Abstract

Our ROV, Wagyu, consists of a unique combination of a PVC pipe frame, 3D printed motor shrouds, an overhanging mesh netting, and a hydraulic claw apparatus. The Wagyu was designed to complete two courses, each with its own set of tasks such as going through hoops or manipulating objects. In order to complete these tasks, we improved upon ROV designs from previous years by cycling them through the Engineering Design Process(EDP). Essentially, the Wagyu is the culmination of three years of Seaperch designs and experience. Because of this, several aspects are designed to increase the effectiveness of the ROV. For example, the controller for the ROV was modified to be more ergonomic and the shrouds were designed to increase motor output. Each feature of the final design went through the EDP and was tested multiple times in order to optimize the Wagyu as much as possible. Because of this, the Wagyu is the result of constant improvement since our first year competing in the Seaperch Competition as we continually look back at our previous designs in order to better our creations. We intend to continue improving on our Seaperch designs until we graduate.

Task Overview

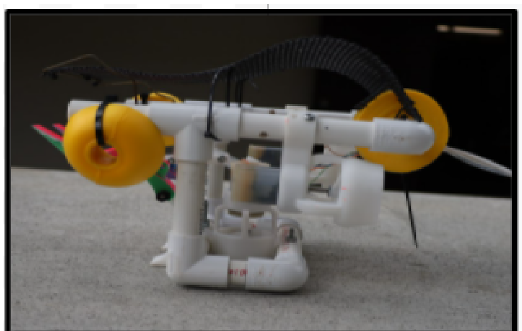
The Seaperch Competition requires the ROV to complete various tasks. These tasks are divided between the Obstacle and Challenge courses. The courses have objectives that test the capabilities and versatility of the ROV. Each task within the two courses is worth a certain amount of points. The goal is to obtain as many points as possible within the given time frame.

The Obstacle Course is composed of a straightforward set of five hoops arranged at various angles and positions. To complete the course, the ROV must pass through each hoop in an over-under pattern. After passing through the fifth and farthest hoop, the ROV must surface the water before going back through the obstacle course in the reverse order. You are allowed to do the Obstacle Course two times, but the better of the two runs will be your score. There is also a two-minute time limit to complete the course, failure to complete it within the allocated time bases your score on the progress of your ROV.

The Challenge course consists of four separate tasks, each involving manipulation and readjustment of different objects and their location. The first task is disarming the mine with a 1¼ inch PVC cross-connector mounted on a PVC pipe. The mines only deactivate by turning the cross-connector a full 90 degrees. We could also lift the cross-connector off the PVC for extra points. Because of this, we add a hydraulic claw to allow us to manipulate the PVC and other objects within each task. The second task is to open the Disposal Vault door. To do this, the ROV must turn a spinning latch that keeps the vault closed. For extra points, it is possible to place the mine on the vault door to close it afterward. The third task is to remove various pieces of floating trash from the Garbage Patch, the designated area for the trash. An overhanging mesh-netting allows our ROV to pull the floating trash out of the Garbage Patch. The fourth and final task is to transport a variety of sunken trash from platform to platform. The hydraulic claw also has the dual purpose of manipulating the sunken trash.

