



PASADENA, CA, USA

ROBO RAIDERS TECHNICAL REPORT



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Abstract

The 2026 MATE ROV Competition challenges teams to develop technologies capable of supporting scientific research, environmental monitoring, offshore energy operations, and under-ice exploration in harsh marine environments. In response to the MATE Request for Proposals (RFP), the Pasadena City College Robo Raiders made significant modifications to an existing Remotely Operated Vehicle (ROV) to improve its cold-water marine research, offshore energy system maintenance, and simulated under-ice mission capabilities.

In addition to pre-existing features such as a modular HDPE frame, corrosion-resistant components, a two camera feedback system and tethered control, our ROV showcases a newly designed 3 degrees of freedom manipulator arm. This payload is capable of three distinct motions: elbow rotation, wrist rotation, and claw manipulation. Our new arm is more affordable, easier to manufacture and repair, and adds an additional wrist rotation capability.

Through rigorous testing, Robo Raiders has demonstrated that the arm's wrist rotation is ideal for collecting coral and biological samples, servicing eDNA sensors, deploying subsea power connectors, and assisting with offshore wind infrastructure tasks. These are tasks that may need to be performed off the waters of Newfoundland today. Additional features of our ROV include photogrammetry, and float deployment. Efforts to incorporate a real-time onboard leak detection and microphone are ongoing.

Robo Raiders consists of eight student engineers and a biologist from different backgrounds, ranging from first-generation college students to a high school student. Through technical innovation, teamwork and research, Robo Raiders developed a system that addresses the 2026 MATE ROV Champions objectives.

* AI use

Robo Raiders used Artificial Intelligence only when absolutely necessary. Example use cases include gaining in-depth information about the software code from previous years and searching for components suitable for tasks, dimensions, or budget. The team has used a non-AI spell checker for proofreading.

Teamwork

Team Structure

Robo Raiders consists of eight student engineers, one of whom is currently in high school. Due to the comparatively low member count, each member is assigned at least two company roles. The roles of specific team members as shown in the title page is presented in the below organization tree:

The team is organized into major divisions led by three leadership roles: CEO, CTO, and CFO.

The CTO oversees all technical aspects of the ROV, including the chassis, thruster mounts, payloads, and float design. Serving as the primary technical authority, the CTO maintains broad knowledge of the vehicle and coordinates design and integration efforts for other engineers, who use CAD modeling, 3D printing, and prototyping to refine designs and test performance in underwater environments. The CTO serves as a multidisciplinary leader with knowledge spanning all technical areas.

The Electrical Lead manages internal circuitry and power systems, including power distribution, sensor integration, waterproofing, and electrical safety in high-moisture environments.

The Software Lead oversees control system development, sensor data visualization, and software integration. The software team develops systems for precise navigation and manipulation while integrating cameras, motor controllers, and a user interface that provides real-time operational feedback during missions.

The Mechanical Lead builds and tests the mechanical and structural devices of the ROV. Under the leadership of the Mechanical Lead, engineers ensure that the ROV is properly designed, constructed, and repaired if needed.

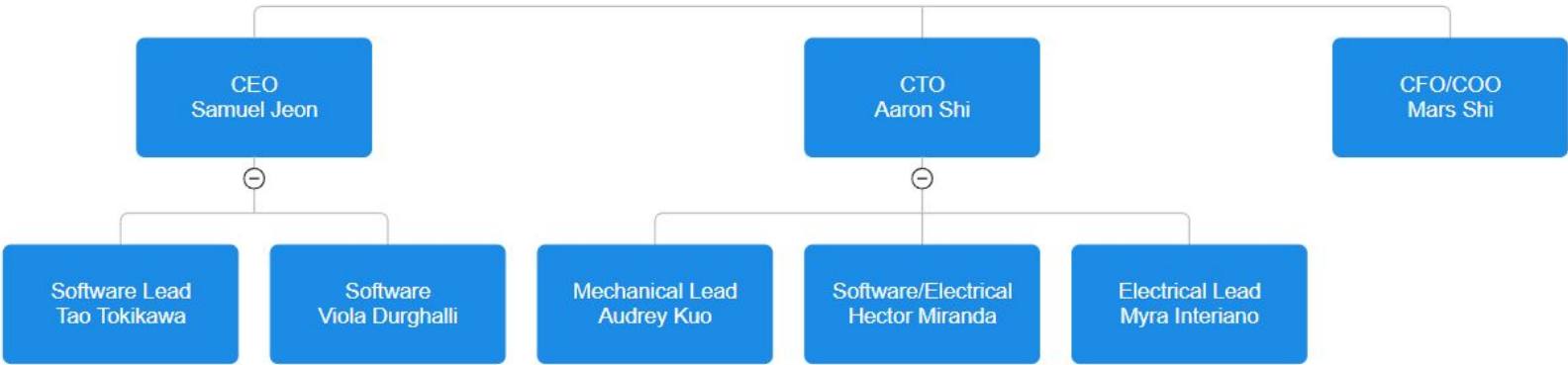


Fig. 0: Team’s Organization Diagram

Project Management

Timelines and goals revolved around Pasadena City College semester schedule. The fall semester was spent building foundational skills through smaller scale experiments and learning opportunities. By the winter, team members are familiar with the progress made by last year's team, and where improvements can be made. The entirety of spring is spent testing new solutions.

In order to facilitate collaboration, the Robo Raiders used Discord as the main hub of communication. The server was organized into different categories, with announcements and goals regularly announced. Github was used for version control for the software team. After every major change to software, a commit was made to keep track of progress and prevent conflicting codebases. Important files were added to Google Drive for all members to access.

The team holds in-person meetings every Saturday with the ROV and float available to work on. Every member interacts with each other on a equal basis; organizational roles are merely to divide tasks and do not hold a rigid command structure or hierarchy outside of work.



Fig. 1: Organized work cabinet space

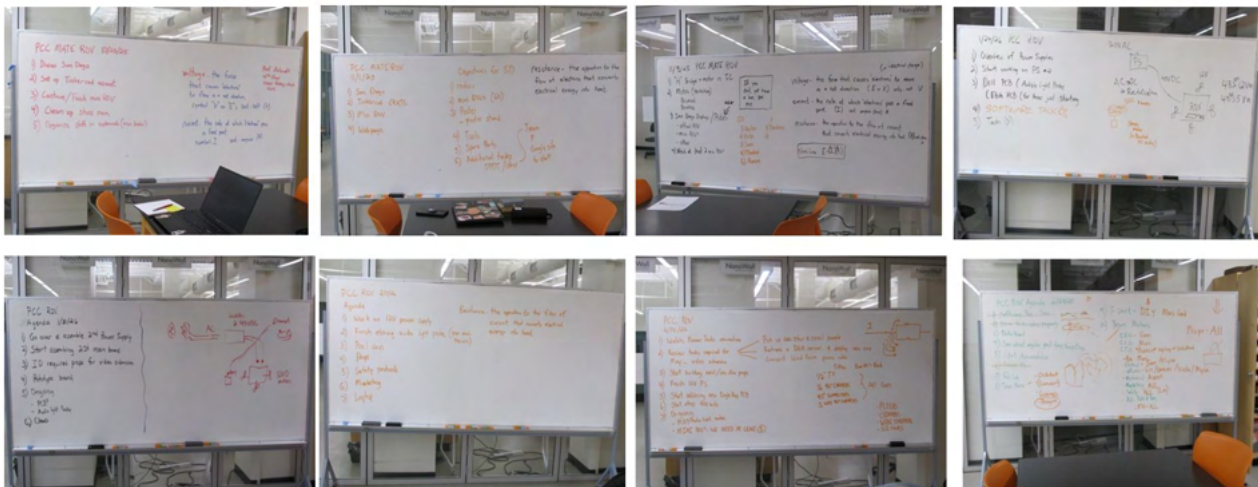


Fig. 2: Meeting agendas were posted each Saturday

Design Rationale

Engineering Design Rationale

The Robo Raiders' ROV design was driven by three guiding principles: modularity, mission versatility, and engineering efficiency. Our frame is constructed from CNC-machined HDPE, chosen for its corrosion resistance and near-neutral buoyancy. The modular frame allows for rapid assembly and tool swapping during testing or competition adjustments. Propulsion is provided by four Blue Robotics T200 thrusters, configured for maximum maneuverability using a trapezoidal layout. Two horizontal thrusters enable forward/reverse and yaw, while two angled vertical thrusters manage ascent and descent with minimal torque drift. Custom 3D-printed thruster guards improve thruster safety.

