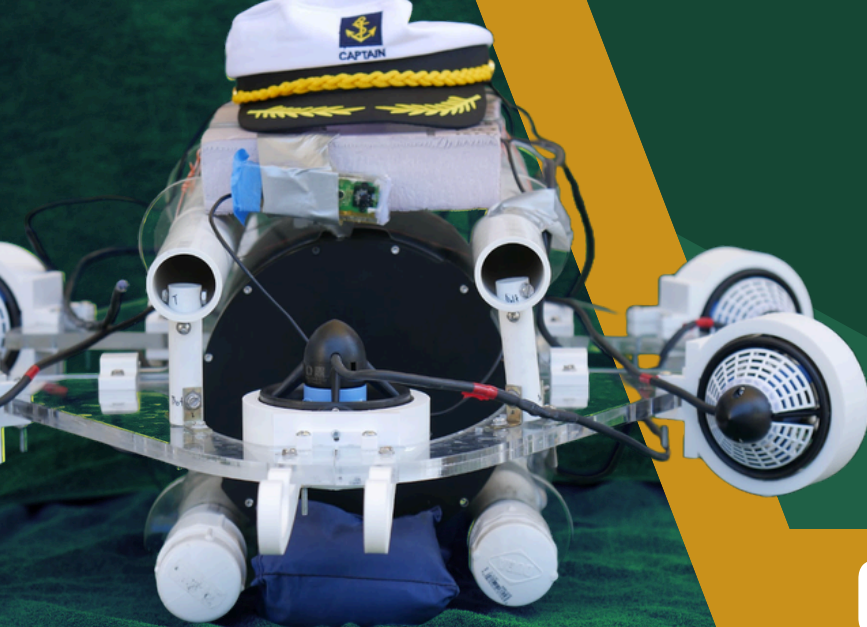




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CAL POLY UROV

2026 TECHNICAL DOCUMENTATION



CAL POLY UROV - CALIFORNIA POLYTECHNIC UNIVERSITY

SAN LUIS OBISPO, CA, UNITED STATES



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Advisor: Dr Siavash Farzan

ABSTRACT

Cal Poly UROV is a student-led project from the California Polytechnic State University (Cal Poly) in San Luis Obispo that specializes in marine robotics and in-house design and manufacturing. Our team, with the mentorship of electrical engineering professor Dr. Siavash Farzan, proudly embodies Cal Poly's "Learn by Doing!" motto by providing students with hands-on design, manufacturing, business, graphic design, and leadership opportunities that will allow them to dominate the industry post-graduation.

We have competed in the MATE ROV competition's World Championships of the MATE ROV competition three times since our establishment in 2015. This year we are expanding the team from 7 to 25+ members, and completely overhauling our company structure to allow us to be more competitive.

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TEAMWORK

PROJECT MANANGEMENT

Our company consists of five core teams, each responsible for their own specialized components—or subsystem—on the ROV:

Mechanical, Electrical, Firmware, Software, and Business.
Each team is managed by a subteam lead and managed by the team CEO and advisors.

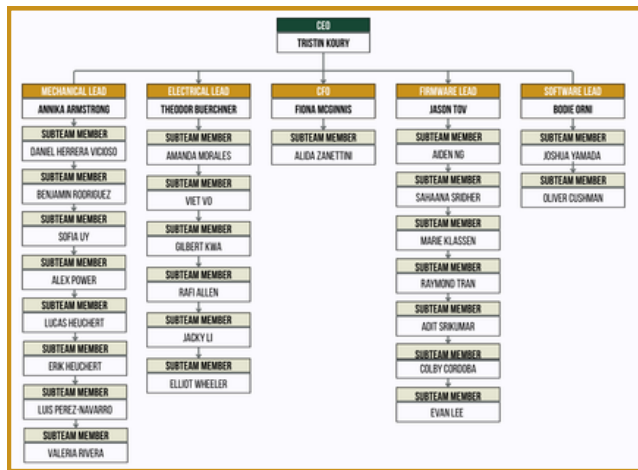


Figure 1: Cal Poly UROV Org Chart

PROTOCOLS & OPERATIONS

Protected parts and systems require supervision before use to ensure equipment safety and proper handling procedures. Weekly standup presentations are conducted to communicate progress, blockers, and subsystem integration concerns across all subteams.

The mechanical subsystem condensed several years of iterative design development into a single competition cycle through rapid prototyping, redesign, and accelerated subsystem testing.



PROJECT SCHEDULE

Our timeline was initially drafted on whiteboards and later refined into a Gantt chart with deliverables using Trello. This workflow allowed teammates to remain accountable for tasks, maintain deadlines, and coordinate subsystem integration and testing schedules.



Figure 2: Cal Poly UROV Gantt Chart

2026 CAL POLY UROV



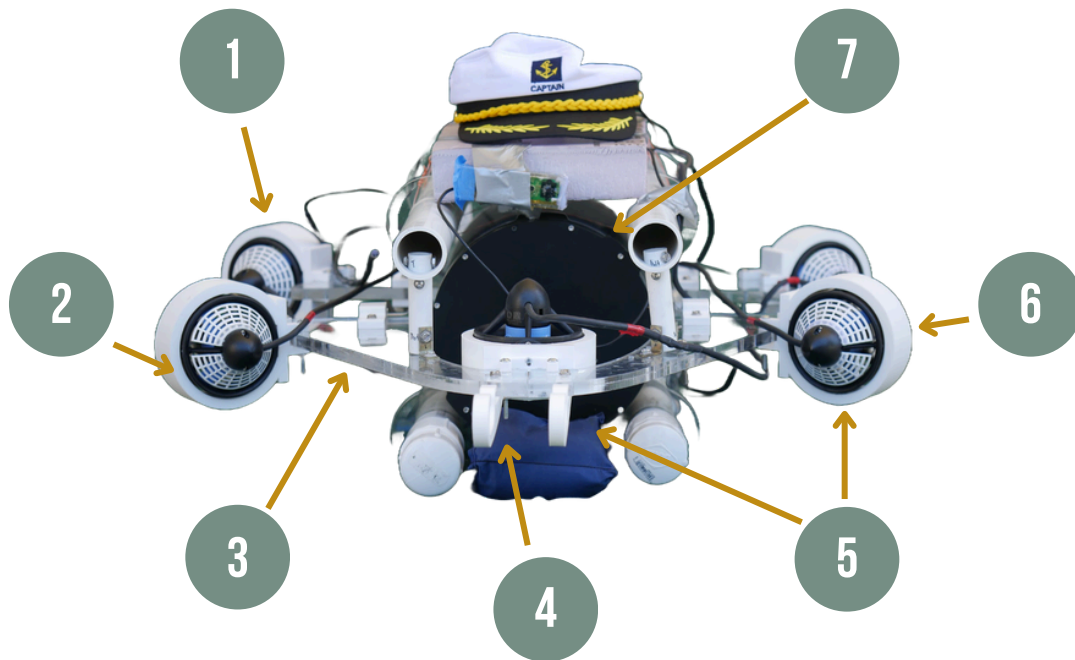
Figure 3: 2026 Cal Poly UROV Team

2026 LEADERSHIP



Figure 4: 2026 Cal Poly UROV Leadership Team

MEET LEBRON



1. Six-Thruster Configuration

- The ROV uses six thrusters to provide efficient propulsion and precise underwater maneuverability. Four angled horizontal thrusters control translation and yaw, while two vertical thrusters control depth and pitch.

2. Five Degrees of Freedom

- The propulsion system allows the ROV to move forward/backward, strafe left/right, ascend/descend, rotate, and maintain pitch stability, improving control during mission tasks.

3. Acrylic Frame

- The frame is constructed from clear cast acrylic because it is lightweight, corrosion resistant, durable, and easy to machine. The frame design also reduces drag while maintaining structural strength.

4. Manipulator Claw

- The custom claw was designed to securely grasp, transport, and release mission objects with precision and control during underwater operations.

5. Custom 3D-Printed Components

- Custom 3D-printed parts were used throughout the ROV to create mounts, tooling, and subsystem supports. These components allowed rapid prototyping, easier modifications, and lower manufacturing costs.

6. Thruster Shrouds

- Protective shrouds were added around each thruster to improve operator safety and reduce the risk of damage from debris or collisions.

7. 9.5-Liter Anodized Aluminum Locking Enclosure

- The electronics enclosure protects critical onboard systems from water exposure and pressure during operation. The anodized aluminum design improves durability, waterproofing reliability, and heat dissipation.

• Strain Relief Systems

- Strain relief was added to tether and internal wiring connections to reduce cable stress and prevent electrical damage during operation.

• Protected Electronics System

- Internal electronics were organized within protective casing to improve reliability and reduce the risk of component failure.

• Overload Protection

- Electrical overload protection systems help prevent damage to onboard electronics and improve operational safety.

• Additional Interior Casing

- Additional protective casing was added inside the enclosure to secure sensitive components during transport and operation.

• Ergonomic Handles

- Ergonomic handles improve portability and allow safer deployment and recovery of the ROV.

• Low-Temperature Operation

- The ROV is rated to operate in temperatures as low as -4°C , allowing reliable performance in cold underwater environments.

• Software Power Limitations

- Software-based power limits help protect electrical systems and maintain safe operating conditions during use.

