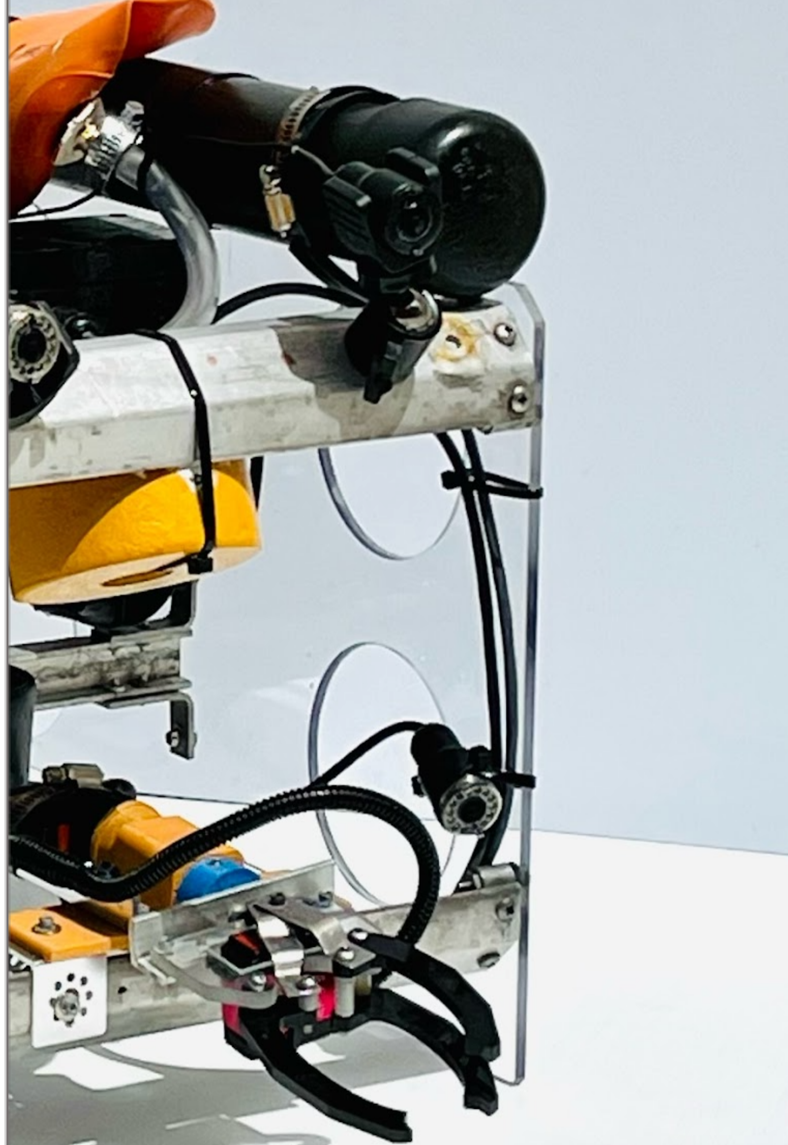


Phoenix Robotics

Colin Price: Chief Executive Officer, Pilot

Carson Stein: Chief Operating Officer

Kristofer Gajadharsingh: Chief Technology Officer, Co-Pilot

Joshua Chao: Chief Safety Officer

Cecilia Lund: Chief Marketing Officer

Xia Collier: Assistant Technology Officer

Mohammed Badri: Vertical Profiler Specialist

Gavin Udagawa: Props Specialist

Mr. Eric Fernandez: Mentor

Mrs. Elena Fernandez: Mentor

Ms. Elena Glow: Mentor

2022-2023 MATE ROV (REMOTELY OPERATED VEHICLE) COMPETITION

Phoenix Robotics

Brooks DeBartolo Collegiate High School
Tampa, Florida, USA

Table of Contents

Abstract

Phoenix Robotics is a company of students from Brooks DeBartolo Collegiate High School located in Tampa, Florida. Our team is dedicated to designing, engineering, and programming remotely operated vehicles to satisfy the needs of our clients. We have an intrinsic compassion for using technology to solve environmental issues, providing technical knowledge to others, and sharing our mission with the community.

This year, our company designed and built a Remotely Operated Vehicle (ROV) with multiple specialized payloads for the tasks proposed within the Marine Advanced Technology Education (MATE) Competition manual. In order to demonstrate the lift capability of the ROV described in Task 2.6, we installed a steel hook at the bottom center of our ROV to alleviate unnecessary stress on our claws. We constructed a light shaft: a narrow tube with an LED light inside. This gives us precision while positioning the illumination source in the one-inch coupling to irradiate the diseased coral in Task 2.3. Our specially designed cup allows us to move and acclimate the fry to their natural habitat.

The Phoenix Ocean Explorer (POE) was specially built to facilitate the completion of the UN Sustainable Development Goals and the tasks described in MATE's 2023 manual. The ROV's ability to complete these tasks demonstrates the company's competence and deep concern for the environment in which it operates. Its ability to irradiate coral, recover fish populations, and remove debris proves the company's capabilities to improve the ocean's state.

Figure 1: POE completing Task 2.6 Heavy Container

Figure 2: Phoenix Robotics company
Photo by Yamir Charriez

All photos were taken by Eric Fernandez of Phoenix Robotics unless noted otherwise.

Teamwork

Project Management

Phoenix Robotics is a company full of diverse and involved members, some of the largest obstacles are coordination and planning. Having ambitious goals and aspirations requires commitment from each employee, with communication between members through various messaging mediums presenting itself as a vital part of maintaining high productivity. WhatsApp is one of the most vital tools in this, serving as a bridge for the company across a myriad of devices, essentially keeping track of the company's attendance and responsibilities. This was further maintained through the use of Google Sheets to provide visual organization of schedules. Documentation for each company department was organized through Trello, which enabled members to compartmentalize previous, current, and future tasks. This also allows for the administration to plan future meetings based on what tasks require the most attention. Total time spent in meetings was largely dependent on the progress of ongoing projects; For example, at the beginning of the year, meeting dates were Tuesday through Thursday from 3:15-5:00 PM. In January, this progressed to meetings every school day from 3:15-6:00 PM to meet the deadlines established internally, by competitors and within the organization. With the daily meetings, the company scheduled additional meetings during school breaks and weekends, ranging from 3-5 hours. Aside from set meeting dates, online conferences were utilized for specialized tasks throughout the year, A GANTT chart, which shows the amount of work done in relation to the amount planned for those periods, was also made at the beginning of the year that tracks the estimated time for each system. See Appendix A

Interpersonal Communication and Teamwork

Over half of the company was replaced by new members this year, most of which required extensive training. While this left a hole in the company, as many of the experienced employees moved on, it created a plethora of fresh and energetic ideas brought on by these new team members that replaced them. The experienced employees left on the team were forced to quickly acquire the skills they didn't learn from their time with the company. This created a lot of strain but cultivated creative innovations. The new team members had to adapt and closely follow and learn from the more experienced employees. Senior Employees also provided newer employees with safety training.

