



Phoenix Robotics

2025-2026

Brooks DeBartolo Collegiate High School

Tampa, Florida, USA



Company Members:

Kristofer Gajadharsingh, Senior:
Chief Executive Officer & Co-Pilot

Ivanna Fuenmayor Schwartz, Junior:
Assistant Marketing Officer & Pool Side Assistant

Anthony Lozano, Sophomore:
Assistant Profiler Specialist & Diver

Jeneque Grubb, Sophomore:
Chief Marketing Officer & Pool Side Assistant

Izabella McDonald, Sophomore:
Photographer & Assistant Marketing Officer

Timothy Chao, Freshman:
Chief Operating Officer & Pilot

Coda Schrader, Freshman:
Chief Technical Officer & Control Side Assistant

Pranav Kumar Sirimalla, Freshman:
Design Specialist & Control Side Assistant

Ivanna Betancourth, Freshman:
Chief Safety Officer & Tether Specialist

Dezirae Gardner, Freshman:
Profiler Specialist & Assistant Design Specialist

Eric Fernandez, Elena Fernandez, Chris Hochman,
Mohammed Badri & Bryce Phuphanich:
Mentor

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Abstract

Phoenix Robotics is a company composed of students based out of Brooks Debartolo Collegiate High School. Throughout the company's fourteen year history, Phoenix Robotics has designed and constructed numerous quality ROVs that have competed in various competitions. For this year's MATE ROV competition, company members decided to remodel and repurpose last year's ROV, the Phoenix Ocean Explorer (POE).

The main focus was the refinement of POE's manipulators, frame and camera systems. Using Onshape, students refined the manipulator design and reviewed potential mounting ideas for the frame and camera system. With the addition of these modifications, POE is better equipped to complete the tasks tailored to this year's theme. The company also aimed towards improving their Vertical Profiler through its design, wiring, code and buoyancy engine.

POE was specifically designed with a wide variety of features that allow it to perform various tasks in different underwater ecosystems. POE is capable of operating in tropical and polar oceanic temperatures, equipped with cutting-edge technology that aids in efforts to preserve marine ecosystems. POE showcases its ability to assist in the preservation of the Marine environment by performing tasks that represent real life problems. Some of POE's duties include replacing an eDNA sensor, installing micropiles, flying over a transect, tracking icebergs, using image recognition to identify invasive species and testing whale safe fishing gear. This document describes in great detail POE and its different components from the onboard electronics all the way to external manipulators added for the completion of specific tasks.



Figure 1: The Phoenix Robotics Team | Photo by Bruce Kensky

Teamwork

Project Management

Phoenix Robotics is divided into 5 main departments; Electronics, Design, Documentation, Marketing and the Vertical Profiler. Leadership roles in each department are decided by the Chief Executive Officer, based on each member's strengths, weaknesses and areas of expertise. Below these leadership roles are specialists and assistants that are able to learn more about what a specific department does throughout the course of a year, so they can continue the cycle of teaching. Using this structure, Phoenix Robotics is able to efficiently produce an ROV and Vertical Profiler that are able to carry out the proposed tasks every year. Refer to Figure 2 for the company's roles.

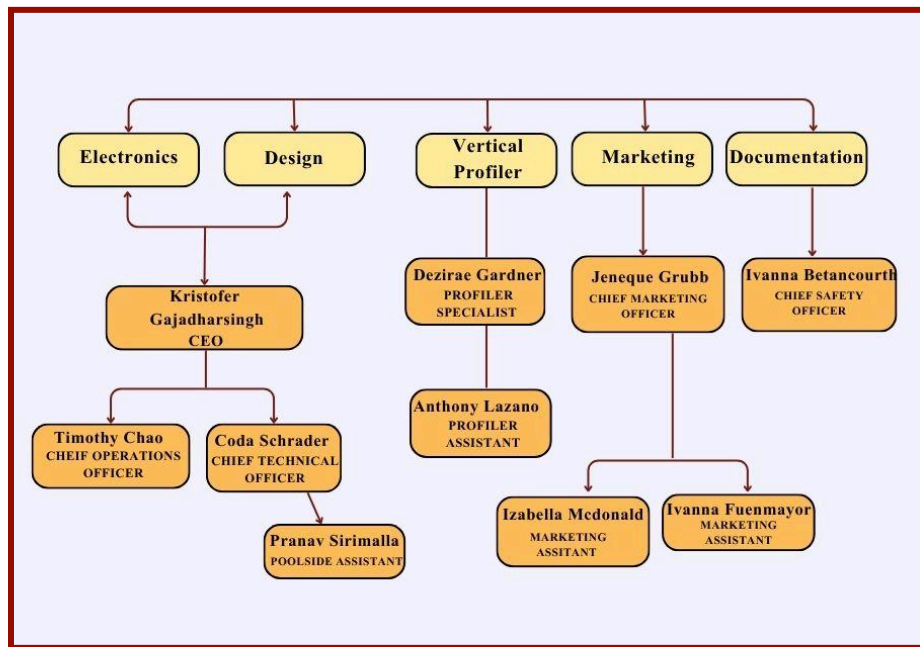


Figure 2: Company Departments | Diagram by Jeneque Grubb

Communication

Efficient communications is one of Phoenix Robotics biggest priorities when structuring the company and managing workloads. Discord is the company's primary method of communication; the server built on this app is divided into chatrooms with designated purposes, such as announcements or deadlines. Discord was chosen to meet the need for accessibility for all members, while also allowing leadership to contact specific team members. The company also utilizes Google apps such as Sheets, Drive and Docs to store and send out any important information or resources between team members. The company's primary form of communication provides accessibility to resources, protocols and procedures to guide new members through certain scenarios, like leaks or electrical issues. Refer to Figure 3 to see the company's schedule this year to keep the company on time.

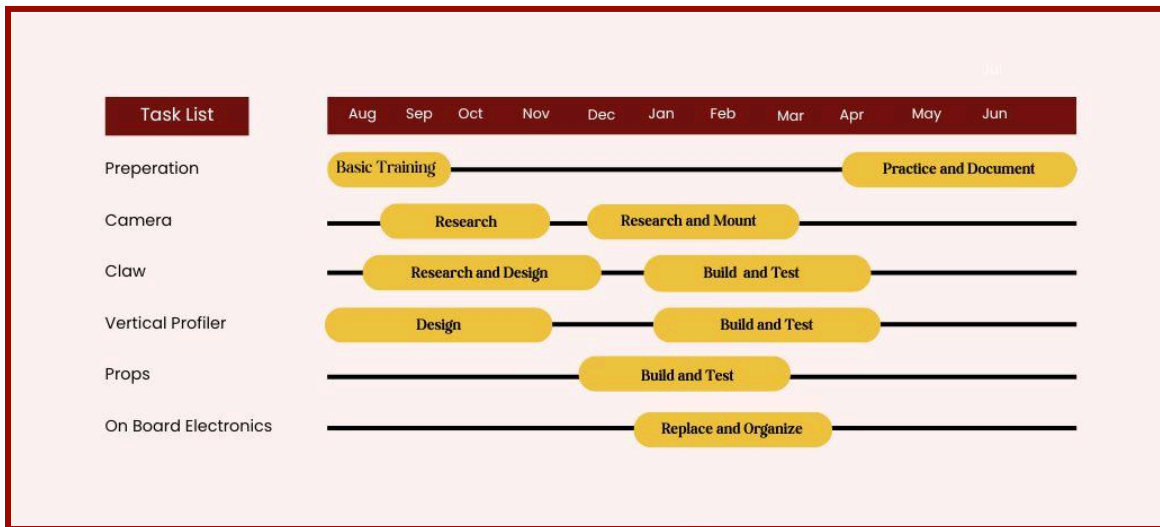


Figure 3: Design Schedule | Diagram by Jeneque Grubb

Design Rationale

Structural Assembly

Frame

The frame's amenities consist of an onboard electronic tube constructed from polyvinyl chloride (PVC), structural sleeves, wings which flare out from the sleeves, skis on the bottom of POE to prevent damage of the bottom, handles and a tether strain relief. The onboard tube is constructed from a 9.5 centimeter inner diameter (ID) clear PVC tube that is 45.7 centimeters long. This tube is encircled by a 10.2 centimeter ID PVC tube with cutouts to create transparent viewing windows, helping to identify water leakage and the functionality of the electronics. The onboard tube is sealed using a 10.2centimeter, watertight flexible rubber cap, tightened by a 316 stainless steel hose clamp. Additionally, the company uses precautionary measures for POE, especially during its waterproofing. By using water absorption packets, color changing humidifying packets and a removable marine divers wax around the rubber cap, no water is able to leak in and the onboard is completely safe during runs and practices.

