figure 4. Mana Robotics Slack Workspace Discussion

2.4 Work Philosophy

Our development cycle emphasizes both collaboration and independence, grounded in our mission to design and build underwater ROVs that support the preservation and understanding of Hawai‘i’s marine ecosystems through innovation, sustainable design principles, and teamwork. While members are responsible for leading their specific subsystems, they are also expected to engage in interdisciplinary problem-solving and contribute actively to broader team discussions. This structure not only fosters a shared sense of accountability and ownership but also reinforces our commitment to sustainability and the protection of the ocean environment we call home. Through this integrated and mission-driven approach, each member gains a deeper understanding of the project as a whole and the real-world impact of our work.

3. Design Rationale

3.1 Structural Frame and Buoyancy

Ulua's frame was designed with stability and hydrodynamics in mind. The structure is composed of laser cut aluminum, 3D-printed floats, and acrylic mounts to reduce drag and simplify mounting of mission tools. Our buoyancy system includes cut polyurethane foam blocks and polyurethane pour foam tested across multiple dives. Balancing foam with the ROV's mass was essential to achieving neutral buoyancy, allowing Ulua to hover mid-water without propulsion.

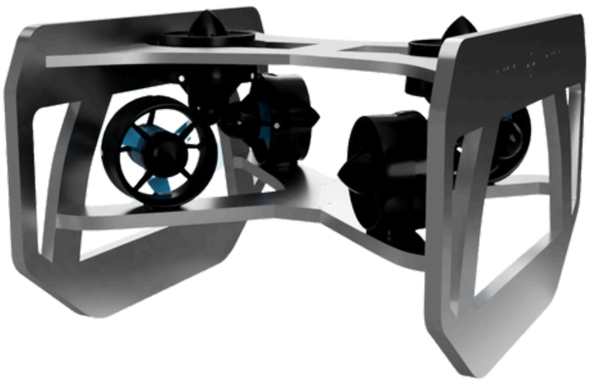

Figure 5. Aluminum Frame Model

3.2 Enclosure and Electrical

A Blue Robotics 4" x 200 mm cast acrylic enclosure houses all internal electronics. Cable penetrators were sealed using marine epoxy, and vacuum testing is performed before every dive. Inside, we used terminal blocks to manage power (12VDC and ground), a Pixhawk 4 flight controller, a Raspberry Pi 3B, 6 bi-directional speed controllers, and a camera.

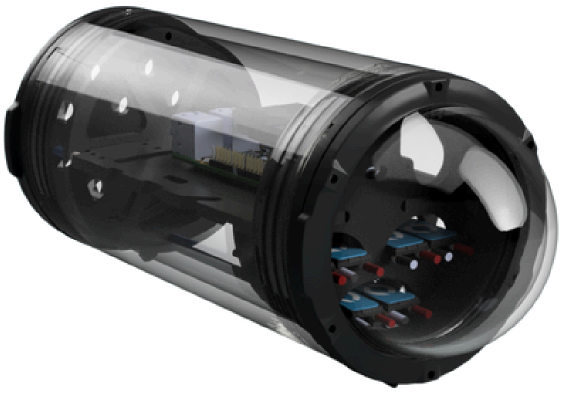

Figure 6. Enclosure Model

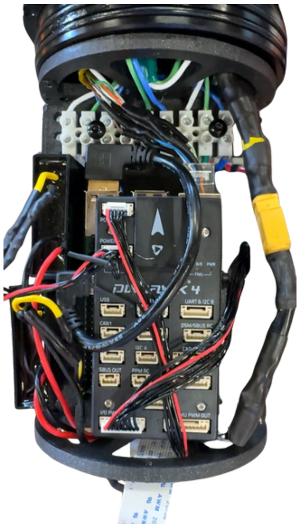

Figure 7. Pixhawk Mounted Above RaspberryPi

3.3 Control System

The control system is built around a Raspberry Pi 3B connected to the Pixhawk 4. An Xbox controller interfaces with the topside application QGroundControl to control movement, while a rotary pneumatic valve opens and closes the pneumatic claw. The depth sensor feeds data to the autopilot, which helps the pilot assess vertical movement in real time. The system was tested to ensure consistent signal latency across 15 meters of tether.