Design Approach

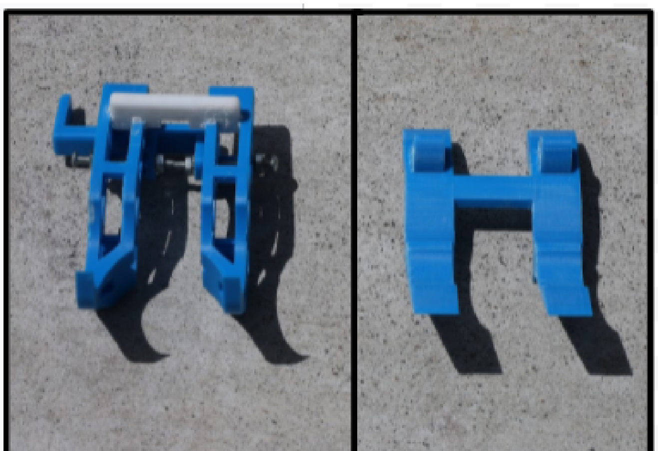
In order to complete these courses and obtain the maximum amount of points possible, the ROV must be capable of completing all the competition's tasks. Each component of the ROV was iterated to maximize its effectiveness, keeping several concepts in mind while designing the specialized parts; based on a total of three different ROVs that were placed in the Regional Seaperch Competition, being the Philips, T.C.T., and N.E.R.D.S. The Wagyu drew upon the most successful design aspects of those 3 by combining them to create the most well-rounded ROV possible, which included optimizing its movement and capability to manipulate various objects. Each of the ROVs that the Wagyu drew upon had variations of the same components: a PVC pipe frame, 3D printed motor shrouds, a hydraulic claw apparatus, and an overhanging mesh netting. Some aspects of the previous iterations had to be slightly modified and others had to be completely redesigned to fit the Wagyu.



All of the components fit within the 12" x 11" x 8" frame

The frame of the N.E.R.D.S. was used for the base due to its versatility and size. The design had a smaller and lightweight build, while also being capable of holding the other components of the ROV within it. For example, the motors and shrouds were able to fit in the center and rear of the ROV, and the hydraulic claw apparatus of the N.E.R.D.S. was able to fit in the front.

There were some complications in the N.E.R.D.S. design and required modifications in order to complete certain tasks. One of the aspects of the design adjusted was the hydraulic claw apparatus. The original design for the hydraulic claw came from the N.E.R.D.S. This design was inspired by modern hydraulic systems used in machinery and ROVs ("ROV Manipulator Arms"), with a single actuated claw that rotates from a pivot with the linear motion of a hydraulic piston. The bottom claw acts as the counterpart of the actuating claw, allowing for the bottles and balls to be manipulated. The top claw is powered by a syringe with a special 3D printed joint, imitating a hydraulic piston (Brain, 2001). The claw was able to grab all of the Sunken Trash items, however it was unable to lift the mine fully off the PVC pipe in the 1st Task. The Philips' hydraulic claw was able to manipulate the mine, with an upward curve protruding from the top claw. This mechanism was applied to the Wagyu, being combined with the prongs of the N.E.R.D.S. claw to create an entirely new design, capable of completing all of the tasks.



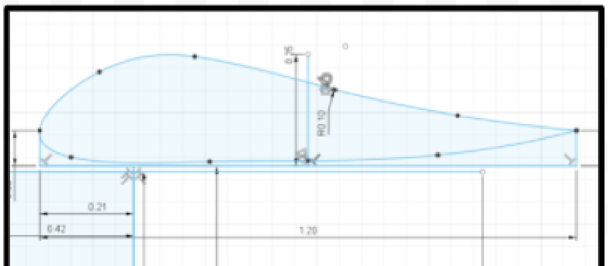
Two of the previous Top Claw iterations. The final iteration is not depicted here.

Another modification to mention was the iterations of the shrouds. The N.E.R.D.S.' 3D printed shrouds were from the previous year's designs; the shrouds functioning well but heavy. This gave Wagyu an increase in speed, but at the cost of the budget. In order to fix this, both the

Philips and the T.C.T's shrouds were used as starting points for creating a new shroud design for the Wagyu. The variation of camber in the shroud was tested to find the optimal curvature, with inspiration from the patent of ring-shaped shrouds that were designed after airfoils (Gratzer, 1992) and their properties to control air pressure for lift (*Principles of Flight)*. The similarity between aerodynamics and hydrodynamics being based on the motion of fluids, the shrouds could be modified for a maximized output velocity (Editors of Encyclopedia Britannica, 2006). These new shrouds combined the lighter weight from the T.C.T. with the passive capability to increase the velocity from the Philips; effectively cutting down the cost and weight of the Wagyu's final shrouds while still retaining the movement capabilities.

Three of the motor shroud iterations. The final iteration is on the far left.