• Specifications:

- **Dimensions:** 107.95 cm × 71.12 cm × 33.02 cm
- **Weight:** 15.8 kg
- **Estimated Cost:** \$6,000+
- **Student Work Hours:** 8,000+ hours

DESIGN RATIONALE

INNOVATION & PROBLEM SOLVING

Our project was blessed with the gift of hindsight after learning from our mistakes last year, which has granted us a strong foundation for making improvements this year. Some of the biggest issues with last year's product included a lack of internal mounting hardware for the PCBs, causing them to float freely and unprotected; poor waterproofing methods; an over-insulating enclosure material; and at the root of it all, an uncoordinated and poorly executed management structure. Given the cost and importance of our PCB stack to this year's ROV, it was imperative we found a better way to store them inside the enclosure. Our solution was to create a lattice structure that would slot down into the enclosure and could be bolted into easily-accessible mounting holes. This lattice has three sections: the top circular frame that constrains the structure's motion while inside; the middle plate that the STM Link, USB extender, and IMU boards live; and lastly, the basement where the main board stack and heat sink reside. This setup makes it easy to make modifications to the mechanical setup of the electrical system, diagnose and repair the electronics, organize cables, and most of all—conduct post-dive diagnostics.

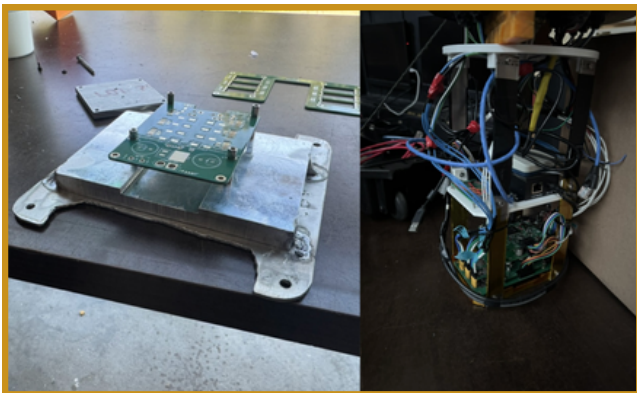


Figure 5: V1 vs V2 Electronics

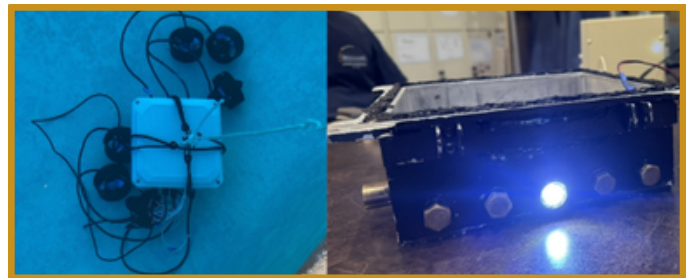


Figure 6: V1 vs V2 Enclosures

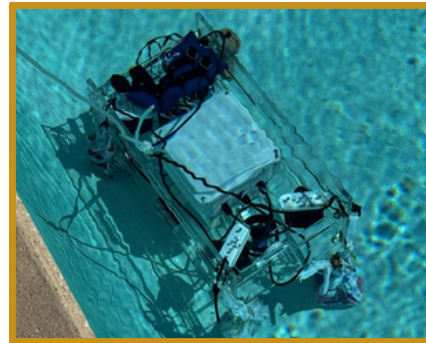


Figure 7: ROV V1

Although our team is over a decade old, there was no functional infrastructure nor veteran members with prior experience designing a functional ROV coming into this year, leaving us to start from square one. Instead of seeing this as an obstacle, we saw it as a bold opportunity to learn starting from fundamentals (or witness our ROV's electronics die a fiery death)! To accommodate this learning curve, we allocated space in our timeline for experiments and testing to ensure the functionality of our components. The first phase of our design process was research & development (R&D). During this phase, we consulted the MATE website to derive inspiration from and reverse engineer systems used by other teams. Once we had enough information to work off of, we got to brainstorming our own systems. These brainstorming sessions typically consisted of “chalk talks” where a small group would go over major constraints and try to eliminate glaring design flaws. This would help prevent minor issues from cascading into major problems later on that could prove mission-ending.

Once an initial design proposal was formed, a preliminary design review (PDR) was held wherein the section lead responsible for the team designing the component in question as well as the CEO would have to approve the design before moving forward to prototyping. Since our budget was limited early-on, this checkpoint helped save ourselves from spending money on faulty designs. After getting approval, the design entered the second phase—manufacturing and assembly.

VEHICLE STRUCTURE

The vehicle structure was designed to balance **durability, modularity, manufacturability**, and hydrodynamic performance while remaining **lightweight** and cost effective. The frame serves as the foundation for all onboard systems, supporting the enclosure, propulsion system, payload tooling, tether routing, and buoyancy components while maintaining structural rigidity during operation.

The frame is primarily constructed from clear cast acrylic due to its corrosion resistance, ease of manufacturing, relatively low cost, and compatibility with available fabrication equipment. Acrylic could be precisely laser cut using Cal Poly manufacturing resources while also allowing for straightforward drilling and assembly of mounted components. In addition, acrylic does not corrode in saltwater environments and provides sufficient rigidity to withstand operational loads and hydrodynamic forces encountered during competition tasks.

The geometry of the frame was heavily influenced by the propulsion layout and buoyancy requirements of the ROV. Water flow cutouts were incorporated throughout the frame to reduce hydrodynamic drag and minimize interference with thruster intake streams. Additional structural extensions beneath the lower frame lowered the center of mass beneath the center of buoyancy, improving passive roll stability during operation.

Subsystem integration and serviceability were major considerations throughout structural development. The frame was designed to allow easy access to internal systems, rapid replacement of components, and straightforward mounting of payload tools and electronics. Standardized mounting hardware and custom 3D-printed PETG mounts were used throughout the vehicle to simplify manufacturing, maintenance, and subsystem replacement.

DESIGN EVOLUTION

A major focus of the redesign was correcting issues from the previous vehicle. Last year's ROV suffered from poor waterproofing, unsecured electronics, limited thermal management, and an electrical system that was difficult to diagnose or repair. These failures directly shaped this year's design priorities: **improve waterproofing** reliability, **securely mount** internal electronics, reduce **wiring complexity**, and create a **more serviceable** system. The enclosure design changed significantly throughout development. The team first selected an IP68-rated polycarbonate electronics box because it was affordable, large enough for the electronics, and appeared suitable for underwater use. However, repeated water tests revealed persistent leaks, and later FEA simulations showed that the box would deform under competition pressure. After this failure, the team developed two backup solutions in parallel: a repaired aluminum enclosure from the previous ROV and a Blue Robotics aluminum tube enclosure. After testing both options, the Blue Robotics tube was selected because it provided the best balance of waterproofing reliability, strength, and integration with the updated electronics system. The internal electronics layout also evolved considerably. Last year, circuit boards and wiring were loosely arranged inside the enclosure, which made the system fragile and difficult to maintain.

This year, the team designed a structured internal lattice to hold the PCB stack, USB extender, IMUs, and heat sink in fixed positions. This improved cable organization, protected solder joints, simplified troubleshooting, and made post-dive diagnostics much easier. The electrical system was also redesigned around custom PCBs instead of loose development boards and jumper wires. Four custom PCBs were developed to improve power distribution, reduce wiring harness complexity, protect components from electrical shorts, and increase serviceability. The new system includes dedicated boards for ESC power distribution, 48V-to-12V conversion, 48V-to-5V conversion, and STM32 microcontroller control. Thermal management became another major design improvement. After overheating and electrical failures in the previous system, the team developed a conductive heat path from the power electronics to an aluminum heat sink, then into the aluminum enclosure and surrounding water. This allowed the enclosure itself to act as part of the cooling system. Overall, the ROV evolved from a loosely integrated and failure-prone system into a more organized, modular, and serviceable vehicle. Each major redesign was driven by testing, failure analysis, and lessons learned from previous iterations.

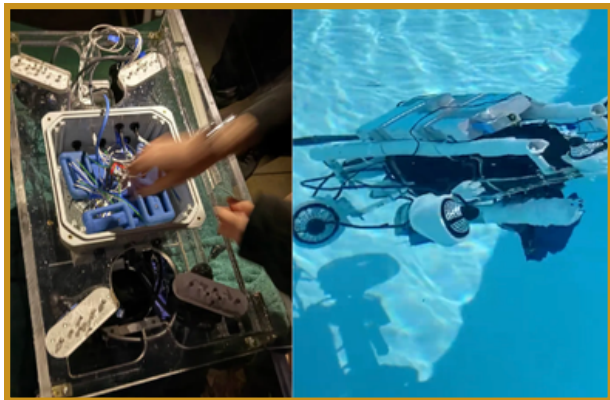


Figure 8: V1 vs V2 ROVs

ELECTRICAL

Last year's electrical system relied heavily on rushed power distribution boards, loose jumper wires, STM32 development boards, and bulky DC-DC converters connected through fragile wiring harnesses. The lack of safety features, exposed solder connections, and disorganized wiring made the system unreliable and difficult to repair, ultimately resulting in multiple electrical shorts and damaged microcontrollers. To address these issues, the team designed a fully custom electronics architecture consisting of four PCBs focused on improving reliability, modularity, and serviceability. The new system includes dedicated boards for ESC power distribution, 48V-to-12V conversion, 48V-to-5V conversion, and STM32 microcontroller control. Board-to-board connections were used wherever possible to eliminate unnecessary wiring and improve power delivery. The power conversion systems also incorporated fuse protection, decoupling capacitors for transient suppression, low-dropout regulation, and optoisolation devices to protect PWM outputs driving the ESCs and servos.

