Phoenix Robotics

Technical Documentation 2025

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Tampa, Florida, USA

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Table of Contents

Abstract

Phoenix Robotics is a diverse company of eleven students based out of Brooks DeBartolo Collegiate High School that specializes in the design and development of ROVs[1]. For 2025, the company expanded its workforce, with both new and returning members, each sharing a competitive ambition for innovation in marine robotics. This year, the company presents an ROV designed to fulfill the RFPs[2] proposed by MATE[3] for the 2025 MATE ROV Competition. The final product is a culmination of uniquely crafted components each tailored to maximize performance with minimal compromise. This effort has led to the creation of POE—the Phoenix Ocean Explorer.

POE is the result of thousands of man hours dedicated to the formulation of a state-of-the-art product. POE features a tough and lightweight frame, four high-power thrusters, two symmetrical manipulators, an in-situ pump, a fishing net, four cameras, a variable buoyancy system, and all associated safety features. These attributes in conjunction with the company's standing expertise in marine engineering instills the company with confidence in their ability to fulfill MATE's RFPs in this year's demonstration. The design philosophy behind POE prioritizes its ability to perform tasks that aid and facilitate environmental conservation. This is illustrated through its ability to complete the RFPs, which serve as analogs to real-world applications of ROVs.

The following document outlines the design philosophy, timeline, and rationale behind POE's functionality, operation, and payloads.

Figure 1: The Phoenix Ocean Explorer
By Gavin Quijano

Figure 2: Phoenix Robotics personnel
By Dan Allen

[1]Remotely Operated Vehicle (ROV): an unmanned underwater robot controlled from the surface.
[2] Request for Proposal (RFP)
[3] Marine Advanced Technology Education (MATE)

Teamwork

Project Management

Compartmentalization

To optimize performance and ensure efficient task completion, company members were organized into various work groups based upon their skill sets. Phoenix Robotics is structured into five distinct departments: Construction, Electronics, Vertical Profiler, Documentation, and Marketing. Each department is led by a returning member who acts as a project manager, responsible for delegating tasks, setting deadlines, overseeing safety, and guiding new members in executing specialized tasks. These leaders collaborate with one another to ensure seamless integration across the full ROV and vertical profiling systems, simulating real-world corporate and engineering structures.

This division of work promotes autonomy within departments. Members are encouraged to make decisions, explore innovative approaches, and solve challenges specific to their domain. For instance, the Electronics department independently prototyped a new circuitry for improved electronics input, while the Construction department assembled the claw mechanism. These opportunities create and encourage active participation and critical thinking, helping members grow confident in their specialties.

At the same time inter-departmental collaboration remains essential. No department functions in isolation—Construction and Electronics must coordinate motor placement, power demands, and physical integration. These interactions mirror real-world systems engineering, where subsystems must be compatible, efficient, and safe. For example, the placement of thrusters required simultaneous considerations from both Construction (for mounting and structure) and Electronics (for wiring, controls, and power distribution). This taught members how to balance independence with system-level coordination, teamwork, and developing standardized practices.

Phoenix Robotics also fosters entrepreneurial leadership within this structure. Department leaders are responsible not only for execution, but for guiding peers, assessing risks, and adapting plans—key qualities of project managers in industry. In preparation for critical design reviews, these leaders organized workflows, ensured goals were met, and promoted skills such as self-discipline, initiative, adaptability, and cross-functional communication.

The organization of Phoenix Robotics simulates industry-standard workflows while nurturing creativity, leadership, and cross-functional collaboration. Members gain experience not only in building a robot, but in managing a project, leading a company, and solving problems as professionals.

Communication

Effective communication is critical to Phoenix Robotics' ability to coordinate a large company and manage complex, multi-department projects. To ensure consistent attendance and alignment across departments, the company implemented a structured communication strategy utilizing platforms such as Discord, Trello, Google Workspace, and Zoom. Each tool was selected for its strengths and was integrated into a cohesive communication system that enables efficient collaboration, resource management, and task execution.

Discord serves as the company's central hub for real-time communication. Its combination of group text, voice channels, and file-sharing capabilities allows company members to quickly announce updates, troubleshoot problems in real-time, and build community across departments. Department leaders use Discord to notify specific members with reminders, share links to CAD[4] files or documentation, and hold quick voice meetings.

Google Calendar is used to schedule meetings and notify both students and parents, improving transparency and accountability. This centralized scheduling tool ensures that all members are aware of expectations and can coordinate their availability, leading to higher attendance participation.

Trello is implemented for project tracking and task delegation. With visual task boards organized by each department, Trello allows the company to assign responsibilities, set deadlines, and monitor progress. Each card includes descriptions, attachments, and status tags (e.g., "To Do." "In Progress," "Completed,"), which creates transparency and

[4]Computer-Assisted Design (CAD): computer-based design software

ensures that no task is overlooked. The use of Trello trains members in how to efficiently use project management techniques, and develops critical organization skills.

Google workspace is the company's primary platform for digital document collaboration. Shared Google Docs, Sheets, and Slides streamline document editing, revision history, tracking, and file organization. These files are accessible to all members, which make it easy for departments to reference data, integrate designs, and prepare engineering documentation efficiently.

Zoom is used for virtual meetings when in-person attendance is not viable. These meetings ensure continuity in leadership and task progress, especially during critical planning phases. For example, Zoom is often used for parent meetings, project updates, or notification of meeting changes.

By leveraging multiple communication platforms for specific needs, Phoenix Robotics creates a comprehensive system that enhances project clarity, increases efficiency, and prepares members with professional-level communication and collaboration skills. This strategic integration allows all company members to stay informed, engaged, and aligned, contributing to the company's overall success in designing and delivering functional ROV and vertical profiler systems.

each company member has their own personal goals that call for a large time commitment. To work around this, Phoenix Robotics generates schedules according to the anticipated workload, varying over the school year from the months of August to June. The company meets during the summer after each international MATE ROV Competition to discuss the trajectory of the upcoming year and to start planning for the new year. The month of August is used to discuss membership, recruitment, marketing to new members and other logistics. At this point, meetings are scheduled to be two hours, beginning at 3:10pm on alternating school days. The company gradually meets more frequently as responsibilities undergo refinement, including an additional day to meet as necessary. This continues until the company meets nearly every day of the week for 4–8 hours a day, depending on the scenario. With this schedule in place, the company performs the majority of its work in the latter half of the competition season (*See Figure 3*). Earlier months are dedicated to recruiting and introducing new members to fundamental principles of engineering. This time is also used to train these new members in certain safety procedures alongside filling the gap in knowledge between new and returning members. This ensures that the whole company is capable of operating the necessary equipment to develop the ROV in the coming months.

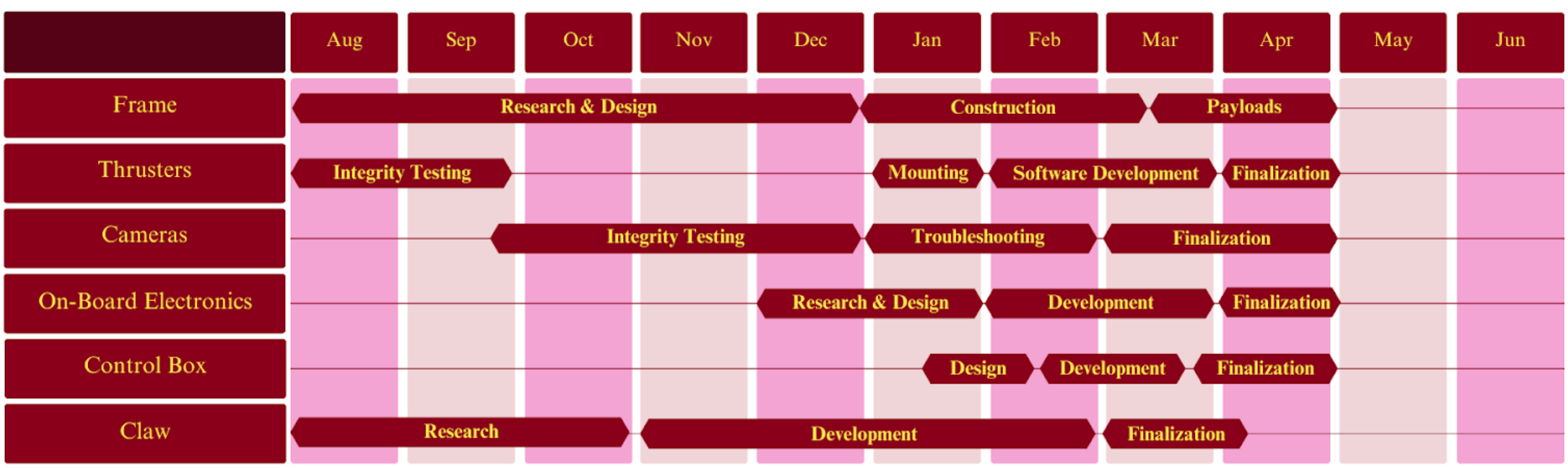


Figure 3: Gantt chart illustrating system development over time
By Gavin Quijano

Scheduling

One of the biggest challenges for the company was coordinating and planning meetings. Coordinating efficient meetings poses significant logistic issues as

Company procedures

Regarding company procedures, each meeting follows a similar three-step process. First, the full company comes together to discuss what each group's goal is for the day, share important announcements, or ask initial questions. Second, each department splits up to complete their given tasks for the day. Finally, the company once again reconvenes to discuss their progress, whether they reached their goal for the day, and what issues they faced. Certain protocols, such as keeping a quiet working environment, refraining from sudden movements, and focusing on completing work throughout the entirety of the meeting, were expected and enforced behaviors.

