Fact Sheet

Team Name
Bort

School/Organization represented
Springfield High School

City, State, Country
Springfield, MA, United States

Competition Class
High School PVC

Years participating in SeaPerch:
2

SeaPerch Image

Our SeaPerch is unique because: we constructed our frame out of lightweight CPVC pipe, used adjustable motor mounts to allow fine tuning of thrust, found an alternative to pool noodles that provided more control over buoyancy, and came up with a simple, but effective hook design.

Our biggest takeaway this season is: that we gained experience working closely with a team and resolving conflicts. We planned to create a very compact ROV, but learned that the frame needs features to provide stability. In the end, our small frame combined with the use of CPVC resulted in a fast, maneuverable ROV.

SeaPerch design overview: We made our frame out of narrow CPVC pipe and placed the turning thrusters close to the center of mass. Our motor attachment system allowed us to adjust the angle of our motors so that we could adjust the angles of the thrusters more easily while testing the ROV in the pool. Buoyancy was placed along the top CPVC sections above the turning motors and at the back of the ROV to offset the weight of the vertical thruster. A simple hook made from a wire coat hanger was used to transport the cubes, rings, and rods.

Team Image

Team Members:
Lisa, 9th grade
Janine, 9th grade
Nelson, 11th grade
Becky, 9th grade
Ralph, 9th grade

Teacher Name(s):
Kevin Fletcher

Mentor(s):
Sandy Andrews, Orichalcum, Inc.

1. Abstract

This year's SeaPerch competition involved an Obstacle Course and a Challenge course, as described in Reference (1). We began by asking ourselves what features would be most important to getting high scores on these courses. Based on our experience with SeaPerch last year, we believed the most important vehicle feature for the Obstacle Course was speed, so we considered designs that minimized weight and drag to meet this goal. The Challenge Course was more complicated than the Obstacle Course and required us to pick up objects and move them to an elevated scoring platform ten feet away. This required greater maneuverability so that we could precisely pick up and place objects, possibly at the expense of speed. The stock ROV kit does not include any parts that can be used to pick items up, so we also needed to design something to move the items.

Since this was our second SeaPerch season, we had specific scoring goals for each course that we hoped to attain. Last year our best Obstacle Course time was 46.5 seconds and we wanted to improve upon this, with the goal of breaking 40 seconds. Last year we completed the Challenge Course, but could not get the maximum time bonus. With a more compact frame and more practice, our goal was to get the maximum amount of points in under 5 minutes, for a score of 23 points.

During the season, we experimented with three primary ROV (remotely operated vehicle) design iterations. One of those ROV frames was designed to be adjustable and included several variations with the tradeoff of speed vs. stability. Each ROV was subjected to three in-pool tests to measure performance. Our first design was fast, but too difficult to control, and our second design over-compensated from the first and was very stable, but slow. Our third design was clearly superior in both the Obstacle Course and Challenge course, as the results in Section 4 demonstrate. By the end of our last practice, we had met our goals for both courses, and hope to improve on those results between now and the competition.

2. Task Overview

There are two aspects to this year's SeaPerch Challenge. The first is an obstacle course. For the obstacle course, our ROV needs to maneuver through a series of five submerged hoops oriented at different angles, surface after passing through the fifth hoop, and then retrace the path heading back toward the pool wall. We get two attempts to complete the obstacle course and our effectiveness is judged based on speed of completion. There are penalties if the ROV cable gets tangled on the hoops.

The second challenge involves transporting rings, cubes, and rods from a staging platform to a scoring platform. There are three of each item type, or nine items to transport in total. Our ROV is only allowed to transport one item at a time between the two platforms, which are submerged about 20 inches below the water surface and ten feet apart. The scoring platform has two levels, a lower level with a safety rim to prevent items from falling off and an upper level without the rim. We receive two points for each item placed on the more challenging upper level and one point for each item placed on the lower platform. The time limit for completing the event is fifteen minutes. If all items are placed in less than fifteen minutes, one bonus point is awarded for every two minutes below the fifteen-minute limit, to a maximum of five bonus points if completion time is less than five minutes. If an item is dropped to the pool floor, it remains in play and our ROV can retrieve it and place it on the scoring platform. There is a two-minute penalty if we need assistance from a diver.

Since the obstacle course is simple compared to the challenge course, the majority of our design modifications were aimed at improving the ROV's ability to complete the challenge course. We needed to attach something to the ROV frame to allow it to pick up and transport the nine items. Since the cubes have hollow interiors and the rings and rods both have nylon loops, it seemed like a hook or rod would be a good tool moving the nine items. To improve speed for both the obstacle and challenge courses, we removed the netting from the stock SeaPerch kit and explored more compact frame designs to reduce drag.

