AQUACATS

CUESTA COLLEGE

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2025 ROV Technical Documentation

Table of Contents

Abstract

The AquaCats Robotics Team is a first year Pioneer company composed of students from Cuesta College in San Luis Obispo, California. Their vehicle, the *Seapounce*, was engineered to meet mission challenges focused on marine renewable energy, environmental restoration, and underwater archaeology.

This year's design process emphasized reliability, affordability, and simplicity. The team adapted a Blue Robotics-inspired Eagle Ray frame with modular improvements, including a waterproofed claw and a custom-coded Python control interface.

Through iterative testing, team collaboration, and innovation in both hardware and software, the AquaCats have developed a robust, mission-ready ROV that reflects the engineering values of safety, performance, and responsible design.

Figure 1: Cuesta AquaCats team photo

Company Overview and Project Management

The AquaCats Robotics Team operates as a student-led engineering company within Cuesta College. Our multidisciplinary team includes students from biology, engineering, and computer science programs. The team is organized into four departments — mechanical, software, safety, and marketing — each led by a designated sub-team leader.

Our CEO coordinates overall strategy, timelines, and communication with mentors. Each department works semi-independently while reporting to leadership through weekly stand-up meetings and a shared digital workspace (Discord and Google Drive). This structure promotes accountability and rapid prototyping while allowing for cross-functional innovation.

The team meets in person once once per week and maintains asynchronous collaboration between meetings.

