

HMS SeaBots: Ranger Team

Harrington Middle School

Mount Laurel, NJ 08054 USA

An After School Extra-Curricular Program

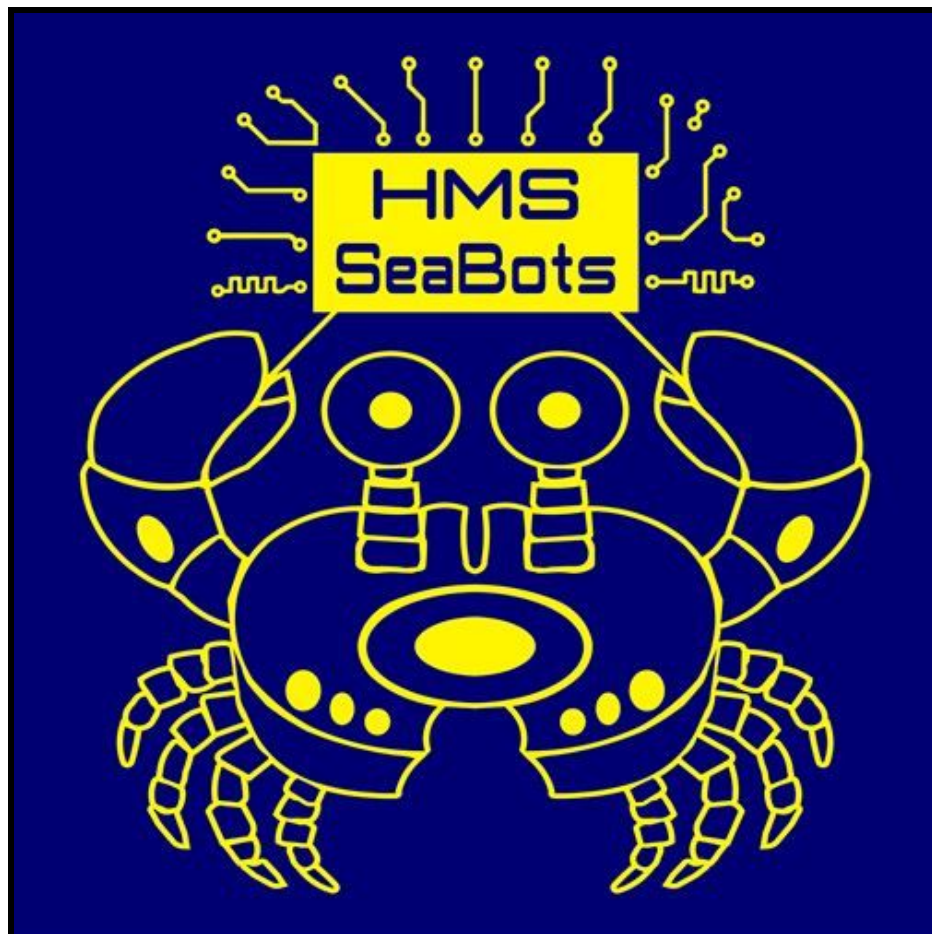
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2016 MATE International ROV Competition
Technical Report

Table of Contents

Section	Page
1. Abstract	2
2. Acquisition and Application of Technical Skills	2
3. Description of Project Management	3
3.1 Team Schedule	3
3.2 Company Flowchart	3
3.3 Team Assignments	4
4. Understanding of ROV	5
5. Mission Descriptions and Point Values	6
6. Design Rationale	7
6.1 Corporate Team Memory	7
6.2 Frame and Flotation	7
6.3 Tether Wiring	8
6.4 Control System	8-10
6.5 Manipulator Arm	11
6.6 Cameras	11
7. Control Box Circuitry	12
8. System Decisions (New vs. Reused/Commercial vs. Original)	13-14
9. Systems Integration Diagram (SID)	15
10. Technical Flowcharts	16
10.1 Hardware Flowchart	16
10.2 Software Flowchart	16
11. Safety Philosophies and Features	17
12. Job Safety Analysis	18
13. Challenges: Technical and Non-Technical	19
14. Lessons Learned	20
14.1 Technical	20
14.2 Interpersonal	21
15. Reflections	22
16. Troubleshooting Techniques	23
16.1 Control Box	23
16.2 Arduino	23
17. Future Improvements	24
18. Budget	24
19. References and Acknowledgements	25
19.1 Sponsors	25

1. Abstract

Our company is a new division of the HMS SeaBots, who were established in 2014. Our goal is to produce exemplary underwater remotely operated vehicles. Our company consists of mechanical engineers, electrical engineers, and software engineers who each bring their special skills and expertise for building a great product. All of our engineers are also responsible for marketing tasks. Our current vehicle is specifically designed to complete missions from the Gulf of Mexico to Jupiter's Moon Europa. Our electrical engineers have built a state-of-the-art control box stocked with Sabertooth circuit boards and potentiometers. Our ROV also features neutrally buoyant tether to prevent any possible tether issues while performing the missions. We used the MATE Triggerfish Vector design as a base model, although we reduced the frame size to allow us to maneuver the ROV more efficiently and effectively. Our ROV control box features two SainSmart Arduino Uno boards. The first Arduino controls our manipulator arm's HiTec HS-646WP Servo using a potentiometer. The arm's gripper will give us the ability to pick up samples and objects. The second board is used to relay data from a DS18B20 Temperature Probe back to an LCD Keypad Shield mounted in the control box. The sensor will allow us to measure the heat of the venting fluid in the Mission to Europa. The HMS SeaBots believe our ROV is well suited to perform in the harsh environment of both inner and outer space.

2. Acquisition and Application of Technical Skills

Each member of our team is extremely experienced in underwater robotics.

- We have all taken a STEM ocean exploration class at Harrington Middle School in which we learned *why* and *how* our oceans are explored, and then worked on teams of four to build fully functional ROVs.
- For the past two years, we have all been members of two different underwater robotic teams.
- In the summer of 2015, four of our members took a MATE online summer workshop entitled "Diving into underwater sensors and Arduino" so that we would be able to incorporate the Arduino Uno into our ROV. After learning the basics of Arduino, we decided to use a microprocessor to control both a temperature probe and manipulator gripper.
- Last year, three of our team members had the opportunity to attend the 2015 MATE Pennsylvania Regional Competition, where two of us were able to join the HMS SeaBots Ranger team on the pool floor. Here we gained valuable experience which has helped us in preparing for the 2016 MATE Pennsylvania Regional Competition.
- In February, two of our team members had the opportunity to attend the 2016 Villanova ROV Workshop to acquire more information to prepare for the competition.

All of these experiences have provided our team with a strong foundation and understanding of remotely operated vehicles. We feel we are well suited to provide NASA and Oceaneering Space Systems a team and a ROV that are capable of completing all the Gulf of Mexico to Jupiter's Moon Europa tasks.

3. Description of Project Management

As a team, we planned our entire year’s work on day one. We laid out the work on a spreadsheet to increase our productivity and maximize work efficiency. Sections of the technical report were given to people based on their chosen engineering position. Following our original schedule, our team members worked effectively and efficiently to complete all aspects of our project. For example, while some of us were working on the shrouds for the motor, others were working on a design for the manipulator arm and ROV. To make sure the schedule was being followed, our CEO made sure everyone was on task and working on essential pieces of the technical report and/or the ROV. Even though we fell behind at times, we feel the schedule allowed us to get our product materials ready for our clients.