Last year's rushed waterproofing process also led to catastrophic electrical failure after the enclosure was flooded with non-conductive oil. This year, the team dedicated five months to waterproofing development and validation before integrating electronics into the enclosure. Marine silicone was added around passthroughs to reinforce sealing reliability, resulting in a watertight enclosure and fully functional electronics system.

To address overheating concerns, the team also developed a conductive thermal management system. Heat generated by the DC-DC converters is transferred into an aluminum heat sink plate, then into the aluminum enclosure walls and surrounding water, allowing the enclosure itself to function as part of the cooling system.

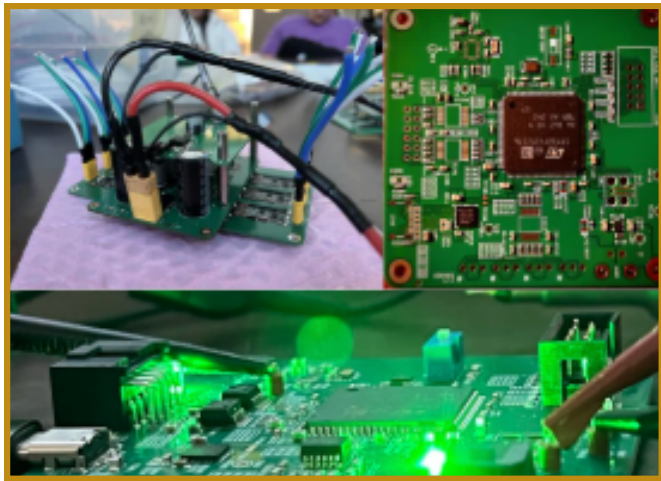


Figure 9: Close up of our custom PCB's

HARDWARE BASED SYSTEM

The ROV's control system is built around an in-house ROS2 environment running on a Jetson Orin Nano topside computer connected to an onboard STM32 microcontroller via UART. The STM32 handles direct communication with the thrusters, servos, and IMUs, while ROS2 enables concurrent execution and communication between separate software nodes for serial communication, controller input, camera processing, control calculations, and overall system management.

A graphical user interface was developed using Foxglove and includes dual camera feeds, system logs, and controls for functions such as thruster enable/disable, PID activation, and image processing. Computer vision is implemented through Python OpenCV libraries using edge detection and feature matching algorithms to assist with measurement and counting tasks. The control system also supports closed-loop stabilization using dual IMUs. Sensor data from both IMUs is fused using a Kalman filter and fed into PID control loops that stabilize the ROV's velocity and orientation. These setpoints can be adjusted to maintain stable movement or hold position during operation and can be enabled or disabled through the GUI.

ROV-SIDE FIRMWARE

The ROV firmware system is built around an STM32 microcontroller that communicates with onboard thrusters, servos, and IMUs through a custom PCB and connector network. The STM32 generates PWM signals for motor control, communicates with sensors over I2C, and exchanges telemetry and command data with the topside computer through UART-over-USB communication.

To maximize reliability and simplify development, the communication protocol was intentionally kept lightweight, with topside sending compact 10-byte command packets and the ROV returning 3-byte response packets. Larger telemetry transmissions, such as IMU data, include basic checksum verification for error detection.

The ROV's cameras bypass the microcontroller entirely and connect directly to topside through a USB 2.0 Ethernet extender. USB 2.0 was selected over USB 3.0 because it provided sufficient video quality while reducing power consumption and system complexity, allowing reliable communication at distances up to 50 meters.



Figure 10: Control Station for ROV

CRITICAL ANALYSIS

At its core, the ROV is a giant system comprising a bunch of smaller subsystems: mechanical, electrical, firmware, and software. Much like organs, should any one of these subsystems fail independently, the dependent body system would fail altogether. Even further, it is of specific significance to separate time and temperature (and for mechanical, pressure) as testing variables to understand potential points of failure for each subsystem. Our testing methodology reflects this holistic concern by requiring each subsystem to be thoroughly independently tested before being integrated into the ROV.

WATERPROOF TESTING

A mechanical component must go through 3 primary tests before being considered waterproof: an initial 5-minute test for diagnosing any unforeseen leaks; a 30-minute water test to ensure that the pressure vessel is waterproof at surface depth for an extended amount of time; and lastly a pressure test at competition depth (~20ft) for 30 minutes to ensure that the vessel remains water-tight under operational stress; for this year, the maximum testing depth available was 6' 6" at the campus pool; next year we plan on finding a deeper testing facility, or potentially deploying it in the ocean. These tests must be done in order (5 minute, 30 minute, and then 30 minutes at depth) to properly diagnose points of failure.

In order to prevent inconclusive results, a pretest checklist must be completed. Basic pretest tasks include ensuring that the inside of the pressure vessel is completely dry, there is no water along the lid/sealing surface, and all passthroughs are appropriately tightened.

Once these tasks are complete, paper towels are taped around each potential point of failure inside the enclosure (passthrough locations, large O-rings, and gaskets); this allows for us to easily diagnose the location of the leak, and use a targeted approach to fixing the issue.

Should a part fail, and the point of failure was a design flaw rather than an implementation flaw, a redesign will be made and reviewed, and the testing process will repeat.

FIRMWARE TESTING

The firmware system was developed first with dev boards, jumper wires, and bread boards. When the MCU PCB was completed, we ran full functionality tests before integrating them with the power boards. We were able to test full communication, IMU reading, and thruster/servo PWM outputs. Once the MCU and power boards were fully integrated into the ROV alongside the thrusters, we developed a testing protocol to verify thrusters before deploying the ROV. At startup, each thruster is given a 0us PWM signal to ensure that they do not spin at all. To boot a thruster, it is given a 1500us PWM signal which is neutral thrust, at which point they beep to signify communication is good. Due to noise, this signal may vary in pulse width causing an insignificant amount of thrust. After verifying each thruster booted successfully, we deploy the ROV.

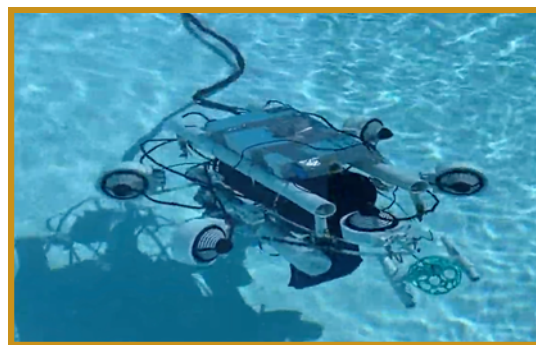


Figure 11: ROV Water Testing

PROPULSION

The ROV utilizes a six-thruster configuration to allow for motion with five degrees of freedom. Two vertical thrusters at the front and back of the ROV are responsible for depth and pitch control. Four thrusters positioned at 30 degree angles on either side of the ROV are responsible for horizontal translation and yaw control. The 30 degree angle was chosen for two reasons. First was to provide more power for forward and backward motion, which is where higher speeds would be more beneficial. The second reason was to ensure that there would not be interference between the intake streams of the thrusters on either side of the ROV, and that each thruster would be pulling water from a separate supply.

Having six thrusters in only vertical and horizontal directions meant that the ROV would not be able to move along one axis. Roll was chosen as the lowest movement priority because it does not provide a significant advantage towards the ROV's ability to complete tasks. If roll control were to be implemented, it would most likely only be used to correct for tipping, which is already done naturally by the ROV's weight and buoyancy balance.

The first consideration for the form of the frame was the orientation of the thrusters. The design uses six thrusters. Two are vertical thrusters responsible for depth and pitch control. The other four are used for translation and yaw control. These four are in an X formation on the perpendicular to the vertical thrusters. This means there is no direct roll control on the ROV. Other methods in the frame design were used to counteract roll from the competition currents and will be discussed later.

Originally, the four thrusters were angled at 45 degrees for ease of vectoring, control, and symmetry. It was believed that this way the same voltage would result in the same thrust for either direction. This design presented two issues. According to actuator disc theory, the thrust produced by an impeller is a function of the amount of mass that passes through it and the difference of velocities of the fluid after passing the impeller. At a 45 degree angle, the thrusters are close enough that the pairs on the front and back are pulling water from the same spot. This cuts the amount of water that either can pull and drops the efficiency for the thruster. Also, this means there is much larger diminishing returns on increasing the voltage to the thrusters. As they spin faster, both motors try to pull more water and decrease how much water the other motor can actually pull and both lose efficiency. The second issue was that the thrusters have an inherent forward and backward which have different efficiencies due to the blade designs. This means even at a 45 degree angle they would not have the same forward and backward thrust.

To combat these issues, a new design approach was used. Instead of treating each thruster as equally responsible for all types of motion, the front pair were designated the primary forward movers and the back pair were the primary reverse movers. The front pair have their designed forward pointed in the ROV's reverse direction, and the back pair have their designed forward pointed in the ROV's forward direction.