3. Design Approach

As discussed in Section 2, our main challenge was to modify our ROV so that it could efficiently pick up the nine challenge objects and transport them to the scoring platform. The cubes present an additional challenge because their weight adjusts the center of mass of the ROV, greatly changing the way that it navigates through the water. Since time is a factor for both the obstacle and challenge course, we also considered ways to increase speed and reduce drag.

We wanted a design with a higher maximum velocity compared to last year, so our initial idea was to start with the smallest frame possible, which is basically equivalent to one of the challenge cubes with motors attached. A sketch of the side view of this design is shown in Figure 1 and Figure 2 shows what the ROV looked like after we constructed it. Our thought was that a small frame would maximize velocity for the challenge course and be nimble yet controllable for the obstacle course. We placed the turning motors outside the ROV frame to provide maneuverability and the vertical thrust motor through the center of the frame. We thought this was an aggressive approach for a first design, but that since we got an early start, we would still have time to go in a different direction if things did not work as expected.

Initially the ROV was very negatively buoyant (Reference (2)), but we were able to fix this issue by adding pipe insulation around the vertical thruster, which is not shown in Figure 2. Pipe insulation was used instead of pool noodles because we felt that it gave us more control over the positioning and amount of buoyancy added. After fixing the buoyancy, the ROV was functional, but drove in loops and was uncontrollable. We tried several adjustments, but could not find a way to fix this because the motors produced too much thrust relative to the frame size. As a team, we decided that our best option was to modify this design to improve our ability to control the ROV.

Our second design focused on the ability to control the ROV, possibly at the expense of speed. To cut down on weight and reduce drag, we constructed this vehicle out of CPVC, rather than PVC. ½" CPVC pipe has an outer diameter of 0.625" as compared to 0.840" for PVC pipe and CPVC also

