Haddonfield Naval Engineers
SeaPerch 2021

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Abstract:

The process of creating a functional and realistic SeaPerch design presented numerous challenges to the team, including COVID-19 related restrictions. We had to take fresh and flexible approaches to our challenges this year in order to be successful. In this document, we first disclose an overview of the tasks the craft must carry out including navigating contaminated waterways and delivering a payload to eradicate a toxic problem in a local pond. After familiarizing ourselves with the task, the team began the design process. The design approach explains the ways in which the team researched and applied knowledge of naval engineering in order to conceptualize and refine our final design. During this stage, criteria such as the dimensions of the competition area, course obstacles, and real world applications were considered. After explaining the many revisions and brainstorming sessions the team worked through, the final design is introduced.

Next, there is an in-depth recount of our trials in craft assembly as well as a section about testing in which the numerous tests members conducted to ensure neutral buoyancy and the craft's navigational abilities are explained. Once the design approach is concluded, a concise yet informative summary of the results are included. These results describe how the team will go about additional testing and fine-tuning the performance of our craft in simulated environments for qualities besides neutral buoyancy and navigational ability. Penultimately, we examined our work leading up to the results, and assessed our performance as engineers and peers, while looking ahead to final preparations for competition day. Finally, the document's appendices contain budget management, a description of our wonderful and dedicated SeaPerch team, and acknowledgements.

Task Overview:

In this year's international competition, there is a new challenge, the real-world application poster. Our team chose to pursue this project so we could learn firsthand how ROVS are used in the field. We had many options for problems to address, but we set our sights on a local problem. This problem was favored among team members because it was an issue we were already (at least in some capacity) familiar with and cared about. The local pond, Hopkins Pond, has recently experienced massive outbreaks of harmful algae, and we decided to solve this. Their invasive blooms crowd bodies of water, blocking sunlight to underwater vegetation. They congest and cause suffering to ecosystems overall. We started out by researching the scope of the problem and the algae itself. We discovered that the algae taking over Hopkins Pond was not actually a plant, but rather it was a bacteria known as *Microcystis*, more commonly known as blue-green algae (See figure 1 in Appendix C). *Microcystis* is dangerous as it produces neurotoxins that can be harmful to people and animals. It was surprising that the algae could be harmful outside of the ecosystem in which it thrives.

After further research, we learned that Eleocharis Yokoscensis, an underwater flowering plant could combat the algae blooms by decreasing phosphates in the water, a vital component of photosynthesis in *Microcystis.* The most efficient method of depositing the plant seeds in Hopkins Pond's water was found to be via water soluble gel capsules. They would neither harm the ecosystem nor be difficult to implement into our craft. We performed tests to achieve negative buoyancy within the capsules so they would sink and deposit seeds properly. Different amounts of clay, soil, and seeds were tested until a balanced portion of every material fit in each capsule. Now, the plan is to navigate our craft throughout select parts of the pond. With the capsules nestled inside of the craft's skeleton, they will begin to dissolve when the craft is submerged, as the craft's skeleton will flood. As the capsules dissolve, the craft will travel along its path, allowing seeds to flow out of the craft and sink to their planned locations. The Eleocharis Yokoscensis will grow, gradually eliminating the blue-green algae that harms our local Hopkins Pond.

Design Approach:

The design process of our craft involved numerous activities that introduced and familiarized us with essential information while also allowing us to determine an efficient craft design. We conducted individual experiments as well as group discussions that taught members the major concepts of naval engineering. Our focus was to adapt the typical format of our work to fit with current circumstances while also using said circumstances to our advantage.

Prior to discussing craft designs, members were required to research and develop a basic understanding of terms such as buoyancy, as well as the usage of ROVs in the military. This foundation would be beneficial to everyone going forward as members could come to more informed conclusions about naval engineering as well as be able to interpret how aspects of a design might affect the craft's overall performance.

