River City Science Academy Mandarin

Technical Report for Lily Pads Seaperch Team

Team Members

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Abstract

The technical report will explain most of the challenges encountered by the team and how the team tried to solve them using the Engineering Design Process (EDP). The team had many challenges that had to be solved, the main one being buoyancy. Every time the team changed something in the Remote Operated Vehicle (ROV), buoyancy had to be tested. Other problems that the team worked through were increasing the speed of the ROV by reducing drag, and configurations of hooks to perform the best possible job. For every single change, the team had to do the steps of the EDP. One example of working through the process is while the team worked with the hook. The team brainstormed what was needed to complete the missions and selected a metal hook. The hook did work well "carrying" the batteries, but it was too heavy, so the team had to go back to brainstorm to see what it could come up with to solve that. The team selected a couple of hook designs and materials that they thought would work well. Then the team had to test them to see which one performed better. The team ended up with the clothes hanger hook since it was light and strong. But the team realized that this hook alone would not be enough to complete all the missions in the course. After some testing, the team ended up with two hooks. One that would handle tasks 1 and 4 and another hook that would handle tasks 2 and 3.

The team wanted to reduce the drag of the ROV to make it faster. The team researched some possible ways to reduce drag and decided that the best way for the team to achieve that was by reducing the height of the ROV by as much as possible. The team built and tested four different main frame configurations and chose the one that performed the best. Then we worked on that one frame to find ways to make it even better. The final ROV is the best the team has built since starting in Seaperch. The ROV can perform all tasks in the mission course. The team must increase practice time with it to make the drivers more comfortable using it. One aspect that might be unique is that both hooks in the ROV bend to be out of the way for the obstacle course, making the ROV even smaller.

Task Overview

The theme this year is Space Exploration and teams must complete a simulation of an International Space Station (ISS) Extravehicular Activity (EVA) Mission that an ROV might encounter while assisting astronauts on an EVA outside the ISS. (*Seaperch, 2022*) The tasks for the competition are the following: 1) Navigate through the Obstacle Course: The ROV needs to travel through 5 hoops at different heights and angles as fast as possible. After reaching and going through the farthest hoop the ROV must surface and then submerge and come back through the course. 2) Complete all the "Missions" in the Missions Course. These are separated into tasks. There are 4 different tasks that we must complete to earn all points. Task 1 is the turning of a latch to gain access to the battery compartment and opening the battery panel access. The door (panel access) must be opened enough for the ROV to be able to enter. For Task 2, cables must be disconnected from batteries. For task 3, there are two subparts. A) Move "used" batteries from the Battery Compartment to the Battery Pallet and B) Move "new" batteries from the Battery Pallet to the Battery Compartment. The ROV must transport the batteries through the battery panel opening. For task 4, Tools must be transported from the EVA Tool Tray to the Tool Caddy.

The team designed the ROV to be as small as possible to be able to navigate through the obstacle course as fast as possible. The reduced size would allow the driver to have fewer situations in which the ROV hits the hoop and gets stuck in the hoop. In addition, the new cable sleeve creates less friction on the hoops and is lighter than the original cover, allowing the ROV to move faster in the course.

The hooks are designed to complete specific tasks in the Missions Course. The ROV has a bottom hook that allows it to pick up the batteries and pull the cable connections to the batteries and a front hook that allows it to turn the latch, pull the door open and "grab" the tools through the yellow rope to carry them to the tool caddy. The team's ROV performs all tasks adequately, but in the future, the team will continue with the EDP and make improvements to the ROV to reduce the times for tasks completion and increase operational resiliency.

Design Approach

The team will be using NASA's BEST Engineering Design Process (EDP), as stated on the *Engineering Design Process* website (*May, 2018*) since this is the one, that is used in school (Figure 1.) The team started with last year's ROV and then started testing it to see how they could make it faster. The team used the EDP to achieve that goal. As the team started modifying the ROV, the members realized that they needed to adjust buoyancy for every new design.