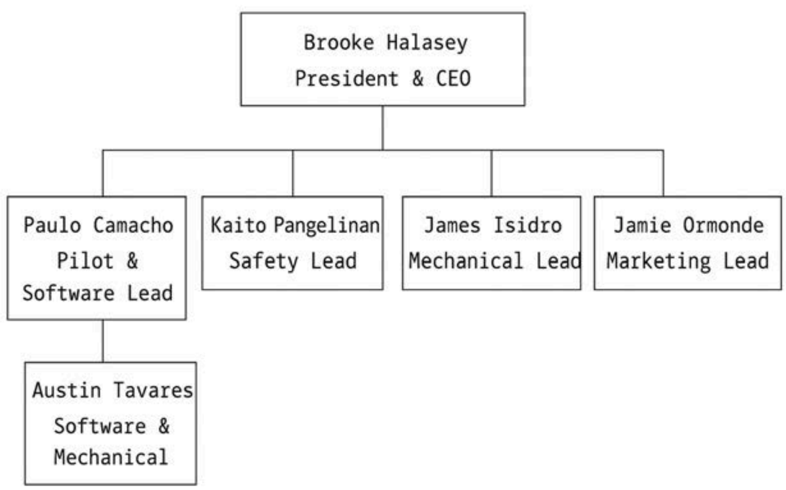

Figure 2: Cuesta AquaCats Team Organization

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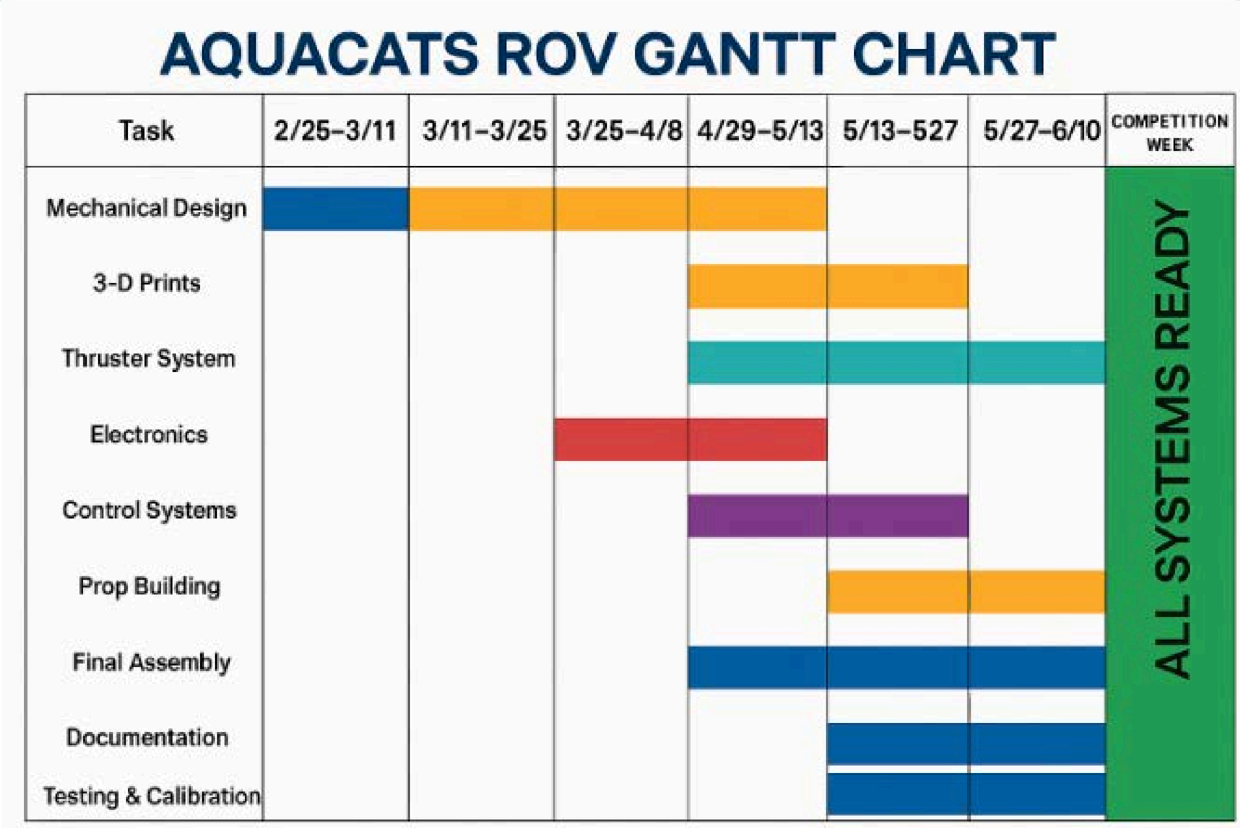

Figure 3: Cuesta AquaCats GANTT chart (timeline of events)

Safety Philosophy

The AquaCats team prioritizes safety in every stage of the ROV development process — from design and fabrication to testing and operation. Our safety protocols follow MATE's safety guidelines and OSHA best practices, ensuring the wellbeing of all team members, mentors, and equipment. Each team member was trained in the proper use of tools, personal protective equipment (PPE), and emergency procedures before beginning work on the ROV.

Workplace Safety and Procedures

Our team is committed to maintaining a safe and organized working environment to protect all members, including students, mentors, and guests. We adhere to a structured set of safety protocols derived from best practices in ROV construction, electronics handling, and underwater operations. These procedures are integrated into our daily workflow and rigorously enforced to minimize risk and promote a culture of safety.

Key Safety Measures

- **Personal Protective Equipment (PPE):** Team members are required to wear appropriate PPE—including gloves, safety goggles, and masks—when performing tasks such as soldering, applying epoxy, or handling potentially hazardous materials. This ensures protection from fumes, particulates, and burns.

- **Power Disconnection Protocol:** The ROV remains completely disconnected from any power source during wiring, maintenance, or mechanical adjustments. This eliminates the risk of electrical shock or accidental activation of moving components.

- **Safety Observer Requirement:** The ROV is only powered when at least one designated safety observer is present. The observer is responsible for monitoring the work area and ensuring immediate response in case of emergency.

- **Work Area Organization:** The workspace is kept clear of unnecessary tools, wires, and materials to minimize tripping hazards and ensure quick evacuation routes in case of an emergency.

- **Vacuum Testing:** Before any pool testing, a vacuum test is conducted on the ROV's electronics canister to ensure all housings are properly sealed. The canister must maintain a vacuum pressure for a minimum of 5 minutes without significant loss, confirming its waterproof integrity.

