Abstract:

This Technical Design Report shows our engineering design process to create our final ROV. Our aim was to create an ROV that advanced nearly ever aspect of the standard design. Using many years of experience and testing, we developed the most optimal design for the challenges faced during competition. We accomplished this by using 3D-printing and Computer-Aided-Design technology to completely redesign the body of our robot. In doing this we were able to change minute details of the design to work the best in competition. This report details how we worked within the parameters of the stock class to develop a fully redesigned ROV to achieve the best possible results. Focusing on aspects of the design such as reducing drag, increasing speed, and increasing maneuverability increased the efficacy and efficiency of our ROV. Using scientific testing, we determined the most effective components and designs and were able to use this data in developing the final design. Continuing to improve this design is an additional focus of ours and is another benefit of computer design and 3D-printing. Using these technologies, we are able to constantly iterate our design to continue to improve upon our design. Through our engineering design process, we have developed a robust and effective ROV for competition.

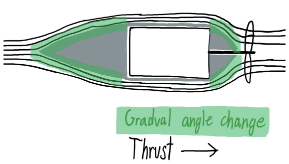
Task Overview:

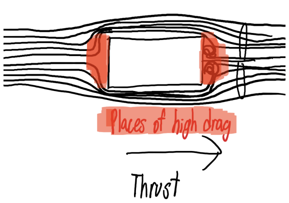
When designing this season's ROV, we reviewed our previous SeaPerch experiences to develop the ideal approach. Competing in prior International competitions, we were able to observe a variety of different designs for ROVs that were novel in many ways. This prompted us to decide that we would need to completely redesign the stock ROV to fulfil our ideal requirements. Breaking away from the simple PVC design allowed us to think fully outside of the box to improve almost every aspect of our ROV. To organize development, we listed the most valuable qualities of an ideal ROV such as speed, size, and maneuverability. A key part of completing the challenges is speed, so we focused on reducing the drag experienced by our ROV. We also wanted the design to be smaller than the original SeaPerch to be able to fit through hoops in the Mission Course easier. Additionally, a smaller ROV would be more agile than the stock model. Lastly, we knew the ROV needed to be highly maneuverable. It has to complete the challenges in a skilled manner to win the competition. We took these key points and adapted our ROV to best complete the challenges.

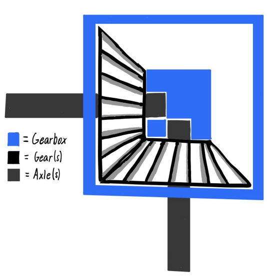
Design Approach:

For this year's SeaPerch, our team aggregated ideas we developed over years of competing. We decided the most effective and flexible way to manufacture a robot was in Computer-Aided Design and 3D printing, and we began brainstorming on theoretical designs that could manifest our ideal ROV. Our first design kept the same motor positions while decreasing the cross sectional area to reduce drag. Further developing this idea, we moved all motors into the most compact position in the same x-y plane. This design had many problems, including that, by condensing everything into one plane, the ROV became extremely unstable, constantly flipping. Our next iteration aimed to fix this issue by spreading out the left and right thrusters slightly to improve controllability and adding a top float to improve stability. Additionally, we rotated the vertical motor into a horizontal position while adding a right-angle gearbox to improve hydrodynamics. Each of these changes allowed us to perform much better than stock ROVs in competitions.

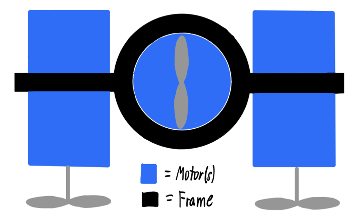
A large part of the design process was working on the best way to decrease the cross-sectional drag of the ROV to allow the seaperch to travel faster with higher efficiency (Faber 2019). We did this by streamlining the shape of every part, including designing more efficient floatation, motor pods, and a 3D-printed, 90-degree gearbox to allow the vertical-thrust motor to mount horizontally. In order to decrease the drag of the flotation, we designed and 3D-printed the floats to allow the angle of incidence and angle of departure of the pods to be as small as possible. Using plastics in 3D-printing also allowed the float to be smoother than the traditional floatation, and therefore more hydrodynamic (Nisbit 2019). Motor pods decreasing the initial and departure angle of the water decreased the volume of turbulent water around the motors. A decrease in turbulent water leads to an increase in efficiency of the motors, allowing the ROV to travel faster. In order to similarly streamline the body of the ROV, we decided to place the up/down control motor horizontally inside of the body. Execution of this required converting the horizontal rotation of the up/down motor into vertical thrust. Our team turned to 3D-printing again to solve this problem. We designed 3D-printable gears with 45 degree angled teeth, axles to connect the gears with the motor and propellers, and a gearbox to hold everything together while allowing enough room to reduce friction. The diagram to the left shows a cross-section of the assembled gearbox. By using new technologies to their maximum ability, we were able to significantly reduce the amount of drag the ROV experiences, increasing the speed of the robot.



