GEARS, Inc

General Engineering And ROV Specialists

Eastwood Schools | Montgomery, Alabama, USA

Technical Documentation

2024 MATE World Championship

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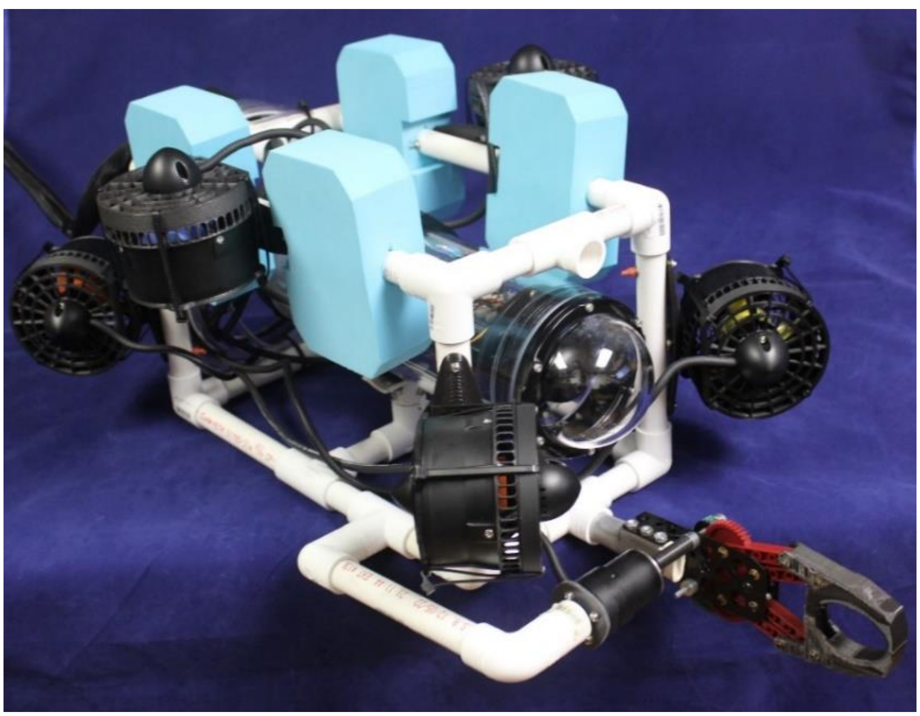
1. Abstract

General Engineering And ROV Specialists (GEARS) is comprised of six homeschooled students from Montgomery, AL. Established in 2023, GEARS was created after several members visited the 2022 Dauphin Island Sea Lab (DISL) MATE competition. Due to our team's previous robot development projects, we are experienced in robot design and development. Our engineers have specific skills in custom 3D printing and design, hardware assembly, software development, and data collection and analysis. 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 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 2.0.

Designed to address all challenges outlined by MATE efficiently, the Vaquita 2.0 is equipped with several key features to ensure its success. These features include six powerful Blue Robotics thrusters allowing smooth mobility and enhanced speed, a specialized manipulator with 3D-printed "fingertips" for strong grips on objects of any size, and a high-definition camera giving 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.



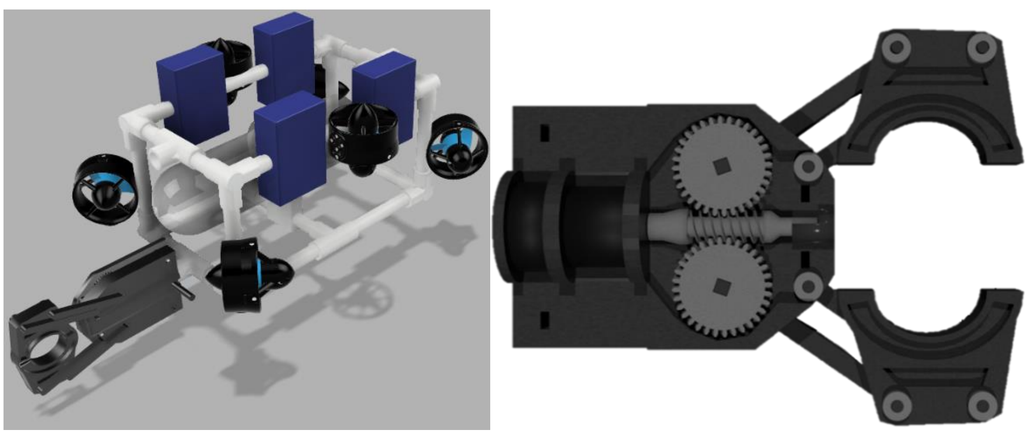
A full body image of the Vaquita 2.0. Photo by Rachel Smith.

2. Design Rationale

This year, the GEARS robotics team assembled the Vaquita 2.0 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. In addition, multiple software programs including Fusion 360, Blender, BlueOS, and QGroundControl were used to design and program the robot expertly.

2.1. Overall Vehicle Design & Systems Approach

The Vaquita 2.0 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 requirements. 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, multiple manipulator grippers were designed and printed before the final design was chosen to improve the ROV's grip. However, numerous ideas, such as a rotating wrist for the manipulator, were rejected and discarded. 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 manipulator. Our final product resulted in the Vaquita 2.0, which meets all weight, size, and functionality requirements.



2.2. Mechanical Design

A total of $4,659 was spent to build the Vaquita 2.0, a 12 kg ROV that measures 73 x 44 x 30 cm. We chose ½ PVC for the structure because it is strong, durable, and easy to work with when fixing buoyancy. For Vaquita 2.0 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 has not changed from the original octagonal design. This setup gave our robot full vertical, horizontal, and rotational movement. Once the framework for Vaquita 2.0 was done, the remaining components were added. A Blue Robotics watertight enclosure was secured onto the center of the ROV's structure. This protects the electrical components from water damage. A manipulator was attached to the front of the ROV. This claw system was fully 3D designed and printed. A Blue Robotics waterproof motor actuates this system. 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 2.0 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 2.0 achieves optimal functionality within budget constraints, maximizing the return on investment for its users. Performance is important in underwater exploration, and the Vaquita 2.0'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 configuration, coupled with an octagonal layout, 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.