One characteristic of a successful ROV is achieving and maintaining neutral buoyancy. Neutral buoyancy is when an object's density is equal to the density of the water around it. In order to familiarize ourselves with this concept, each member of the team created a neutrally buoyant craft out of materials found in their homes (See figure 2 in Appendix C). We discussed our designs and how to achieve this with our ROV. Achieving neutral buoyancy will allow for smooth and easily controlled movements. Neutral buoyancy is the perfect center allowing us to move freely with ease because then, we can move vertically and horizontally without resistance.

At the start, each member of our team created a CAD rendering of a craft, using Tinkercad. Designs varied from small, box shaped crafts to flatter and larger shapes as well (See figure 3 in Appendix C). Most designs included a probe with a hook which would be used to transport and release our capsules. This exercise helped familiarize members with the creative process of designing a craft as well as the modeling software itself. Before moving on, the team agreed to implement certain features, such as a compact craft frame that conserved resources and ensured craft stability.

It took multiple trials to refine our ideas into a single design concept. Each design pod had free rein over the structure of the craft (however they were still encouraged to include previously discussed features) resulting in a large variety of ideas presented. The tried-and-true designs by the team's veterans were combined with a fresh perspective from new members. This contrast in perspectives allowed for interesting dynamics between new and returning members, as well as thoughtful conversations about different craft designs. The product of this activity was a rough, yet comprehensive, model that would be used for further expansion on the idea.

Eventually, the team was confident enough to begin narrowing down Tinkercad models to a final design. At this point, design pods were instructed to use their combined experience and knowledge to create an optimal design for the ROV. Members regrouped and discussed the differences and similarities in their models. While each group presented their model, everyone took notes on the attributes that stood out in each model. After everyone presented, our team collaborated to create the requirements that our model would need to include. These requirements were a probe (preferably containing a hook for interacting with objects), dimensions such that no singular dimension was larger than 8 inches (due to the size of the original mission), a rectangular shape (primarily to maintain a low center of balance), and 3 motors for propulsion (one vertical, fixed atop the bottom part of the frame facing upwards, while two remained on the back of the craft, equally distanced).

The requirements for our craft's design were becoming increasingly specific as we continued our design process. Our final design session left no part of the craft up for debate; the dimensions, shape, motor locations, and the method of wiring our team planned to use was all finalized. After this final session, we had a concrete design for our craft and we were ready to make our 3D design a reality.

While modeling our craft, several design tradeoffs were considered: internal wiring or external wiring, whether or not to have a crossbeam on the bottom of our craft, an angled front or a flat front, colored or white PVC corners, and finally a motorized or stationary probe. We discussed the pros and cons of each choice, which made some decisions easier and some more difficult. Eventually, we came to a consensus on each trade-off. These decisions included: internal wiring, no crossbeam, an angled front, colored PVC corners, and a stationary probe. We chose internal wiring because it was safer as wires would not snag on anything. We chose to not have a crossbeam because it would make our craft lighter and faster. We also decided to have an angled front to improve our craft's hydrodynamics. Colored PVC corners in the front would help the visibility of the craft as well as let us identify the front of our craft from the back. Finally, we chose a stationary probe because it would be much lighter than a motorized one (See figure 4 in Appendix C for images of tradeoff subjects).

We dedicated an entire session to creating our physical craft. One group was responsible for editing the 3D model to fit our requirements and measuring the dimensions of all the individual PVC components. Another group created a parts list of all the materials we needed to construct our craft. The final group cut PVC piping into the proper measurements. Through the combined efforts of our group members, we were able to assemble the parts for our craft in one session.

After creating all of the parts for our craft we began the task of building the skeleton of our final Perch. We took our PVC components and began to assemble them based on our 3D CAD model. We encountered challenges along the way, including mis-measurements, broken parts, and frantic recutting of PVC to make sure there was no strain on specific pieces. In one session, we built a skeleton for our final craft, including markings for drilling holes.

In the following session we were faced with the challenge of actually drilling those holes. We used a power drill to cut out holes in all of the markings, taking turns until we had finished all of them. These holes allow us to wire our craft utilizing internal wiring, thus allowing water to flow through the craft freely. Without these holes, we could run into complications, such as air getting stuck in unexpected spots, causing our craft to sit unevenly.