3.4 Thruster and Propulsion Layout

We used six T200 thrusters from Blue Robotics: four vectored in an X-configuration for lateral and rotational control, and two vertically aligned for heave. This setup provides six degrees of freedom. ESCs are mounted inside the enclosure, and PWM signals are managed through the Pixhawk.

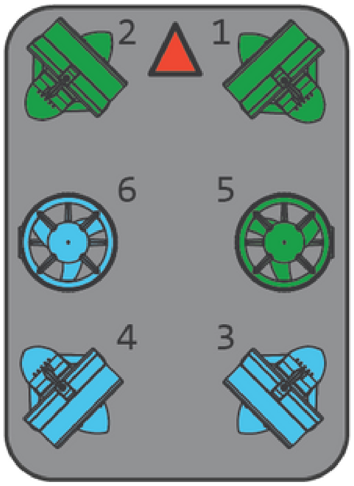

Figure 8. Vector Configuration (Credit: ArduSub)

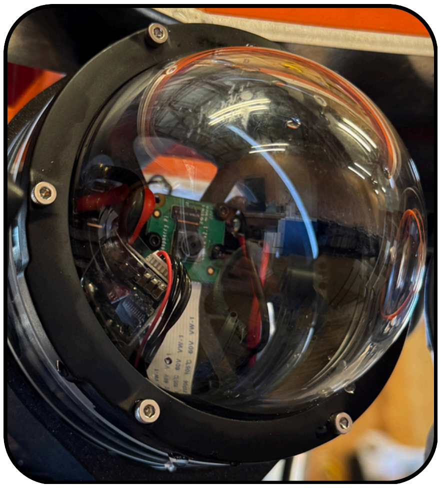

Figure 9. Camera Inside Enclosure

3.5 Sensor and Camera Configuration

Ulua's sensor and camera system was initially built for deep-water ocean exploration, prioritizing durability and long mission capacity over compactness or agility. Originally designed to gather ecological video and depth data in open-water reef environments off Hawai'i—sometimes collecting debris like scrap metal or golf balls—the ROV featured high-resolution sensors, deep depth tolerance, and internal logging over live feedback. Ulua now uses a forward-facing wide-angle camera housed behind a polycarbonate dome in the electronics enclosure, and a Bar30 depth sensor on the rear endcap for real-time readings via QGroundControl. Though selected for deep-sea use, these components perform well in shallow pool settings, aiding neutral buoyancy during fine maneuvers. A leak detector, part of the original safety system, is now integrated into the topside software to immediately alert pilots of water intrusion. Future upgrades include a second camera aimed at the manipulator for better task visibility.

3.6 Build vs. Buy, New vs. Used

As a first-year MATE ROV team, we chose to purchase most major components to ensure reliability and ease of integration, sourcing key items like thrusters and enclosures from Blue Robotics. With limited access to legacy systems or spare parts, starting from scratch allowed us to focus on foundational learning in underwater robotics while

Figure 10. Cat6 Ethernet Cable

minimizing the risk of hardware failure. At the same time, many structural and mission-specific parts, including the claw, frame mounts, and buoyancy system, were fabricated in-house. We selected a Raspberry Pi and Pixhawk combination for its adaptability and future-proofing potential, and the ROV was designed with modularity in mind to enable reuse of high-cost components like ESCs and thrusters in future iterations. We also leveraged existing engineering tools and supplies—such as Ethernet cables, a 3D printer with PLA and ABS filament, and a wide range of hand and power tools. These resources helped reduce startup costs and allowed us to focus our budget on critical systems that couldn't be built internally.