With a waterproof BlueTrails Engineering Servo case and two DC motors, our claw is able to grasp, twist and turn. A dual-camera system provides both high-res imagery and spatial awareness, with feeds integrated into a graphics user interface (GUI). The control system, powered by an Arduino Mega 2560, features a custom firmware architecture that responds to an Xbox controller and logs telemetry for diagnostics.

Our team placed a humidity and temperature sensor inside the canister to monitor vehicle health. Robo Raiders is also currently integrating a microphone with the ROV.

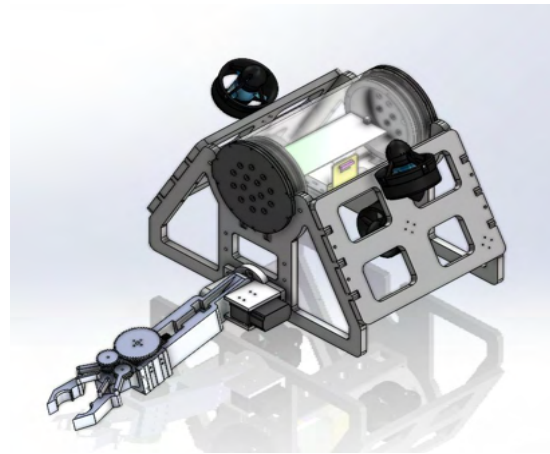


Fig. 3: ROV's CAD Design

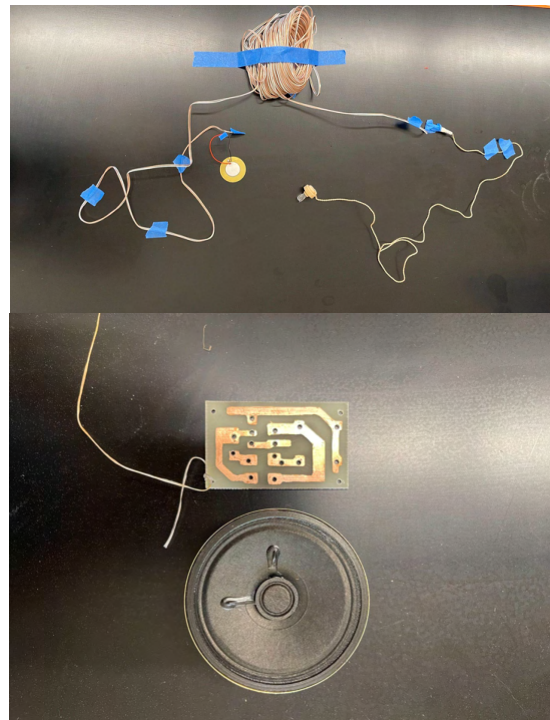


Fig. 4 & 5: Onboard piezo microphone development

Innovation

Arm Design

Robo Raiders has developed a completely new arm design with significantly lowered manufacturing costs and more degrees of freedom. A noteworthy feature of the design as shown in Figure 4 (below) is a sliding carriage system operated by a DC linear actuator that enables both rotational and linear motion. The addition of rotational motion has proven to be a breakthrough during our trial ROV operations.

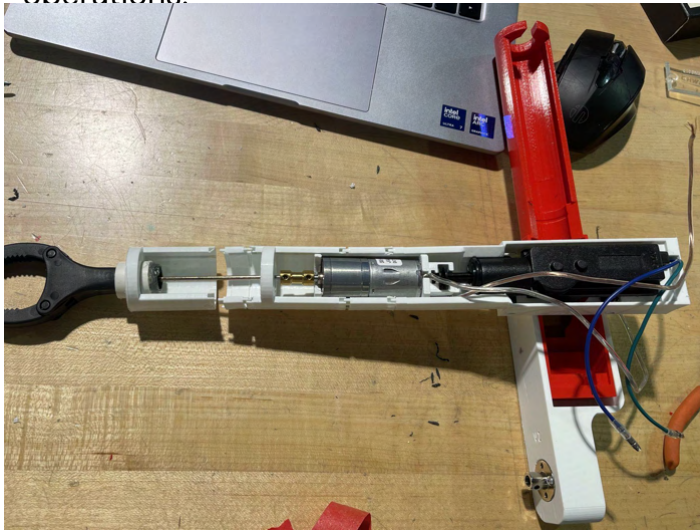


Fig. 6: New claw with rotating wrist

Excluding the central driveshaft and the two DC motors, the arm is 3D printed. As such, Robo Raiders has improved upon our repair capabilities. Fixes and part replacements that used to take days, if not weeks, now take no longer than two minutes. Using inexpensive and off-the-shelf DC motors has allowed the team to become less reliant on expensive pre-built components for the arm. The team is currently experimenting with various methods of waterproofing the arm. Further details about the design and mechanics of this arm will be discussed in later sections of this document.

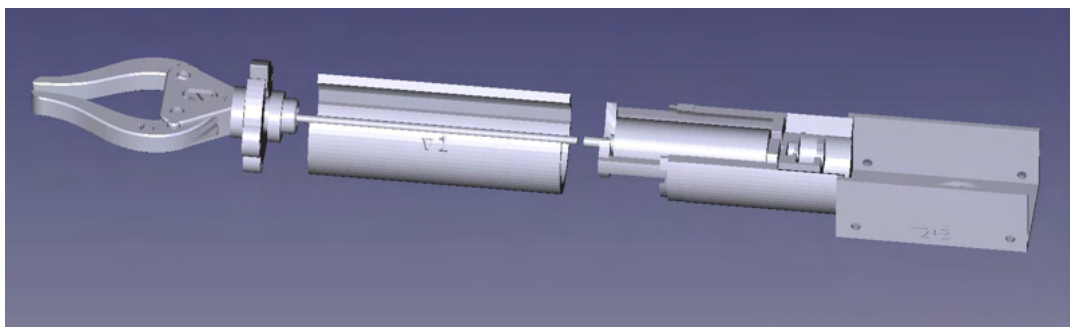
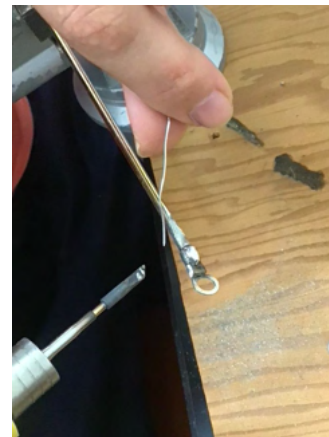


Fig. 7: New claw with a wrist, exploded view (FreeCad). Not shown: door lock actuator..

Problem Solving

Robo Raiders ensures that every member knows something about everything, and that team members aren't limited by their title. Doing so has added much flexibility to our meetings and brainstorming sessions.

Throughout the season, Robo Raiders has faced a number of technological, administrative, and logistical challenges. Here are some of the ways we tackled them as a team.

Robo Raiders does not have access to the school pool due to an administrative blockage. As a workaround, the team identified several local pools compared metrics such as rent cost and distance. After evaluating the tradeoffs, the team tested the ROV at a suitable location. This mobile approach to working unexpectedly resulted in the team expanding its public outreach and becoming proficient in setup and teardown.

