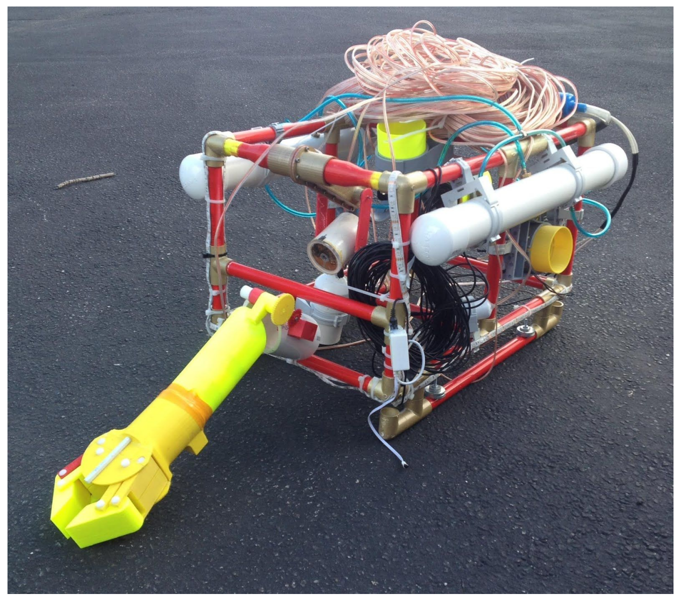
2014 MATE Regional ROV Competition, Ranger Class

S.P.I.E.S.

Sound Preservation- Integrated Electronic Systems, New Haven, CT

"Phillip"



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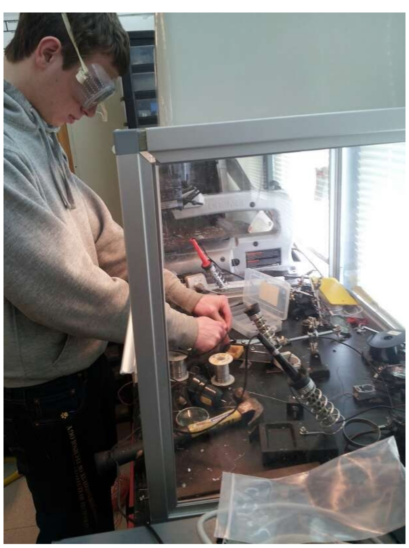
Testing *Phillip*

Abstract

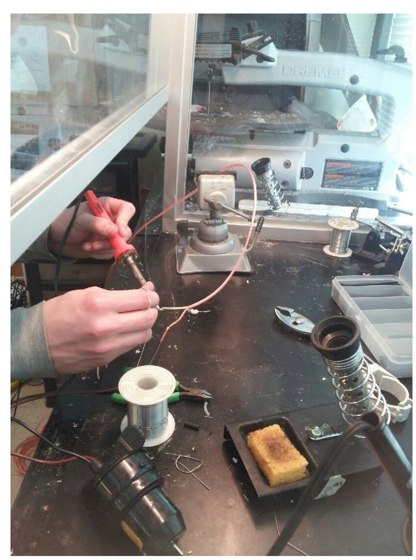
Sound Preservation-Integrated Electronics Systems is a publicly funded organization specialized in the production of Remotely Operated Vehicles, more specifically, those designed to operate within an aquatic environment. MATE, our current consumer, called for the production of an ROV capable of accomplishing tasks related to the Great Lakes, for which there are three main concerns: shipwrecks, science, and conservation. In order to complete the tasks assigned to us by MATE, our company had to overcome many challenges when it came to designing and building a compact and versatile ROV. The frame itself is simple, with plenty of room for customization while on the job. Attached to the frame are an all purpose manipulator, auger for biological sampling, conductivity sensor, rangefinder, variable buoyancy, and cameras. Each of these systems will be necessary in the pool and in the field to complete various tasks needed for a scientific expedition. This process dealt a lot with overcoming challenges, especially those which come from working in cramped environments. Problem solving skills were essential to the success of this project. S.P.I.E.S. is constantly working to improve their products from experience. With time and patience we have built an ROV capable of meeting MATE's needs.