- **Thruster Safety:** All thrusters are equipped with protective guards to prevent accidental contact with spinning propellers. Before activation, each thruster is checked to confirm it is unobstructed and securely mounted.

- **Tether Management:** The tether is secured using strain relief mounts on both the ROV and surface ends. This reduces stress on internal wiring and prevents disconnection or damage during operation.

- **Component Inspection:** Prior to deployment, a visual inspection is performed on all wiring, connectors, and electronic components to identify any signs of wear, corrosion, or loose connections. This helps prevent electrical faults and ensures system reliability.

- **Battery and Power Verification:** Battery voltage levels are checked to ensure they are within safe operating range before connection. This prevents electrical surges or power instability during operation.

- **Emergency Response Preparedness:** A clear emergency power-off plan is in place and reviewed by all team members. Roles are assigned to ensure fast and coordinated action in case of an electrical failure, water leak, or personnel injury.

- **Safety Checklist Protocol:** A printed and laminated safety checklist is reviewed and signed by responsible team members before each deployment. This checklist includes verification of mechanical integrity, electrical safety, watertightness, and emergency procedures.

Conclusion

Our team prioritizes safety in every phase of design, construction, and testing. By integrating structured protocols and fostering accountability, we ensure the wellbeing of our team and the reliability of our ROV in all operating conditions.

Engineering Design Rationale

The Cuesta AquaCats designed and constructed the SeaPounce ROV from the ground up, using a customized kit inspired by the Eagle Ray platform. In addition to core kit components, the team integrated both commercially sourced parts and custom-designed elements. The frame was precision-cut using a waterjet at Cal Poly, while most 3D-printed components were fabricated either on campus at Cuesta or with Brooke’s Bamboo x1 carbon.

The frame is built from High Density Polyethylene (HDPE), a material with a density similar to water. This choice of material allows the ROV to maintain near-neutral buoyancy with minimal need for additional weight compensation. To enhance retrieval capabilities, the team developed a 5-volt claw capable of gripping and securing objects.

For maneuverability, the SeaPounce employs four T200 thrusters provided by Blue Robotics. Two thrusters are mounted externally to provide vertical lift, while the remaining two are embedded within the frame to allow for horizontal and translational movement.

Vehicle Structure: Frame

The AquaCats designed the frame of our ROV with three core priorities in mind: durability, ease of fabrication, and underwater performance. After evaluating multiple materials, we selected **High-Density Polyethylene (HDPE)** due to its excellent corrosion resistance, ease of machining, and neutral buoyancy — a major advantage for underwater robotics.

To achieve precision and repeatability, the frame components were cut using **waterjet machining**. The HDPE structure combines both solid and hollow segments to balance strength and weight, ensuring rigidity without requiring excessive ballast. This lightweight nature not only improves handling and storage but also supports efficient energy use by minimizing the vehicle's total mass.

We also prioritized modularity in our design. The frame is assembled using **standardized fasteners**, allowing for quick disassembly and maintenance with common tools — a practical feature for both troubleshooting and transport.

From a safety perspective, all edges of the frame were intentionally **rounded** to reduce the risk of injury to users and potential harm to the surrounding marine environment.

This attention to detail ensures that the frame supports both **technical performance and environmental stewardship** in the field.

Figure 4: Cuesta AquaCats HDPE Assembled Frame (cut by waterjet)

Canister

At the center of the ROV frame is a clear acrylic watertight enclosure from Blue Robotics, designed to protect the vehicle's electronic systems during underwater operations. This professionally manufactured canister provides a sealed, pressure-resistant environment for components such as the control board, Arduino, and power distribution systems.

To maintain an effective waterproof seal, the canister uses O-rings as static gaskets, selected for their affordability, reliability, and ease of replacement. The end caps are modular: one is transparent (for camera) and flat, while the other is equipped with ports for cable penetrators, allowing power and signal lines to enter the enclosure without compromising its integrity.

