Abstract

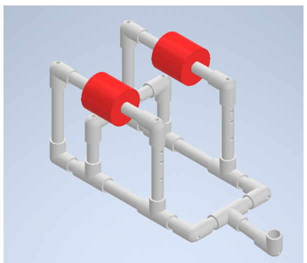
The main objective of this year's SeaPerch competition was to design an ROV that can collect garbage in waterways using various modifications that help increase the efficiency, speed, stability, and functionality of the ROV. Initially, we brainstormed many different ideas and modifications to the standard model in order to maximize the performance of the ROV. Upon testing each of these modifications in Inventor AutoCAD and VPerch, we came to the conclusion that a compact design would allow for the ROV to move faster. Based on this conclusion, we devised various designs to minimize the overall weight, surface area, and drag. We tested out three main designs until finally deciding on angling the sides of the ROV outward to allow for more sufficient water flow and increased stability. Our ROV design uses biomimicry and is heavily inspired by the structure of manta rays, especially its wings, which will essentially help with underwater flight and smooth gliding. Additionally, we decided that two individual floats on each side, a hook in the front to pick up the trash, mesh along the base, and altered position of the motors would be the most optimal and efficient way to help the ROV move faster while completing the given tasks. Through many trials, we found that certain angles and locations of the motors on the ROV provided more stable turning speeds and came to the conclusion that placing the two horizontal motors on the interior of the frame and angling them outward would allow for the most effective energy use. From our design process, we also learned that the ROV would be most stable with a float on both the right and left sides of the frame. In terms of trash collection, including both mesh along the bottom and a hook in the front proved to be the most successful in trials, as well as the most conducive use of material. Despite the numerous issues we faced throughout the design process, especially when using Inventor and VPerch to visualize modifications, we were able to resolve those issues, come up with a functional and efficient design, and use them as a learning experience.

Task Overview

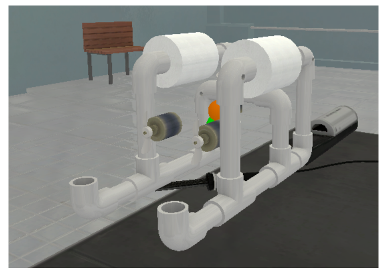
Our ROV will perform the required task of collecting garbage present in the ocean to keep it clean. Since the task requires the removal of pieces of trash, disarming of mines, and disposing trash in underwater vaults, we attached a pipe extending from the base with a small 90 degree angled pipe connected to it. This will allow for the trash to be picked up easily and efficiently and can help the ROV push certain objects which can be involved in the disarming of the mines. Secondly, we added a mesh to pick up objects that can not be picked up by the hook. We also have placed motors in the interior of the ROV and have them facing outward for quick and precise movements. Finally, we made our ROV smaller than the original prototype given to allow for more swiftness when navigating through the water.

Design Approach

Given the mission course and objective of the ROV, our team's first step was to brainstorm modifications that could be made to the standard ROV model in order to optimize speed, stability, ease of turning, and ability to carry out the aforementioned tasks successfully. We decided to use VPerch to test out our initial designs. After building the standard ROV described in the SeaPerch build manual, we decided to add a 2.5 inch PVC pipe protruding horizontally from the front of the ROV to help pick up "trash" in the task courses. However, as there was nothing to stop the items from sliding off of the pipe, a 1" elbow was added to the end of the pipe, with the opening facing upwards (Model 1). This addition proved to be effective in picking up and carrying pieces of trash to their designated locations. Initially, we thought that adding two pipes and elbows to the front of the ROV would enhance its ability to carry trash, but eventually, the design was proven to be unnecessary and a waste of material (Model 2). Although it isn't visible in Models 1 and 2, at that point, the design we had in mind would have a mesh base to carry trash that couldn't be held by the hook.

