SeaPerch Technical Design Report 2025
SITHS Special Operations
Staten Island Technical High School

ABSTRACT

With this season being our team's fourth year participating in SeaPerch, we have applied everything we learned into this year's ROV. Following the Engineering Design Process (EDP), we began our season by asking each team member to create and present two complete ROV designs with hooks. After coming together to discuss our models, we combined the best components of each idea into 3D models. We tested a modified ROV frame and four hooks to maximize speed, maneuverability, and cost, all while not sacrificing practicality and a coherent solution to both the obstacle and mission course. With the repeated concept of hooking onto rings being presented in a new perspective, we have spent these last few months building and testing various hooks and an ROV that would complement their capabilities. Through a collaborative and iterative design process, we developed a more compact and hydrodynamic ROV frame than last year.

To enhance visibility so the controllers can distinguish directions easily during the competition, we spray-painted the front elbows green and the back red. Besides the frame, we focused on refining our hook designs for optimal efficiency. Our custom 3D-printed hooks, constructed from Polylactic Acid (PLA) filament, improved visibility and increased functionality for sample collection. Each hook has a unique C-shaped connector to provide a more secure attachment to the ROV. After rigorous testing of our T-shaped and Cross hooks, we successfully optimized performance through a balance of speed, versatility, and functionality.

Reflecting on our season, we recognize the importance of preparation and have established clear goals to refine our design and testing processes further, strengthen our collaborative efforts, and push the boundaries of our ROV's capabilities in the future.

TASK OVERVIEW

This year's SeaPerch competition prioritizes the speed and agility of the ROV when navigating through the mission and obstacle courses focused on coral reef restoration. For the obstacle course, robots must swiftly navigate through five 18" hoops oriented at different angles and come back. Following that, teams move onto the mission course. This part of the competition tests the ROV's ability to move through doors and obstacles and transport samples to demonstrate its capability to monitor the environment's health and restore colonies of coral reefs. In the mission course, the ROV must first be able to carry marine life from the top of the hatch door to the front platform, which requires a durable hook. After that, it should also open that door to access the bio-buckets underneath. Next, the ROV must bring new species and sea sponges located on the front platform and place them inside the buckets. Then, it has to move two coral samples from the back to the front platform to hang them on the coral tree. Points can also be earned by collecting deep-sea samples on the deep dive platform, placing them in the buckets, bringing sensors from the surface vehicle, and putting them on their respective markings on the front and deep dive platforms. Finally, the hatch door must be reclosed at the conclusion of collecting points with the bio-buckets. There are numerous tasks to complete, which further emphasizes the need for a versatile hook.

Our team decided that the best way to complete these tasks was with two custom 3-D printed hooks designed to complete multiple tasks efficiently. By increasing the versatility of the hooks, the ROV can score more in less time. As we design, we need to ensure that the hooks are not too large to interfere with one another, as the frame is scaled down this year. Their size must not block the robot from quickly completing the obstacle course while being big and balanced (center of gravity) enough to move the coral samples around without being weighed down or tilted to one side. Lastly, we have to consider speed and buoyancy to optimize the timing and movement of a diverse range of samples, creating the best ROV to help restore the homes of millions of organisms.

DESIGN APPROACH

After carefully reviewing this year's challenge objectives, each member was tasked with researching ways to increase the ROV's efficiency in completing courses. Based on their findings, everyone sketched two full designs with hooks. We then met to evaluate each concept and integrate the strongest elements into one design. Finally, we decided on two frames and four hooks to test.

The Building Process

During the engineering design process (EDP) build stage, we divided into five groups: Vehicle Frame & Assembly, Thrusters, Tether Cable, Control Box, and Courses. The Vehicle Frame & Assembly group disassembled last year's ROV to repurpose its parts. The second group assembled the thrusters by drilling holes in the thruster housings, assembling the motors, and attaching propellers and tether cables to the motor terminals (SeaPerch, 2021). The third group water-blocked and mounted the tether cable securely with zip-ties. The fourth tested the functionality of last year's control box. When the fifth and final group finished building the courses, we attached the hooks, motors, and pool noodles to the ROV to prepare for testing.

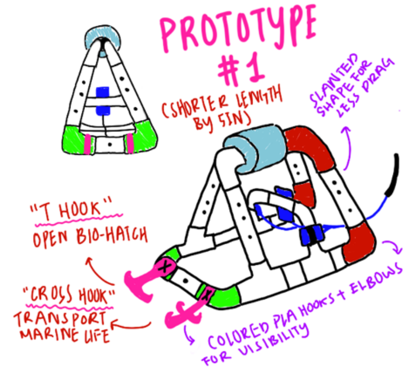

Figure 1. First ROV prototype.

Frame Iterations

To improve the ROV's mobility, we focused on maintaining balance and increasing speed. Last year, our ROV completed the courses in a good amount of time, but we hope to improve it further by analyzing its drag and center of mass.