Rather than a custom internal frame, we mounted the electronics to an aluminum plate secured to one of the end caps. This mounting solution offers a stable, durable base for the supply and control boards while allowing for easy removal and servicing of the electronics as a single unit.

This primarily off-the-shelf solution from Blue Robotics ensures our system benefits from proven reliability and high performance in demanding marine environments, while still being adaptable to the specific needs of our ROV.

Figure 5: Cuesta AquaCats Canister (Blue Robotics)

Electrical

The electrical system of *Seapounce* is composed of both topside and onboard components, designed to ensure reliable power delivery and control during underwater operations. The system integrates components provided by MATE, along with custom wiring and layout by AquaCats team members.

At the heart of the onboard system is the Eagle Ray Control Board, which interfaces with the Electronic Speed Controllers (ESCs), supply boards, and supporting DC converters. These components are securely mounted inside a waterproof Blue Robotics acrylic enclosure, which shields the electronics from water and pressure while allowing for organized cable routing through marine-grade cable penetrators.

Figure 6: Cuesta AquaCats Control Board and Power Supply

Topside, *Seapounce* is operated using a standard laptop and Xbox controller, which connect to the control system via USB. Our team opted for the bench power supply, offering consistent 48V DC output for lab testing and pool runs. This decision improved safety, simplified power monitoring, and eliminated the need for battery charging protocols during development.

A 22.9-meter (75-foot) tether connects the topside electronics to the vehicle, delivering both power and data. The tether was strain-relieved at both ends and organized to reduce drag and prevent tangling during operation.

This integrated system allows the pilot and support crew to safely and efficiently operate *Seapounce*, while maintaining full visibility and control over propulsion, camera feeds, and claw actuation during mission tasks.

Software

The ROV control system is built using Python to provide a responsive, user-friendly graphical interface for operating the vehicle. The application integrates video streaming, joystick-based thruster control, and serial communication with an onboard Arduino Mega. It is designed to offer real-time feedback and robust performance in underwater environments.

The software architecture is modular, with separate components for video capture (VideoThread), joystick input (JoystickThread), and Arduino communication (ArduinoThread). Upon launching the application, the main interface initializes a live video feed from the ROV camera, detects an Xbox controller for input, and establishes a serial connection with the Arduino via USB.

The Xbox controller input is continuously read and translated into pulse width modulation (PWM) values, representing full reverse to full forward thrust. These PWM values are formatted as JSON and transmitted to the Arduino, which parses the data and maps it to four motor control outputs corresponding to the ROV's forward, turning, and vertical movement.

The Arduino receives this data via a USB tether and controls the thrusters through standard ESCs (electronic speed controllers), using the Servo library to output precise

PWM signals on digital pins D22, D24, D26, and D28. A delay is incorporated at startup to allow ESCs to arm safely. The control loop is designed for stability and responsiveness, with automatic fallback to neutral when no input is detected.

The application also includes a status bar displaying real-time feedback on joystick connectivity, thrust status, and claw control. This visual confirmation ensures the operator is always informed of the ROV's current state.

This software was custom-developed for our SeaPounce ROV using open-source tools and can be extended to support additional sensors, logging, or autonomous behaviors as needed.

Propulsion

SeaPounce's propulsion system is driven by four **T200 brushless thrusters** from **Blue Robotics**, each powered by a 12V **electronic speed controller (ESC)** and precisely controlled via **PWM signals from an Arduino Mega**. These high-performance thrusters are known for their durability, waterproof design, and high thrust-to-weight ratio, making them an ideal match for underwater robotic applications.

Figure 7: Cuesta AquaCats T200 Thrusters (Blue Robotics)

Thruster Configuration

SeaPounce utilizes a **vectorized X-configuration** to achieve enhanced agility and simplified mechanical design. This layout maximizes degrees of freedom while minimizing component count:

- **2 vertical thrusters** are mounted centrally for lift and descent, contributing to depth stability and pitch control.