However, one feature that remained constant throughout the three ROV's was an overhanging mesh design. The "whale-mouth" design choice in question was reused from last year; inspired by the feeding methods of baleen whales (Tresfon). While each ROV implemented its own unique version of this, the differences were negligible, as the concept was the same for each; an open front frame with a mesh netting suspended above it. This was designed to allow the ROV to remove the Floating Trash from the Garbage Patch in a way similar to how baleen whales feed on large amounts of krill in one sitting.



This is a 2D sketch of the shape of the low camber shroud in fusion 360. The entrance of the left has a large lip and ends on the right with a tapered output.

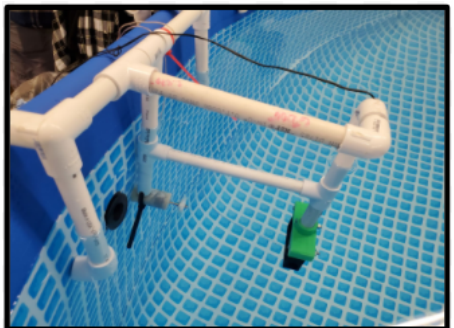
Once all the design aspects of the components were adjusted and implemented into the Wagyu, several tests and simulations were conducted to further improve the design. The ROV was tested both as a whole as well as its individual components, focusing on the effectiveness of the claw apparatus, shrouds, overhanging net until its functionality and efficiency reached satisfactory levels with the team overall.

The curve of the overhanging mesh netting is what allows it to take in the floating trash.

Experimental Results

As part of the design process, the Wagyu was tested multiple times to identify flaws and other areas of improvement.The conditions and procedures of these tests were recreations of the environment the Wagyu and its components were expected to perform in. Some variables may not have been accounted for or variables that affected the test results may not be present in the actual competition.

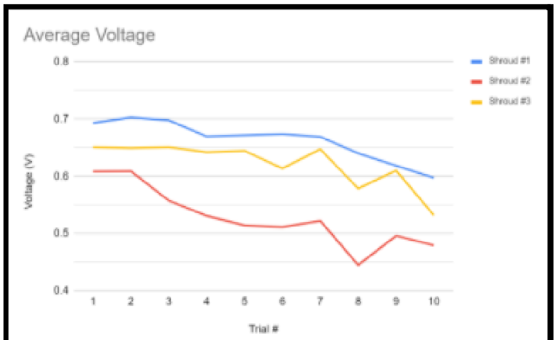
The first test conducted was a shroud test. Three shroud designs from previous ROV's were tested to determine which one was the most effective. The effectiveness of the shroud was measured by its output velocity. This was measured by the shroud's ability to turn a computer fan and generate volts. Each shroud was attached to a PVC pipe apparatus that held the shroud at a constant distance from the computer fan underwater.



A picture of the PVC pipe apparatus used to test the shrouds.

Each shroud was tested a total of ten times and observations were made through analyzing a recorded video of the trial. Whenever the voltage that was tracked through the anemometer changed, that datapoint was recorded; 25 of these data points were recorded for each trial, and the average voltage for these points was calculated. Each shroud was based on research on hydrodynamics which resulted in their varying designs(Faber 2019). The results of each of the motor shrouds were then compared to determine which shroud was the most effective.

A factor to consider is that as the trials progressed, the battery voltage decreased which resulted in the motors not being as strong. To combat this, the battery was charged before testing the individual shrouds. Throughout the trials, shroud #1 (blue) consistently produced the highest average voltage. In consort with these results, we chose to use shroud #1 in the final design of the Wagyu.



A graph comparing the average voltage for each shroud.

The second test was a driving test. The various iterations of the Wagyu were driven in a pool with a model of the competition game pieces. Analysis of the ROV's functionality and driving times were done using recordings of the various practice runs. This data was then interpreted to decide what improvements could be made; some of these improvements include driver and tether combinations, design flaw identification, and overall performance. For example, shroud placement was changed from on top of the frame to below the frame to keep the shrouds underwater when the Wagyu surfaced. Driving wise, different combinations of driver and tether were tested to see which team members could complete the tasks in the least amount of time. Driving times were tracked to monitor progress as well.