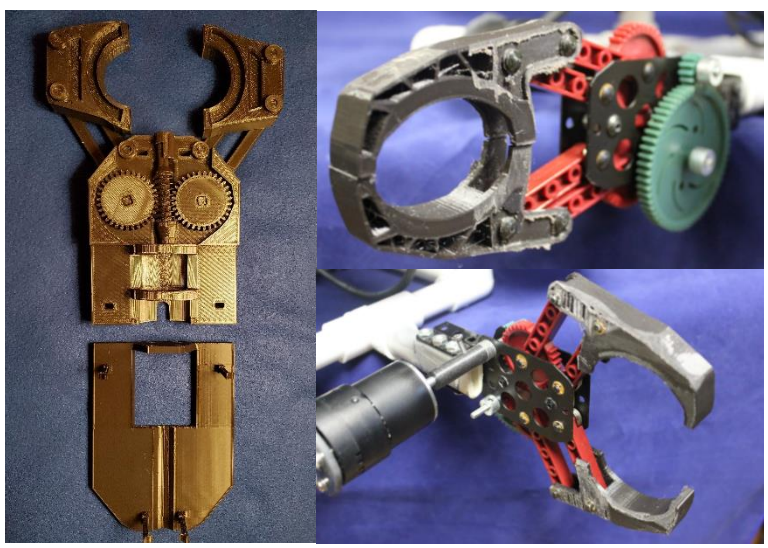
Front and back views of the ROV's thrusters. Photos by Rachel Smith.

2.4. Manipulator

The Vaquita 2.0's manipulator is specially designed to accomplish MATE tasks. The manipulator system was designed in Blender 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 manipulator. For example, if a piece's design is faulty or requires modification, it can be easily replaced by a redesigned reprint. The manipulator utilizes two grippers, which rotate smoothly on linkages. The geared bases of both grippers are rotated by a worm gear. The inside of the grippers is lined with a ridged foam padding, which conforms to the shape of any object held by the manipulator. This greatly increases the friction between the grippers and the object. A custom protective cover attaches onto the side of the manipulator system, which prevents outside elements from entangling in the gear system. This cover also allows waterflow over the motor to prevent overheating.

A Blue Robotics M200 motor was used to operate the manipulator. It is mounted into a specially designed compartment on the manipulator. This brushless motor can run safely while submerged in water. While this motor possesses a high max rotation speed of 2751 rpm, it lacks the torque to run the manipulator effectively. To compensate for this, a worm gear was mounted onto the motor's shaft to significantly reduce the final rotational speed while increasing its torque.

This 3D printed system is an updated version of the manipulator system. The previous version, which was comprised of a modified VEX claw, needed to be replaced. Though this system functionally operated, there were multiple issues that needed to be resolved. First, the gears on the old system were exposed, which violated safety requirements. Second, the previous motor mount was unreliable and bulky, which often resulted in mechanical disconnect between the motor and the manipulator. Finally, lacking a customizable manipulator structure, the old system could only be modified to a certain extent. This ultimately led to the decision to create an entirely new system.



Vaquita 2.0's new manipulator vs. original. Photos by Jacob Shaffer and Rachel Smith.

2.5. Camera

The Vaquita 2.0 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 means that one camera can be used to view straight forward for safe navigation and then quickly tilt down to get a full view of the manipulator while grabbing or placing objects. This feature is essential for completing both coral transplantation tasks and the acoustic Doppler current profiler (ADCP) placement.

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 field lacks many of the floating obstacles present in last year's competition, it was deemed unnecessary.

2.6. Buoyancy & Ballast

When designing Vaquita 2.0, 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. Complete flooding of the frame is necessary because, otherwise, Vaquita 2.0 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. Since our ROV is composed of light materials and contains a high-volume brain tube, it is easily susceptible 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. 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 2.0 without any ballast or foam is:

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

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. These tubes also allow for future hydraulic applications. 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 (4 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. 7 meters of extra tether were added on to the necessary 11 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

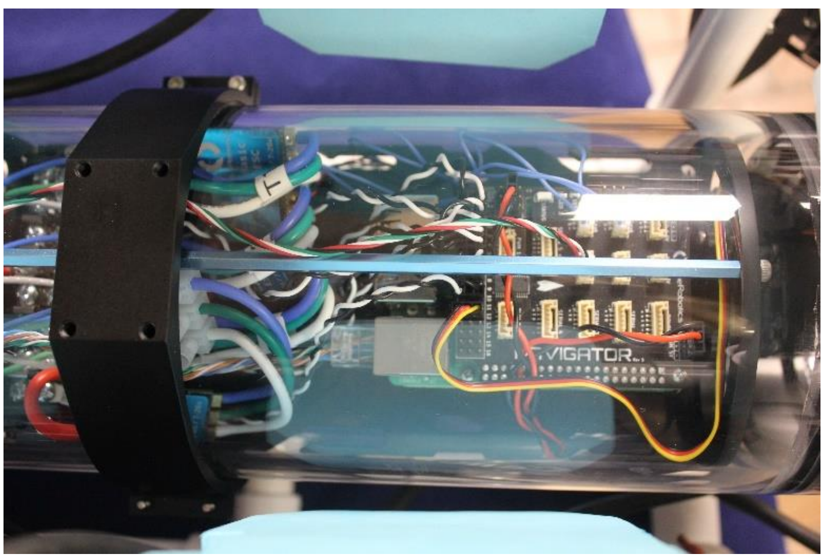
The Vaquita 2.0 was designed with multiple innovative properties. For example, the original manipulator lacked grip when holding small objects. To resolve this problem, special 3D-printed pieces were designed to replace the manipulator's "fingertips". Also, the gears in the original manipulator did not always mesh. The entirety of the new manipulator has been precision manufactured with 3D printing so that all pieces fit together perfectly. A hook was also attached to the side of the claw to aid in performing certain tasks. In addition, the ROV's four horizontal thrusters were positioned to provide optimal movement. With four of the thrusters rotated at 45˚

from each other, the ROV is capable of rotating in place and accelerating horizontally in any direction regardless of direction. The hollow tubing inside the tether currently provides buoyancy, but it can be used for hydraulic operations if needed in the future.