During a nighttime ROV deployment session, the pilot had difficulty seeing underwater props through the onboard camera due to insufficient lighting. Team members considered several solutions, such as adjusting the camera settings and repositioning the props. Finally, we mounted a spotlight on the ROV frame. This temporary hack proved to be so effective that we are currently working on a permanent solution.

The pilot had challenges grabbing the oil rig power plug prop due to the shape of the claw. Having extremely limited materials and tools at hand, the team was forced to carefully weigh the benefits and drawbacks of every proposed modification to the claw. After careful deliberation, the team ziptied metal wires to the claw for an additional point of contact, which turned out to be the solution.

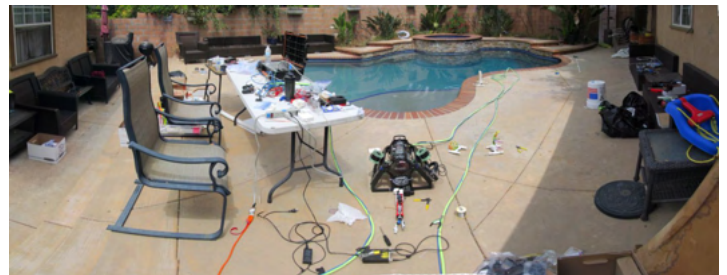


Fig. 8: May 16, 2026; Airbnb pool, morning after submission of qualifying video.



Fig. 9: Robo Raiders preparing for deployment at Polytechnic H.S. pool in Pasadena, CA

System Approach

In designing our ROV, our team did our best to make components work with each other, instead of completely separate designs. A hook drilled directly onto the ROV frame would interfere with operations, so we combined it with the rotational section of our claw, so it could be rotated upwards to avoid scraping the pool floor during tasks.

Both the internal and external cameras on our ROV enable us to see the props being grappled by the claw, and the flexible arm of the external camera also enables us to keep the payload in view in any position.



Vehicle System

Philosophy

A key focus for the Robo Raiders' ROV is affordability. By repurposing tools and utilizing inexpensive parts, the manufacturing costs of the ROV decrease, making it more accessible. The addition of a linear actuator and repurposed grabber tool to interact with props dramatically reduced the costs to build the payload, whilst still maintaining all necessary degrees of movement to complete tasks.

Another improvement in system structure was made on our 3D-printed claw. The claw uses PLA as a material and is limited in strength, especially between layers.

By researching solutions in 3d printing forums, namely *PLA Baking: The Secret to a Stronger and More Rigid PLA* by Trizzy Orozco, we decided to use the moderate technique of baking to improve strength. By baking our claw in an oven at 110°C, we were able to partially melt our claw to improve strength, using a low-cost solution to achieve more with cheap materials like PLA.

Electrical System

The team has reused the ROV's electrical system from last year, after determining that the system currently implemented is already optimized for our purposes. The previous team provided the following reasons for adopting the electrical system, and our reasons have largely remained the same.

The ROV's electrical system is controlled by an Arduino Mega 2560 microcontroller. This microcontroller is mounted on a main PCB developed by SeaMATE for the Eagle Ray System. The board controls all thrusters and motors, and distributes power to peripheral components such as cameras and sensors.

The electrical system is powered by our 48V DC source through a 50-ft tether. Two step-down converter circuits onboard the ROV convert the incoming 48V to 12V for the thrusters. Each daughter board handles two thrusters.

The SeaMATE Eagle Ray main board (shown in Figure 9) is a purpose-built PCB that supports integration of the Arduino Mega 2560. This board includes dedicated ports for motor controllers, sensors, and DC-DC converters. Its standardized design has helped Robo Raiders work with adding new components to the system and making repairs to it.

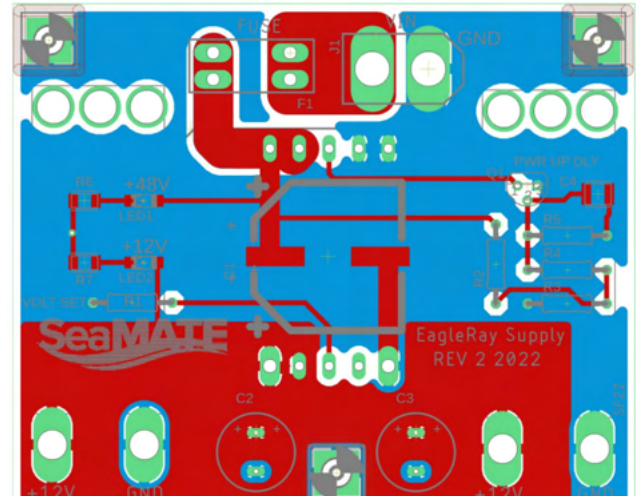
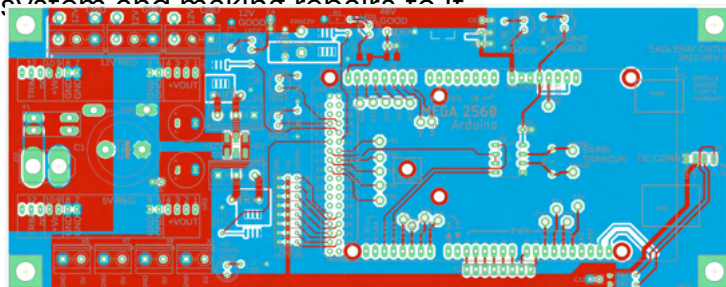


Fig. 11: Thruster PCB Layout

The board layout features clear trace routing and heat dissipation, with critical power and control lines isolated for easy identification. The use of a pre-designed and tested SeaMATE board helped the team save time and budget.



Fig. 10: Main Board PCB Layout (left) and actuarial (right)

Electrical System

Tether

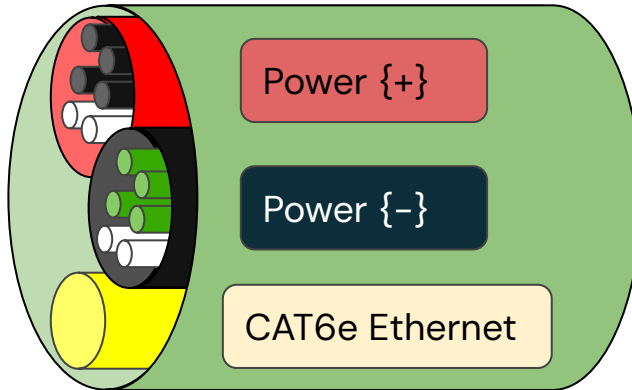


Fig 12: Tether Cross Section

Key metrics of the tether:

- 50 feet length
- 48V DC power & data transmission
- 12 conductors: 4 black, 2 white, 4 green, 2 white
- 2 Shielded CAT6e Ethernet cables for communication

Canister

- Clear acrylic electronics canister sealed with O-rings and penetrators for waterproofing
- Contains critical electrical components, including the main control board, converters, and ESCs
- Internal forward-facing camera provides operational visibility
- Flexible, labeled wiring improves organization and serviceability
- High-voltage and signal lines are separated to reduce interference
- Modular card cage system allows quick access and easier maintenance

Tether Safety and Handling

- ❑ **Inspect** the tether before deployment for damage and secure connections.
- ❑ **Deploy** carefully to avoid tangles and ensure steady communication.
- ❑ **Monitor** tether tension throughout the mission to avoid overloading.
- ❑ **Adjust** length and routing dynamically based on vehicle movement.
- ❑ **Retrieve** methodically to prevent twisting.
- ❑ **Check** the tether post-mission for wear or damage.

