GEARS, Inc

General Engineering And ROV Specialists

Eastwood Schools | Montgomery, AL, USA

Technical Documentation

2025 MATE ROV Competition

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Lead Programmer: Grady Smith 2nd year
Lead Marketing: Rachel Smith 2nd year
Tether Operator: Paul Flomer 1st year
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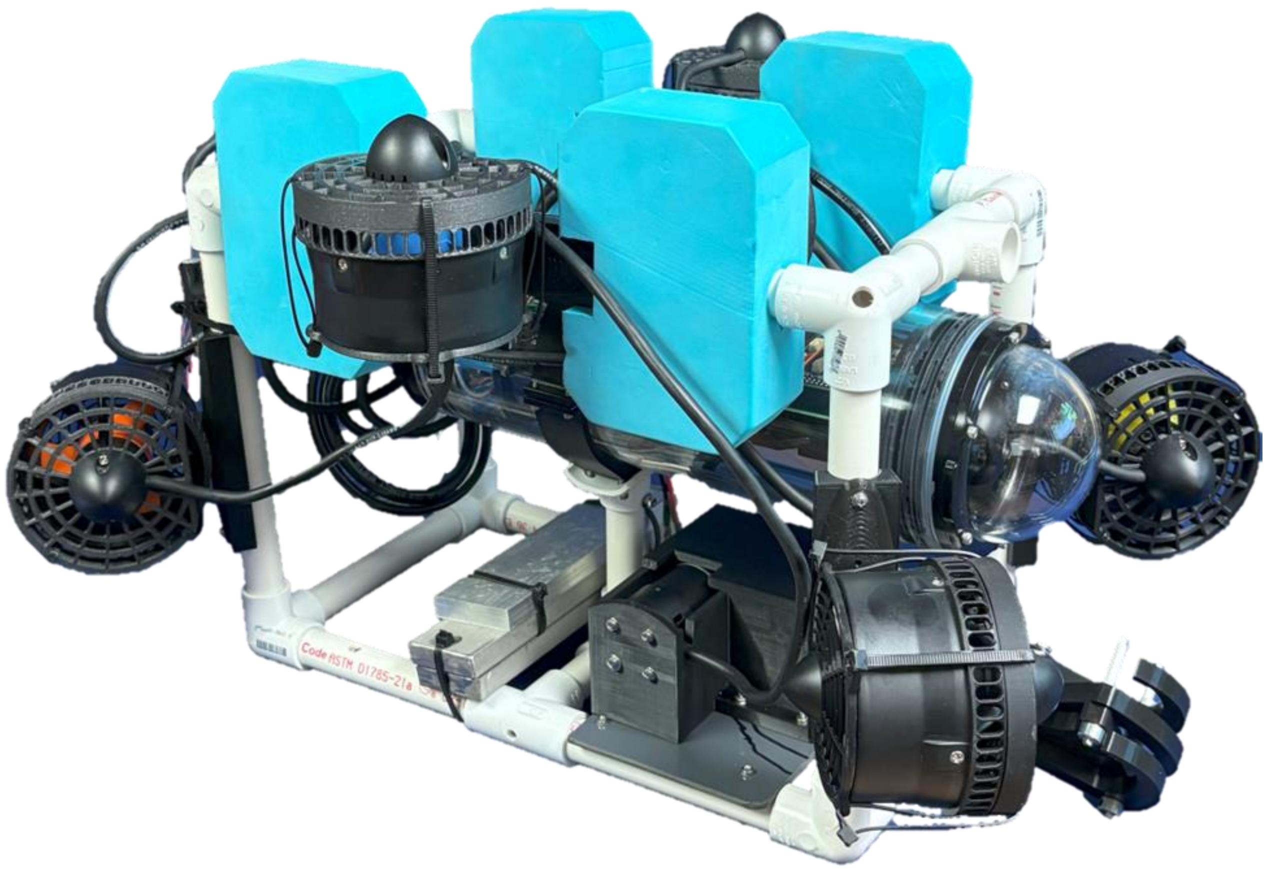
1. Abstract

Established in 2023, General Engineering And ROV Specialists (GEARS) is comprised of nine homeschooled students from Montgomery, AL. With members experienced in engineering, problem-solving, and creativity, our team is dedicated to addressing and combating global ecological issues through quality engineering and technology.

GEARS was tasked with designing and constructing an ROV (Remotely Operated Vehicle) versatile enough to fulfill tasks related to oceanic and environmental challenges faced by researchers worldwide. Our team examined the problems associated with creating a single robot that can multitask across multiple scenarios and meticulously developed, refined, and assembled our newest robot, the Vaquita 3.0.

Designed to address all challenges outlined by MATE efficiently, the Vaquita 3.0 is equipped with several key features to ensure its success. These features include six powerful Blue Robotics thrusters allowing smooth mobility and amplified speed, a specialized claw with enhanced dexterity, and a high-definition camera providing increased visibility. Backed by skilled engineers, our robot is capable of aiding in various real-world environmental challenges, such as monitoring climate impact and protecting endangered ecosystems.



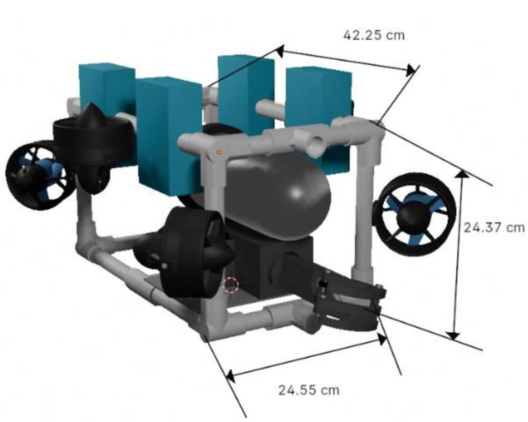
A full body image of the Vaquita 3.0. Photo by Caleb Anglin.

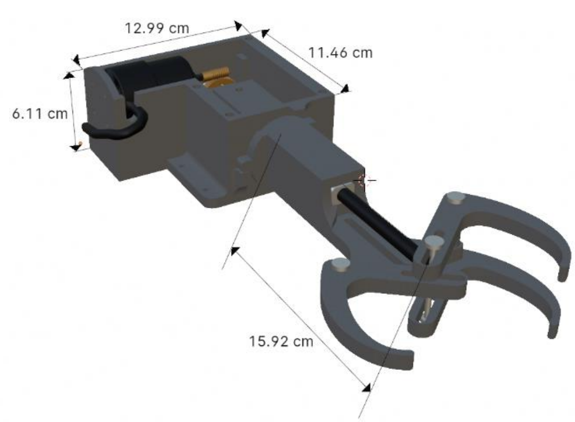
2. Design Rationale

This year, the GEARS robotics team assembled the Vaquita 3.0 for the Ranger class MATE ROV Competition. PVC pipes and connectors make up the main structure of the ROV because they are light, cost-effective, and provide flexibility in design. This pressure-resistant material creates a robust rectangular frame to which all components of the vehicle are mounted. On the software side, multiple programs including SolidWorks, BlueOS, and QGroundControl were used to expertly design and program the robot.

