Phoenix Robotics

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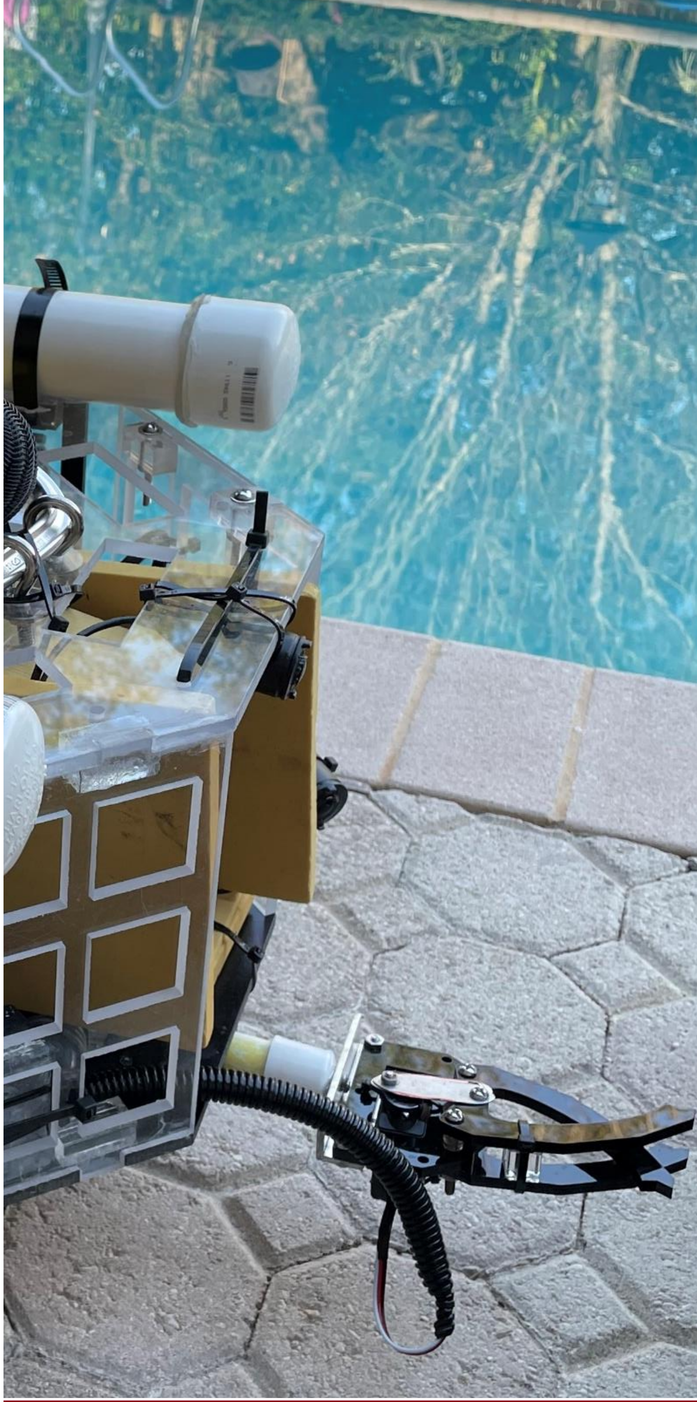

2021-2022 MATE ROV (REMOTELY OPERATED VEHICLE) COMPETITION

Phoenix Robotics
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Table of Contents

Abstract

Phoenix Robotics is a company of 12 students based in Tampa, Florida, focused on the advancement of technology in the fields of mechanics, engineering, and programming. Attending Brooks DeBartolo Collegiate High School, the company has determined members with intent to raise awareness and solve the ocean's most pressing concerns.

This year, Phoenix Robotics presents a custom built ROV with the intention to accelerate the progress of the UN Sustainable Development Goals. Using two laser-cut claws, the ROV can manipulate items such as in Tasks 2.2 Maintaining a Healthy Environment and 2.4 Farm Seagrass. The company created a pin extractor to remove fastening devices, which was utilized in *Task 1.1 Replacing a Damaged Section of an Inter-Array Power Cable* and *Task 1.3 Monitor the Environment*.

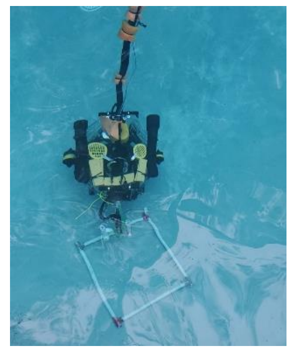

Figure 1: POE competing Task 2.4 Farm Seagrass

The Phoenix Ocean Explorer (POE) covers every MATE specified requirement, maximizing safety and efficiency to complete every task stipulated in MATE's 2022 manual. The application of these simulated tasks in ocean conservation displays the team's capability to make a real-world influence, primarily emphasizing on the improvement of the marine biosphere through the UN Sustainable Development Goals. These goals are further progressed using this ROV in the improvement of maintenance of offshore windfarms and protection of marine agriculture.

Figure 2: Phoenix Robotics team
Photo by Elena Fernandez.

All photos were taken by Elena Glow of Phoenix Robotics unless otherwise noted.

Teamwork: Project Management

Project Management

This year, the company experienced an influx of new members. While the absence of previous senior members left a discrepancy in both personnel and experience, the returning and new members joined under their shared passion for robotics to assume the leadership and responsibility required. Employees are delegated tasks based on their various skillsets and areas of expertise (*see cover page for roles*); newer employees shadow their seniors to learn firsthand the skills and techniques required to construct a working ROV. With groups completing their respective tasks, members were able to monitor one another, creating learning and collaboration opportunities. Furthermore, company members supervising one another invigorates safety practices. No one is working or operating machinery alone, ensuring the safety of all members and the training of the new employees.

Figure 3: Employees epoxying shrouds

Scheduling and Planning

Since Phoenix Robotics is a company full of diverse and involved members, one of the largest obstacles is coordination and planning. Having ambitious goals and aspirations requires commitment from each employee. Communication between members has proved essential to maintaining high productivity and attendance.

Various messaging mediums are utilized for efficient communication. Before each meeting, a reminder message from the team administration is sent out to prompt the members to attend, while doubling as an attendance check. The WhatsApp application is one of the most vital tools in this, serving as a bridge for the company across a myriad of devices. Google Calendar also serves as an integral part of scheduling. The organization of the meeting schedules is visible to members and their families, permitting them to keep track of the progress and schedule. Documentation for each company department is organized with the application Trello, enabling members to compartmentalize previous, current, and future tasks, with who is responsible for each. This also allows for the administration to plan future meetings based on what tasks require the most attention.