3. Software and Electronics

3.1. Onboard Electronics

The Vaquita 2.0 is equipped with a Raspberry Pi 4 B as the brain, a Blue Robotics Navigator flight controller, leak sensors, a thermometer, 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. In addition, the thermometer allows operators to be informed of the development of dangerous temperature levels in the enclosure. With proper monitoring of these sensors, disastrous and costly damage to all the electronics can be avoided. Vaquita 2.0 utilizes six blue robotics T200 thrusters to provide propulsion and one M200 motor for its manipulator. Each of the motor wires enters the watertight enclosure through a Blue Robotics WetLink Penetrator and connects to a Blue Robotics Basic ESC, which in turn connects to the Navigator Flight Controller.



Vaquita 2.0's onboard electronics. Photo by Rachel Smith.

3.2. Electrical

Vaquita 2.0 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 30-amp fuse on the surface to prevent damage from shorts and large current spikes. Power is connected to the Navigator Flight Controller through a 5 V power supply unit and to 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 2.0 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 2.0 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 first-ever Float, Squid, is designed to collect pressure data during two vertical profiles of the pool and transmit that data to the Float Operator's computer. Squid uses a buoyancy engine composed of an IP54-rated linear actuator driving a syringe to dynamically Float and sink in the water. Squid's housing is mostly composed of a 4-in, Schedule 40 PVC pipe to keep water out and stand up to intense pressures up to 1516 kPa. One end of the pipe is capped with a 4in to 2in PVC adapter which fits tightly around the syringe. The other end of the pipe is capped by a 4-inch twist-tight plug for easy access to the electronics, which was also used as a pressure release. However, since this proved ineffective at releasing pressure, we drilled a hole into the float and plugged it with a rubber cork. This modification allowed the float to meet the safety requirements. Squid is powered by a 12 VDC power pack composed of 8 alkaline AA batteries which runs through a 5-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. A Blue Robotics Switch is used to activate Squid because this switch is waterproof up to 950 meters. Finally, a Blue Robotics Subsea LED Indicator is connected to the ESP32 and is used to inform the Float Operator of Squid's progress during vertical profiles. An electrical System Integration Diagram for Squid can be found in Appendix A.

Full body image of the Squid Float. Photo by Nickolas Schmidt.

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, we have a significantly increased budget this year. 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 on it, and a better understanding of the rules.

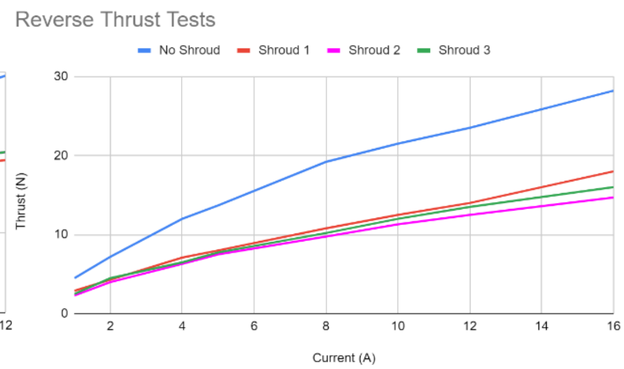
A good example of re-using materials is our manipulator, the VEX manipulator, which was built during a previous robotics competition for prototyping. This version seemed to work because it was the proper size for competition objects, made from tough materials, its gearing was compatible with the Blue Robotics M200 motor, and while we had to buy the motor, the VEX manipulator did not incur additional costs on our new team. However, after testing, we decided that a brand-new manipulator system was needed. Instead of buying a commercial claw which would have been extremely costly, we designed and printed a new manipulator that was specifically designed to complement our needs. This drastically cut down on costs while providing extreme flexibility in the manipulator's design. Additionally, this year, we crafted our ROV and Float's frame entirely from ½ inch and 4-inch Schedule 40 PVC. We utilized 3D printers to 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 manipulator'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 purchased this 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 Appendix C Actual Expenses and Donations table by looking at the Category column.

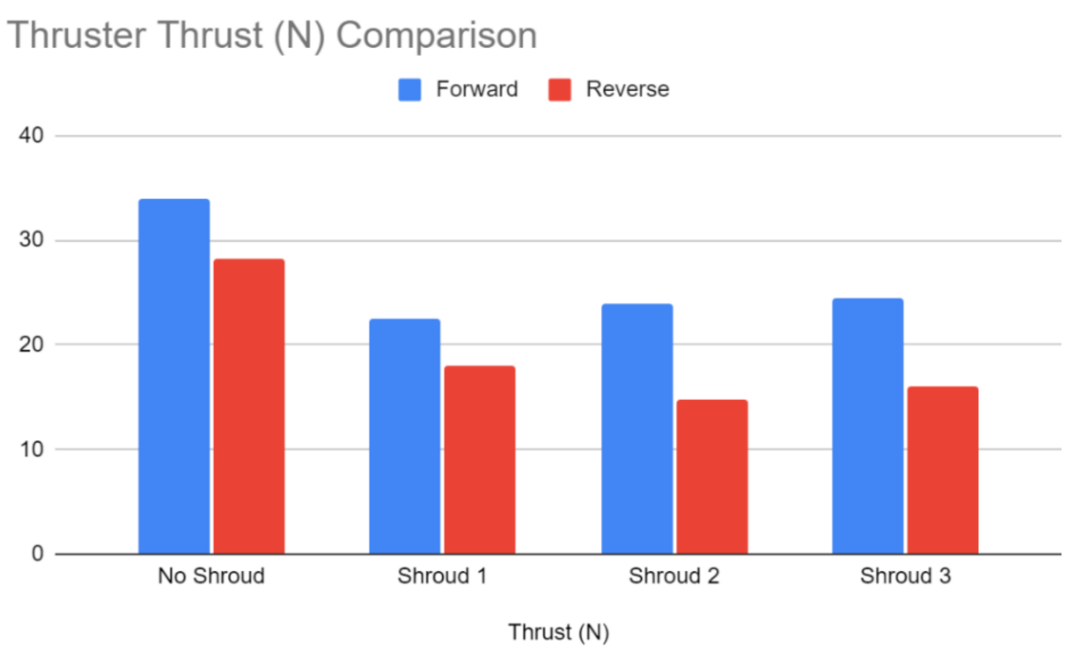
6. Testing and Troubleshooting

Vaquita 2.0 is GEARS' first-ever 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 would implement the proposed solution, test it, and, if needed, repeat the process until we have a functional and reliable product.