2.1. Overall Vehicle Design & Systems Approach

The Vaquita 3.0 was carefully developed over a period of four months. While brainstorming ideas, our developers prioritized simplified functionality. Whenever possible, the method that produced an optimal result with minimal difficulty was chosen. This was done to fulfill the customers' needs while reducing material and production costs. The entire team brainstormed the optimal method to achieve all necessary vehicle design requirements, including size, weight, safety, and ease of transport. A whiteboard and scratch paper were utilized to problem-solve and depict ideas. Every proposal was tested for merits and drawbacks. The best idea was then implemented on our ROV and Float. For example, after extensive discussion and brainstorming, we decided to reuse the PVC frame from last year and modify it to meet this year's tasks. This allowed us to dedicate more time to improving last year's design instead of building an entirely new frame. In addition, after the regional competition, we decided to redesign the water sample collector and choose an alternate design. These changes improved the tool's water collection capacity, reliability, and accuracy. This change would provide faster and more reliable water sample collection. After designing the entire ROV in Fusion 360, the components were then assembled to build our ROV. This includes the thrusters, onboard control system, structure, and claw. Our final product resulted in the Vaquita 3.0, which meets all weight, size, and functionality requirements.





Images of 3D models depicting the full body of the Vaquita 3.0 and its claw. Photos by Jonathan Pace.

2.2. Mechanical Design

A total of $3,871 was spent to build the Vaquita 3.0, a 10.8 kg ROV that measures 60 x 44 x 35 cm. We chose ½ inch PVC for the structure because it is strong, durable, and easy to work with when fixing buoyancy. For Vaquita 3.0 to fulfill our needed tasks, we had to improve mobility and reduce weight, drag, and complexity. Though a smaller size means our electronic components must fit in a smaller space, we could work around this constraint through careful design and efficient cable management. This compact frame also makes the ROV easier to transport and manage. The ROV uses an octagonal thruster layout which gives our robot full vertical, horizontal, and rotational movement. Once the framework for Vaquita 3.0 was done, the remaining components were added. A Blue Robotics watertight enclosure was secured onto the center of the ROV's structure which protects the enclosure from collisions while also balancing the ROV. The enclosure protects the electrical components from water damage. A claw was mounted onto the base of the ROV. This claw system is constructed from custom 3D printed parts, a linear actuator, and a Blue Robotics waterproof motor that operates this system. Finally, a singular low-light HD USB camera from Blue Robotics was mounted inside a glass dome. This provides the ROV's driver with a high-definition video feed.

2.3. Propulsion

The Vaquita 3.0 ROV utilizes six Blue Robotics thrusters, strategically chosen to balance power consumption, cost-effectiveness, and performance. These thrusters boast a remarkable capability, generating up to 24.5 newtons of force each, ensuring the vehicle's ability to navigate challenging underwater environments efficiently. To optimize power consumption without compromising performance, each thruster is engineered to operate within a range of 12.5 to 13.8 amps, providing the necessary thrust while minimizing energy usage. This careful consideration ensures prolonged mission durations without sacrificing maneuverability or speed. In terms of cost-effectiveness, the selection of Blue Robotics thrusters signifies a deliberate choice to balance affordability with performance. By leveraging these high-quality thrusters, the Vaquita 3.0 achieves optimal functionality within budget constraints, maximizing the return on investment for its users. Performance is important in underwater exploration, and the Vaquita 3.0's thruster layout reflects this priority. Two thrusters are strategically positioned perpendicular to the vehicle's frame, facilitating smooth ascents and descents, while the remaining four thrusters, located at the corners, enable precise horizontal movement. This octagonal configuration enhances steering capabilities, ensuring unparalleled agility and responsiveness in navigating complex underwater terrain. The design incorporates safety features to protect both the vehicle and its operators. Six 3D-printed thruster guards, crafted from PLA plastic, serve as a cost-effective solution to mitigate the risk of propeller damage and potential injury. By preventing contact with objects larger than 1 cm, these guards ensure safe operation without compromising the vehicle's performance or mission objectives.

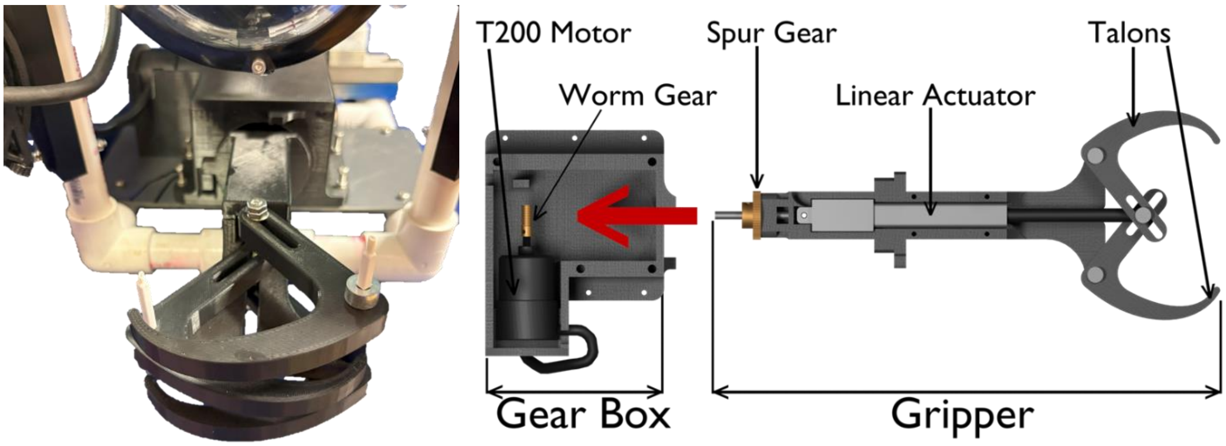
Front and back views of the ROV's thrusters. Photos by Rachel Smith.

2.4. Claw

The Vaquita 3.0's claw is specially designed to accomplish MATE tasks. The claw system was designed in SolidWorks then 3D printed in separate pieces, which were then assembled. This modular design was chosen to provide maximum flexibility in the design and application of the claw. For example, if a piece's design is faulty or requires modification, it can be easily replaced by a redesigned reprint. The claw system consists of two major sections, the gearbox and the gripper. The gripper consists of two pieces that securely hold a 4-inch pulse linear actuator. The linear actuator operates a pin that causes three talons to open and close. A circular extruded section of the gripper allows it to smoothly rotate within a hole in the gearbox. The gearbox includes a motor mount for a Blue Robotics M200 motor which facilitates the claw system's wrist movement. The motor rotates a worm gear which interlocks with a spur gear attached to the base of the gripper section.

The Blue Robotics M200 brushless motor can run safely while submerged in water. In addition, this motor's high max rotation speed of 2751 rpm enables the claw's wrist joint to rotate swiftly. The linear actuator was waterproofed with wax to prevent water damage while in use.

This unique design provides the claw with enhanced dexterity, allowing for more precise manipulations of the ROV's environment. The gripper can rotate 90 degrees, which provides both horizontal and vertical grips. While the horizontal grip improves thermistor replacement and pCO_2 sensor installment, the vertical grip excels at cargo cover removal and releasing of medusa stage jellyfish.



Top - Vaquita 3.0's claw. Photo by Caleb Anglin. Bottom – 3D model of labeled claw by Jonathan Pace.

2.5. Camera

The Vaquita 3.0 is equipped with a singular low-light HD USB camera from Blue Robotics, featuring high-definition imaging, expansive wide-angle coverage, and color correction capabilities, complemented by a 150-degree tiltable camera mechanism. The camera is strategically situated in the front dome of the ROV to get the widest field of view possible and keep the system in a watertight environment. The tilt system is positioned to allow the pilot to change the vertical pitch of the camera easily. This allows our ROV to use a single camera to view straight ahead for safe navigation then tilt downwards to view the claw while grabbing or placing objects. This feature is essential for completing both water sample collection and sacrificial anode replacement.