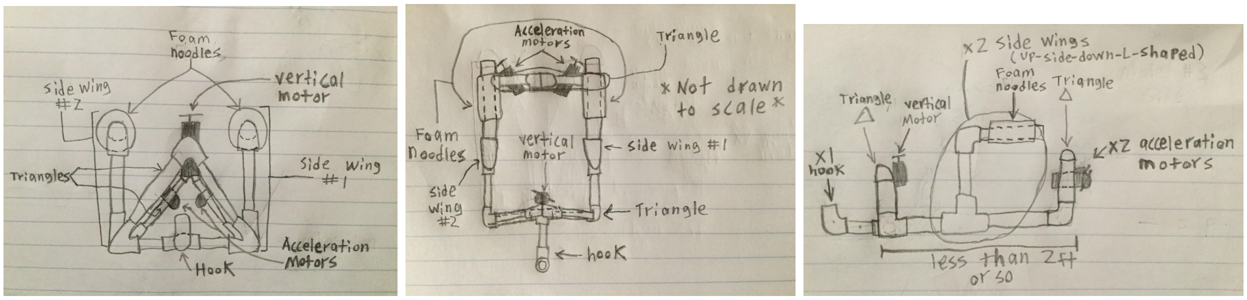


Model 1



Model 2

Furthermore, we noticed that the angle and position of the motors on the standard build could be altered to optimize speed and turning abilities. To determine the best location and angle for the motors, we conducted several tests on VPerch, each with the motors placed and angled differently on the standard model, as explained in the Experimental Results. Once we found the best angle for the motors, which we decided was in the interior of the frame and angled outward, we had to devise a design that would optimize stability and speed while being as hydrodynamic as possible. Based on the initial model, we decided that the overall design should be on a smaller scale as that would reduce the drag of the structure and allow for an overall smoother motion. As for the shape of the ROV, one of our initial designs converged the top two pipes to create a triangular prism model. While this would ideally prove to be effective in the speed of the forward motion, having only one float on the top would decrease stability when turning. Keeping the same structure, we considered putting the floats on the base pipes, one on each side, but that would've resulted in the ROV flipping over and, once again, instability. We then decided to move on to the position of the vertical motor since keeping it where it was would cause it to be blocked by the pipe above it. At first, we thought of moving the motor to the front of the frame on the top pipe, but this would cause a greater lift to the front of the ROV and may subsequently cause it to flip over. In our next steps of the design process, we chose to keep the triangle shapes at the front and back of the ROV but to remove the top pipe. We decided that if we weren't going to put the float there, there was no need for that pipe and it would be a waste of material. To resolve the issue about the location of the floats, we decided to place the floats on pipes extending out of the base and creating an upside down L-shape (Model 3).

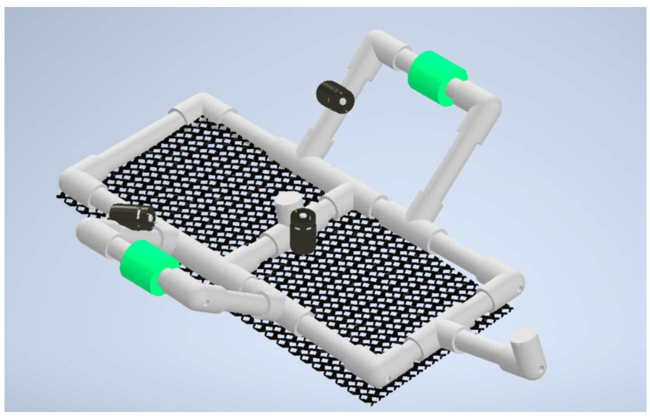


Side Front Top

Model 3

Having a float on each side extending from the base would provide maximum stability when turning and moving forwards or upwards.

While this design could be effective and functional for the given task, there were aspects of it that could be improved to reduce surface area and use less parts. From what we learned from our past designs and trials, our team was able to construct our final ROV design (Model 4).