Material

There were several key innovations that contributed to POE's efficiency in terms of cost, speed and precision. The frame is primarily designed with PVC and high density polyethylene (HDPE). HDPE was decided upon due to the multiple benefits that this material has to offer in comparison to other materials. HDPE is widely available, cost-effective, durable, lightweight and less dense than water. The company sourced HDPE in the form of commercial cutting boards, which were then machined using CNC. Refer to Figure 4 which better illustrates the primary factors used to evaluate the most appropriate materials to use.

	HDPE	PVC	Acrylic	Aluminum	Polycarbonate
Cost	Low	Low	Moderate	Moderate	High
Density (cm/g ³)	0.93	1.2	1.2	2.7	1.38
Impact Strength (J/m)	260	74	440	294	250

Figure 4: ROV Frame Materials | Table by Timothy Chao

Tether Strain Relief

The Tether Strain Relief system is a precautionary measure to ensure that no damage can occur between the onboard electronics and the tether. This particular design utilizes a U-bolt to absorb the tension and hose clamps and carabiners to direct the tension. This prevents any chance of damage between the onboard electronics and the control box.

Dimensions

The dimensions of POE determine its ability to successfully navigate the tasks in this year's competition. The tasks required an ROV capable of performing at greater speeds and maneuverability, unlike in other years. For example, in *Task 2.2 Iceberg Tracking*, one must survey 5 points, located on 4 of the vertices of the iceberg. Hence, POE is lighter, resulting in swift and easy turning movements. This maximizes the success during mission operations. Refer to Figure 5 below to see POE's dimensions.

Height	Length	Width	Weight
26.0 cm	86.4 cm	53.3 cm	9.2 kg

Figure 5: POE's Dimensions | Table by Timothy Chao

Accessories

Experiments were conducted to find the quickest and most reliable way to add accessories to POE in order to complete each task. The company was able to accomplish this by using cutouts in the HDPE panels for easy attachment. The panels were machined using a computer numerical control machine, or a CNC machine. The company commissioned a local corporation, PlasticsAmerica, to machine the HDPE panels, since Phoenix Robotics does not possess a CNC machine. This allowed the company to add any accessory to POE, quickly and easily. These accessories include buoyancy material, cameras and other accessories needed for tasks. A good example of this is in *Task 2.3 Testing Whale Safe Fishing Gear*, which requires POE to pick up a heavy lobster pot that the manipulators could not lift. To solve this, the company attached a stainless steel hook to the front of POE, making it possible to grab onto the handle and bring the lobster pot to the surface.

Accessories were also attached to the manipulators. In order to complete *Task 3.1 Micropile installation*, a magnet was attached to the left manipulator to help withdraw the metal pin from the micropile.

Mechanical Systems

Propulsion

POE uses four Blue Robotics T200 motors, along with 4 basic electronic speed controllers (ESC). The company chose T200s because of the precision, speed and efficiency, which is critical for this year's tasks. Each motor draws a maximum of 17 amps and operates on 12 volts. To prevent the motors from overdrawing too many amps, the company created a code that limits the Pulse with Modulation (PWM), to ensure the motors draw a safe amount of amps so the system doesn't overdraw.

The first two T200s are oriented straight up to allow for heave/vertical movements. The other two motors are oriented straight forward to allow for surge and yaw movements. The surge and heave allows POE to move in the water and the yaw allows for turning of POE. The company had the option to include a roll to POE, however the tasks this year make having a roll obsolete, as none of the tasks require tilting, unlike previous years. This makes piloting of POE simple and straightforward. This positioning is optimal for this year's tasks because it focuses on speed and agility, which is especially apparent in *Task 1.2 Coral garden ridge modelling*. Two of each motor are located on the left and right side of POE, along the transverse line. They generate 2.91 kilograms of backward thrust and 3.70 kilograms of forward thrust. This helps POE maneuver through the water quickly to complete the tasks in an efficient and timely manner. The thrusters were placed strategically on the transverse line of POE to ensure that the center of thrust is in line with the center of mass, maintaining stability.



Figure 6: T200 | Photo by Kristofer Gajadharsingh

Manipulators

POE has two independently operated manipulators, mounted symmetrically beneath each wing of POE and extended in front of the robot. The company did this to help the copilot to clearly see where the manipulators are located in front of the cameras. The new dual manipulator setup has evolved to meet the task requirements by being able to accomplish both steps on *Task 3.2 Powering an oil platform from a wind turbine* by grabbing onto the cover of the oil platform port and installing the power connector into the port. The manipulators have



Figure 7: ROV Manipulators | Photo by Kristofer Gajadharsingh

three prongs so they can grab onto items or species such as the corals in *Task 1.1 Collect species from the coral garden* efficiently since they can grab fully around an object. The manipulators mounting bars and prongs were laser cut from a 6.4-millimeter thick acrylic sheet using a Glowforge™ laser cutter and screwed onto the primary mount which is the base of the gripping mechanism. Each manipulator has two axes which allow them to grasp onto an object and rotate it. These axes are powered by analog servos. The gripping mechanism, located in front of the manipulator system, is operated by a servo with a T25 horn. The aluminum linkages are the key part to the manipulator's movements. Each manipulator has 2 aluminum linkages where one end is connected to the prongs and the other end is connected to the horn. Because of this setup, when the servo turns the horn clockwise the manipulators open and vice versa. This provides efficiency for opening and closing the manipulators. The rotation mechanism uses a second servo which is mounted on the base of the manipulator arm. This servo uses a

circular horn which is secured with four screws to a PVC end cap attached to the end of the manipulator's body. All pipes and fittings used to assemble the manipulators are 1.3 cm PVC. A spacer was added above the servo to help offset the manipulator's assembly from the wing. This prevents the rotational servo from getting stuck to POE's wing and leveling it out. The manipulator's gripping mechanism is connected to the manipulator's arm by a 90 degree angled bracket on the primary mount, which is secured by two screws. There is also a third screw which is drilled from the manipulator's mount to the manipulator's arm which provides rigid support for the manipulators. A PVC pipe assembly, including female adapters at both ends, connects the manipulator assembly to POE. A custom 3D printed, rotational bracket was made to mount the manipulators to the frame.

Buoyancy

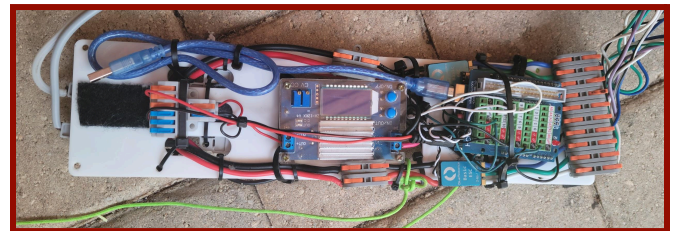
Buoyancy dictates if an object sinks or floats. On POE, the company uses both static and variable systems to easily change its position in the water column. High density foam is used for static buoyancy because it could be strategically stacked on POE's wings in such a way that it did not significantly alter its hydrodynamics. Further, this material is not compressible at the depths used in the competition. For the variable buoyancy, the company attached a wheelbarrow inner tube to the top of POE, connected it through a vinyl tube running down the tether and attached it to a dual action pump. The dual action pump was easily accessible to the copilot, allowing quick control of the air inside the rubber bicycle tire and enabling instant changes in buoyancy. This allowed the company to save time when ascending or descending.