After the completion of our craft's frame and wiring, we needed to work on our control box. It includes two toggle switches that control our port and starboard motors as well as two buttons controlling our vertical motor. To create our control box, we needed to solder the pieces to our control board, however this was not an easy task (See figure 5 in Appendix C). We ran into multiple problems while soldering our control box, such as accidental solder bridges and over-soldering on our alligator clips. Once our control box was completed, we moved on to neutral buoyancy.

Our next priority was to achieve neutral buoyancy. We used our measurements to calculate a rough estimate for the amount of flotation needed. The equation we used to calculate the neutral buoyancy of our craft was: Buoyant force = fluid density * gravitational acceleration * fluid volume. We filled up a tub with water and submerged the craft. We then added and took away pieces of floats as needed until our craft was neutrally buoyant (See figure 6 in Appendix C).

We also had to calculate the speed and force that our craft had. For speed, we measured the length of the tub, and then timed how long it took for our ROV to travel that distance. We did this three times and found an average time and speed. For force, we used a spring scale and attached it to our craft. As it was pulled, we measured the force, and took an average to find the force that our ROV had.

Results:

In the next month, we will be testing our prototype in an Olympic-sized swimming pool to replicate the conditions of the competition. The goal of this activity will be to finalize the craft before competition. We should observe our craft successfully navigating a reconstruction of the structures and obstacles designed for the competition. A highly functional probe as well as a neutrally buoyant craft are necessary to carry out the tasks efficiently. Should the craft produce unexpected results, the team will take the opportunity to make changes to the craft.

Based on past experiences, the team expects to be required to make minor adjustments that improve upon the existing functionality of the craft. Essentially, the craft should be more optimized than not by the time the testing phase begins.

In addition to testing our craft, we also needed to test our method of cleaning Hopkins Pond with gelatin capsules full of seeds. To do this, we filled the capsules with seeds and dirt to attempt to achieve negative buoyancy so the capsule would sink. We learned that the dirt was not dense enough to make the capsules sink. We then tried clay which was much denser than dirt and made the capsules negatively buoyant. We then tested how long it took for the capsule to disintegrate by placing one filled with food coloring in a beaker while timing it with a stopwatch. We discovered that the capsule opens after about 35 minutes submerged and about 24 hours to fully disintegrate (See figure 7 in Appendix C).

Reflections and Next Steps:

While we theorized how our craft will perform in a real-world course, we needed to test it in an actual aquatic environment. We will test our craft in a pool at the Katz Jewish Community Center to see how it performs (See figure 8 in Appendix C). We need to test to see if the motors function properly, and if our wiring remains safe and functional. In addition to gauging the performance of the craft, our pool testing will allow us to determine which two of our team members are capable of operating the craft together.

Our craft was originally constructed to compete in the Greater Philadelphia SeaPerch Challenge. We considered the competition course with every design decision we made for our craft. Our craft is built to be maneuverable and compact in order to navigate the tighter confines of the Philadelphia course. Our current team had not faced that new style of course through their years in SeaPerch, and it raised a fresh challenge in the creation of our craft design. Even with the challenge of the new course, we were still able to use strategies from earlier SeaPerch years, including the placement of the motors. Our team positioned our horizontal motors spaced evenly on the back of our craft, and placed our vertical motor in the center of a PVC grid on the bottom level of our craft, to optimize the movement of our craft.

This craft design also functions in our new challenge, the real-world application project. Our team has been preparing for this new segment of the competition. In this project, we had to put our craft to the test by solving a real-world issue, similar to how the navy utilizes ROVs in the field. We chose a problem that hits close to home for our craft to address, specifically at our local park, Hopkins Pond. Hopkins Pond has been plagued with algae blooms for multiple years, and is a problem that our county has been trying to solve. After researching and discussing potential solutions to the algae problem, we have planned to drop Eleocharis Yokoscensis seeds in water soluble gel caps, allowing these plants to grow, and remove some of the phosphate that Microcystis (also known as Blue-green Algae), needs to create glucose and to grow and thrive. This process will neutralize the Microcystis problem not only for the moment, but for future years to come. Using algae-eating bacteria was a solution our team originally planned to use, but we realized that although it would be effective in removing algae, it would severely damage the ecosystem of Hopkins Pond. Eleocharis Yokoscensis will not harm the local pond life, and its population growth will not be unchecked because it dies out as fast as it propagates.