The schedule of the company evolved on account of what tasks were completed, the status of each job, and the discrete company and employee needs. At the beginning of the year, Phoenix Robotics met every Monday and Thursday after school from 3:15-5:00 PM. In January, this progressed to meeting every day after school from 3:15-6:00 PM to meet the deadlines established internally by the company and externally by the competition. With the daily meetings, the company scheduled additional supplementary meeting sessions over school breaks and weekends. Organized by the leadership, these meetings range from 3-5 hours; the team was notified of these meetings often a week in advance and received reminder messages. Individual departments of the company also met over Zoom to work on their department-specific projects. Zoom meetings were also utilized in the multiple parent meetings coordinated throughout the year. These meetings were conducted to inform them about the company's progress, to plan for competitions (e.g., registration, rooming, etc.), as well as the achievements made by the company thus far. A Gantt chart was also made at the beginning of the year to track the estimated time for each system. See Appendix A.

Meeting Organization

At the beginning of each meeting, the team would discuss the tasks and goals for the day and week, make any more announcements, and ask questions. Once the assignments were delegated, the employees would work on them. The administration also held the responsibility of supervising the rest of the team and offering any advice or help if needed. Once the day is over, the team convenes to discuss progress and make any notes or plans. Throughout the day, standard procedures would be enforced and the importance of maintaining an ergonomic workplace would be stressed.

The Assembled ROV

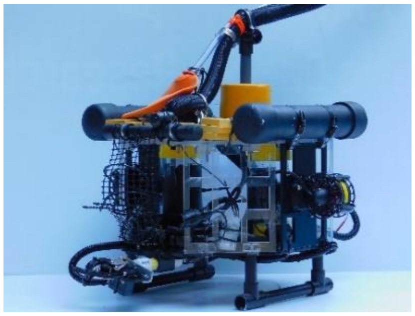

Figure 4: Completed ROV – Front

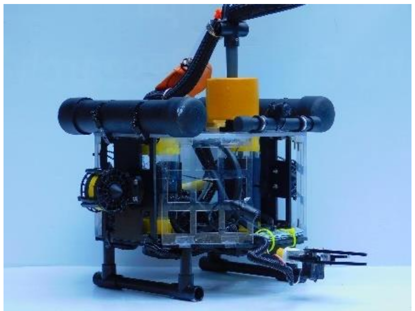

Figure 5: Completed ROV – Rear

Design Rationale

Engineering Design Rationale

The overall design of the Phoenix Ocean Explorer was made to complete the MATE missions with adaptability in mind as well. When the frame was being constructed, many mounting areas were made available to have ideal locations for necessary payloads.

POE is equipped with two claws for efficient completion of tasks, maximizing the machine's productivity when under time constraints. Additionally, the Phoenix Ocean Explorer has factory waterproof brushless thrusters that were tested and compared against other thrusters to ensure that the force generated relative to amperage drain is high in comparison to other thrusters.

Innovation

The company implemented many features when constructing the ROV resulting in its greater cost and speed efficiency. One of the most significant innovations that were introduced was the frame, which was cut from a polycarbonate panel, as opposed to acrylic, using an outsourced water-jet cutter. Seen on figure 13, polycarbonate is on the lower end of both cost and density while being on the higher end of strength.

3D printing allowed for customization while being cost-effective. Using the company's in-house 3D printers, the only purchase necessary for 3D printed parts was PLA plastic. This innovation has enabled the company to custom fit parts to any of the ROV's needs, for example, the forward/backward thruster mounts were designed with recessed holes to attach to the thruster as well as mounting holes for the frame.

The up/down thrusters are mounted inside of an acrylic tube. This innovation allows water from the thruster to be pushed only in the desired direction, optimizing the force produced. The optimization of thrust in this way allows for low-cost thrusters to be highly effective.

Innovation can also be seen in the utilization of top-side electronics. While devices of this complexity typically include an electronics enclosure, the company decided to use other means. In the previous year, implementation of on-board electronics reduced tether weight, but it did not accommodate the amount of amperage needed for an efficient machine. Adding tether wire would solve this but doing so takes away the main value of onboard electronics of having a small tether. Thus, the company opted to eliminate the liability of on-board electronics after previous poor experiences.

Problem Solving

When approaching a problem, Phoenix Robotics aims to find the most efficient, cost effective, and long-lasting solution. The company follows a structured outline for problem solving, beginning with the identification of the root cause. Once the root cause has been confirmed, the employees begin the troubleshooting process to find the best solution. For example, when thrusters were not properly functioning, employees were able to track the issue to a poorly factory-issued ESC after tracing for voltage readings and noticing the ESC as a large source of heat. After finding this root cause, it was a quick and simple fix to replace the ESC and have fully functional thrusters again.

Systems Approach

When designing the Phoenix Ocean Explorer, some of the main considerations were maintaining a light, speedy, and adaptable system. All three of these considerations have been achieved. Keeping POE lightweight enables thrust to act more effectively, which works in hand with the speed goal. Maintaining symmetry helps in not only balancing the machine, but also in straight navigation with minimal to no drift when the tether is effectively managed. Lastly, the claws enable the ROV to be adaptable to a multitude of situations in a timely fashion due to the claw's locations being on each side of the ROV.

Vehicle Structure

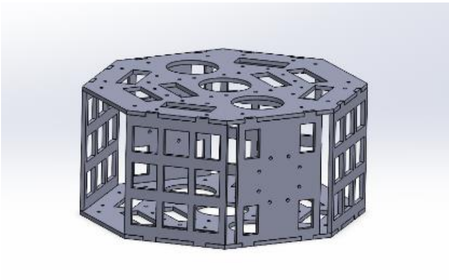

Figure 6: ROV Frame Schematic. (Left)

Figure 7: Elena and Julie assembling the ROV frame. (Right)

The Frame

The ROV frame is made of black and partially transparent 6.35-millimeter polycarbonate sheeting that was designed in SolidWorks and cut using a waterjet cutter at the Georgia Institute of Technology. The use of this material enables our design to have increased manufacturability due to its ease of manipulation. Polycarbonate would allow the company to make changes to the frame such as making holes for systems previously unaccounted for. The density of polycarbonate at 1.24 g/mL keeps the frame slightly negatively buoyant and keeps the frame economical. The size of POE is 79 by 58 by 56 cm due to the storage method of the ROV. The company chose to design the ROV with mobility capabilities in mind. Using a large box from previous years, all the designs had to keep the inside size of the box in mind.

Below is a table illustrating the considered materials and the primary factors used to evaluate which was most appropriate for the frame.