Figure 1: First ROV frame design

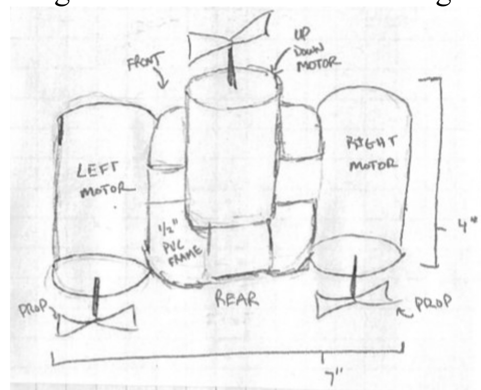


Figure 2: First ROV created

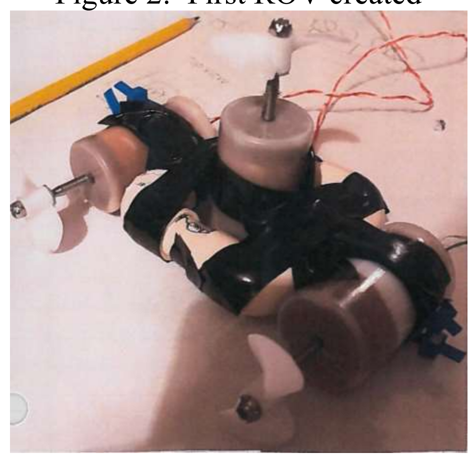


Figure 3: Second ROV design

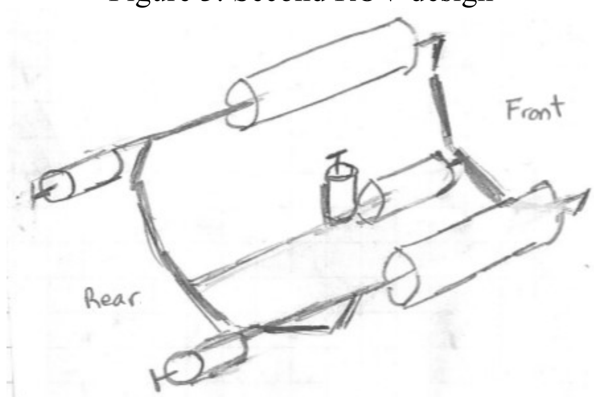


Figure 4: Second ROV created

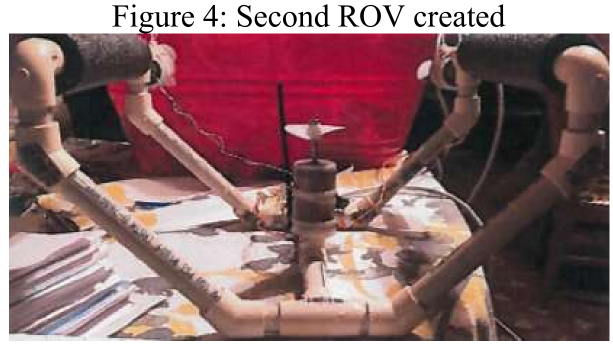


Figure 5: Third ROV frame design

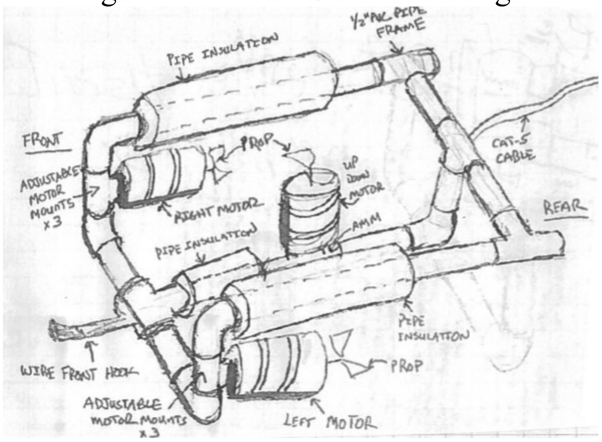


Figure 6: Motor attachment design

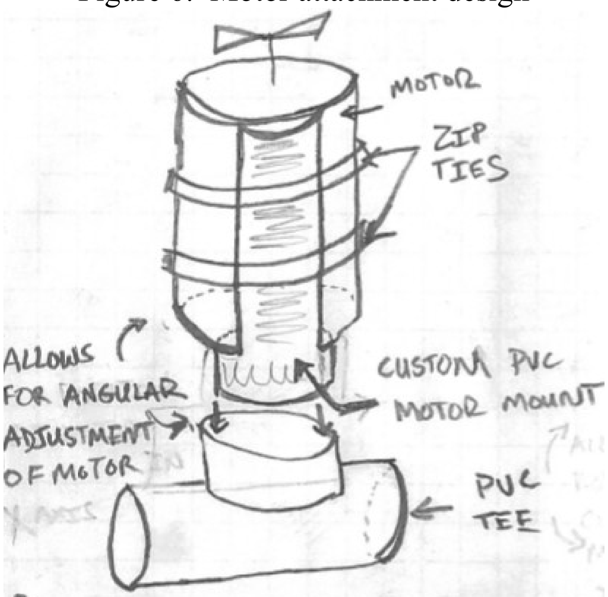
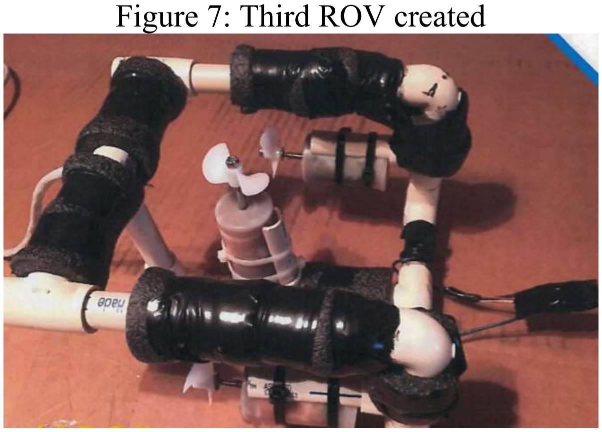


Figure 7: Third ROV created



has thinner walls than PVC pipe. Together, these factors mean that a CPVC frame is much lighter than a PVC frame of the same scale. For example, we weighed a CPVC elbow connector and it was 10 grams, but a PVC elbow connector was 21 grams.

A sketch of our second design is shown in Figure 3 and Figure 4 shows the constructed ROV. This design had a long, U-shaped hull with turning motors at the back and buoyancy placed near the front of the vehicle. To offset the buoyancy, the vertical thruster is placed near the front of the ROV. As the figure shows, this frame is much larger than our first design, but we made several sets of CPVC pipe sections with different pipe lengths so that we could experiment with how frame size affected performance when testing in the pool. As we will discuss more in Section 4, this design achieved our goal of improving stability and control, but even with the smallest set of CPVC pipe sections, we felt that the ROV was too slow to meet our goals.