3.1 Team Schedule

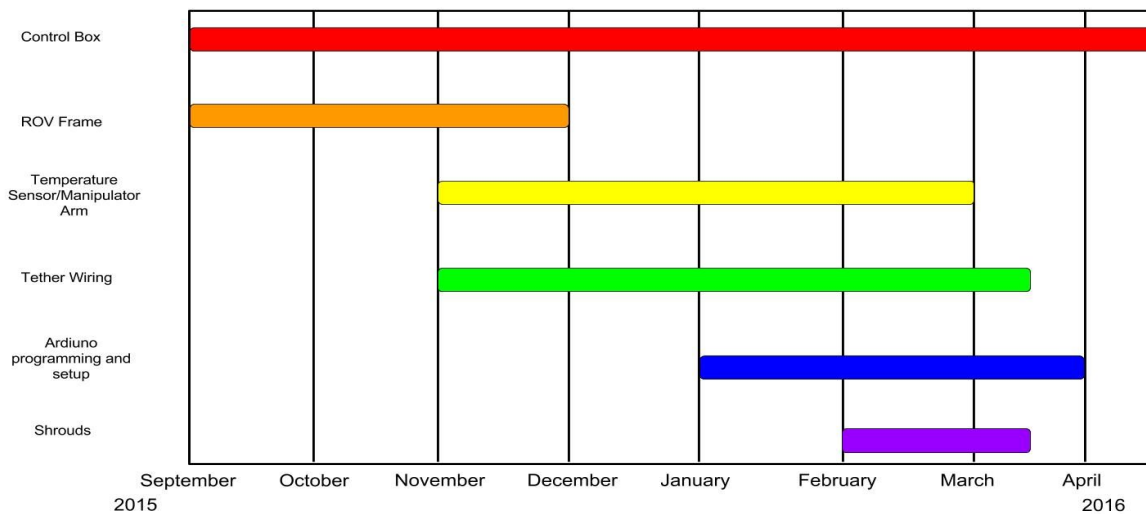


Figure 1: Gantt Chart Showing the Year’s Plan for the ROV Completion

3.2 Company Flow Chart

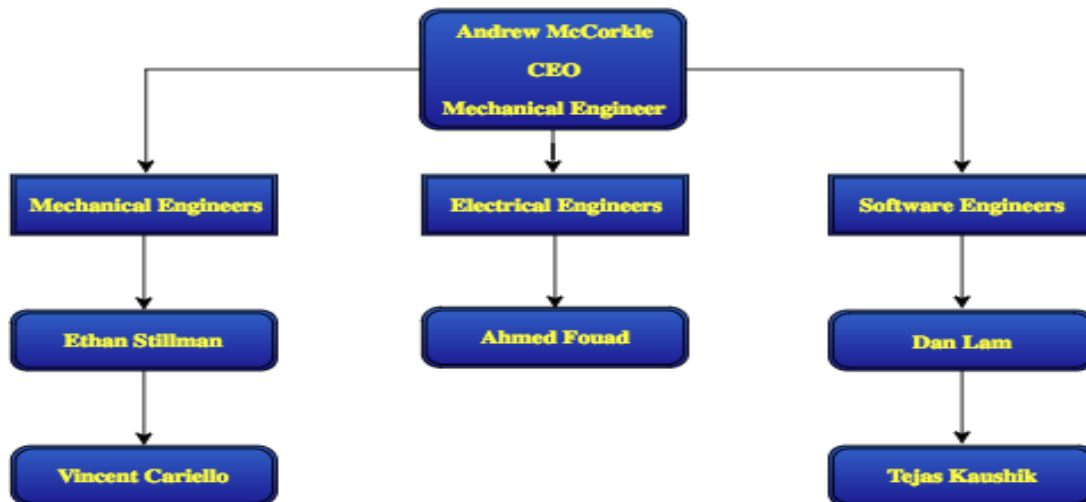


Figure 2: Defines Members and their Roles

3.3 Team Assignments

Mechanical Engineers	Electrical Engineers	Software Engineers
<ul style="list-style-type: none"> ❖ Design and build the ROV frame, modeled after the basic MATE Triggerfish Vector design. ❖ Research shrouds and then design the most efficient shrouds possible to be 3D printed. ❖ Work on the placement of the gripper, as well as the temperature sensor. 	<ul style="list-style-type: none"> ❖ Assemble the control box and solder all of the connections. ❖ Waterproof all the electrical connections. ❖ Connect the ROV to the control box. ❖ Illustrate the SID. 	<ul style="list-style-type: none"> ❖ Assemble the manipulator arm. ❖ Program the Arduino for the manipulator arm and the DS18B20 temperature sensor. ❖ Work with the electrical engineers in the wiring of the Arduino board and breadboard in the control box.

Figure 3: Job Descriptions

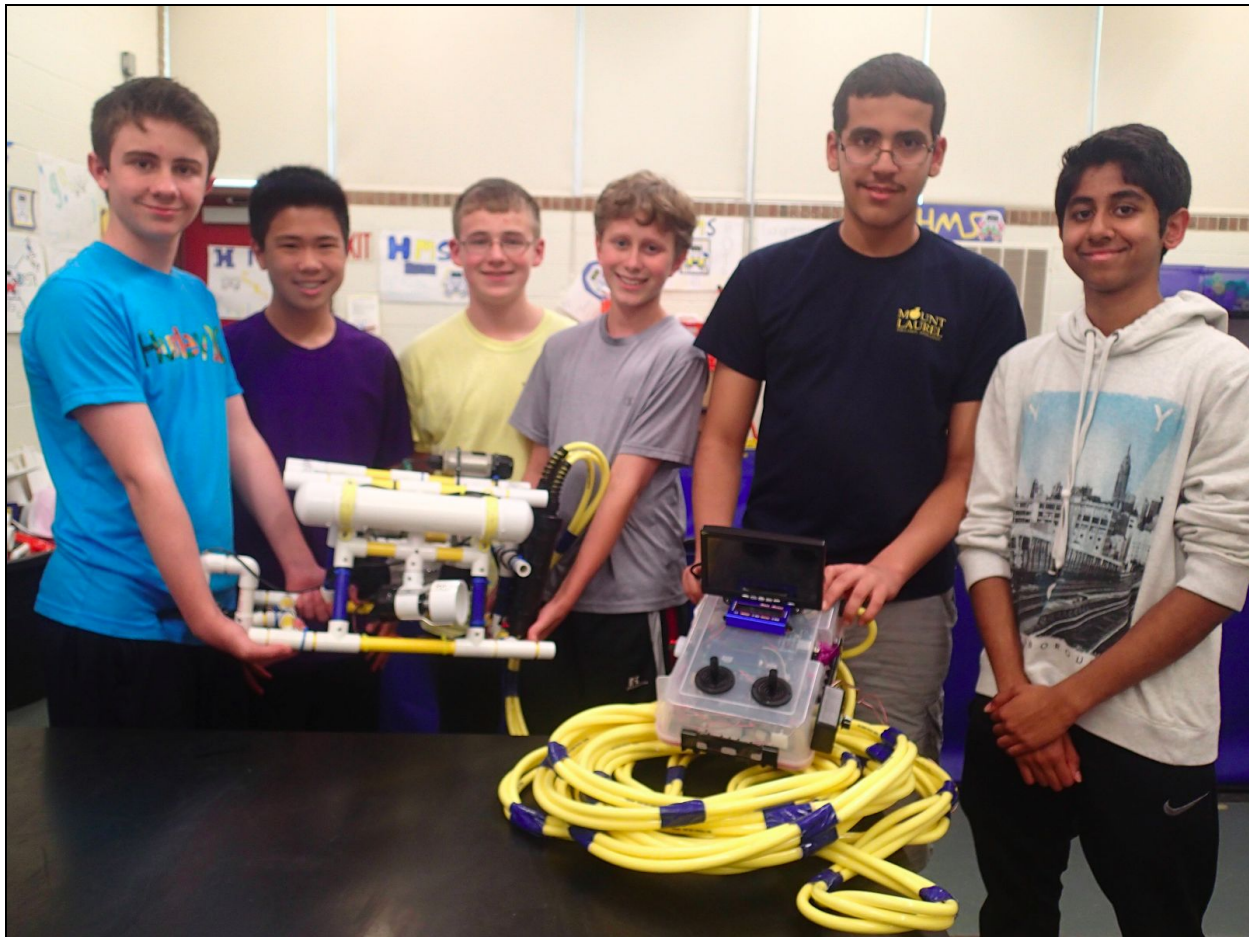
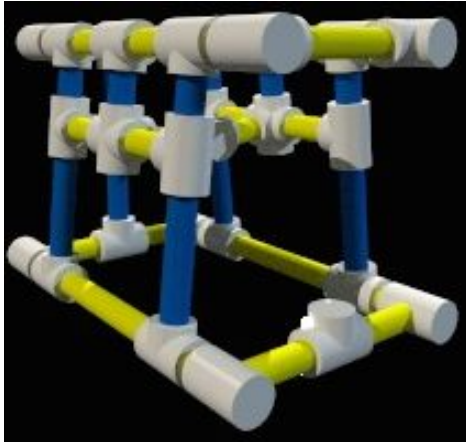


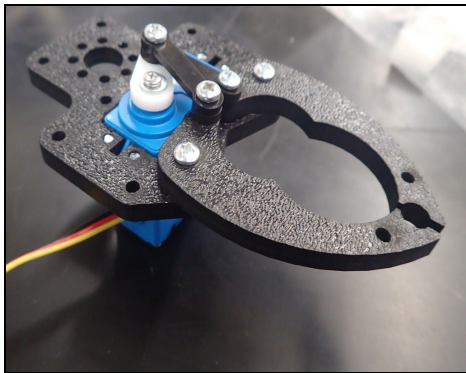
Figure 4: Team Photo with ROV
(Photo Credit: M. Barrett)

4. Understanding of ROV



Our team wanted to use the Triggerfish Vector design for our ROV. However after reading the mission specs, we soon realized that the ROV was too big to earn the bonus points for size, so we shortened the dimensions. Given the new size, the motors no longer fit within the frame, so we decided to place them directly in the center of the ROV, branching off of a single PVC cross. With a set frame size, we then began working on a manipulator arm design.

Figure 5: Modified Triggerfish Vector Sketch
(Credit: Created by D. Lam in Clara.io)



Originally, we had a hydraulic gripper design, but it soon evolved into a robotic arm run with an Arduino. The gripper is made from ABS plastic, and is run by a single servo motor that is wired in the tether. The arm is reliable and strong and will make the pool challenges easier to complete. The arm will allow us to pick up coral samples, flip and carry the CubeSats, transport objects, and more.