Safety

Our ROV was designed with safety being our main priority. Working in an aquatic environment calls for special measures when dealing with personal safety. All systems with the exception of the variable buoyancy are enclosed within the frame of the ROV itself. This ensures that while performing missions underwater, no contact with walls or props as a result of unpredicted currents or unforeseeable events will damage the vehicle or its systems. The propellers are enclosed in brightly colored motor housings, which bring attention to the fast moving parts and prevents injury from freely spinning propellers. With no sharp edges, the vehicle is safe to hold and carry by a single person. The tether has extra length to allow for proper movement underwater, and with team members controlling how much of the tether goes out, it can be ensured that there are no tangles underwater which would severely hamper the effectiveness of the ROV. During the production of the vehicle itself safety was of most importance. Company members working with solder or power tools were required to wear safety goggles at all times. Proper ventilation was provided by the use of a fume hood. Those company members working with especially dangerous parts such as the propellers, which are coated in a toxic layer of beryllium, were required to wear face masks as to not inhale the dust. Gloves were used to protect members working on especially sharp objects. As with all companies working in a shop, company personnel had to meet dress requirements including closed toed shoes, and no baggy clothing which could get caught on objects easily. By abiding to these requirements the construction of Phillip was accomplished without any serious injury.



Preparing the soldering station



Carefully soldering a motor

Design Rationale

4.1 Frame

The Frame design we went with was meant to be simple and functional. Keeping in mind the various tasks we would have to complete, especially those which took place inside the shipwreck itself. We set out to build a compact frame which would give us room for maneuverability in tight quarters. The front and back of the ROV are squares with a dimension of 30cm x 30cm. Across the front is a PVC support which stands as a base for the manipulator to attach to. The sides of the ROV have one support each, which are the sites of the two longitudinal thrusters. There are also supports on the top and bottom of the frame. The support on top is offset in order for the placement of a lateral thruster to be centered in the ROV, while the bottom support is used as a base to attach the pump for the variable buoyancy system. The back of the ROV is home to two thrusters for forward and reverse movements. During the design process we wanted to leave room for any and all additions that came about during the construction of the ROV. This included leaving room for camera placement, the auger, rangefinder, and variable buoyancy system. The bottom of the frame is home to two skids which serve a dual purpose. Not only do the skids keep the ROV from scraping the bottom of the pool or sediment, but they are also weighted as a means of ensuring even flotation when the variable buoyancy system is at work. The frame is constructed out of PVC. PVC was chosen for its light weight as well as its functionality. All in all, the frame was designed with simplicity and functionality in mind.

4.2 Variable Buoyancy

The variable buoyancy system we designed provides the ROV with a substantial system for flotation. We decided to make a variable buoyancy system that utilizes an air compressor. Electrically activated solenoid valves were used to operate the system. Two solenoids were used for each tube, one controlling the exhaust and the other being for the air in-line. Push buttons are used which open the air-in valve which pushes air into the buoyancy tubes and pushes the water out allowing for positive buoyancy. To achieve negative buoyancy we simply shut off the valve for the air-in, turn on a 1500ml/min water pump, and open the exhaust valve which allows air to surge out and water to flow in effectively sinking the ROV.