	Polycarbonate	Aluminum	Carbon Fiber	PVC	Acrylic
Density (g/mL)	1.24	2.7	1.76	1.35	1.19
Tensile strength (MPa)	80	90	3950	28	70
Elastic modulus (GPa)	2.5	70	238	-	3.3
Cost	Low	Moderate	High	Low	Low
Ease of Manufacturing	Easy	Moderate	Hard	Easy	Easy

See Reference 2

Figure 8: Table of materials considered for the frame.

Vehicle Systems

Claws

Figure 9: The 3-pronged claws utilized on the ROV.

POE is equipped with two claws on opposite ends of the ROV, allowing the ROV to complete tasks more efficiently through the reduction of surface trips. Having the manipulators on either end of the ROV enables it to be able to lift items without having to turn a full 180 degrees, conserving time. These manipulators are used for assignments such as *Task 2.1 Inspecting an Offshore Aquaculture Fish Pen* and *2.4 Farm Seagrass*. Claw parts were initially made of acrylic, but they often broke when experiencing over-extension of manipulator arms. The joints were then replaced with waterjet cut polycarbonate to reduce the possibility of breakage during operation. Additionally, with most of each claw being cut from a single file, exact copies can be made if either manipulator was to be damaged or defective.

Figure 10: The camera box.

Camera System

There are six cameras strategically mounted on the vehicle to minimize vision dead zones. They are factory-made waterproof for fishing purposes. The cameras are essential for navigation and the use of claws. Specifics of camera angles and use are discussed in the Camera and Camera Box sections. The current system was previously found effective; thus, it is used again.

Thrusters

Figure 11: Hawk Hobby Brushless Thruster

When reflecting on company performance in previous years, the conclusion was reached that a faster ROV results in better performance. Bluerobotics' T-100s were used in previous years; however, they are no longer being made. Instead of investing in the T-200 thrusters, the company bought an alternative brand of factory waterproof thrusters. There are four Hawk Hobby brushless thrusters mounted on the Phoenix Ocean Explorer, each factory waterproofed. A single thruster has the cost of $52.99; other than the four designated to the P.O.E, two extra thrusters were purchased in the event of a problem. Each motor is powered by a Bluerobotics Electronic Speed Controller (ESC) inside of the control box. The thrusters have a ring of yellow tape around it to comply with OSHA standards for moving parts as well as 3D printed shrouds in accordance with MATE specifications to prevent injury. Through extensive testing of the selected thrusters along with usage of the Phoenix Ocean Explorer, the company has determined that these thrusters are effective in moving the ROV through thoughtful navigation while being capable in moving POE at high speeds to meet the MATE stipulated tasks efficiently. Tests of these thrusters are discussed in the Propulsion section.

Control/Electrical System

Software

Figure 12: Inside view of the control box.

The company software was written in the Arduino IDE using C++. This part of the software is used to control the thrusters, as well as the movement of the manipulators. This software, paired with the electronic speed controllers, gave the ability for the thrusters to have greater movement variety. The other part of the software uses Python. The function of this section is for *Task 2.2: Using AI to Differentiate "Morts" From the Fish Pen.* See Appendix C: Software.

Control Box

The Phoenix Ocean Explorer is powered through Anderson Powerpole connectors that leads into the control box. The control box is equipped with two controllers, each utilizing two joysticks. For the driving controller, one joystick is for forward, backward, left, and right movements while the other one facilitates vertical movements, up or down. The company uses the other controller for claw movements with one joystick per claw. Each manipulator can open, close, rotate clockwise, and rotate counterclockwise. Cabling is organized under an acrylic panel to protect wiring and maintain screwed-in connections without having exposed metal.

Software is used to control the company's thrusters through an Arduino nano communicating to electronic speed controllers (ESC). The claws are controlled through an additional Arduino nano, which relays directions to two Cytron control boards. View Appendix C: Software to see code used.

Electronics are put entirely in the control box as opposed to having an on-board electronics tube because it is less of a liability to have electronics on the surface as it eliminates the risk of a flood to all electrical components.

Camera Box

Figure 13: Julie constructing the Camera Box in the previous year.

The cameras and monitors are powered by an Anderson Powerpole connection, which receives power from the control box. There are three dual-view monitors mounted within the camera box that allow the pilots to remotely access all six cameras. Pilots can switch between different views and monitors. One screen is used to observe the front and back claws, another for front and back views, and the last for down and left perspectives. Plugs and electronics in the camera box are organized through an acrylic panel interface.

Tether

The tether consists of 6 camera feeds, three eight-lead cables with each lead being 18 AWG. It is wrapped in a light-weight sheath with buoyant material distributed along it to prevent drag. Strain relief is incorporated coming into the control box through grommets and on the ROV using a clamp system.

Tether management protocol includes maintaining a neat coil and ensuring that the POE is never being pulled on by it. This is enforced through always having trained tether personnel handling the tether when the ROV is in motion. When POE is transported, the tether is looped and clamped.

Payloads and Tools

Pin Removing Apparatus

Equipping POE with the Pin Removing Apparatus allows for the completion of tasks such as *Task 1.1 Replacing a damaged section of an Inter-Array Power Cable* and *Task 1.3 Monitor the Environment*. The apparatus traps the pins on one of many beaded zip ties and then the ROV can go backwards to pull out the pins.

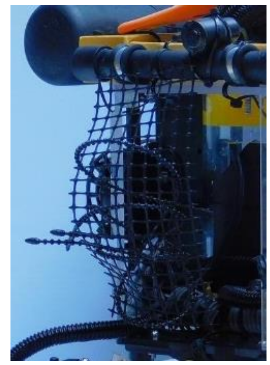

Figure 14: Pin Removing Apparatus

Vertical Profiler

To accomplish *Task 3.1: Mate Floats,* different vertical profilers have been constructed. The primary vertical profiler's structures revolve around the use of a 100cc syringe that takes in water to descend and then releases that water to ascend.

This buoyancy engine uses a 9v power supply, an integrated 5-amp fuse located within 5 cm of the battery, and an Arduino Uno that tells a Cytron control board when to flip polarity. This causes the servo to change directions when moving the syringe assembly and forcing water in and out to alter the profiler's buoyancy.

The company created a second float designed to complete two vertical profiles along the depth of a pool. The device completes its vertical profiles using a 1250 GPH bilge pump motor and timer system. This simple system is negatively buoyant; the float requires the motor to drive it upward. An Arduino board uses a timer program which sends signal to a Cytron relay, turning the power to the motor on and off when triggered. This was the first float created as bilge pump motors have proven to be reliable.