Figure 6: Mechanical Gripper
(Photo Credit E. Stillman)

Our engineers also researched several ROV concepts and principles. We mastered topics such as buoyancy, drag (predominately pressure drag), weight, hydrodynamics, center of gravity and buoyancy, and force vectors. The ROV was built mainly for precision. This led to engineering design tradeoffs on the ROV. Speed became less important leading us to worry less about drag. The MATE Triggerfish Vector design is not necessarily the best design for speed, but it is a great design for doing the workload required in both inner and outer space.

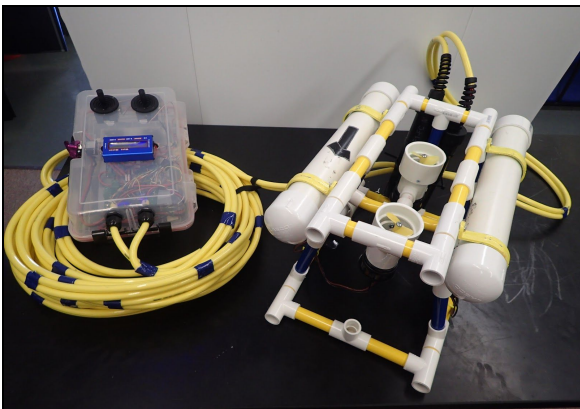


Figure 7: ROV with tether and control box
(Photo Credit E. Stillman)

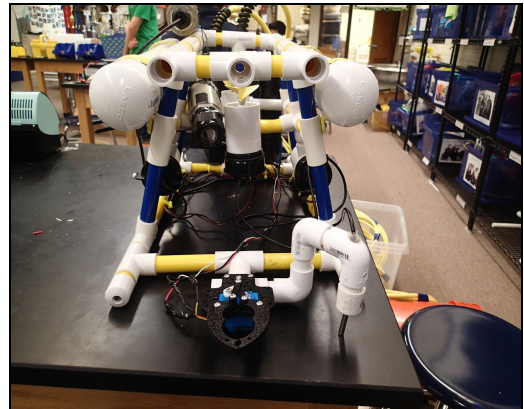


Figure 8: ROV with gripper & temperature sensor
(Photo Credit E. Stillman)

5. Mission Descriptions and Point Values

OS = Outer Space IS = Inner Space

Mission	Section	Mission Description	Points
Mission to Europa	OS		100
Inserting Temperature Sensor	OS	Insert the Temperature Sensor into the Venting Fluid	10
Measuring Temperature	OS	Measure the Temperature of the Venting Fluid	20
Thickness of Ice	OS	Determine how thick the ice crust is	10
Depth of The Ocean	OS	Determine the depth of the ocean from the bottom to the ice crust	10
Connecting the ESP	OS	Lay the ESP cable through two waypoints, open the door to the communications hub, and plug in the ESP cable into the port	50
Mission Critical Equipment	IS		40
Identifying Serial Numbers	IS	Find and identify the serial numbers of the CubeSats	20
Recovering CubeSats	IS	Recover 4 mission-critical CubeSats and put them into the Collection Bucket	20
Coral Study	IS		30
Photographing Coral	IS	Photograph two different coral colonies	10
Comparing Photos	IS	Compare the photos from now and the photos from previous years to assess their condition	10
Retrieving Coral	IS	Retrieve two coral samples to the surface	10
Forensic Fingerprinting	IS		40
Collecting Samples	IS	Collect one sample of two oil mats from the seafloor	10
Returning Samples	IS	Return the samples to the surface	10
Analyzing a Chromatograph	IS	Analyze a Gas Chromatograph of each sample to determine the oil's origin	20
Rigs To Reef	IS		50
Installing a Flange	IS	Install a flange on top of the oil well	10
Securing the Flange	IS	Secure the flange to the oil well with one bolt	10
Installing the Well Cap	IS	Install the well cap onto the top of the flange	10
Securing the Cap	IS	Secure the well cap to the top of the flange with two bolts	20
Total			260

Figure 9: Descriptions of each mission and their corresponding point value

6. Design Rationale

6.1 Corporate Team Memory

Our company's engineering design process began after we were given the initial product demonstration and mission specifications. Each member also conducted individual research to understand concepts pertaining to their position. Our team analyzed these early specifications and began our initial brainstorming. After receiving the final mission specs, our perspectives of the challenges became very clear. As a team, we perused the mission tasks to get a complete sense of what we had to accomplish. This set the course for the rest of our design process. Our ROV designs were first created using the 3-D imaging software Clara.io to accurately size and design the ROV.

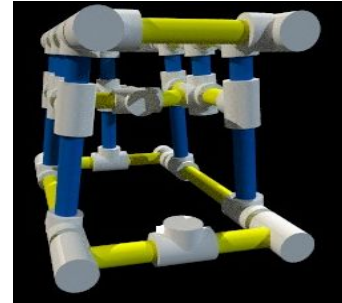


Figure 10: Triggerfish Vector Sketch

(Credit: Created by D. Lam in Clara.io)

6.2 Frame and Flotation

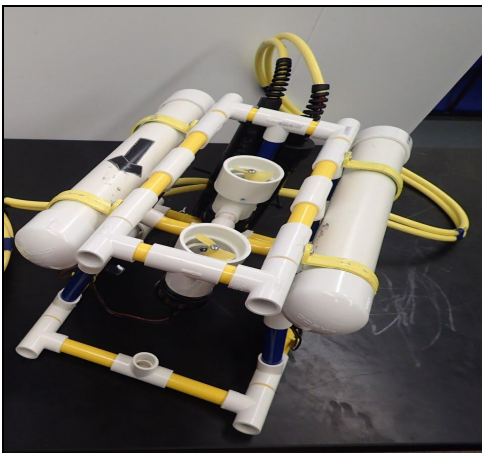


Figure 11: ROV frame
(Photo Credit: E. Stillman)



Figure 12: Buoyancy tube placement
(Photo Credit: E. Stillman)

Our Mechanical Engineers created the final ROV frame after several design modifications. We used the **Triggerfish Vector** design as a model because we thought it would be the most optimal design to use. The frame, made out of $\frac{1}{2}$ " PVC pipe, is stable and strong. We reinforced the PVC connectors with stainless steel screws. We kept speed in mind by keeping the frame as small and light as possible to reduce pressure drag. The frame was also condensed in size to earn bonus points for size, which ultimately reduced the weight and frontal surface area, again reducing drag. Our two vertical motors are centered lengthwise and mounted on a cross on the inside of the frame which is connected to pieces of bent PVC pipe. We bent the pipe because the Vector design has slanted vertical parts of the frame, not allowing us to lay a perfectly horizontal pipe across the center. To bend the pipe, we filled two small pieces of PVC pipe with sand and heated it with a heat gun in order to bend it to the desired angle. Next, we had to attach our buoyancy tubes. We had to accurately adjust our buoyancy to keep the ROV in a neutral position. Two congruent capped **buoyancy tubes** made of 2" PVC pipe were placed evenly along the top of the ROV. This placement promotes a stable ROV with an optimal center of buoyancy.

6.3 Tether Wiring

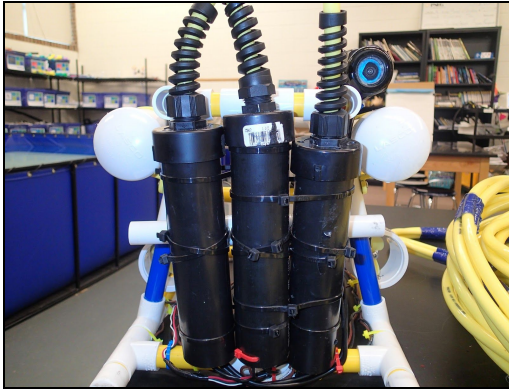


Figure 13: ABS tether tubes
(Photo Credit: V. Cariello)

To make our tether wiring organized and aesthetically pleasing, we added the unique application seen in Figure 13. It is composed of three 1-½" **ABS tubes** each capped with a **strain relief**. This keeps the wires protected and together. Making the wire connections is done simply by loosening the strain relief and sliding the bundled wires out of the tubing. This addition was cheap, simple to implicate, and proved to be beneficial.



Figure 14: Neutrally buoyant tether
(Photo Credit: V. Cariello)

A special feature that we used to improve our ROV was **neutrally buoyant tether**. Two 16 meter pieces of tether were donated by VideoRay. This application will reduce the chance of getting tangled in the water when completing the missions. Originally we only used two tethers, but later added a third due to interference we were experiencing on our camera monitor. Fortunately we had 50' of tether leftover from a previous year.