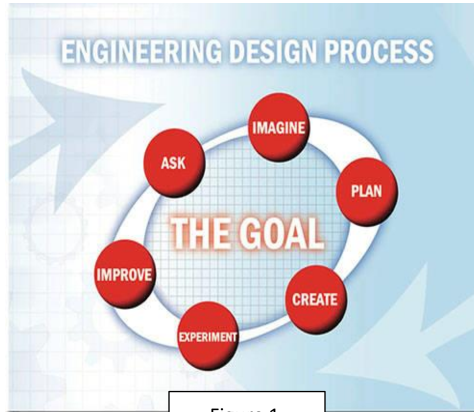


Figure 1.

Ask: The first problem that the team had to solve was the buoyancy on the ROV. The ROV needed to have neutral buoyancy in the water. After modifying for the first time, the ROV would not submerge in the water.

Imagine: The team came up with different ideas of materials to use to improve the buoyancy of the ROV. The foam in the kit, a bought buoy, and a 3D printed buoy was tested. The team decided to use the foam since it was easier to work with.

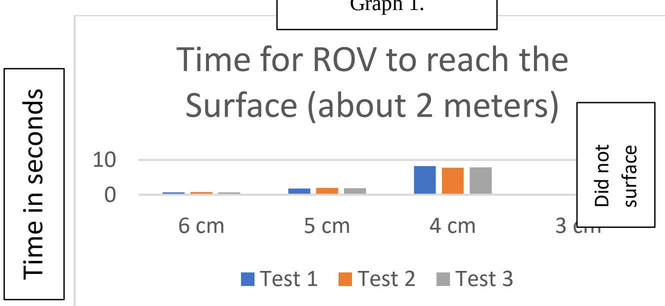
Plan: The team planned to test foam amounts to get a "slightly positive" buoyancy (*Moore, 2017*) for the ROV. Members already knew that the amount that came with the ROV kit was too much foam. Team members planned to start with a length of 6 cm and cut in 1 cm until desired buoyancy was achieved.

Create: The ROV was built and added the starting amount of foam was. The team realized that they could get rid of a section of the ROV that had no purpose other than support during the building process. They could compensate for that by gluing a couple of sections.

Experiment: The team tested the amount of foam until it achieved "slightly positive" buoyancy, or as close as possible. The ROV was placed at the bottom of the pool (2 meters) and the time was measured until it reached the surface. The goal was to have the most amount of time, but it would still surface.

This was the test:

Graph 1.



Amount of time to surface in seconds	6 cm (length of foam)	5 cm (length of foam)	4 cm (length of foam)	3 cm (length of foam)
Trial 1	0.7	1.8	8.2	NA
Trial 2	0.8	2	7.8	NA
Trial 3	0.7	1.9	7.9	NA
Average	0.73	1.9	7.97	NA

Table 1

The data shows (Graph 1 and Table 1) that the team needed 4 cm of foam to achieve the desired buoyancy.

Using the *Determination of Mass, Volume & Ballast* website (*Seaperch, 2020*) team members calculated the volume of the foam used and its density.

The volume of a hollow cylinder: $V=\pi*H(R^2-r^2)$ Where: H = height, R = the outside radius, and r = the

Mass of foam (4cm long) is 2.5 grams. H= 3 cm R=2.75 cm r=1 cm. $V=(3.14)(3\text{ cm})(2.75^2-1^2)=(3.14)(3\text{ cm})(6.56\text{ cm})=61.80\text{ cm}^3$

Density = $\frac{m}{V}$= 0.040 g/cm^3 Density of water= 1 g/cm^3. So, the foam is a lot less dense than the water.