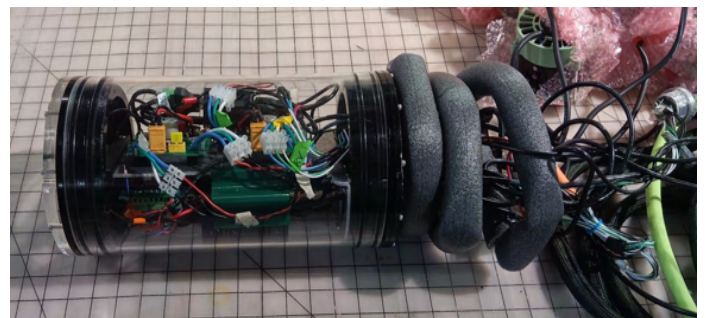


Fig 13: The Canister

Control System

We reused the ROV's control & software system from last year, after confirming that it remains well-suited for our needs.

The Octobots' ROV control system consists of a two-part architecture: a Surface Station for operator input and feedback, and an Embedded System for direct control of actuators and sensors. Communication between these systems occurs over a 115200 bps USB serial link sending raw binary commands to the arduino from our laptop.

Surface Station and Embedded System

Surface Station incorporates a C++ Graphical User Interface to acquire joystick and sliders' inputs alongside with data visualization purposes, where voltage, temperature, and PWM status are provided. Inputs from the pilot are converted to commands dictionaries, which are translated to raw binary data sent via USB communication. Onboard embedded controller decodes this information and produces proper pulse-width modulation by calling `servo.writeMicroseconds()` function.

Float System

Onboard data acquisition has undergone certain improvements. The float system has been redesigned to use depth-based triggering when storing measurement results rather than a timer as previously implemented. As a result, data will be gathered only when a necessary depth level is reached, increasing its relevance for missions conducted by the vehicle.

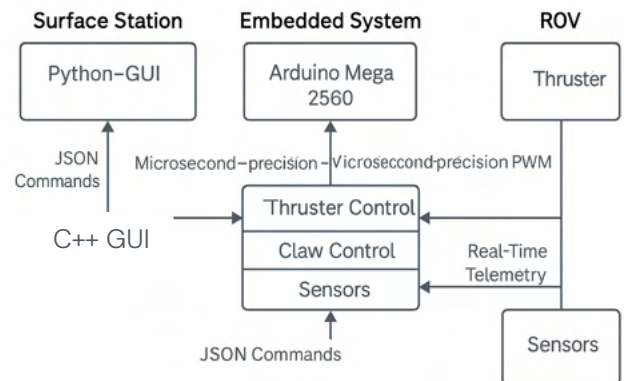


Fig. 15: ROV's summarized Control System

Optimization

In order to increase efficiency, large amounts of code from both client side and firmware have been rewritten in C++. Thus, there is no need to use any additional communication protocols, which ensures the shortest possible lag time during ROV operation. At the same time, compatibility of the software with the PlayStation controller remains unaffected, allowing for more comfortable pilot interaction with the vehicle.

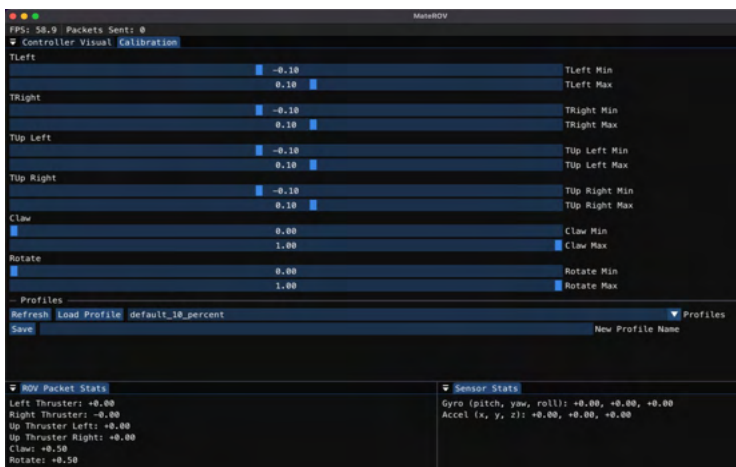


Fig. 14: Controller Visual Calibration Code

Propulsion

Thruster Specifications

We reused the ROV's thruster system from last year, after confirming that it remains well-suited for our ROV movement needs.

Our ROV uses four Blue Robotics T200 thrusters, each capable of producing up to 6.4 lbf of thrust. This provides more than enough power for quick, controlled movement, and helps the ROV resist drifting from currents during mission tasks. The T200s are efficient for our electrical system because they operate at 12V, allowing power to be supplied through a step-down voltage converter. They are also rated for depths up to 300m, making them highly durable for competition conditions. Their four M3 mounting holes allow flexible placement and easy customization on our frame.

To improve safety and reliability, we added custom 3D-printed thruster guards. These guards help protect the propellers, pool objects, and mission materials, making the ROV better suited for tight underwater spaces and benthic environments.

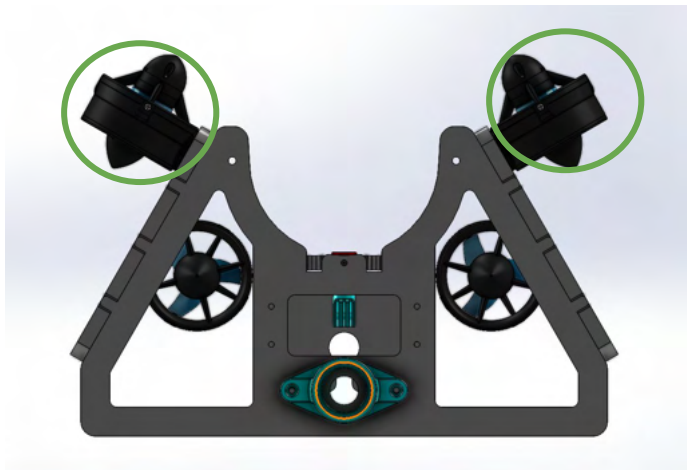


Fig. 16: Side - Mounted Thrusters

Thruster Configuration

Our four-thruster configuration is based on a trapezoidal frontal cross-section. Two thrusters are mounted inward on the side plates and face forward, allowing the ROV to move forward and backward. Because these thrusters are aligned with the ROV's center of mass, the vehicle can pivot smoothly by running one thruster forward and the other in reverse. This gives the pilot precise turning control while keeping the design simple and efficient.

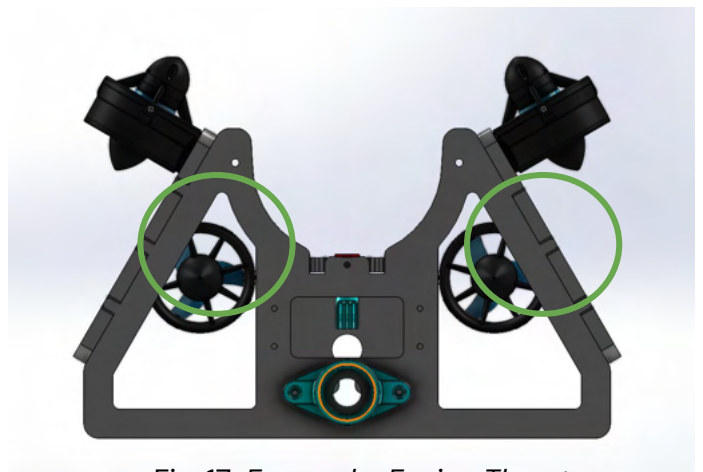


Fig. 17: Forward - Facing Thrusters

The two other thrusters are mounted at the top of the trapezoidal frame to control vertical movement. Since they are positioned at equal opposing angles, their sideways force components cancel when both thrusters receive the same power, allowing the ROV to move up or down smoothly. This angled layout also gives the ROV limited yaw control, which can be fine-tuned through small thruster-position or ballast adjustments.