Meeting Organization

At the start of every meeting, the company discusses the goals and objectives for the day and week. If employees need to make announcements or ask questions, they do so during this time frame. After beginning remarks, the employees split up and work on tasks specialized toward their current capabilities. Senior employees took special care to make sure all Phoenix Robotics employees demonstrate correct safety procedures and are able to solve difficult issues. Following the day's activities, the team meets back in the designated room to discuss the progress made, as well as any problems or changes to their task.

The Assembled ROV

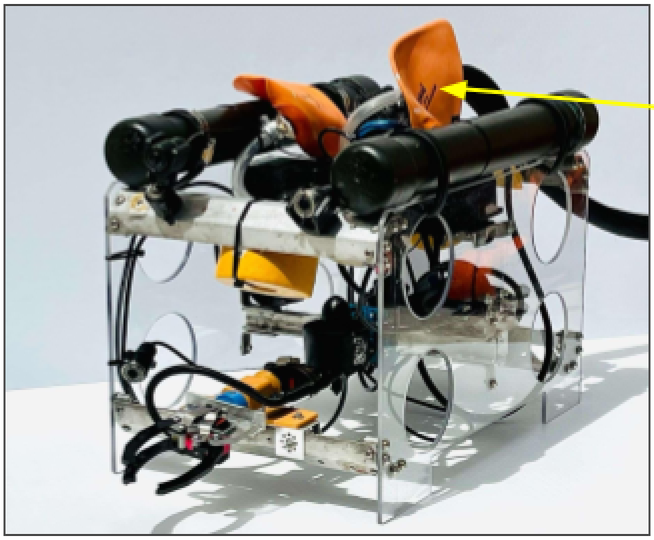
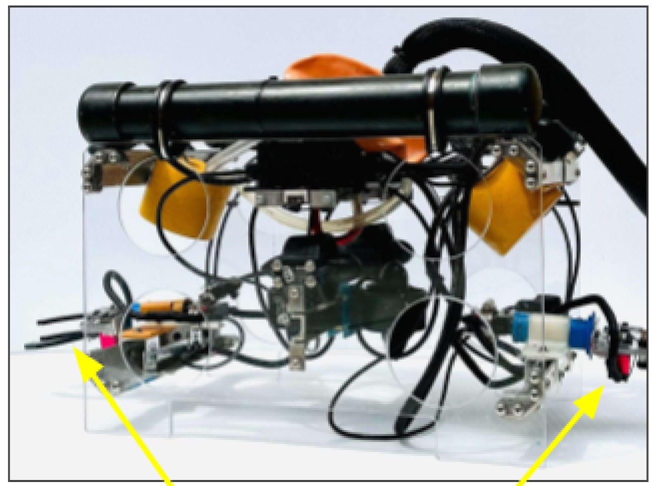


Figure 3: Assembled ROV - Front
Photo by Yamir Charriez

Variable Buoyancy

Figure 4: Assembled ROV - Side
Photo by Yamir Charriez



Double, 2-axis manipulators

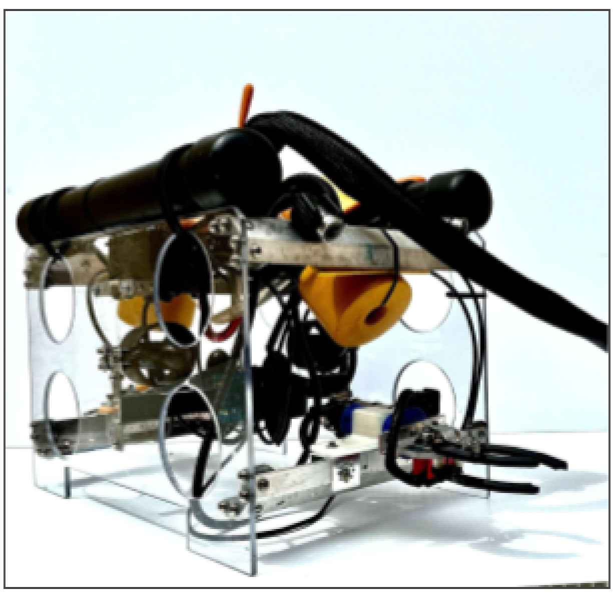


Figure 5: Assembled ROV - Rear
Photo by Yamir Charriez

Design Rationale

Engineering Design Rationale

Our vehicle design implements an internal motor placement to protect the thrusters and to ensure the ROV remains compact. Our plan was to use off-board electronics and instead utilize electrical junction boxes. This removed unnecessary weight from the ROV providing a better thrust-to-weight ratio. Another key consideration was including two claws instead of one, increasing our payload capabilities. This saved time spent completely rotating the entire ROV to retrieve or manipulate an object. We determined that an exact replica of the gripper used would be capable of finishing a significant portion of the mission. We incorporated two for increased reliability as well as speed of operation because the device would be frequently utilized.This is significantly useful in Tasks 1.0 with mounting solar arrays. We incorporated Polycarbonate (Lexan) panels for mounting with the intention of repurposing metal from a military laptop case for the frame structure. We discovered, however, that it was possible to remove a significant portion of the aluminum structure and replace it with polycarbonate panels, thereby reducing weight and material consumption. Polycarbonate was chosen for the side panels because of its tensile strength and resistance to cracking and fracturing. The aluminum struts and polycarbonate are securely fastened together with threaded machined aluminum joints, which are tightened with stainless steel hardware and galvanized to prevent rust. Polycarbonate panels provide mountable space for horizontal thrusters, cross sections to support vertical motors, and electrical junction boxes. In order to provide easy access and grab points, large circles were cut out in polycarbonate panels. The company's decision to incorporate this design into the ROV reduces the large surface area protruding from the center rotation point, which in turn provides less resistance when rotating. Aluminum cross sections were added to the ROV in order to provide support for the vertical thrust and electrical junction boxes.

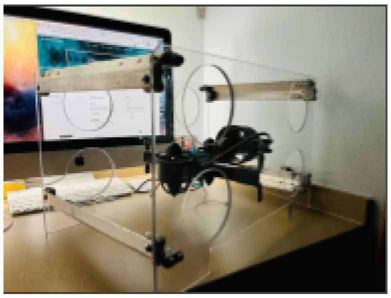


Figure 6: Early ROV prototype
Photo by Carson Stein

Innovation

Motor shrouds were 3-D printed using PLA. In an effort to make the print strong enough to withstand stress and to fit the IP-20 requirement, the shrouds were made wider and thicker than ideal, resulting in a larger decrease in efficiency seen in tests of speed. The solution to this problem was researching alternate shrouds which resulted in the discovery and purchase of miniature metal fan grates that were durable, met the IP-20 requirement, and maintained high efficiency for the motors.

