Gateway Senior High School

Technical Design Report for *HydroDynamics* SeaPerch Team

ABSTRACT

This technical design report details how team *HydroDynamics* developed their Remotely Operated Vehicle (ROV) to effectively tackle the Mission and Obstacle Courses in the 2025 SeaPerch season. Using the Engineering Design Process (EDP), the team overcame many challenges in creating their novel ROV. They designed a fast, lightweight vehicle with a plexiglass biplane wing base, which was cross-braced with fins. The fins helped counteract the poor stability caused by a small-sized ROV. To reduce drag, the team used syringes filled with air instead of pool noodles for buoyancy. Also, a grooved hook was designed to grab objects in the Mission Course and position them behind the vertical motor. This allowed the ROV to lift heavy objects by pitching up and using the rear motors.

As a part of the team's testing process, they experimented with different types of counter-rotating propellers instead of the co-rotating propellers supplied by SeaPerch. Despite the team's hypothesis that the SeaPerch propellers would have the worst performance, they surprisingly provided the ROV with the best speed and stability. The team also tested how fast the ROV navigated the Obstacle Course with a standard cable versus a coverless braided one. They believed the braided cable would reduce the drag and the influence on the ROV's movements. A stunning difference of ≈24 seconds faster completion time was recorded with the braided cable.

To summarize their experiences during this season, the team reflected on their ROV's design and ways to improve it. They thought that covering the braided cable with a Polyethylene Terephthalate (PET) sleeve could help protect it and further reduce drag. In addition, they imagined that switching to tinted plexiglass could help with visibility. Finally, they envisioned adding handles and larger buttons on the controller to improve the pilot's performance. Overall, the team's ROV had many novel features that set it apart from the polyvinyl chloride (PVC) vehicles. The ROV's unique design helped it perform about twice as fast as the standard Utility ROV in the Obstacle Course (SeaPerch Build Manual, 2021).

TASK OVERVIEW

The 2025 SeaPerch challenge, consisting of two pool courses, focuses on Environmental Monitoring – Coral Restoration. The timed Obstacle Course tests the speed of the ROV: navigate through five hoops, surface, and retrace the route. The Mission Course involves five scored tasks (max. 110 pts) completed on the following set-up: a "surface vehicle" with the sensors; the front platform with a coral tree, seagrass area, and deep-dive platform; and the back platform with the bio-buckets and hatch. Task #1 (max. 14 pts): Open the hatch, gaining access to the bio-buckets (4 pts). All objects placed in the bio-buckets will now be awarded points. At the end of the run, lock the hatch (10 pts). Task #2 (max. 25 pts): Remove the marine life from the hatch (3 pts) and place it on the front platform (6 pts); move a new species from the seagrass area to a bio-bucket (10 pts) while maneuvering through the hatch (6 pts). Task #3 (max. 21 pts): Grab the coral samples from the bio-buckets and hang them on the coral tree (6 pts each). Earn bonus points for driving through the hatch (3 pts each) and hanging them on different branches (3 pts). Task #4 (max. 24 pts): Transport the sea sponge and the deep-sea coral sample to the bio-buckets (10 & 8 pts, respectively). Maneuver each object through the hatch (3 pts each). Task #5 (max. 16 pts): Retrieve the blue and red sensors from the surface vehicle and place them in the marked areas on the front and deep-dive platforms (6 & 10 pts, respectively). A 5 pts bonus will be awarded if all tasks are completed in under 6 mins and another 5 pts for under 4 mins.

The described pool courses and tasks tremendously impacted the final design of our vehicle. Our ROV's compact, stable, and lightweight structure enhances its speed and maneuverability allowing for a competitive completion time in both courses. The use of syringes and braided cable reduce drag, especially on the rings in the Obstacle Course, thus improving the ROV's speed. A grooved hook is specifically designed to complete all tasks in the Mission Course: it lifts all objects with loops by securing them behind the up/down motor for an easy lift; it turns the latch, while the ROV maintains pressure to keep the hatch shut; and it transports the sea sponge by stabbing it.

Design Approach

Our team utilized *NASA's Best EDP* (Figure 1) to create our novel ROV. After competing in SeaPerch for two consecutive years, we recognized the importance of a good balance of *speed* and *stability*. We strove for a fast, *lightweight* vehicle that was also *stable* and *maneuverable*. To achieve this, we *asked* questions about our goal, *imagined* possible solutions, *planned* a design, *created* a working model, *experimented* with it, and revised it to *improve* our ROV. Using this approach, we designed a robust ROV to successfully complete both pool courses.