- **2 diagonal horizontal thrusters** enable forward/reverse movement and pivot-based turning (yaw control).

This configuration provides **three to four degrees of freedom** with just four thrusters, balancing functionality with system simplicity and power efficiency.

Hardware Advantages

Each T200 thruster is a **sealed, waterproof brushless motor** with encapsulated windings, eliminating the need for shaft seals and increasing resistance to pressure and corrosion. Their **polycarbonate construction** provides both structural strength and impact resistance — key factors for ROV operation in unpredictable underwater environments. The **ESCs** are controlled through software-generated PWM signals, allowing for fine-tuned variable speed control via Xbox controller input.

Trade-Offs and Design Decisions

- **Cost vs. Performance**: While more expensive than basic brushed DC motors, the T200s offer **superior thrust output, longer operational life, and reduced maintenance**, justifying their selection for a first-year competition team aiming for high reliability.

- **Power vs. Safety**: Operating at **12 volts** ensures compatibility with the Eagle Ray-style control and supply boards, while minimizing overcurrent risk. The system was calibrated to balance thrust output with heat and current limitations.

- **Safety vs. Efficiency**: To protect operators, marine life, and competition divers, the team designed **custom 3D-printed safety shrouds** for each thruster. These guards provide essential protection with minimal performance loss, prioritizing safety without compromising mission capability.

Buoyancy and Ballast

SeaPounce uses a **static ballast system** designed to achieve near-neutral buoyancy without relying on active components. The vehicle is intentionally configured to be **slightly positively buoyant**, allowing it to float gently when no thrust is applied. All vertical movement — including diving and surfacing — is handled entirely by the thrusters.

The main floatation comes from the sealed electronics canister and other naturally buoyant components such as the HDPE frame. To achieve balance and neutral buoyancy in water, we added **strategically placed metal weights** to the underside of the frame. These weights can be adjusted or repositioned as needed during testing to account for shifting balance or changes in payload.

Unlike some designs that use PVC tubes filled with sand or other buoyant compartments, we opted to avoid additional trapped air volume in our ballast approach. This decision helped simplify underwater tuning and reduced variability during pressure testing. Through iterative pool trials, the team identified the approximate ballast mass needed and fine-tuned the distribution to maintain level posture and steady control underwater.

Payload and Tools

SeaPounce is equipped with a streamlined payload system designed to meet core mission objectives while maintaining simplicity and reliability.

Camera System

The ROV uses a single forward-facing USB camera for real-time video feedback. The camera is mounted centrally at the front of the frame to provide clear visibility of the operating environment and payload interaction zone. Video data is transmitted topside via a **USB-over-Ethernet extender**, integrated into the main tether. This allows the pilot to navigate, align with mission targets, and observe manipulator actions in real time from the surface laptop.

Gripper Mechanism

A mechanical claw is mounted beneath the ROV and actuated by a compact **5V servo motor** controlled via the Arduino Mega. The gripper is designed for simple open/close operation and enables the team to retrieve small objects, interact with underwater props, or complete simulated mission tasks such as moving rings or containers.

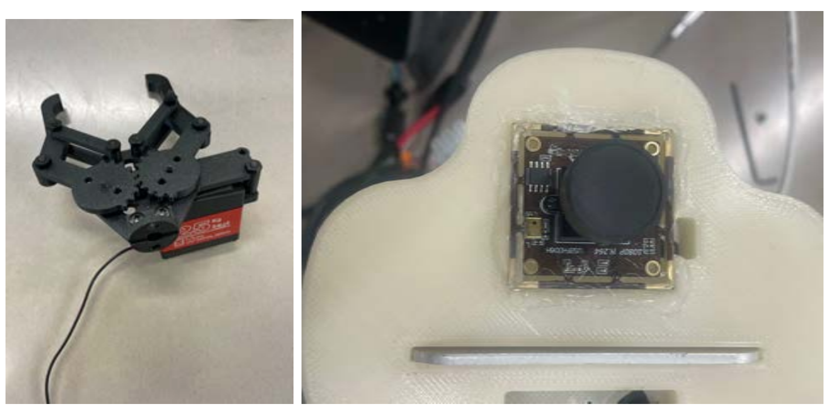

Figure 8: Cuesta AquaCats Servo-Controlled Claw and USB Camera

Lighting and Sensors

Due to the well-lit pool environment and limited sensor requirements in the RFP, additional onboard lighting or instrumentation was not included. However, the system is designed to be expandable should future missions require more advanced payloads such as sonar, depth sensors, or environmental probes.