Another benefit of this buoyancy system is its ability to assist in lifting heavy objects during missions such as *Task 2.3 Whale Fishing Gear*. This assistance is made possible by using the variable buoyancy system in addition to the thrusters, allowing POE to ascend and deliver heavy items to the poolside. System operation occurs when the copilot pumps air into the variable system which in turn significantly increases POE's buoyancy. The combined forces of the buoyancy system and the thrusters enables the company to complete the task fast and with ease. Additionally, the system reduces stress on the motors, helping increase their longevity.

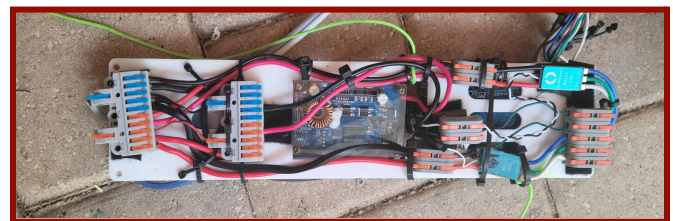
Electrical Systems

OnBoard Electronics Tray

The onboard electronics were carefully planned throughout the year to meet the company's requirements for a fully functional POE. The 3.2mm acrylic tray, which houses all the onboard electronics, is precisely cut using the company's laser cutter. The tray is designed with a length of 45.7 cm so it fits inside the 9.5 centimeter clear PVC tube. The tray combines the electronics needed to control POE's thrusters, including four BlueRobotics ESCs, an Arduino UNO with a shield and a voltage regulator set to 5 volts to power the Arduino board. Nylon strings are also tied onto the tray, allowing company members to safely remove the onboard system without damaging any of the electronics.



Figures 8 & 9: Onboard Electronics | Photos by Bryce Phuphanich



Tether

POE's tether is 16.7 meters in length and contains two 16 gauge wires, one 12 gauge wire pair, the analog camera system wires, the digital camera system wire and the variable buoyancy tubing. The tether is thoroughly sheathed to protect the wires from any cuts or abrasions that may accumulate from constant movement across

surfaces. Segmented pool noodles are secured around the outside of the tether using cable ties to provide buoyancy, allowing the tether to float. These noodles are spaced strategically so the tether remains neutrally buoyant in water. This minimizes the tether's influence on POE's mobility and improves the pilot's handling during operation. When operating POE, it is essential to ensure that enough tether is reeled out to allow smooth movement without causing strain or pulling on POE. Proper tether management involves continuously monitoring POE's movements and anticipating the amount of tether required for specific tasks. This proactive approach maintains optimal maneuverability, prevents entanglement, excess tension and ensures safe and efficient operations.

When handling the tether, the company places strong emphasis on proper tether management and protection. Management is achieved through a system of carefully coiling and uncoiling the tether whenever POE is moved, keeping it organized and easily deployable at all times. The company protects the tether by mitigating tether contact damage and degradation across its length and at targeted abrasion points. Finally, the company regularly monitors and detangles the wires inside the tether when necessary to prevent strain and wear. Using all of these practices has significantly improved the tether's longevity throughout the year.

Control Box

The Control Box operates and maintains two critical systems: the manipulator control system and the first half of the thrusters control system. While some components of POE utilize software, the system is primarily hardware based, as electronic components are the main elements controlling both the manipulator and thruster systems. Although certain electronics are stored onboard POE, most of the system's electronics are housed within the surface control box. The control box contains an emergency stop switch, the powerline for the camera box and the main power line for POE, which is connected to a 25 amp fuse for protection. The

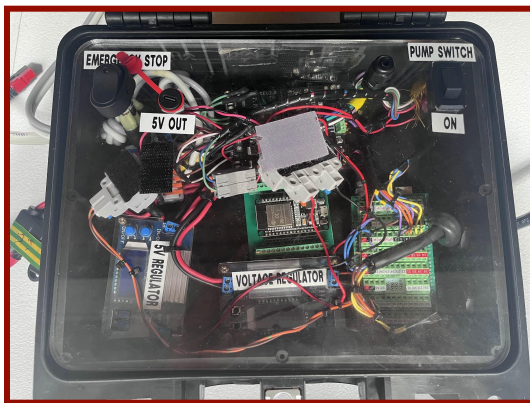


Figure 10: Control Box | Photo by Kristofer Gajadharsingh

manipulator system consists of two MDD10A Cytron motor drivers that convert the digital signals into analog signals for the servos, an Arduino Mega connected to two joysticks for the input control and a voltage regulator set to 9 volts to power the system. For movement and navigation, the surface thruster control system includes an ESP32 board that uses bluetooth communication to connect to an Xbox controller. The controller sends input signals to the ESP32, which then transmits the commands down the tether to control the thrusters. A voltage regulator set to 5 volts powers the ESP32 board. To ensure safety of company members and the integrity of POE, the control box includes an emergency stop switch capable of shutting down the entire system in case of any compromise or emergency. Additionally, the control box features strain relief protection on the back of the control box using self tied knots and grommets to reduce stress caused by pulling or tension on the wires.

Cameras

POE is equipped with four analog fishing cameras recycled from the previous year's ROV model, along with one digital endoscope purchased by the company this year. These cameras were selected because, when combined, they provided a cost effective solution while still delivering all the functionality and capabilities required for this year's tasks. The company reused the previous year's camera box to provide video output for all analog cameras and purchased a mini-computer to install inside the camera box for connection to the digital camera. This setup allowed the company to easily obtain live analog video feeds while also capturing images from the digital camera for use in 3D modeling during *Task 1.2 Coral garden ridge modelling* and for measuring keel depth in *Task 2.2 Iceberg tracking*.



Figure 11: Digital Camera | Photo
by Kristofer Gajadharsingh

The analog cameras were connected directly to the surface, bypassing the onboard control systems. Their video feeds were displayed on three monitors inside the camera box, with two of the four analog cameras connected to a single monitor capable of switching between feeds. Similarly, the digital camera was also connected directly to the surface, bypassing the onboard control systems. The digital camera connected through USB to the mini-computer inside the camera box, which was then connected to a monitor, keyboard and mouse to allow captured images to be processed and manipulated. Inside the camera box, Anderson power pole connectors provided power through the main control box. The camera box power line passed through a 25 amp fuse located within 30 centimeters of the power connection and was regulated to 12 volts using a voltage regulator to ensure stable voltage while preventing spikes and current overdraw. The camera system was isolated from the other control systems, receiving only power and video signals, which improved overall modularity and reliability.

All five cameras were strategically positioned on POE to assist in completing the required tasks. The analog cameras were arranged to provide a top forward facing view, a right side forward facing view, a bottom forward facing view and a left side downward facing view. These orientations were chosen so the pilots could maintain visibility of what is in front of POE from multiple angles at all times. More specifically, the bottom forward facing camera allows the pilots to clearly view both manipulators during operation. When combined with the top and right side forward facing cameras, the system provides reinforced visibility from multiple perspectives, making manipulator control easier for the copilot. The left side downward facing camera was specifically positioned to assist with *Task 1.3 Fly a transect over the coral garden* and *Task 2.1 Mitigate invasive species*, as it allows the company to complete these tasks without needing to angle POE downward in the water. The digital camera is mounted facing forward on top of POE. This placement allows POE to capture a full view of *Task 1.2* and *Task 2.2* for accurate imaging and data collection.

