PHOENIX ROBOTICS
Tampa, Florida

Brooks Debartolo Collegiate High School
(Tampa, Florida)

Technical Documentation

Meet the Team:

- Paul Fernandez ‘19 **CEO, Design Engineer, Senior Advisor**
- Natan Egosi ‘20 **Software Engineer, Electrical Engineer, CTO**
- Matthew Fernandez ‘21 **Pilot, COO, Safety Officer**
- Eryk Chazares ‘21 **Company Documentation Officer (CDO), Company Development Officer (CDO)**
- Nicholas Tassistro ‘21 **Co-Pilot, Claw Manager**
- Jadon Jackson ‘21 **Tetherman**
- Julie Fernandez ‘22 **Prop Designer, CFO**
- Joud Elsherbiny ‘22 **Assistant Tetherman, Underclassman Representative, Poolside Mechanic**
- Sam Glow ‘22 **Diver, Assistant Tetherman**

Mentors:

- Eric Fernandez
- Chris Hochman

BROOKS DEBARTOLO
COLLEGIATE HIGH SCHOOL

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Abstract

In response to the request of the Eastman Chemical Company for the creation of a remotely operated vehicle that can navigate the freshwater environments of the Kingsport area, the Phoenix Robotics team presents the U.S.S. Phoenix. The vehicle has proven able to accomplish tasks of monitoring the Boone Dam foundation, maintenance of local waterways through water quality analysis, and recovering as well as identifying Civil War era artifacts.

The U.S.S Phoenix team has always focused on improvements, this year being 3D printed thruster shrouds and a stronger motor system for better mobility in inspecting the dam foundation. The utilization of a torque efficient claw with rotational capacities furthers the vehicle's ability for retrieval and transportation of artifacts and water quality equipment. Also included is a user-friendly control system for improved navigation along the various rivers and a specialized micro-ROV for a more precise analysis of possible leakage in the dam structure.

The Phoenix Robotics team, a subsidiary group of the Science & Technology Club, will be going on its 7th year to the MATE ROV competition and is made up of a company of 9 personnel. The individuals chosen for the team represent the best that Brooks DeBartolo Collegiate High School Science & Technology Club has to offer, being both flexible and professional in a multitude of situations. The combination of excellent members and resources has all contributed to the assurance that the U.S.S. Phoenix is the most capable vehicle at completing the given tasks.

Company Overview

a. Structure

Our company is comprised of 9 members. During the past months, the 9-person company spent more than 2000 man-hours in a tireless educational journey, starting with five new members to the team this year that were fascinated by engineering. They can now program a fully-fledged ROV that has a computer interface and can perform image processing. Also, there were others who knew very little about sealing and product design and can now build a stable submersible vehicle that can stand more than 48 hours of water test.

b. Project Management

We believe a successful project starts by an unwavering trust and proper communication between all team members. We set a SMART (specific, measurable, attainable, relevant, and timely) goal to keep team members oriented and on track of the priorities. A timeline was laid out by experienced team members who competed in last year's MATE ROV international competition and were assisted by the sponsor. While developing the project plan, we ensured that each member in the company had a specific responsibility that represented his or her strength, while allowing them to improve their weaknesses. The design of the vehicle was pursued for a number of reasons, one of which was increased hydrodynamics. It was also created with modularity and flexibility in mind allowing for a versatile amount of area for peripheral payloads. In regards to the testing of the design and basic troubleshooting there were many attempts towards the refinement of the vehicle in order to ensure that the objectives were met. In early September, the new members were trained by returning members and were taught basic skills of how to solder, important communication skills, and the basics of tether management. By the end of the training, under the guidance of our veterans, they began working with the team. The training helped them learn quickly the process of building and maintaining an ROV from scratch. The mechanical engineers started by searching for improvements based on previous years' designs. Beginning with the shrouds, testing many prototypes took place before selecting the best design. Senior advisors offered their feedback to correct design flaws in order to avoid operational issues that might appear later in fabrication. Furthermore, after fabrication it went through many modifications before finding the best design. The design of the electrical system has to satisfy also the restrictions that mechanical engineers put, which is why there were weekly meetings before the design of the system and the suggested modifications. Before integrating the system, a unit testing must be applied on every sub system.