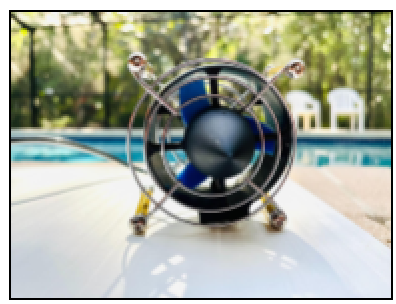


Figure 7: Shroud on a thruster
Photo by Carson Stein

Bottom sleds were integrated in the frame of this model to provide rigidity and stability. This new design feature is demonstrated in the elongated, protruding corners of our polycarbonate sides. Through this modification we maintained the required clearance for our on-board systems while providing a method of propping the ROV up to protect the natural environment it operates in.

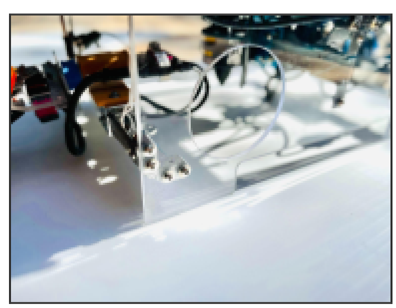


Figure 8: Redesigned ROV feet
Photo by Yamir Charriez

Design Rationale

System Approach

When designing the Phoenix Ocean Explorer, some of the main considerations were maintaining a light, efficient, and adaptable system. 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, contributing to navigation with minimal to no drift to either side 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.

Figure 9: Company member removing protective plastic from polycarbonate sheets

Vehicle Structure

The structure of our frame originally revolved around a completely aluminum frame, but we found that we could lose a large amount of the aluminum structure and replace it with large lexan polycarbonate panels, which saved material and decreased the overall mass of our ROV. Lexan polycarbonate was chosen for the panels as opposed to other brands of polycarbonate because its tensile strength gave it the ability to hold the ROV together. The aluminum struts and polycarbonate are securely fastened together with threaded machined aluminum joints, which are tightened with all stainless steel hardware. The dimensions of our frame are 48.26 cm lengthwise, 27.94 cm heightwise, and 30.48 cm widthwise.

Design Rationale

Control/Electrical Systems

Software

The ROV software was written in the Arduino IDE using C++. Specifically, this software controls the four brushless thrusters and four servos, which control the manipulators. The thruster code reads the inputs from an analog controller and interprets them for the ESCs. This allows precise forward and reverse speeds with our thrusters. See Appendix D.

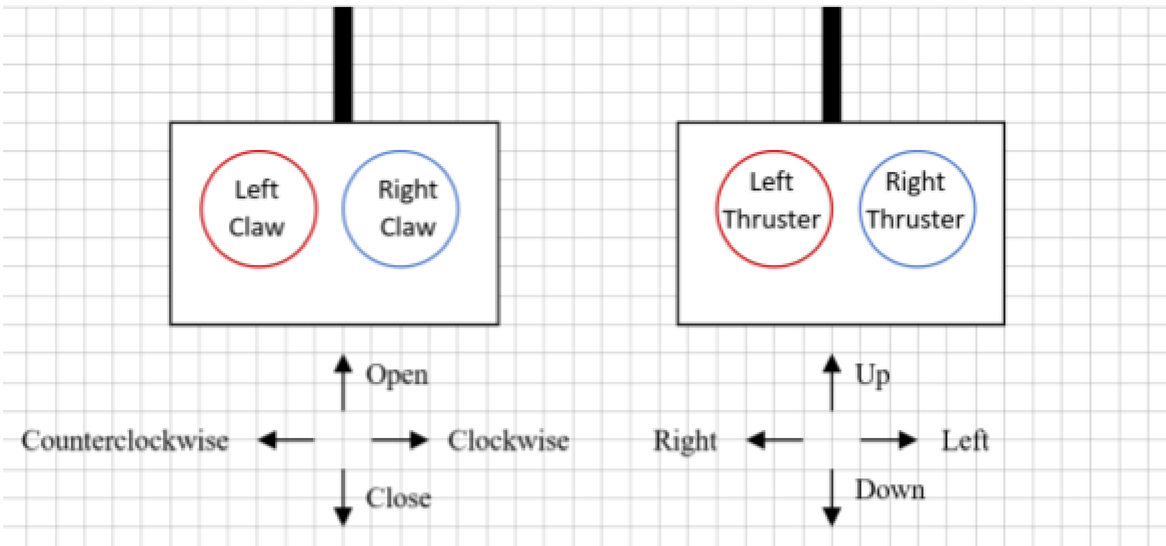


Figure 10: Servo and Thruster Controls

Control Box

The Phoenix Ocean Explorer MK2's control system comprises two Cytrons, two Arduino Unos, voltage regulators, and an emergency shut-off switch. Two controllers control the thrusters and manipulators. One controller (with two joysticks) facilitates power to the thrusters. Pushing up or down on the joysticks allows the ROV to rise and fall. The horizontal directions on the joysticks move the left and right thrusters, allowing for forward, backward, and rotational movements. The other controls allow for clockwise and counterclockwise rotation of the manipulators and claw opening and closing.

One Arduino Uno interprets our software and communicates it to the electronic speed controllers on the thruster, which makes it possible for precise speeds forward and backward. The other Arduino relays information to the Cytrons, allowing the servos to move clockwise and counterclockwise by reversing the polarity.

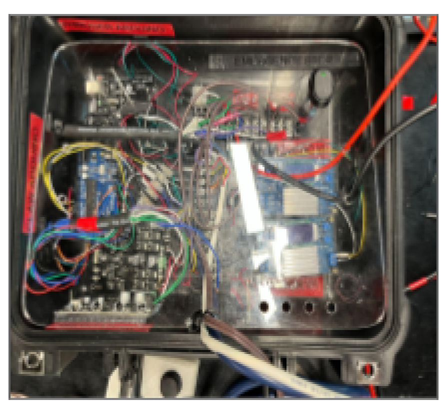


Figure 11: Inside the control box.

This system is kept in a control box on the surface instead of an onboard control box. Eliminating flooding or water damage to our electronics and lowering the weight of the ROV. The control box is modular and repairable; wires are easily removable through the wire glands and are secure but allow for easy removal of wires from the box. An acrylic sheet over the electronics protects them from debris and allows bus board connection without exposed wiring.