Bernoulli's Equation, $P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$, shows the conservation of energy in a fluid, while the drag force equation, $R = \frac{1}{2}\rho C A v^2$, calculates the resistance opposing an object's motion. These equations highlight that drag increases with surface area, meaning a larger surface area leads to more resistance, which reduces the ROV's speed and efficiency (Elert, 1998). We focused on reducing drag to improve speed and addressed the ROV's upward tilt underwater. We discovered that placing the center of buoyancy slightly higher and the center of mass lower helped keep the ROV upright during operations (Wright et al., 2014).

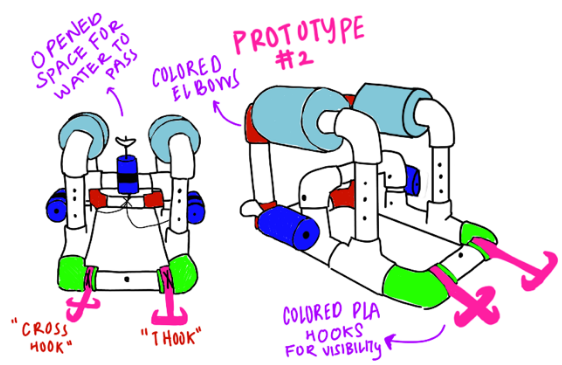

Figure 2. Second ROV prototype.

With our research in mind, we constructed our first prototype with two slanted sides and the center of mass positioned slightly backward, creating a triangle-shaped frame to reduce drag (see Figure 1). To enhance hydrodynamics, we reduced the length by 5 inches and the height by 1 inch from our previous design. However, this prototype failed due to insufficient space for water flow, as the vertical motor was placed too close to the top piece of PVC. Returning to the EDP planning stage, we reverted to the frame from our first season that advanced us to internationals, reduced its size, and adjusted the center of gravity (see Figure 2). After testing this updated design, the ROV was still slightly large, preventing it from tilting down to enter the bio-basket to transport the hanging corals. Due to the tee connectors, we could not reduce the length significantly. Instead, we trimmed an inch off the back PVC, shortened and angled the hooks to improve reach in the bio-basket (see Figure 3). Additionally, we

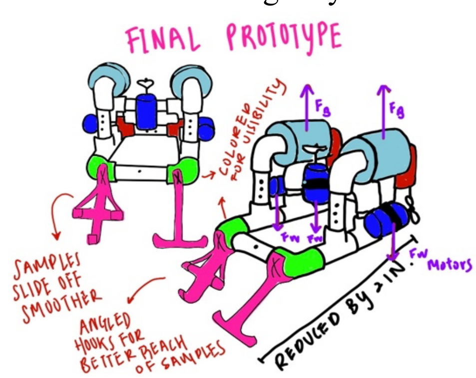

Figure 3. Final ROV prototype, being slightly back heavy and at rest.

spray-painted the rear and back elbows neon green and red (see Appendices A and B), as both colors have improved visibility underwater (Uglene, 2011).

Hook Design Process Iterations

Our hooks from our first year were made from aluminum, but its high density made adjusting the ROV's center of mass difficult without constantly reevaluating the pool noodles' buoyancy and volume. Therefore, we switched to 3D printed hooks to easily design and modify dimensions within millimeters of precision using Inventor. At first, we used Thermoplastic Polyurethane (TPU) filament, as the material is highly elastic and could reduce the risk of our hooks breaking underwater (Rodríguez-Parada et al., 2021). However, we found its flexibility excessive, making it difficult for operators to establish a consistent method for grabbing samples.

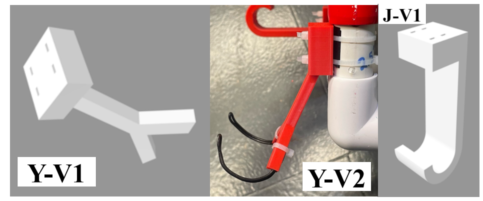

Figure 4. Y and J-Hook Prototypes.

For our final iteration, we used polylactic acid (PLA) to ensure solidity in our hooks, as PLA is rigid (O'Neill, 2022). This material also allowed us to further explore our hooks' novelties, such as creating steeper curves, editing dimensions, and incorporating a bright red filament for better visual distinction. Testing results led us to decrease the length and expand the height of the hooks, creating more negative space to ensure an increased chance of picking up objects.

Hook Design Iterations

This year, we focused on four hook designs to optimize our ROV's performance. We created the Y Hook to pick up and transport marine life and samples without anything falling off. The double branch would provide more contact points with the object, making it less likely to fall off the hook during operation. This concept is supported by the "Cradle Grabhook," a real-life hook used to secure heavy loads. Its simple U shape allows the object to sit at the bottom, distributing force evenly and reducing stress concentration (Close, 2025). While modeling the Y Hook (see Figure 4), we realized we could not 3D print the curvature at the ends because they kept breaking off with the support. We decided to print the hook without the curvature, and instead create indents to insert bendable metal wires for the curves (see Figure 4 Y-V2). However, the wires would detach, so we decided not to use this hook design.