We decided not to reuse the two Barracuda kit cameras from the original Vaquita because of their low resolution and incompatibility with the onboard controller. In addition, their size would have required us to use a larger frame, reducing the ROV's maneuverability. We did consider using one of the supplied cameras as a rear-view camera, but since the game tasks do not require viewing multiple angles at once, the added cost and construction complexity were not worth the benefits.

2.6. Buoyancy & Ballast

When designing Vaquita 3.0, our goal was to make the ROV neutrally buoyant. Mathematically, the ROV must have a buoyancy force equal to the water it displaces. The calculation below shows that the buoyant force is equal to the product of ROV's volume, density, and gravity. The PVC frame has 14 strategically placed drilled openings that allow water to flood and drain from the PVC structure in seconds. Without complete flooding of the frame, the Vaquita 3.0 would inconsistently tilt from trapped air bubbles. Due to the location of the openings, any air captured while breaching the surface can easily be released by motor-powered tilting underwater. The ROV's large surface area relative to its volume increases hydrodynamic drag, making it more susceptible to displacement and instability when exposed to water currents. To provide stability and prevent unwanted pitching and rolling, 1.5 kilograms of ballast was mounted into the frame of the bottom side of our ROV. However, the flooded frame and heavy ballast increased the weight force over the buoyancy force, effectively sinking our ROV. To regain neutral buoyancy, we added foam blocks to the top of the ROV. When the claw was added, an additional pool tube was attached to the rear of the ROV to counteract the change in buoyancy, overall making the front of the ROV more buoyant. By adding the extra ballast in the rear, we were able to level out the ROV. The positive buoyancy force from the top of the ROV and the opposing force from the bottom provide stability and prevent unwanted pitching and rolling.

The buoyancy force of Vaquita 3.0 without any ballast or foam is:

$$FB = p \cdot V \cdot g = (1000\ kg/m^3) \cdot (5{,}974\ cm^3) \cdot (9.8\ m/s^2) = 58.55\ \text{newtons}$$

FB: Buoyant force
p: Density of the fluid
V: Volume of the fluid displaced by the object
g: Acceleration due to gravity

2.7. Tether

The ROV's tether consists of four components: one 10 gauge 2-wire cable, an ethernet cable, a PVC 1/4 "OD tubing, and a PVC 3/8 "OD tubing. The two 10-gauge wires transmit 12 volts of DC power to the ROV, reducing the voltage drop from the long distance. The ethernet cable sends signals to and receives data from the ROV. The two PVC tubes allow the tether to achieve neutral buoyancy, which reduces drag. An expandable braided cable sleeve holds the wires, tubes, and cord together, reducing the risk of the tether snagging on field pieces. The length of tether is 18 meters to ensure that the ROV can reach all the demo field with tether to spare. This was calculated by using the Pythagorean Theorem with the max distance of demonstration objects (10 meters) and max depth (four meters) representing the two sides of a triangle. This creates a hypotenuse or max tether length needed to submerge in order to complete all requirements. Seven meters of extra tether were added on to the necessary 11 meters to ensure that plug ins are a safe distance from the water and all demo objects are reachable even after being disturbed.

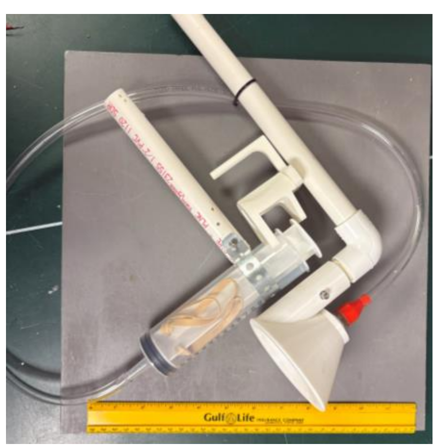
The tether is coiled around a cord storage reel, which the Tether Operator carries. During the product demo, the Tether Operator will control the amount of slack in the tether to ensure that the tether does not obstruct the ROV's path while ensuring that the ROV has enough tether to maneuver its way through the water easily. The expandable sleeving is attached to the PVC structure of the ROV using a pipe clamp. The wires have sufficient slack so that the expandable sleeving and frame take any strain applied to the tether. The strain on the on-board control system from the tether is controlled by the tether connection shown below.

Left: The ROV's tether connection. Right: The ROV's tether. Photos by Rachel Smith.

2.8. Innovation

The Vaquita 3.0 was designed with multiple innovative properties. Our custom 3D printed claw includes a rotatable wrist joint which enhances our ROV's grasping dexterity. Its modular design allows individual pieces, such as the talons or linear actuator holder, to be modified or replaced without requiring complete reconstruction of the claw. In addition, the ROV's four horizontal thrusters were uniquely positioned to provide optimal movement. With four of the thrusters rotated at 90˚ from each other, the ROV is capable of rotating in place and accelerating horizontally in any direction.

A unique tool was created to collect water samples. It is comprised of two major sections which are connected by plastic tubing. The first section consists of a PVC arm which attaches onto the ROV directly under the claw, a rubber band powered syringe mounted onto the end of the PVC arm, and a 3D printed clasp which prevents the syringe from extending. The second section is constructed from a PVC arm mounted onto the top of the frame, a 3D printed guiding funnel, and a metal needle. Plastic tubing connects the back end of the needle to the syringe. Surrounding the needle, the funnel guides it into the opening of the water collection bucket. When the claw tightens its grip, it pulls the clasp off the syringe. The syringe then extends and pulls liquid through the needle and tubing into the syringe to be carried to the surface for testing.

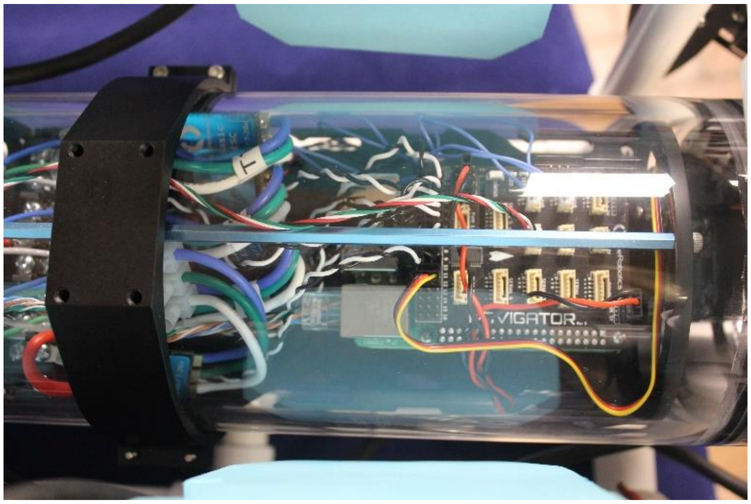


Water sample collection tool, taken by Caleb Anglin

3. Software and Electronics

3.1. Onboard Electronics

The Vaquita 3.0 is equipped with a Raspberry Pi 4 B as the brain, a Blue Robotics Navigator flight controller, leak sensors, and a camera, all enclosed in a Blue Robotics Watertight Enclosure. The USB camera directly connects to the Raspberry Pi, while all other electronics are connected to the Raspberry Pi through the Navigator flight controller. A leak sensor is placed in the front and back of the watertight enclosure to give operators constant and reliable feedback on the moisture levels inside the enclosure. With proper monitoring of these sensors, disastrous and costly damage to all the electronics can be avoided. Vaquita 3.0 utilizes six blue robotics T200 thrusters to provide propulsion, one M200 motor to rotate its claw, and one linear actuator to open and close the claw. Each of the motor wires enters the watertight enclosure through a Blue Robotics Wet Link Penetrator and connects to a Blue Robotics Basic ESC, which in turn connects to the Navigator Flight Controller.