Design Rationale

Structure

Frame

The frame features an on-board electronics tube, a structural sleeve, wings that flare out from the sleeve, skis, tether strain relief, and handle supports. The on-board tube is a 3.75-inch ID[5] by 45.7-centimeter long clear PVC[6] tube, which is glued concentrically into a 4-inch ID PVC sleeve using Oatey PVC solvent and cement. Four windows were cut into the bottom and top of the sleeve to not forgo the transparency of the clear tube within it. This configuration expresses both sturdiness and utility, as the sleeve proves to be sturdier and safer for mounting opportunities thanks to its thicker wall. Furthermore, the transparency of the clear tube is used to confirm both water leaks and electronics' functionality. The tubes are sealed with a Fernco 4-inch flexible rubber end cap. The cap is then tightened down with a 316 stainless steel hose clamp. As a final precautionary measure, removable silicone diver's wax is applied around the edge of the rubber end cap to help ensure a watertight seal.

Bolted to the top of the sleeve is a pair of flat wings that flare out and down at a 45-degree angle. Each wing is secured with seven bolts and four corner braces each. These wings were machined using CNC[7] from sheets of HDPE[8] to have rectangular planiforms with twenty-two rectangular perforations cut into each sheet. Phoenix

Robotics had these sheets machined by a company called Plastics America INC, which is a company that specializes in plastics manufacturing. These perforations enable water to pass through when ascending or descending underwater, improving the ROV's hydrodynamics and efficiency. The perforations also provide mounting opportunities for peripherals such as cameras and claws. The largest perforation, a 12.7-centimeter ID circle in the middle of each wing, encircles the vertical thrusters. This enabled all four thrusters to be centered along a transverse line, which improved balance and control over prior models.

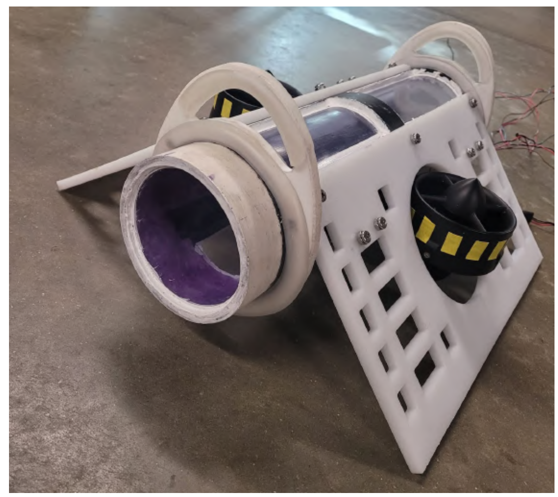


Figure 4: Stripped ROV frame
By Gavin Quijano

The handles on the posterior and anterior end of the sleeve were hand cut from a sheet of 9-millimeter thick HDPE. Their form consists of a 11.5-centimeter ID circle and an arch across the top. The sleeve rests inside the circle, while the user lifts the ROV by the arches. The handles are fitted with a rubber lining on the inside of both the circle and the arch for comfort, safety, and friction while handling.

The frame sports four 1-inch PVC skis that are strapped to the bottom of the four lateral corners of the HDPE panels with 316 stainless steel hose clamps. The hose clamps are lined with rubber strips to provide better grip and protect the frame from scuffing. The skis are included in the design of the frame because they elevate POE's resting position in such a way that the horizontal thrusters are not resting on the surface

[5] Inner Diameter (ID): diametric measure of the empty space within a pipe.
[6] Polyvinyl Chloride (PVC): a hefty, industrial plastic often sold in the form of piping or tubes.
[7] Computer Numerical Control (CNC): a computerized system of machining that eliminates human error.
[8] High-density Polyethylene (HDPE): a high-density variant of the most widely produced plastic resin.

when aground. This keeps the weight of the ROV from damaging the thrusters' mounts. Moreover, the skis protect the sea floor when landing for photographic tasks.

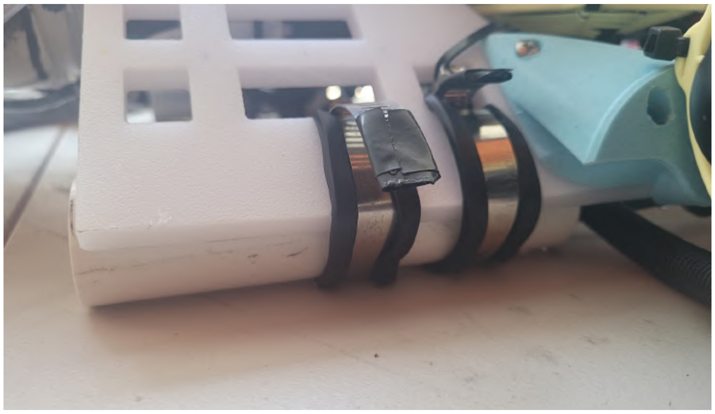


Figure 5: PVC ski mounted to the frame
By Gavin Quijano

Tether Strain Relief

Damage to the connection site between the tether and the ROV was a major concern. This was addressed by developing a strain-relief system on the rear end of the ROV. The strain relief involves a U-bolt installed into a 4-inch PVC end cap, a carabiner, and two hose clamps. This allows any tugging or strain to be redirected to the wires, U-bolt, and carabiner, as opposed to the connection site itself. This increases the effective strength of the site drastically, allowing the ROV to be held from the tether without fear of damaging any electronics.

The system itself is constructed by installing a U-bolt into a PVC end cap. This was done by drilling two holes, spaced apart according to the width of the U-bolt, and threading the U-bolt into these holes. Then, nuts were screwed onto the U-bolt to keep it from falling out. These nuts were permanently locked in place using Loctite Threadlocker red 271. Another, larger hole was drilled into the rounded end of the PVC end cap. A 1.5-inch PVC elbow piece was then glued into the opening using Oatey PVC solvent and cement. This relocates the exit site of the wires, improving the way they feed into the strain relief. Additional holes were drilled to accommodate more wires. These holes were outfitted with grommets to provide safety to the passing wires. The structure was then waterproofed by adhering JBWeld SteelStik to the open sites, which also provided a structural basis to support the wires. Once cured, the structure was painted with two layers of 3M 5200 Marine Sealant. This sealant cures into a rubber-like substance that's adhered to the surface. This creates an incredibly reliable water-tight seal that also remains slightly flexible, allowing the wires to adjust while not compromising the integrity of the seal.

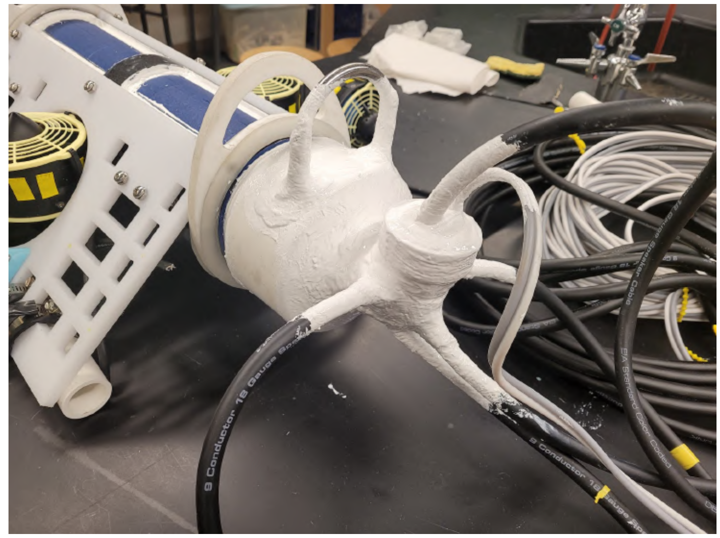


Figure 6: Completed sealing of the tether strain relief
By Gavin Quijano

Figure 7: Completed tether strain relief system
By Gavin Quijano

Dimensions

The dimensions of the ROV were designed to successfully navigate this year's tasks. As such, the company optimized the ROV's functionality while maintaining a profile of 86.4 by 53.3 by 38.7 centimeters. This maximizes functionality, while remaining small enough to flawlessly navigate the shipwreck in *Task 1.1*, and the offshore solar panel array in *Task 2.2*. Furthermore, the light weight makes it easy for poolside personnel to deploy and retrieve the ROV during operation.

Weight	**Length**	**Width**	**Height**
10.7 kg	86.4 cm	53.3 cm	38.7 cm

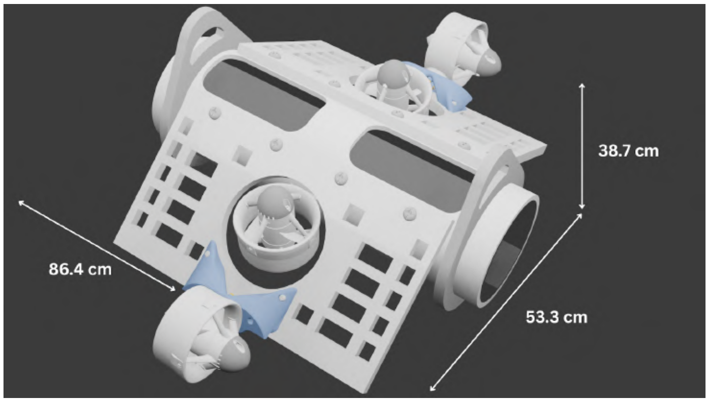


Figure 8: Completed ROV frame with dimensions
By Carson Stein

Vertical Profiling Float

This year's vertical profiling float the Sun Eel was designed to mimic profilers used out in the real world, more specifically those used in the Argo Float Program[9]. The large size of the profiler accommodates a vast array of payloads for environmental monitoring, improving its ability to handle the mission tasks. To accomplish all of this, 6-inch clear PVC tubes were chosen for the profiler's body. Clear PVC was chosen for both its aesthetic value and its use in determining the status of all the profiler's internal hardware, like the buoyancy engine. The overall height of the vertical profiler measures 80.5 centimeters.