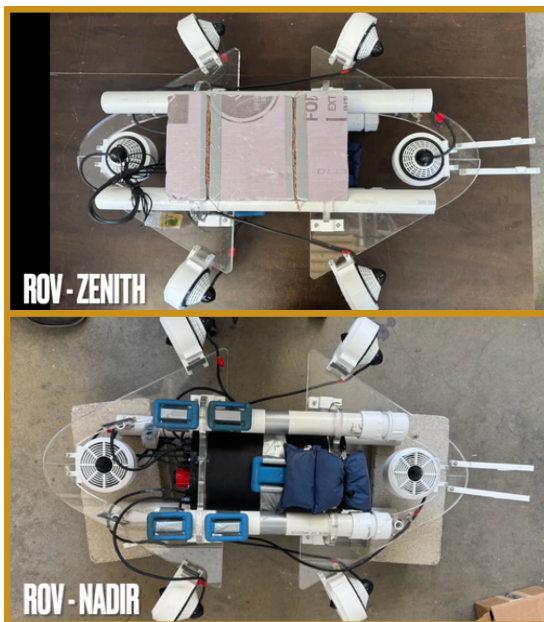


Figure 12: ROV Zenith / Nadir Views

BUOYANCY & BALLAST

The ROV was designed to be as close to neutrally buoyant, with a slight preference for sinking over floating. The intention was to allow for maximum control over the ROV by limiting any movement that is not prompted by the pilot (natural floating and sinking). The design also took into account the fact that some amount of natural movement would be unavoidable in an aquatic environment, so a weight distribution was chosen to ensure that unprompted movement would shift the ROV closer to the objects it would be interacting with rather than away from them (by sinking at a slow, controlled rate that is easy to counteract).

The structure of the ROV was designed around the enclosure, which is the system's largest source of buoyancy. In addition to the electronics and thermal management systems, the enclosure also carries 9.5 liters of air, which contributes about 21 pounds of buoyant force to the system. The tube itself only weighs about 12 pounds, so the additional components on the ROV would need to add up to an additional 9 pounds to achieve neutral buoyancy. The thrusters provided 5 pounds, and the 3 remaining pounds were incorporated into the frame in the form of sand-filled PVC support beams.

After preliminary testing, it was determined that the layout of the ROV did not allow for sufficient control and balance. Having the center of mass and the center of buoyancy both near the geometric center of the ROV prevented self-correcting for changes in pitch and roll. To shift the center of buoyancy upward, floatation foam was added to the top of the ROV. To counteract this added buoyancy and move the center of mass down, additional weights were added at the base of the frame, functioning as supporting feet for the ROV.

PAYLOAD & TOOLS

The ROV comes equipped with several instruments to assist in the completion of tasks, all of which are continuing to be iterated upon to ensure optimal performance. The ROV's manipulator began as a set of stationary hooks that were modelled to fit each of the competition elements. At the time of qualification, a pair of these 3D printed hooks was mounted to the front of the ROV. Each hook had a curved prong for carrying long beams and a longer straight prong for lifting cords and picking up specimens. In the time since qualifying, the team has been working to replace these hooks with a motorized claw that opens and closes with assistance from a single servo.

Additionally, the ROV also carries two cameras to help the pilot with navigation, perform photogrammetry, and complete computer vision tasks.



Figure 13: ROV with Stationary Hooks

MATERIALS

The ROV comes equipped with several instruments to assist in the completion of tasks, all of which are continuing to be iterated upon to ensure optimal performance. The ROV's manipulator began as a set of stationary hooks that were modelled to fit each of the competition elements. At the time of qualification, a pair of these 3D printed hooks was mounted to the front of the ROV. Each hook had a curved prong for carrying long beams and a longer straight prong for lifting cords and picking up specimens. In the time since qualifying, the team has been working to replace these hooks with a motorized claw that opens and closes with assistance from a single servo.

MISSION PLAN

Our mission planning is structured in order to maximize the number of tasks completed. This is achieved through task ordering that starts simple and grows progressively more complicated. It also takes into account task time. For example, the Iceberg tracking task requires a risk analysis. As such, the inspection and measurements conducted by the ROV are completed as soon as the ROV enters the water, to ensure sufficient time to assess the iceberg risk. These considerations minimize the number of tasks 'left on the table' so to speak. Effects on other tasks are also considered. In the Basin Tank, the retrieval buoy will only be released after at least 10 minutes have passed. This ensures that the buoy tether does not interfere with the ROV while it attempts to complete other tasks in the area. Note due to the current lack of devices such as the buoy anchor spool system, certain tasks will not be attempted. This may change if the necessary hardware is developed in time for the product demonstration.



Figure 14: Successful ROV Task Run

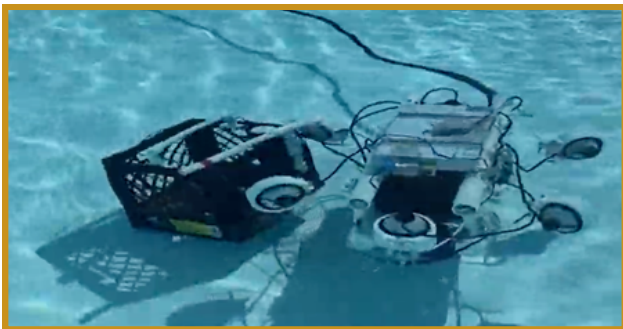


Figure 15: ROV Attempting a Task

TASK ORDER

The current proposed ordering for each venue is as follows:

Flume Tank (15 min)

1. Task 2.2 - Survey Iceberg
 - a. Survey Iceberg Base
 - b. Measure keel depth
2. Task 1.2 Model Coral
 - a. Measure Coral Length
 - b. Begin scaling the 3D model
3. Task 2.1 - Count Invasive Crabs
4. Task 1.1 - Collect Coral Species
5. Task 1.3 - Maintain Position in Current

Offshore Engineering Basin Tank (15 min)

1. Task 3.2 Remove the Oil Platform cover
2. Task 2.5 - Recover the old EDNA sensor
3. Task 2.5 - Install the new EDNA sensor
4. Task 2.3 - Release the retrieval buoy
5. Task 3.2 - Retrieve the power connector
6. Task 3.2 - Lay the power connector through the waypoint
7. Task 3.1 - Place the Bubble curtain
8. Task 3.1 - Install the micropile
9. Task 2.5 - Connect the EDNA sensor to the observatory.

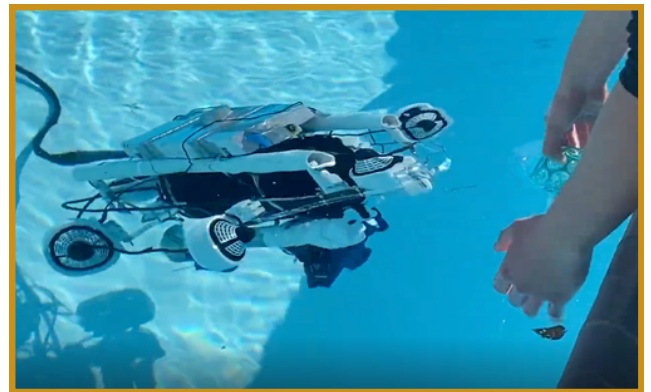


Figure 16: Successful ROV Task Run

OUR FLOAT PROFILING SYSTEM USES TWO ADAFRUIT FEATHER RP2040 RFM69 BOARDS COMMUNICATING OVER A 915 MHZ RADIO LINK. BOTH UNITS USE THE ADAFRUIT FEATHER RP2040 RFM69, INTEGRATING AN RP2040 DUAL-CORE ARM CORTEX-M0+ PROCESSOR (264 KB SRAM, 8 MB FLASH) WITH AN ONBOARD RFM69HCW 915 MHZ RADIO TRANSCEIVER. THE UNDERWATER UNIT INTERFACES WITH AN MS5837 PRESSURE AND DEPTH SENSOR OVER I2C VIA A STEMMA QT CABLE, PROVIDING THE PRESSURE (0-30 BAR, 0.2 MBAR RESOLUTION) AND DEPTH READINGS. FLUID DENSITY IS CONFIGURED TO 997 KG/M³ FOR FRESHWATER TESTING. THE UNDERWATER UNIT IS POWERED BY A SINGLE-CELL LIPO BATTERY VIA THE FEATHER'S JST CONNECTOR WITH AN ONBOARD 3.3 V REGULATOR SUPPLYING ALL PERIPHERALS. THE TOPSIDE UNIT IS POWERED OVER USB.

ON STARTUP, THE UNDERWATER FIRMWARE ALLOCATES A 1000-PACKET HEAP BUFFER (16 KB). EACH LOOP ITERATION READS PRESSURE AND DEPTH FROM THE MS5837 AND STORES A SENSOR PACKET (THAT HOLDS MILLISECOND TIMESTAMPS, PRESSURE, AND DEPTH DATA) INTO THE BUFFER. THE FLOAT DOES NOT TRANSMIT DATA WHILE THE DEPTH EXCEEDS 0.1 M. DURING THIS TIME, IT ONLY LOGS DATA AS 915 MHZ RADIO DOES NOT PROPAGATE THROUGH WATER. ON SURFACING, THE FULL BUFFER IS FLUSHED OVER RFM69 RADIO ONE PACKET AT A TIME, FOLLOWED BY LIVE STREAMING OF CURRENT READINGS. IF THE BUFFER FILLS, THE HEAP IS AUTOMATICALLY DOUBLED IN CAPACITY. AT ONE SAMPLE PER SECOND THE INITIAL 1000-PACKET BUFFER IS ABLE TO STORE APPROXIMATELY 16 MINUTES OF DATA.