Design Rationale

- The brains behind the motor control system- an Arduino Uno controlled by two joysticks, connected to an 8-piece relay board- is very robust, and runs on original code that takes the input from the joysticks, and converts it to 3 dimensional motion of the ROV. The programing of the Arduino allows for the ROV to move in diagonals, as opposed to simply straight lines, which further decreases the amount of time it takes to complete a task.
- When designing our ROV, the frame was created in a way in which it is adaptable in order for it to accommodate changes. This allows our company to engineer a way to do all necessary tasks. 3D printed shrouds were designed to fit on our thrusters and meet all safety requirements. The control box was designed using a relay board following arduino code.
- The engineering design process was pursued in the fabrication of the vehicle, however, due to the versatility of previous designs, certain aspects simply innovated upon existing systems. The tasks provided by the competition for this year would require the implementation of a gripper system, micro-ROV, tether management system, and a thermometer. Through an appropriate understanding of the tasks and what was being asked, innovation could then commence. Methods utilized by professionals in solving similar situations as well as analyzing parallel systems from previous years would suffice for the significant portion of the research. The specific solutions were then approached in order to satisfy the conditions asked, such as a calibrated thermometer that runs the length of the tether in order to accurately record temperatures. Various prototypes of each system were made and troubleshot. Several thermometers were utilized prior to finally choosing the most accurate and reliable system. This process was utilized for each system and for the actual construction of the frame.
- Before determining the motor position on the frame of the ROV, we took measurements of thrust capabilities of motors. Based on these values, we determined where the best positions of the motors should be. For example, by putting the forward/backward motors in the back corners of the ROV, they create a larger torque when turning the ROV. This affected the design of the ROV for optimal motor placement. Thrust capabilities of each motor was done with the ballard test, which use torque measurements to determine the thrust.

Vehicle Features

· 2 axis-motor controlled claw -Enables the machine to manipulate its environment
This function may have use in remotely operated robots designed to pick-up and open objects.

· 5 high-definition waterproof cameras -Gives the operators visual and spatial awareness when performing task
Waterproofed cameras have an important function in machines built to communicate visuals from underwater to an above land station.

· Hydrodynamic Aluminum frame -Machine quickly maneuvers through the water and makes more efficient use of motors
When designing a machine used to maneuver underwater, a light, aluminum frame must be used to keep movement efficient.

· Measuring system -Gives Operators standardized system to determine object dimensions
Allows for the easy communication of measurements.

· Magnetic OBS release system -Data collected from OBS released safely to surface using electromagnets which must be purposefully activated
The use of electro-magnets that can be purposefully activated allows for the transference of information easily.

Build vs Buy, New vs Used

The inclination of the team was always to recycle materials from decommissioned machines or current inventory. Recycling and incorporating "used" components is important to our company because it reduces overall machine costs, material acquisition time and environmental impact. However, the reality of used components is that materials may be inconsistent to design specifications and potentially unusable. A citable example is the recycling of PVC piping. PVC piping, when new, is a fantastic material due to its structural strength to withstand sub-surface pressures, modularity, viability and relative inexpensive cost. But, when recycled PVC piping is used it may be cut in incorrectly in undesirable ways or useless lengths. It may also have been subject to epoxy adhesives that are difficult to separate from PVC fixtures for reuse. Most times, "new" materials are preferred, their condition are in line to standards, and tolerances. While this is true, our company advocates for reduction of human waste in the environment.

The purchasing of materials or the “buy” tactic in creating an ROV also boasts of both positive and negative attributes. Buying certain components is a necessary evil.
There is a general quality to ready-made motors, cameras, etc. a quality that is supported by manufacturers in warranty and technical specifications such as electrical information as well as equipment capability. In addition, some components may not be practically built, thus purchasing them is more intelligent. However, there are limitations with buying some components. Some complete systems such as complete control boxes and even entire machines cost in upwards of tens of thousands of dollars. If these expenses were decided it could double or triple the cost of the machine, making it more difficult to replicate, and making it more difficult to market to shareholders.

Building means creating from individual components/ materials. Effectively built parts are created with much planning and respect to other systems of the machine.
Built parts are also created by members of the Team, if they are responsible in coordinating their plans and sharing information, such components can be serviced, troubleshot and maintained accordingly. Unfortunately, built components take the most time create. The human condition also prevents them from being without flaw. As mentioned previously, built parts can be the most desirable, when they are properly implemented, and their information is accessible. This does not happen in most cases, designs are sometimes created with more creativity at the trade off an elementary understanding of architecture. The skill of the builder is variable.

Safety

The vehicles safety features include: shrouds to protect from laceration due to propeller revolution. The coloring on the shrouds matches OSHA standard *1910.44*, yellow to mark “marking physical hazards such as: Striking against, stumbling, falling, tripping, and "caught in between." Other safety features include fuse boards, a fuse running to each component module for every pair of motors and a main line fuse running from the power source to all systems of the ROV. An additional switch is in place on the PD8 power distribution module to allow for analog electrical system disconnect.

