Scuba Rats Technical Design Report

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Abstract

This paper goes over our 2020-2021 SeaPerch ROV design, innovation, and overall experience. Firstly, our design approach was to take pre-existing concepts that we had established in the 2019-2020 season and improve them in new ways, such as the new bow shape, netting, and motor placement. This allowed us to expand upon ideas that we had never gotten a chance to complete with due to the 2019-2020 season being cut short due to COVID-19. It also allowed for us to expand upon the unique ideas of our bow shape, use of bird netting, and PEX pipe in our novel Seaperch design. Additionally, this paper details the several qualitative experiments that we conducted while creating our ROV that aided us in adjusting our design, specifically the buoyancy and the further securing of loose objects. Following this, we reflected on this unorthodox season, it's challenges, benefits, and our plans for the future. Finally, following these sections one can find other information about our 2020-2021 SeaPerch season such as references, acknowledgements, budget, and our fact sheet.

Task Overview

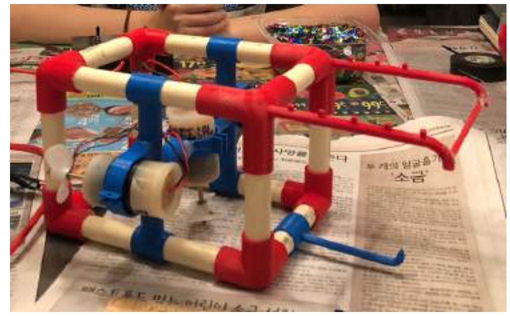
In the Seaperch 2021 regionals challenge, our ROV will attempt to complete three separate pool tasks: the speed challenge, obstacle course, and the waterway cleanup mission. The waterway cleanup challenge is also an element of the international challenge. The speed challenge is a simple one - teams have 3 minutes to get their bot from point A to point B in the least amount of time possible while staying submerged. To accomplish this challenge, we decided to make a bot that was lightweight by making the dimensions small and using narrow PEX piping rather than the larger PVC piping.

The next challenge is the obstacle course, where the ROV must navigate through 5 rings with a diameter of 18", surface, and then return through the rings within five minutes. For this challenge we wanted a bot that is easily maneuverable, so, we chose a frame design that would lead to a compact, but stable, design to help account for this challenge.

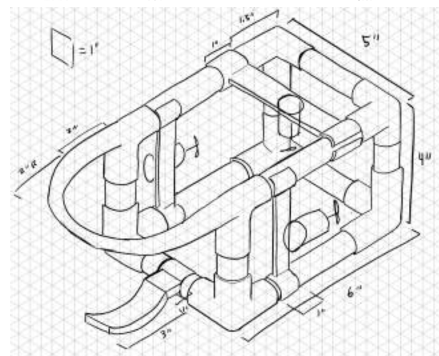
The largest and most complicated challenge is the waterway cleanup mission, which consists of several different tasks. The first task is the Active Mine, where the ROV must maneuver to an "active mine", disarm it by rotating and removing the "arming device", and place the device on the base plate of the disposal platform. The next challenge is the disposal vault challenge, where the ROV must maneuver to the Disposal Vault Gate, open it, deposit objects by dropping them into the hoop, close the vault gate, and re-latch the gate. Additionally, there is the sunken waste challenge, where the ROV must retrieve sunken waste and mines from the waste platform and deposit them onto the Disposal Vault Platform. To prepare for these tasks, we ensured that our hook was strong by adding screws to the base of it and once again reinforcing the concept of a bot that was easily maneuverable. Finally, there is the Garbage Patch Challenge, where the ROV must retrieve floating items debris from a ring and bring them to team members on the pool deck, who will then take them and deposit them onto the pool deck (Seaperch 2021). To account for this, we created the bow part of our ROV with netting that would serve to retrieve the objects, tuck them under the net, and take them to the pool deck.

Design Approach

While coming up with and making changes to our ROV design, we analyzed each of the challenges and how our ROV would be able to overcome them. We were also taking inspiration from our 2019-2020 school year SeaPerch design, since the competition had gotten cut short and we were still inspired to expand upon the ideas we had built up previously. The 2019-2020 design that is shown in Figure A was the basis of many of the ideas that we used in our ROV this year, as demonstrated in Figure B, which is our initial sketch of our ROV design. The 2019-2020 design inspired our 2020-2021 ROV's basic frame design, the concept of having a bow at the front of our ROV, as well as changes to our motor placement.