Thruster guards, tether combinations, and custom manipulators were all tested to find the optimal combination for Vaquita 2.0. The first component we tested was how different 3D-printed thruster shrouds affected the thrust output of T-200 thrusters. While the difference between the thruster guards was insignificant, the testing process allowed us to have quantifiable data to compare all three designs and see the reduction in thrust of about 30% due to the shrouds. We decided to use shroud 3 since it resulted in the lowest current draw. The thruster test data is depicted in the charts below.

Thruster Test Results





Shown in the photo below, our T-200 Blue Robotics thrusters underwent in-house testing utilizing a 380 L stock tank and a Vernier Force Sensor. The force sensor was secured to a metal frame constructed by our team from recycled metal brackets mounted on the stock tank, with the

T-200 Thruster secured to the underwater end of the lever and the Force Sensor connected to the above water end of the lever. The results from this process were recorded and used to create the charts above.

Thruster guard testing. Photo by Rachel Smith.

The next thing tested was the buoyancy of different tether combinations. The original tether combination consisted of one 14-gauge cable, one PVC 3/8"OD tube, and an ethernet cable. This combination was very buoyant. After testing the tether with the ROV, we found that the 14-gauge cable was insufficient for the power requirements of six T-200 thrusters, resulting in unacceptable voltage drops and permanent loss of Vaquita 2.0's control. To resolve the issue, we reviewed multiple Blue Robotics Forums and MATE archives for past ranger competitions. We found that, at a minimum, we would need to use one 12 AWG cable to provide the necessary current to all electrical components and avoid excessive voltage drops. Before testing, we decided that the optimal tether would be slightly negatively buoyant. This is because a buoyant tether pulls the back end of the ROV float upward while at depth. A negatively buoyant tether also creates drag as it is pulled along the bottom of the pool and interferes with demonstration field pieces. Ultimately, we chose a 10 AWG cable as it will allow us to add more electronics in the future and guarantee that a voltage drop does not impact the electronics. In order to make the tether slightly negatively buoyant, we had to use a line of both PVC 1/4"OD tubing and 3/8"OD tubing. All our tether buoyancy tests are shown below.

Tether Buoyancy Tests

Power Cable	Communication Cable	PVC Tube(s)	Observed Buoyancy
14 AWG	Cat 5	3/8	Very Buoyant
12 AWG	Cat 5	3/8	Negatively Buoyant
12 AWG	Cat 5	1/4	Neutral
10 AWG	Cat 5	3/8	Negatively Buoyant
10 AWG	Cat 5	1/4	Very Negative
10 AWG	Cat 5	1/4 & 3/8	Slightly Negative

One challenge we encountered was a faulty camera. The camera had been used in several tests but eventually stopped working because its mount was putting pressure on one of its resistors. We received a Blue Robotics Technical Bulletin about the issue, but it was too late by the time we fixed it. The camera had to be scraped, and a new camera was attached using a modified mount.

We custom-designed three different fingertip pairs to modify our VEX claw. The deciding factors on which fingertip design to use were compatibility with the VEX claw and the ability to grip a wide range of object sizes. Once we 3D printed the first design, we encountered a problem: the design was incompatible with our VEX claw. The second design suffered from its grippers interfering with each other and preventing it from closing. So, we had to design a third pair of fingertips, the one currently on our ROV. It met all our qualifications: It was compatible, durable, and able to firmly grip small and large objects. After fixing the compatibility, we ran into another problem: we could not get the motor to work in QGroundControl. Eventually, our testing uncovered that the ESC motor controller from Blue Robotics was faulty. After these challenges, our gripper ran smoothly.

Unfortunately, this manipulator design encountered numerous issues, and a new design was chosen. First, the VEX claw's gears were exposed, which violated safety requirements. Second, the former manipulator's motor mount was bulky and inconsistent. If the mount was jostled, the manipulator and motor could experience mechanical disconnect, effectively disabling the manipulator. Finally, we determined that the VEX claw could only be modified to a certain extent. To further improve the manipulator, we needed to completely redesign the system and 3D print it. This resulted in our current manipulator, which contains a specially designed motor mount and enclosed gearing.

Numerous challenging obstacles were encountered throughout the development of Vaquita 2.0. However, they were successfully conquered through collective teamwork and perseverance.

7. Project Management

7.1. Company Structure

The GEARS company consists of six 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, from left to right: Nickolas Schmidt is our President and project manager. Caleb Anglin is our CEO and Float Operator. Grady Smith aids in programming and CAD design. Jonathan Pace acts as the team Tether Operator. Rachel Smith covers team marketing material and is our data analyst. Jacob Shaffer is our CTO and ROV pilot. All team members perform various other tasks as needed.

The GEARS team. Photo by D. Smith.

7.2. Scheduling and Planning

To adequately plan for both the Regional and World competitions, 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.

Task Schedule

Project	Assigned To	Due Date
Marketing Brochure	Rachel	April 1st
Poster ready for print	Rachel	April 11th
SIDs	Jacob	April 12th
Company Spec Sheet	Rachel	April 15th
Company Safety Review	Caleb	April 15th
Tech Doc	All	April 18th

Presentation Outline	Nickolas	April 19th
Tool Take List	Jonathan Pace	April 24th
Presentation Slides and First Practice	All	April 24th
Float Document	Caleb	April 23rd
Demo Strategy Finalized	Jacob and Nickolas	April 24th
All Worlds Documentation	All	May 21st

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 628 in-person hours across 36 meetings while designing, constructing, and testing the 2024 ROV. The roster used to monitor meeting attendance is provided below.