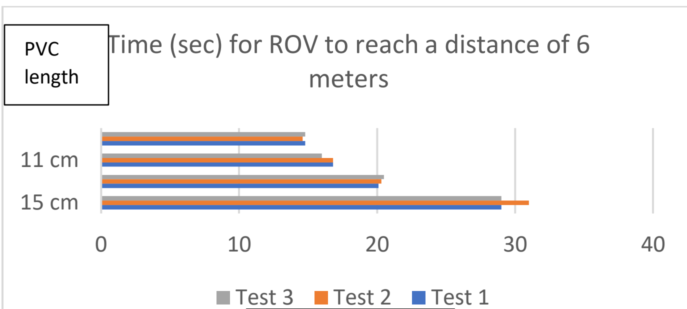
The team had to repeat this test many times since the configuration of the ROV changed many times. For the rest of the report, assume that this test was done for the design.

Improve: The team improved the buoyancy of the ROV by adding foam to the inside of the polyvinyl chloride tubes (PVC). This allowed the team to reduce the amount of foam on the outside of the ROV, reducing the drag of the ROV.

The team wanted to increase the velocity of the ROV even more. They had to go back to the Imagine step of the EDP to try to figure out a way to achieve that.

Imagine: The team needed to decrease the drag on the ROV to increase the velocity. After discussing a few ideas, members decided on reducing the length of the PVC "uprights". The team imagined that this would decrease the drag and it would also decrease the mass of the sub allowing the thrust of the motors to be used more efficiently while lifting the batteries.

Experiment: The team tested the time it took the ROV to reach 6 meters from rest, while they reduced the length of the "uprights". Three tests were performed for each length. This is the test:



Graph 2.

Time to reach 6 m from rest

Length of PVC "upright"	Test 1 seconds	Test 2 seconds	Test 3 seconds	Average (Seconds)
15 cm	29	31	29	29.6
13 cm	20.1	20.3	20.5	20.3
11 cm	16.8	16.8	16.0	16.5
10 cm	14.8	14.6	14.8	14.7

Table 2.

The test (Graph 1 and Table 1) shows that as the length of the "upright" pieces was reduced, the velocity of the ROV increased. The team could not reduce the length of the uprights anymore because of space. The motors needed some space to be placed and work.

The team used the *Velocity Calculator* website (*Mucha and Czernia, 2022*) to Calculate the Velocity of the distance covered by the improved ROV.

$V = \frac{Distance}{Time} = \frac{6\ m}{14.7\ s} = 0.41$ m/s in a straight line

The original ROV design/1st version

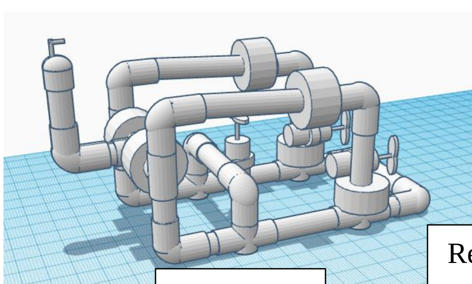


Figure 2.

Final ROV Design/4th version

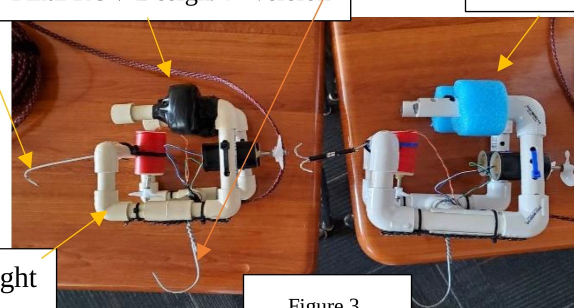


Figure 3.

The pictures (Figure 2 and Figure 3) show that the ROV went through a lot of changes. The final picture shows the final hook for batteries, that performed well while still being light. As the team tested different hooks, they used multiple steps in the design process, going back and forth in the design process. For example, the first hook they tested worked very well, but it was extremely heavy, requiring a lot of foam, which reduced the speed of the ROV. The team had to go back to the brainstorming step to come up with other ideas. The team ended up using the hook from a clothes hanger. The tests demonstrated that this hook performed well while still being light.

Experimental Results

The following are the forces that are acting on the ROV with their directions.