For our third design, we wanted to keep the stability of the second design, but increase speed. We sketched a narrower CPVC frame with the turning thrusters placed closer to the center of mass, as shown in Figure 5. For the previous design with the turning thrusters near the back, the ROV turned downward when trying to move forward.

We also designed a motor attachment system that allowed us to adjust the angle of our motors, as the sketch in Figure 6 shows. This allows us to adjust the angles of the thrusters more easily while testing the ROV in the pool. Figure 7 shows the constructed version of our third design. Buoyancy was placed along the top CPVC sections above the turning motors and at the back of the ROV to offset the weight of the vertical thruster.

For all of our designs, we used a simple hook to transport the cubes, rings, and rods, as shown in Figure 5 and Figure 7. Early on, we found that a simple 2" loop made from a coat hanger with a slight upturn at the front could easily pick up all obstacle types, maintain control of them while transporting them to the scoring platforms, and release them where we wanted. Given the effectiveness and simplicity of this hook design, we focused our efforts on improving our frame and practicing driving the ROVs, rather than working on hook design.

As we will discuss in Section 4, the 3rd design met our goals and further designs were not created.

4. Experimental Results

We used a series of in-pool tests to judge how well each ROV design worked. The simplest test was a 25-yard sprint to test velocity. For each of the three designs, we measured how quickly we could travel 25 yards submerged just below the water surface three times. Results for this test are shown in Table 1, with times reported in seconds. As discussed in Section 3, Design #1 was difficult to control, so even though the top speed was fast, motion was not in a straight line. Because of this, times were long and variable. Design #2 shows times for frames using short, medium, and long sections of CPVC pipe. When using the long CPVC sections shown in Figure 4 the ROV was slow, but it was much quicker when using shorter pipe sections for the frame. Design #3 had a smaller and more hydrodynamic frame compared to Design #2 and was the quickest design by a wide margin. Both Design #2 and #3 had consistent times for their three runs.

On a night when we had access to a SeaPerch Obstacle and Challenge course, we measured the time it took each ROV to complete the Obstacle Course and Challenge Course three times. Before measuring times, we practiced on each course with each ROV. Practically, Design #1 was too difficult to control to complete either course, so times for this design are labeled "N/A". For Design #2, we only tested the "Short CPVC" version on the courses because the other two versions were too slow in the speed test.

With Design #2 and #3 we were able to complete both courses. With Design #2 we could place all nine items, but could not get all items on the more difficult top platform within the 15-minute time limit. Design #2 was easier to control compared to Design #3, but Design #3 was so much faster and more agile that it easily outperformed Design #2. On the Obstacle Course, Design #3 was almost twice as fast as Design #2 and on the Challenge Course, Design #3 consistently got all items on the top platform in about 8 minutes.

Based on these results, we selected Design #3 as our competition ROV and spent our remaining SeaPerch time practicing on the courses to improve our times. Table 4 shows a log of our Obstacle Course times at each pool practice. Over six practice sessions, we reduced our average time from about 48 seconds to just under 40 seconds. Table 5 shows a log of our Challenge Course results at each pool practice. Over six practices we reduced our runtime by four minutes and met our goal of a 23-point run.

Table 1: ROV times for sprint test

	Run #1	Run #2	Run #3
Design #1	56.3s	34.7s	43.2s
Design #2 Long	37.8s	36.7s	39.3
Design #2 Medium	31.5s	30.6s	32.2
Design #2 Short	25.2s	26.7s	24.8s
Design #3	15.2s	13.3s	14.4s

Table 2: ROV times for Obstacle Course

	Run #1	Run #2	Run #3
Design #1	N/A	N/A	N/A
Design #2	94.0s	85.6s	92.5s
Design #3	53.4s	47.6s	49.1s

Table 3: ROV results for Challenge Course

	Run #1	Run #2	Run #3
Design #1	N/A	N/A	N/A
Design #2	15:00 17pts	15:00 15pts	15:00 16pts
Design #3	8:32 21pts	7:15 21pts	7:44 21pts

Table 4: Log of Obstacle Course Times

Date	Run #1	Run #2	Run #3
March 13	48.7s	46.9s	
March 20	47.5s	44.5s	43.2s
March 27	43.5s	44.9s	
April 3	42.5s		
April 10	39.2s	40.6s	
April 17	41.3s	37.8s	39.3s