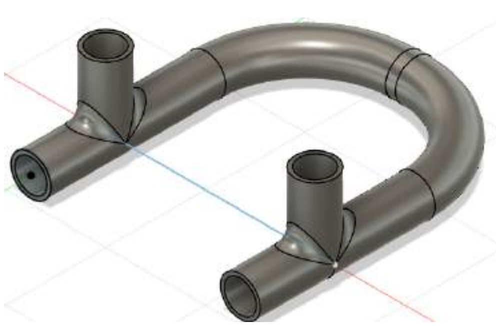


(Figure A) ROV Design from 2019-2020 Competition



(Figure B) Sketch of initial ROV design for 2020-2021 competition

Our frame design was engineered to be lightweight and quick, but also easily maneuverable. This is why we decided right out of the gate to make our pipes out of the smaller PEX pipe rather than the larger PVC pipe available in the 2020 - 2021 school year; the smaller pipe sizes would allow us more freedom to fit our motors with their guards inside of the frame of our bot. Thus, we created a basic frame design that was small and lightweight, but we still had the problem of maneuverability on our minds. Therefore, we decided to continue forward with the rectangular design from the 2019-2020 school year, which we knew from experience was a maneuverable shape due to the way that the shape creates some drag in the water, but not enough to completely hinder its performance.



(Figure C) 3D Model of Bow

Another essential part of our novel SeaPerch design is the bow, a circular shaped 3D printed part at the front of our ROV that is shown in figure C. The bow was designed to pick up trash in the garbage patch portion of the waterway challenge and serve as a general tool to scoop items from the surface of the water. It achieves this by utilizing a mesh material secured on top of the bow, the buoyancy of the floating objects, and the rim of the bow to secure the objects underneath the ROV. While this mesh was originally supposed to be the black polyethylene mesh that the stock SeaPerch ROV bot uses, we decided to switch our material to bird netting because it was more cost effective, light, and was easier for our team to acquire (RoboNation, 2020).

The concept for the bow was a design which we had improved upon from the 2019-2020 school year where we secured a

(Figure D) ROV while netting was being added, demonstrating the position of the motors and netting figuration.

portion of a fishing line in small hooks, similar to the laces of an ice skate, in order to create a system that would operate similar to our current bow. However, this design did not perform well in practice due to the bow shape and hooks being easily breakable. We decided to improve upon our design this year by making the bow thicker and using bird netting secured with zip ties rather than the weak fishing line and hook method from the past.

Additionally, one of the main problems that we encountered when testing our old design was that the bot was uncontrollable when picking up items and could be hard to maneuver due to all the motors being in a line, which gave it an axis that it rolled on and a large amount of torque when performing tasks. To improve upon this, we made sure that our motors were not in line by placing the right and left motor more toward the bow of the ROV and the vertical motor more toward the stern, as sketched in Figure B. However, this lineup had to be scrapped during buoyancy testing, as the design with the left and right motors toward the stern with the vertical motor toward the bow ended up being more stable and balanced. This newer configuration of the motors can be seen in figure D.

Finally, a smaller problem with our old design was that the motors were not adjustable, which we aimed to fix in the new version of our ROV by making the poles holding the motors clamps that could be taken off and moved. This both helped and harmed our bot, and some consequences of this will be expanded upon in the experimental results portion.

(Figure E) The final design of our ROV

However, the making of the frame also presented issues to us as a team. While we were first putting together the ROV, we had discovered that our 3D prints had slightly different measurements than our original model due to mistakes and inclarities in our design. Yet, we overcame this challenge by adjusting the size of our original pipes to match the 3D prints and ending up with a smaller ROV than we had originally planned for. Another problem we encountered was the control box, which had several unsolved problems and that we ended up having to almost entirely replace. However, even with these problems, we made the necessary adjustments and changes to our ROV and ended up with our final design.

The final design is shown in Figure E, which is the culmination of all of these efforts and more. It combines both new ideas from this year and improvements upon ideas from our past SeaPerch design through the use of the engineering design process. This time and refinement has allowed us to create a novel SeaPerch ROV where all of the parts serve a specific purpose and have correlation to the SeaPerch 2020-2021 competition.