F_B: Buoyancy ↑

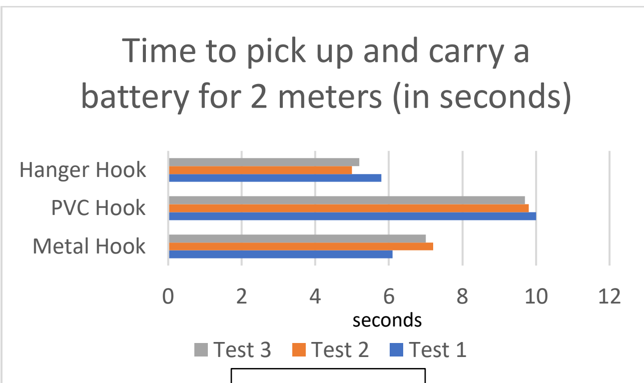
F_g: weight ↓

F_T: Thrust →

F_D: Drag ←

Buoyancy is one of the forces that the team is always working with since they want to maintain a "slight" positive buoyancy for all ROV versions they have made. The team has reduced the weight of the ROV as much as possible to allow the thrust from the motors to be as effective as possible. The thrust is the only one that the team can not work on since we must use a specific type of motor and it has a specific amount of thrust. The team keeps working on the ROV's drag.

One of the tests that the team had to perform was hook testing. The team started with a PVC hook and it worked well, but it was too bulky. Then they tested a metal hook. The team soon realized that they had a hook that was too heavy, they had to go back and brainstorm what types of hooks they could use. The team came up with a clothes hanger hook. The team tested all three hooks to see which one would be better in the ROV.

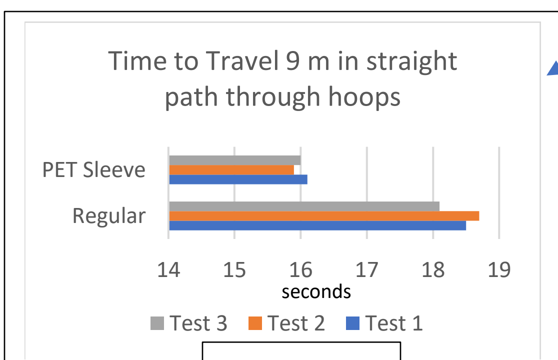


Graph 3.

The PVC hook dropped the battery in two of the tests increasing the time.

The test (Graph 3) shows that the hanger hook performed better than the other two hooks. The hanger hook was able to complete the test about 2.5 seconds faster on average.

Another test the team performed was to compare the regular cable with a cable that was stripped of the cover and the cover replaced with a Polyethylene terephthalate (PET) Sleeve. The team tested the time it took for the ROV to travel 9 meters through 5 hoops in a straight path.

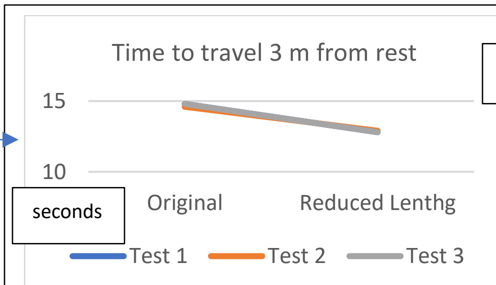


Graph 4.

The test (Graph 4) results demonstrate that the PET sleeve has less friction over the hoops and floor. The ROV was able to travel the distance about 2.5 seconds faster on

Another test the team performed was to reduce the length of the horizontal PVC tubes. This reduced the mass of the ROV, and the thrust given by the motors was used more efficiently.

The test (Graph 5) to the left shows that the reduced mass allowed the ROV to travel the set distance faster. The ROV traveled the distance 2 seconds faster on average.



Graph 5.

Reflection & Next Steps

Following the design process, allowed the team to solve problems they encountered with the ROV to make it work properly. The team was able to work on the problems one at a time and by following the EDP they were able to know for sure what modifications are done truly were better for the ROV and allowed the team to do the tasks in a better time. The team had to move through the EDP many times.