If we receive permission from the local government, we will deploy our craft in several pond locations. This will be beneficial for maximizing the spread of the seed capsules, which will be housed in our craft's probe. After releasing the capsules in all of the pond locations, all we can do is wait for the seeds to disperse and grow. Not all of the seeds will be able to grow for a number of reasons, such as the local wildlife consuming them, but the use of the gel capsules will help in the growth process of the aquatic vegetation. The Eleocharis Yokoscensis will grow within the span of a few months and will deprive nutrients from the algae growths, eliminating them from the pond.

If this process works in the ways that we have designed, the next steps would be to offer our methods to nearby townships with a similar Blue-Green Algae problem. If these additional ventures are successful, the hope would be to partner with a larger nationwide company to allow our design and methods to be used nationally to help remove this toxic problem from cities and towns around the country.

Acknowledgements:

A special thank you to Mr. Kozak for being an inspirational mentor throughout this year's SeaPerch Competition. Another special thanks to the Katz JCC (Katz Jewish Community Center) for letting us utilize their pool for testing. Thank you to Mrs. Matozzo for allowing us to use space in her school to conduct our meetings, and allow us to meet in the Teacher's Lounge for the SeaPerch competition.

References:

May, Sandra. "Neutral Buoyancy." *NASA*, NASA, 21 July 2015, www.nasa.gov/audience/forstudents/k-4/dictionary/Neutral_Buoyancy.html.

Sullivan, Eric. "GLOSSARY OF NAVAL ARCHITECTURE ... - Hcmut.edu.vn." *Naval Engineering Encyclopedic Dictionary*, 2015, www4.hcmut.edu.vn/~vtcang/course/SPMan-205/AMC-ShipProduction/definitions.pdf.

US Department of Commerce, National Oceanic and Atmospheric Administration. *What Is the Difference between an AUV and a ROV?*, 1 June 2013, oceanservice.noaa.gov/facts/auv-rov.html#:~:text=ROVs%20are%20often%20used%20when,us%20safely%20study%20the%20ocean.

US Environmental Protection Agency, Harmful Algal Blooms, 19 December 2019, https://www.epa.gov/nutrientpollution/harmful-algal-blooms

Appendix A:

Component	Vendor	How was the component used?	Cost (in USD)
½” 135 degree corners (4)	FORMUFIT	Frame of the craft	$ 5.79
½” 4 way cross pvc connecter (1)	FORMUFIT	Frame of the craft	$ 1.76
½” 3-way elbow pvc fitting connector (6)	FORMUFIT	Frame of the craft	$ 10.26
½” 4 way t pvc connector (1)	FORMUFIT	Frame of the craft	$ 2.19
Standard SeaPerch Kit	SeaPerch	Frame, motors, control box, flotation, and or wiring	$ 0
		TOTAL COST OF SEAPerch	$ 20.00

Budget Explanation:

For the craft this year, we made the decision to construct the prototype that we had been designing virtually. We were able to do this after we were given the go ahead to begin meeting in person. Because of this, we spent $20.00. All of our budget was used to create a structural frame with a very different profile compared to the stock Sea Perch. The team needed the 135 degree corners in order to get the slant shape that we have designed for hydrodynamics. The team purchased 3-way corners that were colored red so we could differentiate the front from the back as well as so we could add height to our craft. We used the 4-way T pvc to house our vertical motor in the center of the craft for both protection and stable motor placement.

