1. Abstract

The 2021 Seaperch Competition consists of an obstacle course and a challenge course, waterway cleanup, as illustrated by Reference 1. We began our design process by building the stock SeaPerch with the instructions in Reference 6. After performing water tests with this design, we were able to brainstorm and assemble a plan for modifications to the stock design which would optimize our performance in the aforementioned tasks.

An overarching goal of our design process was to find an optimized balance between multiple trade-offs. The first was size vs. maneuverability. We noticed the smaller our design, the harder it was to steer. The second trade-off is stability vs. speed. When our designs were built for speed, they had issues with balance which dampened the ROV's ability to efficiently carry sunken debris. Our compromise was such: we would make sure that our ROV design was valued stability and maneuverability over speed. This had the benefit of enabling very strong performances in the challenge course as well as consistency in the obstacle course, even though our times could have been faster with a smaller design. To successfully complete the challenge course, however, we also needed to design a device capable of easily picking up and depositing sunken trash. We devised two hook models for this purpose.

Through this process we have created an ROV which has met our goals of stability and strong performance in the challenge course and have gained many lifelong skills in the process.

2. Task Overview

There are 2 aspects to this Seaperch competition, the first task being the competition of an obstacle course. The course consists of 5 underwater hoops arranged at equal intervals and oriented with varying angles(2). The ROV must maneuver through all of the hoops, surface, and then retrace it's steps to get back to the pool wall where it started. Teams are judged by the time (best out of 2 attempts) it takes them to complete the course.

The second task is the challenge course: waterway cleanup. In this challenge, there is a submerged "vault" with a latch that must be opened. Upon opening the vault, the ROV must retrieve pieces of sunken debris from the pool floor, one at a time, and drop them into the vault. Points are awarded for each item placed in the vault within the given time period. Needing a diver to intervene results in a time penalty.

Completing the obstacle course requires optimizing the ROV for speed and maneuverability, however, it can be completed without any major design innovations. Waterway cleanup, on the other hand, requires the development of new devices to be completed effectively. Our design approach was thus focused on optimizing our ROV design for the waterway cleanup operation.

We designed and tested multiple hooks with the goal of enabling the ROV to pick up and deposit its target objects with as simple and efficient of maneuvers as possible. We then had to adjust the buoyancy and balance of the ROV to enable it to swiftly and stably carry objects. After achieving a successful design for the waterway pickup challenge, we attempted to better optimize our speed and maneuverability for greater success with the obstacle course.

3. Design Approach

After completing the stock SeaPerch design (1), we brainstormed modifications to improve the speed, maneuverability, and functionality of our ROV to enable more efficient and faster completion of the tasks explained in section 2. We will discuss our ideas in three sections: Frame Modifications, Hook Additions, and Motor Adaptations.

Figure 1 (α)

Figure 2 (Early β)

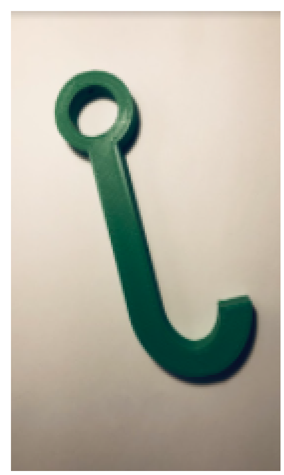

Figure 3 (Final β)

<u>Hook Additions:</u>

A hook stood out to us as the simplest and most maneuverable option for picking up sunken debris. Using tinkercad (4) we designed two hook variants: Variant Alpha (**α**) and Beta (**β**).

With our first design, Variant Alpha (Figure 1), we wanted an arm capable of opening the vault latch and picking up objects. **α** protrudes from the front of the ROV frame. Our first iteration of **α** looks like a key. Notches running along the shaft and a lip at the end of the shaft stop objects from sliding off. The ring at its other end fits around the PVC frame to create a secure connection. We originally screwed **α** in place, but this stopped us from reorienting it into a position that wouldn't negatively impact our maneuverability in the obstacle course. After adjusting the diameter of the ring, we have achieved a secure fit which enables easy reorientation of **α**. We also removed the notches from **α** because they didn't affect its performance and decreased its structural integrity.