Vaquita 3.0's onboard electronics. Photo by Rachel Smith.

3.2. Electrical

Vaquita 3.0 runs on 12 VDC power. No AC power is used. All connections to power were made with screw terminals for a stable connection. The main power line runs through a 25-amp fuse on the surface to prevent damage from shorts and large current spikes. Power is connected to the Navigator Flight Controller through a 5V power supply unit and to the Sabertooth motor controller and each of the ESCs. The Raspberry Pi and Low Light HD USB camera are powered by the Navigator Flight Controller. An electrical System Integration Diagram (SID) of the ROV can be found in Appendix A.

3.3. Command and Control Software

Vaquita 3.0 is piloted by a Windows laptop on the surface running QGroundControl, an open-source flight control software recommended by Blue Robotics. A Logitech F310 gamepad is connected to the laptop for a more ergonomic piloting experience. Vaquita 3.0 runs Blue Robotics' open-source BlueOS operating system with ArduSub firmware. We chose this software because it was developed by Blue Robotics and seamlessly integrates with our Blue Robotics hardware.

4. Float

Our third-ever Float, Nautilus, is designed to collect pressure data during two vertical profiles of the pool and a period hovering at 2.5 meters in the pool and transmit that data to the Float Operator's computer. Nautilus uses a buoyancy engine composed of an IP54-rated linear actuator driving a syringe in and out to dynamically ascend and descend in the water. It uses rocks suspended in a plastic enclosure as ballast. Nautilus's housing is mostly composed of a foam-core PVC tube that can withstand pressures of up to 888 kPa. The float is 600 mm long and 115 mm in diameter (not counting end cap). One end of the tube is capped by the 3d printed part, which fits tightly on the pipe and is sealed by epoxy. The other end of the pipe is capped by a mechanical test cap for easy access to the electronics. Our pressure release is formed by a hole in the side of the float plugged by a rubber stopper. This allowed the float to meet safety requirements. Nautilus is powered by a 12 VDC power pack composed of 10 NiMH AA batteries, which runs through a 2-amp fuse before powering any of its components. The onboard electronics are controlled using MicroPython software through an ESP32 microcontroller. The linear actuator is connected to a reversing relay controlled by the ESP32. A pressure sensor is also connected to the ESP32 and collects pressure data during the two vertical profiles. An electrical System Integration Diagram for Nautilus can be found in Appendix A.

Full body image of the Nautilus Float. Photo by Paul Flomer.

5. Build vs Buy, New vs Used

GEARS operates as efficiently and as organized as possible, which means our Build vs Buy decisions are carefully considered. Fortunately, thanks to our generous sponsors over past years our inventory this year includes high-quality products. This allowed us to invest in better electronics, products, and tools that were needed for this year's ROV and Float. Our team dedicated extensive time to researching the best products to purchase, ensuring optimal value for our investment. When making this decision, the team's primary focus was what we needed to buy and what we already had or could create in-house. While we had a generous budget, we kept in mind not to recklessly spend money on things that we already had or could make in our shop. GEARS constructed a mock-up of this year's MATE field with materials we already had and pre-purchased. This was an important decision because it gave our team the opportunity to practice with game pieces and better understand the rules.

The claw showcases this philosophy. Since our budget did not permit us to buy a commercial claw, we decided to stick with last year's idea of a custom, 3D-printed claw. However, instead of reusing last year's claw design, which contained multiple issues, we decided to design and construct an entirely new claw. This claw included the flexibility and cost benefits of the 3D printed design while lacking the issues of the last design. In the end, we decided to build a new claw instead of buying a commercial claw or reusing an old one.

Additionally, this year, we crafted our ROV's frame entirely from ½ inch PVC. We utilized 3D printers to make the float components and tailor specific parts of the ROV, significantly decreasing the cost of prototyping designs. These parts include thruster mounts, thruster shrouds, and a shaft adapter for our claw's motor. 3D printing not only reduces the number of parts required but also eliminates the need to rely on manufacturers, allowing for quick reprints if needed without worrying about shipping delays. 3D printing also makes our ROV remain safe for aquatic wildlife. Despite the higher costs associated with investing in quality, the GEARS team recognized its importance. Some of the more expensive items that we were able to reuse that were purchased last year include Blue Robotics T-200 Thrusters, a Navigator Flight Controller, and a Raspberry Pi 4, along with various components, specialized tools, and equipment necessary to ensure the safety and successful functioning of our ROV and Float in all tasks. A full list showing the origin of the ROV and field parts can be found in the Appendix C: Accounting Expense Detail table by looking at the Source and Category columns.

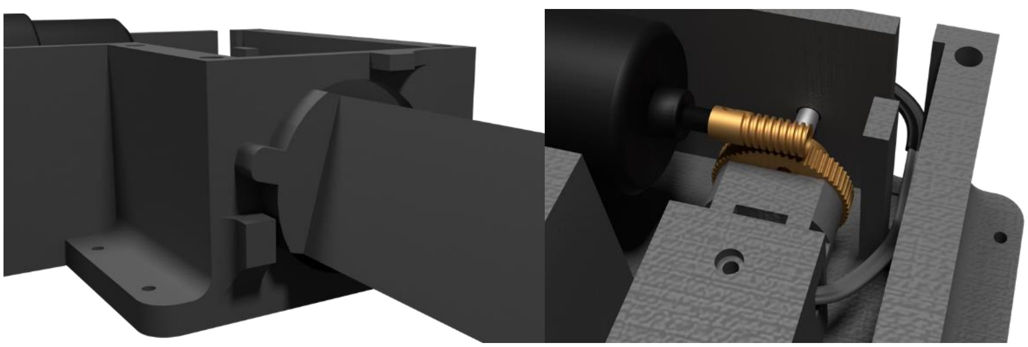
6. Testing and Troubleshooting

Vaquita 3.0 is GEARS' second year using an ROV with a watertight enclosure for an onboard control system. Because of this, numerous opportunities for testing and unavoidable troubleshooting challenges were introduced during this year's competition. We use the same process to resolve every problem we encounter. We start by identifying the underlying problem and then discuss a solution. After that, we implement the proposed solution, test it, and, if needed, repeat the process until we have a functional and reliable product.

One of the main examples of testing and troubleshooting this year involved our Sabertooth motor controller and the linear actuator used to open and close our claw. Initially, we had difficulty sending signals from the controller to the actuator. To diagnose the issue, we used both an oscilloscope and a high-precision multimeter to verify that the correct signals and power were reaching the Sabertooth—visualizing the incoming waveforms and measuring voltage. This testing process led us to identify the root cause: an incorrect DIP switch configuration on the Sabertooth. Once resolved, this significantly improved the performance and reliability of our claw.

While this year's claw is specifically designed to account for the issues encountered last year, there were multiple issues that arose. The claw went through numerous prototypes to solve these issues. One of the main problems stemmed from the linear actuator's wire. When the claw rotated its wrist, the wire trailing out from the gripper would get wrapped up and risk entangling into the gears operating the wrist. This would cause damage to both the wire and the gears. To resolve this issue, we designed barrier extrusions that restricted the claw's movement and removed the possibility of the wire getting wrapped up with the gripper. A special barrier was also added to hold the linear actuator's wire away from the moving gears.

In addition, the previous prototype of the claw design did not allow easy access to the linear actuator in case of malfunction or replacement. This fault caused major issues when the linear actuator suddenly stopped working at the beginning of our regional competition. This experience encouraged a redesign that allowed the linear actuator to be easily removed from the claw for inspection, maintenance, or replacement.