4. Payload and Tools

4.1 Gripper

Ulua's primary payload tool is a pneumatic claw. Printed from high-quality PLA plastic, it includes a mechanism to grip objects underwater. The claw is operated by a manual air pump system located topside and controlled via a rotary 3-way manual valve toggled by the pilot. The modular claw can be removed or swapped with future tools via a standardized mount system. The manipulator on our ROV features a unique interleaving claw mechanism, where each claw slides through the other as it closes. This design allows the gripper to form a tight and continuous seal around an object, maximizing surface contact and minimizing slippage. Originally developed to pick up golf balls during early prototyping, the claw mechanism proved highly effective at securing spherical and irregularly shaped items. For the MATE ROV competition, the design was scaled up and structurally reinforced to handle larger and more complex underwater tasks. The sliding claw approach ensures versatility and reliability in a wide range of marine manipulation scenarios, aligning with our mission of supporting ocean preservation through practical and innovative engineering.

Figure 11. Prototype Gripper Design

4.2 Photosphere Creation

To meet the requirements of this year's 360° photosphere task, our team has implemented a streamlined approach using a video-based capture system and the commercial photo stitching software PTGui. Instead of capturing individual still images at varying angles and distances, we record continuous video footage from a fixed position inside the 1-meter red square. This method allowed us to ensure all seven colored targets—five submerged and two floating—are visible within the frame as the ROV slowly rotates to capture the full environment.

After the mission run, we extract a series of high-resolution frames from the recorded video. The selected frames are then imported into PTGui, a photo stitching software optimized for creating seamless panoramic and spherical images.

By using the software, we can automatically align overlapping images, merging them into a continuous spherical projection. The resulting photosphere can be rotated freely in all directions without visible edges or seams, meeting the competition's definition of a "true" 360° photosphere.

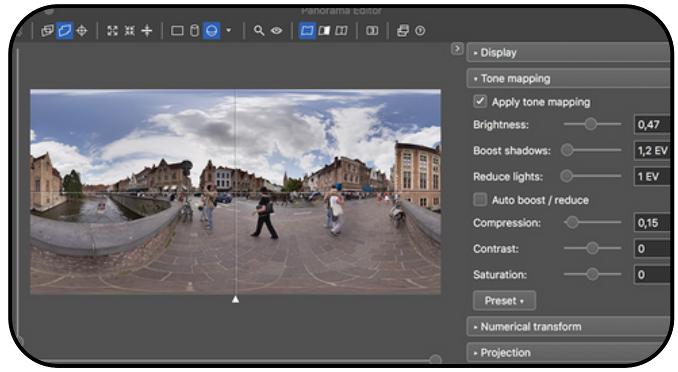

Figure 12. PTGui Software (Credit: PTGui)

To remain cost-efficient, our team intentionally uses the free trial version of PTGui, which includes a watermark. Since the watermark does not interfere with the visibility of any of the required targets and does not impact the scoring criteria, this decision allows us to complete the task without incurring additional software expenses.

This approach was chosen for its simplicity, flexibility, and compatibility with our existing onboard camera system. By leveraging video data instead of discrete still images, we reduce the complexity of the capture process and ensure we can gather all necessary visual information in a single dive.