Member Attendance Roster

Student First	Total	16-Nov	7-Dec	14-Dec	4-Jan	11-Jan	18-Jan	25-Jan	30-Jan	31-Jan	1-Feb	15-Feb	22-Feb	29-Feb	7-Mar	11-Mar	14-Mar	21-Mar	28-Mar	30-Mar	2-Apr	4-Apr	9-Apr	11-Apr	15-Apr	16-Apr	18-Apr	20-Apr	23-Apr	25-Apr	26-Apr	27-Apr	28-Apr
Caleb	28	X	X		X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X
Jonathan	26		X		X	X	X	X				X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Nickolas	19	X	X	X				X		X			X	X	X		X	X							X	X	X	X	X	X	X	X	X
Jacob	30	X		X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Grady	28	X	X	X		X	X	X		X	X	X	X	X	X		X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X
Rachel	26	X	X	X	X	X	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. 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	100	100	90	92	100	100	100	100	90	90
Jonathan	20	100	100	100	100	100	100	100	100	100	100	93	100	100	92	100	100	100	92	90	95
Nickolas	20	92	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Jacob	20	100	90	100	100	100	90	100	100	90	100	94	100	100	100	100	100	100	92	90	100
Grady	17	100	100	100	100	100	100	100	100	100	100	100	100	100	92		100	100		100	
Rachel	20	100	100	100	100	100	100	100	100	100	90	100	100	90	100	100	100	100	100	100	100

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 the 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 Job Site Analysis (see Appendix B for JSA). 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 2.0 and Squid. 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. Squid's O-ring twist cap was specifically chosen for its ability to release any dangerous pressure build-up inside the float before the conditions for a violent explosion can occur.

9. Construction and Operational Checklists/Protocol

This checklist dictates the most efficient way to construct the ROV. All time estimates are with four team members available.

Teather (One 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)

- Follow the BlueRobotics manuals for the electronics tray and camera tilt assemblies
- 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, thermometer, and camera
- Wire ESC for each thruster or motor and attach penetrators
- Test thrusters 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
- Attach camera dome and penetrator end cap to enclosure following O ring sealing process from Blue Robotics

Structure and buoyancy (3 hours)

- Cut PVC pipe and collect all necessary joints
- Drill holes in floats 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

Propulsion and Manipulator (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 programing
- Assemble the manipulator parts with the motor inserted into its housing
- Insert motor PVC connection pipe into T joint
- Tie down loose wires with zip ties or wrap around structure

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

This checklist 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 (5 minutes)

- 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 reuse parts to save costs and minimize waste. We used information from GEARS' previous year's budget to baseline a $10,000 budget for the year 2024. See the Account Balance Accounting table in section 9.3 below for high level details of our budget. A travel budget of $4000 was included to provide funds for the World Championship. For the regional competition we allocated $732 to include food and donated fuel for travel to DISL. These expenses are listed in the Appendix C table.

10.2. Funding

GEARS relies solely on fundraising, donations, and fees. Donations were collected from generous parents and investors in our local community. These donations included financial support as well as robot parts and publishing materials. The company collected $9,639 from sponsors, plus additional funds from T-shirt sales and meal fees for a total of $12,431. See the 2023-2024 Income table below for detailed accounting of our income.

2023-2024 Income

Date	Sponsor / Organization	Received
7/9/2023	Cornerstone Detention Products, Inc.	$350
7/9/2023	Petranka Contracting LLC	$500
8/17/2023	Studio JASmith	$350
9/26/2023	HeartWise	$200
9/28/2023	EMNA	$1,439
1/1/2024	Basecamp	$300
1/4/2024	Dogwood Forge	$100
1/6/2024	MathWorks	$1,000
1/11/2024	AFCEA Education Foundation	$2,500
1/15/2024	Mary Sumner	$1,000
1/31/2024	exp Realty	$200
2/22/2024	Petrunic Orthodontics	$200
5/20/24	Schmidt Scholarship Travel Stipend	$1,500
Sponsor Total		**$9,639**
Sales	T-Shirt Sales	$210
Fee	DISL Meal Fees	$424
Fee	Worlds Travel	$2,158
Total Income		**$12,431**

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, tools, and travel. Our expenses totaled $11,107, including donated and re-used items for the competition year. This leaves $1,324 for future needs.

Account Balance Accounting

Category	Budget	Purchased	Donated	Re-use	Total
Competition	$750	$546	$685	$0	$1,231
Field	$150	$76	$12	$0	$88
Float	$250	$218	$103	$35	$356
ROV	$4,700	$4,549	$34	$76	$4,659
Tools	$150	$326	$0	$56	$382
Travel	$4,000	$583	$3,808	$0	$4,391
Total	**$10,000**	**$6,298**	**$4,642**	**$167**	**$11,107**
Total Income					$12,431
Balance					**$1,324**

11. References

"2023 Competition Archive." *Materovcompetition.org*, materovcompetition.org/2023-competition-archive. Accessed 14 Apr. 2024.

"Blue Robotics Community Forums." *Blue Robotics Community Forums*, discuss.bluerobotics.com/. Accessed 15 Apr. 2024.

Moore, Steven W, et al. *Underwater Robotics : Science, Design & Fabrication*. Revised Edition ed., Monterey, Ca, Marine Advanced Technology Education (Mate) Center, 2019.