6.4 Control System

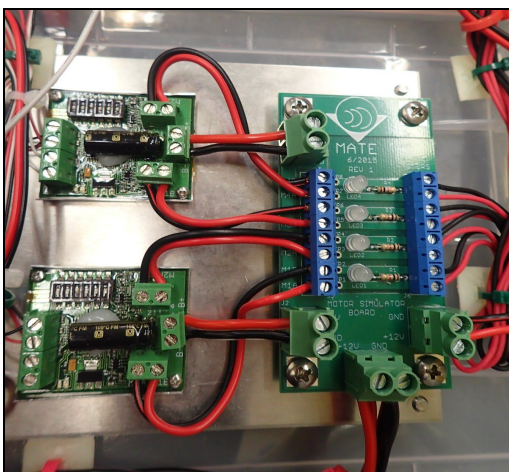


Figure 15: Sabertooths & MATE Simulator Board (Photo Credit: E. Stillman)

Figure 15. shows the system that is responsible for controlling our ROV motors. Signals come from a set of two potentiometers, which travel down wires to the two **Sabertooths PCB** (smaller PCBs on the left side). The Sabertooths are powered by wires from the **MATE Simulator Board** (the larger circuit board on the right side), which is powered by a 12 Volt battery. The signals then leave the Sabertooths from a pair of terminal gates on the sides of the Sabertooth. The simulator board allows us to see in which direction the motors are going when the joystick is pushed in a certain direction. The LEDs tell us in which direction a motor is going by showing colors from red to green.

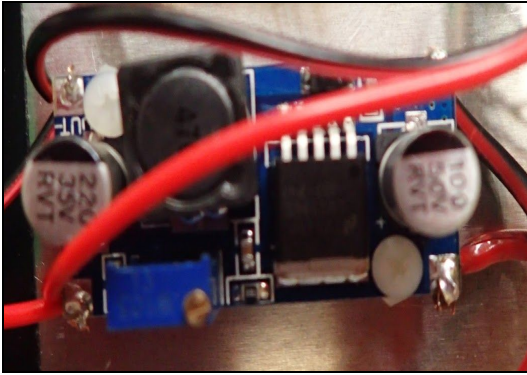


Figure 16: Voltage regulator
(Photo Credit: E. Stillman)

The next component in our control box is a **voltage regulator**. The voltage regulator is used to maintain a constant voltage level while electricity flows through the circuit. This board is essential for powering the Arduino that controls our temperature sensor and the robotic gripper. One of the two regulators enables us to actually determine and change the voltage that the regulator will output.

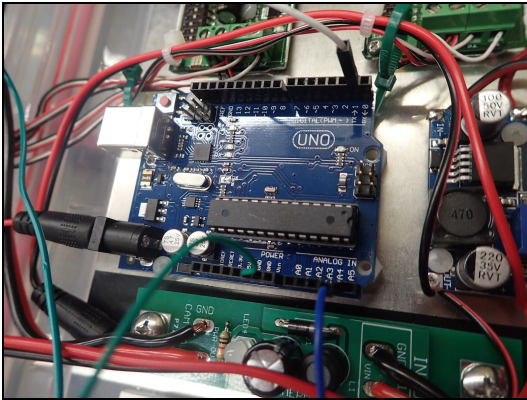


Figure 17: Arduino Uno (Servo Control)
(Photo Credit: E. Stillman)

The first **Arduino** we used is responsible for controlling the servo using data from a potentiometer. This Arduino is powered by the main power source through a voltage regulator. This connects through the Vin pin in the Arduino. The main power also powers the servo that controls the gripper on the arm. Data from the potentiometer is sent to analog pin 1 in the Arduino. The program converts this reading into degrees, which is sent up through digital pin 1 to control the servo. All of these components share a common ground.

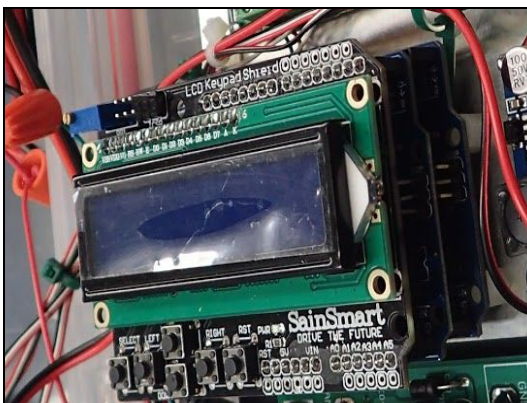


Figure 18: LCD Keypad Shield (Temperature Display)
(Photo Credit: E. Stillman)

A crucial component in our control box was the **LCD keypad shield**. It mounts directly onto an Arduino Uno circuit board and allows display and control using programmable buttons (although we didn't end up using them, as they weren't needed). Our program simply displays the temperature in Celsius and Fahrenheit on the LCD, allowing us to complete the Mission to Europa. Only 3 pins need to be used: Data on pin 3, Power on 5V, and Ground on GND.

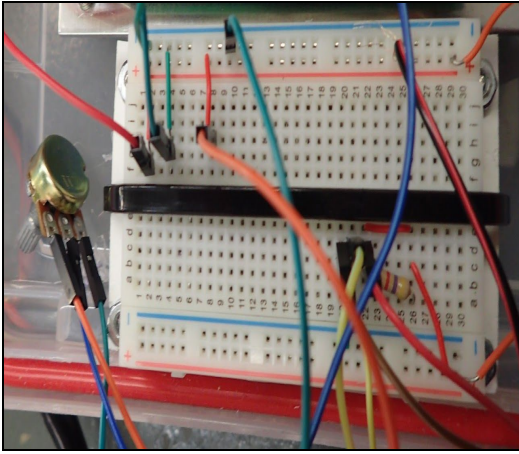


Figure 19: Breadboard
(Photo Credit: E. Stillman)

The **breadboard** mounted in our control box was used to make electrical connections easier and to allow for multiple inputs into a single Arduino pin. For example, an Arduino Uno only has two pins for GND. It is difficult to plug multiple pins into the Arduino, so a breadboard is used for something like the common grounds in the servo circuit. It is also easier to have secured wires compared to open ones, and components such as resistors are easier to mount on a breadboard. All of this microprocessing technology is new to the HMS SeaBots Ranger Team and therefore had to be purchased.

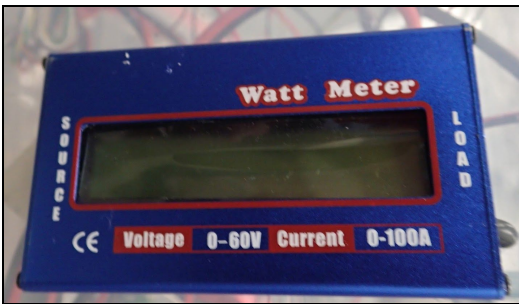


Figure 20: Watt Meter
(Photo Credit: E. Stillman)

The **watt meter** is attached to our control box for two reasons. One of these reasons is safety; the meter makes sure that the control box is not receiving too much electricity. It also enables us to monitor the amperage, voltage, and the watt hours that flows through our system.

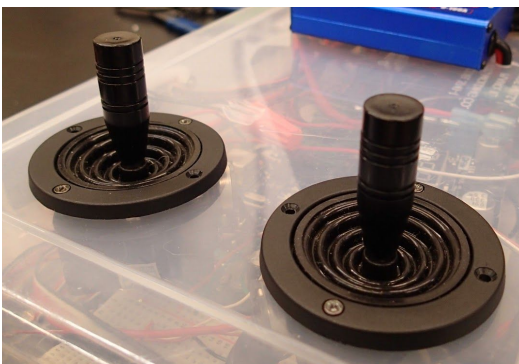


Figure 21: Joysticks on our control box
(Photo Credit: E. Stillman)

The **joysticks** are what allow pilots to navigate the ROV. Each joystick consists of two potentiometers, one for each motor. The joysticks allow us to control the speed of the motors. After soldering the wires to the pots, they needed to be calibrated. This was obvious due to the fact that the propellers would spin on their own, without us touching the joysticks.



Figure 22: Kill switch (Photo Credit: V. Cariello)

The **kill switch** is an essential safety measure. The kill switch turns off ("kills") power to the ROV. In case something goes wrong, such as two wires touching that shouldn't be touching, short circuits, fire, etc., the kill switch allows a fast and easy method to kill the power. The plastic lid on top of the switch is attached to a spring, causing the slightest touch to the plastic to flip the switch off quickly.