Buoyancy and Ballast

The ROV was designed to be overbouyant. Our team achieved neutral buoyancy by adding a 2 lb weight and multiple small weights. This adjusted the total weight of the ROV to weigh down as much as the buoyant force provided by our canister. In future runs, if we still notice some drifting too small to be neutralized, our team plans to add small plastic tubes with mini detachable weights to balance more precisely and easily. These containers will be added where needed to serve the purpose of balancing roll forces and add more stability.



Fig. 18: 3 lbs balancing weight

Payload and Tools

Manipulator (Claw)

The ROV's claw was specifically designed to tackle most of this year's tasks: grappling, pinching, and twisting. After evaluation of the tasks, we determined 3 degrees of freedom on the claw would be necessary to complete all tasks. Thus we set the requirements for the claw to be able to (1) Close, (2) Rotate, and (3) Elevate. The basis for the claw is the pinching function to close the claw. Gaining inspiration from trash picker-uppers, a similar design was chosen for our claw.



Fig.19: *Linear actuator*

This design needed a linear actuator, and we chose an off-the-shelf door lock actuator running at 12V DC since we had that power source available. With a pulling power of 1200N, it was deemed sufficient to provide the grappling power to pick up props.

For requirement (2) Rotate, the shape of the linear actuator stops the possibility of rotating it. Therefore we decided to mount our rotation motor after the linear actuator, i.e. the rotation motor would move linearly with the claw. A 12V brushed DC motor was chosen for this task. Using a brushed motor enables water resistance also.

Finally, for (3) Elevate, the existing servo design was kept giving enough freedom to raise props to ease operations.

For the perhaps most important part, the claw itself, a brand new design was needed. The main objective for designing was grappling the base of the coral, a 2 inch end cap. We do this with an elliptical hole to close onto the end cap. Then, we also need pinching power for other tasks. This is achieved by a straightedge on the tip of the claw. The shape of the claw was modeled in Solidworks and printed, with a thickness of 35 mm, the same thickness as our shroud on the right in the diagram.

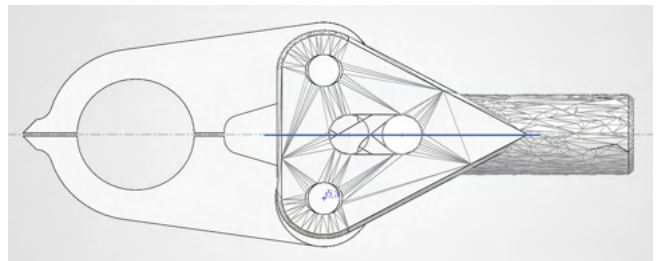


Fig. 20: *Actuator claw*

Camera

The Robo Raiders ROV is equipped with two cameras, one internal (PiCamera Module 3) and one external. The first camera is mounted directly above the manipulator claw, inside the canister. Its purpose is to provide the pilot with a clear, top-down view during manipulation tasks. The second camera is mounted on an adjustable arm attached to the main ROV frame and housed in a waterproof GoPro case. This camera's flexible gooseneck arm provides a visibility to tools that work underneath the frame of the ROV. Its main purpose is to guide the hook system attached to the bottom of the frame.

Computer Vision

Our team uses a Python and OpenCV based algorithm to identify crab species shown in our main camera feed. Reference images of each crab species are first converted to grayscale and processed using ORB (Oriented FAST and Rotated BRIEF) feature extraction. During live video capture, ORB keypoints and descriptors are computed for each webcam frame and compared against the reference descriptors using a brute-force Hamming-distance matcher. Lowe's ratio test is applied to remove weak or ambiguous matches. When enough reliable matches are found, RANSAC (RANDOM SAmple Consensus)-based homography estimation is used to verify that the matched features forms a consistent geometric transformation. If the number of inliers passes a set threshold, the projected corners of the reference image are used to draw a bounding box around the detected crab. The system then labels the detected species and displays live counts for each crab type.

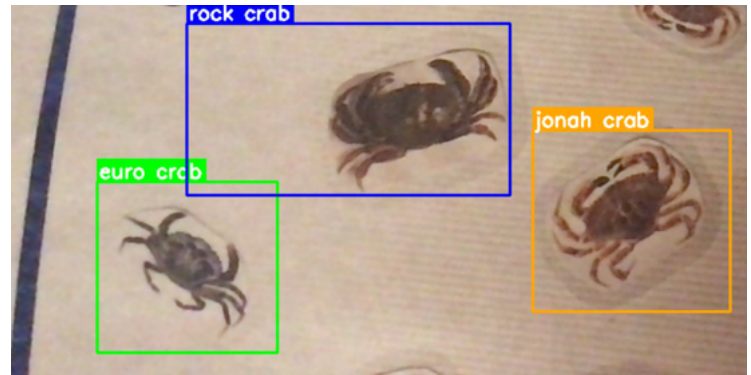
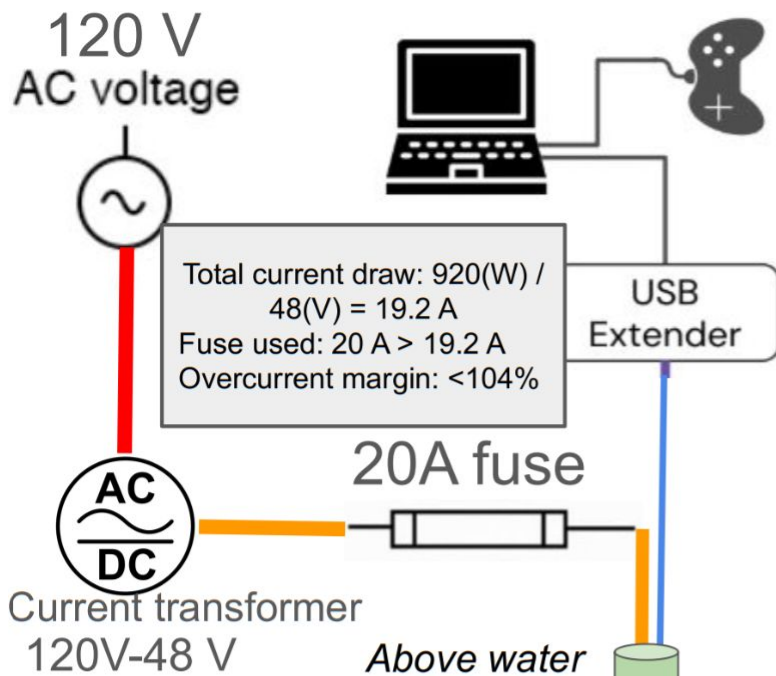