Safety Procedures

When doing a wet system operation test, there is a risk of electrical shock or electrocution, thus our company checks all waterproof and insulation elements prior to putting our ROV near water. We use the proper amount of voltage for a given fuse in order to prevent overvoltage. Additionally, to prevent electrical fire from damaged components, our company checks for proper insulation of all wires and electrical components. For the safe transportation of the U.S.S. Phoenix, two members are required to transport it in order for it to not be dropped or damaged. To keep our company members safe, each individual must wear safety goggles at all times and wear gloves when using power tools.

When operating our machine, we utilize a variety of checklists in order to ensure the safety of company members and avoid damage to the ROV. Our checklist for basic product demonstration procedures includes checking of all system fuses, the assurance of functionality of all systems, the securement of the micro-ROV, the proper organization of wiring, and the overall stable mounting of all components.

Motor Shrouds

Advantage:

Protect from laceration due to propeller revolution

External power supply

Advantage:

Protected from water

Allows for control shut off

Smoothed frame

Advantage:

- Prevents lacerations when handling frame

Fuse boards

Advantage:

- Controls Amperage to safe levels

Voltage Regulators

Advantage:

- Controls Voltage to safe levels

3D Printed Shrouds

Advantages:

Allow people handling the ROV to be protected from injury

Are easy to see due to yellow coloration

System Labeling

Advantages:

Prevent misinterpretations leading to hazardous accidents

Soldered and Shrink Wrapped Joints and Junctions

Advantages:

Reduces risks of shorts

Troubleshot Arduino Code

Advantages:

We know the ROV will always function in a safe manner

Ventilated Electrical Systems

Advantages:

The electrical systems will not overheat

Marketable Features

Adaptable control system

Easy to use and repair power/distribution system

Well-organized control box

Camera positions can easily be changed

Arduino code can be changed for the control box if needed

Programmed ROV to move in diagonals, which saves time

The ROV is capable of:

Removing debris

Identifying object's color and size

Testing magnetization

Testing water temperature of a given space

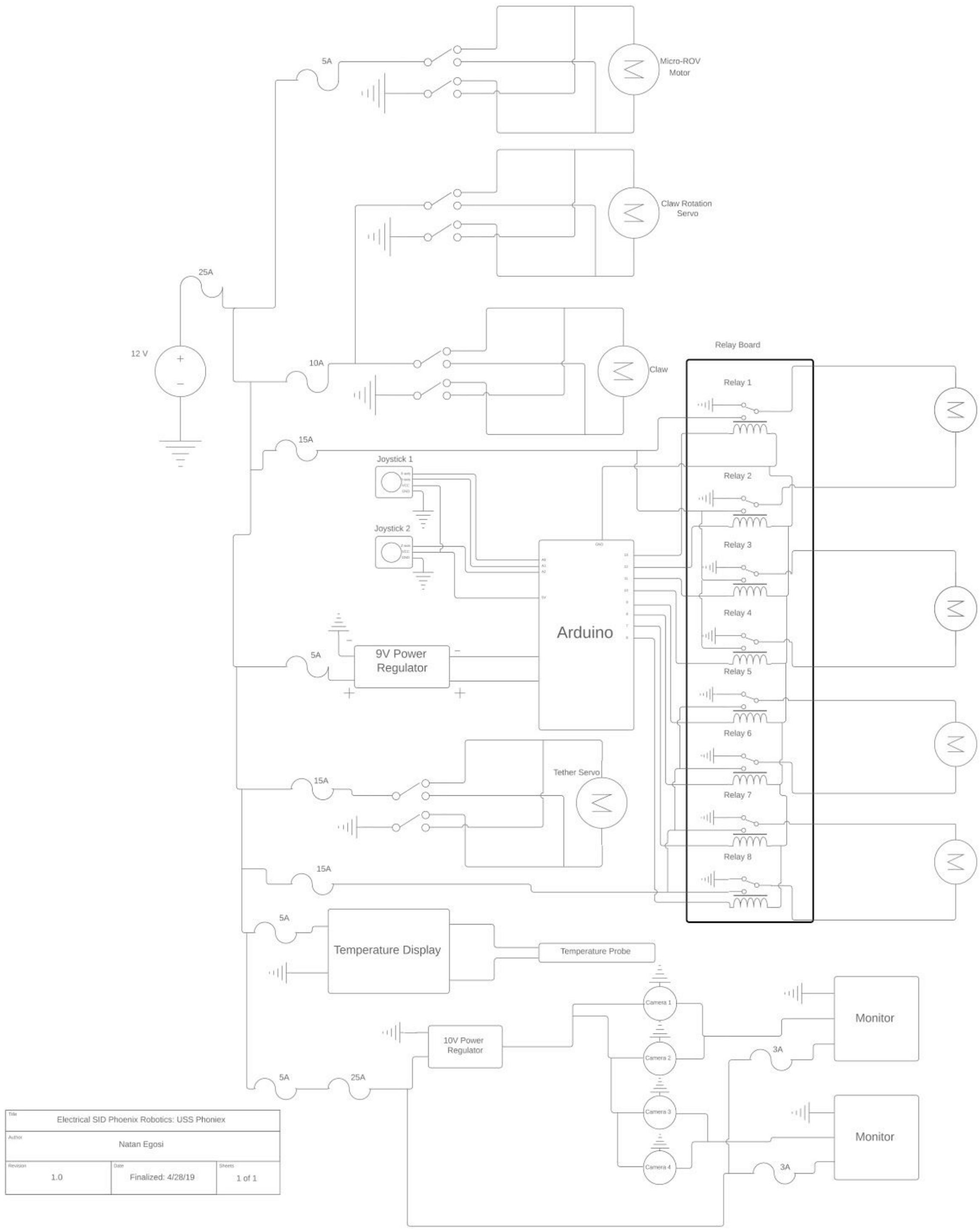
Fitting into restricted spaces through the use of a micro-ROV