6.5 Manipulator Arm

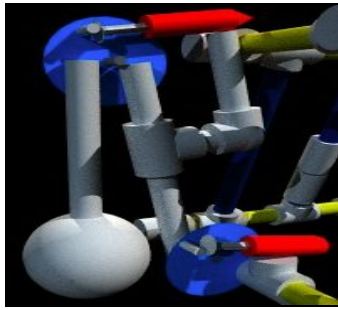


Figure 23: Hydraulic Arm Sketch (Photo Credit: Created by D. Lam in Clara.io)

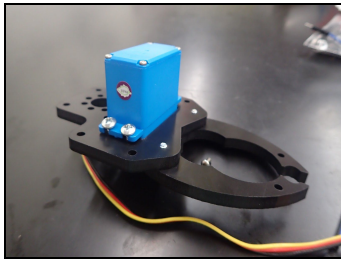


Figure 24: Underside of Gripper Showing the Servo (Photo Credit: E. Stillman)

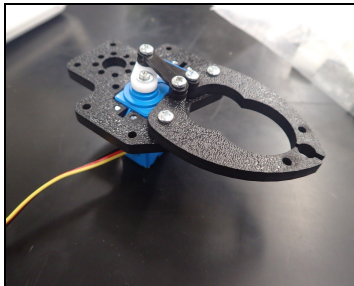


Figure 25: Topside of Gripper (Photo Credit: E. Stillman)

Our **manipulator arm** went through several phases. The first concept researched was hydraulics for the arm. The design included two joints and a claw. The joints were designed to work as a rotary disk attached to a ball-bearing joint. A syringe was to be attached to a pole protruding from the disk. Another syringe would be topside, and the two would be connected with aquarium tubing. The syringe would then push and pull on the pole so that the corresponding disk would turn, moving the arm up and down. The last extension of the arm would holster the claw. The claw would work with one syringe pulling at the gripper that would slightly slide the gripper back, sliding the claw shut. In order to accomplish the Inner and Outer Space ROV missions, the manipulator with a gripper was constructed as our **electronic arm**. We thought it would be stronger and more reliable than the fluid hydraulics mentioned in the section above. The **gripper** we used consists of ABS plastic and a waterproof servo. The servo is secured to the ABS mount by 4 screws which features a plastic hinge to control the static gripper by pulling and pushing on a set end opposite to the side that grips the objects. This works by having a hinge between them, so as the servo pulls on the back end of the gripper, the rest of the gripper rotates around the set screw in the plastic located around the mounted servo. The static part of the gripper allows the control of two grippers simultaneously, which simplifies the process to using only one servo. This type of manipulator arm is inexpensive and efficient. The gripper is applicable to all the missions and will hopefully serve us well.

6.6 Cameras



Figure 26: Camera (Photo Credit: E. Stillman)



Figure 27: Waterproofing in Process (Photo Credit: E. Stillman)

The **cameras** are waterproofed backup cameras manufactured for automobiles. We customized and upgraded the waterproofing with several features. The camera is housed in acrylic tubing with an acrylic faceplate. This kept the cameras light and safe. To secure and add extra safety to the cameras, they were then placed in a watertight PVC strain-relief cap. PVC was then attached to the cap, and another cap was placed in the back. This housing provides safety from physical damage, water damage, and organized the wiring. This housing is a new design for our team and will hopefully serve us well because last year's team went through several "waterproof" cameras.

7. Control Box Circuitry

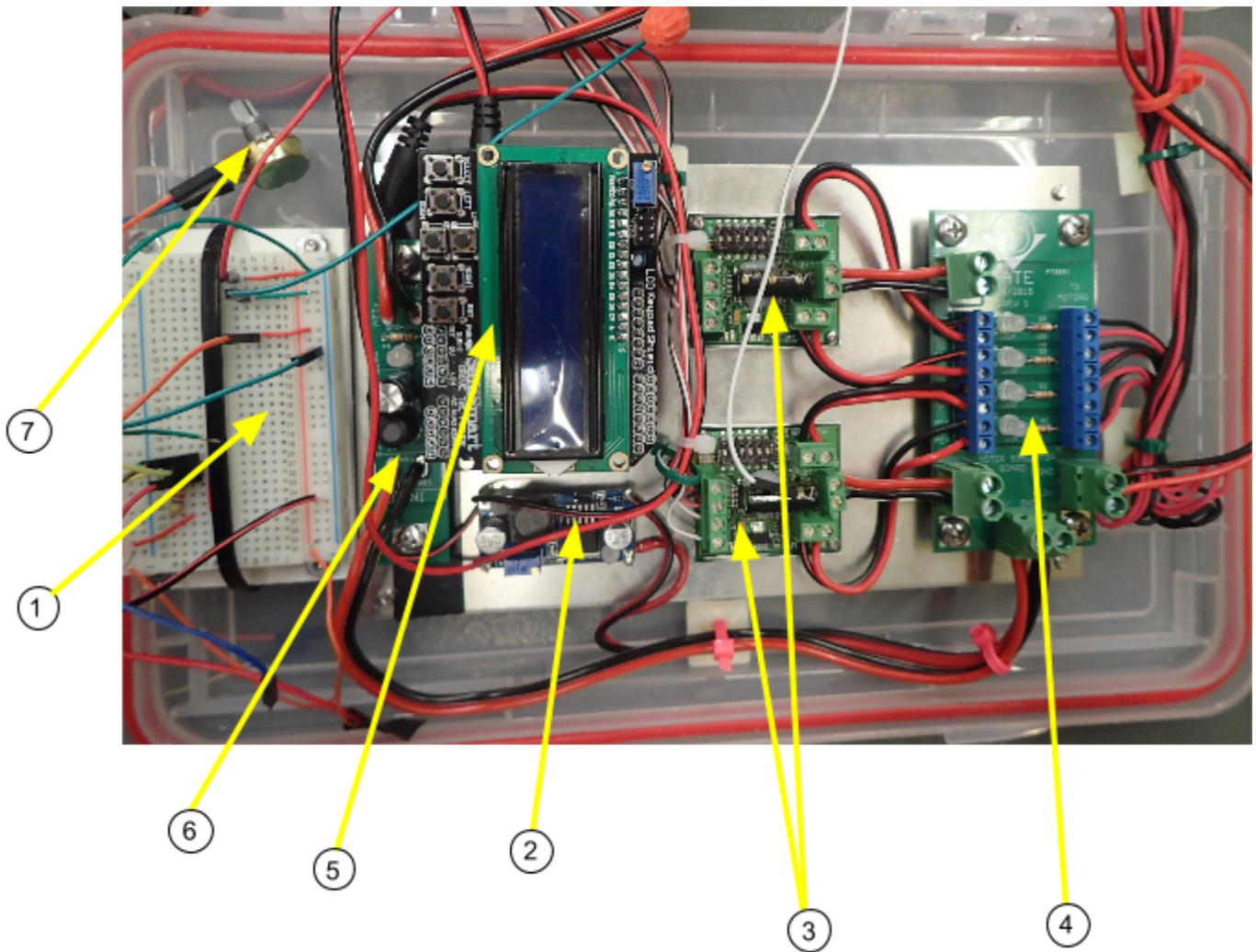


Figure Key	
1.	Breadboard
2.	Arduino Voltage Regulator
3.	Sabertooth Circuit Boards
4.	MATE Simulator Board
5.	Arduino Circuit Boards and LCD Shield
6.	Camera Filter
7.	Servo Controller (Potentiometer)

Figure 28: Labels of the Circuitry used in the Control Box

8. System Decisions (New vs. Reused/Commercial vs. Original)

Propulsion System

2 Sabertooths 2x5 (New, Commercial)

- The sabertooths that were used last year fell apart. The circuit boards detached from the heat sink plates. We tried glueing them back on, but to no avail. Also the velcro would not hold to the bottom of the control box.

MATE Motor Simulator Board (New, Commercial)

- The MATE Motor Simulator Board is an addition to this year's MATE ROV kit. This board was a great addition to the kit because it allowed us to test the system without connecting the motors.

2 Joystick JH-D202X-R2 Potentiometers (New, Commercial)

- The joysticks that we used last year could not be reused. The potentiometer wires were soldered to the joysticks. We learned last year, the hard way, that the potentiometers are temperature sensitive. In addition, the potentiometer pins were damaged due to overheating them last year.

4 DC Bilge Pump Motors (New, Commercial)

- Even though the DC Bilge Pump Motors are exactly the same as last year's motors, we wanted to use new motors to ensure they did not fail. Also, new motors were included in the MATE Triggerfish kit.

Power System

Kill Switch (New, Commercial)

- The kill switch we used last year was mounted on a metal plate and attached to the side of the control box. Removing the kill switch from last year's control box would require the removal of soldered wires which could possibly overheat the switch and damage it. We decided to use the kill switch that was included in the new MATE Triggerfish Kit.

RC Boat Heli Watt Meter Digital LCD Display DC 60V 100A Battery Power Analyzer (New, Commercial)

- The watt meter we used last year was mounted on top of the control box, in front of the joysticks. We chose to use the new watt meter that came in the MATE Triggerfish kit instead of removing the soldered connections.

Manipulator and Add-On System - Assembled from various parts

HS-646WP Servo (New, Commercial)

- This year, we decided to use a waterproof servo powered manipulator arm. Last year's HMS SeaBots used hydraulics. This decision required a new servo to be purchased.

Actobotics Standard Gripper Kit A (New, Commercial)

- This was our gripper for the manipulator arm. The gripper and the servo provided us with a more reliable method of grasping objects.

DS18B20 Temperature Probe (New, Commercial)

- The temperature probe was a necessary purchase for monitoring the hydrothermal vents in the Mission to Europa. We chose a temperature probe that was cost effective and simple to implement using the Dallas Temperature Library.

2 R3 SainSmart Arduino Uno Boards (2 New, Commercial)

- The addition of the Arduino system is new for the company this year. One came with the MATE Triggerfish kit and the other was purchased online. One of the boards is used for the temperature sensor and the other for control of the servo motor.