5. System Integration Diagrams (SID)

5.1 Electrical Integration Diagram

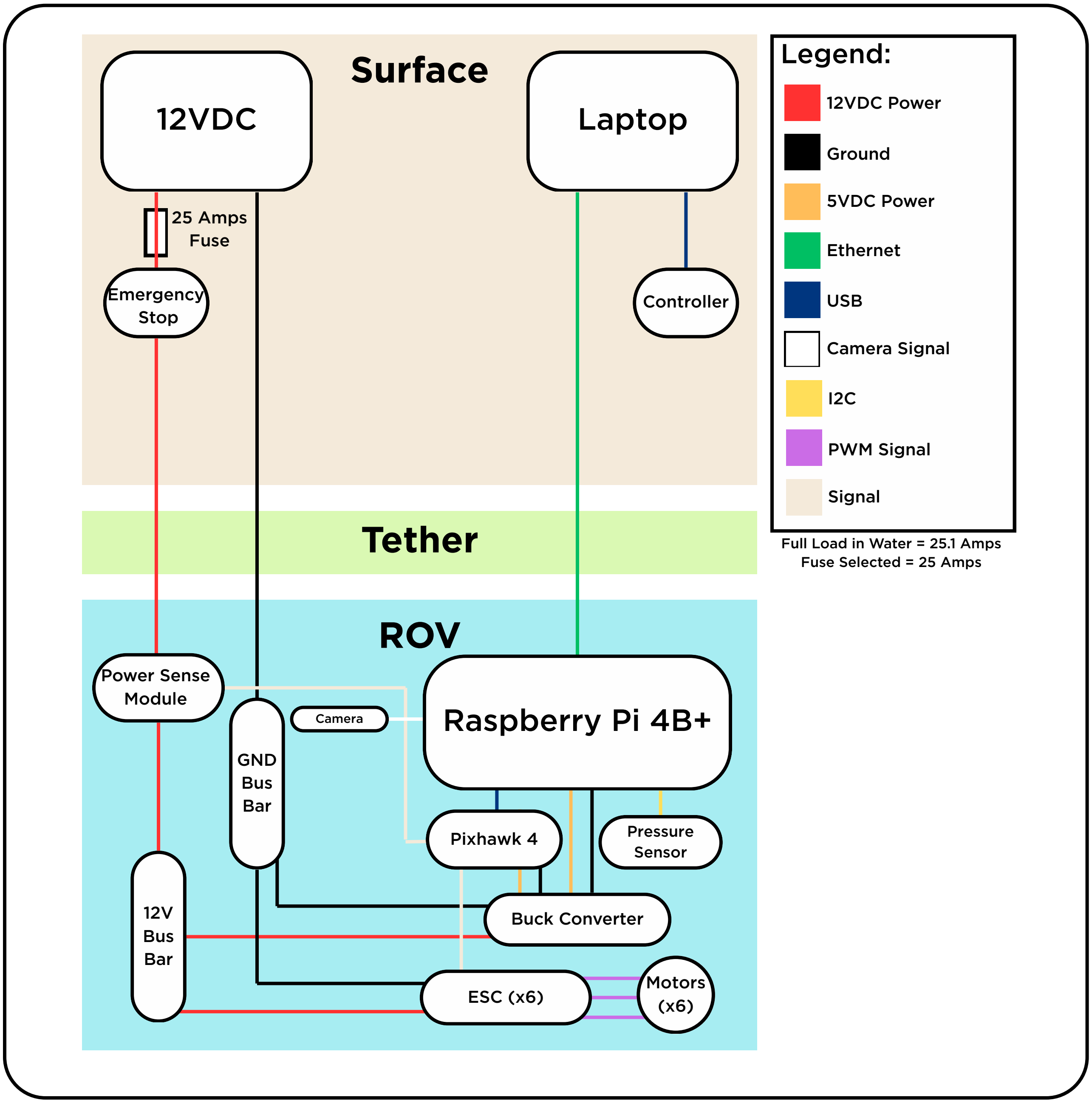

Figure 13. Electrical Integration Diagram

5.2 Fluid Integration Diagram

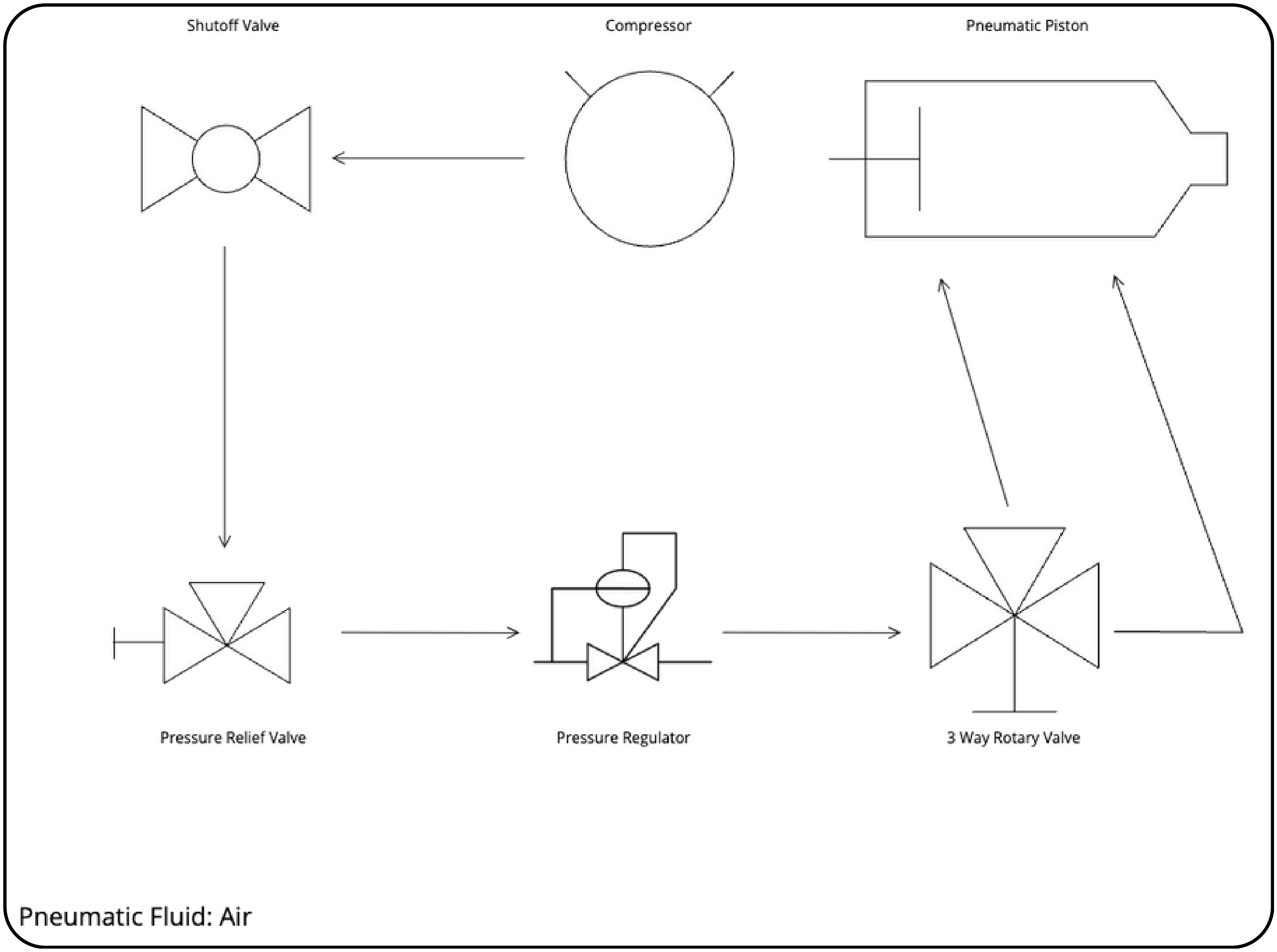

Figure 14. Fluid Integration Diagram

6. Safety

6.1 Safety Features

Safety is a foundational priority in our ROV design and operations. We have implemented a range of physical and electronic features to minimize risk to both users and equipment.

Our ROV is equipped with thruster guards, a strain relief system, and rounded frame edges to prevent injury or electrical shock during handling and protect marine life from exposed propellers. The motor guards are iP2X compliant and courtesy of UWROV, while our frame design minimizes snag points.

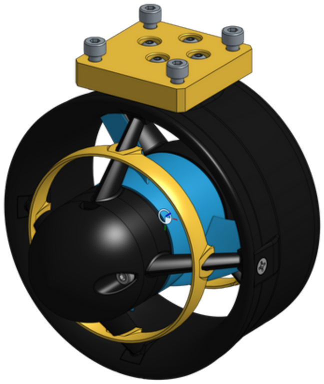

Figure 15. Motor Guard (Credit: UWROV)

To avoid condensation and internal moisture buildup, our electronics enclosure includes silica gel packets that wick away humidity. This simple yet effective solution helps protect sensitive circuitry from long-term corrosion and water damage.

Figure 16. Silica Gel Packet

Additionally, we use an internal leak detection sensor. This system is integrated with our topside software to provide real-time alerts to the operator, allowing for immediate corrective action before critical failure occurs.