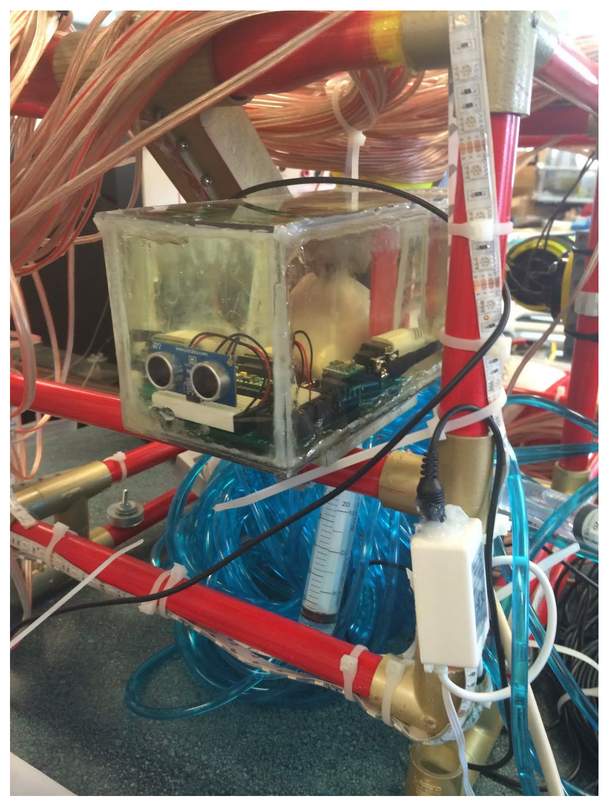
4.3 Auger

Auger inside PVC housing

The auger was designed with one task in mind, to collect the microbial sample which is represented by agar in a red solo cup. Since the agar is jelly-like, the use of a syringe to collect the sample seemed illogical and far too difficult. We began to brainstorm ideas, and this ultimately led to our first design, an auger based off of a drill bit. The auger allows us to easily get through the wrap which covers the cup the agar is held in and also to drill into and collect the agar. The auger is powered by a gearbox, that was geared down to provide more torque while sacrificing revolutions per minute. It was determined that more torque would be beneficial in this specific scenario. The PVC tube surrounding the auger prevents agar from falling out of the sides. Overall, this auger provided us with a time-efficient piece of equipment used to collect an agar sample.

4.4 Rangefinder

When the team found out that a piece of equipment would be needed to measure the distance of the ship, many different tools came to mind. Ultimately we found that an Ultrasonic Rangefinder would be the best option for us to use. The Rangefinder measures distance by sending pings of sound out and calculating the amount of time it takes for them return and complete the circuit. This information is sent through Basic Stamp,a programming software which records the time for one ping to complete its circuit and converts that time into a distance. In order to make the Rangefinder work underwater we had to put together a



Rangefinder mounted on frame

Plexiglas box and fill it with oil. Oil, which has a density close to that of water, but not conductive, was needed so the Rangefinder will not short, nor stop due to the presence of glass. We also used oil because it is not a conductor and will not short the system. The box was made 18.8cm x 8.8cm x 9.2cm so that there was enough room for the Rangefinder and the wires to fit without any problems. The box was then put on a hinge that can be rotated by hydraulic power. This allows us to measure different dimensions of the ship without moving the whole ROV. The Rangefinder is a simple and effective way to measure distances through programming software.

4.5 Cameras

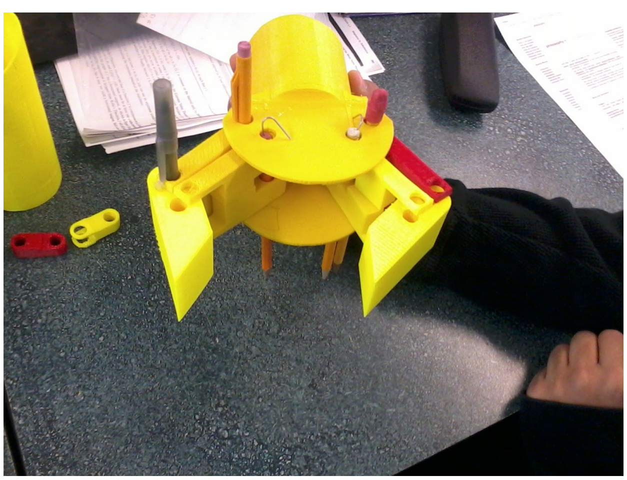
Our Sound School ROV Team predecessors had, in previous years, waterproofed cameras with RCA outputs for use in their vehicles. They had always used these analog outputs to directly input into their analog monitors. With the intention of digitally expressing multiple video inputs simultaneously on a single display, which was a prior incapability of our systems, we decided on using RCA to USB video adapters for this system. For ease of viewing, a single monitor split between multiple video inputs would be beneficial.

4.6 Rotating Camera

The rotating camera was designed with the intent to be able to capture views at multiple angles without adding excess weight that comes with additional cameras. A tee-joint located mid-frame houses two identical gearboxes which rotate a camera in a semicircular sweeping motion. Knowing that we would need to fit into small areas, having a large and bulky housing that sticks off of the frame was not ideal. The tee-joint and the camera supports can fold down into the vehicle, allowing us to keep the vehicle the compact size it is. With many tools towards the front of the vehicle, we mounted the camera on the top bar of the frame, fitting the pieces into the original design. Two o-rings seal the holes for the gearbox shafts, while screws and silicon provide the rest of the waterproofing for the tee-joint. Overall, the rotating camera provides the ROV with a weight and space efficient way to view multiple angles and tools.