Design Features:

Motors have been upgraded from 1000 gph to 1250 gph

This makes the ROV faster and able to lift more

SID


5A
Micro-ROV
Motor
Claw Rotation
Servo
25A
12 V
10A
Claw
Relay Board
Relay 1
15A
Joystick 1
Relay 2
Joystick 2
Relay 3
Relay 4
Arduino
5A
9V Power
Regulator
Relay 5
Relay 6
Tether Servo
15A
Relay 7
15A
Relay 8
5A
Temperature Display
Temperature Probe
Camera 1
Monitor
10V Power
Regulator
Camera 2
3A
5A
25A
Camera 3
Monitor
Camera 4
3A
Electrical SID Phoenix Robotics: USS Phoniex
Natan Egosi
1.0
Finalized: 4/28/19
1 of 1

Critical Analysis

Testing and Troubleshooting

As the systems for the ROV were being constructed, they were all troubleshot individually in a thorough manner, and then troubleshot once again after they were all combined. As a whole, the ROV was tested in various ways: The motors were tested on the ROV to determine lifting capability, and to determine if the ROV would be more efficient with a more positive buoyancy level, or a more negative one. This task was done multiple times to determine the acceptable buoyancy.

We decided to use 3D printed shrouds for the ROV using PLA plastic, as it is an eco friendly material. We designed a prototype initially, which we printed and actively tested in the pool prior to competition. After testing and noting where we can improve, we redesigned it, and adjusted infill percentage for the 3D print, outer wall thickness, and other factors that add strength and aesthetics to the final product. In the pool, the ROV's speed was tested by calculating how fast it can move from point to point. This was done for both the forward and backward direction. Based on this, we determined whether we want to adjust the propeller shape to give us a higher speed for one direction, while reducing speed in the other. We decided to keep speed advantages of forward and backward at a minimal level, so we can have a good speed moving in all directions.

Challenges

One of the technical challenges we faced this year included finding a good way to mount or vertical motors. We designed a 3D printed mount which we attached to the ROV and tested in the water, but we soon noticed that our design created weak points in the printed part, which -if used further- could lead to part failure. So we went back to our CAD software and discussed an improved design, which we printed with a different infill density, wall thickness, and other settings that improve strength. Now we have a strong, functional, and environmentally friendly vertical motor mounts.

A major challenge in any team is communication. Within our group, we were facing issues with listing all necessary tasks at hand, and then assigning said tasks to certain people, and then tracking their progress. This isn't a simple task to do with just a group chat. This issue was solved when one of our members brought up a free team organization software that is now an integral part of our team interworking. We use it daily, and can track each member's progress with their individual and group tasks.

Lessons Learned

Our team learned about the importance of prototyping and testing before putting anything permanent on the ROV. This was especially important when it came to 3D printing. Because 3D printed parts are used throughout our ROV, we were quick to learn about which designs (shapes, infills, patterns, etc.) were important to consider when designing a part.

The team also learned about how communication is crucial to have efficiency and continuous progress. When leaders and team members cannot communicate effectively, then there are increased chances for misunderstandings, which in turn creates higher chances of mistakes. We saw this in action right as we started using our organizational software. Communication increased, everybody could see what everyone else was doing and the progress they were making, and we began moving much faster then we had been in the past.