Reflection & Next Steps

This competition season has taught our team the lesson of planning ahead. Even though we were familiar with the competition as we had participated last season, it did not change the fact that we needed to improve a lot of design aspects before we were ready to compete. The Pandemic caused everyone's schedules to be changed or postponed, including our team. With the VEX Robotics Competition being postponed into January and February compared to the normal November-December time period, we did not have much time to work on our SeaPerch ROVs. This led to us having to cram to get functioning robots, leaving only a fraction of the time we had last season to practice. However, we were not completely lost as we wrote out plans for our new design from last season so we had a basic idea of where we needed to go. We plan to record our experiences and write out improvement plans at the end of this season to prepare ourselves for the next season.

Throughout the course of the season, we encountered several difficulties regarding our 3D prints. All of our 3D designs ended up misprinting at least once during the season. Despite our previous years of experience, we failed to anticipate these setbacks and were forced to push back our build plans. Several of our designs also broke or were not made to the correct measurements and had to be reprinted. We plan to cover 3D printing and CADing in our workshop to remind everyone how much time to alot to CADing.

With the limitation on team members due to the COVID-19 Pandemic, this also left gaps in our team's skill sets. Only about half of the team has experience working with 3D-printing and designing with a higher-end program besides TinkerCAD, meaning when a lot of parts were needed, it took a lot of time for one person to do it. We also had a few new members, which did allow us to get simple tasks, like waxing the motors, done more quickly. But, this also meant that veteran members had to take the time to teach and supervise the new members. This left them with less time to work on other tasks that were more complicated and important, like Computer-Aided Designing(CADing). We plan to host a workshop with our team and any incoming members to teach everyone how to use the tools that we use to make the ROV. This way, the team is well-rounded and allows the veteran members to focus more on their work instead of helping the new members. We also plan to recruit more members through promotional videos to showcase our program in hopes of attracting new members.

Taking our newfound experiences, we will be more prepared for the new season as we have gained more knowledge about the fundamentals aspects of our ROV. We learned about the hydrodynamics of the shrouds, the fluid dynamics of hydraulics, and the torque of mechanical claws. Even the competition will differ, these approaches to the challenges may be similar. We will continue to build upon years experience to further improve our Seaperch designs and engineering skills.

Acknowledgements

We would like to thank our Seaperch Program Coordinator, Mr. Ryan Saito for starting up the Castle Seaperch Program and coaching us during competition. Mr. Saito provided us with technical advice for designing, constructing, and piloting our Seaperch as well as supplies and equipment in the form of tools, kits, and 3D printers. We thank BAYER for their monetary support through their grant, which provided us with money for tools, supplies, and entry fees. We would also like to thank Ms. Malia Vaughn for being a co-coordinator with Mr. Saito and providing us access to her classroom for work and storage space. Ms. Vaughn is also a coordinator of James B. Castle High School's STEM Club, whom we would also like to thank for their monetary support. We would like to thank Mr. Raymond Saito for supplying us with the PVC pipe connectors not included in the kits and Mr. Dale Miyade and Ms. Tammi Miyade for providing us with access to a pool for practicing driving and testing the Seaperch. We would also like to thank the Academy of Innovations: Engineering Pathway, headed by Ms. Teresann Taua, for their support through resources like workspaces, tools, equipment, and technical advice. We thank James B. Castle High School's Principal Dr. Bernadette Tyrell for allowing us to use the woodshop building for our various robotics activities and her financial and personal support of the Seaperch Program with equipment and coming to our competition. We would also like to thank the U.S. Coast Guard for hosting the Regional Competition.