Cameras

There are six cameras on the Phoenix Ocean Explorer capturing the essential viewing areas. The company opted for factory waterproof cameras, a crucial element in their reliability. Each camera costs $61.99, leading to $371.94 being spent on cameras on board the vehicle. The camera quality and consistency make each one a beneficial investment for the company despite the

Figure 15: Waterproofed camera used on the ROV.

cost. By incorporating these cameras into the company's viewing system, the Phoenix Ocean Explorer can navigate well in the water; this is especially the case in tasks such as *Task 2.1 Inspecting an Offshore Aquaculture Fish Pen,* where the company's pilot is following a transect line and *Task 3.2: Endurance22* when mapping the wreck.

Propulsion

There are 4 total thrusters on the ROV. Two forward facing thrusters on the outside of the side panels that control horizontal movement like yaw, forward, and backward. Inside of 2 acrylic tubes on the inside of the ROV, the 2 motors that control vertical movement are mounted. The motors being inside the tube increase motor efficiency by pushing the water in a more uniform manner. To determine the thruster to be used, a Bollard's pull test was conducted where power was incrementally increased through a code and reading the different thrust values. After comparing thrust to amperage draw from multiple thrusters, the company concluded that Hawk Hobby brushless thrusters had the best thrust to amperage ratio. Using the View data collected from the tests below. The software controlling them ensures no amperage overdrawing. View Appendix C: Software to view this code.

Power level	1900	1800	1700	1300	1200	1100
Thrust (kg)	7	5.5	3	3.25	5.5	6.5
Amperage	13.5	8	3.2	3.5	8.3	13.5

Figure 16: Average Thrust per Amp

Buoyancy and Ballast

One of the benefits of using polycarbonate is its relatively low density of 1.24 g/mL, thus the frame does not add much negative buoyancy due to water's similar density of about 1.0 g/mL. With a lack of an onboard electronics tube, payloads are among the few systems that need to be counteracted. Static buoyancy used for this includes sealed PVC tubing and high-density foam, all of which are located on the top of the vehicle to ensure that the center of buoyancy remains above the center of mass. Small weights were added to the back and on the bottom to finalize the stabilizing of POE. A variable buoyancy system was added in which an inflatable bladder is filled through a hand pump connected by Tygon tubing. This aids in vertical movement and allows the ROV to adjust when loads that are being carried impact buoyancy.

Build vs. Buy

Phoenix Robotics has the philosophy that building most components is preferred as opposed to buying them. Constructing items in-house means that the company has a gauge on quality and understands how these components work to a high degree. Additionally, making items within the company allows for increased customization for the tasks at hand; however, outsourcing certain products allows the ROV to have superior performance with certain aspects, such as the speed in which POE complete mission requirements.

Bought items that were pre-assembled include 8 cameras and 6 thrusters. Other purchased items include base materials, such as material sheeting, wires, and control boards. Advantages to using a purchased product such as a control board include higher quality materials used on the board and reduced manufacturing costs. Additionally, it allows for more time to be allotted for mission requirements, for example the software needed in *Task 1.4* in which the ROV docks autonomously.

New vs. Reused

New systems are often constructed when either the previous equivalent was ineffective, or MATE's challenge calls for other implements. For example, the company's previous ROV had thrusters that were found to be much too slow to maximize the amount of MATE stipulated tasks desired. Hawk Hobby Brushless Thrusters that are manufactured waterproof were rigorously assessed by the company and determined to be a cheaper and more powerful alternative to the Blue Robotics' T-100 thrusters previously used.

Another example is the utilization of polycarbonate over acrylic in both the claws and frame. Employees observed frequent cracking of acrylic pieces on the claws in previous years and were concerned for the structural integrity of an acrylic frame. The usage of polycarbonate in both components promotes a long-lasting machine with less likelihood of significant damage.

Parts that are reused from previous years often remain the same due to the item being highly functional and extensive knowledge of the piece. For example, the primary employee who made the camera box previously (Julie Fernandez) remains on the team, thus a deep understanding of its functionality remains in the company's institutional knowledge. Reusing the camera box saves both time and expense. Additional systems that are like previous years are the variable buoyancy system and the claw design. As with the camera box, extensive knowledge remains in the company's institutional memory for these components, and they were found to be highly effective in previous years.

Safety

Phoenix Robotics follows the rationale that every working member must have not only a deep understanding of proper safety procedures, but also enforce such procedures among themselves. Seven employees are Manufacturing Skill Standards Council Certified Production Technicians. These members have an OSHA 10 certification; the company's key personnel are all qualified in this manner. The Chief Safety Officer, Chief Executive Officer, Chief Operations Officer, Chief Technology Officer, Chief Financial Officer, Chief Documentation Officer, and 3D Printing Specialist all have this qualification and can employ it in maintaining a safe workplace.

Personnel safety is the main priority, with safety glasses always being worn to protect employees from any flying debris. Individuals wear gloves when handling anything sharp or drilling as well. Members with a safety certification from the Manufacturing Skill Standards Council teach proper tool handling and operation while enforcing proper procedures. All of those that are a part of the company are responsible for safety, allowing for universal benefit.

Qualified personnel also taught equipment safety to the remainder of the company. For example, employees have learned proper preventative maintenance procedures for tools utilized to minimize the amount of breakdown maintenance required. For items such as drill bits, employees have learned to be wary of the piece's tolerances to prevent wear and the item from breaking.

The building process and materials used in the fabrication of the Phoenix Ocean Explorer incorporates safety. Sharp corners were eliminated through sanding to reduce the risk of cuts. Additionally, motor shrouds have yellow safety tape which follows OSHA safety standards indicating moving parts. There is an accessible kill switch to cut power quickly in case of an emergency. The clear octagon shape of the robot was chosen to allow for modular construction and easy access to any potential safety issues. Cabling on the machine and control station is secured to be protected from tension, keeping the wires from becoming damaged. These connection points are inspected before each use. Wires on the ROV are additionally surrounded by expandable braided tubing to further reduce safety risks related to the electrical wires. Furthermore, shrouds are placed on the motors to protect divers from the moving parts and divers are trained to keep away from the ROV during operation. Refer to Appendix D: Safe Operation for more safety practices.