Figure 9: The Sun Eel
By Gavin Udagawa

With this height, The Sun Eel can be divided into two distinct sections. The top section houses the data systems and buoyancy engine, while the bottom section contains the electronics and ballast weight. These sections are connected with a 6-inch rubber PVC pipe coupling, which streamlines access to the internal components. This design enables maintenance tasks to be split between two people, reducing downtime and maximizing operational time. It also improves the machine's repairability and upkeep, enabling it to last longer than harder-to-repair alternatives.

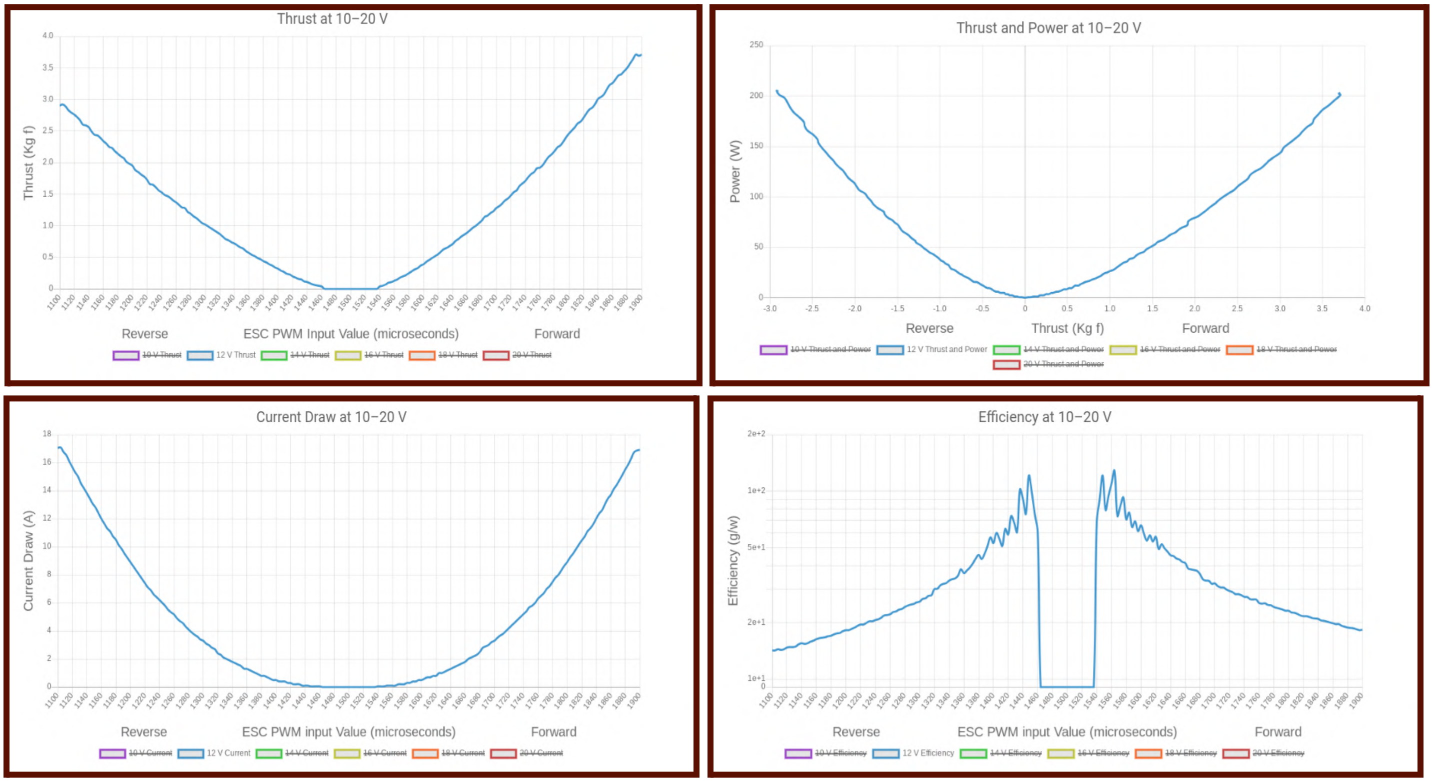
Mechanical Systems

Propulsion

Last year, the company researched reliable brushless motors for ROVs and discovered a reputable company, Blue Robotics. They presented a thruster and basic ESC[10] that aligned with the necessary performance as evaluated using the bollard test (*See Testing and Troubleshooting for more information*). This was demonstrated to the company in both the testing phase and throughout the 2023-2024 MATE ROV Competition. An executive decision was made to reutilize the T200 thrusters on this year's ROV, both to optimize cost efficiency and because the units remain in excellent operational condition. The T200 Thruster from Blue Robotics features an innovative fully-flooded brushless motor design that sets it apart from traditional underwater thrusters. This patented design lets the entire motor be submerged in water, with the windings and stator encased and the magnets and rotor coated for waterproofing. The fully-flooded architecture provides a number of advantages. First, it enables natural water cooling of the motor, improving thermal performance. Second, it allows the plastic bushings to be water-lubricated, eliminating the need for a separate lubrication system. Finally, by avoiding compartments filled with air or oil and shaft seals, the design is inherently pressure-tolerant without the need for complex pressure compensation mechanisms.

[9] Argo Float Program: An international oceanic float research program

[10] Electronic Speed Controller (ESC): Electronic circuit that adjusts the speed of an electric motor



Figures 10-13: Graphs illustrating various electrical aspects of the T200 thrusters By Blue Robotics

The thruster body and propeller are constructed from durable polycarbonate plastic, with only a few exposed components made from corrosion-resistant marine-grade 316 stainless steel. This simplicity, combined with a minimal number of parts, allows Blue Robotics to offer the T200 at an affordable price point, making it a perfect choice for POE. At its core lies a three-phase, brushless, out-runner motor topology, which operates with an ESC to run the thrusters. The company uses software that was written in C++[11]. This software allows basic function of the thrusters using two axis joysticks on an Xbox One controller which gives the pilot the ability to use variable speed control. This year, the company has implemented a four thruster system which has proven sufficient for the tasks at hand and additional thrusters were found to be unnecessary as the current thrusters are strong and effective when driving the ROV. The Blue Robotics T200 thrusters, when operating on a 12-volt and 24-amp system, generate 2.91-kilograms of backward thrust and 3.70-kilograms of forward thrust. This power output helps the ROV maneuver through the water quickly, allowing it to complete all tasks in an efficient and timely manner.

[11] A general-purpose programing language

The thrusters were placed strategically on the transverse line of the ROV to ensure that the center of thrust is in line with the center of mass, maintaining stability. Two thrusters are facing up while the other two are facing forward, allowing for both vertical and horizontal movement in the water. The ROV can be rotated using differential thrust with the horizontal thrusters. While balanced, this configuration lacks the ability for lateral translational movement. This is a trade-off that was decided based on the necessary mobility to complete the tasks of the competition. The company found that lateral translational movement was an unnecessary degree of mobility because no task required such movements. In addition, the ROV could complete all the tasks with the four thrusters. All of this did not justify the expense of additional thrusters to enable it.

The horizontal thrusters are mounted with custom-designed 3D printed mounts that hug the corner of the HDPE panels on either side. Four 8-32 bolts and accompanying nuts secure the mount to the panel, while four M3 bolts fasten the thruster to the mount. The vertical thrusters are mounted via four flat head M3 screws that penetrate the PVC sleeve of the frame. These pass through a Blue Robotics thruster mount and insert into the threads of the thruster, securing it to the sleeve. The inside of the PVC sleeve is countersunk to allow the transparent PVC to slide in seamlessly without interacting with the M3 screws.

Figure 14: The mounted thrusters
By Gavin Quijano

Claws

POE is equipped with two independently operated manipulators, mounted symmetrically beneath each wing of the ROV. This dual-manipulator setup allows for *Task 1.2 Replacing a Damaged Thermistor* and *Task 2.2 Placing a Hydrophone in a Designated Area*, to be completed simultaneously. Additionally, they enable the ROV to hold large or otherwise unwieldy items, improving efficiency during missions. The manipulators are positioned to optimize reach and stability while performing tasks such as measuring shipwreck lengths, replacing damaged thermistors, collecting water samples, and collecting jellyfish across multiple stages of development.

Figure 15: POE grasping the handles of the medusa catcher
By Gavin Quijano

Each manipulator features two axes of motion: grasping and rotational movement, both powered by analog servos. The grip mechanism operates via a servo with a 25T[12] horn. The servo drives a pair of custom cut aluminum linkages, each approximately 38-millimeters in length. Each grasping mechanism requires two aluminum linkages; these linkages have one hole drilled on each side for mounting. One end is fastened to the claw prong, while the other is attached to a 25T servo horn, converting rotational motion into linear force.