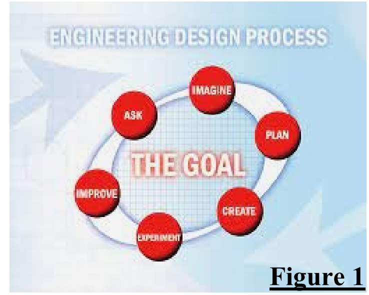


Figure 1

Ask: Our team's primary focus was on the speed and stability of the ROV. We brainstormed and agreed that an ROV would be most stable at a large size with a high surface area like the standard Utility ROV and fastest if it is small and lightweight with a *streamlined* shape. We wanted to achieve a balance between those two seemingly opposite characteristics.

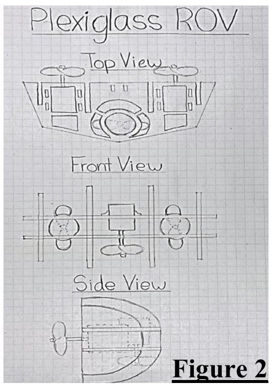


Figure 2

Imagine: We thought of two ideas for the design, both of which were inspired by a B-2 bomber plane's wing shape and its "high *aerodynamic efficiency*" (B-2 Spirit, 2015): a plexiglass ROV and a 3D-printed ROV.

Plan: We *planned* to design the plexiglass ROV as shown in Figure 2: plexiglass sheets in a biplane wing structure cross-braced with fins to help with stability and maneuverability. We imagined placing the motors in between the sheets. The 3D-printed ROV was planned with a similar wing shape (Figure 3).

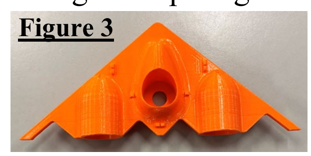


Figure 3

Create: After we laser engraved the plexiglass plates, we assembled the ROV with motors and fins. We also 3D-printed the other ROV after modeling it in AutoDesk Inventor. Overall, we deemed the 3D-printed design to be too complex and difficult to make quick adjustments to. On the contrary, the plexiglass ROV was quick to make and easy to adjust in the workshop or at the pool. Thus, we proceeded with the latter.


Figure 4

Experiment: First, we tested the stability of the ROV by holding and pushing it through the water in a water tank. This test was not precise; however, it was a start since we didn't have anything more buoyant than water on the ROV at the time.

Improve: During our experiment, the ROV was very reactive to slight forces and would tilt with minor changes in direction, so we increased the size of the fins multiple times to find the best fit (Figure 4).

Now that our frame was ready, we used the EDP again to address our next concern: *buoyancy*.

Ask: From the last two years of competing, we preferred a neutrally buoyant ROV because "neutral buoyancy ensures that the ROV remains at a constant depth" (Neutral Buoyancy for ROVs, 2023). However, the pool noodles we used for floatation in the past caused much drag and absorbed water. We wanted a better solution to reduce the drag and keep the ROV neutrally buoyant.

Imagine: At 2024 SeaPerch Internationals, we came across a design that used syringes filled with air to keep the ROV neutrally buoyant. Our team loved this idea, and we decided to try it for our ROV.

Plan: We *planned* to mount syringes above the ROV frame so that it would have a lower risk of flipping over. Our team decided to laser engrave holes throughout the frame and fins, which allowed for the use of zip ties to hold the syringes.

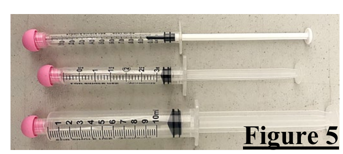


Figure 5

Create: We bought syringes in 1ml, 3ml, and 10ml sizes (Figure 5) and engraved holes in the frame.

Experiment: At the pool, we used trial and error to find the accurate amount of air across multiple syringes to keep the ROV neutrally buoyant.

Improve: During testing, we realized that some syringes had to be placed in awkward positions due to poorly placed mounting holes. We re-engraved the plates to have more favorable mounting holes.