Fig. 21: *User view of identified crab species*

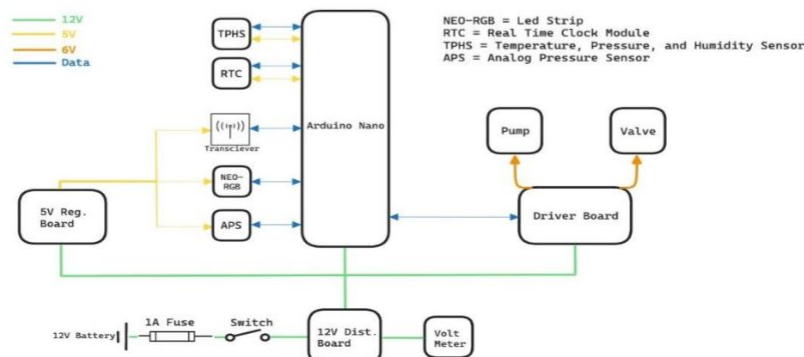
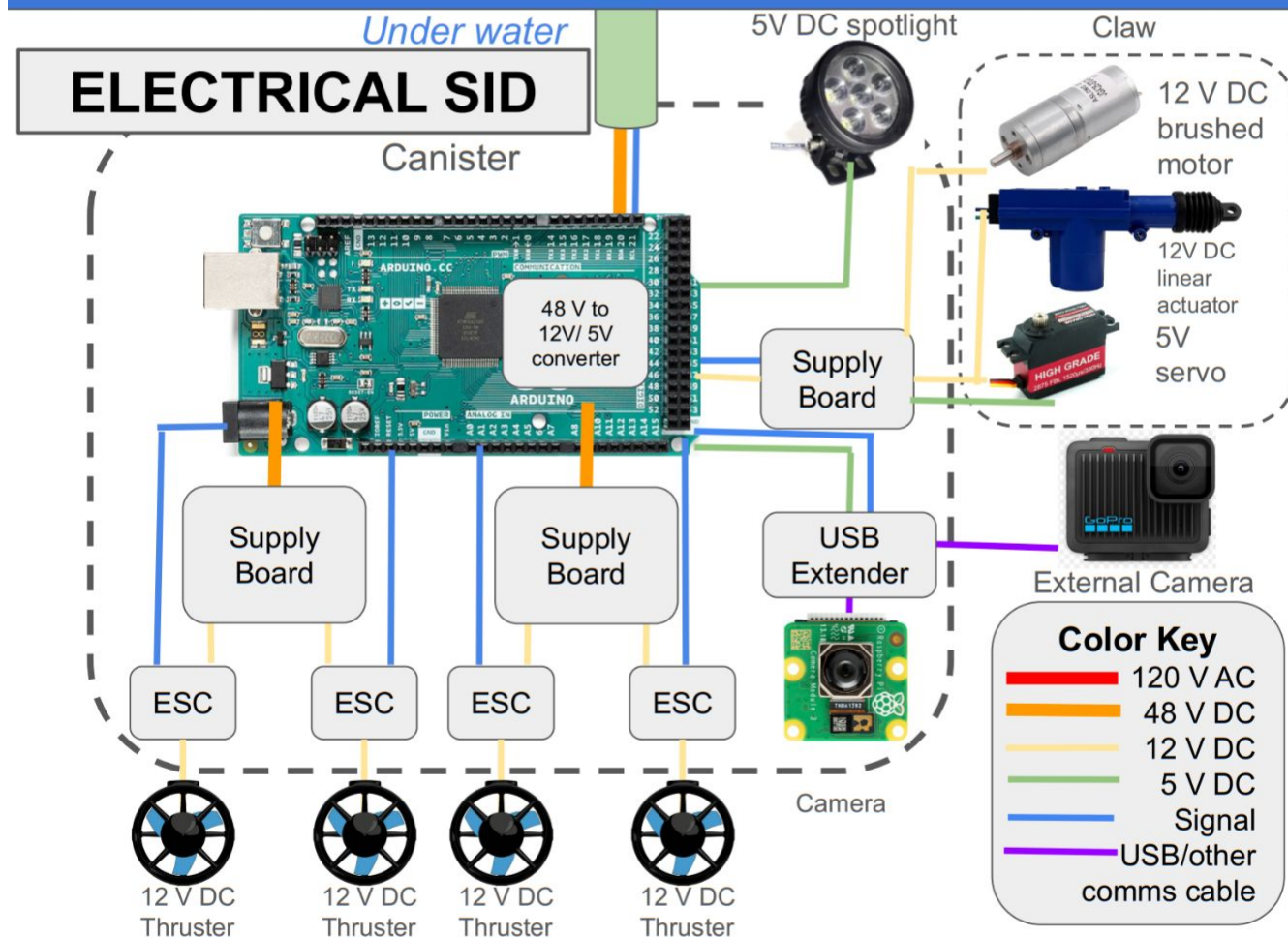
Build vs. Buy, New vs. Used

Our ROV has been continuously improved by previous years of teams. Most of its and electrical systems and structure discussed earlier in the document originate from an EagleRay kit purchased several years ago.

A specific New vs. Used decision: In feeding power to the two 12V DC motors on our newly designed arm, we faced the challenge of wiring. The original claw only uses one marine 3 pin cable, so to successfully integrate our claw, we expected to purchase a new marine connector from BlueRobotics. Instead, we disconnected one of the two USB cables going to the external cameras. Thus, we freed 4 cables and changed the approach from "buying" to "building". We were able to reuse the old cables and power the 2 DC motors for our claw.



Component Name	Est. Peak Load
4 x T200 Thrusters(12V)	820 W
2 x Claw DC motors	60 W
2 x Cameras	12 W
Floodlight	18 W
MISC. Electronics	< 10W
TOTAL LOAD	920 W



Safety Rationale

Our safety protocols listed in the following page were established with the following goals in mind:

Personnel Safety

- Reduce injury risks from machining tools, rotating thrusters, high-current systems, and deployment activities.
- Use Safety glasses, secured clothing/hair, and thruster guards to minimize operator hazards.

Equipment Safety

Use:

- 20 A fuse to prevent overcurrent conditions.
- Waterproof canisters with O-rings and penetrators to protect electronics from water intrusion.
- Top / bottom ether strain relief to reduce cable fatigue and connector damage.
- Real-time voltage and temperature telemetry to identify faults before component failure.

Operational Safety

Perform and create:

- Pre-deployment checklists to verify tether condition, 48V voltage, serial communication, and enclosure seal.
- Deployment roles (pilot, tether management, safety oversight) to improve coordination.
- Controlled tether routing and system monitoring to reduce entanglement, communication loss, and unexpected behavior.

Vehicle-Specific Safety Features and Task Precautions

- **3D-printed IP20 thruster guards:** prevent object intrusion and damage to props and motor by blocking objects from entering such as human fingers
- **Acrylic pressure canister:** sealed with O-rings and wetlink penetrators.
- **Tether management protocol:** tether operator feeds manually to maintain slack and prevent strain or snagging.
- **Emergency shutdown:** pilot can immediately disable the system with a kill switch from the topside station.
- **Leak monitoring:** seals inspected pre-deployment; bubbles and telemetry monitored during operation.
- **Manipulator safety:** electronically controlled actuation speed and power minimize damage to mission props and arm structure.



