TECHNICAL DESIGN REPORT

Team: NZ Aqua Alphas
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Abstract

Our ROV design is novel as it has been inspired by a Star Wars Tie Fighter and the America's Cup racing boats. It is a sleek hashtag-shaped ROV made from metal rulers and expanding foam. We went away from the normal starter kit ROV because we wanted to make something faster and unique compared to the conventional ROV. We believe that the sleek and hydrodynamic shape of our ROV reduced surface tension and drag in the water. Our average time for the obstacle course is 64.4s and our fastest time was 42s. During our design and testing process, we came across some problems (such as, piloting straight, motors failing, propellers falling off) for which we found reliable solutions. With this modified design we won the 2020 Regional competition (Auckland) and the NZ National tournament (Masterton).

We could improve on the engineering design process by recording test runs for each of our different modifications as it will help show the pros and cons of each one. We could also learn calculations (such as weight, buoyancy, the center of gravity, etc) to speed up the design process. A key positive in our design process was our decision to have changeable attachments on the ROV for specific courses. The 2021 America's Cup challenge held in Auckland inspired us to think up ideas for a new ROV that could hydrofoil and travel faster above water to the location of the course and then dive to carry out the challenge.

Task Overview

The tasks for the 2021 International Seaperch Challenge are similar to the 2020 Regional competition (Auckland). The 2020 NZ National tournament (Masterton) used different challenges. The tasks that we designed for are:

- **Active mine:** disarm mine by pushing T-shaped pipe piece by 90 degrees. ROV needs good maneuverability to push the pipe.
- **Vault:** open the vault by pushing the gate latch pipe and then close by placing a weighted ball on the gate closing arm.
- **Floating garbage:** using the ROV or an attachment push all the objects out of the ring. ROV needs to be able to sink and resurface quickly while pushing objects with force.
- **Sunken garbage:** pick up sunken objects using specific ROV attachments and move them to the disposal area. Hooks need to keep objects in place and not get stuck on the course.

Design Approach

Approach to Engineering Design Process

For the 2019 NZ (Auckland) competition and the 2020 World Championships, we took inspiration from a Star Wars Tie Fighter (Star Wars, n.d.) and the America's Cup racing boats (Emirates Team New Zealand, n.d.). We converted a standard kit ROV to a Tie Fighter that had two wings, a beam connecting it in the middle forming a hashtag but with no bottom wings to reduce drag and weight. We used foam for the wings to generate a consistent buoyancy level. And we kept using pipes as the structure of the ROV but we added an extra horizontal pipe for stability. With this design, we won the NZ competition and qualified for the 2020 World Championships but could not compete due to COVID restrictions.

For the 2020 Regional competition (Auckland), 2020 NZ National tournament (Masterton), and the 2021 International Seaperch Challenge, we wanted to improve on our successful 2019 design. The engineering design process we used was to:

- Utilize as much of the existing ROV but make modifications to improve speed and maneuverability.
- Design attachments for the specific courses selected for the competition. We wanted to have specific attachments for each course and therefore needed to be able to remove and attach them quickly during the competition.
- Test our ROV extensively in our school pool so that we can be prepared for anything that would go wrong during the competition.

Design Iterations

During preparation for the 2020 Regional competition (Auckland) and the NZ National tournament (Masterton), we had the opportunity to improve on our successful 2019 ROV design. We changed the material design entirely. Instead of using pipes for the structure, we used metal rulers to reduce weight and drag. We kept the foam as our buoyancy conductor because it was performing well. As the metal rulers were thinner and harder, our ROV was more sturdy. As the structure was now metal the ROV had more abrasion resistance, that is, could withstand a repetitive process like rubbing or scratching (Accurate Plastics, n.d.). We believe that the sleek and hydrodynamic shape (S. Ewington, personal communication, n.d.) of our ROV reduced surface tension (USGS, n.d.) and drag in the water.

We also designed different modifications for our ROV. Figure 1 below, shows one of the hooks we designed. We used light metal rods and bent the edges so that it would be easy to pick up objects and they wouldn't fall off. We used cable ties to attach these modifications, so that we can quickly remove them between courses, especially for the obstacle course where we did not want any added weight.