Receipts for items purchased for prototype:

Items Ordered	Price
1 of: *DIYMAG Powerful Neodymium Disc Magnets, Strong, Permanent, Rare Earth Magnets. Fridge, DIY, Building, Scientific, Craft, and Office Magnets, 1.26"D x 1/8"H, Pack of 6* Sold by: DIYMAG (seller profile)	$9.49

Items Ordered	Price
1 of: *FORMUFIT F0123WE-RD-10 3-Way Elbow PVC Fitting, Furniture Grade, 1/2" Size, Red (Pack of 10)* Sold by: Amazon.com Services, Inc. Condition: New	$17.08
1 of: *FORMUFIT F0123WE-WH-10 3-Way Elbow PVC Fitting, Furniture Grade, 1/2" Size, White (Pack of 10)* Sold by: Amazon.com Services, Inc. Condition: New	$15.21

Appendix B:


Our craft

11 Years participating in SeaPerch
1 Times at the International SeaPerch Challenge

Our SeaPerch is unique because: (100 words MAX)

Our craft is unique because of its shape, its size, and its design. Its shape is like no other because of its hydrodynamics, and the difficulty to get the pieces that cause our craft to slant forward. Its size is also very different. The competition space this year is much smaller than in years past. We had to size down our craft considerably to fit in the competition area. Finally, our design is completely unique. We spent many hours prototyping and designing virtually before we even started on our final craft. This is a well engineered design for our needs.

SeaPerch Design Overview: (100 words MAX)

Our craft has a well-engineered frame for hydrodynamics. It also has three motors, two in the back for directional control, and one in the center of the bottom of our frame for vertical control. We also have three floats on the top of our frame engineered perfectly for neutral buoyancy. We have two colored pieces in the bottom corners of the front. These are to help us visually and to let us know where the front of the craft is at all times. Finally, we have a probe in the front designed to pick up virtually anything that we need.

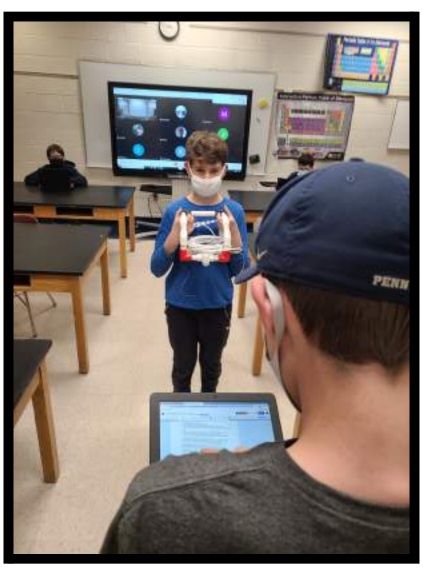
Our biggest takeaway this season is: (100 words MAX)

This year, our team recognized more than ever the importance of flexibility. With the COVID-19 pandemic came many challenges regarding group meeting sessions, effective collaboration, and full-team participation. COVID-19 forced our team to work virtually for most of the year, making communication between team members difficult. Even after returning back to in-person meetings, some members had to remain virtual. Flexibility was essential to address these new challenges.

Appendix C:

This was the first meeting the team was able to have in person after working virtually for months.

The team decided to wire the craft internally. This shows team member Miles carefully feeding the wiring into the craft in preparation for motor placement.



In order to check the pseudocode, team members Ryan and Liam performed a dry run of the code to check for any bugs or redundancies.

Team member Cameron led a group of CAD specialists in creating a full rendering of Sea Perch Prototype. This prototype was turned into a working model after the CAD rendering was completed.