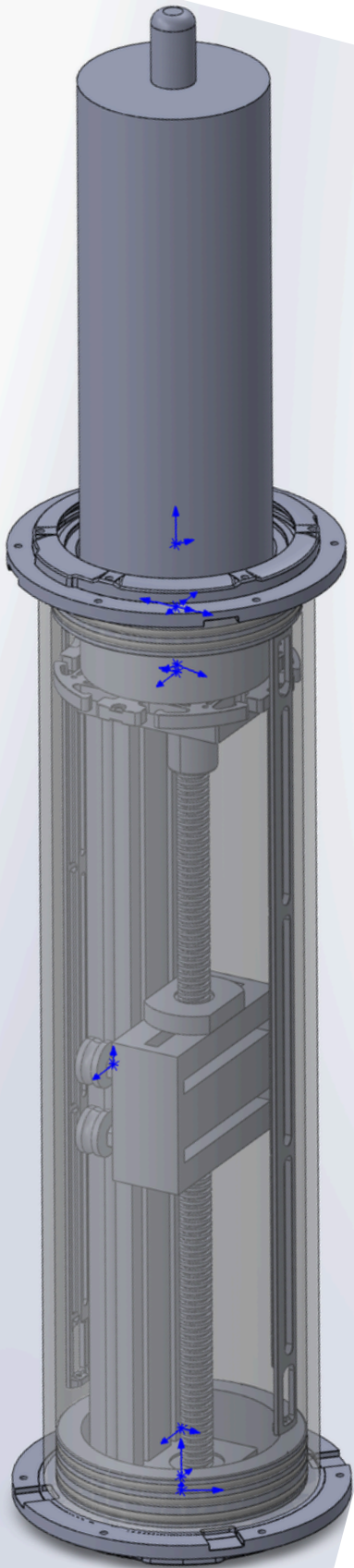
THE TOPSIDE FIRMWARE RECEIVES EACH PACKET, VERIFIES ITS LENGTH, AND OUTPUTS STRUCTURED SERIAL DATA AT 115200 BAUD PREFIXED WITH LIVE OR BUFFERED BASED ON THE PACKET TIMESTAMP. THE SURFACE PYTHON APPLICATION PARSES THE SENSOR PACKETS AND CREATES LIVE PRESSURE AND DEPTH PLOTS, WITH BUFFERED DIVE HISTORY SHOWN AS DASHED LINES AND LIVE DATA AS SOLID LINES.

SAFETY REQUIREMENTS VERIFICATION

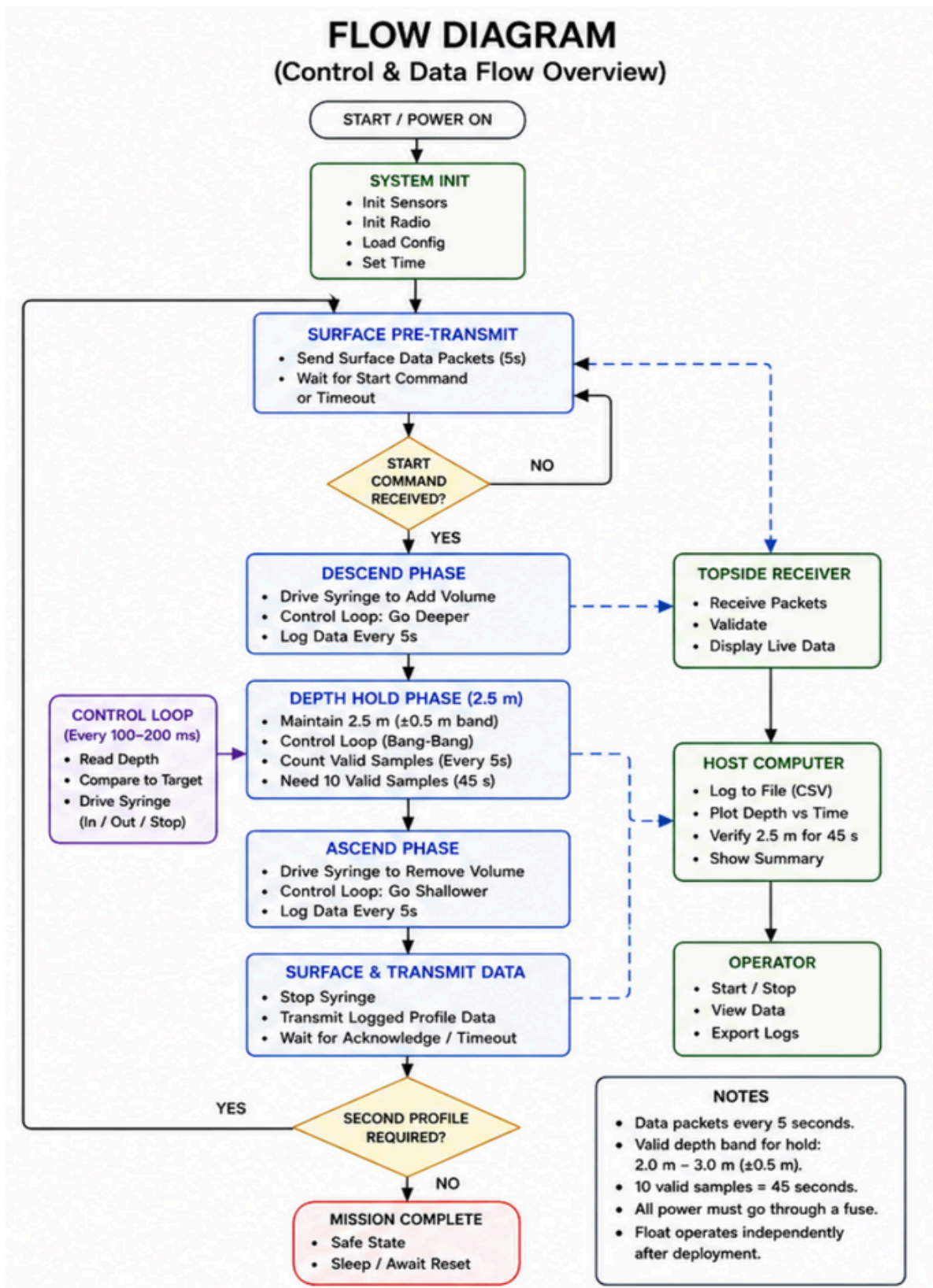
- ELEC-NRD-001:** THE UNDERWATER FLOAT IS POWERED BY A SINGLE-CELL LIPO BATTERY (3.7 V NOMINAL), REGULATED TO 3.3 V ONBOARD. ALL VOLTAGES REMAIN UNDER THE 12 VDC MAXIMUM RESTRICTION.
- ELEC-NRD-002:** THE FLOAT DOES NOT UTILIZE ANY THRUSTERS OR CAMERAS. ALL VERTICAL MOTION IS ACCOMPLISHED BY THE MECHANICAL BUOYANCY ENGINE.
- ELEC-NRD-003:** WHERE THE BATTERY IS HOUSED
- ELEC-NRD-004:** A FUSE IS PLACED IN SERIES WITH THE BATTERY POSITIVE TERMINAL TO PREVENT EXCESS CURRENT DRAW, SIZED TO THE MEASURED FULL LOAD CURRENT OF THE SYSTEM.
- ELEC-NRD-005:**

MODE	FULL LOAD AMPS (MA)
LOGGING (RADIO OFF)	< 50
TRANSMITTING (RADIO ON)	~130

ELEC-NRD-006: ON MEMORY ALLOCATION AND REALLOCATION FAILURE, THE FIRMWARE STOPS IMMEDIATELY WITH A SERIAL ERROR MESSAGE. ON RADIO OR SENSOR INITIALIZATION FAILURE, THE FIRMWARE STOPS, PREVENTING OPERATION IN AN UNDEFINED STATE.



FLOAT FLOW DIAGRAM



BUILD VS. BUY VS. USED

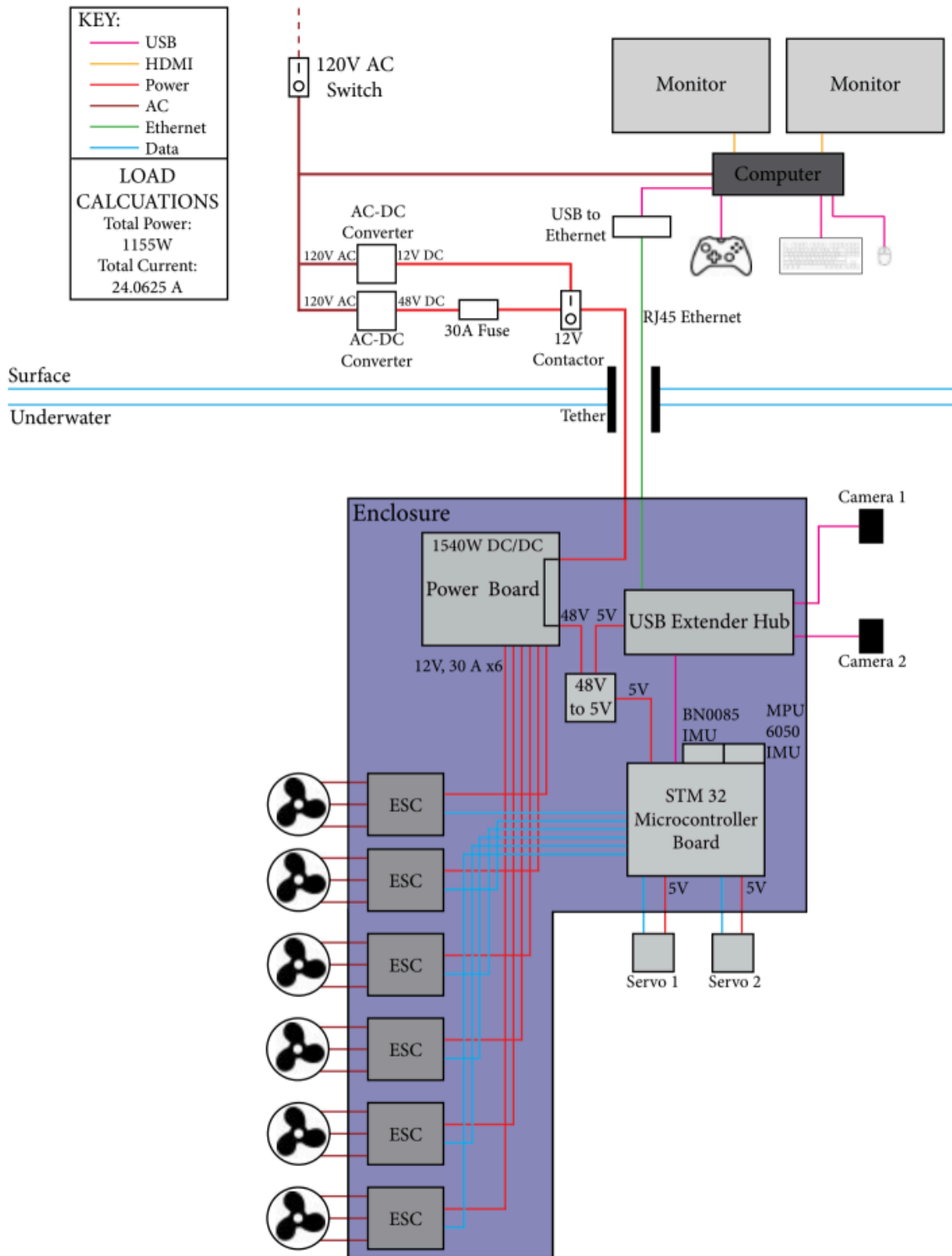
Throughout development, the team balanced custom-built systems with commercially available components in order to maximize reliability, reduce costs, and improve overall vehicle performance. Commercially purchased systems such as thrusters, cameras, communication hardware, and enclosure components were selected for their proven reliability and ease of integration.