Table 5: Log of Challenge Course Results

March 13	9:12 21pts	7:15 20pts	7:08 21pts
March 20	6:54 22pts		
March 27	7:21 22pts	6:47 22pts	
April 3	6:36 22pts	6:43 20pts	5:27 22pts
April 10	5:38 22pts	4:34 23pts	
April 17	4:57 23pts	4:22 23pts	4:49 23pts

5. Reflection & Next Steps

This year we put more effort into SeaPerch and learned more than we did last year. Last year much of our time was spent building the stock SeaPerch model and learning how to drive it. The modifications that we made were small relative to the stock model. Having that experience, we were able to start this year knowing how ROVs handle underwater and had a better understanding of what modifications would be worthwhile, so we were able to experiment with ROV designs that were very different than the stock SeaPerch ROV. Last year we learned that reducing ROV size improved speed and we took this to the extreme with our first design, but it taught us that having a stable model that is easy to control is as important as top speed. It would have been interesting to spend more time with our first design to see if there was a way to improve its maneuverability without going to a larger ROV design. If we compete again next year, we would like to spend more time with the Design #1 concept to see if we can make a similar frame that is controllable.

Our second design introduced us to working with CPVC. The CPVC reduced the frame weight of the ROV more than in half and also reduced drag. For Design #2, we thought these features of the CPVC would allow us to use a larger, more stable frame, while maintaining a high top velocity, but this turned out to be incorrect. The switch to CPVC gave us more options for design and this was our most fun model to experiment with since it had an adjustable frame size. Although the second frame design was not successful, CPVC played an important role in the success of Design #3. Design #3 took the concept of the minimalist design, but enlarged it slightly to improve stability. The small frame combined with the use of CPVC resulted in a fast, maneuverable ROV.

There are several ideas that we were not able to experiment with this year that we would like to explore if we compete again next year. This year we considered the idea of designing 3D printed propeller shrouds, but we couldn't because we didn't have access to a 3D printer. Our school is installing a few 3D printers this Spring and several of our team members are taking a 3D printing class next fall. The option of including 3D printed parts opens up many new options for designing lightweight, hydrodynamic frames. We have also seen other teams use propeller shrouds to gain more thrust from the motors and we would like to use the 3D printer to experiment with propeller shrouding designs. Section 9.6 of Reference (3) discusses the different characteristics of a propeller. For the past two years, we have used the propellers in the stock SeaPerch kit, but we would like to test other propeller designs.

Beyond SeaPerch, we gained experience working closely with a team for a long period of time. Sometimes members wanted to do things differently and it wasn't always easy deciding what decision to make. The technical writing skills involved with writing this report is an area that will be important in college and in the real world. Some team members have written technical reports in school, but we needed to rely on online resources, such as Reference (4), because this isn't an area where we get much practice in school. We also learned how to apply the engineering design process and how to solve problems in general. These skills will help us in the future whether we choose to pursue a career in engineering or take another path.

6. Acknowledgements

We would like to thank:

Our teacher, Mr. Fletcher for facilitating our team.

Our engineer mentor, Mrs. Andrews for meeting with us weekly to discuss our progress, explain the engineering design process, and give pointers on how to write a technical report.

The school for providing us a SeaPerch kit and after school access to the Tech Shop.

Our parents for getting us to practices and supporting our efforts.

7. References

(1) 2020 International SeaPerch Challenge. (n.d.). Retrieved from https://www.seaperch.org/2020challenge

(2) Buoyancy. (n.d.). Retrieved from https://scienceprimer.com/buoyancy

(3) Eastern Edge Robotics (2010 December). Underwater Robotics for High School Students. Retrieved from https://www.marinetech.org/files/marine/files/Curriculum/Other%20Curriculum%20Resources/MIROV2MANUAL.pdf

(4) Prance, H. (2010, April). Guide to Technical Report Writing. Retrieved from http://www.sussex.ac.uk/ei/internal/forstudents/engineeringdesign/studyguides/techreportwriting

(5) Underwater ROV. (n.d.). Retrieved from https://www.instructables.com/id/Underwater-ROV/

Appendix A: Budget

Component	Vendor	How was component used?	Cost (in USD)
1/2-in x 5-ft CPVC pipe	Lowes	Frame structure	$2.17
5 – 1/2-in dia 90-Degree Elbow CPVC Fittings	Lowes	Frame joints	$1.65 ($0.33/each)
7 – 1/2-in dia Tee CPVC Fittings	Lowes	Frame joints	$2.45 ($0.35/each)
1 – Wire coal hanger	Recycled	Hook	~$0.10
16” pipe insulation	Lowes	Buoyancy	$0.22
		Total Cost of SeaPerch Components	$6.59