Acknowledgements

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

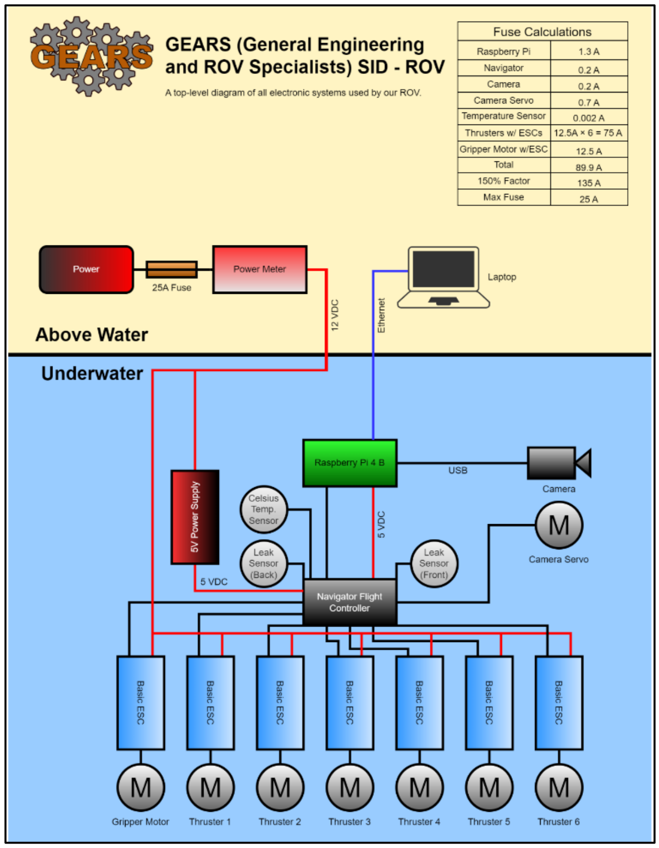
• Our mentor, Arthur Lee Sumner

• Our Parents

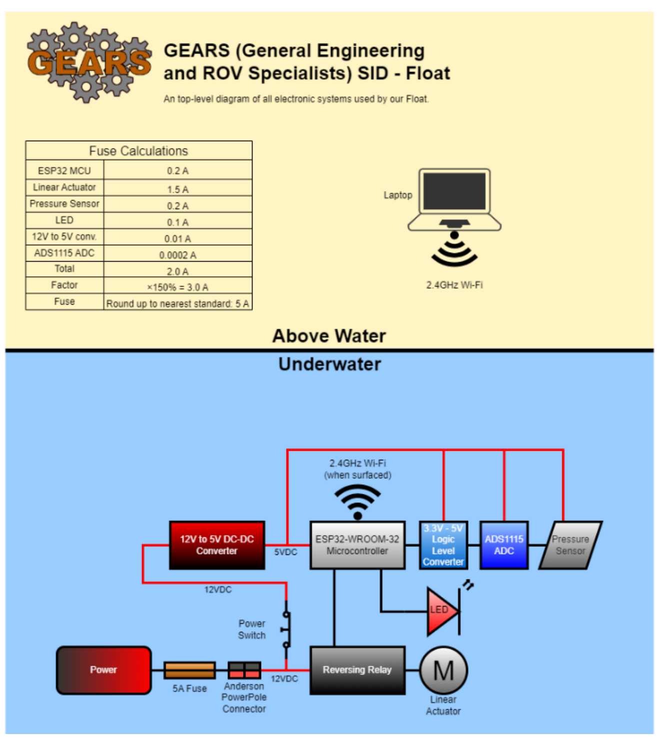
• Our Investors

Appendix A: System Integration Diagrams (SIDs)

ROV (Top) and Float (Bottom)



Fuse Calculations	
Raspberry Pi	1.3 A
Navigator	0.2 A
Camera	0.2 A
Camera Servo	0.7 A
Temperature Sensor	0.002 A
Thrusters w/ ESCs	12.5A × 6 = 75 A
Gripper Motor w/ESC	12.5 A
Total	89.9 A
150% Factor	135 A
Max Fuse	25 A



Fuse Calculations	
ESP32 MCU	0.2 A
Linear Actuator	1.5 A
Pressure Sensor	0.2 A
LED	0.1 A
12V to 5V conv.	0.01 A
ADS1115 ADC	0.0002 A
Total	2.0 A
Factor	×150% = 3.0 A
Fuse	Round up to nearest standard: 5 A

Appendix B: Job Site Analysis (JSA)

Task	Hazards	Controls
1: Entering/exiting the pool deck area **and** **5: System breakdown**	Slipping	All team members must wear closed toed shoes with a good grip. Inform judges and team members of any puddles in the workspace.
	Dropping objects	Ensure all team equipment is contained and can be comfortably carried to the workstation.
	Lifting strain	Heavy objects should be carried by multiple people.
2: System set up	Getting water on 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.
	Tripping over wires	Keep the ROV tether away from the rest of the setup wires. Lay all wires flat on the ground when crossing pathways and coil them out of the walkway when there is excess.
	Environmental threats	Check the weather before and during an attempted run of the ROV in outdoor pools.
3: Power up checks	Shock hazard	Ensure all wires are properly connected and non-tether wires are clear of the water.
	Voltage Spikes	Connect power supply before turning on the ROV.
4: Pool side operations	Tether Operator slipping or falling into pool	Train the tether Operator how to properly stand, coil, and feed during operations. Always have a trained lifeguard present.
	Injury from ROV	The tether Operator should wait 3 seconds after getting confirmation from the driver to interact with the ROV.