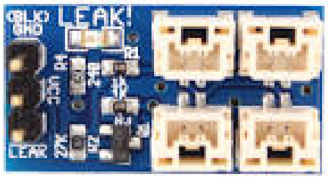

Figure 17. Leak Sensor (Credit: Blue Robotics)

Figure 18. Emergency Kill Switch

A topside kill switch is installed directly on the ROV's power line. This allows operators to instantly cut power in emergency situations, ensuring the safety of both the pilot and surrounding equipment.

6.2 Safety Procedures

To maintain a safe working environment at all times, our team adheres to the following protocols:

- Team members are required to wear safety goggles and closed-toed shoes whenever handling tools or working on the ROV.
- All electrical tools are used only under the supervision of a mentor or qualified adult.
- A fully stocked first aid kit is readily accessible at the worksite, and a designated mentor is present during all build and test sessions.
- Work areas are kept organized and free of tripping hazards, with all equipment returned to storage after use.
- Clear verbal communication is maintained during all technical operations to prevent missteps or accidental activation of systems.

6.3 Dive Checklist

Before all dives, the following checklist is performed to ensure the ROV is fully sealed, secure, and operational:

- Perform a vacuum pressure test to ensure enclosure is properly sealed.
- Twist tether thimble to ensure it is properly attached.
- Verify that the vent plugs are properly installed in both enclosures.
- Visually inspect all screws holding the back end caps and dome.
- Tug each thruster to confirm they are firmly mounted to the frame.
- Inspect the o-ring seals on the enclosure to ensure they are intact and lubricated with silicone grease.
- Test thrusters in manual mode to verify functionality before placing in water.
- The pre-dive checklist is signed off by mentor.

7. Critical Analysis

7.1 Vehicle Testing

We approached vehicle testing using a structured, staged methodology. Initially, we conducted component testing on dry land to validate the functionality of subsystems, including autopilots, thrusters, and tether connection. After individual systems passed bench testing, we performed integrated dry runs to verify system communication and ensure safety protocols were followed. Following this, we carried out wet tests in a controlled pool environment. These tests began with assessments of buoyancy and trim, and were followed by evaluations of propulsion, manipulator functions, and camera performance. After each test session, we held debriefs and documented the findings to record any issues, assess performance, and prioritize the next set of improvements.

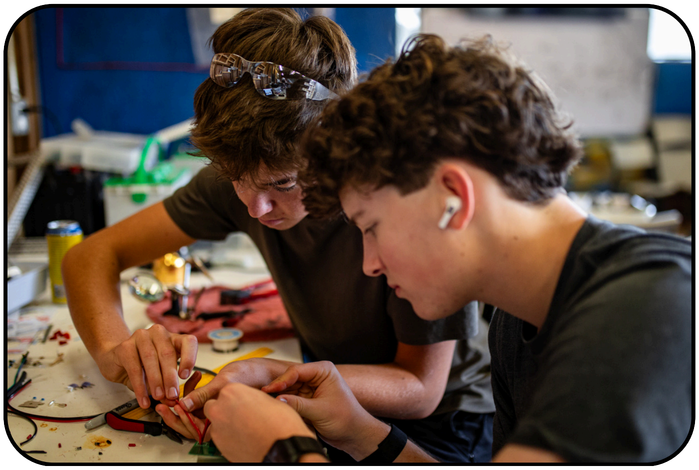

Figure 19. Engineers Testing a Control Board. From Left to Right, Robert M. (10th), Finlay M. (10th)

7.2 Troubleshooting Strategies

Our team employed a systematic approach to troubleshooting, beginning with isolating the source of the issue through observation, error logs, and physical inspection. When a subsystem failed or underperformed, we used modular testing to isolate affected components. For software or electronics issues, we utilized multimeters, diagnostic LEDs, and serial console outputs to trace faults. Mechanical problems were addressed by inspecting for stress points, misalignments, or loose fasteners. We also relied on inter-team communication through Slack and shared logs to track recurring problems and avoid redundant fixes. Regular checklists and pre-dive inspections helped prevent common failures and ensured problems were caught early.