Custom-built systems—including the PCB stack, internal electronics mounts, thermal management system, and portions of the frame and tooling—were designed in-house to improve modularity, organization, and subsystem integration. Whenever possible, components and materials from previous competition seasons were reused to reduce project costs while still meeting the performance requirements of the vehicle.

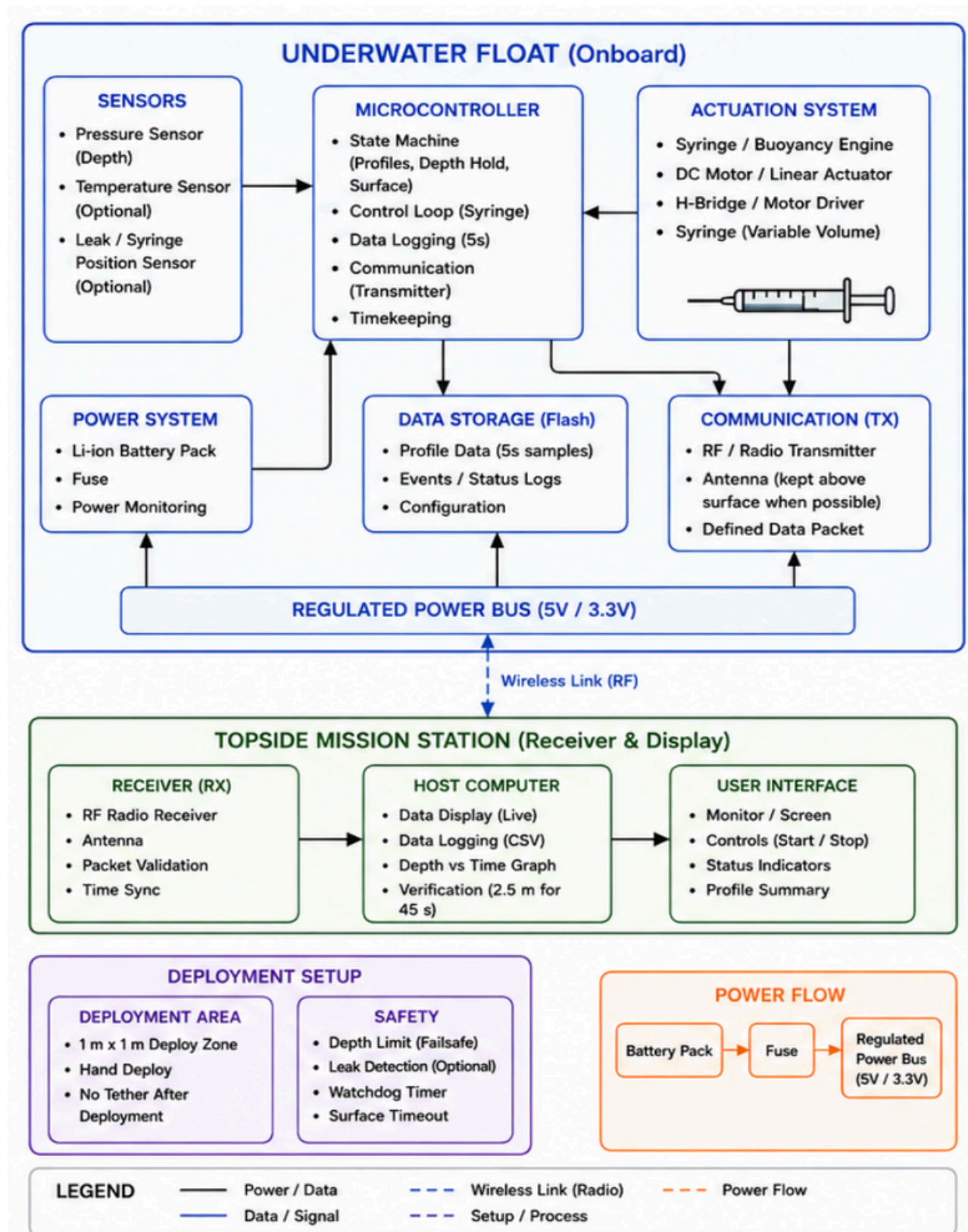
BUILD vs. BUY NEW vs. REUSED									
SUBTEAM	PART	LINK	BUILD / BUY	NEW / REUSED	JUSTIFICATION FOR STATUS	COST	DOLLAR VALUE	TOTAL COST	TOTAL PRODUCT VALUE
MECHANICAL	Waterproof Enclosure	https://www.polycase.com/zq-080804#ZQ-080804-13	BUY	NEW	BUY: last year's was built, had major structural issues; in the interest of getting a working design waterborne, decided to offload the work onto a manufacturer, that way we can focus our efforts on manufacturing and designing other more technically involved aspects of the ROV NEW: last year's enclosure is broken, so we automatically had to get a new one in order to have a functional ROV	\$60.00	\$60.00	\$1,932.20	\$4,142.52
	T200 Thrusters [SPONSORED]	https://bluerobotics.com/cart/	BUY	NEW	BUY: building these would be cool, but ultimately too many points of failure without better manufacturing equipment NEW: were able to get better thrusters (compared to the T100's) through donation, might as well use them!	\$0.00	\$1,880.00	REMAINING FUNDS:	
	PolyMax PETG [SPONSORED]	https://us.polymaker.com/products/polymax-petg	BUY	NEW	BUY: not entirely sure how we'd manufacture this; melting down previous prints would be much less cost effective (energy cost) NEW: same justification as for "BUY"	\$0.00	\$180.32	\$2,067.80	
	Acrylic Stock [2' x 4', 2" thick]	https://www.centralcoastplastics.com/all-items/pi/premium-clear-acrylic-sheet	BUY	NEW	BUY: needed stock to allow for freedom to alter frame design from last year's; didn't pay for laser cutting but had to pay for the material NEW: old stock was not machinable	\$120.00	\$120.00		
	Waterproof Enclosure (Tube)	https://bluerobotics.com/store/waterlight-enclosures/wte-vp/	BUY	NEW	BUY: The team did not have any prior experience with waterproofing and had already experimented with modifying cheaper bought enclosures and upgrading custom enclosures from previous years. Eventually decided to buy a new enclosure to ensure the safety of our electronics and allow the mechanical team to focus on other ROV systems. NEW: We did not have a working enclosure from a previous year to use as a starting point. This decision was only made after trying to repair past enclosures	\$1,000.00	\$1,000.00		
	Frame (Acrylic and PVC)		BUILD	REUSE?	BUILD: The frame of the ROV needed to be designed to accommodate our tube enclosure, thruster layout, and mission tooling. The frame would be more customizable if it was built in-house, and it doesn't require any specialty tools to manufacture. REUSE: The frame design was completely new, but many of the materials were reused as a cost-saving measure. The purchased acrylic stock mentioned above was modified from another design, and the PVC pipes and additional acrylic were found from previous years' stock	\$0.00	\$150.00		
	Underwater Cameras		BUILD	NEW	BUILD: The base of each camera was a store-bought webcam, which did not come waterproof. These cameras were dismantled, flooded with epoxy and/or silicone, then potted in new containers. This option was chosen over buying a pre-waterproofed camera in order to save money and get the team more experience with waterproofing. NEW: The cameras that had been used in past years were damaged from corrosion and could not receive signals.	\$90.00	\$90.00		
	IP68 Waterproof Servo		BUY	NEW	BUY: Buying a servo that was already rated to be waterproof to some extent gave the team a head start on sealing the system and allow them to focus more on the design of the actual claw rather than preventing a leak in the servo. NEW: Our old servos drew excessive current and were too powerful for the tasks they would need to perform. New servos were selected to better align with electrical requirements.				