Images of 3D models depicting claw wrist constraint and wire holder. Photos by Jonathan Pace.

Numerous challenging obstacles were encountered throughout the development of Vaquita 3.0. However, they were successfully conquered through collective teamwork and perseverance.

7. Project Management

7.1. Company Structure

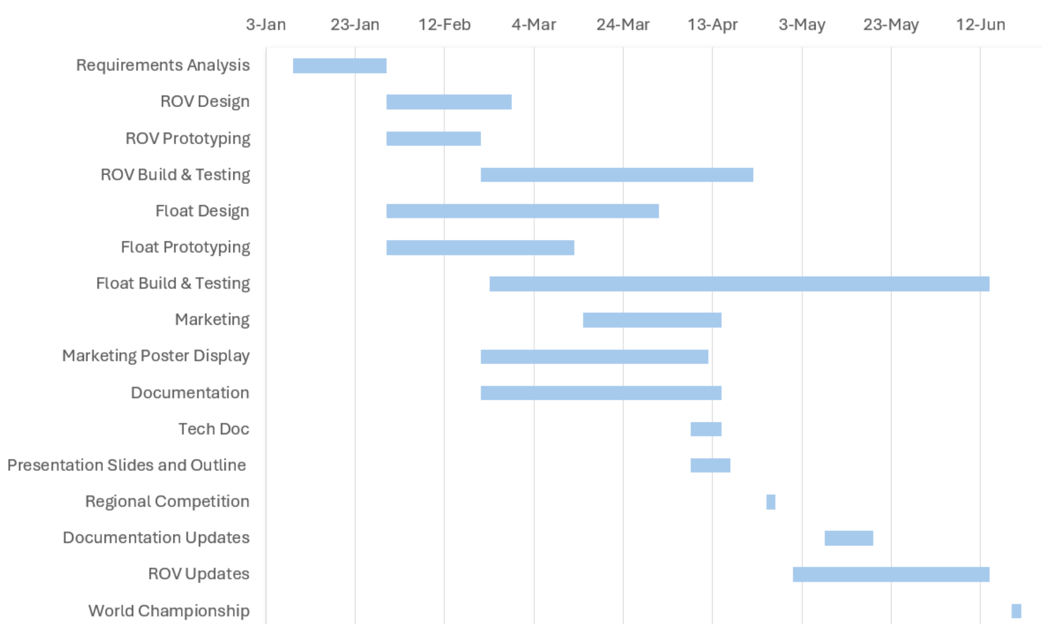
The GEARS company consists of nine members skilled in engineering, problem solving, and creativity. For maximum efficiency, a chain of command was required. Without this organizational structure, work could not be completed on time, if at all. To make sure that everyone understood their responsibilities, company members were assigned a job based on the schedule and each member's individual interests and skills. Pictured below: Caleb Anglin is our President and project manager. Jonathan Pace is Vice President and ROV pilot. Grady Smith is our Lead Programmer. Paul Flomer acts as the team Tether Operator. Rachel Smith covers team marketing material and is our data analyst. Joshua Chung, Richard Smith and Sam Morris are our technicians. All team members perform various other tasks as needed.

The GEARS team. Photo by Lee Sumner.

7.2. Scheduling and Planning

To adequately plan for the competition, we created a detailed schedule before the release of this year's manual. Doing this allowed us to stay on track once the season started. Our schedule included all tasks to be completed for each assignment. Each task was assigned a completion date and a project head to maximize efficiency. This schedule was created in Basecamp, a web-based tool for project management. Through Basecamp, the company could view the schedule, tasks, and due dates.

2025 Schedule



Team meeting attendance was recorded using a spreadsheet. This information, along with our task schedule, helped ensure we did not fall behind. Team members spent a total of 670 in-person hours across 22 meetings while designing, constructing, and testing the 2025 ROV. The roster used to monitor meeting attendance is provided below.

Member Attendance Roster

Student First	9-Jan	30-Jan	20-Feb	27-Feb	6-Mar	13-Mar	1-Apr	3-Apr	8-Apr	10-Apr	12-Apr	15-Apr	17-Apr	19-Apr	21-Apr	22-Apr	25-Apr	26-Apr	27-Apr	1-May	8-May	15-May
Caleb	X	X	X		X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Joshua	X	X	X	X	X	X	X	X	X	X	X	X				X	X	X	X	X	X	
Paul	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Isaac	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X		X
Sam	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X		X	X	X
Jonathan	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Grady		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Rachel	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X
Richard		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

7.3. Managing Resources

In addition to scheduling, Basecamp was used to house a repository for all GEARS' technical information. This includes current and previous years manuals; score sheets; brainstorming ideas; education and training materials; and technical diagrams and photos.

8. Safety

Due to the unique conditions and hazards associated with an underwater environment and our team's relative inexperience operating around such an environment, safety is a vitally important consideration for GEARS while planning for and competing in the MATE ROV competition. We're fortunate to have an in-house lifeguard—Caleb Anglin—who is certified in Lifeguarding, CPR/AED, and First Aid. To facilitate safe operation during the construction of our ROV, each member of our team was required to pass a safety test for all power tools used during construction, as well as a general safety test regarding safe conduct while within the work area.

Member Safety Test Results

Student First	Tests Passed	General Shop Safety	Electric Drill	Heat Gun	Soldering Iron	Belt Sander	Finishing Sander	Rotary Tool	Saber Saw	3-D Printer	Air Compressor	Band Saw	Belt/Disc Sander	Bench Grinder	Drill Press	Disc Grinder	Reciprocating Saw	CNC Router	Compound Miter Saw	Horizontal Band Saw	Table Saw
		Required				General										Senior					
Caleb	20	100	100	100	100	100	100	100	100	100	100	94	100	100	92	100	100	100			
Joshua	4	100	100	100	100																
Paul	10	92	90	100	100	100	100					93	100		100				100		
Isaac	30	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Sam	15	100	100	100	100	100	100	100	100	100	100	100	100	100	100						
Jonathan	26	100	100	100	100	100	100	100	100	90	100	100	100	90	92	90	100	100	92	90	100
Grady	28	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Rachel	4	100	100	100	100																
Richard	27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	95

The scores for the tests can be seen in the table above. A blue box represents both a passed test and completed hands-on training. As you can see from the table, each of our team members passed the tests and received hands-on training for all needed tools. The required tools represent those tools that are necessary to be certified on to participate in the team, the general tools represent those tools that are used most frequently and are accessible to most students, and the senior tools represent those tools that are specialized and require greater skill and maturity to operate safely. In addition to the safety tests, our team created a list of procedures to follow before entering the work area or using a tool to mitigate hazards that could arise during work. This list included:

- Check attire for any unsafe articles, such as open-toed shoes, baggy clothing, or loose jewelry, which might get caught in a machine.
- Tie back any long hair to avoid it becoming caught in a machine.
- Make sure to wear hearing protection when loud machinery is in use nearby.
- Check for any hazards present in the work area.
- Make sure to know the location of the team's first aid kit.
- Be familiar with the machine user manual and follow the included instructions.
- Always wear the appropriate safety gear when using any tool.
- Always be careful and alert when operating any tool.
- Turn off any machine requiring adjustments before making said adjustments.
- Immediately report any issue with a machine to the mentor if one should occur.