Our goal with Variant Beta was to make a hook able to more easily pick up, travel with, and deposit the challenge course objects. **β** looks like a large fish hook which protrudes from the base of the ROV frame, directly below the central motor and center of mass. This hook features the same PVC attachment ring as **α**. Our original design (Figure 2) was very small and proved too difficult to pick up any rings with, so we lengthened it in our final design (Figure 3).

We ultimately kept both hook variants on the ROV because they both perform better than the other at certain tasks within the challenge course.

<u>Motor Adaptations:</u>

We had two main ideas for our motors and ended up implementing only one. Our first idea was the addition of variable resistors in our control box. This way we could precisely control the amperage which the motors received, and thus the speed at which they provide the ROV. After testing our ROV in the pool for the first time, we realized that it will never need to travel at a speed slower than its maximum and concluded to use the simpler, original control box design.

Our second idea came from the frustration of imprecisely attaching the ROV motors to the frame with zip ties (Figure 4). Our solution was developing a set of 3D printed motor mounts to more securely attach our motors with more precise alignment, improving the speed and accuracy of our underwater movements.

Figure 4 (Napkin Mount 1.0)

Our first design (Figure 5) featured a holster for the motor, secured to the frame by a loop similar to, but longer than those used in our hook designs. However, the complex shape of this design resulted in low quality prints and it was impossible to secure the motors with these mounts without having to remove the propellers first. Our second design (Figure 6) is much simpler. It still relies on zip ties to secure the motor, but provides a larger surface area indented in the shape of the motor capsule to keep the motor securely in place. This mount can be screwed into the PVC through a pilot hole printed into the design (to prevent the PLA from cracking) to further ensure that the motor does not rotate about the PVC (z-axis), disrupting the ROV's forward motion.

Figure 5 (Napkin Mount 2.0)

Figure 6 (Napkin Mount 3.0)

<u>Frame Modifications:</u>

In redesigning our frame, we wanted to increase the speed of the ROV while maintaining stability and control. This turned into a balancing act as, generally speaking, a larger frame creates more stability but less speed and vice versa with a smaller frame.

We brainstormed ideas for a complete redesign of the frame, but ultimately decided that we did not want to take that risk given our limited ability to test the ROV, as discussed in section 5, and given that the current design, with a few modifications, fits our needs very well.

In modifying the frame, we made the decision to prioritize stability and control over speed as this is what would help us pick up the most objects in the challenge course, and while hindering us from moving as fast in the obstacle course, still granting us easier control to maneuver through the hoops.

The original frame does provide a lot of stability, however, it is overly large for our needs. We shrunk the ROV by ⅝” in height and 1 inch in length to provide greater speed without losing a substantial amount of stability. These values were chosen in order to shrink the ROV without moving the motors too close together and to keep the center of gravity in the location of the middle motor.

We also added a bar of PVC across the base of the ROV, directly below the central motor (and center of mass), to which our hook attaches (Figure 7).

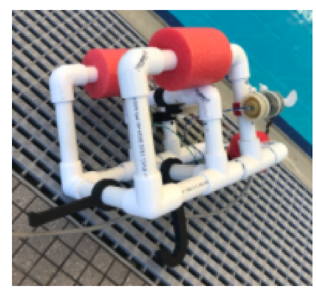

Figure 7 (Paper Towel - Stock Noodles)

To increase the ROV's speed, we sculpted our pool noodles (the buoyancy provider) in a way that reduces drag (Figure 8).

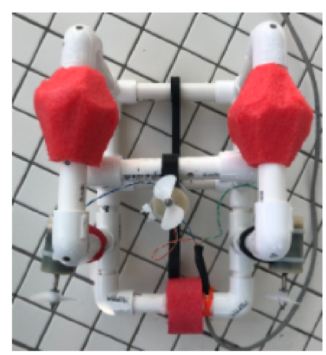

Figure 8 (Paper Towel - Sculpted Noodles)

4. Experimental Results

While designing and building our ROV, we had three opportunities to practice and experiment in the pool. Since we only had three times within a few weeks before the competition, we could not experiment to as thorough extents as we would have liked. We still, however, did experiment with some different variables in order to make sure we were using the best designs we could. We ended up testing the efficiency of the Alpha and Beta Hooks with trials testing how long it took to retrieve 5 rings (Table 1) and the differences between the stock buoyancy design vs. our sculpted buoyancy design (Table 2 & Table 3).