Servo Control System (New, Commercial)

- The only electronic component of the manipulator control box is a potentiometer. It was mounted inside a purchased project box.

SainSmart LCD Keypad Shield (New, Commercial)

- To display temperature, we needed an LCD display. A new purchased LCD Keypad Shield could mount directly onto the Arduino to allow for display of temperature.

Camera System - Assembled from various parts

2 Car Backup Cameras (New, Commercial)

- The cameras from the previous year's team were water damaged. For this reason, new cameras were purchased.

Camera Housing (New, Original)

- The previous year's company did not add additional waterproofing to the "waterproof" car backup cameras. Water broke through the seal and damaged the cameras. Therefore, this year it was decided to enclose each camera inside a protective housing.
 - The Acrylic tubing is capped with an acrylic lens and sealed with an acrylic epoxy to hold the cap in place.
 - The tube is then inserted into a large Heyco Cord Grip on the side of the lens for secure waterproofing
 - The camera and camera wiring are inserted through the back of another smaller Heyco Cord Grip which will be the rear of the housing.
 - Both cord grips screw onto PVC threaded ends. These ends are inserted into a PVC coupling and are secured with PVC glue.
 - Lastly, caps for the Heyco Cord Grips are screwed on and tightened to create a tight seal for the wiring and front of the camera.

9. Systems Integration Diagram (SID)

HMS Seabots
 Ranger Team
 Harrington Middle School
 S.I.D.

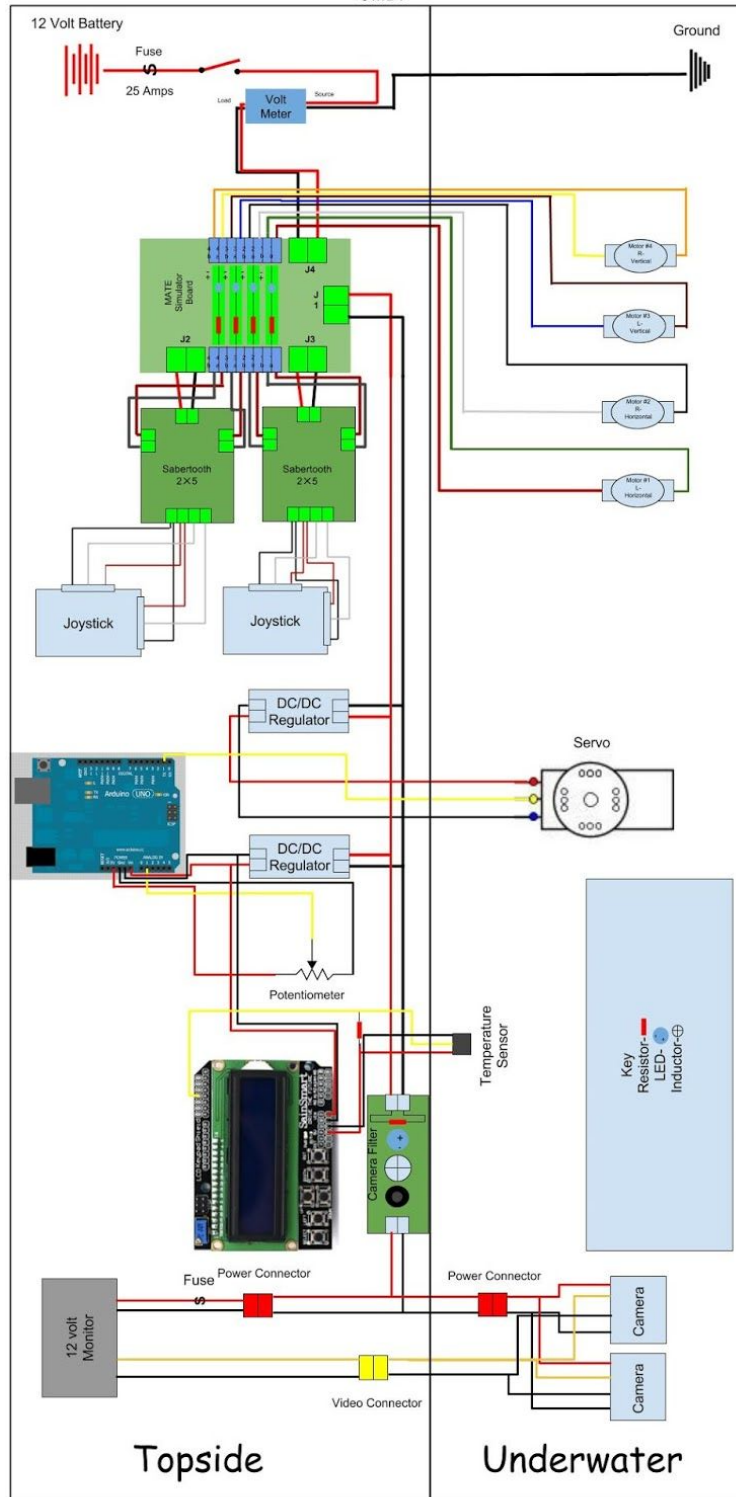


Figure 29: A Full Diagram of the Systems Running our ROV

10. Technical Flowcharts

10.1 Hardware Flowchart

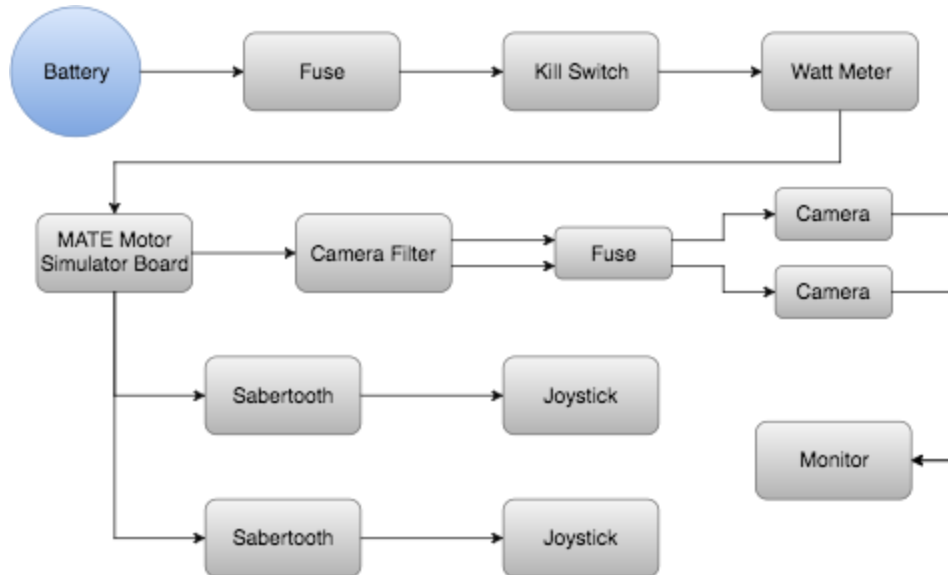
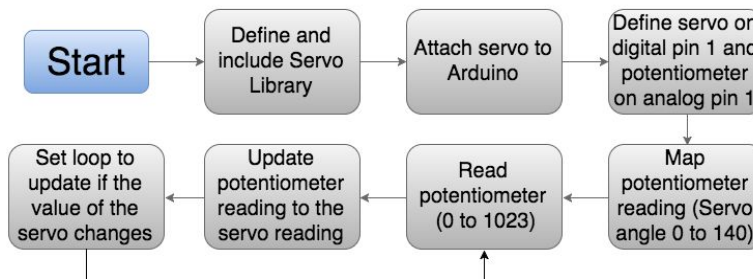


Figure 30: Motor control hardware flow chart

10.2 Software Flowcharts

Servo (HiTec HS-646WP)



Temperature Sensor (DS18B20)

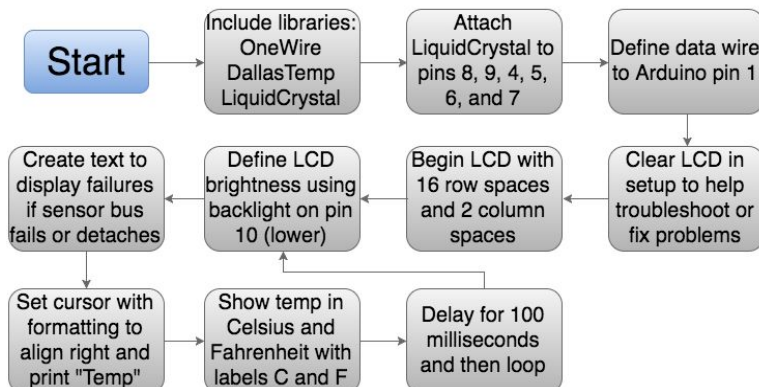


Figure 31: Servo and Temperature Software Flowcharts

11. Safety Philosophies and Features

Incorporating safety is very important to our team, as it can prevent dangerous accidents and help protect the ROV. It is better to be safe than sorry, as a malfunction can bring an ROV to its death. Time is well spent when putting safety precautions into place. It is important to prevent things like short circuits, electrocution, fires, and cuts. The dangers that come from neglecting different risks is too great to simply ignore, so we always go out of our way to make sure that precautionary measures are in place.