Model 4

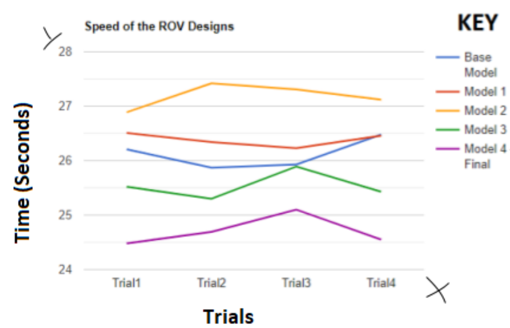
Stemming from the standard ROV build, we decided to keep the rectangular base, PVC "hook," and motor positions that we had decided on earlier. We also left the mesh bottom that was present in the initial build because it would be used to carry the trash pieces that couldn't be carried by the hook. The arch that was in the middle of the ROV was replaced with a horizontal pipe connecting the right and left sides, with a tee connector in the middle of the pipe facing upwards. This tee connector would be used to place the vertical motor. We decided this was a better alternative to the arch because it used less pipe and was just as effective. PVC caps were placed on the open tee connector and elbow to prevent excess water from flowing in. Additionally, the right and left sides that were initially perpendicular to the base were both angled 60° outwards to increase speed of turning as well as the stability when moving forward. For our design, we decided to research biomimicry, the design of models based on biological entities. After looking into different aquatic organisms and how their anatomy allows them to move swiftly through the water, we came across the manta ray. The pectoral fins of this creature essentially help with underwater flight and smooth gliding. These outturned fins were an additional reason for angling the sides of our ROV 60° outwards. The ROV as a whole was scaled down 25%. From our research, testing, and numerous designs, this model would most effectively complete the task at hand.

Experimental Results

To test our four modifications, we used the VPerch simulator and timed each of the trial runs to make qualitative and quantitative observations. For each of the four designs, we timed the ROV to see how fast it would travel to reach three lines of the pool, the turning speed of the ROVs, and at what angle and also side the motors were to test the stability and efficiency. At first, we measured the times of the base model to set a control for the rest of the trials. After our first modification of adding a single hook, we noticed that our trial times went up, likely from the weight of the extra pipe. Then, we added a second hook, and this increased our trial times even more, leading us to resort back to our initial use of only one hook. Initially, we wanted to add the extra hooks in order to increase the amount of trash that the ROV could pick up, however, we realized that 1 hook would suffice and wouldn't be too heavy. In our third model, which was both smaller in scale and more hydrodynamic in shape, our trial times reduced, proving that our modifications were effective. However, we believed that more modifications should be made to improve both the speed and stability of the ROV. We concluded that Model 4 had the greatest speed and acceleration due to its small, compact form. The open shape of the model allowed more water flow. It retained the hooks which were present in all the previous models, but also cut down on excess material in the main body, which gave us more speed and handling of the ROV.

Design Models	Trial 1	Trial 2	Trial 3	Trial 4
Base Model	26.21 seconds	25.87 seconds	25.93 seconds	26.44 seconds
Model 1	26.51 seconds	26.34 seconds	26.23 seconds	26.46 seconds
Model 2	26.89 seconds	27.42 seconds	27.31 seconds	27.12 seconds
Model 3	25.52 seconds	25.30 seconds	25.89 seconds	25.43 seconds
Model 4 - Our final model	24.48 seconds	24.69 seconds	25.10 seconds	24.55 seconds

Graph 1: ROV times crossing 3 pool lanes (20.96 ft)



In the standard build, we noticed that the speed was not optimal and the turning was not smooth. This seemed to be partially caused by the angle and position of the motors. In our initial tests, we attempted to keep the base model standard while simply adding or changing small parts in order to accurately measure the effectiveness of the modification we were making. With the purpose of idealizing the speed and turning of the design, we first tried angling the motors that would aid with left and right turning 45° inwards. We then tested this out in the VPerch pool simulation to see if our prediction would prove to be accurate. While this did increase the speed, we continued to try positioning and angling the motors differently to determine which combination would maximize the speed of the standard build ROV. In the next two trials, we compared this design to one where the motors were placed on the interior side of the same back pipes but angling them 45° outward in one trial and 45° inward in another trial. After seeing the changing in speed and turning smoothness, we were able to conclude that there was only a minimal difference when placing the motors on the inside versus outside of the frame, but turning was more controlled when the motors were angled outwards.