Software

POE's hardware and design is visually dominant, however its software plays a critical role in controlling its movement. The code is written in Arduino C++ and processes bluetooth input from the Xbox controller before sending the data to an Arduino Uno through two wires connected to the RX and TX ports on the ESP32. The system operates using a master-slave configuration, where the ESP32 functions as the master by sending instructions, while the Arduino acts as the slave by executing the commands. By sending PWM signals to the Arduino, the system prevents overloading the ESP 32, ensuring consistent and reliable control of POE. Refer to Figure 12 for a better understanding of the thought process of POE's thruster software.

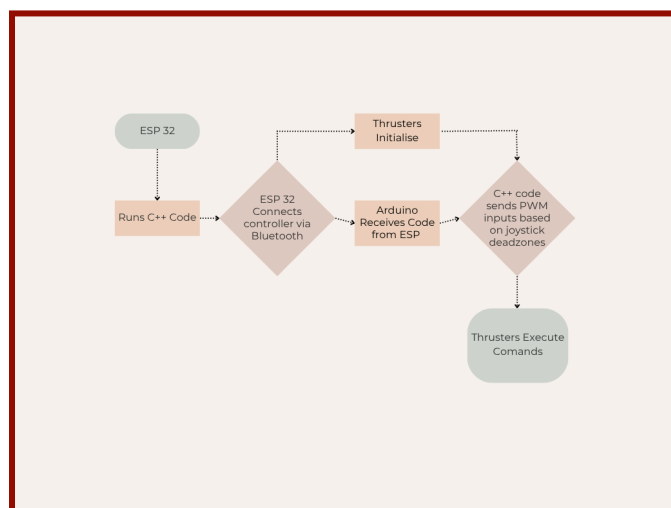


Figure 12: Software | Diagram by Timothy Chao

Vertical Profiler

Housing

For this year's Vertical Profiler, the company recycled a housing while replacing the internal components and sealing all potential water entry points to prevent leaks. At the top of the profiler is a 4 inch dome cap connected to a 4 inch acrylic tube that houses the buoyancy engine and water valve. Below this section is the center compartment, which features a rubber gasket secured with hose clamps and divers' wax to prevent water from infiltrating the profiler's internal systems. The Vertical Profiler also uses a stainless steel push button switch protected by a plastic cover and sealed with three layers of 5200 marine sealant to ensure proper waterproofing and protection of the switch and its internal components. The tube continues downward to its bottom 4 inch PVC flat cap, reinforced by a 4 inch polycarbonate disc coated with 5200 marine sealant to further prevent water entry. Inserted in the center and perpendicular to these plates is a 1 inch PVC tube fitted with a rubber stopper that acts as the pressure relief valve. The PVC tube also includes a 4 inch sleeve attached at the base of the Vertical Profiler, providing both structural support and protected grounding. The sleeve contains four holes designed to eliminate trapped air pockets when deploying the profiler in water.



Figure 13:
Non-ROV Vertical
Profiler | Photo by
Kristofer
Gajadharsingh

Electrical System

The Vertical Profiler uses an ESP32 board, an MDD 10A Cytron motor driver, a Micro SD Card Module, an I²C converter, a Bar02 sensor, a 12 volt NiMH battery pack and a 5 amp mini blade fuse. These components control both the motor system and the storage and transfer of collected data into the company's software interface. Most of the electronics are housed on a tray positioned in the middle section of the Vertical Profiler, while the data collecting electronics are stored inside the dome cap located on top of the Vertical Profiler. These components were selected for their compatibility with the motor system and the web serial interface. Additionally, the tray design helps protect the electronics from water damage, as it is enclosed from both the top and bottom while positioned securely within the upper section of the 4 inch tube.

Buoyancy

The Vertical Profiler uses a motorized lead screw buoyancy engine that controls its vertical position in the water column. The entire profiler is positively buoyant to the point where weights have to be used to reach its Functional Surface Buoyancy (FSB), which is still slightly positive. This buoyancy is calibrated through the use of 7.23 kg of lead. This allows the profiler to rest at the surface and accomplish its vertical up and down cycle, while avoiding the ice sheet during all portions of *Task 4 MATE Floats*. This year's buoyancy engine uses its lead screw design paired with a 100cc syringe that is powered by a 12 volt 100 RPM DC motor. The lead screw system was selected for its reliability and was further improved this year by replacing the previous servo driven system with a more durable and dependable motor and gears. The company conducted extensive research and testing on alternative motors to determine the most effective option for the task requirements. Through testing, the 100 rpm motor proved to provide the most consistent timing during operational cycles while also delivering significantly greater power than the previous servo system. The motor is securely connected to the 100cc syringe through the lead screw assembly. The lead screw contains an aluminum cube that firmly secures the syringe plunger, ensuring stability and smooth operation while the motor performs its cycles.

Build vs. Buy

Manipulators

The manipulators were constructed using PVC components, servos, acrylic prongs and assorted hardware. The company chose to build the manipulators instead of purchasing pre-made systems from companies such as Blue Robotics in order to reduce costs and maintain greater control over customization and design. The manipulator prongs were laser cut from acrylic sheets and readily accessible hardware was used during assembly. Although designing and configuring custom manipulators required additional time and effort, the company determined building the manipulators provided the best balance between budget, available time and team expertise. The only externally sourced components were the servos, as the company does not possess the specialized machinery necessary to manufacture motors in house. These servos were purchased from an online retailer and integrated into the custom built manipulator system.

Cameras

The digital and analog camera systems were all purchased components. These include the endoscope, mini-computer, mouse, keyboard, fishing cameras and monitors. The company chose to purchase these items because they were cost effective and offered reliable performance without significant disadvantages compared to designing and building custom alternatives. The only camera related item built by the company was the camera box. The camera box is custom built to accommodate the specific size and spacing requirements of the company's camera systems. This design allows the video feeds to be displayed efficiently while also providing properly sized openings for wire management and cable routing into and out of the box.

Components	Build		Buy		Final Decision
	Pros	Cons	Pros	Cons	
Propulsion	Specific and adaptable	Difficult and takes time	Waterproofed and powerful	Expensive	Buy Blue Robotics T 200s
Camera System	Customizable	Difficult and takes time	Quick and reliable	Expensive	Buy both the analog and digital cameras
Manipulators	Customizable	Takes time	Professional and sturdy	Expensive and unfit	Build both manipulators
Enclosure	Specific and customizable	Takes time	Professional and sturdy	Expensive	Build enclosure to house the electronics
Buoyancy	Customizable in shape	Takes time	Professional and durable	Expensive	Build the buoyancy material onto the robot
Electrical Systems	Specific and customizable	Takes time	Reliable	Takes time to arrive	Build the electronics

Figure 14: Build vs. Buy | Table by Pranav Kumar Sirimalla

New vs. Reused

Software

Much of POE's software this year was reused from the previous year. The primary reason for this decision is that POE is mainly a hardware based system with little software, meaning that much of the core code remains universal across different versions of POE. Another advantage of reusing the previous year's software was that the code had already been thoroughly developed and tested. This resulted in responsive, reliable and easy to use controls for the pilot and copilot. In addition to the reused software, two new programs were implemented this year to support *Task 2.2 Iceberg Tracking* and *Task 1.3 Coral Garden Ridge Modelling*. These programs worked alongside the newly added digital camera system to provide accurate measurements and generate 3D models for the tasks.

Manipulators

The company reused the manipulator design from previous years due to its reliability and efficient performance. While the overall design remained the same, several improvements were made during construction this year. The company incorporated washers to better distribute force around the screws and added lock nuts to secure the hardware and maintain the structural integrity of the manipulators. These modifications helped resolve previous issues where screws would gradually loosen during operation, causing parts of the manipulators to detach during mission runs.

Cameras

The analog camera system integrated on POE was strategically reused from the previous year due to its proven performance and reliability. During past competitions and practice runs, the analog setup consistently provided durability, functionality and sufficiently clear visuals for underwater navigation and task completion. Components reused from this system included the fishing cameras, monitors, camera box and its supporting electronics, as they saved time for other innovations.