Camera Box

POE's camera box is much smaller due to the modern connections that contain one power wire and one camera wire rather than one power wire and two camera wires. The camera box contains three monitors that are able to display two cameras per monitor, facilitated by the ability to change video settings. This allows us to utilize six cameras on our ROV and switch between them effortlessly. Additionally, the camera box has its own 15 amp fuse and an 8-amp regulator designed by Anderson Plug. The camera box is detachable through the wiring of the cameras, which has a male to female connection that allows for easy setup and more flexibility from having fewer wires to manage.

The camera wires are comfortably set in the control box and acrylic tube for variable buoyancy. The more compact look of this year's camera box is due to the fact that the cameras used this year require fewer wires to operate. Overall, this creates more space for other components of the camera box and less clutter, which decreases the chance of wires losing connections. Having multiple cameras mounted on our ROV allows us to have as much awareness as we can while in the water while also watching the progress of our ROV and how it interacts with the environment. For more information camera placement and specification see Cameras, pg 11.

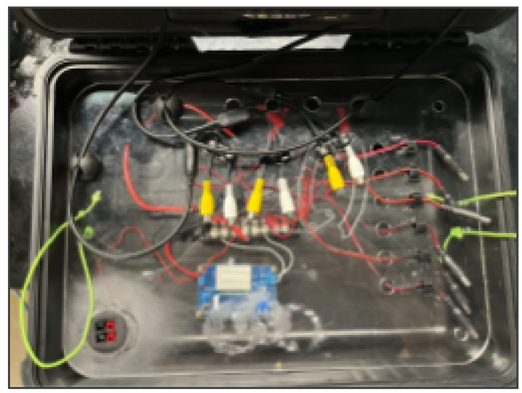


Figure 12: Inside view of the camera box

Tether

This year the tether was made up of two wires with nine conductors each at an AWG of 18, six camera wires, and an acrylic tube for buoyancy. The tether sheath was specially designed with a velcro closing system that allows wires to be tightly wrapped. Wrapped around the tether are buoyancy tubes that alleviate the tether's weight in the water.

The tethers for strain relief use a carabiner, and tension is put on a metal ring. Wire glands in the control box and acrylic boxes eliminated stress by clamping onto the wires. The Chief Operations Officer ensures that the tether is always properly handled, including ensuring that the coil is neatly coiled.

Design Rationale

Payloads and Tools

Manipulators

Two duplicate manipulators are used, one on the front and backside of the Phoenix Ocean Explorer; this allows pilots to use both directions on the ROV effectively the same, thus doubling the capability of our vehicle. The claws themselves can rotate a full 360°, and the claws can open 270°. Each claw uses two servos, one for rotation and one for opening and closing the claws. They are attached to an aluminum bracket and then to a PVC tube with a frictionless connection that still keeps them securely in place. The claws can swiftly complete tasks such as Task 2.7, installing the long-term camera, acclimating and releasing the Northern Redbelly Dace fry from Task 2.5, and placing the syringe for Task 2.3.

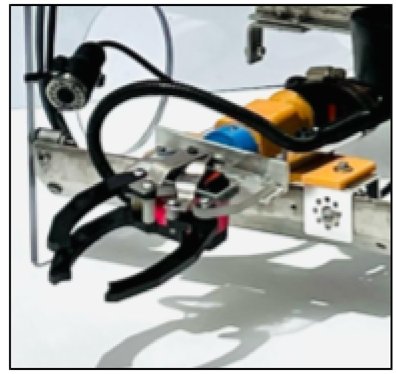


Figure 13: Manipulators
Photo by Yamir Charriez

LED Light Shaft

The LED light shaft is a Plastic tube with an LED protruding from the end. The LED is utilized in task 2.3 to irradiate diseased corals. The LED shaft is fastened to the ROV with cable ties, and a camera centers its attention from a bird's-eye view to accurately see where we need to administer it. The LED is waterproofed with hot glue on the LED and marine grease on the inside of the aluminum straw. Its thin design allows it to get into tiny spaces and cure coral in virtually any area.

Steel Hook

The testing of the hook's capabilities with various weights has demonstrated its durability and reliability. In each test, the hook remained securely attached to the ROV without any damage or detachment.The maximum load the hook was tested was 13 kg. This is a testament to the strength of the connection between the hook and the ROV. To further ensure safety, heat shrink has been implemented to prevent accidental slippage of the hook, while red tape has been used to clearly mark sharp areas of potential danger. With this level of attention to detail and safety, researchers can confidently utilize this hook for a wide range of underwater tasks with peace of mind that it will perform as expected.

Pump

Included with the POE is a centrifugal pump to complete Task 2.2 eDNA collection. The pump is fastened to the ROV by two cable ties and is a centrifugal pump that was repurposed from a fish tank filtration system. The pump is attached to the top of a screw-on cup that holds the collected eDNA. Along with the pump, a sheathed, sharp edge is used to pierce any plant fiber or material; it is also marked with yellow tape. Lastly, a switch is used to run the pump, and it is left on for 10 seconds to collect sufficient liquid to displace the volume in the container.

Design Rationale

Vertical Profiler

Phoenix Robotics underwent a significant transformation in vertical profiler design using knowledge from last year's vertical profiler. Through the use of two air pumps the vertical profiler can seamlessly profile up and down and transmit the time and company number when it hits the surface.

A Cytron interprets code from an Arduino which provides autonomous control to the pumps. Three 9V batteries are used on this redesign, one for the two air pumps, one for the transmitting device and one for the Arduino and Cytrons. Each battery has its own 5-amp fuse and switch integrated into it. The Cytrons receive signals from the Arduino that tell it when to pump.

This year, Task 3 also required a transmitter that relays the time and company number; this was achieved through the use of a real time clock and a node MCU, which sends the signal whenever the vertical profiler is at the surface.

Figure 14: ROV camera on a swivel

Cameras

There are six cameras on the Phoenix Ocean Explorer, two of which are on swivels which allow for quick adjustments. Similar to last year, the company decided to use waterproofed fishing cameras, because of their reliability and ease of use. The camera quality and reliability continue to allow the pilot to have a perfect perception of the ROV underwater. They also facilitate the completion of tasks such as Task 2.7 by flying the transect, or Task 2.5 by viewing different species of fish. The last two cameras are used to see the claws and facilitate the completion of Task 2.6 inspecting buoy ropes for damage and Task 2.4 monitoring seagrass habitat.

Propulsion

The ROV has four thrusters inside its frame. Two of these thrusters face forward and are connected to the polycarbonate side panels. They control ROV forward and reverse movements. Connected to the aluminum bar that runs through the ROV are vertical movement thrusters. They allow the ROV to move up and down. We used the Bollard test to determine kilograms of thrust per amp. An in-series multimeter reads the amps, and a scale was used to collect thrust data. PWM input was slowly increased while amps and kilograms were collected. We then compared the results to last year's motors and the T100, deciding that these motors had acceptable performance.. The inclusion of yaw and pitch was considered, but were feckless for this mission. It was decided that the additional cost and complexity would be unnecessary.