The rotation mechanism uses a second servo, mounted at the base of the manipulator arm. This servo utilizes a circular horn, secured via four screws to a ½ -inch PVC end cap which is attached to the end of the claw body. All pipes and fittings used to assemble the claw are ½-inch PVC. A spacer was added above the servo to offset the claw assembly from the wing, making the claw arm level with the wing. This makes the claws more intuitive for the copilot to handle.

The primary claw structure was repurposed from a previous year's design, offering time-tested durability and reliability. The claw mounting base and prongs were laser-cut from a 6.4-millimeter thick acrylic sheet using a Glowforge™ laser cutter. Screws and spacers were used to secure the claw prongs to the base. The servo responsible for opening and closing the claw is housed within this primary mount and secured using cable ties.

Figure 16: The claw grasping mechanism
By Gavin Quijano

A secondary aluminum mount, fabricated from a 90-degree angle bracket, is attached to the primary mount via two screws and connects to a PVC end cap

[12] 25-tooth (25T): Refers to the cog-shaped insert on the servo's head

through an adjacent third drilled hole. This configuration provides rigid support and rotational alignment. A PVC pipe assembly, including female adapters at both ends, connects the claw assembly to the ROV's main frame. A custom 3D-printed, rotational bracket was made to mount the claw to the frame. The female adapters are placed on each side of the mount, with a PVC pipe fitted in the center hole. The female adapters prevent axial movement of the manipulator during operation, increasing stability and positional accuracy.

Buoyancy

Without buoyancy, the ROV is negatively buoyant, making its density greater than 1g/cm^3. A neutral buoyancy of 1g/cm^3 is desirable because it enables the ROV to float in place without adjusting the Z-axis propulsion. Remaining stationary is an important ability, as it streamlines the completion of the tasks of the MATE ROV Competition. If the ROV was not neutrally buoyant, the pilot would need to constantly adjust the vertical position of the ROV with the thrusters, distracting from the completion of the task at hand. To obtain neutral buoyancy, high-density foam was strapped to the topside of the ROV 525.8 cm^3 was necessary to achieve neutral buoyancy. The foam is organized into blocks of varying sizes, placed across the ROV according to its weight distribution. The ROV's buoyancy should also be neutral across its length, ensuring it is level. This is achieved by attaching the foam according to the weight distribution of the ROV. Through experimentation, the foam positions were finalized in such a way that it remains at rest when placed 1.5 meters under the water's surface

A variable buoyancy bladder is placed on the top of the forward window, slightly forward from the center of gravity. This bladder is inflated and deflated through a hose that connects to a surface-side air pump. The hose runs alongside the tether, however it does not pass through the tether strain relief, because it would compromise the ability to inflate the bladder. Meanwhile, strain on the hose does not pose a threat to the safety of the vehicle. The forward position allows the buoyancy to offset the weight of objects being carried in the claws. The weight carried by the claws can be disruptive to the ROV's operation, as it compromises the angle of the thrusters relative to the ground by pitching the ROV forward. To counteract this, the variable buoyancy was installed, serving as a counterbalance to maintain neutral buoyancy and level pitch. The variable buoyancy also allows the ROV to navigate aquatic systems of varying salinity.

Figure 17: The variable buoyancy system
By Gavin Quijano

Net

POE is also equipped with a net, used to collect the fish eggs under the solar panel array in *Task 2.2*. The net is fashioned from a modified spatula and a fishnet stocking. The form of the spatula creates an inverted shovel that is used to break the water surface, while the fishnet retains all captured fish eggs. The positioning of the topmost camera provides an optimized viewing angle, enabling the pilot to effectively aim for target eggs.

Figure 18: The net
By Gavin Quijano

Buoyancy Engine

The Sun Eel's buoyancy engine is a water-based weight system. The engine consists of a 60-milliliter syringe and LEGO system bricks, which are reinforced by a frame of two equally sized stainless steel strips, allowing for a sturdy design and seamless operation. The buoyancy engine's lead screw extends and retracts the syringe's plunger. This movement in turn forces water to enter the syringe, increasing the average density of the vertical profiler and causing it to sink. Conversely, when ejecting water, the average density of the profiler will fall below 1 g/cm³, causing it to float back to the surface. The lead screw is connected to the plunger by a 3D-printed mount made of PLA[13], friction-fitted and reinforced with epoxy putty. The syringe's movement is driven by a 360° continuous servo motor connected to the lead screw using a 3D-printed coupling, also made of PLA.

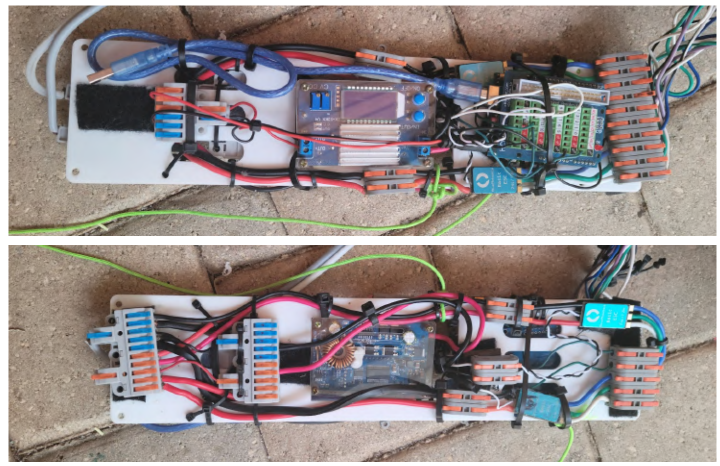
Figure 19: The buoyancy engine
By Bryce Phuphanich

Electrical Systems

POE's electrical system is designed to be a reliable and modular aspect of the ROV. The ROV uses two electrical systems, including a modular on-board system and a surface-side control box, connected to one another via a 16.7 meter tether.

On-Board Electronics Tray

The on-board electronics tray is composed of a 3.2-millimeter thick acrylic tray that was laser cut in house on a Glowforge ™. The tray is inserted into a 3.75-inch ID clear PVC tube. On the tray there are electronic components, including an Arduino Uno, four Blue Robotics ESCs, and a 5-volt voltage regulator. Each component is meticulously wired with appropriately gauged wires, allowing power and signal to run efficiently throughout the system. To streamline the connection process, each wire is routed into a WAGO[14] snap-fit connector. The company found that not only do these connectors eliminate the need for soldering, but it also saves valuable build time with regards to troubleshooting (*See Testing and Troubleshooting for more information*). Furthermore, it allows all components in the system such as the ESC's to be modular, granting a plug and play action for the user. Lastly, bright nylon strings are tied to the tray, allowing them to stand out against the other wires while packed in the tube. These strings allow personnel to pull the tray out without damaging the electrical components.



Figures 20-21: The on-board electronics tray
By Gavin Quijano

Control Box

The on-surface control box is a Seahorse SE300 Waterproof Protective case that houses four WAGO connectors, two Cytron MDD10A 10-amp DC motor drivers, an Arduino Mega, an ESP32, a voltage regulator set to 9 volts, and a voltage regulator set to 5 volts. All of these instruments are connected to five wires; three 16-gauge wires and two 12-gauge wire pairs. Two of the three 16-gauge wires are used to receive signals from the claws and thrusters, while the other 16-gauge wire is used to send signals to the claw's controller. The two 12-gauge wire pairs are used to power the whole ROV and the camera box. A separate 12-gauge wire is sent outside the control box and has a 25-amp fuse connected to the wire, which is used to connect to the power supply, where the fuse is 23.5-centimeters away. All the wires that are sent inside and outside the box are first sheathed to protect the wires from any cuts or abrasions and to keep all the wires grouped together as a way to easily troubleshoot an issue within the control box. The wires are then inserted through water-resistant grommets to protect

[13] Polylactic Acid (PLA): A biodegradable polymer used as a 3D print filament
[14] A robust but reversible wire connector using spring clamps

the electronics from water damage. An acrylic sheet is used to protect the wiring inside the box. Three laser-cut holes in the acrylic sheet house an emergency stop switch, the pump's two-pronged switch, and a 5-volt USB-C output to power the Xbox One controller that drives the thrusters.

Figure 22: The on-surface control box
By Bryce Phuphanich

Tether

POE's tether is 16.7 meters in length and contains two 16-gauge wires, a 12-gauge wire pair, the analog camera system's wires, and the variable buoyancy hose. The ROV's tether is thoroughly sheathed to protect the wires from any cuts or abrasions it may accumulate from prolonged use. Segmented pool noodles are strapped around the outside of the tether using cable ties to add a degree of buoyancy to the tether. These noodles are then spaced such that the tether is neutrally buoyant in water. This minimizes the tether's influence on the mobility of the ROV, improving the pilot's handling. Improved handling better enables the pilot to complete the assigned tasks of the MATE ROV Competition by improving precision and accuracy. When operating with the tethering system for the ROV, it is important to ensure that there is enough tether reeled in to allow smooth movement without causing strain or pulling on the ROV. Proper tether management involves continuously monitoring the ROV's movements and predicting the amount of tether required for certain tasks. This proactive approach maintains optimal maneuverability, prevents entanglement, and excess tension. It also ensures the safety and efficiency of operations, especially during complex navigation in challenging environments.