4.7 Manipulator

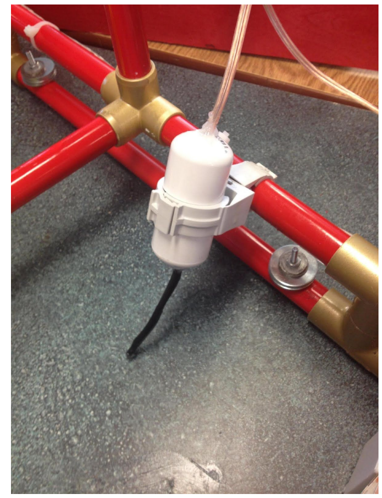
The manipulator started out with a common obstacle, which was: how do we pick things up and open doors if necessary? We began brainstorming ideas of how we were going to go about completing this year's task. When we began, we sketched many ideas of how we were going to really design the manipulator, we found ourselves designing a manipulator with one joint and an opening and closing mechanism for the grippers. The manipulator works by having the servos connected to a laptop on the surface and being programmed to turn for a certain amount of time. The gears are directly connected to the forearm, this forces the forearm to move along with the gear which is turned by the gear connected to the servo. The hand is a simple linear actuator. When the actuator pushes out, the claw opens, and when the actuator is withdrawn, the claw closes. After deciding how we were going to operate our major parts, we needed to decide on dimensions because we did not want to offset the whole vehicle, but we also did not want to lose all of the manipulator's versatility. We decided on making the whole manipulator sixteen inches, we found that at this length it would not complete throw off the center of gravity, but it will also not hinder the maneuverability. When we were given the task of bending the arm we came up with the idea of custom gears and servos in order to move the forearm. The manipulator is made with 3D Printing technology; everything is made to our exact dimensions with very little variability.



Manipulator claw
First Version

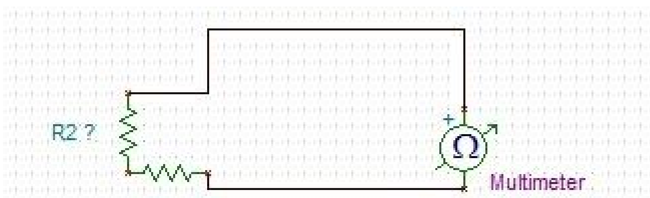
Assembled and mounted manipulator arm

4.8 Conductivity Sensor



Conductivity sensor fully assembled

The conductivity sensor is a simple circuit board with one 4.7k ohm resistor attached to two gold plated semi-conductors. The circuit runs to a multimeter which reads the resistance across the entire circuit between the two probes. Water with salt will have a lower resistance as it is more conductive while water without salt will have a high resistance. With this knowledge we are capable of determining which cup holds the "ground water" and which holds pool water. This simple circuit meets all the needs required of it during the competition.



Schematic of conductivity sensor

4.9 Propulsion

Motor inside housing

The thrusters of the ROV were designed to be able to move the vehicle in all directions. The two rear thrusters, 1000 gallon per hour pumps, provide the forward and reverse movement. The lateral thruster is also a 1000 gallon per hour pump, which is aimed upwards to work with the buoyancy system providing extreme upwards propulsion. The two side-to-side thrusters are 750 gallon per hour pumps, which allow for more precise movement, especially while taking the “sonar” scans. With these thrusters, the ROV is able to maneuver easily to accomplish all tasks.

4.10 Control Box

The control box was designed to be as compact as possible. With a width of 36.5cm and a length of 66.5cm we left as little wasted space as possible while still accounting for functionality. The box itself has a built in stand for a single laptop which shows direct video from the Rotating Camera (Design Rationale 4.5). Housed on either side of the laptop stand are the switches which control the five thrusters. In order to be as user friendly as possible the switches for the thrusters on the left side of the ROV are on the left side of the control box while those switches controlling the right side thrusters are located on the right side of the control box. The box also features a cut out for a multimeter, the purpose of which is to to read the resistance across the conductivity sensor.

4.11 Tether

In order to have adequate room for the ROV to operate, it was calculated that we would need 23 meters of wire to reach all corners of the operating zone at the maximum depth. To organize our tether it has been sheathed in a mesh material called Tech Flex.

Electrical Schematic

Troubleshooting

Throughout the course of the project, our company saw many things go wrong with the designs of various systems. Our approach when these systems stopped working was to stay calm, collect our thoughts, and develop a solution, which were then tested to be seen if proven effective.