We came across some problems during our pool testing due to this modified design and had to find reliable solutions. These are summarized below:

- Our ROV kept gliding towards the left side even though we were trying to drive straight. We noticed that one of our wings was angled out of place and not parallel with the other. We, therefore, broke our ROV skeleton and re-glued it making sure that both wings were parallel to each other. This solved the problem.

- The propellers were a constant problem as they kept falling off the motor shafts. This rendered our ROV unmovable and wasted a lot of our testing time in the pool. Our mentor, Sarah Ewington, explained that dried super glue could be stuck in the propeller shaft and that the motor shaft was smooth meaning there was less surface area to stick to. We cleaned out the propeller shafts using paper clips. We used sandpaper to roughen up the motor shafts and used waterproof glue. This reduced the problem significantly but was not a permanent solution. A more permanent solution could be to have threaded motor and propeller shafts.
- Sometimes motors would not respond. Initially, we thought this was due to a lack of battery charge but then we realized that the motors were old. We, therefore, decided to buy new motors but we still were not getting the power we expected. After changing motors multiple times, we concluded that it was not the motors but the tether cable (which was quite twisted). A new tether cable solved the problem. We also got a cable organizer from home so that the new tether cable would not get twisted in the future.

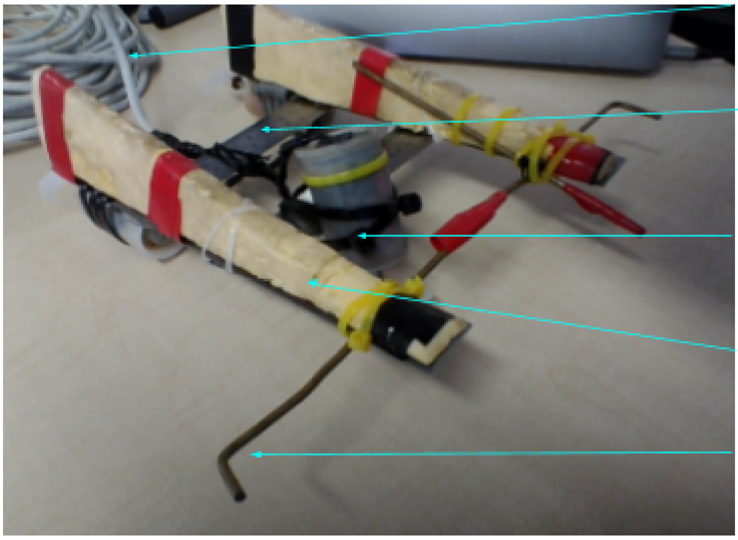

Figure 1: Final ROV design with attachments used in NZ National Competition.

Final Design and Bot Novelty

For the 2021 International Seaperch Challenge, we would have used our final design used in the NZ National Competition. This design is novel as it has been inspired by a Star Wars Tie Fighter (Star Wars, n.d.) and the America's Cup racing boats (Emirates Team New Zealand, n.d.). It is a sleek hashtag-shaped ROV made from metal rulers and expanding foam. We went away from the normal starter kit ROV because we wanted to make something faster and unique compared to the conventional ROV. We didn't focus on the aesthetics of the ROV. We focused more on its performance and quality.

Test Results

Our original 2019 ROV achieved the fastest time of 37s in the obstacle course. With our 2020 changes in the design, we tested our ROV's speed and maneuverability in our school pool using the obstacle course rather than the Vault course. Table 1 shows the results from these test runs. We have not shown incomplete test runs resulting from motor or propeller failure.

Trail Run	Time(seconds)	Comments
1	90	Slowest time
2	87	
3	83	
4	61	
5	63	
6	47	Hooks added
7	58	Hooks added
8	56	Hooks added
9	57	Hooks added
10	42	Hooks added- Fastest time

Table 1: Table showing times achieved for obstacle course test runs.

Figure 2 shows that we progressed well and that our times got better as we made modifications and improvements to the ROV. This is a positive data set because in the graph the regression line is angled down towards the right, indicating that the more runs we did the faster we got (this makes it positive). In this data, our average time is 64.4s and our fastest time was 42s.