Experimental Results

(Figure F) First ROV Float Test

(Figure G) Final ROV Floatie Placement

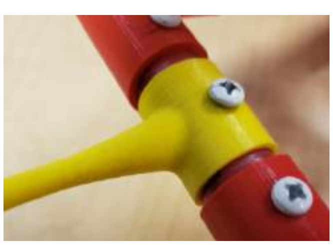
For the 2021 year, we conducted a series of tests in the water for float testing and driving for our ROV. We received data that was more qualitative rather than quantitative, so for this page we have integrated a few images that reflect our experimental process.

Starting with our float tests, we pre-drilled some holes into our bot before putting it in the water to see how it sank. As it sank, we observed that the bot was already well-balanced so there was no need to add any additional ballasts. After our first test, we did add a few additional holes in the pipe so the bot could be more easily submerged. Once we determined that there were enough holes of entry in the bot, we moved on to adding floatation.

We wanted our bot to be somewhat submerged, with only the top reaching the surface. Since our bot was already lightweight, not much floatation was needed. We experimented with a wide variety of orientations to achieve slightly positive buoyancy so that the ROV can still float up as a maneuvering tactic (Thone, 2009). We rearranged the motors so that the side motors were positioned towards the sten and the vertical motor was more upfront near the bow. This was so we could have a higher center of mass, enabling the SeaPerch bot more balance (Seaperch, 2020). Figure G was our final float test design. Since our bot is more back heavy due to the weight of the motors, we balanced out the weight by adding the floatation there.

(Figure H) SeaPerch left motor guard fastened to the bot with electrical tape.

Our first driving tests proved to be very informative, as we quickly recognized that the bot was unstable. When driving in a straight line, the bot tilted to its side as it went along. (It didn't matter if it was moving forwards or backwards, as it had the same effect either way.) Through trial and error we realized that it was because one of the side motors wasn't properly fastened to the base. We stabilized the side motor guard by fastening it with electrical tape. Figure H exhibits the electrical tape job on our portside motor guard.



(Figure I) ROV Hook Stabilized with Screw

After fixing the side motor issue, we practiced driving and interacted with obstacles and weights in the water. The first few trials were all experimental and after some time we got accustomed to navigating the bot. However overtime the hook shifted while driving, to the point that almost everytime we interacted with a weight, it had to be adjusted back to its normal position. Some adjustments were made by drilling holes and attaching a screw to accommodate our needs.

Reflection and Next Steps

This SeaPerch season was rife with unconventionality, from having the first part of our season being completely online, only having one in person meeting a week, to having to work separately, it truly was a season unlike any that we have participated in previously. Needing to work virtually due to COVID-19 challenged us as a team, but ultimately led us to creating stronger communication and management skills. We shared information through calling, sharing our screen, and sending progress images to ensure that the product we were creating, while we were creating it separately, was not made without the thoughts and ideas of the entire team going into it. This collaboration has given us vital skills for the future, for being able to communicate concisely with others in a virtual setting has been shown to be an essential skill in the modern workplace. However, the nature of our virtual season was only a small portion of what made up the 2020-2021 SeaPerch experience.

Another skill that we learned through this year was perseverance and how to work with unexpected situations. For example, throughout the creation of our ROV's control box, it had to be resoldered several times, and eventually scrapped due to it not working properly despite being soldered correctly. Despite this frustrating situation putting us behind on being able to test our ROV in the water, we still persevered and did what needed to be done to get the motors working properly. This experience taught us both how to not let shortcomings consume us as well as increased our skills with soldering, both skills that will be useful in the future, the former more so on a personal level and the latter more so on a professional level. This perseverance led us to gain more familiarity with the design process as we had to continually work to solve problems and refine our novel SeaPerch design.

This year has not only educated us on a physical engineering point, however, this school year has also furthered our understanding of documenting our processes, conducting experiments, and writing technical reports. While we understood the basic concepts of constructing a SeaPerch ROV, writing a technical report was an entirely new challenge and experience for us as a team, and one that will surely be beneficial to us in the future. A large part of engineering is documenting, analyzing, and being able to communicate your ideas clearly, skills which have been honed during the 2020-2021 SeaPerch season.

Finally, this year has inspired us to continue on with SeaPerch into the 2021-2022 school year with even more experience underneath our belt. In the future, we would like to not only focus on creating an ROV design that works well, but also one that is even more unique and new than our current design. In many ways, our current design is the natural progression of our design from the 2019-2020 school year, a continuation born from the fact that our old design never got to reach its true potential, but in the future, we would like to push the boundaries of what a SeaPerch ROV can be. Some concepts we have considered have been incorporating more 3D printing into our design, using other materials for buoyancy such as styrofoam, and more novel and unique hook designs that are specialized to the challenge.