Design Rationale

PWM Input (analog controller input)	110 0µs	1200µs	1300µs	1400µs	1600µs	2000µs
Thrust (kg)	2.9	3.3	4.1	4.5	5.1	5.7
Amperage	3.0	4.3	5.4	6.6	7.2	8.5

Data was collected through the use of a Bollard's test, PWM serial monitor, and a multimeter.

Buoyancy and Ballast

One advantage of using polycarbonate is its low density of 1.24 g/mL, which approximately signifies that the frame does not add significant negative buoyant force due to water's similar density of around 1.0 g/mL. To ensure stabilization the center of mass is kept below the center of buoyancy. A drawback of not having an onboard electronics system is the inherent buoyancy that it would provide, but we planned for this through the use of static buoyancy. High-density foam and enclosed PVC tubing are both used as static buoyancy in this scenario, and all of them are mounted on top of the vehicle to maintain the center of buoyancy just above the center of mass. In order to completely stabilize POE, light weights were added to the bottom as well as the rear. Payloads such as the heavy container require buoyancy countermeasures. A variable buoyancy system that involves an inflatable bladder that is filled using a hand pump is used to increase the buoyancy and keep stabilization while it holds heavy objects.

Build vs. Buy

When it comes down to the materials to build the ROV, we either have to purchase or build the components used on the machine. Phoenix Robotics attempts to build most components in house, but in some circumstances this is impossible or will make an unreliable product.

Building products in house guarantees reliability, repairability, and a genuine understanding of the product. When the price of an item outweighs the time to create it, we purchase high-quality products from reputable suppliers. This ensures synergy of our high-quality products with bought quality products. Our six cameras were purchased due to the risk of water-damage which created a liability. Buying professionally sealed cameras eliminates this issue. Our thrusters were also purchased because we knew they were high-quality. Designing our own thrusters would result in a large time commitment. Electronics such as Arduinos, Cytrons, and voltage regulators were also bought due to the cheap price compared to the time it would take to make them in house. With this extra time the company can concentrate on developing products such as the claws, the control box, and the frame of the ROV. In addition, it can focus on systems such as the pump and LED shaft.

New vs. Reused

Phoenix Robotics finds genuine pride in reviving and reusing objects that are then implemented into the Phoenix Ocean Explorer. We draw inspiration from our previous ROVs, identifying specific systems that performed well, then implementing and upgrading them into our current ROV. This allows for a deep and ingrained understanding of ROV and its systems by all company employees.

Design Rationale

An example of a new item would be the polycarbonate sheets that were bought and cut specifically for their strength and durability; this also makes it a difficult material to reuse. Another example of a newly used component was the acrylic water-proof pots. Although company employees have no past experience with this water-proofing measure, it worked perfectly and will most likely be reused in the future.

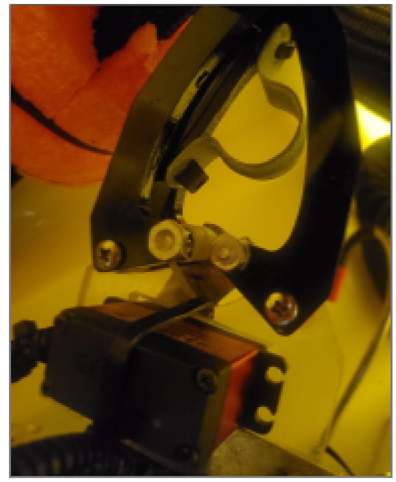


Figure 15: Metal ring added to the manipulator

Many systems were reused and upgraded, for example the camera box, which was made smaller and had more modern connection, but reused many principles from past camera boxes. The claws and buoyancy tubes were also a reused system that needed simple repurpose to be effective on this year's ROV.

Safety

Phoenix robotics understands the need and importance of safety within an effective work environment. With three members that are certified production technicians through the manufacturing skill standards council (MSSC), all employees are trained in standard procedures and effective risk management behaviors as described in our Job Safety Analysis (JSA). Wearing gloves and/or goggles is necessary when working with power tools and preventing injury, just as critical is the training, use and procedure of these tools to prevent injury/damage to personnel and equipment via misuse. Misuse of tools and lack of PPE is not tolerated within Phoenix Robotics. Personnel found in violation of safety procedures are reprimanded for their violation and reeducated in procedures so that mistakes aren't repeated. This maintains a safe work environment.

When it comes to poolside safety, there are many things that need to be considered so that everything can run safely and efficiently. One way this can be done is by sanding down any sharp edges on both the props and the ROV itself to ensure any personnel handling them won't suffer any harm. When working poolside, one must ensure that all the props are stored in the correct manner. This is to keep the area open and accessible to all without the risk of running into anything while working. Another thing to think about is the way that props are put into the water because it's imperative that one doesn't risk wetting the electronics when inserting anything into the water due to it potentially destroying any electronics. For a full list of safety procedures see Appendix E.

Critical Analysis

Testing

The company faced a large challenge completing Task 1.1, specifically pushing the carabiners onto the metal ring. The claws were too wide to properly grip the PVC tube, this created an issue as the carabiner would push itself out of the claw instead of clipping onto the metal ring. We attempted to change the center position of the claw but this didn't work, we also attempted to find a better way of grabbing the PVC pipe itself to no avail. Eventually, the company found the perfect solution, installing a metal ring in the middle of the claw. This closed the gap in the middle of the claw and allowed for a better grip of the PVC.

Troubleshooting

During the programming of the wifi module of the vertical profiler (Node MCU), the company encountered multiple challenges that needed to be overcome. One of these challenges was the incompatibility of libraries, which did not work harmoniously with each other. Moreover, the company faced a scarcity of documentation suitable for their specific use case. To address these obstacles, the company diligently studied the Real Time Clock (RTC) and the wifi module separately, investing weeks in acquiring the necessary knowledge. By merging their understanding and conducting comprehensive research, they successfully developed a functional wifi module capable of transmitting time every second, leveraging the utilization of Web Serial. However, direct integration of the RTC signals with Webserial transmissions proved unfeasible. Instead, the company resorted to displaying all RTC transmissions to the Serial Port, converting them into strings, and utilizing them in the system.

In regard to the programming of the Air pumps and the Air valve, the company initially intended to utilize an Adafruit CRICKET, but after careful consideration, they opted for an Arduino Uno. To exert control over the power supply to the pumps, a double motor Cytron was employed. Additionally, another Cytron was utilized for the air valve. During the testing phase, it became evident that a single battery, when routed through the Arduino to power the Cytrons, did not provide sufficient voltage to operate the pumps optimally. This resulted in the pumps either operating at an excessively slow speed or failing to turn on altogether. Consequently, the company adopted the solution of using dedicated batteries for the pump cytons, as well as a separate battery for the Arduino.