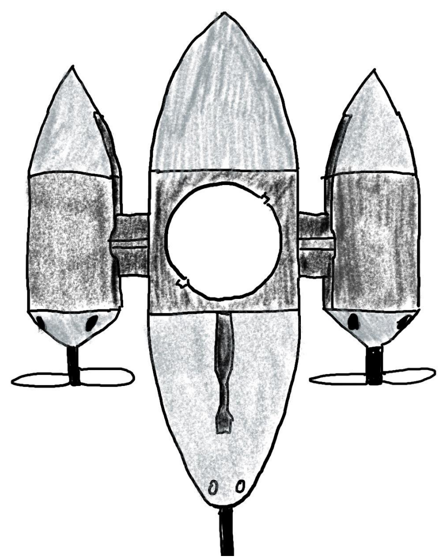




By designing the ROV in computer aided design, we were able to precisely design and measure every part of the robot to calculate the exact volume of flotation required to create a neutrally buoyant ROV without using the bulky, inefficient, and unreliable pool floats. This allowed the ROV to be more reliable in the water because we wouldn't need to worry about water logging of the floatation. In the software used to model the ROV, we were able to create every part with immediate feedback on how much that part would weigh and how much water it would displace. Using this information along with the measurements taken from the non-3D-printed parts allowed us to design parts to be exactly neutrally buoyant. Using Archemides's Principle for buoyancy, we know that, for an object to be neutrally buoyant, the weight of the water displaced must equal the weight of the object displacing the water (Lavallo, n.d.). Comparing the weight of the parts as a whole to the amount displaced, calculated by the CAD software, allowed us to be sure that the Seaperch would be neutrally buoyant.



Making all of these changes at once caused the ROV to be extremely fast and maneuverable, many times more than we intended. In order to combat this side effect of speed, we changed the location of the motors to slow the turning speed of the robot. In the first iteration, the thrust motors were as close to the vertical motor as possible. During testing, we quickly lost control which increased event times. To slow the rotation speed, we spread out the thrust motors, seen in the diagrams to the right of the first iteration (above) compared to the final iteration (below). This used Archemides's Law of the Lever to give us more rotational torque in exchange for rotational speed. Archemides's Law of the Lever states that a larger motion with less force further from the fulcrum uses the same amount of energy as a small motion with more force (Dijksterhuis, 1987). This is how we were able to slow down our turning speed to improve the Seaperch's dexterity.

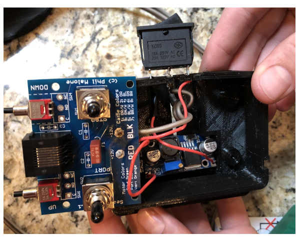


These changes to the final ROV design allowed the Seaperch to be faster, exactly neutrally buoyant, and more controllable than previous ROV designs. We used the 3D-printed parts to increase the hydrodynamics of the ROV which increased the efficiency, 3D-printed floatation to increase the reliability of the ROV, and motor spacing to increase the controllability of the ROV. Each of these design choices allowed us to create the best possible ROV using available materials and guidelines.