<table>
<tr><th colspan="2">Safety Procedures</th></tr>
<tr>
<td>Daily Safety Inspection List:
➢ An Inspection of PPE for damage.
➢ Dispose of any damaged PPE.
➢ Review employees' daily work tasks and ensure safety requirements are met.
➢ Inspect hand tools and powered tools to ensure they are in good condition. Damaged, uncalibrated, or unsafe tools are to be tagged and removed from use.
➢ Perform a visual inspection of the work area. Be mindful of trip hazards (cords) and slip hazards (standing water).
➢ Inspect our power components to ensure there is no shock risk.
➢ When working outside be aware of weather changes and act quickly to follow precautions in case of thunder.</td>
<td>Construction Safety:
➢ Employees are all responsible for identifying and reporting potential risks to the safety manager.
➢ Employees must be trained to use power tools.
➢ Protective gloves should be used when transporting unfinished materials.
➢ For heavy items ensure safe lifting techniques or assistive equipment is used.
➢ Employees should not wear loose clothing or loose jewelry. The loose hair should be tied back.
➢ Equipment should be shut off when not in use. Equipment manuals should be easily accessible.
➢ All work areas are to be kept properly ventilated.</td>
</tr>
</table>

Pre-Operation Inspection:	Operational Safety:
➢ Inspect power source, plugs, power strips, etc., are in a safe and dry space to prevent damage, shortening, or the risk of shock to an employee. ➢ Set up the workspace so that commonly used tools are within reach for efficiency and organization. ➢ Check controls to make sure they work before the ROV enters the water to be fully prepared for operation. ➢ The position of moving parts should be inspected to ensure they are in a safe position before starting work. ➢ Visual inspection of both ends of the tether to ensure wires are connected. These connection points tightly are at risk of becoming unsecured. A visual inspection should be the first step. If a problem is suspected, confirm the power is off and perform further inspection.	➢ Only employees with a current swim test certification on file can work as a diver. ➢ Whenever a diver is in the water both the employees assigned to monitor props and tether are responsible for ensuring the safety of the diver. One of these employees must also have a swim certification on file. ➢ The tether monitor will ensure it is maintained in a way that it does not get tangled or pose a risk for the diver, the props/ROV and/or employees outside the water. ➢ All employees should be trained in the use of the emergency off switch. ➢ When working with wet equipment ensure the water runs off away from workspaces.

Critical Analysis

Testing

Due to previous disappointments in thruster quality, the company was extremely focused on thruster selection this year. Using a prototyped thruster mount, Bollard Pull Tests were conducted, measuring amperage inline and the pull force of thrusters. A simple mount was prototyped for use in said test in a 20-gallon container. For example, the thrusters pull 3.2 amps while applying 5.5 kg of thrust. This performance is higher than T-100s and bilge pumps motors the company has used in the past, making the Hawk Hobby Brushless Thrusters ideal for the overall design of the vehicle.

Troubleshooting

When building a complex electrical system, issues are inevitable. One of the most tedious troubleshooting processes arose when one of the phases to a brushless thruster became discontinuous; the thruster moved in sporadic jolts and then stopped running. First, the company worked to confirm that the ESC connections were all intact. Next, the company did research about potential causes. One source showed a thruster with the same symptomology, leading to a continuity test, using a multimeter, on the lines running to that specific thruster. The test revealed that one of the contacts lost continuity, which was an easy fix, as spare leads were intentionally put on POE for any unexpected payloads.

During the process of finding the discontinuous line, the ESC for that thruster was replaced to determine if it was damaged. The new ESC connected to the thruster was faulty, leading to a sporadic jolting of the thruster due to an over amperage draw from the newly replaced ESC. The company discovered this after conducting research on the faulty piece of equipment, learning that the ESC will heat up very quickly when pulling an unusual number of amps or volts. This process of theorizing, discussion, testing, and eliminating possible causes was continually utilized as a formula for troubleshooting the various problems encountered.

Accounting

Budget

A realistic Budget this year was established in the first three weeks of meetings and was utilized frequently to make cost-effective decisions. Purchases were made through the approval of mentors and forwarded to the Chief Financial Officer to ensure proper documentation.

Affording higher quality wire for the thruster system was a priority this year, as it was seen as crucial to the success of the team. This was attained by budgeting the thruster costs as lower than in previous years. As mentioned in *Vehicle Systems,* these thrusters decreased costs greatly and allowed the budget to be adjusted accordingly.

Furthermore, travel costs accounted for 12 employees and two mentors and were estimated at $2,000 for the regional competition and $22,000 for the international competition. This predicted cost included hotel fees, plane fares, and van costs. (See Appendix E)

Cost Accounting

Many company costs were derived from purchased materials and hardware for construction, as well as in electronics for the vehicle’s function. Significant expenses crucial to the ROV’S development include the polycarbonate used to construct the vehicle’s frame and the Hawk Hobby thrusters to increase maneuverability. Other electronics purchased include digital servos for providing motion in the vehicle’s claws and cameras that provide viewing of tasks under water. Half of the six cameras were parent donations, as well as various prop materials and necessary tools. To track purchases, donations, and re-used materials, a Google Sheet was regularly updated. A comprehensive chart of costs can be found under Appendix F: Costing.

Acknowledgement of Contributors

Phoenix Robotics is extremely grateful to their GoFundMe donors, as their support facilitated the purchase of many critical components. Phoenix Robotics greatly appreciates Publix for its financial contribution, allowing for other vital materials to be purchased. Phoenix Robotics would finally like to thank Calypso of Tampa for teaching employees how to dive through PADI's Open Water certification and educating these employees regarding coral reef conservation. Calypso of Tampa also generously offered the company to utilize their pool for testing systems and practicing tasks with the Phoenix Ocean Explorer. Money generated from a school-wide fundraiser with PDQ also aided the company in funding the machine. Phoenix Robotics could not have progressed as far as it has without the help of these sponsors. Office Dynamics has also printed Marketing Displays regularly for the company and is thus also a significant contributor.

Additionally, Suzanne Fernandez, Larry Gil, and Terrie Gil have graciously allowed the company to use their respective pools for practice runs and testing.

The members of Phoenix Robotics are extremely grateful to Mr. Fernandez and Mrs. Fernandez for being mentors. They provided an environment where the team was able to learn and grow abilities to meet the many challenges presented throughout competition preparation.

Lastly, Phoenix Robotics is very appreciative of MATE for hosting this competition, and for providing amazing educational opportunities for many.