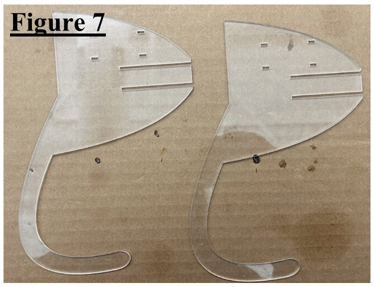
With design and buoyancy planned out, we still needed a hook to perform tasks in the Mission Course.

Figure 6

Ask: We *asked* what our goal was for the Mission Course, and the obvious answer came up: to be able to complete all tasks in a timely fashion.

Imagine: Our team *imagined* a two-hook design because although most of the tasks only required a single hook, we noticed that it would be a challenge to transport the sea sponge with a singular hook. We had two ideas for the hooks: 3D-printed hooks (Figure 6) and plexiglass hooks (Figure 7).

Figure 7



Plan: We *planned* to slide the 3D-printed hooks between the two planes and secure them with a pin. For the plexiglass hooks, we redesigned the fins to have a hook extended from the back. Both designs would mount the hooks in the rear of the ROV.

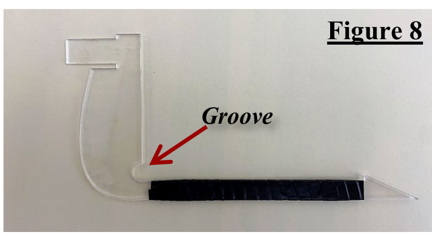
Create: We *created* the plexiglass hooks by re-engraving the fins, and we 3D-printed the other set by modeling with AutoDesk Inventor.

Experiment: During our practice at the pool, we realized that both designs obstructed the ROV's movement in the obstacle course. In addition, the plexiglass hooks were invisible in the water, and the 3D-printed hooks would cause the ROV to *pitch* and *roll* uncontrollably. We decided we needed a redesign and returned to the Ask step of the EDP.

Ask: Our new goal was to have a single hook design that would be clearly visible, not obstructive, and would not compromise the stability of the ROV while being capable of completing all tasks.

Imagine: With our limited time, we *imagined* that a plexiglass hook would be easiest to test and modify, so we proceeded with this idea.

Figure 8



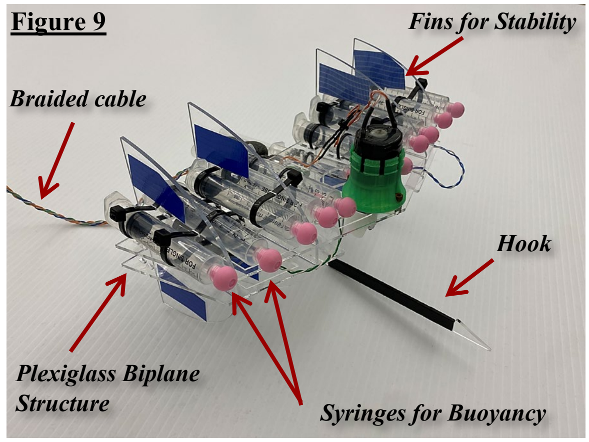
Plan: We *planned* to design a plexiglass hook with a groove for the object to slide behind the up/down motor (Figure 8). We believed this would preserve the ROV's speed *pitching* up.

Create: We engraved the hook and the grooves necessary for its attachment to the ROV. We also taped the hook with electrical tape for visibility before testing in the pool.

Experiment: When we tested at the pool, the hook worked as intended: consistently lifting all the objects while allowing for smooth obstacle course runs. To score the sea sponge, we simply stabbed it.

In summary, our current ROV has a very unique design with numerous novel features that set it apart from other designs (Figure 9). The plexiglass material makes the ROV light, streamlined, and efficient. The braided cable significantly reduces the drag, allowing for much faster obstacle course times. Other unique features of our ROV are the fins, which stabilize the ROV, and syringes filled with air for buoyancy, which are easy to adjust and reduce the drag. Finally, our custom hook with the groove allows us to easily lift all objects. We are continuously working on improving our ROV and will persist in improving our overall design with the EDP.

Figure 9



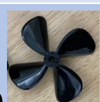
Experimental Results

We experimented with various modifications for our ROV in an attempt to improve its speed and maneuverability.

Experiment 1: testing different propellers for the two rear motors of the ROV. While practicing with the ROV, we observed rolling of the vehicle while driving straight. We researched that propellers rotating in the same direction, as provided by SeaPerch, may lead to angular acceleration, which could cause rolling and possibly yawing. "If they went the same way, there would be added steering torque as you navigated through the water" (Propeller Rotation Explained: How to Choose Between Left and Right, 2022). We hypothesized that the co-rotating propellers on our ROV were causing the rolling our vehicle was experiencing.