The team was able to improve the ROV so that it performs substantially better than the basic kit one that comes in the box. The team was able to make it faster by decreasing the amount of drag. Also, the team was able to increase the efficiency of the motors by reducing the mass of the ROV by decreasing the amount of PVC used. In addition, the team was able to reduce the friction on the ROV and cable by reducing the lengths of the "uprights" and changing the cover of the cable to one that had less friction over the plastic hoops and was lighter.

In addition, throughout the EDP process, the members learned to work as a team and be more understanding of each other. Allowing them the confidence to share ideas no matter how "silly" they thought they might have been. The team also learned new STEM concepts and how to apply them. The teamwork and the new knowledge acquired will help them in the future as they keep working on the ROV this year and in future years. The team does still have more modifications to do on the ROV. One of the modifications that they are still working on is changing the ROV's frame from regular PVC to a frame made with chlorinated polyvinyl chloride (CPVC). (Figure 3) The team just adopted this frame and will continue testing it so is ready for The Seaperch Challenge.

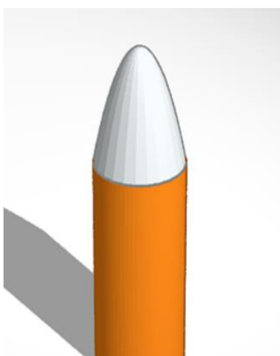


Figure 4.

Another modification that the team has planned is to get rid of the foam. The foam works well for the ROV buoyancy, but it creates additional drag on the ROV, and they seem to absorb water after a while affecting the buoyancy. The team plans on 3D printing buoys (Figure 4). The proposed shapes of the buoys will further reduce the ROV's drag and the team thinks that the buoys will not absorb water since they will be sealed. Doing this will allow the team to always have the same amount of buoyancy on the ROV. The team plans to print them in a shape that would reduce the amount of drag. This will require testing all the different proposed shapes. The team will continue working on the ROV to make it more stable. The team must keep testing this since the current model could use improvements in this area. Another proposed improvement is to change the data cable for one that has a smaller diameter. If the diameter of the data cable can be reduced and re-sleeved, they would be able to reduce the friction on the cable even more. The team will have to perform tests for all these ideas, and they will use the EDP as they work on each one. The team is also trying to find ways to increase the revolutions per minute (RPM) of the motors. A team member suggested that a second wire be added to the positive side of the motor increasing the amount of current and decreasing the resistance the cable creates. This requires the team to build a cable and the connections to the controller. The team will work on this soon to see if it increases the RPMs enough.

In summary, throughout the EDP that we used to build the ROV, the team learned how to work together to overcome any difficulties they had. They were able to improve the ROV so that it would perform to expectations, but they also learned that working as a team allows them to overcome any weaknesses that they might have. In addition, the team learned many new STEM concepts that helped them in the EDP and that would also help them in the future. The team knows the future will be technology-based and everything that they are learning now, they will be able to use at school and in career plans.

Acknowledgments

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Budget

Appendix A: Budget

Parts used are from the Seaperch Kit. The only additions to the ROV are listed below:

Component	Vendor	How was the component used?	Cost
Backer Rod	Home Depot	Help with the buoyancy of ROV	$0.22/feet 1.5 feet used for a total of $0.33
Hooks (hanger)	Donated by parent	To pick up "batteries" and ropes	$0.90
Sleeve	Amazon	To reduce friction on the cable	$0.14/feet 50 feet used for a total of $7.00
Zip ties	Amazon	To secure cable	$0.06 each Three used for a total of $0.18
CPVC Pipe	Home Depot	Frame of ROV	$0.69/ ft 2 ft used for a total of $1.38
CPVC 90 degree elbows	Home Depot	Frame of ROV	$0.25 each, 12 used for a total of $3.00
CPVC Tee	Home Depot	Frame of ROV	$0.95 each, 2 used for a total of $1.90
Total			$14.69