We are not certain how much the speed improvement is due to our design modifications or due to our team getting better at piloting the ROV with practice.

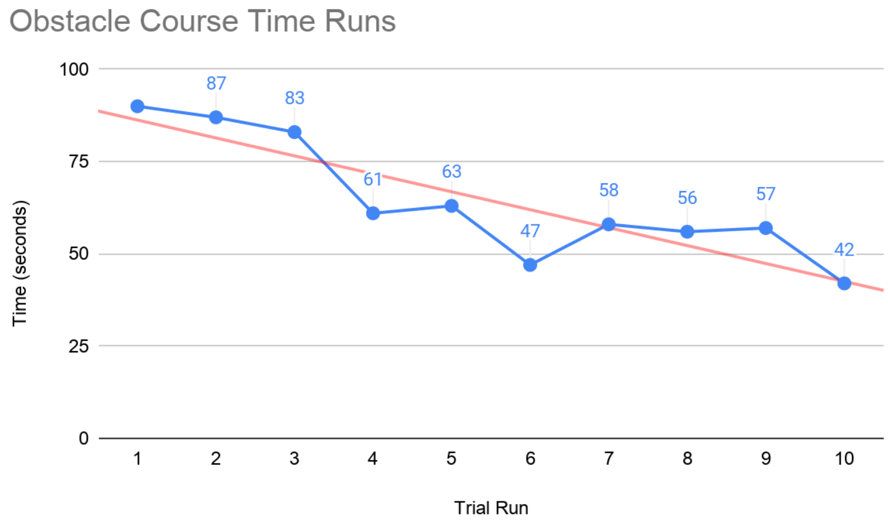

Figure 2: Graph showing times achieved for obstacle course test runs.

Reflections and Next Steps

We won the 2020 NZ National Competition. Throughout this competition, our ROV performed well in most of the courses. However, we can continue to improve on how we undertook the design process and we believe that we can continue to make improvements to our ROV.

Our reflection on the engineering design process:

- We could improve on our recording of data. We could record test runs for each of our different modifications as it will help show the pros and cons of each one. Also, this would help us in the future as we will be able to compare one idea to another.
- When we made our ROV, we did not do any calculations (such as weight, buoyancy, the center of gravity, etc). We made improvements through iterative modifications. In the future, if we learned how to do these calculations we could speed up the process and investigate more modifications.
- One of the positive reflections is our decision to have changeable attachments on the ROV for specific courses. For example, for the hooks course, we had two side hooks and one central hook, however, for the see-saw course we removed these and used a single strong bar for easily pushing the see-saw. This concept meant that we had an ROV that was able to change to suit the circumstance.

Some improvement ideas for the future could be:

- Though our different hook designs were good at picking up objects and dropping them into spaces (e.g. Vault), they were not as good at placing objects on specific things (e.g. hooks on the wall). We will look to design additional hooks.
- We have been thinking of possible hydrofoil designs that we might be able to construct. We got the hydrofoil idea from America's Cup boats, the AC-75 (Emirates Team New Zealand, n.d.). Since America's Cup was hosted here in Ackland, our whole school and the country were in a buzz. We were inspired and made us think up ideas for a new ROV that could hydrofoil and travel faster above water to the location of the course and then dive to carry out the challenge.