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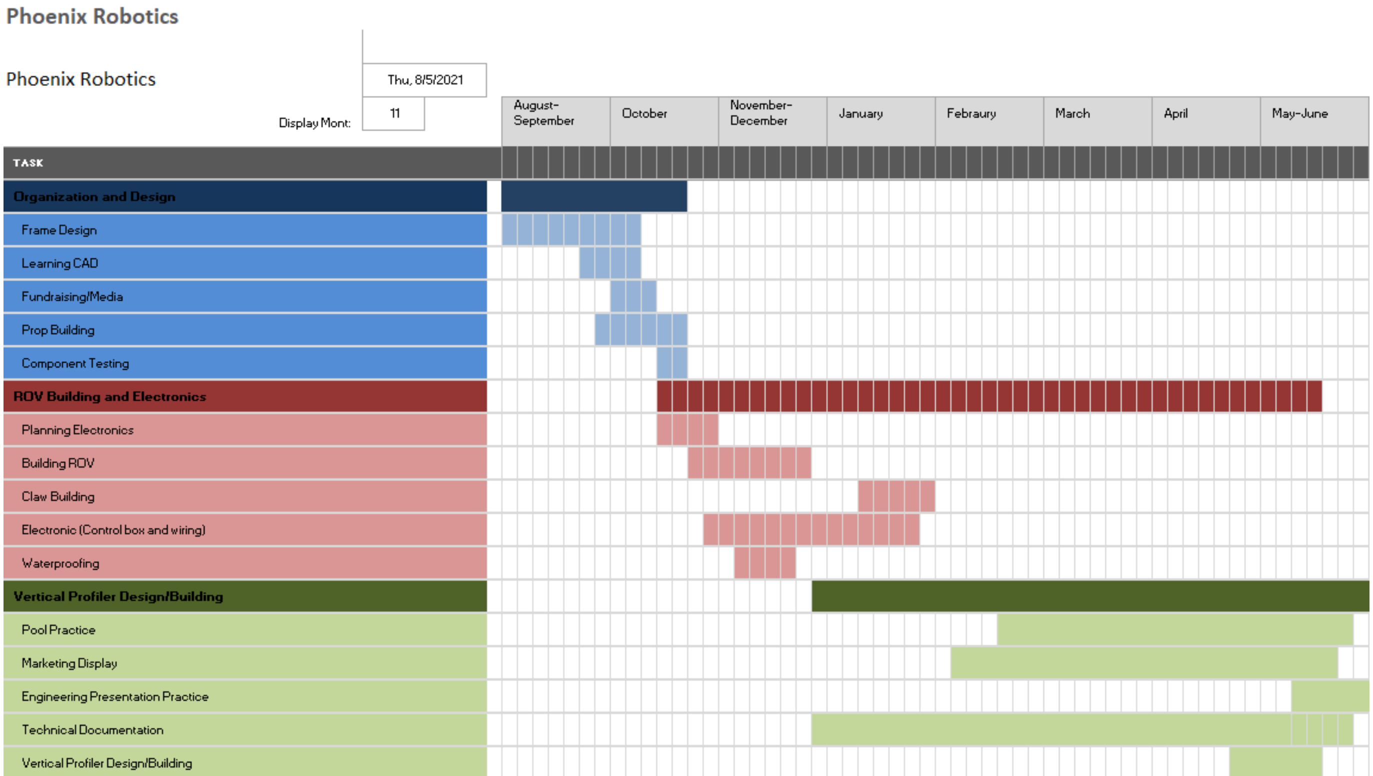
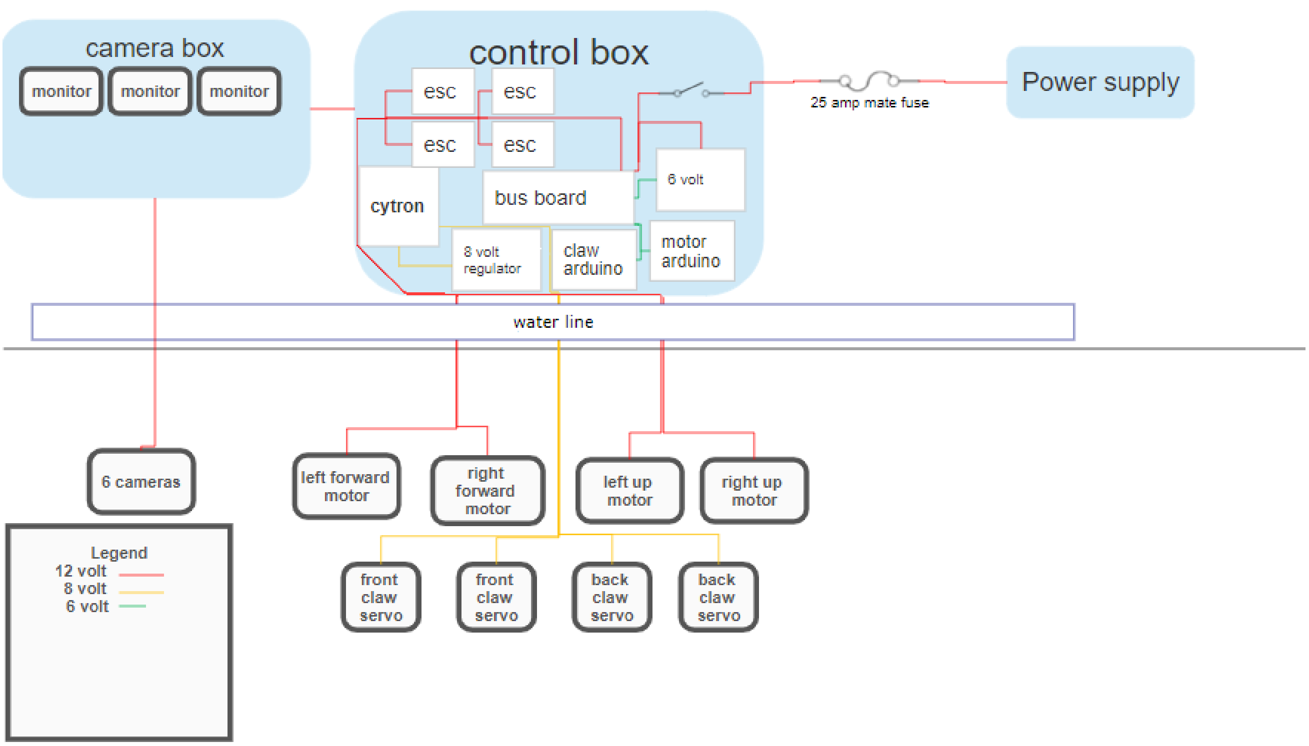
Appendices