Our team also formulated a list of hazards that could be present at the job site and created our own Jobsite Safety and Environmental Analysis (see Appendix B for the JSEA). We derived this list by studying the environment while visiting last year's competition and thoroughly examining potential hazards that could theoretically arise during the competition. We then determined the proper precautions to mitigate risk and trained our team members accordingly. Primarily, it is paramount to be attentive regarding the development of threats and be aware of the proper course of action should an issue occur. The safety of those handling or working with our equipment underwater was a major consideration in the design process of both Vaquita 3.0 and Nautilus. No sharp edges exist on either machine. Propeller guards provide IP-20 protection, ensuring that no appendages can come into contact with fast-spinning propellers. Nautilus's pressure plug, installed in the center of the lid, ensures the release of pressure before any excess pressure situation can occur.

9. Construction and Operational Checklists/Protocol

The checklist below dictates the most efficient way to construct the ROV. All times are estimates based on four available team members.

Tether (1 hour)

- Stretch power cable, ethernet, and two PVC tubing out to 18 meters
- Slide sleeve over all four lines. Leave 1 meter of tubing for both PVC lines, .5 meters of ethernet cable, and .5 meters of power cable in excess on the ROV end of the sheath
- Feed the excess lines through strain relief and clamp down sheath end to PVC
- Cut the lines so 2 meters of ethernet, 2.5 meters of power cable, and 2 meters of both PVC tubes on the above water end of the sheath are in excess

Watertight Enclosure (8 hours)

- Attach and wire the Raspberry Pi and Navigator flight controller
- Attach penetrators and wire up the power and ethernet cable
- Wire and place leak sensors and camera
- Wire ESC for each thruster or motor and attach penetrators
- Follow the Blue Robotics manuals for the electronics tray and camera tilt assemblies
- Wire the Sabertooth motor controller and linear actuator.
- Run power from the Sabertooth to the linear actuator through a penetrator
- Test all electronics to make sure they are wired properly
- Slide electronics tray into enclosure making special note to ensure that none of the ESCs are in contact with one another

Structure and Buoyancy (3 hours)

- Cut the PVC pipes and collect all necessary joints
- Drill holes in float to snugly fit on ½ PVC pipe
- Assemble and tighten connections with clamps
- Drill holes for drainage on every bottom and top corner for drainage and holes for the zip ties that secure the ballast
- Cut plastic sheet and secure it with bolts onto the base of the ROV

Propulsion and Claw (2 hours)

- Replace the propellers on the thrusters so there are three clockwise and three counterclockwise while making special note of the direction for each
- Screw thrusters on to 3D printed mounts
- Attach mounts to frame at proper locations and angles for the octagonal layout programming
- Assemble the manipulator parts with the motor and linear actuator inserted into their housings
- Bolt the claw onto the plastic sheet on the ROV
- Tie down loose wires with zip ties or wrap around structure

ROV Tools (1 hour)

- Cut two PVC pipes to the correct lengths.
- Attach plastic container onto one PVC arm
- Attach 60 ccm syringe and metal pin onto the other PVC arm

Final Review (2 hours)

- Melt all cut zip ties and tighten structure with clamps
- Place ROV in water and monitor for water leakage
- Pilot ROV for 15 minutes while completing tasks and running thrusters at speed

The checklist below dictates the order to perform setup and breakdown for safe operations.

Pre-Demonstration Checklist
- Ensure Float batteries are installed and charged
- Check robot for loose items
- Power on all 3 laptops

Poolside Checklist
- Connect Power cable to power supply
- Connect Ethernet cable to pilot's laptop
- Open & unlock all 3 laptops
- Connect Logitech F310 controller to pilot's laptop
- Launch QGroundControl on pilot's laptop
- Place ROV in water
- Provide enough slack for ROV deployment
- Power on Float

Breakdown Checklist
- Remove ROV from water
- Remove Float from water
- Power off Float
- Disconnect Ethernet cable from pilot's laptop
- Disconnect power cable from power supply
- Coil tether
- Disconnect Logitech controller from pilot laptop
- Close all three laptops

Post-Demonstration Checklist
- Clean camera dome
- Check ROV for any loose items
- Review demonstration strategy and adjust ROV

10. Budget and Cost Accounting

10.1. Budget

GEARS operates on a strict budget and cannot afford to waste or misuse funds due to errors in design practices or electrical malfunctions. The company met at the beginning of the build year and assessed the MATE competition requirements and supplies needed to complete the mission tasks effectively. Next, we inventoried materials already on hand to re-use parts to save costs and minimize waste. We also used information from GEARS' previous year's budget and projected costs to attend both the regional and World competitions to baseline a $12,000 budget for the year 2025. Knowing we would re-use over $3,000 worth of ROV parts this season, we created a ROV budget of $4,000 to cover the value of re-used parts and allow us room to buy more if needed. Our travel budget of $6,000 included food and donated fuel for travel to both the regional and World competitions. See the Account Balance Accounting table in section 10.3 below for high level details of our budget.

10.2. Funding

GEARS relies solely on fundraising, donations, and fees for our expenses. Donations were collected from generous parents and investors in our local community. The company collected $2,850 from sponsors, plus additional funds from T-shirt sales and meal fees for a total income of $3,795. After adding the value of donated supplies/travel and re-used parts, our total value came to $14,201. See the 2024-2025 Income table below for detailed accounting of our income.

2024-2025 Income

Date	Sponsor / Organization	Received
8/27/2024	Chick-fil-A Prattville	$200
9/17/2024	Heartwise	$200
9/17/2024	Cornerstone Detention Products, Inc.	$350
11/7/2024	Joyce Porter	$100
1/1/2025	Basecamp	$300
1/1/2025	MathWorks	$1,000
1/30/2025	Aca & David Gibbons	$150
1/30/2025	Smith Family	$150
2/27/2025	Chung Family	$150
3/6/2025	Next Level Bootcamp	$150
3/6/2025	Darlene's Shells	$100
Sponsor Total		**$2,850**
Sales	T-Shirt Sales	$180
Fee	DISL Meal Fees	$765
Total Income		**$3,795**
Donated Supplies and Travel		$6,685
Re-used Parts		$3,721
Total Value		**$14,201**

10.3. Spending

After brainstorming our initial ROV design, we compiled a list of potential materials. Then we researched the internet for the materials and parts. All purchase requests were submitted to our mentor for approval, agreed upon as a company, and then approved for purchase. Receipts were collected and documented using spreadsheets, allowing the company to keep track of expenditures and avoid overspending. We divided our expenses into categories: competition, field, Float, ROV, and travel. Our expenses totaled $12,271, including donated and re-used items for the competition year. This leaves $1,930 for future needs. See a complete list of expenses in the Appendix C table.

Account Balance Accounting

Category	Budget	Purchased	Donated	Re-use	Total
Competition	**$2,000**	$684	$1,020	$0	**$1,704**
Field	**$100**	$20	$2	$34	**$57**
Float	**$200**	$138	$42	$83	**$264**
ROV	**$4,000**	$257	$11	$3,603	**$3,871**
Travel	**$6,000**	$765	$5,610	$0	**$6,375**
Total	**$12,000**	**$1,865**	**$625**	**$3,721**	**$12,271**
Total Income					$14,201
Balance					**$1,930**

11. References

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"Blue Robotics Community Forums." *Blue Robotics Community Forums*, discuss.bluerobotics.com/. Accessed 15 Apr. 2025.