1. **Kill Switch** - The Kill Switch is able to immediately stop the power that is being sent from the battery to the control box. This is a safety feature that prevents short-circuiting, incidents, or electrical accidents.
2. **Shrouds** - The shrouds are effective in making our motors more efficient by directing the flow of water. Shrouds are also a built-in safety feature. If we were adjusting or modifying the motors and someone accidentally used the switches on the control box, the person making the changes would likely get cut from the spinning propellers. Shrouds also provide protection for the propellers by preventing objects from coming in contact with them, which could cause damage to the propellers and motors.
3. **Fuses** - Fuses are a very important safety precaution in case of any unfortunate events. These events include short circuits, electrical malfunctions, or even power spikes, which will cause the fuse to blow. This ensures that no electrical problems will lead to permanent damage. Our ROV system consists of two fuses: a 25-Amp inline fuse for our main power, and an inline fuse incorporated in the standard camera wiring.
4. **Metal Plate Heatsink** - Inside the control box is a metal plate. It allows for the mounting of printed circuit boards, but it also acts as a heatsink. The heat is held away from the electrical components, increasing efficiency and reducing the risk of overheating of parts, which can lead to many more electrical problems.
5. **Watt Meter** - The Watt Meter helps us monitor the power in our control box. We can see dangerous or wrong values which would help us to troubleshoot a problem and prevent further damage to the control box's components.
6. **Onboard Strain Relief for Wires** - Our three tethers are each fed independently through 2" ABS pipe which are capped with strain relievers. These help prevent damaging the wires by holding them in place. When tightened, the wires cannot be pulled out of the tubing. Without these safety measures, our solder connections may be compromised, therefore reducing the risk of wires potentially getting damaged both in and out of the water.
7. **Waterproofing** - Waterproofing is obviously very important in many parts of our ROV. Without it, our cameras, temperature sensor, motors, wires, and manipulator arm would be damaged after being submerged. If water seeps into any of these places, this could cause short-circuiting and lead to complete failure of our ROV's components.

12. Job Safety Analysis

Task	Hazards	Safety Precautions
PVC Cutters	Blade may slip from hand and hurt you or others nearby.	Point PVC Cutter blade away from body and carefully cut the PVC pipe.
	May accidentally cut own limb(s).	Hold PVC Cutters with a firm grip and be aware of your surroundings.
	Stray pieces of PVC may hit someone if there is ricochet during the process of cutting.	Two people will hold down either side of the PVC pipe, at a distance, to make sure that no pieces ricochet.
Tightening PVC Pipe	Hitting your hand with the mallet.	Make sure that you hit the PVC pipe precisely in the middle.
	Do not overtighten the PVC pipes and connections.	Hit only once or twice with the mallet for a moderately tight fit. Once the ROV is complete, tighten the PVC and connections.
Drilling	The drill could start spinning out along the surface of the control box, potentially breaking something fragile.	Holding the drill exactly at a 90 degree angle, create a small puncture in the surface of the object in order to keep drill in a stationary position.
	Fingers may be hit/potentially cut off.	Keep all hands / fingers at a reasonable distance away from the point of intercept.
Heat Tools (solder iron, heat gun, hot glue gun)	Risk of burning valuable equipment.	Use heat tools at a reasonable distance from equipment and teammates.
	Risk of burning yourself or others nearby.	Be aware of your surroundings at all times.
Testing Electrical Equipment / Power Connections	Electrocution due to direct contact with exposed wires.	Do not touch any exposed wires with your bare hands unless you're sure there is no power connection.
	Potential fire hazard due to exposed wires.	Check for flammable objects around the area(cloth, paper, etc...)
	Electrical shorts when placed in the water.	Do not drop electrical objects into water.
Testing ROV Functions	Risk of injury due to spinning motors.	Do not put fingers near the motors, unless the power is off. Also, we put yellow duct tape on our shrouds so that people would not put their fingers near the motors, when it is on.
	Risk of pinching hands between the manipulator arm.	Slowly clasp arms of the manipulator arm together.
3D Printing Technologies	Breathing in dangerous fume emissions.	3D printers should be used in a well ventilated area. Wear proper PPE in the vicinity of the 3D Printer such as a dust mask, gloves and safety goggles.
Soldering Circuit Boards	Risk of burning yourself and others nearby.	Ensure that the solder iron does not touch anything except the joints, and only for a small period of time.
	Risk of frying circuit boards and components.	Hold control board gently at the corner.

Figure 32: Descriptions of safety precautions taken to prevent injuries

13. Challenges

Technical	
Problem	Solution
The wiring and coding for the DS18B20 temperature probe.	Initially, we had problems trying to wire our DS18B20. We attempted things like not using the 4K resistor, but in the end we went with the simplest wiring. All of the wiring and sample code could be found online, which made it easy for us when a problem arose. Trial and error also solved many problems, as we were able to narrow down what the issue was in order to fix the problem.
The limited amount of resources on using servos from external power with potentiometers to control them.	One of the problems we faced was the wiring for the servo. We wanted to use external power to provide power for the servo, but we didn't want to use this power directly into the potentiometer, as it would damage or even destroy it. We ended up powering both the servo and the Arduino through an adjustable voltage regulator. The potentiometer was powered through the Arduino, which regulated the power down to a safe 5V, while our external voltage regulator was used to reduce the voltage down to a safe amount for the servo, much less than 12V. It ended up being only 4V, as higher outputs led to spasms and loss of control.
Non-Technical	
Problem	Solution
Communication	Like many teams, we needed to establish a solid way of conveying ideas, especially when not every member could make it to every team meeting. We needed to communicate outside of school. One way in which we are able to communicate outside of school is through the use of Google Docs. This is a highly efficient way which allows several team members to work on the same document together at the same time. Team members can edit, comment, critique and more all on one document. Google Docs allows team members to work on any device, in any location with internet access.
Team Dynamics	Several things came into play with this challenge: amount of experience, varying ideas for documentation, and communication. We realized we had to do more brainstorming and make team decisions based on research and not simply based on popularity or friendship. This is something our company will continue to work on.

Figure 33: Examples of Technical & Non-technical Challenges We Faced as a Company

14. Lessons Learned

14.1 Technical

★ **Measure Twice, Cut Once**

We wanted to earn the extra points by reducing the size of our ROV. We quickly checked the measurements of the pipes we were cutting, and proceeded to cut. When we were done, we didn't check to see that the size of our ROV was within the requirements for the extra points. A couple weeks later, we were checking the measurements and actually found out that we were still over the requirements. We looked at the measurements and found out that the only way we could get the correct measurements, was to make a new design. However, we liked the design as it was, so decided to stay with it and forfeit the extra points. We believe we have a good design, but we will not earn as many extra points from the size of our ROV.

★ **Safety First**

We were very fortunate to have correct safety equipment to be able to safely build and modify our ROV, however, sometimes team members can be careless. We learned this lesson a couple of times when we accidentally touched a solder iron to skin causing a minor burn. We always need to practice good safety measures and wear proper personal protective equipment (PPE).

★ **Be Creative**

Without creativity, our team would not be where it is today. Our team has created an ROV using our imagination and creativity. One example is how we bent the PVC pipe to attach our vertical thrusters for optimal placement. We also had to get creative when trying to fit all the extra microprocessing components inside the control box. Our stacking method proved to be very successful.

★ **Be Flexible and Adaptable to Change**

We seemed to be making changes to our ROV weekly. We changed the design, changed the placement of the thrusters, changed the mounting for the temperature probe, and more. Many times, these changes required extra work, but if we felt it would benefit the team or client, the majority typically agreed to the change. If team members did not agree, then compromises had to be made. For example, some members had different ideas for the method of attaching the temperature probe. After evaluating the pool mission and the methods, the members decided on the better design based on our research.

14.2 Interpersonal

★ Teamwork is KEY

Our Ranger Team would not be what it is today if it wasn't for our ability to work together. For example, after our Mechanical Engineers built the ROV frame, it had to be properly wired by our Electrical Engineers. Our Software Engineers had to communicate with our Electrical Engineers to meet the needs of the Arduino. Teamwork brings all the individual systems together as one.

★ Never Give Up

Our company came across many challenges throughout the year. For instance, we wanted to create a manipulator arm that would be easy to use, durable, and not too complicated to build. The arm went through several concept and design phases, in which several of them failed. After many attempts, we managed to successfully create a suitable gripper for our ROV.

★ Everything is a Tradeoff

This year's challenges and regulations created many constraints for our ROV and manipulator arm design. First of all, when we analyzed the Inner and Outer space missions, we found that our gripper could not be static. We needed it to open and close in order to complete some of the tasks. In addition, we wanted to earn the extra points by reducing the size of our ROV frame. However, to keep the design that we desired we could not get the smallest frame for the greatest points. This led us to compromise and accept the medium amount of points and a medium size ROV.