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Appendix A

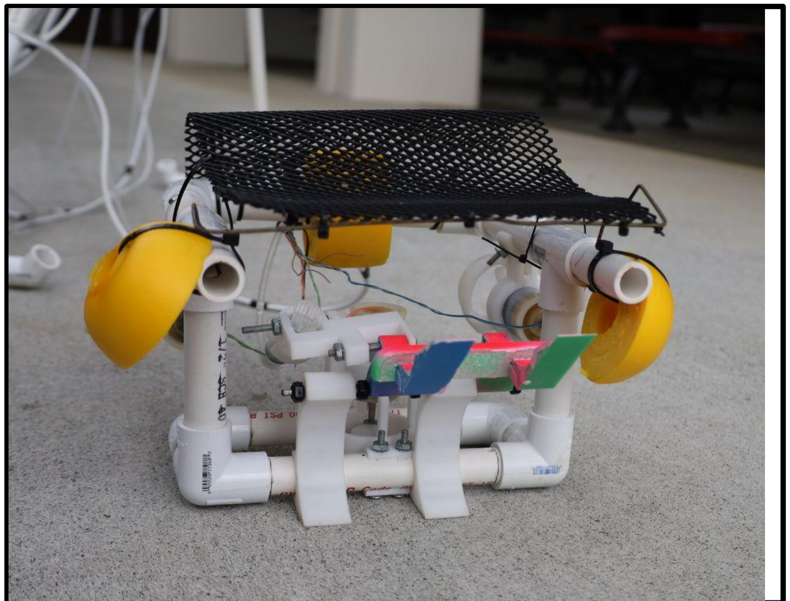
Budget

Component	Vendor	How was the Component Used?	Cost(USD
Top Claw(3D print)	3D printed	Used to grab sunken trash	1.55
Claw Joints(3D print)	3D printed	Used to grab sunken trash	0.40
Horizontal Shrouds	3D printed	To control the output flow of the motors	2.64
Syringe Mount	3D printed	Used to secure syringe to frame	0.39
Vertical Motor Shroud	3D printed	To control the output flow of the motors	1.07
Bottom Claw	3D printed	Used to grab sunken trash	1.1
Hydraulics(Tubing & Syringes)	Flinn Scientific	Used for hydraulic system	6.73
Extra T-Connectors	Seaperch Kit	Part of Frame Structure	3
Yellow Fishing Floats	POP Fishing	Used to create buoyancy for ROV	1.5
Hanger Wire	Walmart	To create guard	0.14
Pan Head Screws	VEX Kit	Used to secure 3D prints to frame	1.1
Keps Nuts	VEX Kit	Used to secure 3D prints to frame	0.33
Metal Bar	VEX Kit	Used to transfer the hydraulic system's linear motion into the claw's rotational motion	1.11
Metal Bar Spacers	VEX Kit	Used to secure metal bar	0.92
Shoulder Button	3D Printed	Makes it more comfortable to hold the controller	0.04
Thumb Stick	3D Printed	Makes it more comfortable to hold the controller	0.12
Total:			**22.14**

Appendix B

Proto Knights

Kaneohe, Hawai'i, U.S.A.



High School Other Materials Division

3 Years participating in SeaPerch

1 Times at the International SeaPerch

Our SeaPerch is unique because:

Many modifications were made to this year's ROV design. The hydraulic manipulator enables the claw to grab from the bottom making it easier to grab the sunken trash. The claw also is able to deactivate and remove the mine. The shrouds are designed with an inner camber to produce an increased velocity. The net was modified to have a lower profile in the front to help the ROV move the floating trash under the ring when necessary, as well as a large opening in the front of the frame to allow the floating trash to be easily collected.

SeaPerch Design Overview:

Our ROV, Wagyu, is the culmination of previous Seaperch ROV's and their iterations. It is the result of three years of improvement in the Seaperch Competition. Its small and compact frame gives the Wagyu speed and maneuverability while also allowing all of its components to fit within it. The hydraulic claw apparatus allows the Wagyu to transport and manipulate sunken trash items while the overhanging mesh net creates an opening for floating trash items. 3D printed motor shrouds add to the Wagyu's movement capabilities and three fishing floats give it balance and stability.

Our biggest takeaway this season is:

Due to COVID-19, we like all the other teams were hit with unexpected roadblocks, such as not being able to work together until later in the season, and not being able to practice at the pool together. Despite many setbacks, the team persevered and dedicated a lot of our own time every week to make-up for time lost due to the late start. It is through our perseverance, we fortunately qualified for the International Challenge for our first time! Perseverance is the word to not only describe our pandemic season, but what the world did this past year.