Our team members developed the skills to 3D design a variety of useful systems using TinkerCAD and 123D Design. They also developed better communication and team building skills involved in navigating and actively using the team organization software.

Future Improvements

Reflection

- Our company has had major improvements in our leadership and overall organization to allow our company to work together and inspire creativity amongst the members of the company.
- We consider our company's leadership and organizational strategies to be our best feature. As for our ROV, we have a very adaptable frame that allows us to accommodate numerous modifications. This gives our team the ability to improve various systems without needing to change the entire design of our machine.
- Improvements that could be made to our ROV include having better shrouds, improving the build quality and materials used to build the ROV.
- The most rewarding part of this experience is learning background information about the state we will be visiting. Our company sees each meeting as a time to work together and help each other succeed as we notice each individual's' weaknesses. .
- In preparation for this event, our company has improved with general management. Additionally, returning members have had the opportunity to teach new members skills such as soldering, tether management, basic electricity, and how to use various other tools.

The Phoenix Robotics team's vast ambition worked both with and against the creation of the most complex ROV that has come out of Brooks DeBartolo. The knowledge we have gained this year will be instrumental in the advancements of future Phoenix members. Firstly, we took on a vast amount of new and unknown technology this year. This includes our using servos for the claw, which took their own layer of coding and hooking up, plus an entirely new waterproofing process. We also built an entire new frame out of aluminum, which is not what we usually use. This took up quite a bit of time and had a learning curve to it just like anything else. Stepping out of our comfort zone however helped us figure out what new technologies we had to our disposal as well to what worked versus what didn't. There was also the challenge of taking up a more robust claw, which had its own challenge mounting and managing it correctly. With some of the new equipment we had to use unique forms of waterproofing because these types of things were never dealt with previously. We had to adjust the brain of our machine to these new types of hardware, as well we be aware of increased need on our power sources. Also, we had the problem of losing some of the experienced members from last year, so everybody had to step up to the plate and take up new jobs and positions. There is a huge variety of different aspects of this machine that changed from previous years, and that we had to be flexible with and integrate it with our previous knowledge. All of this opens a gateway to future Phoenix ROV members with new ways to make an effective ROV, as well as help us make ours. Time was a crunch all the way through, but in the end the hours we put in were worth our outcome. Overall this year was a big step for Phoenix Robotics and we will make next year even better.

Accounting

Budget

Suggested Budget (Air Travel)

Date	Category	Description	Notes	Amount
6/17, 6/23	**Flight**	Flight to Tennessee	There & Back	$1,760.00
6/17-6/23	**Hotel**	Hampton	4 Rooms	$3,467.00
6/17-6/23	**Gas**	Fuel Costs		$200.00
6/17	**Mate Costs**	Additional Charges		$200.00
6/17-6/23	**Cars**	Rental from Enterprise	Truck and Van	$800.00
6/17-6/23	**Misc.**	Additional Necessary Expenses		$300.00
	Total			**$6,727.00**

Cost Accounting

Item	Cost	Quantity	Total
10 count WGCD Joysticks	$11.95	1	$11.95
Dual Wad Heat Shrink	$14.95	1	$14.95
Rubber grommets 19mm	$ 6.25	1	$6.25
Rubber grommets	$ 6.99	2	$13.98
Robotic Claw	$ 9.95	5	$49.75
Motors Bilge Pump	$28.53	6	$171.18
12x12 Acrylic sheets	$41.00	4	$164.00
Relay Boards	$10.99	8	$87.92
Test Thermometers	$15.00	3	$45.00
Phosphate Test strips	$7.00	1	$7.00
LEDs	$31.00	1	$31.00
Liquid Wrench Marine Grease	$7.50	1	$7.50
Mechanical fish reels	$16.95	1	$16.95
MATE pH test strips	$7.91	1	$7.91
TEKTON hose	$11.07	1	$11.07
Vanxse Sony mini spy camera	$16.99	1	$16.99
MATE soft led fish	$8.99	1	$8.99
Schumacher AC/DC power converter	$15.99	1	$15.99
Brill’s AC/DC power adapter	$24.90	1	$24.90
Inner tubes 10 x 3	$11.87	2	$23.74
Annioms 20kg digital servos	$17.89	3	$53.67
Sport hand pump	$17.58	1	$17.58

Speed Kills Latex Bladder	$9.99	2	$19.98
DIY micro-rov camera	$27.99	1	$27.99
Temperature control	$18.95	1	$18.95
Digital Thermometer	$16.16	2	$32.32
Citron 10 DC motor drive shield	$26.00	3	$78.00
Miscellaneous items			$142.90
Recycled items			$1,000.00
TOTAL			$2,128.41

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