While the analog camera system remained effective for general operation, the company implemented a new digital camera system this year to handle tasks requiring accurate measurements and 3D modeling. The analog system, even when paired with an analog to digital converter, could not produce the image quality necessary for accurate modeling and measurements. As a result, the company integrated a digital camera system because it provided higher quality, undistorted images better suited for these tasks. The digital camera system consisted of the endoscope camera, the mini-computer and the associated computer peripherals used to operate and process the captured images.

Safety

Safety Philosophy

Phoenix Robotics' safety philosophy is rigorously applied in all aspects of the company's operations. Safety is integrated into everyday activities and serves as the foundation for all procedures and practices. Members are provided with proper safety education that follows the Occupational Safety and Health Administration (OSHA) standards, including the correct use of tools and adherence to established safety protocols. These practices help minimize the risk of unsafe working conditions. Safety is a critical component of every aspect of the company's work, whether poolside operations or the construction and testing of components.

One of Phoenix Robotics' highest priorities is maintaining a dedicated safety officer who ensures that all members consistently follow proper safety procedures. The company is also supported by three OSHA certified members: the CEO, marketing assistant and Vertical Profiler assistant. Together with the safety officer, they ensure that all procedures comply with OSHA safety standards and that members operate in a safe and controlled environment. If any member identifies a safety concern, addressing it immediately becomes a top priority. Additionally, every member is expected to maintain a thorough understanding of the company's safety procedures and expectations.

By consistently following these protocols, Phoenix Robotics ensures a safe environment that protects team members and allows all work to be performed at the highest standard possible. Refer to Figure 15 for safety procedure parts.

Safety	Procedures
<u>Building:</u> ● Obtain approval from others before working on a task ● Verify there's a suitable space for the task to avoid any messes that can be dangerous for members. ● Verify Personal Protective Equipment is used or readily available ● Confirm all tools are fit and ready for working conditions ● Ensure any moving parts are secured to prevent any damage ● Ensure all cables are intact to prevent any power loss while operating ● Confirm all members are on task at all times	<u>Working:</u> ● Check fuses for full functionality before using POE ● Check batteries and power supply to prevent power loss during operation ● Ensure electronics are in a dry safe place to prevent damage or the risk of electrocuting and damage ● Ensure crucial and easy fix tools are at easy reach at all times such as zip ties, screwdrivers etc. ● Check control functionality before putting POE in water ● Check electronics after POE comes out of water

Figure 15: Safety Procedure Parts | Table by Ivanna Betancourth

Safety Aspects

At Phoenix Robotics, safety measures are not only applied to team members but are also rigorously integrated into the design and operation of POE. POE strictly follows the safety guidelines established by MATE to ensure safe and reliable operation during testing and competition. Refer to Figure 16 for a list of the company's safety features.

Safety Aspect	Description
Skis	Prevents the bottom of the robot to be damaged
Tether Relief	Relieves any strain from the tether
Handles	Makes handling of the robot easier
Round Edges	Prevents any injuries and damage to the environment around
Emergency Stop Switch	Last safety measure in case of leakage or electrical problems
IP-20 Rated Shrouds	Prevents any cuts
Pinch Points	Prevents injuries when handling the manipulators
Caution Tape	Signals hazardous points to prevent mishandling

Figure 16: Safety Features of the ROV | Photo by Ivanna Betancourth

When handling any machine improperly, operation can become hazardous, which is why different precautions are necessary when working with POE. By following proper procedures, the company helps prevent injuries while also minimizing potential damage to POE.

During setup, the camera box and control box must be removed from storage and placed at the control station. This process includes several potential hazards, including lifting heavy objects, exposure to electrical components and possible tether entanglement. Proper safety procedures and careful handling are therefore required throughout setup and operation.

Critical Analysis

Troubleshooting

When there is a problem with one of POE's systems, the company implements a step by step procedure to ensure that all possible causes are determined. Team members collaborate to identify potential problems ranging from simple connection issues to more complex hardware failures. Refer to Figure 17 which illustrates the company's systematic troubleshooting procedures.

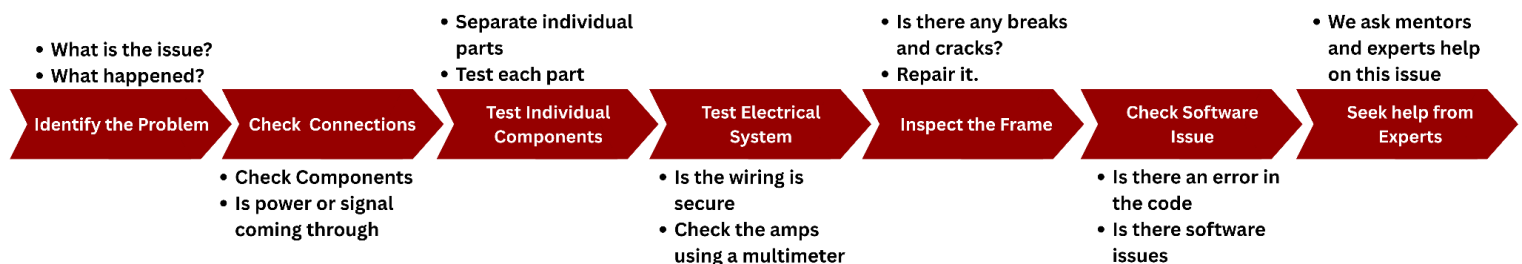


Figure 17: Troubleshooting Procedures | Diagram by Pranav Kumar Sirimalla

Testing

Manipulators Testing

Selecting POE's manipulator system was a lengthy process that involved testing multiple designs and concepts. One of the primary decisions was whether to use a servo driven, hydraulic, or pneumatic manipulator system. This year's tasks mainly focus on picking up, moving and positioning objects in a variety of environments. Hence, the company prioritized completing these tasks quickly while making operation as effortless as possible for the control side. The company began by conducting research on several manipulator systems. The first concept explored was a hydraulic manipulator due to its strength and reliability. To better visualize the design, the company first created a 3D model to determine the possible shapes and dimensions of the manipulator before moving on to physical prototypes. However, testing revealed that hydraulic systems were relatively slow and required significant effort to operate the syringes controlling the mechanism. The company then shifted to testing servo driven manipulators because of their speed and ease of operation. A new prototype was developed that could open and close quickly, making servos appear to be a promising solution for the required tasks. Despite the positive results, the company continued exploring alternatives to identify the most suitable option for this year's tasks. This led to pneumatic testing, which used pressurized air and pneumatic cylinders to operate the manipulators by opening and closing the gripping mechanism. Ultimately, the company chose to move away from pneumatics, as the team was more familiar with servo-driven systems and implementing pneumatics within the given timeframe would have proved too difficult.

Camera Testing

The primary camera system used by the company utilized analog cameras that had already been tested in previous years and proven to be reliable. However, this year's tasks required gathering accurate measurements to measure the keel depth in *Task 2.2 Iceberg Tracking*. The analog cameras presented challenges due to their tendency to generate image distortions that gave inconsistent data. To avoid these complications, the company decided to incorporate a digital camera system specifically for these tasks. Selecting the digital camera system required extensive research and testing. The company's first approach involved using a Raspberry Pi 3 and developing a Python program capable of combining multiple video feeds into a single display window. After testing this setup, the company determined that the Raspberry Pi 3 could not reliably handle the amount of information being processed. The company then upgraded to a Raspberry Pi 5 and integrated the OBS Studio program into the system. Although this configuration performed better than the Raspberry Pi 3 setup, it still lacked the processing power required for consistent and reliable operation as there was a voltage problem with the system. There was also the issue of having to implement more components to complete the Raspberry Pi system. Ultimately, the company concluded that using a Windows based mini-computer was the best solution because it provided a more simple, powerful and stable system. The mini-computer was able to sustain continuous video processing and footage reliably, making it the most effective choice for this year's competition tasks. The computer also provided the ease of setup since it was already integrated into the camera box.