Appendix A: Gantt Chart



Appendix B: SID



Appendix C: Software

```
/
White: Right X
Yellow: Right Y (A2)
Blue: Left Y (A1)
Green: Left X (A0) /
Servo esc_FL; // create servo object to control the ESC (Forward Left)
Servo esc_FR; // Forward Right
Servo esc_UL; // Up Left
Servo esc_UR; //Up Right
int PotVal_LX; //Left joystick values in the X direction
int PotVal_LY; //Left joystick values in the Y direction
int PotVal_RY; //Right joystick values in the Y direction
const int pingPin = 7; // Trigger Pin of Ultrasonic Sensor
const int echoPin = 8; // Echo Pin of Ultrasonic Sensor
int autoDist = 25; //Distance in cm that the ROV must be from the bottom of the
pool for the autonomous task
int drive = 0; //variable that will either be 1 or 0, depending on whether driver has
pushed the autonomous button
int buttonPin = 12; //Pin that is the input for the autonomous button signal
int PiLeft = 5;
int PiRight = 4;

int low = 65; //low end of pot
int high = 915; //high end of pot
int upperboundU = 460; //upperbound of pot for up motors (12V calb: 460)
int lowerboundU = 390; //lowerbound of pot for up motors (12V calb: 390)
int upperboundFX = 580; //upperbound of pot for fwd motors (12V calb: 550)
int lowerboundFX = 450; //lowerbound of pot for fwd motors (12V calb: 500)
int upperboundFY = 550; //upperbound of pot for fwd motors (12V calb: 550)
int lowerboundFY = 490; //lowerbound of pot for fwd motors (12V calb: 500)
int pwmV1; //just a var
int pwmV; //just a var
int pwmV2; //just a var
int pwmV3; //just a var

void setup() {
delay(1000);
// put your setup code here, to run once:
esc_FL.attach(9); //6 is the pin that the ESC is attached to
esc_FR.attach(6);
esc_UL.attach(10);
esc_UR.attach(11);
pinMode(buttonPin, INPUT);
pinMode(pingPin, OUTPUT);
pinMode(echoPin, INPUT);
Serial.begin(9600);
esc_FL.writeMicroseconds(1500);
esc_FR.writeMicroseconds(1500);
esc_UR.writeMicroseconds(1500);
esc_UL.writeMicroseconds(1500);
delay(7000); //Allow for ESC to calibrate
}

void loop() {
//while the LY potentiometer values are outside of the deadzone, run the forward
motors accordingly
while(PotVal_LX > upperboundFX or PotVal_LX < lowerboundFX and drive == 0){
reading();
run_FX();
run_U();
//Serial.println("Driving Normal");
}
//while the LX potentiometer values are outside of the deadzone, run the forward
motors accordingly
while(PotVal_LY > upperboundFY or PotVal_LY < lowerboundFY and drive == 0){
run_U();
//Serial.println("Turning");
}
/reason this isn't in a while loop is because if the LX and LY joysticks aren't in the
other
while loops, than that means that they are both in the deadzones, and the forward
motors shouldn't
be moving, so they are being told not to move/
reading();
esc_FL.writeMicroseconds(1500);
esc_FR.writeMicroseconds(1500);
run_U();
reading();
}
/
The function takes in the joystick values in the x direction. Depending on how far the
joystick is moved, it will affect how fast the motors turn and in which direction. /
void run_FX(){
//if the joystick is in the deadzone, write to ESCs not to move
if (PotVal_LX > upperboundFX and PotVal_LX < lowerboundFX){
esc_FL.writeMicroseconds(1500);
esc_FR.writeMicroseconds(1500);
}
else{
if(PotVal_LX > 512){
pwmV = map(1023-PotVal_LX, low, high, 1100, 1900); //take the potentiometer
values that are between 65 and 915 and convert them to values between 1100 and
1900
pwmV1 = map(PotVal_LX, low, high, 1100, 1900);
}
pwmV = map(1023-PotVal_LX, low, high, 1100, 1900); //take the potentiometer
values that are between 65 and 915 and convert them to values between 1100 and
1900
pwmV1 = map(PotVal_LX, low, high, 1100, 1900);
esc_FL.writeMicroseconds(pwmV); //write the mapped values to the ESCs
esc_FR.writeMicroseconds(pwmV1);
}
}
void run_FY(){
//if the joystick is in the deadzone, write to ESCs not to move
if (PotVal_LY > upperboundFY and PotVal_LY < lowerboundFY){
esc_FL.writeMicroseconds(1500);
esc_FR.writeMicroseconds(1500);
}
else{
pwmV = map(1023-PotVal_LY, 150, 770, 1100, 1900);
pwmV1 = map(1023-PotVal_LY, 150, 770, 1100, 1900);
esc_FL.writeMicroseconds(pwmV1);
esc_FR.writeMicroseconds(pwmV);
}
}

void run_U(){
//if the joystick is in the deadzone, write to ESCs not to move
if (PotVal_RY > lowerboundU and PotVal_RY < upperboundU){
esc_UL.writeMicroseconds(1500);
esc_UR.writeMicroseconds(1500);
}
else{
pwmV2 = map(PotVal_RY, low, high, 1100, 1900);
pwmV3 = map(PotVal_RY, low, high, 1900, 1100);
esc_UL.writeMicroseconds(pwmV2);
esc_UR.writeMicroseconds(pwmV3);
}
}
```

Appendix D: Safe Operation

In the Workplace

General

- Keep a clean workspace to prevent clutter and maintain an ergonomic workspace
- Wear necessary safety protection (PPE) such as goggles and gloves.
- Check all equipment for any abnormalities before use to prevent injury from said equipment.

Glowforge™ Laser Cutter

- Make sure that the cover is fully closed before and when the Glowforge™ is in use to ensure proper function and safety.
- Have the cover closed for a minimum of 20 minutes after use to allow air to filter.
- Check for miscellaneous items/equipment to avoid accidental damage when in use and afterwards.

Solder

- Use protective equipment to avoid contact with harmful substances.
- Wear proper PPE (i.e., personal protective equipment) such as gloves and goggles to avoid injuries.
- Cover exposed wires using marine grade heat shrink to prevent power loss and to avoid electrocution.

Power Tools

- Wear protective glasses to prevent shrapnel from injuring the eyes and wear gloves to limit physical harm to hands.
- Check for obstructions to the power supply that would prevent smooth delivery of power.
- To prevent tools from falling and potentially injuring members and/or tools keep them away from edges of elevated work areas.
- To prevent the possibility of tripping and/or falling, never have hoses and/or electrical cords in walkways.
- Have constant vigilance of surroundings to limit collisions with other employees and to prevent accidents.

3D Printing

- Avoid touching the nozzle when hot to prevent burns.
- Conserve material by eliminating waste from tangled filament in the printer’s work area.
- File sharp edges on newly printed pieces.

Setup, Boot, and Launch

- Ensure a clean and proper workspace.
- To prevent distractions, ensure that the area is clear, and all team members are ready.
- When powering on the ROV, notify all employees to ready the team for further instructions.
- Connect tether wire to camera box carefully to prevent damage to the camera box and electronics.
- Keep the camera box area neat and handle the tether wires with care to prevent damage to the camera box and electronics within.
- After placing the ROV next to the pool, notify the pilot and their crew.