Our first test was the comparison of Hook Alpha and Hook Beta. We placed 5 rings across the bottom of the pool and timed how long it took to retrieve and bring all five rings to the surface. We repeated this five different times with both Hook Alpha and Beta to get a mean time for both. As seen in Table 1, the mean time for Hook Beta was 7.16 seconds faster than the mean time of Hook Alpha. Even though Hook Beta demonstrated faster times, Hook Alpha still proved to be more versatile, including proving useful for opening the vault. Based on these experiment results, we decided to keep and use the Hook Beta for ring retrieval and Hook Alpha for most other objects.

Our second test was the comparison of the stock buoyancy and the sculpted buoyancy. For both the stock and sculpted versions, we timed the time descend five feet, and then the time to ascend five feet. As seen in Table 2, the time to ascend is similar for both. Table 3, however, displays a great difference in descension time between the two, with the sculpted buoyancy design performing 2.67 seconds faster than the stock bouncy. This confirms our thought process that the sculpted buoyancy would be a better version in that it has slightly less buoyancy, helping us descend faster. We were also pleased to know that our buoyancy was not so dramatically impacted that the ROV was slower to ascend. The sculpted design also creates less drag with its more streamlined design.

	Time to Retreive 5 Rings from Pool Floor.1	
Trial	Hook Alpha	Hook Beta
1	79.15 Sec	74.05 Sec
2	80.13 Sec	73.97 Sec
3	81.19 Sec	70.21 Sec
4	76.49 Sec	73.05 Sec
5	79.83 Sec	69.73 Sec
Mean	79.36 Sec	72.20 Sec

Table 1

	Time to Ascend 5 Feet	
Trial	Stock Buoyancy	Sculpted Buoyancy
1	7.86 Sec	6.55 Sec
2	5.85 Sec	6.54 Sec
3	5.06 Sec	5.60 Sec
Mean	6.26 Sec	6.23 Sec

Table 2

	Time to Descend 5 Feet	
	Stock Buoyancy	Sculpted Buoyancy
1	10.83 Sec	6.69 Sec
2	8.97 Sec	7.40 Sec
3	8.92 Sec	6.62 Sec
Mean	9.57 Sec	6.90 Sec

Table 3

5. Reflection & Next Steps

Almost everything we did this season was in some way affected by the COVID-19 pandemic. We were able to make plans and talk through our ideas online, but only one person was able to work on the physical construction of the ROV at a time. Our access to a pool for running tests and practice runs was also very limited due to public health regulations and high demand for pool space from our community, making it impossible to assemble and test many different designs.

Despite the negatives, the challenges we faced due to the COVID-19 pandemic forced us to better manage our time. With our limited pool access, we had to work very efficiently to run all of our tests between design iterations. The circumstances also necessitated better and more frequent communication between each of us team members, our advisors, and pool managers. All of us have greatly improved our communication skills due to this, a skill that we will utilize in higher education, work, and most other aspects of everyday life.

Our approach when designing our ROV was to optimize velocity and maneuverability, something we achieved only after many iterations and experimentations. We succeeded in keeping the ROV controllable, but in retrospect, it likely would have benefitted from a greater reduction in scale. Our speed remained hindered to a degree that would justify a sacrifice in maneuverability, and with more time, we would certainly have achieved this by simply reducing the lengths of the PVC pipes by an experimentally determined factor.

We also tended to opt for the simpler of our ideas to implement on our final design despite our often complex initial ideas. This is quite obvious with our mount designs. When designing Napkin Mount 2.0, we thought that it looked very sleek and would hold the motor very securely, however, when trying to implement the idea, we realized that we would have to remove our propellers and go through far greater effort than it was worth. This led us to develop napkin Mount 3.0, a far simpler design which creates less drag that 2.0 would have and fulfills our needs of securing the motor precisely.

We also learned the lesson of not rushing. Amidst our frantic attempts to fit in all of our experiments during our limited time at the pool, we accidentally cut the wires to our left motor. Thankfully we were able to fix this issue rather quickly with some wire strippers and electrical tape, but the event sure did teach us to never get too hasty while working on the ROV.

Every member of our team is a high school senior planning to attend college next year. Even if any one of us competes in SeaPerch again, regrettably, this team will not. This, however, does not mean that we are done utilizing the skills we have learned throughout this process. We are all planning on entering STEM fields in which we will build on the skills, including CAD, circuitry, and executing the engineering process, that we first learned through this competition. For two of us, competing in this competition is what inspired us to study an engineering field.