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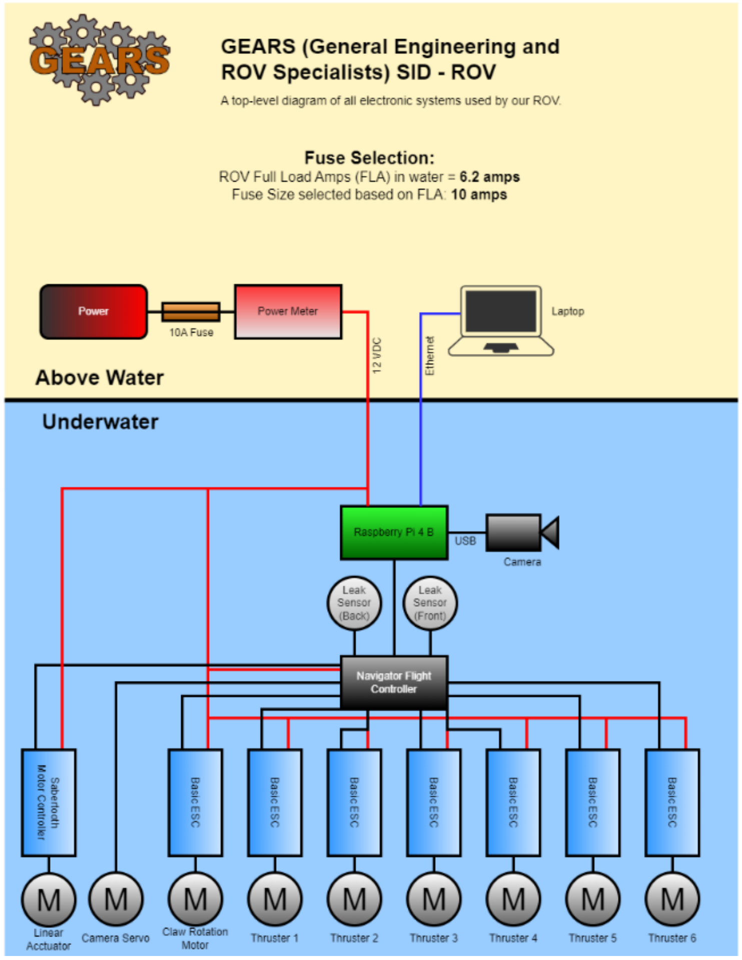
12. Acknowledgments

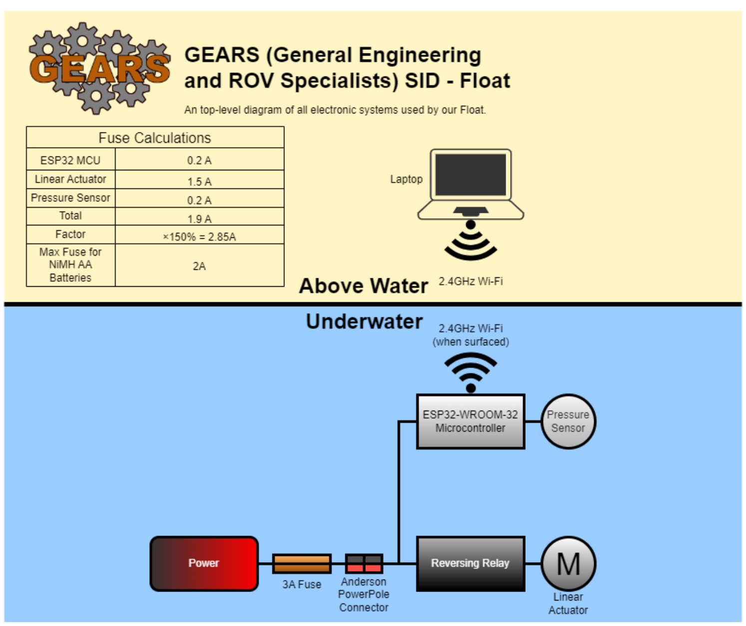
GEARS would like to thank the following people and organizations for making our team possible:

- Our mentor, Arthur Lee Sumner
- Our Parents
- Dauphin Island Sea Lab - Discovery Hall Programs
- Our Investors

Prattville, AL

Appendix A: System Integration Diagrams (SIDs) – ROV (Top) and Float (Bottom)





Appendix B: Jobsite Safety and Environment Analysis (JSEA)

Tasks	Hazards	Consequences	Risk Controls	Persons Responsible
1: Entering/ exiting the pool deck area	Slipping	Injury to company employees	• All team members must wear closed-toed shoes with a good grip. • Inform judges and team members of any puddles in the workspace.	All company employees
	Dropping objects	Injury to company employees	• Ensure all team equipment is contained and can be comfortably carried to the workstation.	All company employees
	Lifting strain	Injury to company employees	• Heavy objects should be carried by multiple people.	All company members
2: System set up	Getting water on equipment	Damage to equipment	• Keep all equipment except the ROV and ROV attachments out of the water. Take care to ensure that non-ROV cables do not contact the water.	ROV Lead / Lifeguard – Caleb
	Tripping over wires	Injury to company employees	• Keep the ROV tether away from the rest of the setup wires. • Lay all the wires flat on the ground when crossing pathways and coil them out of the walkway when there is excess.	Tether Operator – Paul
	Environmental threats	Damage to equipment	• Check the weather before and during an attempted run of the ROV in outdoor pools.	ROV Lead/Lifeguard - Caleb
3: Power up checks	Shock hazard	Injury to company employees	• Ensure all wires are properly connected and non-tether wires are clear of the water.	Copilot - Grady
	Voltage Spikes	Damage to equipment	• Connect the power supply before turning on the ROV.	Copilot - Grady

Tasks	Hazards	Consequences	Risk Controls	Persons Responsible
4: Pool side operations	Tether operator slipping or falling into pool	Damage to equipment Injury to company employees	• Train the tether operator how to properly stand, coil, and feed during operations. • Always have a trained lifeguard present. • Identity who is not a confident swimmer and advise to stay away from edge of pool.	Tether Operator – Paul Lifeguard - Caleb
	Injury from ROV	Injury to company employees	• The tether operator should wait 3 seconds after getting confirmation from the driver to interact with the ROV.	Pilot - Jonathan
5: System breakdown	Slipping	Injury to company employees	• All team members must wear closed-toed shoes with a good grip. • Inform judges and team members of any puddles in the workspace.	All company employees Lifeguard – Caleb
	Dropping objects	Injury to company employees	• Ensure all team equipment is contained and can be comfortably carried to the workstation.	All company employees
	Lifting strain	Injury to company employees	• Heavy objects should be carried by multiple people.	All company employees