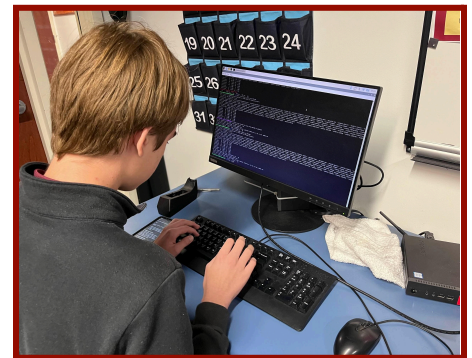


Figure 18: Testing the Pi 5 | Photo by Kristofer Gajadharsingh

Thruster Testing

Technical personnel conducted extensive research to determine which thruster provided the most energy efficient, reliable, and powerful propulsion system for POE. Staff identified preexisting stock and evaluated these thrusters based on forward thrust, reverse thrust, and amp draw. After conducting background research



Figure 19: Bollard Testing | Photo by Kristofer Gajadharsingh

T100 Thrusters and the Blue Robotics T200 Thrusters to determine which of these best fits the company’s needs. Members conducted their own performance testing, including a Bollard test performed within the company’s facilities. The Bollard test utilized a hand-built attachment developed from previous years. During the test, a lab spring scale was connected to a movable PVC assembly and equipped with a hose clamp to secure the motor during testing. When activated, the thruster attempted to swing the PVC assembly upward. To counteract this movement and improve measurement accuracy, the handle of the lab spring scale was secured using a broom aligned with the testing container, ensuring that the gauge measured only the thrust force while maintaining a stable position. Refer to Figure 20 for the lists of the data collected and analyzed at 12 volts.

	T100	T200
Forward Thrust	2.36 kgf	3.71 kgf
Backward Thrust	1.82 kgf	2.92 kgf
Amp Draw	11.5 A	17 A

Figure 20: T100 vs. T200 at 12A | Table by Timothy Chao

Conducting these tests provided the company with a better understanding of the trade offs associated with each thruster option. Although the T200 thrusters had a higher amp draw and greater cost compared to the T100s, the company ultimately selected the T200s because this year's tasks required fast transportation and lifting capabilities. For example, in *Task 1.1*, POE had to collect and transport corals back to shore, while in *Task 2.5*, POE had to remove and replace an eDNA sensor. Overall, the T200s provided significantly greater thrust than the T100s, allowing POE to complete this year's tasks more quickly and effectively.

Vertical Profiler Testing

During the development of the Vertical Profiler, several aspects of the design had to be considered and tested. To calculate the Vertical Profiler’s volume, the company conducted a series of Archimedes type displacement tests in a 114 liter plastic drum filled with water. In turn, a balance was used to determine the Vertical Profiler’s mass. The mass and volume data was used to obtain the Vertical Profiler’s density of approximately 740 kg/m^3 , which is much lower than the density of water at $1,000 \text{ kg/m}^3$. This relationship was used to determine the profiler’s behavior in the vertical water column. In order to determine FSB, the Vertical Profiler was tested in the pool at competition depth and observed. If the profiler sank too quickly, weight was removed. If the buoyancy engine was unable to cycle the Vertical Profiler up and down in the water column or if the profiler tipped sideways and floated improperly, additional weight was added. Ultimately, a total of 7.23 kilograms of weight was used, with a portion of the total weight applied as smaller 7 gram weights added incrementally to achieve precise balance and buoyancy control.

The software and data collection systems were also thoroughly tested above water. Adjustments were made to the web serial interface so that data packets would be received in groups of 20 to 30 packets immediately upon reaching the surface, improving the accuracy and reliability of the depth versus time graphs generated by the

profiler. For the electronics systems, extensive testing focused on the battery pack and motor performance. The 12 volt system was tested to ensure the motor could operate at the maximum allowed voltage. One of the primary challenges involved balancing power delivery between the motor and the other onboard electronics. To solve this issue, the company designed a system capable of switching power between the main circuitry and the motor during operational cycles. A voltage regulator was also implemented to maintain a constant 5 volt supply to the ESP32, protecting the board from burning out. Additional testing was conducted to identify a motor that offered more consistent performance than the servos used in previous years. Through comparative testing, the company determined that the new 12 volt, 100 RPM DC motor provided significantly greater consistency, stability and strength than the previous servo driven system. These conclusions were reached by comparing the performance of earlier buoyancy engine designs, which demonstrated inconsistent operation, against the newer motor driven design. The company also tested multiple external button designs to determine which option would best protect the profiler from water intrusion. After extensive testing, the company selected a stainless steel push button switch sealed behind a bottle cap and protected using marine diver's wax. Attention then shifted to optimizing the layout of the interior electronics. Different board arrangements and wiring configurations were tested within the tray to determine the design that occupied the least amount of space while maintaining accessibility and functionality. Finally, the completed Vertical Profiler underwent seal testing by placing the profiler housing without its internal components into a tub of water to identify any potential leak points. During testing, a significant amount of water intrusion was discovered near the bottom section of the profiler. In response, the bottom coverings were replaced and an additional layer of 5200 marine sealant was applied to ensure proper waterproofing.

Accounting

Budget

Category	Item	Projected Cost	Running Total
Frame	Static Buoyancy	\$20.00	\$20.00
Frame	Variable Bouyancy	\$40.00	\$60.00
Frame	Frame Face Plate	\$200.00	\$260.00
Frame	Attachments	\$50.00	\$310.00
Claws	25kg servomotors	\$60.00	\$370.00
Claws	Claw Body	\$20.00	\$390.00
Claws	Wires	\$40.00	\$410.00
Electronics	Blue Robotics ESCs	\$600.00	\$1,030.00
Cameras	Digital Cameras	\$60.00	\$1,090.00
Cameras	HDPI Splitter	\$50.00	\$1,140.00
Profiler	Electronics	\$180.00	\$1,320.00
Profiler	Frame	\$70.00	\$1,390.00
Travel	Plane Tickets	\$8,573.31	\$9,963.31
Travel	Hotel rooms	\$1,412.60	\$11,375.91
Travel	ROV transport	\$450.00	\$11,825.91
Travel	Rental car	\$1,500.00	13325.91
		TOTAL EXPENSES:	\$13,325.91