★ Time Dedication is Required

The majority of our company members dedicated a great deal of time to ensure the success of our company. Throughout the year, our members worked two hours after school every week, and a minimum of two hours at home each week. As we neared the competition we worked longer hours each week, and even met everyday of the week!

★ Practice Makes Perfect

All of our engineers spent hours of practice perfecting and refining their skills. The engineers studied and researched their subjects to advance their areas of expertise which allowed us to accurately perform our jobs. After completing the research, the Electrical Engineers practiced techniques such as soldering and wire stripping before creating the control box and wiring the ROV. The Mechanical Engineers researched and brainstormed and created ROV designs, and the Software Engineers practiced with the Arduino board before incorporating it in our control system.

★ Pay it Forward

Since it is the Mt. Laurel School District who funds the majority of our underwater robotics programs, we feel it is necessary to give back to our community. This year we participated in three community service events. At our events, we teach community members of all ages how to pilot our ROVs.

- September 2015: Mt. Laurel Fall Festival
- November 2015: Barnes & Noble Mini Maker Faire
- June 2015 (and June 2016): 6th Grade Pool Party

15. Reflections

~ **Andrew McCorkle, CEO, Mechanical Engineer:** As the CEO, I kept my team members focused on their tasks and made sure deadlines were met to keep the project on schedule. I also had to make sure the lines of communication were open between all of my team members. As a MechE on the team, I primarily worked on the design for the ROV and the placement of several of the ROV's special features, including the gripper, cameras, and temperature probe.

~ **Ethan Stillman, Mechanical Engineer:** I worked primarily on designing and constructing the ROV frame. I also worked as a Electrical Engineer at times when our company needed assistance on the control box. Furthermore, I worked as the head Marketing Representative, designing the layout of the technical report. My MATE experience furthered my interest in engineering, and taught me designing skills, wiring, programming, how to use solder irons, wire-strippers, and crimpers.

~ **Vincent Cariello, Mechanical Engineer:** I worked on the frame of the ROV. In addition to the frame, I worked on the cameras for our ROV with the Electrical Engineers. My MATE experience has been an enjoyable one which has also improved my engineering skills significantly, specifically wiring, coding, and the functions of the Arduino circuit board.

~ **Ahmed Fouad, Electrical Engineer:** I was responsible for constructing the control box. In addition to my electrical work, I created many of the team's documents, including the SID, Company Flowchart, and the Design Rationale control box features. My job also included teaching our Scout Team how to build a control box. MATE has furthered my passion for robotics and engineering, opening up many opportunities for me.

~ **Tejas Kaushik, Software Engineer:** I worked on the Arduino programming. Our main focus was to develop a program to maneuver our gripper, as well as use the temperature probe. Furthermore, I helped with the ROV frame and assisting with the marketing material. The MATE experience has provided me with a greater understanding of ROVs and robotics.

~ **Dan Lam, Software Engineer:** My job as the Software Engineer was to work on the ROV software system, which included the Arduino. My past experience with Arduino helped me create functional programs and wiring. Through prior knowledge and research done, I was able to develop the systems for the DS18B20 Temperature Probe and the HS-646WP Servo. I also worked on the mechanics of these systems. My experience in MATE has expanded my knowledge on Arduino and wiring systems overall.

16. Troubleshooting Techniques

➤ 16.1 Control Box

If something goes wrong with the ROV's electrical system, then it is up to the Electrical Engineers to fix it, and fix it fast! The problem could be with the wiring, the motors, the cameras, the sensor, regulators, servo, and more. The EEs have to figure out the source of the problem by troubleshooting. Here are examples of potential electrical problems:

1. The Fuse
 - a. Make sure that the fuse didn't blow
2. The Simulator Board
 - a. Make sure that none of the wires are out of their terminal gates:
 - Power terminals
 - Motor terminals
3. The Sabertooth (2)
 - a. Make sure that none of the wires are out of terminal gates
 - Potentiometers terminals
 - Motor Terminals
 - Power Terminals
4. The Potentiometers (2)
 - a. Make sure no wires are loose, broken, or improperly soldered
5. Voltage Regulators
 - a. Make sure wires aren't loose or barely held together by a wire
 - Input side
 - Output side

➤ 16.2 Arduino Uno and Hardware Components

1. HS-646WP Servo
 - a. Test with another servo
 - b. Connect directly (don't go through the tether)
 - c. Check wiring
 - Look for loose connections
 - Make sure there are common grounds
 - Check power wiring and watch for short circuits
 - d. Check voltage regulator readout
 - Adjust accordingly, high readings can lead power spiking
 - e. Make sure nothing has overheated
 - f. Analyze program to make sure everything is correct
2. DS18B20 Temperature Probe
 - a. Connect directly
 - b. Use default program to test the LED Keypad Shield
 - c. Look at wiring to make sure it's secure and correct
 - d. Make sure the resistor is correct
 - e. Compare the reading to a temperature sensor to test accuracy
3. Uploading Complications
 - a. Verify the program for errors
 - b. Test using different Arduino Uno boards
 - c. Change USB ports
 - d. Uninstall Arduino and reset to initialize

17. Future Improvements

One way to enhance our ROV would be to add a jointed manipulator arm on our gripper. After seeing video footage of ROVs doing actual ocean explorations, we thought of altering the arm to allow it to rotate like a wrist. The Arduino Uno could also be used to control thruster movement through the use of joysticks and additional programming. Some other thoughts are using multiple motors for one direction to increase speed. We could also use a single Arduino boards, so learning how to program and wire just one board would simplify our control box and draw less power.

18. Budget

Funds Date	Type	Category	Expense	Description	Sources/Notes	Cost	Running Amount
9/16/15	Purchased	General	MATE Triggerfish Kit	ROV kit	ROV	\$635.00	\$635.00
9/16/15	Re-used	Hardware	12 Aluminum Brackets	Shroud Support	Motors And Shrouds	\$35.40	\$670.40
9/16/15	Purchased	Hardware	12 Nuts and Bolts	Shroud Support	Motors And Shrouds	\$0.36	\$670.76
9/16/15	Purchased	Hardware	24 Rivets	Shroud Support	Motors And Shrouds	\$0.34	\$671.10
9/16/15	Purchased	Hardware	145 inches of Colored PVC	Material for ROV Frame	ROV Aesthetics	\$14.98	\$686.08
9/16/15	Re-used	Hardware	24 3-Way Connectors	Corner PVC Connectors	ROV Aesthetics	\$30.00	\$716.08
9/16/15	Purchased	Hardware	2 12" of 2" PVC	Buoyancy	Tubes of air to adjust buoyancy	\$3.56	\$719.64
9/16/15	Purchased	Hardware	4 2" End Caps	Buoyancy	Keeps air in the tubes	\$8.32	\$727.96
9/16/15	Purchased	Hardware	4 2" Conduit Clamps	Buoyancy	Holds Buoyancy tubes to ROV	\$38.08	\$766.04
9/16/15	Purchased	Hardware	2ft 1-1/2" ABS DWV Tubes	Stress relief	Keeps stress off tether	\$2.94	\$768.98
9/16/15	Purchased	Hardware	3 1-1/2" ABS caps	Stress relief	Keeps stress off tether	\$9.54	\$778.52
9/16/15	Re-used	Hardware	1 Stress Reliever	Stress relief	Keeps stress off tether	\$8.22	\$786.74
2/9/16	Donated	Power	150ft of Neutrally Buoyant Tether	ROV Line	Control Box and ROV	\$150.00	\$936.74
2/9/16	Re-used	Hardware	4 2-inch Coupling	Shrouds (Safety Layers)	Motors And Shrouds	\$3.92	\$940.66
2/14/16	Donated	Hardware	Arduino Uno R3	Manipulator Arm/Temperature	To use temperature sensor and servo	\$24.95	\$965.61
3/2/16	Purchased	Hardware	2 IP68 Heyco Cord Grip M3234	Waterproofing	Keeps water out	\$5.88	\$971.49
3/2/16	Purchased	Hardware	2 IP68 Heyco Cord Grip M8437	Waterproofing	Keeps water out	\$6.66	\$978.15
3/2/16	Purchased	Hardware	1ft Clear Acrylic Tube	Waterproofing	Keeps water out	\$1.50	\$979.65
3/2/16	Purchased	Sensors	Waterproof DS18B20 Digital Temperature Sensor	Temperature	To measure temperature	\$9.95	\$989.60
3/2/16	Purchased	Hardware	HITEC HS-646WP	Manipulator Arm	To move manipulator arm	\$42.95	\$1,032.55
3/2/16	Purchased	Hardware	Standard Gripper Kit A - Channel Mount	Manipulator Arm	The arm to grab	\$9.95	\$1,042.50
4/6/16	Purchased	Sensors	2 Cameras	Waterproof Camera	Used to see underwater	\$39.98	\$1,082.48

Total Raised	\$145.09
Total Spent	\$1,082.48
Final Balance	\$937.39

Figure 34: Individual Components Project Cost Analysis

19. References and Acknowledgements

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Figure 35: Our Sponsors and their Respective Logos