Appendix C: Accounting Expense Detail

Date	Source	Category	Description	Qty	Total
9/28/23	Re-use	ROV	Electronic Speed Controller	6	$216.00
9/28/23	Re-use	ROV	T200 Thrusters	6	$1,222.60
11/27/23	Re-use	ROV	Power Meter	1	$50.97
12/8/23	Re-use	ROV	Navigator Flight Controller	1	$333.90
12/8/23	Re-use	ROV	Raspberry Pi 4	1	$155.00
12/8/23	Re-use	ROV	Power Supply (5V 6A)	1	$25.00
12/8/23	Re-use	ROV	M10 Enclosure Vent and Plug	1	$9.00
12/8/23	Re-use	ROV	WetLink Penetrator M10-6.5MM-LC (Thruster Cable)	2	$100.00
1/29/24	Re-use	Field	3.375-in Zinc-plated Steel Screw Hook (20)	1	$6.63
1/29/24	Re-use	Field	1/2" Sch 40 Side Out Elbow	2	$4.90
1/29/24	Re-use	Field	1/2" Sch 40 Adapter	2	$1.44
1/29/24	Re-use	Field	3/4" x 1/2" Sch 40 Reducing Tee	4	$6.24
1/29/24	Re-use	Field	2" Sch 40 Tee	1	$4.70
1/29/24	Re-use	Field	1/2" Sch 40 Pipe (10 feet)	2	$8.94
1/29/24	Re-use	Field	3/4" Sch 40 Socket Cap	1	$0.78
1/29/24	Re-use	Field	3/4" Sch 40 Tee	1	$0.82
1/29/24	Re-use	ROV	Cord Storage Reel	1	$12.81
1/31/24	Re-use	ROV	Buoyancy Floatation Belt	1	$21.99
1/31/24	Re-use	ROV	2" Wide 5 Yard Long Hook & Loop Cable Tie Cord	1	$8.99
1/31/24	Re-use	ROV	PVC Tubing 1/4"ID X 3/8"OD (100 Feet)	1	$26.89
1/31/24	Re-use	ROV	Cat5e Outdoor Ethernet Cable (75 Feet)	1	$20.99
1/31/24	Re-use	ROV	1/2" Expandable Braided Cable Sleeve (100 Feet)	1	$15.99
2/2/24	Re-use	ROV	Dome End Cap	1	$40.00
2/2/24	Re-use	ROV	Watertight Enclosure Tube (100 x 300 mm)	1	$236.08
2/2/24	Re-use	ROV	M10 Hole End Cap w/ 14 holes	1	$32.00
2/2/24	Re-use	ROV	O-Ring Sealing Flange (100 mm)	2	$86.00
2/2/24	Re-use	ROV	M10 Enclosure Vent & Plug	1	$9.00
2/2/24	Re-use	ROV	WetLink Penetrator M10-7.5MM-HC (14 Gauge	1	$50.00
2/2/24	Re-use	ROV	WetLink Penetrator - Blank (No Hole)	3	$18.00
2/2/24	Re-use	ROV	Low-Light HD USB Camera	1	$99.00
2/2/24	Re-use	ROV	Camera Tilt System	1	$64.00
2/2/24	Re-use	ROV	Electronics Tray w/ Terminal Blocks	1	$100.00
2/2/24	Re-use	ROV	Watertight Enclosure Clamp (100 mm)	1	$48.00
2/2/24	Re-use	ROV	Propeller Set - Yellow	1	$8.00
2/2/24	Re-use	ROV	Propeller Set - Orange	1	$8.00
2/18/24	Re-use	ROV	1/2" Sch 40 Cross	15	$38.25
2/18/24	Re-use	ROV	1/2" Sch 40 Side Out Elbow	12	$29.40
2/18/24	Re-use	ROV	1 1/2" Sch 40 Cap	1	$1.98
2/18/24	Re-use	ROV	1/2" Sch 40 Tee (10)	2	$10.52
2/18/24	Re-use	ROV	1/2" Sch 40 Pipe (10 feet)	1	$4.51
2/20/24	Re-use	ROV	1/2" Stainless Steel Bar (3 Ft)	2	$172.52
2/20/24	Re-use	ROV	SS Pan Screws, M3 x 0.5mm x 12mm (100)	2	$13.30
2/20/24	Re-use	ROV	SS Pan Screws, M3 x 0.5mm x 35mm (100)	1	$11.89
2/20/24	Re-use	ROV	SS Washers M3 (100)	2	$4.38
2/20/24	Re-use	ROV	SS Washers M4 (100)	1	$3.57
2/20/24	Re-use	ROV	SS Hex Nut, M3 x 0.5 mm (100)	2	$9.46
2/20/24	Re-use	ROV	SS Socket Screws, M3 x 0.5 mm, 12 mm (100)	1	$6.00
2/20/24	Re-use	ROV	Nylon Plastic Cable Tie, 11" Black (100)	1	$12.72
2/29/24	Re-use	ROV	Barracuda Power Kit	1	$35.00
3/11/24	Re-use	ROV	10/2 Direct Burial Speaker Wire (100 Feet)	1	$118.68
3/11/24	Re-use	ROV	PVC Tubing 1/4"OD (100 Feet)	1	$20.89
3/14/24	Re-use	ROV	WetLink Penetrator M14-9.5MM-LC (10 Gauge	1	$56.00
3/28/24	Re-use	ROV	3-D Printed Thruster Guards (grams)	90	$4.50
4/1/24	Re-use	Float	Linear Actuator	1	$26.55
4/1/24	Re-use	Float	Forward/Reverse Relay Module	1	$17.40

Date	Source	Category	Description	Qty	Total
4/1/24	Re-use	Float	ESP-32	1	$15.59
4/1/24	Re-use	Float	Fuse Holders	1	$9.99
4/1/24	Re-use	Float	Pressure Sensor	1	$13.70
4/2/24	Donated	Float	AA Batteries	1	$19.78
4/4/24	Re-use	ROV	Fuses	1	$12.09
4/11/24	Re-use	ROV	Hose Clamps	1	$7.69
1/1/25	Donated	Competition	Basecamp Subscription	1	$300.00
2/25/25	Purchased	ROV	Motor Controller	1	$76.46
2/27/25	Donated	ROV	3-D Printed Thruster Mounts (grams)	210	$10.50
3/5/25	Donated	Competition	Northeast Gulf Coast Ranger Registration	1	$270.00
3/14/25	Purchased	ROV	Actuator	1	$26.55
3/14/25	Purchased	ROV	Gears	1	$10.66
4/1/25	Purchased	Competition	Custom Bags	5	$60.00
4/1/25	Purchased	Competition	Custom Full Sublimation T-shirts	15	$435.00
4/3/25	Re-use	ROV	3-D Printed Grippers (grams)	238	$11.90
4/7/25	Donated	Field	Plastic Box	1	$2.19
4/8/25	Donated	Float	3-D Printed Pressure Housing (grams)	452	$22.60
4/9/25	Purchased	Field	Wiggler Water Snake	1	$19.99
4/9/25	Purchased	Float	O-Ring	1	$8.79
4/9/25	Purchased	Float	Lock Clasp Buckle Latch	1	$6.64
4/18/25	Purchased	Competition	Print Poster	1	$87.24
4/25/25	Purchased	Travel	Competition Meals	11	$765.00
4/27/25	Donated	Travel	Travel to DISL & Return (~510 miles)	4	$285.60
4/30/25	Donated	Competition	World Championship Registration	1	$450.00
5/8/25	Purchased	ROV	Linear Actuator	2	$55.10
5/8/25	Purchased	Float	Linear Actuator	2	$54.24
5/8/25	Purchased	ROV	Gears	1	$11.99
5/8/25	Purchased	ROV	Syringes	1	$9.99
5/8/25	Purchased	Float	Fuses	1	$8.99
5/8/25	Purchased	Float	Marine Weld	1	$5.80
5/8/25	Purchased	Float	Relay	1	$17.40
5/12/25	Purchased	Float	Batteries (24 - AA NiMH)	1	$36.49
5/12/25	Purchased	Competition	Mini Stuffed Animals (150 Each)	1	$40.99
5/12/25	Purchased	Competition	Keychains (50 Each = 100)	2	$35.98
5/12/25	Purchased	Competition	Rubber Bracelets (48 Each = 96)	2	$24.98
5/12/25	Purchased	ROV	Dome End Cap	1	$46.50
5/12/25	Purchased	ROV	WetLink Cable Splice Kit	1	$20.00
6/18/25	Donated	Travel	Travel to World's & Return (~2050 miles)	4	$1,148.00
6/18/25	Donated	Travel	Lodging for World's (6 days)	4	$2,376.00
6/18/25	Donated	Travel	Food for Worlds (6 days)	10	$1,800.00