System Integration

All payload components were selected and positioned to align with competition tasks while maintaining balance and avoiding obstruction of thrusters or the camera view. Control of both video and the claw is fully integrated into the topside software interface, enabling smooth operation with minimal pilot workload.

Testing and Troubleshooting

Sea Pounce's development threw an enormous array of mechanical, electrical, and software hurdles—but with tight deadlines and a cross-disciplinary test environment, our team turned every setback into progress. DOA Electronics: Broken-pin boards → rapid in-house repairs & expedited vendor replacements Comms Failures: Firmware wouldn't handshake with the control board → refined UART protocols & bootloader routines Power & ESC Malfunctions: Inoperative power distribution and thruster controllers → redesigned PCB traces & added surge protection Unified Test Environment: Bench-top rigs, pool trials, and pressure-chamber runs enabled same-day rebuilds and rapid iteration By harnessing our collective skills and unique workflow, we brought Sea Pounce from concept to ocean-ready reality.

During the development of our SeaPounce ROV, we encountered and overcame several challenges in both hardware and software integration. These experiences not only deepened our technical understanding but also improved the reliability and performance of our system.

ESC Arming and Signal Recognition

One of the most persistent issues we faced was that our ESCs did not respond during initial power-up — they neither beeped nor spun the motors. After extensive testing, we discovered that while PWM signals were being generated correctly by the Arduino, the ESCs were not recognizing them due to either timing or signal grounding issues. We confirmed proper operation by:

- Verifying PWM output using an oscilloscope and voltmeter
- Ensuring a shared ground between the ESCs and Arduino
- Adjusting our startup sequence to provide a sustained 1000 µs arming signal for at least 5 seconds before any throttle commands were sent

Incorrect Pin Assignments

The ROV control board uses labeled servo headers (J2–J9) that internally map to Arduino pins D22–D29. Initial documentation incorrectly assigned pins in software (e.g., assuming J5 was D26 rather than D25), leading to non-responsive thrusters. We resolved this by carefully tracing the board layout and correcting the pin mappings in our firmware. Once corrected, all thrusters responded to joystick input as expected.

Serial Communication and JSON Parsing

We encountered issues with data not being correctly interpreted by the Arduino, traced back to JSON payload formatting. The Python software was using a null character (\0) to terminate serial messages, and the Arduino needed to detect this terminator to safely parse each message. Buffering and parsing logic were added and validated to ensure reliable decoding and prevent deserialization errors during operation.

USB Extender Failure

Our system relies on a USB-over-Ethernet extender to transmit both Arduino serial data and video signal to the topside laptop. One extender failed mid-integration, delivering power but no data. After unsuccessfully attempting to source a local replacement, we obtained a working model online. This delay impacted our testing timeline, but ultimately highlighted the importance of verifying all critical components under load conditions before final assembly.

Button control Failure

During initial trials, we noticed not only thruster jitter but also choppy claw movements because we'd originally mapped claw open/close to buttons rather than using the triggers' analog range. We fixed this by adding software deadzones for both the sticks (thrust/yaw) and the triggers (claw), clamping thruster PWM between 1100–1900 μs to eliminate drift, and remapping the left/right triggers to drive the claw servo's PWM continuously (e.g. 1000–2000 μs for full open to full closed). This change—treating the triggers like sticks for smooth PWM control—smoothed out both propulsion and claw actuation, giving pilots precise, drift-free handling

Lessons Learned and Design Improvements

In refining *SeaPounce*, we learned that maintaining agility—making early design calls to avoid decision fatigue and rapidly iterating prototypes—is essential. By assigning tasks based on each team member's strengths, we maximized our troubleshooting efficiency and kept development moving. Embracing a "fail fast, fix fast" mentality with same-day bench tests and pool trials prevented analysis paralysis and sustained momentum. These lessons drove key design improvements: a lighter, quicker-actuating claw; modular, plug-and-play electronics bays for hot-swap repairs; standardized wet-mate connectors and harness layouts for rapid field integration; and embedded firmware watchdogs to ensure automatic recovery from lockups.