Ultimately, the company faced numerous troubleshooting challenges during the testing phase of the vertical profiler, as it involved a completely redesigned system due to the incorporation of new air pumps. Nevertheless, their prior experience working with air underwater, coupled with extensive hours invested in testing and planning for the new system, culminated in the successful implementation of the vertical profiler.

Accounting

Budget

This year's budget was lenient and allowed experimentation with more expensive products. This was due to an additional science fund granted to the club. We still have a budget and limited funds. At the beginning of the year, a wish list is made to organize all the products that will be bought. This is then sent to the Chief Financial Officer for documentation and finally to our mentor for approval.

Even with our lenient budget, upgrading our servos was a high priority for the company this year. We had planned to buy a few servos, test them, and then buy a fair amount of the servos we favored. However, we simply did not have the budget to do this if we were planning to buy four brushless thrusters. To overcome this issue, we decided to use DiamondDynamics brushless thrusters that had been bought in years past but had never been used because they had never worked properly. This saved us a large sum of money and allowed us to purchase the perfect servos, perfecting our claws.

Travel costs accounted for eight employees and three mentors. Travel costs were $2,200 for the regional competition in Boca Raton, Florida, and $26,000 for the international competition. This cost is largely airfare and lodging for our employees. For the full budget, see Appendix F.

Cost Accounting

The largest cost this year was spent on travel costs, specifically hotel and airfare expenses. Buying and testing servos also cost the company a lot of our budget. Many expensive parts that plagued last year's budget were either donated or reused this year. For example, the polycarbonate, aluminum, thrusters, and tether wire was all received for free from donations and recycling. To keep the costs of our purchases and funding we created a Google spreadsheet which can be viewed in Appendix G.

Acknowledgement of Contributors

Phoenix Robotics would like to express its gratitude to the many contributors that have supported the company. Firstly, the company would like to thank Mr. Gajadharsingh for providing the tether cable, cutting the polycarbonate sheets, and disseminating his general knowledge to the team. We would like to thank Mr. Bowdoin for his substantial contributions and enthusiasm in supporting our team's goals. When it comes to budgeting we would like to thank Ms. Bonita and Ms. Trasks, their help procuring and spending funds was immensely helpful. The impact of our mentors' cannot be overstated, Mr. Fernandez and Ms. Fernandez supported the company with a space to work, tools, and transportation. Their support is the reason our company continues to achieve great success and we would like to thank them for their ardent passion and contributions to the company.

We also greatly appreciate the funds provided through our schools science fund through PDQ, Publix, and Brooks charities. Their funding allows the company to thrive and grow. Giving us the opportunity to create phenomenal products year after year and providing funds to travel to international competitions.

Lastly, we have to thank MATE. Their competitions create insurmountable opportunities and experience for our employees. Their competitions not only educate participants on environmental issues, but pushes them to solve them, which has impacted and positively influenced the company as a whole.

References

"Ranger Class Competition Manual." (2023). UN Decade of the Ocean: Diving into Inspire Solutions Because Together Opportunity Runs Deep. 2023 MATE Competition Manual.

"Make better material decisions." Matmatch. (n.d.), Retrieved May 24, 2022, from Mate 2021-2022 Manual. https://matmatch.com/

Moore, Steven W, et al. Underwater Robotics - Science, Design, and Fabrication. Nola Johnston.

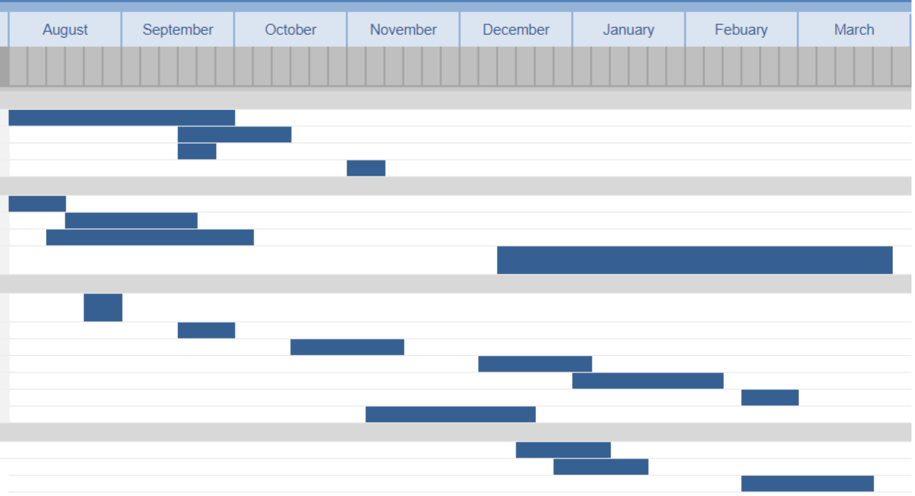
Brüggen, Norbert, et al. The Modeller's World. Traptel.

Appendices

Appendix A: GANTT Chart

Phoenix Robotics Project Schedule

TASK	START	END
Finance		
Fundraising	Mon 8/01/22	Fri 9/30/22
Budgeting	Thu 9/15/22	Sat 10/15/22
Purchasing Components	Wed 9/14/22	Tue 9/20/22
Calculating Spending	Thu 11/17/22	Sun 11/20/22
Mechanical		
Material Research	Wed 8/10/22	Sat 8/20/22
Frame Design	Thu 8/25/22	Fri 9/23/22
Claw Design	Sat 8/20/22	Thu 10/06/22
ROV Full Assembly With Electronic Components	Sun 12/18/22	3/27/23
Electrical		
Thruster Power Testing (bollard's test)	Tue 8/23/22	Fri 8/26/22
Testing Servos	Thu 9/15/22	Fri 9/30/22
Soldering Joysticks	Sat 10/15/22	Mon 11/07/22
Wiring Junction Boxes	Mon 12/05/22	Mon 1/02/23
Building Control Box	Thu 1/05/23	Mon 2/06/23
Assembiling Tether	Wed 2/15/23	Tue 2/28/23
Wiring Vertical Profiler	Mon 10/03/22	Tue 10/25/22
Software		
Coding Servos	Wed 12/14/22	Mon 1/02/23
Coding Thrusters	Fri 12/23/22	Fri 2/10/23
Coding Vertical Profiler/Wi	Tue 3/28/23	Sat 4/15/23