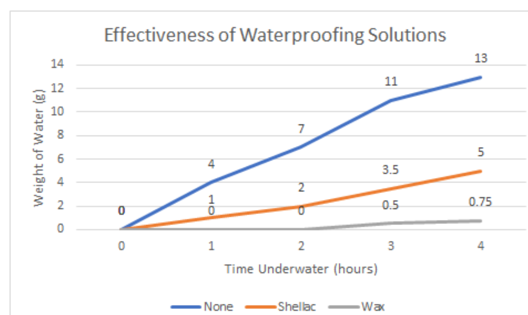
Experimental results:

In any project, it is very important to test each design iteration after development to find what can be improved about the design. In SeaPerch, we used this method to test many design changes over the course of development. We tested multiple floats, different controllers, various attachments, and changes to waterproofing of the ROV.

A vital requirement for a well-functioning ROV is the neutral buoyancy. We achieved neutral buoyancy by designing integrated floats into the ROV and tested a variety of designs to see which would be the most effective. To test, we tested each iteration of floats in a speed and power test. These tests measured the drag each design created and the amount of weight each iteration could lift. Using this data, we selected the most efficient floats. In addition to the integrated flotation, we also tested floats attached to the ROV's tether to create a neutrally buoyant tether. We validated our results in the pool to collect real-world information regarding each combination of flotation.



Along with these changes to the ROV itself, our team tested various configurations of the controller. Changing many factors of the ROV at once leads to a hard adjustment when driving. Our SeaPerch is much smaller than the standard kit ROV, which makes it extremely fast. Speed is extremely advantageous for many situations but is a hindrance in tight quarters. We added buck converters, which reduce voltage output, to the controller to reduce the power sent to the left and right motors. After careful testing, we learned that the buck converter was hindering us more than helping us and we were able to navigate the challenge without them. With practice we could navigate at full speed, so we decided to get rid of the buck converter.



3D printed parts are not waterproof on their own, so after long term usage, they become waterlogged and disrupt buoyancy. Due to this, we needed to find another way to waterproof the flotation. We initially used epoxy, which was not ideal and caused cracks in the print. We then conducted an experiment where we covered three identical prints in various materials to see which one performed the best. One was left as regular plastic as a controlled variable. Another one was sprayed with shellac, and the last was covered in the wax that came with the stock SeaPerch kit. We left all three in 10 feet of water for a 4 hours time period, observing the amount of water that infiltrated the print every hour. When we came back, the control was filled with water, the shellac had a large amount of water, and the wax had little to no water. This also allowed us to waterproof the ROV with the given materials in the SeaPerch kit, so we had no extra cost.

Reflection & Next Steps:

Our team's design process allowed us to develop the best possible ROV for the required tasks. We began by laying out the important challenges the robot would face to organize how we would approach the design process. After organizing the challenges, we were able to come up with parts of the design to optimize. With these in mind, we designed the first iteration of the ROV. This design did not achieve all of the design focuses, so we made the second iteration with parts of the challenges at the forefront of the design. This was not the best design, however, because it was not well rounded, so we made the third iteration of ROV. This design focused evenly on all focus points of our plan, increasing the speed, controllability, and reliability of the seaperch. After much testing with this design, we were able to further improve it with small tweaks, such as waterproofing, and arrive at the final design. Reviewing our process, we can identify valuable processes, such as our rapid development model where we could quickly and easily test various ideas. We can also identify hindrances, such as specific instances where we identified problems with methods yet chose to continue developing these methods. This was the case in one gearbox model, where we continued to develop an inferior design past when we should have designed a new model.

This year's Seaperch ROV was a monumental step toward improving the overall function of the robot, but that does not mean that it is perfect. Using our processes that were beneficial and detrimental, we can determine what we should continue to focus on next year. Some specific factors of the ROV we will continue to enhance are stability and buoyancy. As seen in testing, we went through many shapes and types of floatation, such as increasing the body volume, tuning the body shape, and changing the top float shape. Further improvement could be done to achieve greater stability using the top float. We could also further improve the waterproofing of the ROV. Currently, the waterproofing is adequate for the intended application, but we may be able to further increase the effectiveness to allow the ROV to be even more reliable. This will be especially useful when applying these design choices to real-world remotely-operated-vehicles. Each of these changes could be done to further improve the Seaperch past what it can achieve currently.