Cost Accounting

Source	Category	Item	Unit price (\$)	Quantity	Total	Cost
Reused	Frame	4-in PVC tube	\$15.57	1	\$15.57	\$0.00
Reused	Frame	3.75-in Clear PVC Tube	\$31.99	1	\$31.99	\$0.00
Reused	Frame	1-in stainless steel corner braces	\$1.29	12	\$15.48	\$0.00
Reused	Frame	Stainless steel hose clamps	\$12.99	1	\$12.99	\$0.00
Reused	Frame	Cable ties	\$11.59	3	\$34.77	\$0.00
Reused	Frame	CNC commission	\$225.00	1	\$225.00	\$0.00
Reused	Frame	HDPE cutting boards	\$12.99	3	\$38.97	\$0.00
Reused	Frame	3M 5200 marine sealant	\$22.42	5	\$112.10	\$0.00
Reused	Frame	Fernco 4-in rubber cap	\$4.54	1	\$4.54	\$0.00
Reused	Frame	JBWeld Steelstik	\$6.54	6	\$39.24	\$0.00
Reused	Frame	Heavy duty feminine pads	\$13.95	2	\$27.90	\$0.00
Reused	Frame	Silicone diver's wax	\$10.99	3	\$32.97	\$0.00
Reused	Frame	4-in PVC end cap	\$3.29	1	\$3.29	\$0.00
Reused	Frame	1-1/2-in PVC elbow	\$2.59	1	\$2.59	\$0.00
Reused	Frame	Stainless steel U-bolt	\$8.35	1	\$8.35	\$0.00
Reused	Frame	High-density foam	\$14.99	2	\$29.98	\$0.00
Reused	Frame	1-in PVC tube	\$12.99	1	\$12.99	\$0.00
Reused	Frame	1-1/2-in inflatable tube	\$37.68	1	\$37.68	\$0.00
Reused	Frame	Blue Robotics T200 mount bracket	\$8.00	2	\$16.00	\$0.00
Reused	Frame	PLA filament 1.25 kg	\$30.00	3	\$90.00	\$0.00
Purchased	Claws	25kg servomotors	\$16.99	4	\$67.96	\$67.96
Purchased	Claws	HNJPC Pneumatic Claw	\$60.00	1	\$60.00	\$60.00
Reused	Claws	Cytron MDD10A 10 amp DC motor driver	\$23.50	2	\$47.00	\$0.00
Reused	Claws	Analog joysticks	\$4.99	2	\$9.98	\$0.00
Purchased	Electronics	Blue Robotics ESCs	\$40.00	1	\$40.00	\$40.00
Reused	Propulsion	Blue Robotics ESCs	\$40.00	4	\$160.00	\$0.00
Reused	Propulsion	Blue Robotics T200 thrusters	\$220.00	4	\$880.00	\$0.00
Purchased	Cameras	1pc Black 15 Meter USB Endoscope	\$35.99	2	\$71.98	\$71.98
Purchased	Cameras	HDMI Splitter Extended Display	\$49.99	1	\$49.99	\$49.99
Reused	Cameras	YIWANG cyclical fishing cameras	\$20.00	4	\$80.00	\$0.00
Reused	Cameras	7-in rear-view car monitors	\$35.00	3	\$105.00	\$0.00
Reused	Electronics	WAGO connectors	\$20.95	1	\$20.95	\$0.00
Reused	Electronics	ESP 32 3 pack	\$15.99	1	\$15.99	\$0.00
Reused	Electronics	10 ft USB-C cable	\$11.99	1	\$11.99	\$0.00
Reused	Electronics	Voltage regulator	\$13.65	5	\$68.25	\$0.00
Reused	Electronics	Esp 32 shield 2 pack	\$11.89	1	\$11.89	\$0.00
Reused	Electronics	Rocker Switch	\$8.99	1	\$8.99	\$0.00
Reused	Electronics	WAGO connectors	\$39.95	1	\$39.95	\$0.00
Reused	Electronics	Marine-grade heat shrink tubing	\$15.99	1	\$15.99	\$0.00
Reused	Electronics	Arduino mega	\$55.00	1	\$55.00	\$0.00
Reused	Electronics	50ft Braided wire sheathing	\$186.99	1	\$186.99	\$0.00
Reused	Electronics	25-amp fuse	\$2.98	5	\$14.90	\$0.00
Donation	Electronics	Seahorse SE300 case	\$46.11	1	\$46.11	\$0.00
Donation	Electronics	1/8-in acrylic sheet	\$12.99	1	\$12.99	\$0.00
Donation	Electronics	16.8 meter cables	\$150.00	2	\$300.00	\$0.00
Donation	Electronics	Xbox One controller	\$54.99	2	\$109.98	\$0.00
Purchased	Administrative	Competition Fee	\$450.00	1	\$450.00	\$450.00
Purchased	Profiler	100mm T8 lead screw	\$9.99	1	\$9.99	\$9.99
Purchased	Profiler	Xudoai epoxy putty	\$11.99	2	\$23.98	\$23.98
Purchased	Profiler	5 A 250 V AC-DC fuse	\$5.99	1	\$5.99	\$5.99
Purchased	Profiler	100mL Large Syringe	\$13.99	1	\$13.99	\$13.99
Purchased	Profiler	Bringsmart DC 12V 30rpm Motor	\$21.57	4	\$86.28	\$86.28
Purchased	Profiler	Glass Seal Reed Switch	\$8.99	3	\$26.97	\$26.97
Purchased	Travel	Plane Tickets	\$1,174.54	9	\$10,570.86	\$10,570.86
Purchased	Travel	Hotel rooms	\$156.96	9	\$1,412.64	\$1,412.64
Purchased	Travel	ROV transport	\$1,000.00	2	\$2,000.00	\$2,000.00
Purchased	Travel	Rental car	\$1,500.00	1	\$1,500.00	\$1,500.00
Purchased	Travel	Miscellaneous	\$450.00	1	\$450.00	\$450.00
Donation	Finance	Publix donation	-\$250.00	1	-\$250.00	-\$250.00
Donation	Finance	Guy Harvey Foundation Donation	-\$2,000.00	1	-\$2,000.00	-\$2,000.00
Donation	Finance	Derrick Brook Charities	-\$14,000.00	1	-\$14,000.00	-\$14,000.00
			TOTAL EXPENSES:			\$590.63
			TOTAL EXPENSES EXCLUDING REUSED & DONATED:			\$16,840.63
			TOTAL FINANCIAL DONATIONS:			\$16,250.00

Appendices

Appendix A: Safety Checklist

1. Verify all members have their hair tied back, close toe shoes, and sleeves rolled up
2. It is important to ensure there's clear communication between members
3. Ensure all members are wearing proper PPE
4. Make sure all walkways are clear of any wires and objects
5. Any hazardous materials should be put away after use
6. Ensure all sharp edges and wires are covered
7. Ensure everything is connected before powering on POE

Appendix B: Safe Operation Protocols

Setup

- ☐ Opening of control box and confirming of connections
- ☐ Cameras and pump are connected
- ☐ Configuration and set up of Vertical Profiler
- ☐ Area is cleaned and organized
- ☐ Members are wearing proper PPE
- ☐ Systems are placed at stations
- ☐ Tether and POE are removed from storage and put at poolside

Power-up and Systems Check

- ☐ Alert members when POE is powered on
- ☐ All systems are powered on
- ☐ Thrusters, manipulators, and cameras proper operation and position are confirmed
- ☐ Tether is untangled and coiled

ROV Launch

- ☐ Controlside call out "ROV in water"
- ☐ Poolside places POE in water and notifies controlside
- ☐ Vertical Profiler is powered on
- ☐ Controlside notifies when the demonstration is ready to begin.
- ☐ POE is deployed