Fig. 22: Team members practicing proper lab safety by wearing goggles

Construction Phase	
Category	Checklist Item
Workspace Safety	☐ Ensure workspace is clean, dry, and free from loose tools or materials
	☐ Store materials/equipment to prevent tripping or obstruction
	☐ Maintain clear access to exits, fire extinguishers, and first aid kits
Personal Protective Equipment	☐ Wear safety glasses when cutting, soldering, or grinding
	☐ Machining - Wear safety glasses, Tie back long hair, remove loose clothing / jewelry / no gloves or long sleeves
Tool & Equipment Use	☐ Inspect tools/machinery for visible damage before use
	☐ Confirm guards and emergency shutoffs are present and functional
	☐ Disconnect power before tool adjustments or maintenance
	☐ Use ventilation/fume extraction for soldering or sealing
Electrical Safety	☐ Inspect cables for fraying or exposed wires
	☐ Ensure proper equipment grounding
	☐ Isolate and label any damaged or unsafe circuits
	☐ Keep all liquids away from electronics stations
Operation Phase	
Category	Checklist Item
Pre-Deployment (Power Off)	☐ Member checklist: Pilot (Sam)/Copilot (Mars)/Tether operator(Myra)
	☐ Pilot Confirm launch area is clear of obstructions and personnel
	☐ Tether op. ensure tether is flaked out neatly and strain relief is attached to ROV
	☐ Pilot/Copilot ensure electronics housing is sealed, and all screws are tight
	☐ Copilot ensure power supply and TCU are off before connection
	☐ Copilot perform visual inspection of connectors and wires
Pre-Deployment (Power on, Poolside)	☐ Conduct verbal checklist and confirm team is ready
	☐ Member checklist: Pilot (Sam)/Copilot (Mars)/Tether operator(Myra)/Prop-poolside Manager(Aaron)
	☐ Power on TCU and confirm system voltage is stable, 48V nominal
	☐ Verify ESC startup and thruster responsiveness
	☐ Confirm camera feeds and sensor data are active
	☐ Prop / poolside manager deploy the ROV into the water. Coordinate with Tether Operator during the process.
In-Water Operation	☐ Member checklist: Pilot (Sam)/Copilot (Mars)/Tether Operator(Myra)/Prop-poolside Manager(Aaron)
	☐ Continuously monitor video feed and telemetry data
	☐ Tether Operator observe tether to ensure it is free of snags or excessive tension
	☐ Stop operation if unusual movement or large air bubbles are observed
	☐ Record any unexpected behavior for post-mission diagnostics
Loss of Communication	☐ Attempt soft reset on TCU or surface controls
	☐ If no response, power down and recover ROV
	☐ Resume operation only after verifying all systems are stable
Post-Operation & Pit Maintenance	☐ Power off and fully disconnect ROV and TCU before handling
	☐ Inspect thrusters for debris, damage, or blockages
	☐ Dry electronics housing and inspect for signs of moisture
	☐ Re-lubricate O-rings and seals if housing was opened
	☐ Ensure tether and manipulators are secured and logged for next use

Critical Analysis

Testing and Troubleshooting

Propeller experiment

Using the original stock Blue Robotics T200 propeller, we wondered if a different propeller would be more efficient for our applications. In addition, the propellers generated asymmetrical thrust moving forward and backwards, affecting stability. Therefore, we decided to redesign the propeller shape in order to improve efficiency in these aspects. Referencing above requirements were proposed to fulfill design goals and maintain itself.



Fig. 23: Stock T200 Propeller

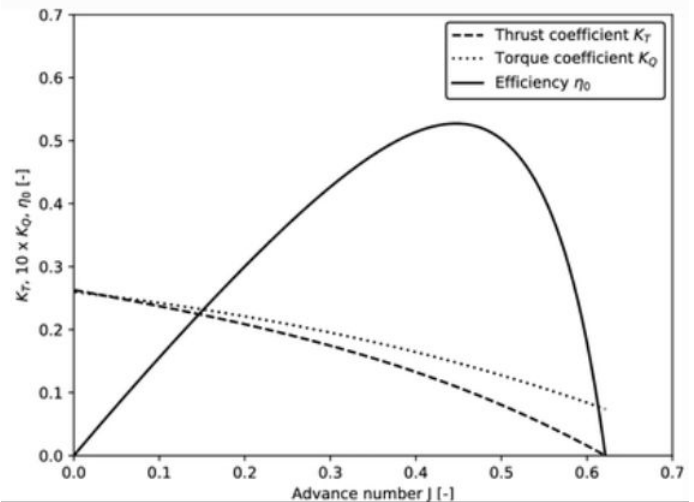


Fig 24. Graph showing decrease of efficiency at low speeds

Following advice in “Autonomous Underwater Vehicle Propulsion Design”, we used simulation software such as OpenProp, to redesign our propeller to achieve mainly asymmetrical thrust. In order to measure the effectiveness of our improved design, it is necessary to measure the thrust of our motor in a controlled environment. Therefore, we constructed a pool [insert image] to be able to run an isolated motor. When testing, there must always be 2 people with safety glasses, and the one holding the battery can unplug immediately in case of an incident. Integrated testing was pushed back due to a leak in the test tank, but it will be done before the competition.



Fig. 25: Assembling the thruster testing aquarium



Fig. 26: 3D-printed prototype propellers



Fig. 27: Mock up of aquarium for testing motors

Testing and Troubleshooting

Wire Corrosion Experiment

This test was performed to evaluate how saltwater corrosion affects the conductivity of wires, and by extension, the operation of our ROV in saltwater environments. The blue and green wires shown in Fig 23. was sourced directly from our ROV.

The following summarizes the results of the test:

	Green (control wire) (Ω)	Blue (saltwater exposed wire) (Ω)
Initial state	0.462	0.459
1 week after saltwater exposure	0.461	1.266

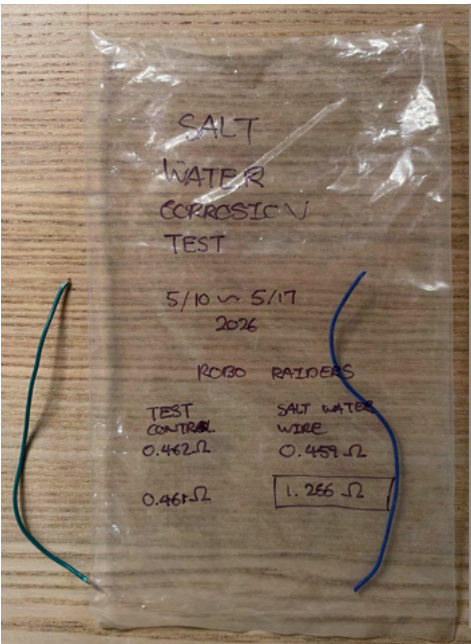


Fig. 28: Wire corrosion experiment

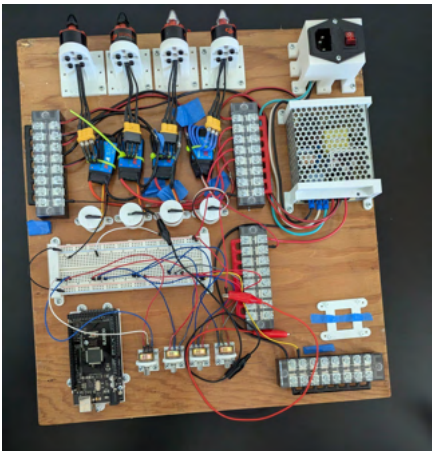


Fig. 29: ROV prototype board



Fig. 30: Frame teardown of ROV for electrical mapping

Prototype Board

We began assembling a prototyping board to test components out of the water. The proto board contains four motors and 4 electronic speed controllers similar to those used on our ROV. For testing purposes we only included a 12V DC power supply. The protoboard also has 4 potentiometers that work with the ESCs to control motor speed, Arduino Mega 2560 and Arduino Ethernet shield for testing microcontroller code. In the future, the board will also have a servo and brushed motor for testing a potential claw prototype. This is still an ongoing project that could benefit future teams' R&D.

Testing and Troubleshooting

Servo Post-incident Analysis

In previous years, servo motors of the type shown above have been used to control the gape of the claw, allowing for positional control. The servo was operated at 5V and so could provide 18 kg-cm of stall torque. The servos were advertised as waterproof, but all eventually failed. Brushed motors, like the type used in these servos work underwater, but the brushes eventually corrode. The team last year decided to purchase a waterproof housing to eliminate the problem, which worked, but was costly. Therefore, we decided to investigate why the previous servos failed. Having this knowledge would allow us to know if there are less costly alternatives that allow the servo to keep working.

In this investigation we took three of the failed servos (figure 27) and opened them up to find out what went wrong. From left to right, the servos were labeled as 1,2, and 3. Servos 1 and 3 were covered with marin epoxy as an attempt to make them actually waterproof.



Electrical Specification

No.	Operating Voltage	5V	6.8V
1	Idle current(at stopped)	4mA	5mA
2	Operating speed (at no load)	0.16 sec/60°	0.14sec/60°
3	Stall torque (at locked)	18 kg-cm	21.5 kg-cm
4	Stall current (at locked)	1.8A	2.2A

Fig. 31: *Advertised information for the servo type used.*



Fig. 32: *Three failed servos from previous years advertised as waterproof.*

Testing and Troubleshooting

Servo Post-incident Analysis

Figure 33 is a closeup image of failed servo 1. The epoxy is concentrated at the top and bottom ends because this is where there are openings in the housing where the pieces come together.