ELECTRICAL	5 x MCU PWR Board	[schematic in Fusion drive]	BUY	NEW	BUY: We designed these PCBs in-house but needed to have them manufactured by a company, since our team does not have the requisite equipment to manufacture PCBs. NEW: Same justification as "buy"; no preexisting designs.	\$4.00	\$4.00
	3 x MCU Board	[schematic in Fusion drive]	BUY	NEW	BUY: Designed in-house, NEW: h	\$52.80	\$52.80
	5 x ESC Board	[schematic in Fusion drive]	BUY	NEW	BUY: h NEW: h	\$70.76	\$70.76
	5 x MAIN PWR Board	[schematic in Fusion drive]	BUY	NEW	BUY: h NEW: h	\$89.30	\$89.30
	2 x Pre-Assembled MCU Board	[schematic in Fusion drive]	BUY	NEW	BUY: h NEW: h	\$180.50	\$180.50
	PCB Shipping Costs + Tariffs	N/A	N/A	N/A	N/A	\$264.84	\$264.84

ROV SID (SYSTEM INTEGRATION DIAGRAM)



NON ROV SID (SYSTEM INTEGRATION DIAGRAM)



SAFETY

To ensure the safety of team members during the design and manufacturing of the ROV, all students are required to complete Cal Poly machine shop safety certifications before operating hazardous equipment. Team members must complete certification training for hand tools and basic shop equipment such as drill presses prior to participating in manufacturing operations. Students who wish to operate advanced equipment—including mills, lathes, or welding equipment—must complete additional hands-on training courses specific to each machine. Team members operating CNC machinery are required to complete an extended multi-session certification course before use.

Additional safety procedures are required for team members participating in vehicle testing and competition operations. Since operators and poolside personnel interact directly with the ROV, tether, and electrical systems during deployment, all competition members attend operational safety briefings covering potential hazards, emergency procedures, tether handling, waterproofing precautions, and electrical safety protocols. These briefings ensure that all operators understand both the risks associated with underwater vehicle operation and the procedures used to mitigate those risks during testing and competition.

Additional Safety notes and processes are noted in Appendix A.

Safety procedures are monitored and updated within our Company Safety Evaluation and Job Site Safety Analysis.

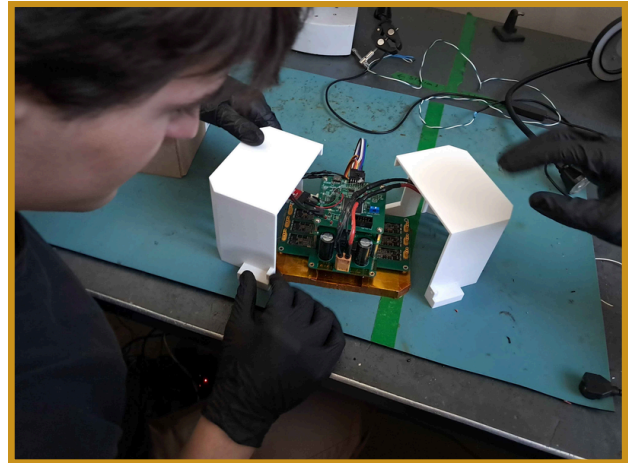


Figure X: PPE utilized while working on delicate ROV parts

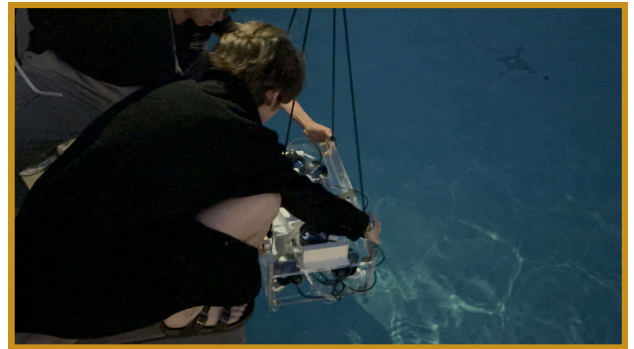


Figure X: ROV Safely being lowered into the testing pool.



Figure X: PPE being utilized while working on the Acrylic Frame

ACCOUNTING BUDGET

Revenue	\$0.00	\$19,500.00
Line Item	Budgeted 24-25	Budgeted 25-26
Public Support	\$0.00	\$19,500.00
Businesses		\$6,000.00
School		\$4,000.00
Individual		\$500.00
Grants		\$9,000.00
Fundraisers	\$0.00	\$0.00
N/A	N/A	N/A
Other Income	\$0.00	\$0.00
Uniform Contributions		
Specialty Apparel		

The team developed a detailed budget at the start of the competition season to allocate resources efficiently across mechanical, electrical, firmware, software, manufacturing, and travel expenses.

Budget planning emphasized cost-effective engineering decisions, subsystem reliability, and the reuse of existing components whenever possible. Funding for the project was supported through school funding, grants, sponsorships, and donations.

Throughout development, careful accounting practices were maintained to clearly distinguish between purchased, reused, donated, and manufactured components while ensuring responsible use of available funds.

Shown above and on the right are the approximated Revenue and Expense items for the 2025-2026 fiscal year.

Estimates were made for a 10 person travel team and with limited fundraising opportunities in mind.

Expenses	\$0.00	\$19,300.00
Line Item	Budgeted 24-25	Budgeted 25-26
ROV Costs	\$0.00	\$6,100.00
Mechanical		\$4,000.00
Electrical		\$1,500.00
Firmware		\$500.00
Software		\$100.00
Construction Costs	\$0.00	\$450.00
Field Elements		\$150.00
Tools and Equipment		\$150.00
Consumables		\$150.00
World Championship	\$0.00	\$10,900.00
Hotel Costs		\$1,500.00
Flights		\$8,000.00
Rental Vehicles		\$700.00
Equipment		\$500.00
Parking		\$200.00
Fundraiser Costs	\$0.00	\$0.00
N/A	N/A	N/A
Business Costs	\$0.00	\$900.00
Uniforms		\$300.00
Specialty Apparel		\$500.00
Office Supplies		\$50.00
Subscriptions		\$0.00
Publicity		\$50.00
Competition	\$0.00	\$700.00
Regional Competition		\$200.00
World Championship		\$500.00
Fuel		\$250.00

Revenue	Funding we expect to receive throughout the 2025-26 season
Line Item	
Public Support	Category: Money donated to the team from companies, Cal Poly, individuals, or grants. (In kind not noted)
Businesses	Donations from local businesses and companies
School	Funding given to us through Cal Poly
Individual	Funding received through individuals
Grants	Funding received through company / school grants
Fundraisers	Category: Money raised from team fundraisers
N/A	
Other Income	Category: Additional Avenues of funding (Primarily through Apparel repayments)
Uniform Contributions	Revenue from apparel reimbursements
Specialty Apparel	Revenue from apparel reimbursements
Expenses	Amount we expect to spend during the 2025-26 season
Line Item	
ROV Costs	Category: All costs related to subteam specific work and ROV / Float construction
Mechanical	Costs related to the mechanical subteam
Electrical	Costs related to the electrical subteam
Firmware	Costs related to the firmware subteam
Software	Costs related to the software subteam
Construction Costs	Category: Costs related to tools, consumable items, and field element construction
Field Elements	PVC pipe and additional materials needed to construct the competition field elements
Tools and Equipment	Any additional tools / equipment that needs to be purchased to construct the ROV
Consumables	Consumable equipment (Shop Towels,
World Championship Travel	Category: All costs related to world championship travel
Hotel Costs	Worlds Hotel Costs
Flights	Worlds Flight Costs
Rental Vehicles	Costs for worlds rental cars
Equipment Transportation	Costs to either ship or transport the ROV to the competition
Parking	Costs for parking permits
Fundraiser Costs	Category: Costs to put on / plan fundraiser events
N/A	
Business Costs	Category: Costs that are non-rov related but needed
Uniforms	Team uniforms (Required competition outfits)
Specialty Apparel	Team apparel that is not required for team members
Office Supplies	Any needed office supplies
Subscriptions	Subscription costs for programs the team utilizes
Publicity	Costs for team banners, flyers,
Competition Registration	Category: Costs to register for MATE events
Regional Competition	Registration for Regional Events
World Championship	Registration for the World Championship
Fuel	Fuel costs or reimbursements

ACKNOWLEDGEMENTS

We would like to thank Dr. Siavash Farzan and Dr. John Seng for their guidance, support, and contributions throughout the development of our company and ROV.

We would also like to thank MOUSER Electronics, the Cal Poly Mechanical Engineering Discretionary Funds Allocation Committee, MATE ROV Competition, and the Marine Technology Society for their sponsorship, funding, and continued support of our company. Their contributions helped make the design, construction, and testing of our ROV possible.