Budget and Cost Accounting

Income	Type	Description	Amount
MATE/MTS	Donated	Eagle Ray Kit (incl. thrusters & ESCs)	$2,500.00
MATE/MTS	Donated	Airfare to Competition	$4,250.00
MATE/MTS	Donated	Lodging at Competition	$2,403.00
MATE/MTS	Donated	Meals	$1,260.00
TOTAL DONATION			**$10,413.00**
Expense	**Category**	**Description**	**Amount**
USB Extender	Electrical	Replacement USB-over-Ethernet Adap	$68.00
Arduino Mega	Electrical	Backup Arduino Controller	$59.00
Servo Motors (x2	Mechanical	5V Waterproof Servos	$30.00
Cables/Wires	Electrical	Assorted Cables, Connectors, Headers	$20.00
Soldering Iron	Tools	For electrical assembly	$99.00
Heat Gun	Tools	For shrink wrap and sealing	$35.00
Helping Hands	Tools	Soldering work station support	$15.00
Solder	Tools	Spool of standard electronics solder	$20.00
Spare ESCs (x2	Electrical	Additional Blue Robotics ESCs	$120.00
Voltmeter	Tools	For diagnostics and troubleshooting	$25.00
Large Case	Transportation	For transporting ROV	$459
TOTAL EXPENSES			**$950.00**

Table 1: Estimated Budget for Cuesta AquaCats

Innovation

The AquaCats introduced several key innovations to improve vehicle functionality without increasing cost. One notable innovation was the design and waterproofing of a servo motor used in the claw mechanism. Initially marketed as waterproof, the servo failed during testing. The team sealed the servo with marine-grade epoxy and injected olive oil to balance internal pressure — a low-cost solution verified through vacuum and pool testing.

In software, the team modified MATE-provided control code to include real-time camera switching, claw actuation, and customizable PID tuning for thruster stability. These improvements allowed for smoother pilot operation and better mission performance.

Figure 9: Cuesta AquaCats SeaPounce

Acknowledgements

The Cuesta College ROV team would like to express our sincere gratitude to everybody at Marine Advanced Technology Education (**MATE)** and the **Marine Technology Society (MTS),** especially **Jill Zande, Tawni Gott, and Matt Gardner** for their extraordinary support. Their generous donation of the Eagle Ray ROV kit and full sponsorship of our **travel, lodging, and meals** made it possible for our students to attend and compete at the international level — an opportunity that would not have been possible without their investment in hands-on STEM education.

We also want to thank **Cuesta College** and the **Mathematics, Engineering, Science Achievement (MESA) program** for providing a dedicated space where our students could collaborate, design, and build SeaPounce. Also, thank you to **Laurie McConnico** and the **NSF-IUSE Award ID 2236402** for their ongoing support.

Special thanks go to the **Allan Hancock College ROV team** for their collaboration and encouragement throughout our design and testing process. Their willingness to share knowledge and troubleshoot with us made a meaningful difference in our progress and confidence as a first-year team.

We would also like to extend our sincere thanks to **Angel Llamas** and **California Polytechnic State University (Cal Poly)** for their generous support in fabricating the HDPE frame for our ROV, *Seapounce*. We are grateful for the collaboration and support from their engineering lab, which made a significant impact on our project's success.

Finally, we are grateful to the **Thunder Bay National Marine Sanctuary in Alpena, Michigan**, for hosting this year's competition. The opportunity to participate in such a well-organized event, surrounded by passionate professionals and peers, will be a highlight of our students' academic journey!