Figure 20. ROV Prototype for Ocean Exploration

7.3 Prototyping

Prototyping was essential in our design process, especially for components such as the manipulator and buoyancy systems. We used early prototypes to evaluate different materials, mechanical linkages, and actuation strategies. These prototypes were tested in isolation to validate core functionality, then refined based on performance feedback from pool trials. For example, our manipulator claw was initially prototyped using 3D-printed components designed for retrieving golf balls. After testing, we scaled and adapted the design for competition-specific tasks, using observations from field trials to guide structural reinforcement and control optimization.

Initially, our ROV was conceptualized for deepwater ocean exploration, with a focus on long-duration operation. This version of the design emphasized ruggedization and autonomous features suited for open-ocean environments rather than pool-based tasks. However, upon committing to the MATE ROV competition, we quickly recognized that the original design exceeded the competition's scale, complexity, and time constraints. As a result, we pivoted and initiated a full redesign tailored specifically for the MATE challenge. This included downsizing the frame, and reorienting the design toward maneuverability and task-specific functionality within a confined pool environment.

8. Accounting

8.1 Team Budget

At the beginning of the project, our team developed a projected budget of $5,600 to guide our fundraising and spending decisions. This projection was informed by prior build seasons, estimated component prices, anticipated travel costs, and known requirements of the MATE ROV competition. The budget was divided into several core categories to ensure comprehensive planning across the entire scope of the project:

Category	Type	Description/Examples	Projected Cost	Budgeted Value
Control System	Purchased	Raspberry Pi, Cameras, Autopilot	500	500
Buoyancy Materials	Purchased	Foam panels, expanding foam	100	100
Manipulator System	Purchased	Pneumatic System	150	150
Tools and Consumables	Purchased	Sealants, Loctite, potting kit	300	300
Travel and Lodging	Purchased	Flights, hotel for team	1200	1200
Registration Fees	Purchased	MATE Competition registration	250	250
Contingency Funds	Purchased	Unexpected expenses	800	800
Electrical Components	Purchased	Thrusters, enclosures, power modules	2300	2300
Prior Equipment	Donation	3D printer, soldering station, tools	900	0
			6500	5600

Figure 21. Budgeting Spreadsheet

This initial budget included cost estimates for both new and reused items. Items we planned to reuse were included at current market value to help calculate our actual fundraising needs.

8.2 Project Cost

Throughout the project, we tracked all purchases, donations, and reused items in a comprehensive cost accounting process. Items are categorized as either purchased, reused, or donated, with reused and donated components reported at their current market value.

Status	Object	Quantity	Total (USD)	Categories
Purchased	Polyurethane Foam Panels	4	73.12	Buoyancy Materials
Purchased	Expanding Polyurethane Foam	1	38.79	Buoyancy Materials
Purchased	Braid Sleeving	1	42	Electrical Components
Purchased	Steel Support Cable	1	8.99	Manipulator System
Purchased	Raspberry Pi	2	97.98	Control System
Purchased	Fork Connectors	1	9.89	Electrical Components
Purchased	Raspberry Camera	2	92.49	Control System
Purchased	Pneumatic Piston	1	12.69	Manipulator System
Purchased	Pneumatic Hose	1	25.99	Manipulator System
Purchased	Pneumatic Lever	1	20.69	Manipulator System
Purchased	Air Compressor	1	49.99	Tools and Consumables
Re-Used	Marine Wire	1	37.88	Electrical Components
Purchased	Vacuum Pump	1	98	Tools and Consumables
Purchased	Wet Link Plugs	1	164.8	Electrical Components
Purchased	Pressure Sensor	1	95.62	Electrical Components
Purchased	Thrusters, ESCs, and Enclosure	1	2012.89	Electrical Components
Purchased	Metal Frame	1	320.64	Frame and Chassis
Purchased	Enclosure Components	1	150	Electrical
Re-Used	Ender-3 3D Printer	5	945	Tools and Consumables
Donated	Prusa Mini 3D Printer	1	459	Mechanical
Re-Used	Soldering Station	1	200	Electrical
Re-Used	Ethernet Cable	1	100	Electrical
Re-Used	Workspace Tools	1	450	Mechanical
Re-Used	Potting Kit	1	10	Tools and Consumables
Re-Used	Loctite	1	10	Tools and Consumables
			5526.45	

Figure 22. Accounting Spreadsheet

After accounting for savings from reused components and donated materials, the effective cost of the ROV was significantly lower than the projected value. The remaining sponsorship funds were reserved for competition registration, team travel, and future R&D projects. This disciplined financial strategy enabled us to allocate resources effectively, respond to unexpected costs, and ensure the success of our ROV while maintaining fiscal responsibility. We were donated a total of $9,000.00 from multiple Anonymous donors and $1,000.00 from Ben Honey throughout our development process.