We encountered problems within the following systems:

Auger- The original design of the auger was flat on the bottom and would not cut into the agar. The solution we decided upon was to add a point, but the point had channels which were too thin, and the agar got caught before entering the main body of the auger. A complete redesign allowed the tip to remain there while keeping the channels thick enough to keep the agar flowing. This proved effective, and it stayed our design.

Rangefinder- At first, the Basic Stamp program was giving off the wrong distance readings. After a program re-write, it began to give the right readings. When waterproofing the rangefinder, the Plexiglas case was sealed with epoxy, silicon, and 5200. However, the oil inside leaked through. With another layer of epoxy, it was sealed and ready for use.

Variable Buoyancy System- This system went through many redesigns throughout the course of the project. At first, we reverse engineered a system from previous years, and began constructing our own system. However, when it went to be tested, it proved ineffective. One redesign after another, the tube configuration and pipe placement changed, but the result did not. We simply could not get it to work. In a final effort, we placed a water pump and an air pump on the system, and this finally achieved the desired effect.

Rotating camera- At first, our design was expected to rotate on two axes. When we went to test the camera, though, the bottom axis proved ineffective. With this, we sought to capture the same angles with the top axis, and in doing so actually saved ourselves from needing another camera to point at the tools.

Challenges

One of the largest problems we faced was the constant redesigning of systems that did not work. Trying to remain calm while we saw our systems fail repeatedly was very difficult. This also cut into our time constraint, another huge challenge. Our vehicle ended up coming together in the last weeks of our time limit, which pressed our team tremendously. We put in extra hours to make sure that we finished the project we all worked so hard on. This time constraint proved stressful, and may have been fixed if we had worked harder earlier in the year. Our team did get distracted, but showed in the end that when we all concentrate and work hard, we can finish what we set out to do.

Lessons Learned

With a project of this magnitude, there are so many lessons to be taken from it. The first lesson that we came away with was that we should increase communication. Through the construction of our vehicle, we realized that although we were divided into sub-groups for design and construction of systems, if we wanted the vehicle to work, we had to have meetings about our progress. Also, when organizing fundraisers, we realized that without communication, we would not be able to successfully complete any project or organization. We also learned that time management is key in any endeavor. We often found ourselves waiting around for parts or other things when we could have been helping others with other systems or working on other parts of our own. If we had done this earlier, we might have been able to complete more, or at least test more so that we can develop more solutions to problems that arose. We also need ownership of tasks. Without it, everyone on the team assumes that tasks are being done by others, when they really aren't getting done. If there had been more task ownership, it is possible that more would have gotten done faster. These lessons will stay with the team for the rest of our lives and will be applied in future projects.

Future Improvements

In the future, our team would make more of an effort to get the project done before the end of the time we have. We thought that the time we had was more than enough, and because of this, used time inefficiently. We soon realized that we were running out of time. So, in the future, we would work harder earlier. We would also increase communication on all parts of the project. Many times, our vehicle and fundraising suffered because of our lack of communication. We would also stick to deadlines that we set. We had an initial set of deadlines for the systems, but continually pushed them off. We feel that sticking to those deadlines would have allowed us to produce a better vehicle.

References

- Stephen W. Moore, Harry Bohm, and Vickie Jensen. Underwater Robotics:

  Science, Design, and Fabrication. Monterrey, MATE: 2010.
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Acknowledgements

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We would also like to thank Jack and Randy from FJ Weidner Inc. for their tremendous help and cooperation when we needed specific parts machined for us last minute.

A special thank you to our regional coordinator, Chris Jakubiak, the University of Massachusetts- Dartmouth, and MATE for hosting the competition.

Appendix A

Safety checklist

Safety Question	Y/N	Equipment Required
Risk of material getting in eyes?		If YES, safety goggles
Risk of cutting/burning hands?		If YES, gloves
Open wounds?		If YES, bandage and cover area of wound
Soldering		If YES, safety goggles, fume hood, proper lighting
Dangerous chemicals?		If YES, gloves, face mask, safety goggles
	Launch Safety	
Tether untangled and wound	All personnel aware	All systems off
Communication is key	Support the launcher	Be aware of wires and tubes
Before engaging systems, clear all personnel	Before beginning missions, test systems	If all systems functioning properly, begin mission