- Place the ROV in the pool with caution with awareness to the tether so it does not get stepped on and/or tripped over and cause injury.

ROV Retrieval

- The deck crew is notified by the pilot when the ROV is surfacing, preparing them for an efficient change of materials or lifting the ROV onto the poolside.
- The pilot releases control over the ROV to allow the deck crew to safely make necessary adjustments to the ROV.
- The ROV is grasped on opposite sides by the deck crew to ensure that the robot is not dropped or mishandled.

ROV Maintenance

- Make sure that all electronics are nominal and sensor readings are correct to ensure accurate data is being provided to the ROV in use.
- Search for holes, water damage, wear, scratches, and other such damage to ensure the safety of the electronics and the ROV from malfunctions and water infiltration.
- After use in the pool, wash the ROV in fresh water to limit damage from repeated exposure to chlorinated water.
- Run the Thrusters for 30 seconds to 1 minute after washing the ROV to prevent buildup from chlorinated water.

Appendix E: Budget

Income				
Source				**Amount**
Previously Funded				$2,000.00
Donation from Derrick Brooks				$23,000.00
Donation from PDQ				$300.00
Donation from Publix				$200.00
GoFundMe Donations				$575.00
Expenses				
Category	**Description**	**Type**	**Projected Cost**	**Budgeted Value**
Frame	Polycarbonate, Acrylic	Purchased	$150.00	$150.00
Electronics	Motors, Servos, ESCs	Purchased	$500.00	$500.00
Cameras	N/A	Purchased and Donation	$380.00	$380.00
Vertical Profiler	Materials for Profiler	Purchased	$70.00	$70.00
Marketing Display	Corrugated Panel, Printing	Purchased	$150.00	$150.00
General	Controllers, PVC	Re-Used	$100.00	N/A
Wire	Claw and Motor Wires	Purchased	$450.00	$450.00
Travel				
Regional Travel	Gas, Hotel Costs, Van	Purchased	$2,000.00	$2,000.00
International Travel	Plane Tickets, Hotel, Van	Purchased	$22,000.00	$22,000.00
			Total Income	$26,075.00
			Total Expense	$25,700.00
			Profit	$375.00

Appendix F: Costing

Date	Type		Item	Amount	Running Balance
N/A	Monetary Donation	N/A	Previously Funded	(+$1000)	$1,000.00
N/A	Monetary Donation	N/A	PDQ	(+$300)	$1,300.00
N/A	Monetary Donation	N/A	Publix	(+$200)	$1,500.00
N/A	Monetary Donation	N/A	GoFundMe	(+$575)	$2,075.00
N/A	Re-Used	Buoyancy	High Density Foam	N/A	$2,075.00
N/A	Re-Used	Materials	PVC Tubing and Ends	N/A	$2,075.00
N/A	Re-Used	Hardware	Metal Pieces and Screws	N/A	$2,075.00
N/A	Re-Used	Materials	Camera Box	N/A	$2,075.00
N/A	Re-Used	Hardware	Screws, Hooks and U-Bolts	N/A	$2,075.00
N/A	Re-Used	Hardware	Controller (PS2)	N/A	$2,075.00
N/A	Re-Used	Hardware	Controller (Claw)	N/A	$2,075.00
11/29/21	Donation	Electronics	Camera (3)	$185.97	$2,075.00
12/1/21	Donation	Tools	Toolbag	$18.45	$2,075.00
12/2/21	Donation	Tools	Pliers	$13.98	$2,075.00
12/2/21	Donation	Tools	Wire Cutters	$25.48	$2,075.00
12/4/21	Donation	Tools	Acrylic Glue	$9.99	$2,075.00
12/4/21	Donation	Tools	Wire Crimper	$27.97	$2,075.00
12/4/21	Donation	Tools	Wire Strippers	$11.99	$2,075.00
1/15/22	Donation	Tools	Prop Fish	$16.99	$2,075.00
11/12/21	Purchased	Sealants and Glues	Plastidip (Cameras and Servos)	$22.10	$2,052.90
11/14/21	Purchased	Hardware	Zip Ties	$10.00	$2,042.90
11/25/21	Purchased	Materials	Polycarbonate Sheet	$69.99	$1,972.91
11/25/21	Purchased	Materials	Sheath	$47.49	$1,925.42
11/28/21	Purchased	Electronics	Blue Robotics ESC (4)	$144.00	$1,781.42
11/30/21	Purchased	Sealants and Glues	5200 3M Sealant	$15.69	$1,765.73
12/3/21	Purchased	Electronics	Claw Wire	$73.99	$1,691.74
12/13/21	Purchased	Hardware	Hawk Hobby Thrusters (4)	$211.96	$1,479.78
12/15/21	Purchased	Electronics	Pyramid Power Supply	$84.98	$1,394.80
12/20/21	Purchased	Materials	Control Box (Apache)	$27.99	$1,366.81
12/20/21	Purchased	Electronics	Thruster Wire	$364.41	$1,002.40
12/21/21	Purchased	Materials	Heat Shrink	$13.99	$988.41
12/25/21	Purchased	Electronics	Servos (4)	$69.98	$918.43
1/14/22	Purchased	Hardware	Isulated Clamp x 5	$4.45	$913.98
1/17/22	Purchased	Hardware	Grommets	$4.51	$909.47
1/24/22	Purchased	Materials	Acrylic Tubes	$34.90	$874.57
2/6/22	Purchased	Buoyancy	Variable Buoyancy Bag	$10.74	$863.83
2/10/22	Purchased	Materials	Corguate Wiring Covers	$32.99	$830.84
2/21/22	Purchased	Materials	Acrylic Tube Coverings	$4.30	$826.54
2/27/22	Purchased	Hardware	Carabine	$8.95	$817.59
3/4/22	Purchased	Buoyancy	Pool Noodles	$5.00	$812.59
3/20/22	Purchased	Buoyancy	Donut Float	$3.99	$808.60
3/30/22	Purchased	Hardware	Large Syringes	$7.99	$800.61
4/3/22	Purchased	Electronics	Servo	$9.99	$790.62
4/25/22	Purchased	Buoyancy	Copper Coated BBs	$4.00	$786.62
4/28/22	Purchased	Electronics	Cytron Motor Driver	$12.65	$773.97
4/30/22	Purchased	Electronics	Arduino Nano	$22.80	$751.17
				Total Spent	$1,634.65
				Final Balance	$751.17