Acknowledgments:

Getting to where we are in SeaPerch takes help from many other people. We would like to thank: Joseph Neal for being our first SeaPerch coach in middle school and teaching us how it works, Todd Rose for coaching us at the high school level, Bonnie and Todd Rose for purchasing our ROV kit, Kelly Doran for allowing us to practice in her pool, Pam Wooddell for designing and making our shirts, David Glenn for hosting practice days before national competitions, everyone we talked to at the first International Competition we attended who inspired us to think bigger, and the SeaPerch volunteers who put on smooth-running competitions for us to compete in. We could not be where we are without the support of these integral people.

References:

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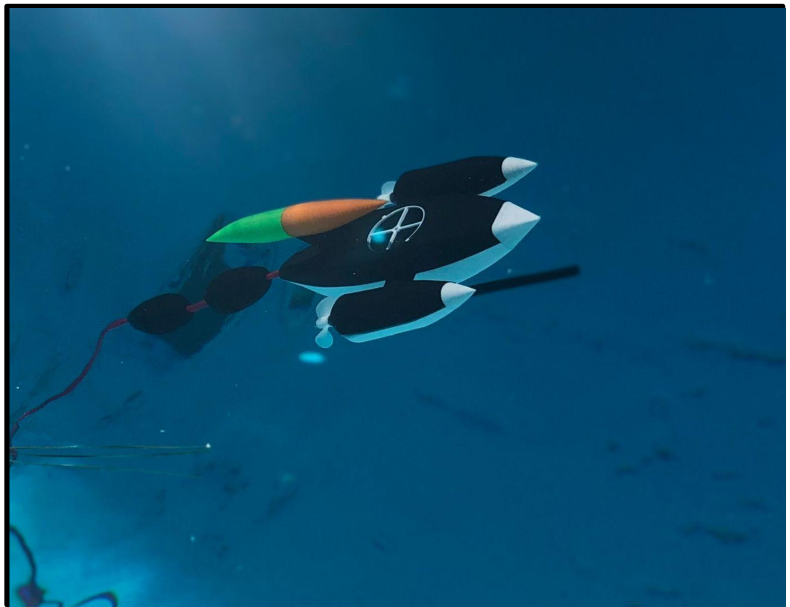
Budget:

Component	Vendor	How was the component used?	Cost (in USD)
Aluminum Rod	Amazon	As a hook on the bottom	$2.54
3D printed parts 369g at $0.05 per gram	Amazon	To build the frame	$18.45
Netting	Amazon	To complete the National challenge	$1.91
Hanger	Amazon	To complete the national challenge	2 hangers at $0.44 per hanger= $0.88

Total: $23.78

Orca Whales

Wilmington Robotics Club, Wilmington, NC, USA



High School

5 Years participating in SeaPerch

4 Times at the International SeaPerch Challenge

Our SeaPerch is unique because: (100 words MAX)

We have completely redesigned the ROV from the ground up through novel Computer-Aided-Design (CAD) software and 3D-printing. Using these technologies, we were able to develop a SeaPerch that is hyper-efficient and extremely effective at each challenge. Designing each part of the robot in CAD software allowed our team to analyze and perfect each part of the ROV. An additional benefit of computer design is that each SeaPerch iteration can be executed in a much more efficient way compared to conventional methods. Changes to the ROV can be added quickly through CAD and manufactured at an unparalleled pace and quality.

SeaPerch Design Overview: (100 words MAX)

Our team was able to greatly improve upon the conventional SeaPerch ROV design by using a new technology, 3D printing. 3D printing allowed us to expand our ability to create custom parts that performed as well as conventionally manufactured parts. By reducing the drag of the body, widening the horizontal thrust motors, and designing and 3D-printing custom floats we greatly increased the effectiveness of the ROV. This caused the ROV to be extremely fast, maneuverable, controllable, and reliable, all attributes that make a leading Seaperch ROV. Focusing on these attributes during development created the most efficient design possible.

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

The benefit of using a development method that is as effective during periods of limited physical meetings as during normal periods. Using Computer-Aided-Design to develop the SeaPerch during Covid-19 allowed our team to continue to collaborate and innovate in a way that is similar to pre-covid levels of productivity. With other production methods, much more emphasis is placed on putting together common pieces in an innovative way. This leads to teams placing more value on in-person meetings as they must be physically working on the ROV. With CAD, our team was able to develop a novel robot without in-person meetings.