APPENDIX A: JOB SITE SAFETY ANALYSIS

Incident Prevention / Issue Awareness

Hazard Type	Risk of Injury & Details	Prevention Measures
ROV Tether	Medium Risk. The ROV tether is attached between the back of the ROV and back of the drivers station. It runs between the pool and drivers station creating a tripping hazard for any members of the drive team.	Team members are instructed not to run near the tether or step over it (except the tether manager when required). The tether manager ensures there are no loops that could catch limbs and checks for damaged wires before approaching the pool. If tether damage is reported, power is shut off immediately.
Water Leaks / Spills	Medium Risk. The ROV is waterproofed, but seal failures may still occur. Water entering the electronics could expose drivers or team members to electrical hazards or release current into the pool. Water carried from the ROV may also spill onto nearby equipment and create safety hazards.	If water intrusion is suspected, all connected power sources are immediately turned off before handling the ROV. Equipment is inspected before launch to ensure enclosures are properly sealed. The ROV is dried with towels or blankets before storage or transport to prevent water damage to nearby electronics and work areas.
Scrapes / Cuts / Bruises from Contact with ROV	Medium Risk. The ROV may cause injuries through exposed propellers, sharp frame edges, or accidental drops. Team members could receive cuts, scrapes, or bruises during repairs, testing, deployment, or retrieval. Hand injuries are also possible if thrusters are touched while powered.	Competition-approved shrouds and finger guards are installed over all motors and thrusters. Team members are instructed not to touch thrusters while power is on. All protruding edges and frame components are deburred and sanded to reduce injury risks. During startup, members stand clear of the ROV while the pilot announces "Power On."
Slipping	High Risk. Pool environments naturally create wet and slippery surfaces. Combined with limited workspace, cables, tethers, and equipment on the pool deck, slipping and tripping hazards are increased.	Team members are required to follow pool safety rules, including no running on the pool deck and maintaining awareness of surroundings. Members avoid stepping over cables or tether lines and maintain safe distances from people carrying the ROV. Non-slip or water-resistant footwear is recommended.
Falling into Pool / Drowning	High Risk. Launching and retrieving the ROV requires members to work near the edge of the pool, creating a drowning hazard if someone slips or loses balance.	Multiple team members assist during launch and retrieval to maintain stability and safe positioning. Members avoid leaning over the edge of the pool while deploying or retrieving the ROV. Team members involved in poolside operations are expected to be capable swimmers, while non-swimmers remain away from the pool edge.
Lifting ROV / Carrying Equipment	Low Risk. Transporting the ROV, driver station, and power systems may cause muscle strain or equipment related injuries. The combined equipment weight is approximately 20 kg distributed across the team.	Equipment is transported either in totes or distributed among 5–6 team members to reduce lifting strain. Proper lifting posture is required during transportation, deployment, and retrieval. Team members maintain safe spacing while carrying equipment, and wires and tethers are secured together to prevent snagging.
Electrical Related Hazards	Soldering Iron – Medium Risk. Soldering irons produce high temperatures and fumes that may cause burns or respiratory irritation. Electrocution – High Risk. Electrical systems near water create a significant electrocution hazard. Exposed Wires / Circuits – High Risk. Damaged or exposed wiring may energize surrounding water or equipment.	Helping hands and proper soldering procedures are used to reduce burn risks. During inspections, the ROV remains powered off until cleared for operation. All electrical connections are checked before launch, and exposed wires are repaired immediately. Equipment near water is positioned away from fluids whenever possible. The pilot ensures no one is touching the ROV during startup and verbally announces "Power On" before energizing the system.
Mechanical Related Hazards	Motors / Thrusters – Medium Risk. Spinning propellers and moving components may injure nearby team members during testing or operation. Tools – Medium Risk. Saws, PVC cutters, wire cutters, and other tools may cause cuts or injuries if improperly used.	Motors are tested only with shrouds attached whenever possible, and members stand clear during powered testing. Team members receive training on proper tool usage and wear gloves or protective equipment when appropriate during repairs or fabrication.
Natural Disasters / Emergencies	High Risk. Although uncommon, emergencies such as severe weather, venue incidents, or city-wide emergencies require preparedness during travel and competition activities.	The team maintains an emergency response and meeting plan with designated gathering locations depending on the situation. Team members travel in groups to ensure accountability and support during emergencies.

ROV Deployment JSA

Step	Task	Potential Hazards	Control	Responsible Person(s)
Pre-Launch	Transportation of ROV	Tripping/Slipping	No running on the pool deck Avoid stepping over cables Maintain a safe distance from people carrying ROV	Team Lead
		Muscle Strain	Use proper lifting posture	
	Equipment Check	Electrocution	Keep ROV powered off during inspection Check that enclosures are sealed before bringing ROV near water	Electrical Lead
	Tether Setup	Tripping	No running near tether Avoid stepping over tether (tether manager exempt)	Tether Manager
		Electrocution	Ensure all connections are secure Check for damaged wires before approaching the pool	
		Entanglement	Ensure there are no loops in the tether that can catch limbs	
Launch	Startup	Electrocution	Ensure nobody is in contact with the ROV during startup Equipment check must be completed before starting up Driver will call out "Power On" to warn others to stand back	Pilot
		Hand Injury	Do not touch thrusters while power is on Finger guards must be securely attached while power is on	
	Tether Management	Tripping	Maintain a safe distance from the tether (tether manager exempt)	Tether Manager
		Electrocution	Shut off power as soon as any tether damage is reported	
		Entanglement	Ensure there are no loops in the tether that can catch limbs	
	Deployment of ROV	Muscle Strain	Use proper lifting posture	Tether Manager
		Drowning	Do not lean over the edge of the pool while deploying the ROV Ensure a lifeguard is present while using the pool	
Retrieval	Removal of ROV from Water	Muscle Strain	Use proper lifting posture	Tether Manager
		Hand Injury	Do not grab thrusters while retrieving the ROV Finger guards must be securely attached while power is on	
		Drowning	Ensure a lifeguard is present while using the pool	
	Exiting Pool Area	Tripping/Slipping	No running on the pool deck	Team Lead

Pre-Deployment Checklist

Power OFF

- ☐ Check that O-rings are not damaged and enclosures are properly sealed
- ☐ Check for loose/disconnected wires
- ☐ Ensure that finger guards are securely attached to all thrusters
- ☐ Check that all bolts are securely attached
- ☐ Check for cracks in acrylic enclosures

Power ON (in water)

- ☐ Check for bubbles, remove ROV from water if leaks are detected
- ☐ Verify that thrusters run properly
- ☐ Verify that controls are oriented properly

APPENDIX B: COST ACCOUNTING

The team maintained detailed accounting records throughout the design and manufacturing process to track project spending, reused components, and donated materials. Budget planning prioritized reliability, waterproofing, electrical redesign, and subsystem testing while remaining within the team's available funding resources.

Whenever possible, components and materials from previous competition seasons were reused to reduce overall development costs without sacrificing performance. Commercially purchased components were selected when proven reliability and ease of integration outweighed the benefits of in-house manufacturing.

A significant portion of this year's budget was allocated toward electrical system redesign, waterproofing development, manufacturing materials, and travel expenses for the MATE World Championship. Detailed accounting tables were maintained to distinguish between purchased, reused, donated, and manufactured components throughout development.

BUILD vs. BUY NEW vs. REUSED										
SUBTEAM	PART	LINK	BUILD / BUY	NEW / REUSED	JUSTIFICATION FOR STATUS	COST	DOLLAR VALUE	TOTAL COST	TOTAL PRODUCT VALUE	
MECHANICAL	Waterproof Enclosure	https://www.polycase.com/zq-080804#ZQ-080804-13	BUY	NEW	BUY: last year's was built, had major structural issues; in the interest of getting a working design waterborne, decided to offload the work onto a manufacturer, that way we can focus our efforts on manufacturing and designing other more technically involved aspects of the ROV NEW: last year's enclosure is broken, so we automatically had to get a new one in order to have a functional ROV	\$60.00	\$60.00	\$1,932.20	\$4,142.52	
	T200 Thrusters [SPONSORED]	https://bluebotics.com/cart/	BUY	NEW	BUY: building these would be cool, but ultimately too many points of failure without better manufacturing equipment NEW: were able to get better thrusters (compared to the T100's) through donation, might as well use them!	\$0.00	\$1,880.00	REMAINING FUNDS:		
	PolyMax PETG [SPONSORED]	https://us.polymaker.com/products/polymax-petg	BUY	NEW	BUY: not entirely sure how we'd manufacture this; melting down previous prints would be much less cost effective (energy cost) NEW: same justification as for "BUY"	\$0.00	\$180.32	\$2,067.80		
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	Frame (Acrylic and PVC)		BUILD	REUSE?	BUILD: The frame of the ROV needed to be designed to accommodate our tube enclosure, thruster layout, and mission tooling. The frame would be more customizable if it was built in-house, and it doesn't require any specialty tools to manufacture. REUSE: The frame design was completely new, but many of the materials were reused as a cost-saving measure. The purchased acrylic stock mentioned above was modified from another design, and the PVC pipes and additional acrylic were found from previous years' stock	\$0.00	\$150.00			
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	5 x ESC Board	[schematic in Fusion drive]	BUY	NEW	BUY: h NEW: h	\$70.76	\$70.76		
	5 x MAIN PWR Board	[schematic in Fusion drive]	BUY	NEW	BUY: h NEW: h	\$89.30	\$89.30		
	2 x Pre-Assembled MCU Board	[schematic in Fusion drive]	BUY	NEW	BUY: h NEW: h	\$180.50	\$180.50		
	PCB Shipping Costs + Tariffs	N/A	N/A	N/A	N/A	\$264.84	\$264.84		

APPENDIX C: REFERENCES

[1] MATE ROV Archive - PurdueROV. (n.d.).
https://20693798.fs1.hubspotusercontent-na1.net/hubfs/20693798/EX22%20Purdue_PurdueROV_SpecSheet_2024.pdf

[2] MATE ROV Archive - UniversityofWashington ... (n.d.-a).
https://20693798.fs1.hubspotusercontent-na1.net/hubfs/20693798/2024_TechnicalDocumentation_EXPNRN_Scoring_Criteria_v0-1.pdf

[3] MATE ROV Archive - AlexandriaUniversity ... (n.d.-a).
https://20693798.fs1.hubspotusercontent-na1.net/hubfs/20693798/2024_TechnicalDocumentation_EXPNRN_Scoring_Criteria_v0-1.pdf