Propulsion

When controlling the thruster system, an Xbox One controller is powered by the MATE power supply. Inside the controller, there is a Bluetooth transmitter, which sends signals to a microcontroller, also known as an ESP32. This microcontroller includes a Bluetooth receiver, which relays the Xbox controller's output signal down the tether via RX[15], TX[16], and ground terminals. On the other end is an Arduino Uno that receives the data sent, reads it, and produces a code that the ESC uses to control the direction and power of the thrusters.

Cameras

The ROV is equipped with four analog cameras, repurposed from the 2023-2024 model. These cameras were selected after evaluating their field of view and their compatibility with the new frame design. The camera box and monitors from the previous year were reused. However, the monitor mounts were replaced with an alternative mount to provide better

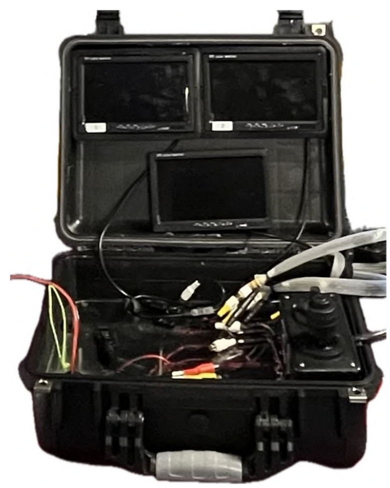


Figure 23: The camera box
By Kristofer Gajadharsingh

adjustability, ensuring that the screens do not overlap and can be angled away from sunlight or repositioned for better visibility for the pilots. Each analog camera is directly wired to the surface, bypassing the onboard control systems. The camera feeds are connected to individual monitors mounted inside the camera box.

[15] Received signal (RX)
[16] Transmitted signal (TX)

Additional power ports were installed in the camera box to supply power to the cameras.

Anderson power pole connectors power the camera box through the main control box. The camera box power line passes through a 25-amp fuse located within 30-centimeters of the power connection. It is then regulated by a voltage regulator at 12 volts to ensure stable voltage and to prevent spikes or current overdraw. The camera system is isolated from other control systems, receiving only power and direct video feed, which improves system modularity and reliability.

For *Task 1.1: Measuring Shipwrecks and Creating a Photosphere*, one of the camera feeds is temporarily disconnected from its monitor and is routed through an ADC[17], which is then connected to a laptop. This allows image capture and analysis using FiJi (ImageJ) software. A 100-centimeter reference bar made of PVC and suspended by string between both claws is used for scale. Once a clear image of the shipwreck with the reference bar is captured, the PVC bar is set to 100 centimeters within the software. FiJi then enables precise measurement of the shipwreck's length, which helps determine the type of vessel and the nature of its cargo.

Also in *Task 1.1*, the ROV is used to create a photosphere of the surrounding environment. The same analog-to-digital setup is used, with the camera feed displayed on a laptop. The pilot rotates the ROV 360° to capture images of the seven targets and their environments. These images are then combined using the digital painting software Krita to form a panoramic image. This panorama is uploaded to Playground, an online photosphere viewer, to produce a 360° view.

Figure 24: The primary front-facing camera
By Gavin Quijano

[17] Analog to Digital Converter (ADC): A cable that converts between analog and digital connections

Claws

The electrical system for the claw consists of four analog servos—two 25-kilogram and two 35-kilogram torque-rated units—each are independently controlled to allow two degrees of motion: grip (open-close) and wrist (rotation). This system is driven by two analog joysticks, an Arduino Mega, and two MDD10A Cytron two channel DC Motor Drivers, all housed in the control box.

Early in the development phase, the company tested both analog and digital servo systems. The digital system utilized 12C communication between an Arduino Mega, an Arduino Uno, and an Adafruit PCA9685 15-channel motor driver. This system allowed the servo range to be limited and required only three signal wires (SCL, SDA, and GND) to be sent down the tether. However, while testing this system on the 16.7-meter tether wire, the I2C signal degraded significantly, this resulted in delayed servo response and unreliable operation. The delay in the digital signal proved unacceptable for operation standards.

Conversely, the analog control system, though requiring two wires per servo (8 wires total for four servos) proved to be far more robust and reliable. The analog servos consistently respond to joystick input with no noticeable delay. Moreover, the motors demonstrated excellent resistance to electrical noise and environmental stressors, such as potential water infiltration of the motor. The servos were chosen after comparative testing between the analog and digital systems in isolation and as a part of the ROV systems. The company found that the analog system has a longer operational lifespan and better tolerance for marine conditions.

The Arduino Mega was ideal for this application due to its abundance of analog and digital pins, supporting simultaneous multi-axis joystick input and control output. The DIYables analog joysticks are used as the interface between input control and output for independent X and Y axis control. The joysticks send analog signals to the Arduino Mega which processes and maps the input values. The joysticks have PWM[18] ranges of 0-1025 and are mapped to run the motor forward or reverse with the center deadzone being

[18] Pulse Width Modulation (PMW): controls the average power or amplitude delivered by an electrical signal

400-600. When the joystick is within the range of the center deadzone, the motor stops. This deadzone is applied throughout the ranges to avoid unintended movement. A short delay at the end of each check cycle ensures smoother motor control.

Vertical Profiler Electronics

In the center of the Sun Eel is the main electronics tray for the profiler. The entire system is powered by a 12-volt 8-AA battery pack that goes through a 0.75-amp fuse and then is regulated down to 5 volts by a voltage regulator. The voltage regulation ensures that all parts of the profiler function at optimal voltage levels. Regulation is essential to the operation of the profiler, as it stabilizes current and protects from overvoltage. A WAGO terminal distributes power for the buoyancy engine and data transmission system.

Continuing with the buoyancy engine, an Arduino Nano provides the movement for the servo. Code communicates the angular position of the servo, which then drives the syringe, adjusting the vertical position of the profiler. The angular position of the servo determines how far along the profiler is in a given cycle. A cycle defines the motion of the buoyancy engine, in which each cycle adjusts the vertical position either up or down. This enables the Sun Eel to descend and remain at 2.5 meters for the necessary length of time before returning.

Lastly, the Sun Eel utilizes a Blue Robotics Bar 30 depth and pressure sensor to collect the necessary data during each profile. This sensor is connected to an I2C level converter, which takes the gathered data and then translates it into a language the attached ESP8266 can read and then transmit. Before this transmission takes place, however, it is stored and held by a MicroSD card memory adapter until thirty-seven data packets have been collected. This enables the profiler to generate a continual timeline of data while underwater, which is then transmitted once it returns to the surface. This eliminates the need for a lengthy antenna. Once the packet limit is reached, it is then sent to the ESP for transmission and received by a WebSerial page on the surface for graphing the depth data over time.

Pump

One of the ROVs payloads is the water collection device, which can extract small amounts of fluid to later test once returned to the surface. To take these samples, a 12-volt pump sucks water into a sealed container. To keep the sample from getting contaminated, a series of check valves are used to keep the collected sample isolated. Once resurfaced, the collection container can be easily removed and reattached by unscrewing the lid of the container. Testing these samples is especially useful in *Task 1.3, Lake Acidification and Invasive Carp*, where these samples can help determine the current state of lake acidification by assessing the pH levels and dissolved carbon dioxide in the water. In addition, these samples can provide information to analyze the eDNA[19] to confirm the presence of invasive carp species.

Figure 25: The pump and receptacle
By Gavin Quijano

Build versus Buy

The decision to build or buy components of the ROV are dependent on the company's available time, funds, and expertise for the given options. Evaluating the company's available resources is an important step in the design process, as it allows assets to be allocated appropriately. Each component is decided on a case-by-case basis, a responsibility allocated to the leading members of each department.

Frame

The frame was constructed from PVC, HDPE, and various hardware components. These had to be purchased, as the company did not have such material on-hand, nor could they be fabricated in-house. The windows in the PVC sleeve were manually cut using a

[19] Environmental DNA (eDNA): The change in DNA location over time

Dremel rotary tool to achieve desired precision. This is in contrast to the HDPE wings, which were machined using CNC, as commissioned from PlasticsAmerica. This was done because the company does not possess a CNC machine, nor could any personnel achieve the desired precision for the wings' perforations through manual fabrication. Precision was important because imperfections may impede the balanced hydrodynamics of the ROV, which would have been difficult to amend. Thus, the HDPE panels were sent to PlasticsAmerica to be machined to the desired level of precision for $225. The handles were carved from the same sheets of HDPE, however the precision of these was less important, so the company opted to carve them in-house to save money. The construction of the frame was completed by company personnel and no external individuals were involved.

Claws

The claws were constructed from PVC, servos, acrylic prongs, and assorted hardware. This is in contrast to purchasing a preconstructed claw, such as those offered by Blue Robotics. The cost of a premade claw outweighed the value of the time it would have saved. Moreover, Phoenix Robotics has a strong history in the construction of custom claws, making the company well-versed in their design and fabrication. As such, the two claws were built from in-house materials. The prongs were laser-cut from sheets of acrylic, while accessible hardware was used to assemble them. While requiring greater time to configure, POE's claws were ultimately decided because of the company's careful balance of funds, time, and expertise. The only out-of-house components were the constituent servos, as the company lacks the proper machinery to construct motors in-house. These servos had to be purchased from an online retailer.

New versus Used

Reusing and adapting proven components reduced build time and budget expenditure while maintaining robust performance, aligning with both the mission requirements and the project's sustainability goals.