Motor placement vs Turning speed and Forward Speed:

Motor Placement (Side of the Frame)	Angle of the Motor	Turning Speed	Forward Speed
exterior	45° inward	Fast, less control	Slow
exterior	45° outward	Slow	Slow
interior	45° inward	Fast, less control	Average
interior	45° outward	Fast, controlled	Average

Reflection and Next Steps

As a team, we all feel that this year's competition was different, to say the least. The lack of a physical kit made it difficult to visualize the structure of the ROV. In addition, not being able to meet physically with one another proved to be difficult, as we weren't able to communicate with each other as well as we would have been. Meeting online resulted in many issues, such as wifi issues, not being able to share work, and not being able to effectively get our point across. Oftentimes, we spent many meetings simply sharing our drawings of the model to get our points across. We also had many issues with translating our drawings into actual CAD models. At first, we tried using VPearch. VPearch had a simple UI and simulation tool, but it was too restrictive and we later found it difficult to make major changes to the basic ROV model. Next, we tried using Autodesk Inventor. Inventor gave us more freedom and allowed us to completely change the initial ROV design. However, due to our lack of proficiency with the software, we ran into numerous technical errors and visual glitches with our model. After numerous trials and extensive research by some members of our team, we were finally able to make CAD models that resembled what we were initially planning for. After gaining some proficiency with the software, it is safe to say that we definitely will be using Inventor, alongside other software to create CAD models sometime in the future.

If we were testing our ROV in a real pool, we would have run many more experiments to further improve our ROV. For one, we would have conducted experiments to determine how the locations and number of ventilation holes affected the buoyancy of the ROV. We would also try to find a workaround to the refraction of light with respect to the ROV and the tether which connects the ROV with the controller. While researching the various problems that we may run into, we learned about Snell's Law and the drastic effect of light on the motion of the ROV. In real life, the light from the ceiling would alter the motion of the ROV, so we would have taken this principle and come up with modifications that would allow for us to accurately control the ROV, regardless of the light. We also learned how it could theoretically be incredibly misleading if the tether and ROV aren't in the location of the pool that we perceive them to be in. If we had a physical kit, we would have tried to integrate a Bluetooth module onto the circuit board that would allow for wireless control.

In addition, being able to witness the real-world functionality of some aspects of our ROV could have benefited our choice of materials. For instance, we could have looked into purchasing stronger motors than the 12V motors given in the kit. This would greatly increase the speed, handling, and overall efficiency of our ROV. Additionally, we could have also looked into using pipe insulation rather than using the pool noodles. From our research, we determined that this could give us more control over the ROV and provide a more stable buoyancy. Regarding the frame of our ROV, we believe that we could have made several adjustments to the ROV, beyond using PVC parts. For instance, we could have looked into materials that would be better suited for the hook of our ROV. While functional, the hook of our ROV could be greatly improved if we used lighter and fewer materials and would have overall allowed for a more compact design.

Beyond SeaPerch, we gained experience working closely as a team over these past couple of weeks. Additionally, we believed that participating in SeaPerch would allow us to further develop our skills. Some of us had previous interests in mechanical engineering and the engineering of fluids, energy, and thermal systems. After creating the ROV and learning how to use basic Inventor tools, their passion for mechanical engineering drastically increased, as they learned how to model different structures and view them from different points of view for product development, design simulation, and many others. In addition to engineering, we also had a couple of people who were interested in biology. After researching the anatomy of various aquatic organisms, their knowledge further deepened their interests in marine biology. Throughout working on this project we have honed our craft and hopefully, these skills will prove useful regardless of the career path we chose.