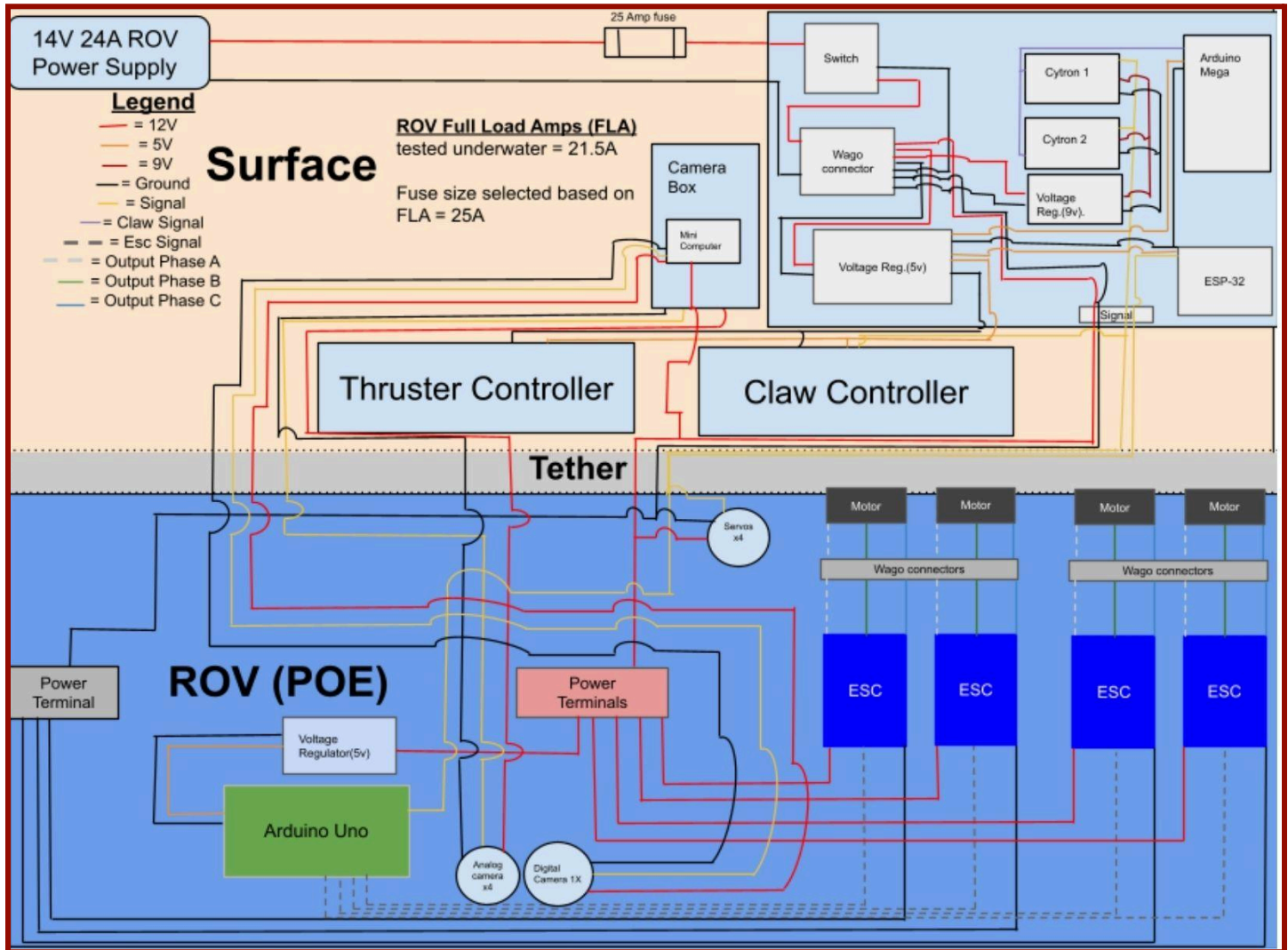
ROV Retrieval

- ☐ Controlside calls out "hand in water" so poolside is ready to retrieve POE
- ☐ Pilot puts down controllers and calls out "ROV out" so poolside can proceed to take the POE out
- ☐ Pilot indicates when POE is powered off
- ☐ All systems are unplugged and put away

ROV Maintenance:

- ☐ Verify all electronics work so POE and Vertical Profiler are good for use
- ☐ Check for any damage
- ☐ Rinse POE with fresh water and dry it so it can be packed
- ☐ Properly coil the tether, pack all electronics and POE

Appendix C: ROV SID



Appendix D: Non-ROV Device SID

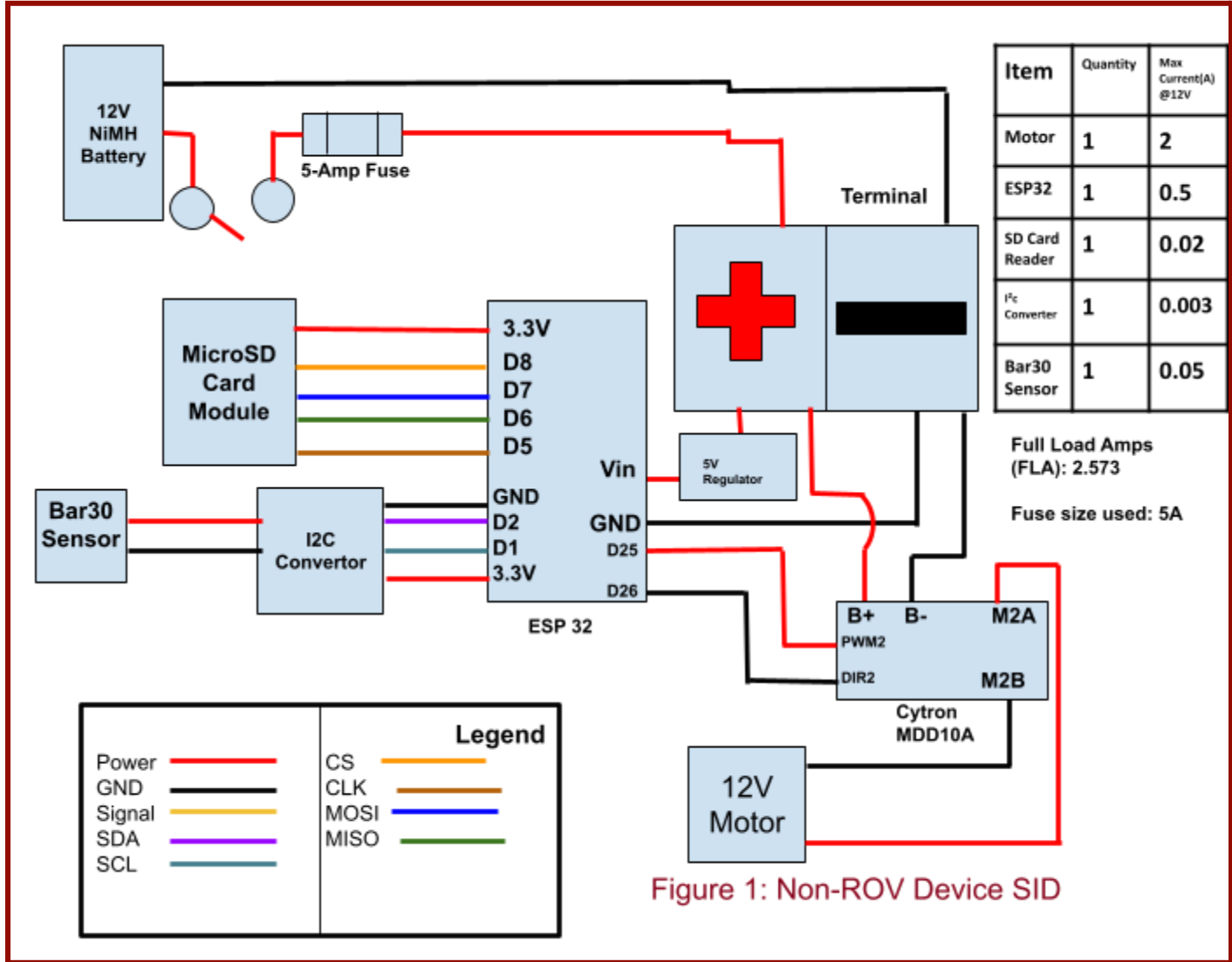


Figure 1: Non-ROV Device SID

Acknowledgements

Thanks To...

2-Extreme Audio - for providing mentorship and wiring

Derrick Brooks Charities - for providing funding

Calypso Dive Shop - for providing funding and facilities

CANDO - for providing partnership and help with corporate responsibility

Cheryl Hyde - for providing access to facilities

Chris Hochman - for providing mentorship

Debartolo Family Foundation - for providing funding

Florida Institute Oceanography - for providing resources and facilities

Guy Harvey Foundation - for providing funding

MATE - for providing mentorship and making this year's competition possible

MidFlorida Credit Union - for providing funding

Mike McGiven - for providing mentorship and funding

Paul Bowdin - for providing funding

Publix - for providing funding

Seth Baklor - for providing documentation advice

The Fernandez Family - for providing mentorship and funding

Nalini Gajadharsingh - for providing mentorship and funding

Adam Hough - for providing mentorship and transportation

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