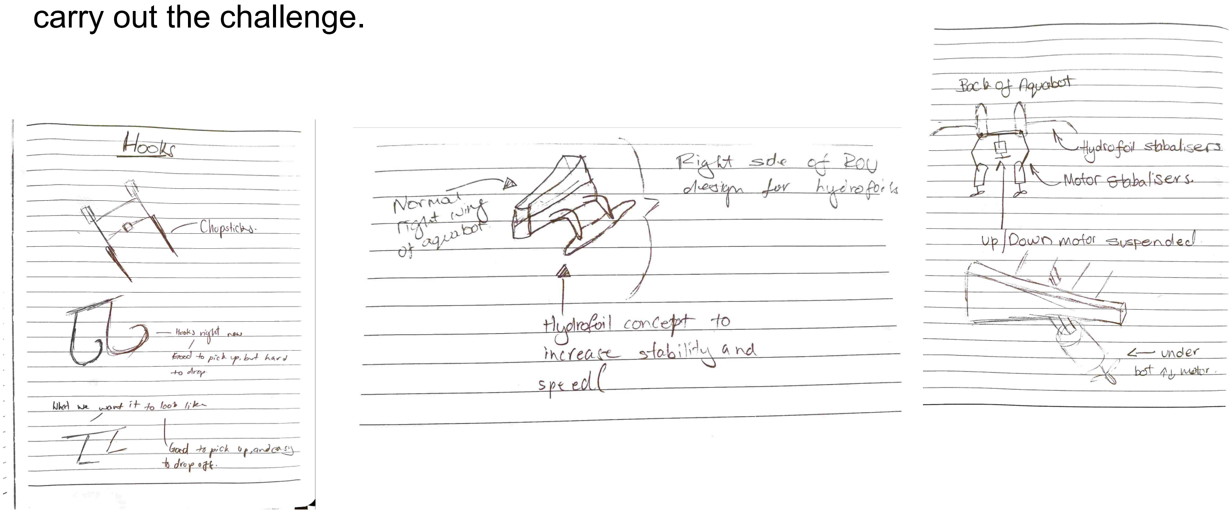

Figure 3: Sketches of Hook and Hydrofoil ideas

Acknowledgments

- Sarah Ewington, Mechatronics Engineer - sarahewington@beca.com
- Brad Hill, Deputy Principal - brad.hill@hobsonville.school.nz
- Abhishek Sharma, Parent/ Supervisor - abhishek.sharma@beca.com

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Appendix A- Budget

This year we did not buy a starter kit. We reused a lot of the materials from our previous years' ROV. However, during our design and build iterations, we needed to replace old motors and the tether cable. We have not included the cost of these in our budget as these would have been included in a new starter kit's cost.

We have included the costs of materials that we used to modify our ROV and for the various attachments that we designed (e.g. electrical tape, superglue, rulers, and foam).

Component	Vendor	How the component was use	Cost (NZD)	Cost (USD)
Rulers x3	Warehouse	ROV skeleton	$6	$4.30
Expanding Foam	Mitre 10	Buoyancy conductor	$5	$3.60
Electrical Tape	Mitre 10	Secure foam to a skeleton and waterproof tether cable connections	$3	$2.15
Superglue	Mitre 10	Attach propellers to motor sharts	$2	$1.45
		Total Cost of Seaperch components	**$16**	**$11.50**

Table 2: Budget and costs for items used to make modifications to the ROV.

Figure 4: Materials used for ROV modifications.

Appendix B- Fact Sheet

NZ Aqua Alphas

Hobsonville School, Auckland, New Zealand

Middle school

- 3 Years participating in SeaPerch
- 3 Times at the International SeaPerch Challenge

Our SeaPerch is unique because: (100 words MAX)

Our ROV design is novel as it has been inspired by a Star Wars Tie Fighter and America's Cup racing boats. It is a sleek hashtag-shaped ROV made from metal rulers and expanding foam. We went away from the normal starter kit ROV because we wanted to make something faster and unique compared to the conventional ROV. We believe that the sleek and hydrodynamic shape of our ROV reduced surface tension and drag in the water. Our average time for the obstacle course is 64.4s and our fastest time was 42s.

SeaPerch Design Overview: (100 words MAX)

For the 2020 NZ National tournament, we improved on our successful 2019 design. We changed the material design. Instead of using pipes for the structure, we used metal rulers to reduce weight and drag. We kept the foam as our buoyancy conductor because it was performing well. As the metal rulers were thinner and harder, our ROV was more sturdy and had more abrasion resistance. the sleek and hydrodynamic shape of our ROV reduced surface tension and drag. We also designed different modifications for each challenge, fixed using cable ties for quick changing between courses.

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

We won the 2020 NZ National Competition. Throughout this competition, our ROV performed well in most of the courses. However, we can continue to improve on how we undertook the design process and we believe that we can continue to make improvements to our ROV. One of the positive reflections is our decision to design individual attachments for the specific requirements of each course. These attachments were fixed with cable ties allowed them to be changed quickly. This concept meant that we had a ROV that was able to change to suit the circumstance.

Appendix C- Engineering Notebook

Not Included.