Frame

The frame was built new because the company wanted to create a more unique product, and to improve upon the complications of previous designs. For instance, the frame of the previous model was poorly designed for the use of four thrusters. The position of the horizontal thrusters introduced an undesired torque on the whole ROV, causing it to pitch forward when the pilot only wanted to drive straight forward. The new frame addresses this by positioning the horizontal and vertical thrusters in-line with the center of gravity of the ROV, reducing the total torque and pitch it produces during operation.

Propulsion

As mentioned previously, the Blue Robotics T200 thrusters were reused from the previous model. Reusing them optimized the company's available time and funds, as only testing was necessary. This eliminated the need to research and purchase new motors. While the hardware was strictly reused, the software was approached from an entirely fresh perspective. Last year, the company developed an analog joystick system but found that they were very sensitive when it came to controlling the ROV. To counteract this problem, this year the company went with a wireless digital design. The system was coded in the Arduino IDE[20] in C++. The code uses RX and TX serial communication that is paired with an Xbox One controller. This is encoded on an ESP32 module which has bluetooth capabilities, located in the control box. This is then sent to an Arduino Uno located on-board. This streamlined approach provides an optimized way to send controller data via three wires down the tether and offers a modular experience allowing for precise variable speed control and improved maneuverability.

Claws

The design of the claws is time-tested and reliable, so it was reused as the framework for both of POE's claws. However, the hardware used to construct both claws was newly fabricated. The construction of additional claw units allowed them to be refined compared to previous units, as company members improved their technique with more experience.

Cameras

The analog camera system used on this year's ROV was strategically reused from last season due to its proven performance and reliability. During previous competitions and practice runs, the analog setup

[20] A open-source software compiler

delivered clear visuals, strong durability, and consistent functionality—qualities that aligned well with this year's operational needs and budget constraints.

Previously, a digital camera system had been explored for its advanced capabilities, but it was not pursued due to high costs and limited personnel experience. Moreover, the use of an ADC opened access to the benefits of a digital system while saving both time and money. So, the company chose to continue utilizing the existing analog system along with an ADC.

To ensure reusability, the company conducted functionality tests. The cameras were powered using the same configuration as last year, and visual performance was assessed by testing the FOV[21], image clarity, and effective viewing distance. Through this testing, the cameras were confirmed to be reliable and remained in excellent condition, solidifying the decision to reuse them.

Tasks 1.1 and *1.3* both require accurate and responsive camera output for precise scaling and target identification. The analog camera system proved capable of meeting these requirements when passed through an ADC to a laptop. This configuration enables the company to accurately measure the shipwreck in *Task 1.1*, as well as generate the photosphere in *Task 1.3*.

By choosing to reuse and enhance existing components, Phoenix Robotics maximizes resource efficiency, reduces costs, and ensures high task performance—key values that reflect real-world engineering practices in sustainable design and system optimization.

Electronics

Many new instruments have been introduced to this year's electrical system. One of the most innovative components would be the ESP32 with Bluetooth module. This allows the ROV to be controlled by an Xbox One controller instead of analog joysticks. The ESP32 takes these inputs and relays them to an Arduino Uno using serial communication. This master-slave[22] system significantly reduces the wires needed to run down the tether. The reduced size and mass of the tether improves the overall maneuverability of the ROV.

The voltage regulators are reused from previous years due to their reliability and ease of use. The Arduino boards are reused from the company's supply because the company has extensive experience with both the hardware and associated software. Moreover, Arduinos effectively met the needs of the company in regards to developing the ROV's subsystems. The company also purchased additional Arduino boards in order to easily replace any faulty or damaged ones. The emergency switch was reused from the 2024 model as it met the company's necessary electrical ratings when supplying power to the ROV. The WAGO connectors were used again for the 2025 model because they granted a significant degree of modularity when wiring to the various systems.

Safety

Safety Rationale

Vehicle Safety Design

Phoenix Robotics takes great pride in adhering to strict safety standards, and abides by these standards in equipment and workplace protocols, as well as the design of the ROV. (*Please see the Phoenix Robotics JSEA[23] for a more in-depth analysis of workplace precautions and protective equipment*). All personnel are urged to wear closed-toed shoes, eye protection, tied back hair, gloves, and welling-fitting attire for the appropriate tasks. Safety is also heavily incorporated into the operation of the ROV, with strict procedures and checks being performed before the ROV even touches the water (*See Operational Precautions)*. All incoming power runs directly into a 25-amp fuse, and power can quickly be turned off using an emergency stop switch located in the control box. Moreover, the power runs through a voltage regulator that stabilizes current draw. All exposed wires are properly sheathed, insulated, and relieved of strain. This extends to the tether, where the constituent wires are sheathed across the full length before passing through the ROV-side strain relief.

All sharp edges are filed down, ensuring personnel safety while interacting with the ROV. Motion hazards

[21] Field of View (FOV): the range of visibility through the cameras

[22] A relationship where one system or component controls others

[23] Job Safety and Environment Analysis (JSEA)

are indicated with OSHA[24]-compliant black and yellow tape. This lets personnel know to respect the power of the motors, and to avoid placing any appendages or loose articles near them. The thrusters are covered with IP-20[25] shrouds, reducing the risk of anything from entering the motor housing. Entanglement poses a significant risk to the thrusters, as multiple tasks this year involve wires connecting props together, such as the power connector to the solar panel array. As such, the thrusters required ingress protection to stop these wires from entangling the motor propellers. Skis protect both the ROV's frame and sea floor from damage while landing. POE is designed to monitor the environment for conservation purposes. With this in mind, destruction of the environment directly contradicts this mission, and as such, the company has implemented this precaution. Handle supports on either end of the ROV make managing deployment and retrieval simple, as they allow poolside personnel to better reach and lift the ROV. The windows on the top and bottom enable personnel to confirm electronic function and check for water intrusion. Absorbent materials are installed beneath the on-board electronics tray to absorb any ingressed water. This stops any potential leaks from totally compromising the internal electronics, while remaining visually apparent though the bottom side windows.

Figure 26: A thruster marked with hazard tape
By Gavin Quijano

As for the non-ROV device, a pressure relief stopper with a diameter exceeding 2.5-centimeters allows for an opening to become available if the pressure within the device is greater than that surrounding it. There is also a 0.75-amp glass fuse within 5 centimeters of the 12-volt AA-battery pack, ensuring that any damage caused by a potential short is minimized. The profiler is constructed from transparent PVC, allowing personnel to visually check the internals without needing to open the tubes.

[24] Occupational Safety and Health Administration (OSHA)

[25] A product that has protection against solid object larger than 12.5 millimeter

Operational Precautions

When handled improperly, any machine can become dangerous. As such, precautions are necessary during ROV set-up, operation, and take-down.

During set-up, the ROV, control box, and camera box must be relocated to the poolside out of storage. This process involves a number of hazards, including lifting of heavy items, exposure to electrical components, and entanglement in the tether. To reduce these dangers, personnel are required to communicate with one another, maintain awareness of their surroundings, and wear appropriate PPE[26].

While operating, poolside personnel are exposed to high speed motors, electrical components, and obstacles to mobility. To address these, personnel must always maintain awareness of their surroundings, tie back long hair, roll up long sleeves, and openly communicate with the pilot. These precautions reduce or eliminate the listed hazards. Rolling back sleeves and tying back hair eliminates the ability for personnel to become entangled in the motors. Proper awareness of the pool deck reduces the chance of tripping or stumbling during operations. Lastly, clear communication lets the pilot know when they can and cannot activate motors or control power to the ROV. This stops the pilot from running the motors while the ROV is out of water, which reduces wear on the thrusters, as the water is no longer lubricating the motor.

Take-down requires the ROV, control box, and camera box to be returned to storage. This exposes personnel to lifting heavy objects, exposure to electronics, and entanglement with the tether. The same precautions are taken as operations set-up.

Personnel

All personnel were individually trained on mandatory safety precautions and procedures to avoid injury or

[26] Personal Protective Equipment (PPE): Equipment that provides protection to the user

danger. As outlined in the Phoenix Robotics JSEA, the company utilizes a three-tiered system of training employees. These tiers include basic safety training, poolside operations training, and CPT[27] certification.

Basic safety training requires individuals to be trained on standard principles of safety. Trained members demonstrate these principals by utilizing devices ranging from screwdrivers to power tools. Demonstrations involve basic construction of a simple component of the ROV or a dedicated display to show the proper techniques for a given tool or environment. Then, the trainee is tasked to mimic the demonstration, providing them with hands-on experience. This is repeated until the trainee understands all the frequently used tools. Additional training is offered to allow them to learn more specialized tools, such as the Dremel rotary tool, belt sander, or soldering iron.

Poolside operations training is offered to all members who attend meetings that involve practicing with the ROV. This involves an information session followed by a week of observations of typical poolside operations. Following this observational period, the trainees are introduced to basic poolside tasks, where they are given in-depth break-downs of poolside expectations, particularly the precautions taken while operating the ROV.

The last tier of safety training is CPT certification, which includes the following aspects to become certified: safety, maintenance, production, and quality. In the safety portion of CPT, members are required to have an understanding of workplace safety procedures, the proper safety measures in the case of an accident, the meanings behind the safety labels placed on dangerous substances, the correct uses of PPE in the workplace, and proper lifting techniques. After passing the safety test, members also become OSHA-10[28] certified. This certification assures that these members can accurately report proper workplace safety procedures, ensuring the safety of all employees.