We noticed that other teams and real-world applications use counter-rotating propellers; therefore, we decided to try driving with different sets of them to compare with the SeaPerch ones. We expected to see more stability, leading to faster and more efficient control when driving. We also hypothesized that counter-rotating propellers could also improve water flow.

Table 1: Time in seconds for 12-foot dash

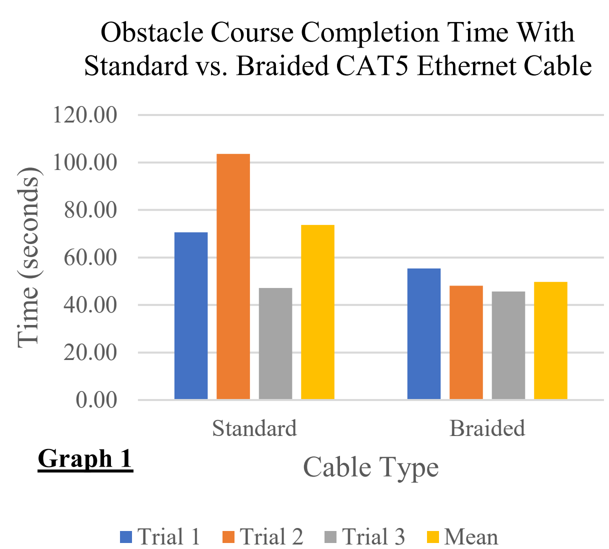
Propellers	Trial 1	Trial 2	Trial 3	Mean
Prop 1 (SeaPerch provided) 	4.98	5.69	4.81	5.16
Prop 2 (Hobby Shop) 	6.63	7.44	7.93	7.33
Prop 3 (Amazon Quad Blade) 	7.58	7.51	7.74	7.61

Each set of propellers was tested in three trials to obtain more accurate results and minimize the effects of pilot error (Table 1). We were surprised with our controversial results, as we observed slower performance and minimal difference in stability. We believed this was because the SeaPerch propellers had a better ratio of pitch to diameter or because of their total size compared to the power of the motor. "…correctly matching the propeller to its specific powerplant is critical to achieving optimal performance" (Leishman, 2023). Thus, we decided to proceed with the SeaPerch propellers.

Experiment 2: obstacle course completion time with different cables. We hypothesized that removing the cover and braiding the wires of the CAT5 Ethernet Cable (Figure 10) would reduce the weight and the drag of the cord through the water and along the rings in the Obstacle Course. To test our hypothesis, we completed the Obstacle Course 3 times with each type of cord and measured the completion time (Graph 1).

Figure 10

We were surprised by how much faster the ROV performed in the Obstacle Course with the braided cable compared to the standard. The ROV finished an astounding 24 seconds faster on average. Not only was it easier for the ROV to maneuver through the rings, but it seemed faster in general. The reduced drag and influence on the ROV's movement clearly made a substantial positive impact on the ROV with speed, maneuverability, and agility. Overall, our results proved that a braided cord worked better for our ROV.



Graph 1

Reflection & Next Steps

By following the EDP, our team overcame many challenges on our 2025 SeaPerch journey. We designed the ROV to be effective at completing both the Mission and Obstacle Courses this year. The EDP helped us make crucial design decisions that shaped our ROV to be fast and stable simultaneously, an issue we struggled with for the past two years.

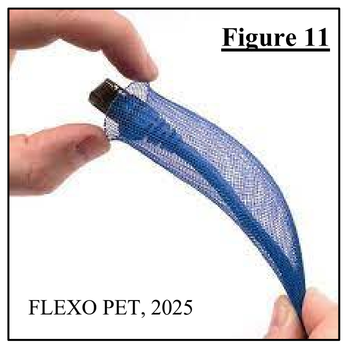
The EDP guided us in choosing a design made of crossed plexiglass plates. This decision proved to be very beneficial, not only for the ROV's performance but also in making quick, impactful adjustments for testing. The high surface area of the plexiglass aided in stability, while the thinness provided a streamlined water flow with minimal drag. Additionally, our use of syringes filled with air for buoyancy worked well to minimize the ROV's drag. Like the plexiglass, the ease of adjusting the air in the syringes was really helpful for us in our limited time in the pool. Although we did not succeed with our original two-hook design, the modification to a single hook worked well and accomplished the goal we set for it. It consistently and effectively hooked all the objects without compromising the ROV's speed in pitching up. It was also able to close and open the hatch.