9. Conclusion

9.1 Challenges

One of the most persistent and technically frustrating challenges our team faced was a vacuum test that repeatedly failed, despite thorough sealing and rechecking of penetrators and enclosures. After extensive troubleshooting and retesting, we determined the root of the issue to be a faulty vacuum pump that was producing unreliable pressure readings. This consumed significant build and testing time as it initially appeared to be a mechanical failure in the ROV. The problem was ultimately resolved by acquiring a replacement pump, which immediately led to consistent and reliable test results.

Another major challenge was the prolonged shipping time for key components due to our team being located in Hawaiʻi. With many parts sourced from mainland U.S. suppliers, delivery delays—sometimes spanning weeks—hindered our workflow and often required schedule changes or interim solutions. We adapted by ordering components in batches early, tracking shipments rigorously, and developing contingency plans with reused parts or placeholder materials to continue progress.

9.2 Teachings

Despite these challenges, our team emerged more resilient and skilled. We learned how to problem-solve under pressure and developed stronger protocols for verifying testing equipment reliability before conducting full diagnostics. The vacuum pump issue highlighted the importance of checking the tools used to evaluate the ROV—not just the ROV itself. We also deepened our understanding of supply chain logistics and project scheduling.

Planning around extended shipping timelines taught us the value of flexibility, early procurement, and internal deadlines. These skills are not only relevant to ROV building but are also transferable to engineering projects in general. Beyond technical growth, the experience strengthened our communication and leadership abilities. Team members took initiative when delays or mechanical setbacks occurred, and collaboration improved through shared responsibilities and transparent planning. In adapting to each new challenge, our group became more cohesive, creative, and effective. Ultimately, these experiences refined both our engineering processes and our team culture. As we look ahead to future competitions and projects, we do so with greater confidence, adaptability, and a shared commitment to excellence in ocean technology innovation.

9.3 Future Improvements

Looking forward, our team has identified several key areas for improvement to enhance the functionality, reliability, and expandability of our ROV system. One area involves adding a second camera angled at the manipulator claw, which would significantly improve pilot visibility and task precision during delicate operations. Another goal is to improve the tether strain relief system by implementing a more robust anchoring method that reduces the risk of cable fatigue and accidental disconnection. We also plan to design and implement a modular tool rail system, allowing for the quick mounting and swapping of multiple payloads depending on the mission. Additionally, we aim to develop a live depth graph on the pilot display to provide continuous real-time feedback on vertical positioning. Finally, we are working toward transitioning from a pneumatic to a fully electric claw system. This change will enhance reliability, increase precision, and allow for tighter integration with our control software.

These improvements will help us streamline operations, better adapt to mission requirements, and push the boundaries of our current capabilities.

10. References

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PTGui, https://ptgui.com/
Fusion, https://www.autodesk.com/products/fusion-360/

11. Acknowledgements

We extend our sincere thanks to the individuals and organizations who made this project possible. Our mentor, Robyn Brewer, offered steady guidance and technical advice that kept us focused and safe throughout the build process. We are especially grateful to our sponsors—anonymous donors and Ben Honey—whose generous support helped turn our ideas into reality. Thanks to the HPA pool staff for providing access to a safe testing environment, and to Blue Robotics for the helpful documentation that supported our technical development. We also acknowledge past MATE ROV teams for their shared insights, which helped us build on proven solutions. Special thanks go to our teachers and classmates for their support, flexibility, and encouragement throughout this build cycle. Their belief in us helped turn a vision into reality. This project was a collaborative effort that extended far beyond our team, and we are deeply grateful for everyone who contributed to its success.