Acknowledgements
We would like to thank:

Our club advisors, Mr. Pandya and Mrs. Stelljes, for facilitating our team and providing the necessary guidance to complete this project

The senior members of our school's robotics club for their insight and feedback throughout our design process as well as for sharing their knowledge from past experiences

Our school for providing us with the resources to complete this project

Without these people, this project would not have been possible.

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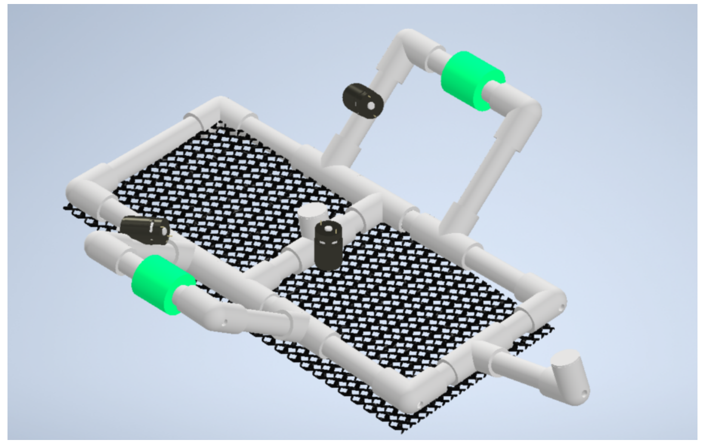
Appendix A: Budget

Component	Vendor	How was the component used?	Cost (in USD)
4 ½" PVC Tees	Home Depot	To construct the frame	4 * $0.50= $2
2' ½" PVC Pipe	Home Depot	To construct the frame	$1.37
2 ½" PVC Caps	Home Depot	To cover the open tee and elbow	2 * $0.53 = $1.06
		TOTAL COST OF SEAPERCH COMPONENTS	$4.43

Appendix B: Fact Sheet

Fact Sheet

Team Name:
Brave Robotics



School Represented:
Manalapan High School

City, State, Country:
Manalapan, NJ, United States

Competition Class:
High School PVC

Years participating in SeaPearch:
1

Times at the International SeaPerch Challenge:
0

Our SeaPerch ROV is unique because: our frame was constructed on a smaller scale, the right and left wings were angled outwards, and the weight was reduced by converting the middle arch into a horizontal pipe. The wings on our ROV were heavily inspired by biomimicry. The pectoral fins of manta rays was our main inspiration, as it would allow our ROV to glide in an aqueous environment. In addition, a PVC hook was added to the front, and the horizontal motors would be positioned on the interior of the frame and angled outwards.

Our biggest takeaway this season is: that we gained experience working closely with a team to put forward our individual skill sets and create an effective design. Some members of our group were unfamiliar with some aspects of the design process prior to competing in SeaPearch this year. However, as we became well acquainted with each other, we were able to aid each other with concepts we struggled with. In addition to that, we also gained experience working with various CAD softwares including Autodesk Inventor. We researched and learned about basic physics principles like Archimedes Principle, drag, Snell's Law, buoyancy and acceleration. Beyond physics we also learned about the application of biomimicry in the real world and tried to incorporate it into our end design. In the end, we created an ROV with a small frame and efficient structure, resulting in a fast, maneuverable ROV.

SeaPerch design overview: We made our frame out of the given PVC pipes and made it more compact than the base PVC model. By using fewer materials, the acceleration of our ROV is much greater than before due to the decreased mass which means a smaller force is necessary to propel the ROV and decreased surface area which will lower the drag force. The opened up shape of the ROV allows for greater water flow. Finally, a simple hook was made using an additional PVC Tee and Elbow to pick up the trash materials from the water.

Team Members: Allen Jiang, Ritvik Sawhney, Yasha Rachakonda, Riya Prakash, Pranav Manikonda, Supratik Bhupathiraju, Jordan Lustig