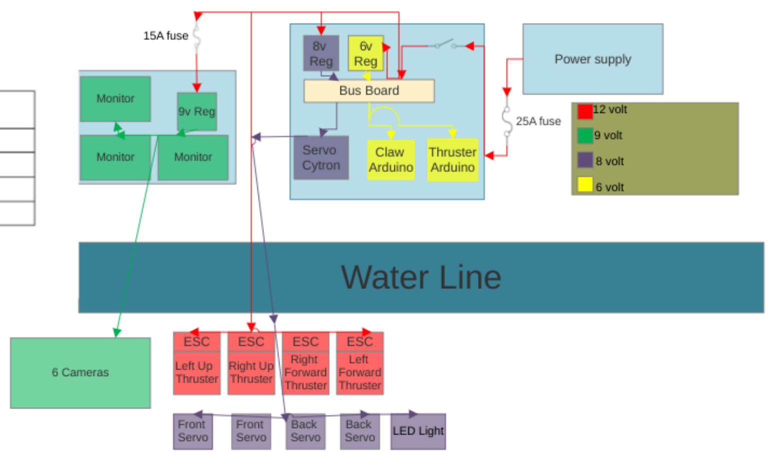


Appendix B: SID

Fuse Calculations

4 Diamond Dynamics Brushless Thrusters	3.25 amps each	13.5 amps total
6 cameras	0.3 amps	1.8 amps
4 servo motors	0.3 amps each	1.2 amps total
Overall	~	16.5 amps
Total amps	16.5 amps x 150%	24.25 amps

The ROV uses a 25 amp fuse.



Appendices

Appendix C: Thruster and servo code

```
#include <Servo.h>

// Joystick Settings
static const int JS_CENTER_0 = 512; // Analog reading at center, 0-1023
static const int JS_CENTER_1 = 512;
static const int JS_CENTER_2 = 512;
static const int JS_CENTER_3 = 512;
static const int JS_RANGE_0 = 511; // Analog range, 0-1023
static const int JS_RANGE_1 = 511; // Set to 128 for Parallax joystick
static const int JS_RANGE_2 = 511;
static const int JS_RANGE_3 = 511;
static const int JS_DIR_0 = 1; // +1 or -1
static const int JS_DIR_1 = 1;
static const int JS_DIR_2 = 1;
static const int JS_DIR_3 = 1;

// ESC/Thruster Settings
static const int MAX_FWD_REV_THROTTLE = 400; // Value between 0-400
static const int MAX_TURN_THROTTLE = 400; // Value between 0-400
static const int MAX_VERTICAL_THROTTLE = 400;// Value between 0-400
static const int MAX_VERTICAL2_THROTTLE = 400;
static const int CENTER_THROTTLE = 1500;

// Arduino Pins
static const byte JS_ADC_0 = A0;
static const byte JS_ADC_1 = A1;
static const byte JS_ADC_2 = A2;
static const byte JS_ADC_3 = A3;
static const byte THRUSTER_LEFT = 9;
static const byte THRUSTER_RIGHT = 10;
static const byte THRUSTER_VERTICAL = 11;
static const byte THRUSTER_VERTICAL2 = 6;

// Servos
Servo thrusterLeft;
Servo thrusterRight;
Servo thrusterVertical;
Servo thrusterVertical2;

void setup() {
// Set up serial port to print inputs and outputs
Serial.begin(38400);

// Set up Arduino pins to send servo signals to ESCs
thrusterLeft.attach(THRUSTER_LEFT);
thrusterRight.attach(THRUSTER_RIGHT);
thrusterVertical.attach(THRUSTER_VERTICAL);
thrusterVertical2.attach(THRUSTER_VERTICAL2);

// Set output signal to 1500 microsecond pulse (stopped comman
thrusterLeft.writeMicroseconds(CENTER_THROTTLE);
thrusterRight.writeMicroseconds(CENTER_THROTTLE);
thrusterVertical.writeMicroseconds(CENTER_THROTTLE);
thrusterVertical2.writeMicroseconds(CENTER_THROTTLE);

// Delay to allow time for ESCs to initialize
delay(7000);
}
```

Appendix D: Safety

General ● **Having a clean and neat work space to ensure efficient** ● **Wearing necessary PPE such as goggles and gloves.** ● **Checking equipment for abnormal**
Glowforge laser cutter **•wearing goggles if the refraction is intense enough to injury the eyes** **•making sure that the protective cover is fully closed** **•Checking for debris before and after to avoid damages.**
Soldering **•using proper PPE,like gloves and goggles, to protect oneself from harmful substances** **•utilizing proper tinning and flux use to ensure high quality soldering job to protect equipment and personnel from electrocution.** **•covering the finished solder with marine-grade heat shrink so to protect and prevent the wires from harm**

Appendices

Power tools **• Proper PPE such as masks to prevent inhalation of hazardous substances, goggles to protect one's eyes, and gloves to limit the harm to the hands.** **• ensure proper power wire handling to prevent a tripping hazard and damage to the cable itself.** **•proper tool placement to stop tools from falling off tables.** **• awareness of when a team member is using power tools**
3D printing **•avoid touching the nozzle to prevent heat injuries** **•maintaining a clean and efficient work space by chipping off excess filament.** **•file sharp edges down to prevent abrasion injures**
Setup, boot, and launch **•maintaining a clean work space** **•ensure all members are ready and on task** **• notify employees when powering on the ROV.** **• keep wires such as power and video wires neat and orderly to prevent damage to the control box and camera box.** **•plug in the camera/control box wires in carefully so as not to damage the wiring.** **•gently place the rov in the pool with regards to the tether as to not trip and cause damage to the tether and/or ROV**
Rov retrieval **•notify the deck crew when surfacing, so as to have them prepare for an efficient dock.** **•The pilot released control of the ROV to allow the deck crew to take the rov out.** **•The ROV is handled with 2 hands at all times to ensure that it isn't mishandled or dropped**
Rov maintenance **•check all electronics and sensors to make sure that they are nominal and that they are functioning properly** **• search for physical damage such as holes, water damage, abrasive damage, wear, and scratches to prevent critical damage and water infiltration.** **•after use in the pool, rinse the ROV in fresh water to mitigate chronic chlorine exposure** **•Run the thrusters for 30 seconds- 60 seconds after washing the ROV to prevent buildup in the motors from the chlorinated water.**

Appendices

Appendix E: Safety Procedures

Safety Procedures	
Daily Safety Inspection List: ❑ Inspection of hand tools and power tools to ensure that they are in good condition ❑ Perform a visual inspection of the work area. Be mindful of trips hazards (cords) and slip hazards (standing water.) ❑ An inspection of PPE for damage. ❑ Disposal of any damaged PPE. ❑ Review employees' daily work taste and ensure safety requirements are met. ❑ Inspect power components to ensure there are no shock risk. ❑ When working outside be aware of weather changes and act quickly to follow precautions in case of thunder or lightning. ❑ Inspect power source, plugs, power strips, etc, are in a safe and dry space to prevent damage or risk of shock to an employee. ❑ Set-up the workspace so that commonly used tools are within reach for efficiency and ergonomics ❑ Check controls to make sure they are functioning as intended before the ROV enters the water to be fully prepared for operation. ❑ Visual inspection of both ends of the tether ensure wires are connected. A visual inspection should be the first step. If a problem is suspected, confirm the power is off and perform further inspection.	**Operational Safety:** ❑ 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. ❑ Employees are all responsible for identifying and reporting potential risk 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 ❑ The tether monitor will ensure the tether 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 of 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.