Failed servo 2, as pictured in figure 35, has minimal epoxy. It seems the intention was to concentrate on waterproofing the site where the wiring must enter the device.

Servo 2 was found to be in good condition inside. We could see that a chip to control the board was attached to the motor. We cut the wires connecting the control board to the motor and tested it with a 9V battery as a power source and found that the motor was still working.

Finally, servo 3 was also in pretty good shape once it was opened. This motor was also tested and was found to be working.

The fact that two out of the three motors inside the servos were found to be working suggest that the servos can be used if the control board is bypassed.

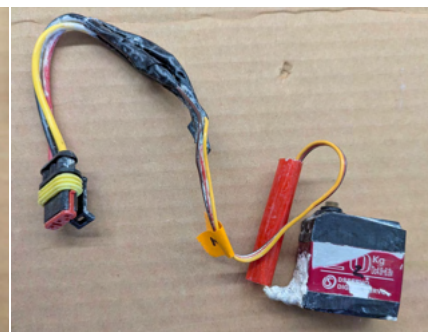
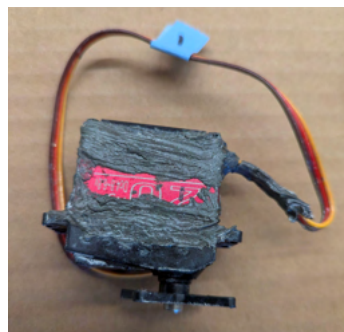


Figure 33: Closeup of failed servo (left) Figure 34: Closeup of failed servo 2 (right)

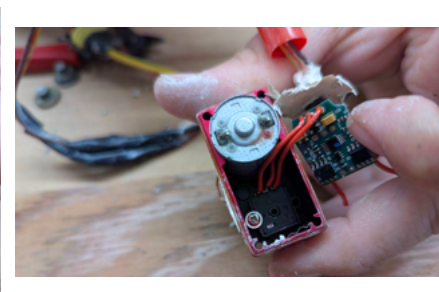
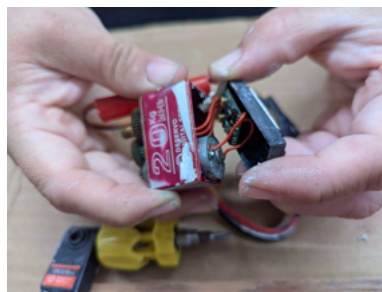


Figure 35: Failed servo 2 open (left)
Figure 36: The motor, no longer attached to the control board (right)

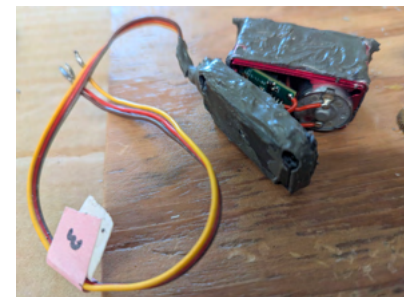


Figure 37: Testing the motor with a 9-V battery (left)
Figure 38: Closeup on the inside state of failed servo 3 (right)

Accounting

Budget

The Robo Raiders entered this competition season with a streamlined and predominantly new team. Fielding an ROV team is a massive undertaking and Robo Raiders decided to leverage existing hardware to practice early and learn from and then decide where innovation could take place. All tools were provided by our team mentor and supplemented by members. This led to a pragmatic approach to expenditures where costs were kept down by such practices as using 3d prints for prototypes and final components. Since the bulk of the ROV was constructed in previous years, that information is provided.

An overview of the funding sources, ROV expenses, and travel cost estimates are provided in the sheet on the left.

ROV Expenses				
HDPE Sheets	1	Reused	\$ 72.38	\$ 72.38
Brushless Waterproof Servos	1	Reused	\$ 67.96	\$ 67.96
T200 Thrusters w/ Penetrator	1	Reused	\$ 600.00	\$ 600.00
Duplicolor Primer	1	Reused	\$ 10.99	\$ 10.99
End Cap	1	Reused	\$ 327.00	\$ 327.00
SER 2000 Servo Kit	1	Reused	\$ 215.00	\$ 215.00
Speed Controller	1	Reused	\$ 144.00	\$ 144.00
Servo Programmer	1	Reused	\$ 9.99	\$ 9.99
USB Camera	1	Reused	\$ 64.99	\$ 64.99
22-Gauge Power Cable	1	Reused	\$ 15.98	\$ 15.98
Wire Battery Cable Lug Terminal	1	Reused	\$ 45.90	\$ 45.90
Splicing Connector	1	Reused	\$ 23.95	\$ 23.95
USB Hub for Camera	1	Reused	\$ 59.99	\$ 59.99
10-Gauge Power Cable	1	Reused	\$ 19.99	\$ 19.99
Circuit Breakers 30A	1	Reused	\$ 41.72	\$ 41.72
Penetrator Socket	1	Reused	\$ 23.95	\$ 23.95
Power Supplies 48V 42ASwitching	1	Reused	\$ 515.00	\$ 515.00
Penetrator PLUG Socket	1	Reused	\$ 14.00	\$ 14.00
Littlefuse Holder	1	Reused	\$ 80.00	\$ 80.00
Wetlink Penetrator M10	1	Reused	\$ 11.99	\$ 11.99
Littlefuse	1	Reused	\$ 7.00	\$ 7.00
Arduino Mega 2560 Rev3	1	Reused	\$ 62.00	\$ 62.00
			Total	\$ -2433.78
Float Expenses				
PHT Sensor	1	Reused	\$ 16.99	\$ 16.99
RF Transceiver Antenna	1	Reused	\$ 12.84	\$ 12.84
12V Battery Pack	1	Reused	\$ 49.99	\$ 49.99
Air Pump	1	Reused	\$ 19.99	\$ 19.99
Analog Pressure Sensor	1	Reused	\$ 21.10	\$ 21.10
Bladder	1	Reused	\$ 29.95	\$ 29.95
			Total	\$ -150.86
Props & Consumables Expenses				
Assorted PVC connectors	N/A	Purchased	\$ 100	\$100
Other consumables	N/A	Purchased	\$ 50	\$ 50
			Total	\$ -150
Travel Expenses				
Flight Tickets	6	Estimated	\$ 1100	\$ 6600
Hotel Lodging	6	Estimated	\$ 1500	\$ 9000
Transportation	1	Estimated	\$ 1400	\$1400
Food	6	Estimated	\$ 400	\$ 2400
			Total	\$ -19400
Category	Notes	Income (USD)	Projected Cost (USD)	Actual Cost (USD)
National Science Foundation: MNT-EC	2025 Grant	\$ 10,000.00		
NSF Grant	2026 Grant	\$ 25,000.00		
Credit Subtotal		\$ 35,000.00		
Miscellaneous Expenses				\$ 0
Travel Expenses				\$ (19400)
Debit Subtotal			\$ (22,134.64)	\$ (22,134.64)
Final Total			\$12865.36	\$12865.36

Acknowledgements

Sponsored by:



The Robo Raiders respectfully acknowledge the individuals and organizations whose guidance and support made this project possible. We thank Mr. Doug Foster for his consistent mentorship throughout the season. We thank Eamon Conklin for giving the team free reign of the Fab Lab. We are also thankful to Brandon Rodriguez, who gave us insight into professional use of ROVs for research projects. Special thanks also go to Professor Jared Ashcroft, who provided critical organizational leadership. He oversaw the team structure, managed budget coordination, and served as the primary liaison between the Robo Raiders and the MATE ROV competition.

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