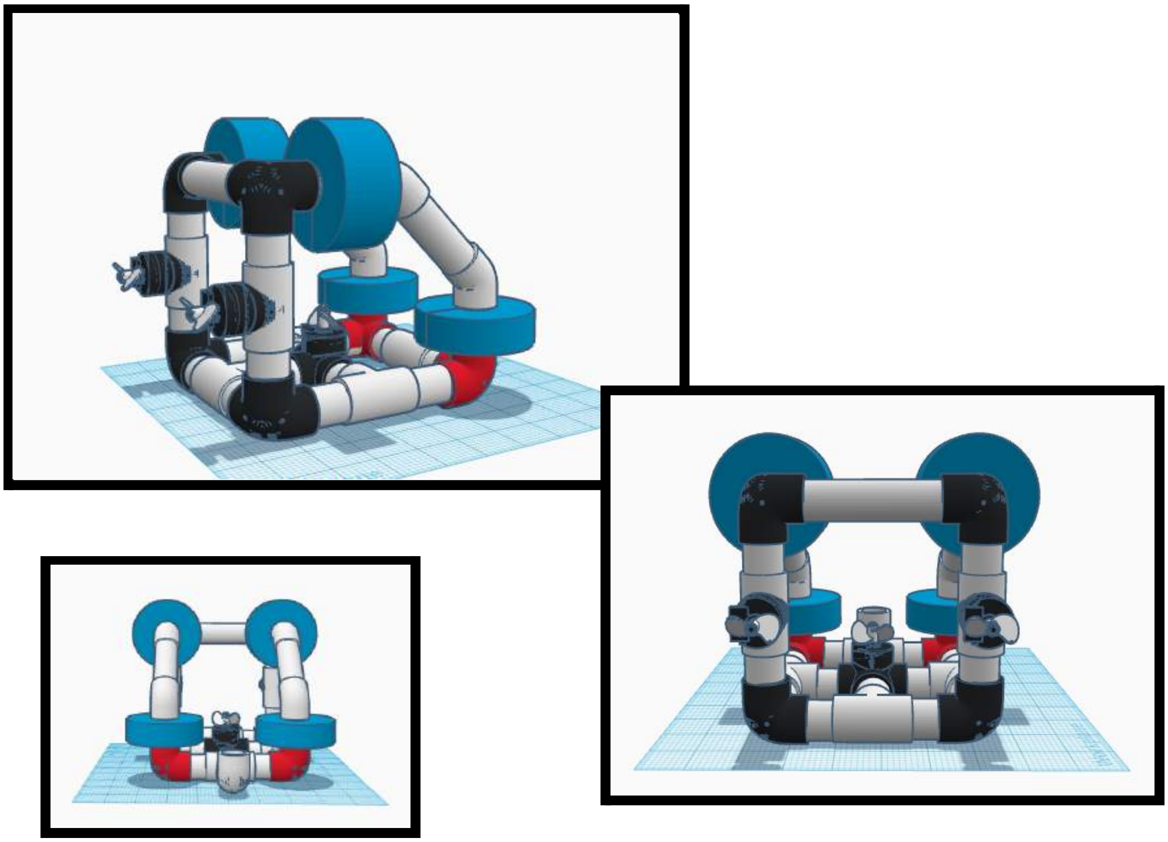


Figure 1:

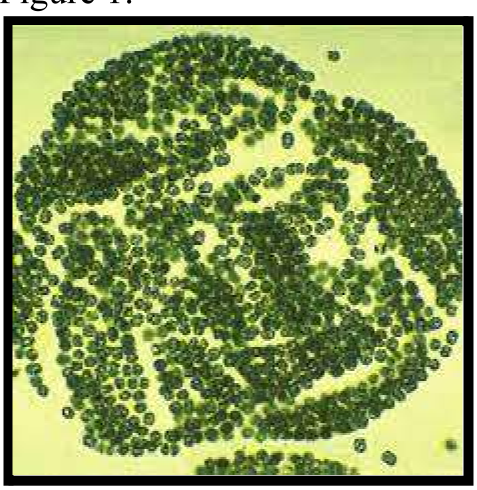


Image from [ResearchGate.net]

Figure 2:

Figure 3:

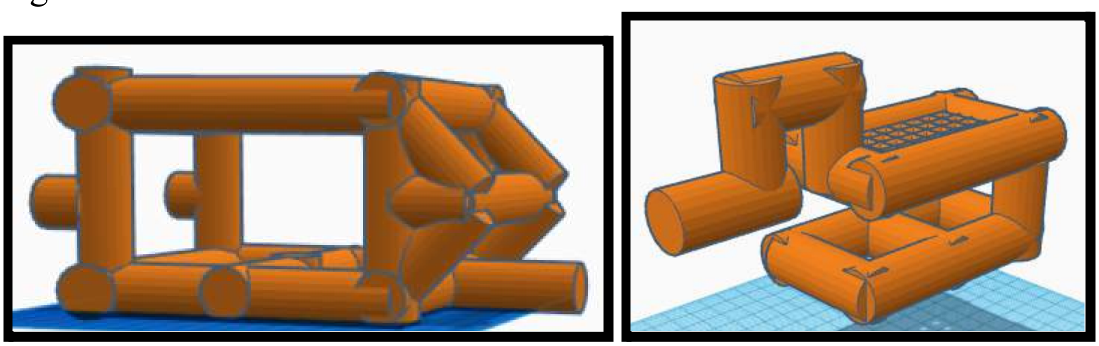


Figure 4:

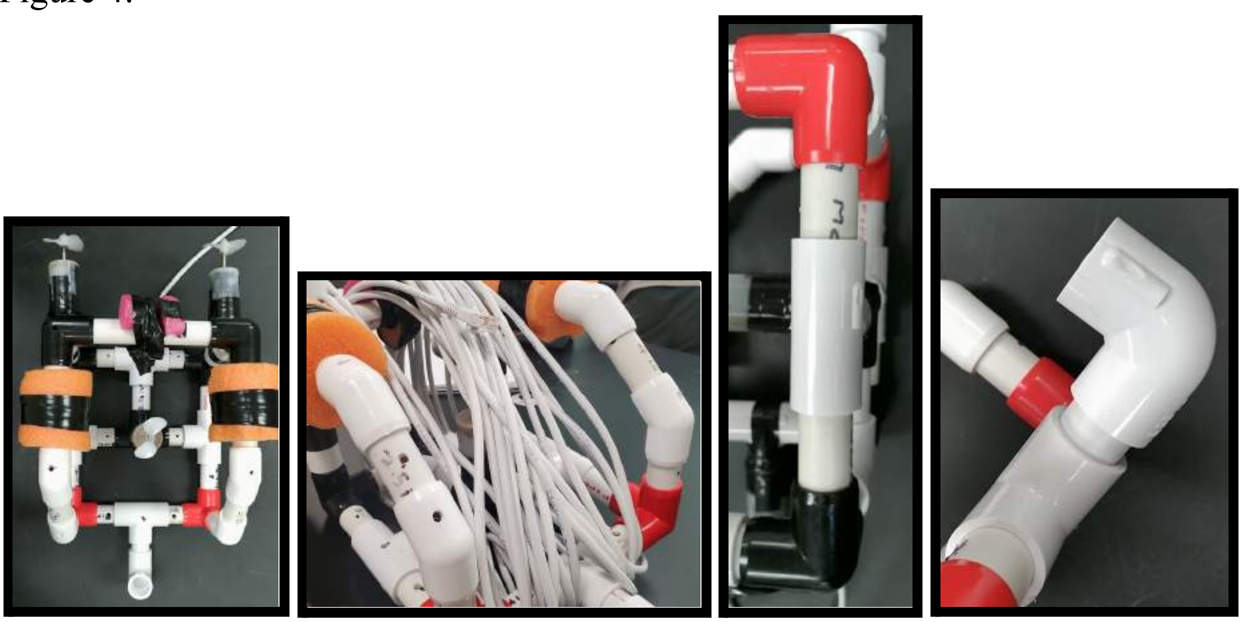


Figure 5:

Figure 6:

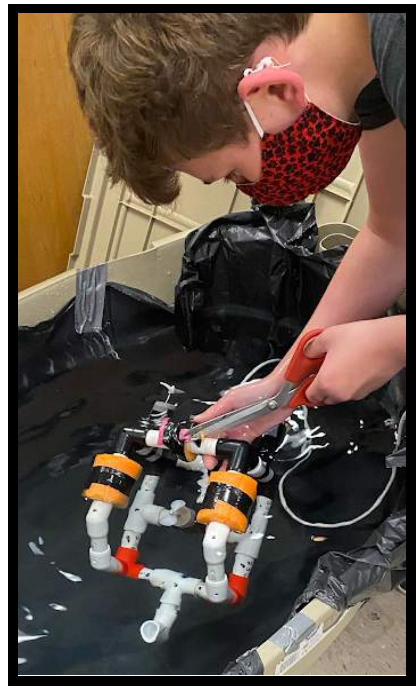


Figure 7:

Figure 8:

Image from Katzjcc.org