Each of us has gained a further set of skills--teamwork, organization, problem solving, and perseverance--that we will use in everyday life from now on.

6. Acknowledgements

We would like to thank:

Our Supervisor, Mrs. Hope Mikkelson, for giving us this opportunity to expand and grow. None of us would have had the motivation to do this if it weren't for you. Thank You.

Our Tech Ed Teacher, Mr. Rick Boehm, for helping us with 3D printing. Making any 3D printed parts would have been very hard without you help. Thank You.

Our Shop Teachers, Mr. Smith and Mr. Zimmerman, for supplying us with tools. Any time we asked for something, you were always willing to help get it for us. Thank You.

Our School District, VASD, for funding the SeaPerch program. Without your funding, opportunities like SeaPerch and countless others would disappear. Thank You.

Our Aquatics Director, Angie Lucas, for letting us use the pool for practice and the regional competition. We know pool space is hard to come by, and you still supported us every step of the way. Thank you.

7. References

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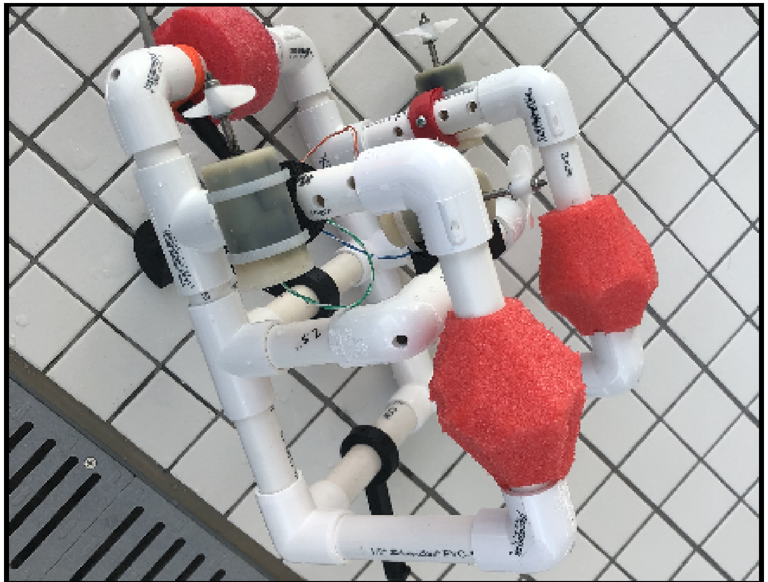
Appendix A: Budget

Material	Vendor	Use	Quantity	Cost per Unit	Cost (USD)
PLA Filament	Makerbot	3D Printed Components. 3 Motor Mounts, 1 Hook, 1 Key to Success	~50g	$0.05/g	$2.50
½” dia 4-Way Tee PVC Fittings	Amazon (Winmax)	Frame Joints	2	$1.20	$2.40
½” dia 3-Way Elbow PVC Fittings	Amazon (Sasonco)	Frame Joints	2	$1.25	$2.50
				Total Additional Cost	$7.40

Team Napkin

Verona Area High School



COMPETITION CLASS

2 Years participating in SeaPerch

1 Times at the International SeaPerch Challenge

Our SeaPerch is unique because: (100 words MAX)

We have two different variations of hooks on our ROV frame for a wider variety of objects. We also used custom made 3D printed mounts for our motors to allow more precise control. To maximise speed we molded and shaped our noodles to provide buoyancy and minimize the drag in the water.

SeaPerch Design Overview: (100 words MAX)

We used a smaller and more compact design than supplied to allow for a faster and more maneuverable ROV, still kept the ROV large enough to maintain stability and control. We also used 3D printed parts to create more precise motor angles. We tried to counteract the size of our ROV by minimizing all possible sources of drag. We did this through modifications like molding the noodles used for flotation and reducing as much front facing surface area as possible.

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

Throughout this season, we all had to work to overcome the challenges the CODIV-19 Pandemic brought with it. Organization and team coordination were big challenges to overcome because we were unable to work in person together for most activities. This whole experience has taught us all that no matter the obstacles, we can always find a way to have fun together working on something we love to do.