Our experiments with the different types of propellers gave us valuable insight into how specific a propeller is to its engine. Although the propellers we tested were counter-rotating, which in theory should have made the ROV more stable and faster, they had other factors such as pitch, diameter, and number of blades that caused the ROV to perform slower than the standard propellers. In addition, the braided cable helped our Obstacle Course times improve significantly by reducing the drag of the cable and its influence on the ROV's movement. The braided cable also rarely kinked and was easy to keep straight, which was super convenient for our team at the pool and for transportation.

Throughout the season, our team formed close bonds during the many hours we worked at the pool and the workshop. We made insightful observations and built off each other's ideas, which helped us develop our amazing ROV. However, we had several ideas we would like to implement in the future.

One such idea was to cover the braided cable in a Polyethylene Terephthalate (PET) sleeve (Figure 11). We imagined this could further reduce the drag, particularly on the Obstacle Course rings. It could also help protect the cords from catching on sharp objects and ripping. A PET sleeve is also simple to take off and put back on if necessary. "The sleeving cuts easily and cleanly with a hot knife and, once installed, will beautify and protect any wire, hose, or cable application" (FLEXO PET, 2025).

Figure 11



FLEXO PET, 2025

Another idea would be to switch to tinted plexiglass instead of clear. We believe this could significantly help with visibility, especially when the ROV is far away at the end of the Obstacle Course. An improved visibility would also help our pilot judge the distance and depth of the ROV.

A third idea we had was to work on improving the comfort of the controller for the driver. We have seen many teams increasing the size of the buttons and adding handles for comfort. This approach focuses on improving the pilot's performance rather than exclusively on the ROV's performance. Converting the uncomfortable SeaPerch controller into something similar to an Xbox controller could be a game changer for us. We believe that with some research in hand ergonomics, we can design 3D-printed attachments to the controller that would reduce strain and improve consistency.

As for us, we plan to mentor a team and help out during the 2026 SeaPerch season. Participating in SeaPerch and qualifying for Internationals for three consecutive years (we placed 6^{th} in 2023 and 3^{rd} in 2024) provided us with unique insight. We believe our experience and passion for SeaPerch make mentoring an excellent choice for next year.

ACKNOWLEDGMENTS

First and foremost, our team would like to acknowledge our wonderful teachers and mentors, Mr. Stamford, Mr. Stone, and Mr. Stockunas. They volunteered their time during and after school to help us design our amazing ROV. Thanks to them, we were able to work in the workshop and the pool. We would also like to thank Mr. Palermo for reviewing our report and Mrs. Stamford for her tremendous support of our SeaPerch activities. Additionally, thank you to the Gateway School District Administration for hosting our regional competition and allowing us access to the pool for practice and time after school hours. Also, we want to acknowledge the team that gave us the idea to utilize syringes instead of pool noodles for buoyancy. Finally, we would like to give a special thank you to Alivia Reeder, Gianna Sample, Sarah Rafiuddin, Sydney Prado, Victoria Colberg, and Yasmin Nazarova for taking their class time to braid our ROV's cable.

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Budget

Team Name: *HydroDynamics* **School/Organization:** Gateway School District – High School

Material	Vendor	Unit Price ($)	Quantity Used	Total Price ($)
Lock Luer Syringe Caps	Amazon	0.11 each	12	1.32
Fifth Pulse 10ml Syringes	Walmart	0.40 each	10	4.00
Fifth Pulse 3ml Syringes	Walmart	0.40 each	2	0.80
0.080 Optix Acrylic Sheet	Home Depot	0.04 per in^2	125.35	5.01
3D-Printed Motor Mount – Securing up/down motor	Custom	0.02 per gram	7.2	0.14
8” Cable Zip Ties – Securing Syringes	Lowe’s	0.09 each	12	1.08
4” Cable Zip Ties – Securing Syringes	Home Depot	0.10 each	14	1.40
Blue Duct Tape - Visibility	Amazon	0.01 per inch	10	0.10

Educator Signature: CRAIG STAMFORD

Final Amount Spent: $13.85