Appendices

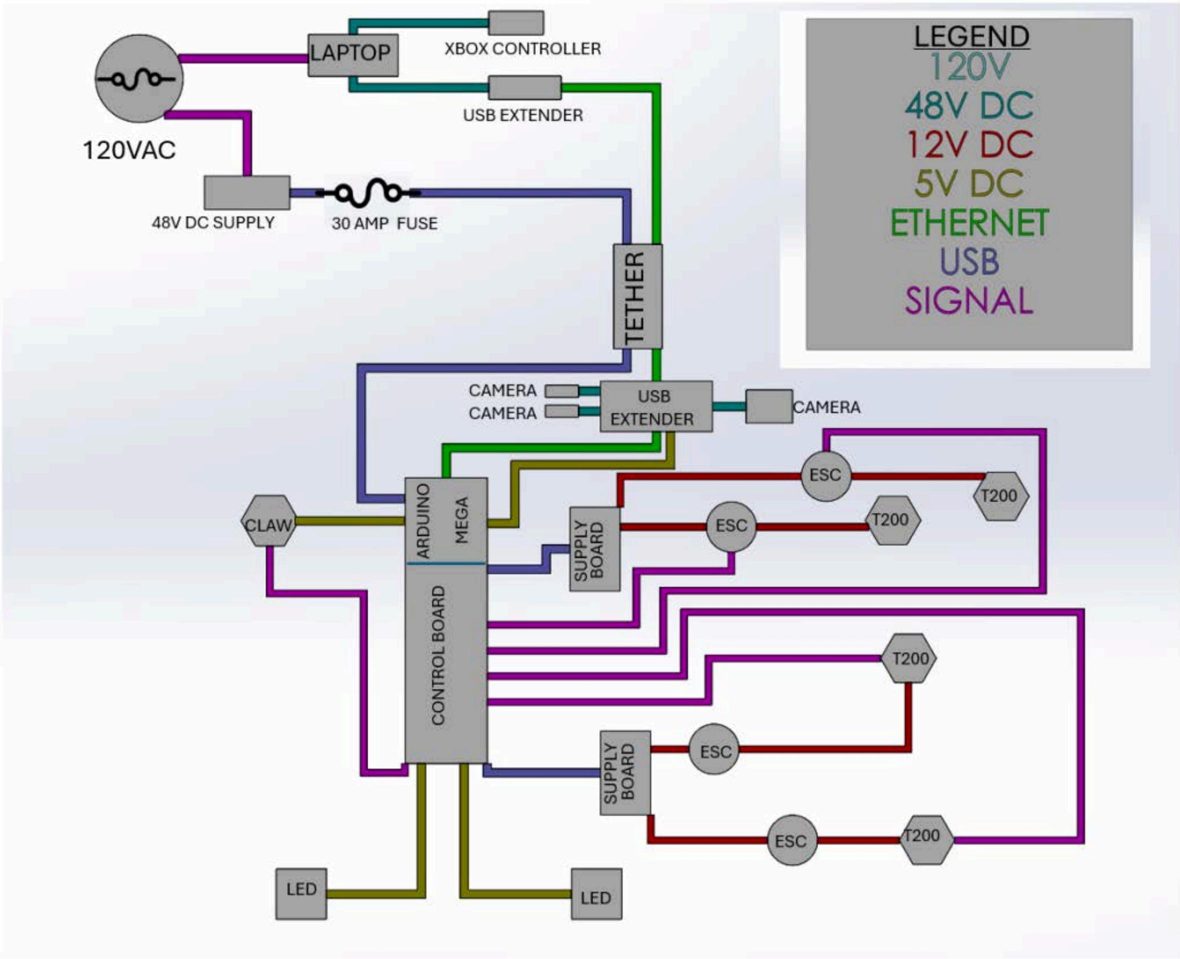

Figure 10: Cuesta AquaCats SID