Appendix C: Accounting Expense Detail

Date	Type	Category	Expense	Description	Qty	Total
7/26/2023	Purchased	Tools	Buoyancy Test	100 Gal Stock Tank for Testing	1	$98.99
8/22/2023	Purchased	ROV	Power	Red Waterproof Solder Seal Connectors	450	$34.99
8/22/2023	Purchased	ROV	Pressure	Clear Camera Dome Cover	1	$20.99
8/22/2023	Purchased	ROV	Power	Waterproof Solder Seal Connectors	300	$16.99
8/22/2023	Purchased	Float	Buoyancy Engine	350ml Large Syringes	2	$14.99
8/22/2023	Purchased	Float	Buoyancy Engine	500 ml Giant Syringe	1	$13.99
8/22/2023	Purchased	Float	Buoyancy Engine	150ml Large Syringes	3	$9.99
8/22/2023	Purchased	ROV	Sensor	5mW Red Dot Laser Head	10	$6.79
8/22/2023	Purchased	ROV	Power	12V Cigarette Lighter Socket Cable	1	$15.30
8/22/2023	Purchased	Tools	Buoyancy Test	Mosquito Dunks, 6-Pack	1	$9.93
8/22/2023	Purchased	ROV	Power	Green Waterproof Seal Connectors	100	$8.99
9/28/2023	Purchased	ROV	Thruster	T200 Thrusters	6	$1,222.60
9/28/2023	Purchased	ROV	Electronics	Electronic Speed Controller	6	$216.00
11/27/2023	Purchased	ROV	Power	Power Meter	1	$50.97
11/27/2023	Purchased	ROV	Power	Battery Status Monitor	1	$116.49
12/8/2023	Purchased	ROV	Electronics	Navigator Flight Controller	1	$333.90
12/8/2023	Purchased	ROV	Electronics	Raspberry Pi 4	1	$155.00
12/8/2023	Purchased	ROV	Electronics	Power Supply (5V 6A)	1	$25.00
12/8/2023	Purchased	ROV	Pressure	M10 Enclosure Vent and Plug	1	$9.00
12/8/2023	Purchased	ROV	Pressure	Pressure Relief Valve	1	$28.00
12/8/2023	Purchased	ROV	Pressure	Pressure Relief Valve Backfill Adapter	1	$11.00
12/8/2023	Purchased	ROV	Pressure	Vacuum Plug	1	$8.00
12/8/2023	Purchased	ROV	Pressure	Penetrator M10-6.5MM-LC	2	$100.00
12/8/2023	Purchased	Tools	Thruster Test	Thruster Commander Thruster Tester	1	$60.00
12/8/2023	Purchased	Tools	ROV	Penetrator Assembly Block	1	$25.00
12/8/2023	Purchased	Tools	ROV	Bulkhead Wrench (M10)	1	$16.00
12/8/2023	Purchased	Tools	ROV	Penetrator Plug Wrench (14mm)	1	$14.00
12/8/2023	Purchased	Tools	ROV	O-Ring Pick	1	$4.00
12/8/2023	Re-use	Tools	Thruster Test	1" x 8' AL Angle (Thruster Force Test)	1	$34.98
12/8/2023	Re-use	Tools	Thruster Test	3/4" x 4' AL Angle (Thruster Force Test)	1	$11.98
12/8/2023	Re-use	Tools	Thruster Test	3/4" x 4' AL Flat (Thruster Force Test	1	$8.98
1/1/2024	Donated	Competition	Management	Basecamp Subscription	1	$300.00
1/4/2024	Donated	Competition	Training	SeaPerch Workshop	1	$150.00
1/29/2024	Purchased	Float	Structure	4" PVC Cleanout Plug	1	$6.54
1/29/2024	Purchased	Field	PVC	1/2" Sch 40 Side Out Elbow	2	$4.90
1/29/2024	Purchased	Field	PVC	1/2" Sch 40 Adapter	2	$1.44
1/29/2024	Purchased	Float	Structure	4" PVC Female Adapter	1	$11.03
1/29/2024	Purchased	ROV	Tether	Cord Storage Reel	1	$12.81
1/29/2024	Purchased	Field	PVC	3/4" x 1/2" Sch 40 Reducing Tee	4	$6.24
1/29/2024	Purchased	Float	Structure	4" Sch 40 Socket Cap	1	$14.80
1/29/2024	Purchased	Field	PVC	2" Sch 40 Tee	1	$4.70
1/29/2024	Purchased	Field	PVC	1/2" Sch 40 Pipe (10 feet)	2	$8.94
1/29/2024	Purchased	Field	Other	10-ft PVC Clear Vinyl Tubing	1	$4.07
1/29/2024	Purchased	Float	Structure	4" Gripper PVC DWV Test Plug	1	$8.50
1/29/2024	Purchased	Field	PVC	3/4" Sch 40 Socket Cap	1	$0.78
1/29/2024	Purchased	Field	Other	Zinc-plated Steel Screw Hook	20	$6.63
1/29/2024	Purchased	Field	PVC	3/4" Sch 40 Tee	1	$0.82
1/29/2024	Purchased	Field	Other	Brass 1/2-in Fip Gate Valve	1	$9.01
1/29/2024	Purchased	Field	Other	Bowl for Brain Coral	1	$0.55
1/30/2024	Donated	Field	Other	Milk Crate	1	$12.48
1/31/2024	Purchased	ROV	Tether	16/2 Direct Burial Speaker Wire	1	$30.68
1/31/2024	Purchased	ROV	Tether	14/2 Direct Burial Speaker Wire	1	$26.03
1/31/2024	Purchased	ROV	Tether	PVC Tubing 1/4"ID X 3/8"OD	1	$26.89
1/31/2024	Purchased	ROV	Buoyancy	Buoyancy Floatation Belt	1	$21.99
1/31/2024	Purchased	ROV	Tether	Cat5e Outdoor Ethernet Cable	1	$20.99
1/31/2024	Purchased	ROV	Tether	Expandable Braided Sleeve	1	$15.99
1/31/2024	Purchased	ROV	Tether	SS Wire Rope Thimbles	12	$13.69
1/31/2024	Purchased	ROV	Sensor	Waterproof Thermal Sensor	5	$11.58
1/31/2024	Purchased	Field	Hardware	Galvanized Steel Tent Pegs	30	$9.79
1/31/2024	Purchased	Field	Hardware	Brass Hose Barb Tee 1/4" x 1/4"x 1/4"	5	$9.29
1/31/2024	Purchased	ROV	Electronics	Hook & Loop Cable Tie Cord	1	$8.99
1/31/2024	Purchased	Field	Electronics	2-Pack Aquarium Thermometer	1	$8.98
1/31/2024	Purchased	ROV	Pressure	J-B Weld 25 ml. Syringe	1	$7.12
2/2/2024	Purchased	ROV	Pressure	Dome End Cap	1	$40.00
2/2/2024	Purchased	ROV	Pressure	Watertight Enclosure Tube	1	$236.08
2/2/2024	Purchased	ROV	Pressure	M10 Hole End Cap w/ 14 holes	1	$32.00
2/2/2024	Purchased	ROV	Pressure	O-Ring Sealing Flange	2	$86.00