Equipment

All personnel are required to wear PPE when performing tasks that can potentially harm themselves and others. All members must constantly wear closed-toed shoes, tie back any long hair, and roll up long sleeves. Safety glasses are required for soldering, drilling, machining, and any task that exhausts fumes or generates particulates. Latex gloves are required when dealing with glue-like substances meant for waterproofing, or sealing and attaching certain objects, as these pose hazards to direct skin contact. Layered cotton protective gloves are required for drilling and machining tasks to protect the hands from trauma. Face shields and masks are required when dealing with harmful substances that can damage the user's eyes and lungs.

[27] Certified Production Technician (CPT)

[28] Indicates completion of a 10-hour OSHA-authorized training

Critical Analysis

Testing and Troubleshooting

Issue Isolation

When working with complex systems that are a part of the ROV, there are bound to be problems. This is most prevalent with electronics, as electrical signals are less apparent than physical systems that one can see. Before a problem can be fixed, it must first be identified and isolated. Once isolated, members use a multitude of skills to troubleshoot and identify the issue at hand. One method is using a multimeter to check for any voltage or continuity inconsistencies in the system. A multimeter is essential in determining problems with faulty electrical systems. Another way to test across numerous systems is uploading test code that checks for responses from isolated parts of the system.

WAGO terminals are snap fit connectors that are used to connect wires in the on-board system. This supports troubleshooting because it enables personnel to disconnect certain wires, ruling out sites one by one until the issue is isolated. Members can check for any loose connections to determine if the issue was due to the wire not being in its proper position.

The ROV must be completely waterproof in order to eliminate the possibility of water damaging the internal electronics. So, it is imperative that all openings are completely sealed. During the first water tests, the ROV showed signs of leaking. It was difficult to isolate the precise location of the leak, compromising the ability to seal it. So, the company devised a cap that has a hose which attaches to an air pump. When pumped, the air inside the on-board tube was pressurized, and escaped from any open seals.

These were then marked, reworked, and resealed. This process was repeated until all leaks were resolved.

Figure 27: The hose-pump cap
By Gavin Quijano

Problem-solving

Prioritization

During the course of construction and operation of different systems of the ROV, many issues will arise all of which have different levels of precedence. When it comes to determining the level of importance, it is necessary to keep a few things in mind such as: what is the issue, how did it happen, who can fix it, how long will it take, and what hazards are involved in the repair. With everything that the company does, safety is the key factor in determining the urgency of a task. Moreover, the responsible personnel must be identified and assigned to resolve the given issue.

Addressing Problems

Whenever an issue arises during the build or operating time, Phoenix Robotics has many different tools and procedures at their disposal to rectify the issues quickly and efficiently.

To start the problem-solving process, the company begins with a cause-and-effect diagram. This is done to get a sense of what has happened and the magnitude to which it occurred. By doing this, it allows the company to effectively and efficiently determine the issues and what caused them. That is not the only approach readily used, as fishbone diagrams[29] allow for a further and more in-depth examination of the issue. Through multiple connecting branches, a complete picture of the cause-and-effect relationship can be examined, allowing for an informed conclusion to be reached and a decision to be made. To reach a decision, Phoenix Robotics brainstorms on how certain actions will be more beneficial than others, as every choice made must be decided knowing it will not harm the company's overall performance. When brainstorming, all members' opinions and thoughts are considered before making the final decision.

Putting all these methods into practice is a constant for the company and is most prominently seen with how this year's controller system was constructed. Last year the analog joystick system was found to be inefficient and costly, as many of the potentiometers on the joysticks gave incorrect values. To solve this issue, the company decided to use a fishbone diagram to determine the reason for the constant variation in signal. After brainstorming on potential solutions, the company eventually decided that the joystick brand was faulty and inconsistent. As a result, the company chose to experiment with an entirely new ESP32 system while keeping the analog system as a back up. As a result of the experiment’s success, the ESP32 system was selected.

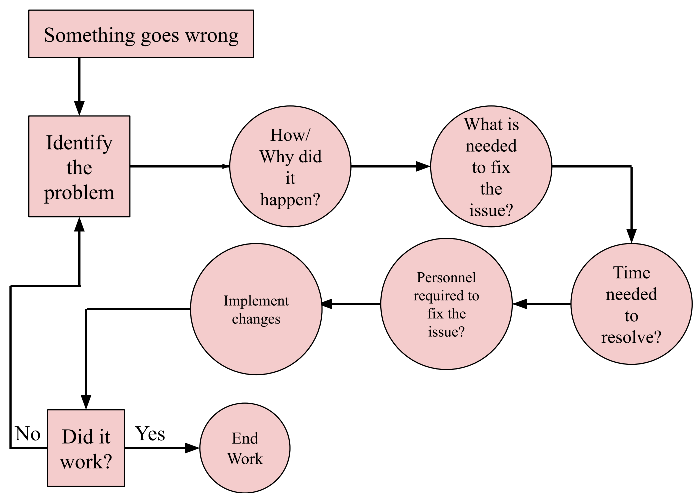


Figure 28: Problem-solving flow-chart
By Gavin Udagawa

[29] A diagram that helps users identify the many possible causes for a problem by sorting ideas into useful categories

Accounting

Budgeting

Budgeting is a critical aspect of engineering and project management. The cost estimate is based on previous years' designs and the current year's mission requirements. Projected costs are categorized into four key expenses: electronics, structural materials, tools, and travel contingency funds. By tracking each purchase, this ensures that each department stays financially on track. The cost accounting process ensures accuracy and transparency through item descriptions, quantities, unit price, running total, and purchase sources, verifying the budget while mitigating any unnecessary costs.

Category	Item	Projected cost	Running total
Frame	CNC commission	225	225
Frame	2nd CNC commission	200	425
Frame	Static bouyancy	20	445
Frame	Variable bouyancy	40	485
Frame	Attachments	50	535
On-board	Thruster electronics	600	1135
On-board	Thrusters	200	1335
On-board	On-board electronics	100	1435
Claws	Electronics	340	1775
Claws	Body	20	1795
Claws	Wire	40	1835
Cameras	Cameras	20	1855
Vetical profiler	Electronics	180	2035
Vetical profiler	Frame	70	2105
Marketing Display	Board	50	2155
Waterproofing	Glues	152	2305
Waterproofing	Junction boxes	40	2345
Waterproofing	Greases	30	2375
Waterproofing	Filament	200	2575
Waterproofing	Nozzels	100	2675
Props	PVC tubing	800	3475
Props	PVC jionts	30	3505
Props	Corregated plastic	10	3515
Props	Wiring	15	3530
Transportation	Plane tickets	6000	9530
Miscelaneous	Miscelaneous	200	9730
			TOTAL: $9730
			TOTAL MINUS TRANSPORT: $3730