Acknowledgements

First and foremost, we would like to express our sincere gratitude to RoboNation for providing us the opportunity to experience such a vigorous hands-on club such as SeaPerch. Additionally, we would like to acknowledge the school and thank them as well for also providing us the tools and technology to help us reach our goal.

Additionally, we appreciate the ones who have helped us along the way. Without these people we would not have been able to get as far as we have today, and we are sincerely grateful for their everlasting support and encouragement.

First off, our fellow club members this year have been fantastic, and the leaders this year have been extremely supportive and helpful throughout the year. Alana has done a wonderful job as president and keeping things orderly, and Bernadette has been very helpful throughout our experimental process (giving tips and advice about the hook and buoyancy, etc.). The other SeaPerch Teams (The Koi Fishes and Spicy Otters) have been our friendly competition from the start, which has inspired us to work harder, so thank you! This year Tracie, Yale and Carly especially have been great to talk with and gain motivation and inspiration from overall.

Of course, we would have never been able to complete this project without the help and guidance of Mr. Quast, the sponsor and club mentor of SeaPerch! Over the years they have taught us the methodology to carry out our project and vision for our SeaPerch as clearly as possible. He has been very patient and helpful especially when working with us to resolve our control box difficulties. It has been a privilege to work under his guidance.

Finally, we would like to give a special thanks to our family members for their everlasting love and support. They have dedicated their time and energy helping us achieve our goal and have consistently supported our efforts to complete the project even with the unfortunate circumstances at hand. It has been a great relief to have such supportive peers and instructors this year, we give our utmost thanks.

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Appendix A: Budget

Component	Vendor	How was the Component Used?	Cost (in USD) (5¢ per gram)
1 3D Printed Bow (44g)	Mr. Quast	The bow enables the bot to move more freely in the water.	**$2.20**
1 3D Printed Hook (3g)	Mr. Quast	The hook was used to give the bot the ability to pick up items.	**$0.15**
1 3D Printed Center Motor Guard (22g)	Mr. Quast	The center motor guard was used to give stability and protect the center motor.	**$1.10**
2 3D Printed Side Motor Guards (21g per print)	Mr. Quast	The side motor guards are to protect the left and right motors.	**$2.10**
6 3D Printed Elbows (12g per print)	Mr. Quast	The elbows were used to connect the pieces of pipe together.	**$3.60**
Bird Netting (6"x13.5")	Lowe's	The 14'x14' bird netting was cut into a 6"x13.5" rectangle and folded 3 times to create the mesh on the bow.	$6.28 for 14'x14' cost of 6"x13.5" = **$0.02**
TOTAL COST OF SEAPERCH COMPONENTS			**$9.17**

Appendix B: Fact Sheet

Scuba Rats

Patriot High School, Nokesville, Virginia, United States

HIGH SCHOOL

3 Years participating in SeaPerch

1 Times at the International SeaPerch Challenge

Our SeaPerch is unique because:

Our SeaPerch is unique because it uses narrow PEX pipe rather than larger PVC pipe in order to give it a small, light frame, while also providing a bright red color that is easy to see in the pool. Additionally, it features the bow at the front of the ROV with bird netting, which is not a standard material used for creating a SeaPerch ROV but that serves a crucial purpose in the design of our ROV and completion of the garbage patch portion of the waterway challenge.

SeaPerch Design Overview:

Our SeaPerch ROV is made out of PEX pipe along with 3D printed components such as the corners, bow, motor guards, and hook. Additionally, our ROV uses bird netting that is secured with zip ties to serve as a tool to collect items from the surface of the water and submerge them by keeping them underneath the bot. Our bot also includes a motor configuration and frame design that is intended to provide stability and maneuverability in the water, but the small nature of the frame itself allows for a lightweight, faster ROV.

Our biggest takeaway this season is:

Our biggest takeaway from this season is the value of having a close knit group for our SeaPerch project and the value of online communication. Our friendship combined with the ability to call each other, share our screen to discuss ideas, etc. allowed us to continually work together to create a final product that we had both fully given our ideas and heart into despite the social distancing protocols of COVID-19. Without our friendship or the ability to communicate online, our project would not have been such an enjoyable or productive experience.