Date	Type	Category	Expense	Description	Qty	Total
2/2/2024	Purchased	ROV	Pressure	M10 Enclosure Vent & Plug	1	$9.00
2/2/2024	Purchased	ROV	Pressure	Penetrator M10-6.5MM-HC	1	$50.00
2/2/2024	Purchased	ROV	Pressure	Penetrator M10-7.5MM-HC	1	$50.00
2/2/2024	Purchased	ROV	Pressure	Penetrator – Blank	4	$24.00
2/2/2024	Purchased	ROV	Structure	Electronics Tray w/ Terminal Blocks	1	$100.00
2/2/2024	Purchased	ROV	Structure	Watertight Enclosure Clamp	1	$48.00
2/2/2024	Purchased	ROV	Sensor	Low-Light HD USB Camera	1	$99.00
2/2/2024	Purchased	ROV	Sensor	Camera Tilt System	1	$64.00
2/2/2024	Purchased	ROV	Thruster	Propeller Set – Yellow	1	$8.00
2/2/2024	Purchased	ROV	Thruster	Propeller Set – Orange	1	$8.00
2/2/2024	Purchased	Float	Electronics	Switch	1	$20.00
2/2/2024	Purchased	ROV	Pressure	Potting Kit (x 10)	1	$10.00
2/2/2024	Purchased	ROV	Pressure	Potted Cable Penetrator	1	$6.00
2/2/2024	Purchased	ROV	Tether	Tether Cable Strain Relief	1	$8.00
2/18/2024	Purchased	ROV	Structure	1/2" Sch 40 Cross	15	$38.25
2/18/2024	Purchased	ROV	Structure	1/2" Sch 40 Side Out Elbow	12	$29.40
2/18/2024	Purchased	ROV	Structure	1 1/2" Sch 40 Cap	1	$1.98
2/18/2024	Purchased	ROV	Structure	1/2" Sch 40 Tee (10)	2	$10.52
2/18/2024	Purchased	ROV	Structure	1/2" Sch 40 Pipe (10 feet)	1	$4.51
2/20/2024	Purchased	ROV	Ballast	1/2" Stainless Steel Bar (3 Ft)	2	$172.52
2/20/2024	Purchased	ROV	Hardware	SS Screws, M3x.5mmx12mm	200	$13.30
2/20/2024	Purchased	ROV	Hardware	SS Pan Screws, M3x.5mm x 35mm	100	$11.89
2/20/2024	Purchased	ROV	Hardware	SS Washers M3 (100)	2	$4.38
2/20/2024	Purchased	ROV	Hardware	SS Washers M4 (100)	1	$3.57
2/20/2024	Purchased	ROV	Hardware	SS Hex Nut, M3 x 0.5 mm (100)	2	$9.46
2/20/2024	Purchased	ROV	Hardware	SS Socket Screws, M3 x 0.5 mm, 12 mm	100	$6.00
2/20/2024	Purchased	ROV	Hardware	Nylon Plastic Cable Tie, 11" Black	100	$12.72
2/27/2024	Purchased	Competition	Team Building	Food for ROV Movie Night	1	$40.48
2/28/2024	Donated	Competition	Registration	Northeast Gulf Coast Ranger	1	$165.00
2/29/2024	Re-use	ROV	Power	Barracuda Power Kit	1	$35.00
3/11/2024	Purchased	ROV	Tether	12/2 Direct Burial Speaker Wire	1	$70.98
3/11/2024	Purchased	ROV	Tether	10/2 Direct Burial Speaker Wire	1	$118.68
3/11/2024	Purchased	ROV	Tether	PVC Tubing 1/4"OD (100 Feet)	1	$20.89
3/14/2024	Donated	Float	Electronics	Ardx Arduino Kit	1	$80.39
3/14/2024	Purchased	ROV	Sensor	Temperature Sensor (I2C)	1	$70.00
3/14/2024	Purchased	ROV	Spare	Basic ESC (T200)	2	$76.00
3/14/2024	Purchased	Tools	Pressure	Hand Operated Vacuum Pump	1	$98.00
3/14/2024	Purchased	ROV	Spare	SOS Probe Tips	1	$8.00
3/14/2024	Purchased	ROV	Spare	Spare Bulkhead O-Ring Set (M10)	1	$3.00
3/14/2024	Purchased	ROV	Spare	Spare Bulkhead O-Ring Set (M14)	1	$4.00
3/14/2024	Purchased	ROV	Spare	Penetrator Spare Seals	1	$72.00
3/14/2024	Purchased	ROV	Spare	Spare Locking Cord and Handles	1	$10.00
3/14/2024	Purchased	ROV	Spare	Spare O-Ring Set (100 mm)	1	$3.00
3/14/2024	Purchased	Float	Electronics	LED Indicator – Red	1	$15.00
3/14/2024	Purchased	ROV	Manipulator	M200 Motor	1	$175.02
3/14/2024	Purchased	ROV	Spare	Molykote 111 (150 g Tube)	1	$32.00
3/14/2024	Purchased	ROV	Pressure	Potted Cable Penetrator (M10 - 8mm)	1	$6.00
3/14/2024	Purchased	ROV	Pressure	Penetrator M10-8.5MM-HC	1	$50.00
3/14/2024	Purchased	ROV	Pressure	Penetrator M14-9.5MM-LC	1	$56.00
3/15/2024	Purchased	Competition	T-Shirts	Custom Full Sublimation T-shirts	14	$406.00
3/21/2024	Re-use	ROV	Gripper	Vex Gear	1	$17.89
3/21/2024	Re-use	ROV	Gripper	Vex Gripper	1	$22.89
3/28/2024	Donated	ROV	Structure	3-D Printed Thruster Mounts/Gripper (g)	276	$13.80
4/1/2024	Purchased	Float	Buoyancy Engine	Linear Actuator	1	$26.55
4/1/2024	Purchased	Float	Electronics	Forward/Reverse Relay Module	1	$17.40
4/1/2024	Purchased	Float	Electronics	ESP-32	1	$15.59
4/1/2024	Purchased	Float	Sensor	Pressure Sensor	1	$13.70
4/1/2024	Purchased	Float	Power	Fuse Holders	1	$9.99
4/2/2024	Purchased	Travel	Food	Competition Meals	11	$583.00
4/2/2024	Purchased	Float	Power	AA Batteries	1	$19.78
4/4/2024	Donated	Float	Structure	Epoxy	3	$22.44
4/4/2024	Donated	ROV	Power	Fuses	1	$12.09
4/9/2024	Re-use	Float	Structure	4" PVC Pipe	1	$34.58
4/11/2024	Donated	ROV	Tether	Hose Clamps	1	$7.69
4/19/2024	Donated	Competition	Display	Print Poster	1	$70.39
4/28/2024	Donated	Travel	Fuel	Travel to DISL & Return (~420 miles)	2	$149.33
5/17/2024	Purchased	Competition	Registration	Worlds Competition Fee	1	$100.00
5/20/2024	Donated	Travel	Lodging	Schmidt Scholarship Travel Stipend	1	$1,500.00
6/18/2024	Donated	Travel	Lodging	Hotel Room Fees for Worlds	6	$3,187.98
6/22/2024	Donated	Travel	Fuel	Travel to Worlds & Return (~884 miles)	3	$471.47