Appendices

Appendix F: International Budget

MATE ROV International 2023 Budget				
Income				
Source				**Amount**
Previously Funded				$750
Donations from Derrick Brooks				$16,325
Donations from PDQ				$300
Donation from Publix				$200
GoFundMe Donations				$200
Science Fund				$5,000
Expenses				
Category	**Description**	**Type**	**Projected Cost**	**Budgeted Value**
Frame	Polycarbonate	Donation	$250	$250
Electronics	Servos	Purchased	$80	$80
Cameras	N/A	Purchased	$250	$250
Vertical Profiler	Materials and Electronics	Purchased	$200	$200
Marketing Display	Corrugated Panel, Printing	Purchased	$150	$150
General	Controllers, PVC	Purchased	$150	$150
Wire	Claw, Motor, Tether wire	Purchased, Re-used	$175	$175
Travel				
Regional Travel	Gas, Hotel costs	Purchased	$3,500	$3,500
Internation Travel	Plane Tickets, Hotel, Van, Gas	Purchased	$16,325	$16,325
			Total Income	$22,775
			Total Expenses	21,080
			Profit	$1,695

Appendices

Appendix G: Accounting

Date	Type	Category	Item	Amount	Remaining Balan
N/A	Donation	Funds	Previous Left Over Funding	(+7000)	$7,000
N/A	Donation	Funds	PDQ Gift Card Fundraiser	(+$760)	$7,760
N/A	Donation	Funds	Publix Charities Donation	(+$250)	$8,010
N/A	Donation	Funds	Parent Monetary Donations	(+$208)	$8,218
N/A	Donation	Funds	Go Fund Me Donations	$100	$8,118
2/7/23	Donation	Electronics	100 ft Tether Wire	$60	8,058
12/22/22	Donation	Materials	2 Polycarbonate Sheets	$365.00	7,693.00
2/7/23	Donated	Materials	10 Aluminum 3" Carabiner D Ring Clips	$9.99	7,683.01
N/A	Reused	Materials	Aluminum frame	$30	7,653.01
N/A	Reused	Hardware	4 Diamond Dynamics 1.2 Thrusters	$256	7,397.01
3/4/22	Reused	Materials	3 Pool Noodles	$4	7,394.01
N/A	Reused	Materials	Vertical Profiler PVC Housing	$9	7,386.01
N/A	Reused	Materials	2 Acrylic Custom Laser Cut Claws	$4	7,382.01
4/17/23	Purchased	Materials	2 Air Bladders	$11	7,371.01
2/7/23	Purchased	Materials	Gallon Bucket with Gasketed Lid	$25	7,346.01
2/7/23	Purchased	Materials	15 Full Thread Zinc Hex Tap Bolts	$9.06	7,336.95
2/7/23	Purchased	Materials	10 5/16-18 Brass Hex Nuts	$4.99	7,331.96
2/7/23	Purchased	Hardware	2 Mini 360 Degree Servo Motors	$15.99	7,315.97
2/7/23	Purchased	Materials	50 ft 2" Braided Tether Sleeve	$75.00	7,240.97
2/7/23	Purchased	Materials	1" Coupling Pipe Fitting	$7.70	7,233.27
2/7/23	Purchased	Materials	10 Zinc Plated U Bolts	$14.99	7,218.28
2/7/23	Purchased	Materials	Envirotex Pour On High Gloss Finish	$19.99	7,198.29
2/7/23	Purchased	Materials	Platypus Softbottle Flexible Water Bottle	$12.95	7,185.34
2/7/23	Purchased	Materials	2" Female Adapter PVC	$5.58	7,179.76
2/7/23	Purchased	Electronics	30 5mm Photolight Resisters	$5.99	7,173.77
2/7/23	Purchased	Materials	4 10 mL Syringes	$7.99	7,165.78
2/7	Purchased	Materials	5 Goture Soft Fishing Lures	$13.90	7,151.88
2/7/23	Purchased	Hardware	Wireless charger PCBA Circuit Board with Coil Pad Charging	$8.69	7,143.19
2/7/23	Purchased	Hardware	Panel Mount Housing for Two Anderson Powerpole Connectors	$26.99	7,116.20
2/7/23	Purchased	Materials	Plasti Dip	$19.99	7,096.21
2/7/23	Purchased	Electronics	3 7" Digital HD Color Screen Monitoring Displays	$120	6,975.21
12/28/22	Purchased	Electronics	6 270 Degree Servo Motors	$94.47	6,881.74
11/20/22	Purchased	Electronics	6 Waterproofed Fishing Cameras	$65.00	6,816.74
4/10/23	Purchased	Materials	9 Volt Battery Holder with Switch	$6	6,810.74
2/7/23	Purchased	Materials	Screws	$68	6,801.75
4/21/23	Purchased	Materials	2pcs Micro Brushless Pump	$15.00	6,786.75
2/7/23	Purchased	Materials	Fuel Lne Hose Water Pipe Air Tubing Spring Clamps	$12.96	6,773.79
4/15/23	Purchased	Materials	Tygon Tubing	$9	6,764.79
4/15/23	Purchased	Materials	5/16" Fuel Check Valve	$10.50	6,756.29
3/25/23	Purchased	Materials	80mm Metal Axial Thruster Shrouds	$25.00	6,729.29
2/7/23	Purchased	Materials	Vinyl Pinstroping 1/8" Tape	$12.99	6,716.30
2/7/23	Purchased	Electronics	50Pcs 5mm LED Lights	$7.99	6,708.31
2/25/23	Purchased	Materials	Waterproof IP65 ABS Plastic Junction Box Enclosure	$35.00	6,673.31
2/7/23	Purchased	Materials	16 Cable Clips	$7.99	6,665.32
N/A	Purchased	Materials	Compressed Foam	$16.50	6,648.82
N/A	Purchased	Materials	Acrylic Sheeting for Control Box	$15.50	6,633.32
2/7/23	Purchased	Materials	240 pcs Breadboard Jumper Wires	$9.99	6,623.33
				Total Spent	**$1,555**
				Final Balance	**$6,623.33**