Figure 29: The initial budget
By Gavin Quijano

Cost-accounting

Figure 30: The finalized accounting
By Gavin Quijano

Accounting

Source	Category	Item	Unit price ($	Quantity	Total	Cost
Purchased	Frame	4-in PVC tube	15.57	1	15.57	15.57
Purchased	Frame	3.75-in Clear PVC Tube	31.99	1	31.99	31.99
Purchased	Frame	1-in stainless steel corner braces	1.29	12	15.48	15.48
Purchased	Frame	Stainless steel hose clamps	12.99	1	12.99	12.99
Purchased	Frame	Cable ties	11.59	3	34.77	34.77
Purchased	Frame	Miscellaneous hardware	N/A	N/A	43.99	43.99
Purchased	Frame	CNC commission	225	1	225	225
Purchased	Frame	HDPE cutting boards	12.99	3	38.97	38.97
Purchased	Frame	3M 5200 marine sealant	22.42	5	112.1	112.1
Purchased	Frame	Fernco 4-in rubber cap	4.54	1	4.54	4.54
Purchased	Frame	JBWeld Steelstik	6.54	6	39.24	39.24
Purchased	Frame	Fishnet stocking	9.99	1	9.99	9.99
Purchased	Frame	Silicone spatula	4.95	1	4.95	4.65
Purchased	Frame	30ct Box of tampons	8.99	3	26.97	26.97
Purchased	Frame	Heavy duty feminine pads	13.95	2	27.9	27.9
Purchased	Frame	Silicone diver's wax	10.99	3	33.97	33.97
Purchased	Frame	Super absorbant diaper polymer	19.99	1	19.99	19.99
Purchased	Frame	4-in PVC end cap	3.29	1	3.29	32.9
Purchased	Frame	1-1/2-in PVC elbow	2.59	1	2.59	2.59
Reused	Frame	Stainless steel U-bolt	8.35	1	8.35	0
Reused	Frame	High-density foam	14.99	2	29.98	0
Reused	Frame	1-in PVC tube	12.99	1	12.99	0
Reused	Frame	1-1/2-in inflatable tube	37.68	1	37.68	0
Reused	Frame	Blue Robotics T200 mount bracket	8	2	16	0
Donation	Frame	PLA filiment 1.25 kg	30	3	90	0
Purchased	Claws	25kg servomotors	16.99	8	135.92	135.92
Purchased	Claws	Cytron MDD10A 10 amp DC motor (	23.5	2	47	47
Reused	Claws	Polycarbonate sheet	35	1	35	0
Reused	Claws	Spray-on PlastiDip rubber coating	18.5	1	18.5	0
Reused	Claws	Analog joysticks	4.99	2	8.98	0
Purchased	Propulsion	Blue Robotics ESCs	38	4	152	152
Reused	Propulsion	Blue Robotics T200 thrusters	220	4	880	0
Reused	Cameras	YIWANG cyclical fishing cameras	20	4	80	0
Reused	Cameras	7-in rear-view car monitors	35	3	105	0
Purchased	Electronics	WAGO connectors	20.95	1	20.95	20.95
Purchased	Electronics	ESP 32 3 pack	15.99	1	15.99	15.99
Purchased	Electronics	10 ft USB-C cable	11.99	1	11.99	11.99
Purchased	Electronics	Voltage regulator	13.65	5	68.25	68.25
Purchased	Electronics	Barrel male xpower connectors 20 p	9.39	1	9.39	9.39
Purchased	Electronics	Esp 32 shield 2 pack	11.89	1	11.89	11.89
Reused	Electronics	Rocker Switch	8.99	1	8.99	0
Reused	Electronics	WAGO connectors	39.95	1	39.95	0
Reused	Electronics	Marine-grade heat shrink tubing	15.99	1	15.99	0
Reused	Electronics	Arduino mega	55	1	55	0
Reused	Electronics	Pump	9	1	9	0
Reused	Electronics	50ft Braided wire sheathing	186.99	1	186.99	0
Reused	Electronics	25-amp fuse	2.98	5	14.9	0
Donation	Electronics	Seahorse SE300 case	46.11	1	46.11	0
Donation	Electronics	1/8-in acyrlic sheet	12.99	1	12.99	0
Donation	Electronics	16.8 meter cables	150	2	300	0
Donation	Electronics	Xbox One controller	54.99	2	109.98	0
Purchased	Administrative	Competition Fee	450	1	450	450
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	6-in PVC end cap fitting	12.09	3	36.27	36.27
Purchased	Profiler	100 mA 250 V AC-DC fuse	5.99	1	5.99	5.99
Purchased	Profiler	#7.5 Lead shot balls 2lb bag	24.99	1	24.99	24.99
Purchased	Profiler	6-in Clear PVC tube	88.95	1	88.95	88.95
Purchased	Profiler	6-in PVC flexible coupling	18.43	1	18.43	18.43
Purchased	Profiler	6-in PVC pipe coupling	17.18	2	34.36	34.36
Purchased	Profiler	6-in PVC end cap	14.99	1	14.99	14.99
Purchased	Travel	Plane Tickets	300	10		
Purchased	Travel	Hotel rooms	1250	2	2500	2500
Purchased	Travel	ROV transport	1500	1	1500	1500
Purchased	Travel	Rental car	800	1	800	800
Purchased	Travel	Rental gasoline	300	1	300	300
Donation	Finance	Derrick Brooks charities donation	-4050		-4050	-4050
Donation	Finance	Paul Bowdin donation	-4050		-4050	-4050
Donation	Finance	Publix donation	-250		-250	-250
Donation	Finance	MidFlorida Credit Union donation	-250		-250	-250
Donation	Finance	Phuphanich family donation	-750		-750	-750
Donation	Finance	Nalani Gajadharsingh donation	-150		-150	-150
Donation	Finance	Jason Gajadharsingh donation	-75		-75	-75
Donation	Finance	Collier family donation	-100		-100	-100
Donation	Finance	Fernandez family donation	-1500		-1500	-1500
			TOTAL EXPENSES			**11584.08**
			TOTAL EXPENSES INCLUDING REUSED & DONATED:			**3484.08**
			TOTAL EXPENSES MINUS TRANSPORTATION:			**1868.93**
			TOTAL FINANCIAL DONATIONS:			**11175**

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MITRE: For providing outreach

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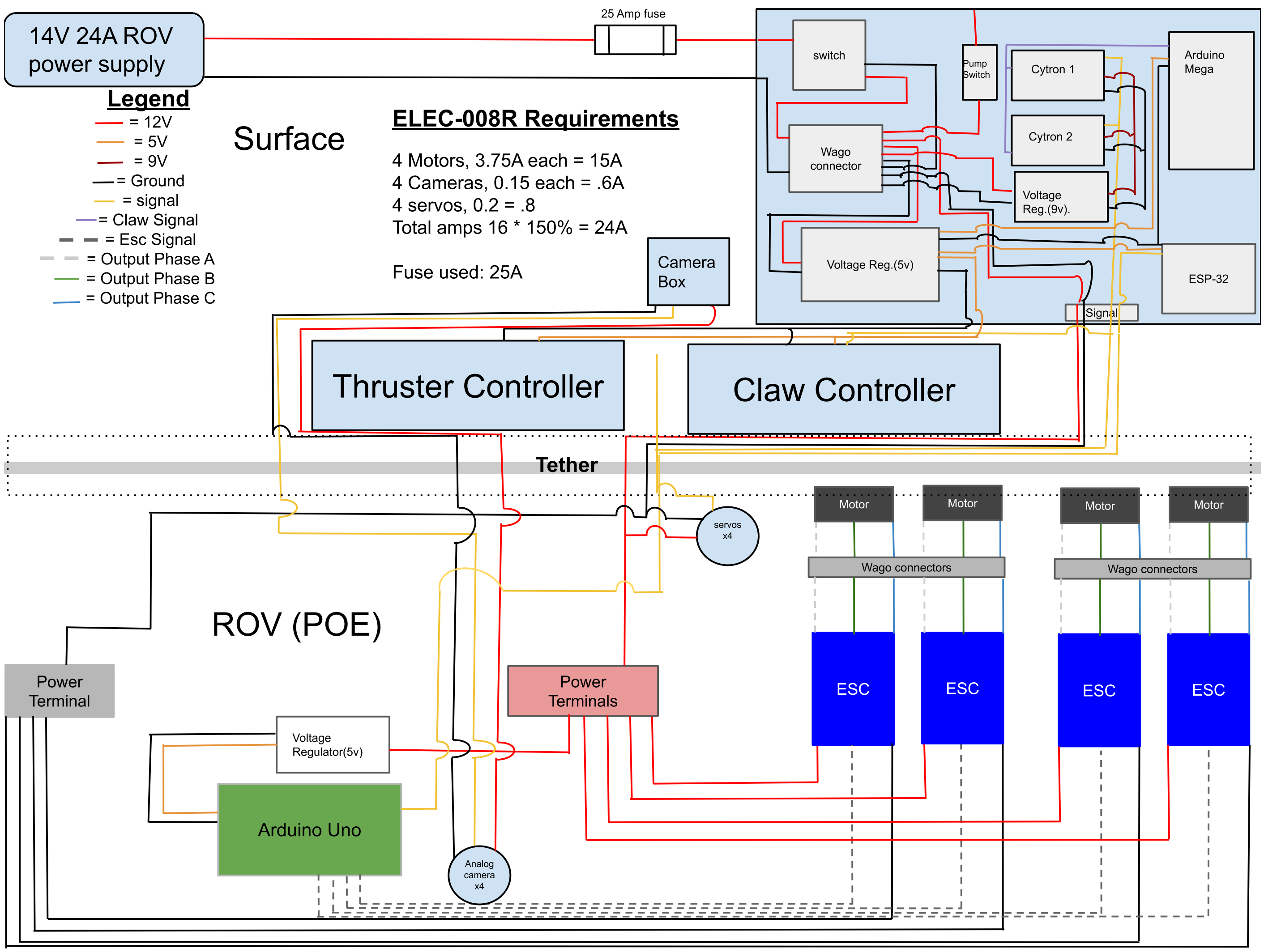
Appendices

Appendix A: ROV SID



Appendix B: Safety Checklist

Safety checklist

1. Unloading

- ☐ Area is cleaned and organized for operation
- ☐ Company members are wearing proper PPE
- ☐ Control box and controllers are placed at mission station
- ☐ Camera box and air pump are placed at mission station
- ☐ The profiler is carried and placed to the mission station
- ☐ Tether is removed from storage and placed on the poolside deck
- ☐ Camera box is carried and placed at the mission station
- ☐ Laptop is carried and placed at the mission station
- ☐ ROV is relocated from storage to the poolside deck

2. ROV set-up

- ☐ Control box is opened and connections are confirmed
- ☐ Analog cameras and air pump are connected
- ☐ The profiler is configured and set up
- ☐ The clip is removed from the tether and tension is relieved from the wire

3. Power and confirmation

- ☐ Pilots announce that power is being fed to the ROV
- ☐ Verbal confirmation that everyone on deck understands that power is being turned on
- ☐ Laptop is powered on
- ☐ ROV is powered, thrusters' and claws' operation is confirmed
- ☐ Cameras' positions are confirmed
- ☐ Tether is laid out and examined for strain, entanglement, or damage

4. Launch

- ☐ Pilots sit down and prepare for product demonstration
- ☐ Vertical profiler is powered on
- ☐ Tether manager provides slack to the ROV
- ☐ The profiler's communications are confirmed
- ☐ Verbal confirmation is given that everything is ready to begin the product demonstration
- ☐ The ROV is deployed into the pool

5. Post-Run

- ☐ ROV surfaces by the pool deck
- ☐ Pilot set down controllers and give go-ahead to take ROV out of the water
- ☐ ROV is taken out of the pool
- ☐ Pilots communicate that ROV is being powered off
- ☐ The laptop and analog camera box are unplugged and closed
- ☐ Pack up control box
- ☐ Pack up profiler and terminate communications
- ☐ Pack up ROV, coil and store tether
- ☐ Depart mission station with all materials