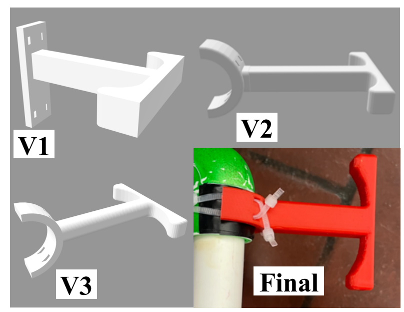

Figure 5. T-Hook Prototypes.

Our second design, the J Hook, was used to grab onto sensors for easy transport (see Figure 4 J-V1). Its curved design enhanced versatility, making the hook adaptable for various tasks with loop-ended objects. In commercial fishing applications, the J hook was found to have deeper hooking locations in fish, such as in the mouth and throat, more than other commonly used hooks, which suggested that the shape could provide a secure grip on the SeaPerch samples (Willey et al., 2016). However, objects would often fall off the J Hook because the curvature of the edges was too gradual.

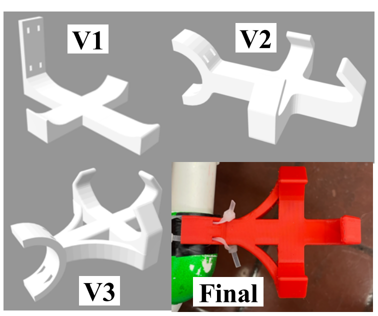

Figure 6. Cross-Hook Prototypes.

Overall, the T and Cross Hooks (see Figures 5 and 6) proved to be the most versatile. Their symmetry and curves at the ends allow for intuitive grasping of objects. The Cross Hook was similar to the Y Hook, with multiple outward extrusions. However, because the cross has extrusions on all sides, it distributes the force of weight more evenly, reducing stress. Additionally, unlike the other two hooks, the T and Cross Hooks were bifunctional, as they could be used to open the bio-hatch and safely transport samples. Lastly, considering the curve of the PVCs and elbows in the frame, we developed a novel approach to attaching the hooks. We designed C-shaped connectors on the hooks to fasten them securely to the ROV (see Figure 6 V3).

EXPERIMENTAL RESULTS

The main objectives of our ROV are efficient maneuverability and precision. To test our ROV, we timed how long it took to finish the Coral Restoration Task, Obstacle Course, and 8 feet as they targeted all skills essential for the competition (maneuvering through obstacles, transporting samples, and speed). The results allowed us to determine what design changes were needed.

Hook Iterations

To test the hooks' efficiency, we placed coral samples into the bio-bucket on the back platform and timed how long it took for each of our hooks to hang each sample onto the coral tree on the front platform (see Figure 7). The T Hook proved to be the fastest, completing the task in an average of 74.2 seconds. The Cross Hook followed closely with an average time of 114 seconds. In contrast, the J and Y Hooks lagged significantly behind, with average times of 170 and 166.6 seconds, respectively. The samples would often slide off the hooks during transporting, which led us to further pronounce our curvature in our other hooks. With our subsequent testing, we found that the Cross and T Hooks were the most optimal choices since they could be used for multiple tasks and had quick times with a highly precision-oriented task. To further improve those designs, we conducted a stress analysis on Inventor to ensure they would not break during operation. The results prove them stable.

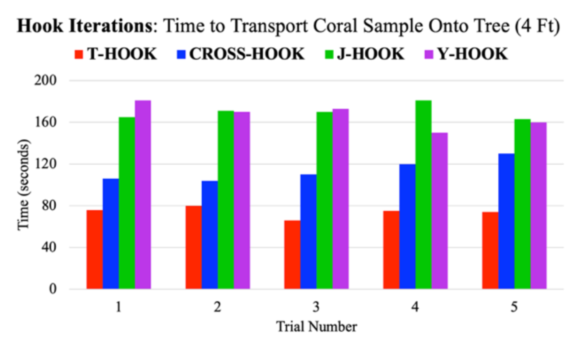

Figure 7. This bar graph shows the different times it took each hook version to hang the coral sample on the tree.

Frame Iterations

For frame design, we conducted a speed and maneuverability test by navigating the obstacle course with three different frames: the triangular shaped frame (TRIANGLE), the larger rectangular frame (RECTANGLE-1), and the slightly smaller rectangular frame (RECTANGLE-2) (see Figure 8 for trial runs). Initially, we compared the TRIANGLE and RECTANGLE-1 frames. The triangular frame was the slowest, averaging 221.8 seconds per trial run, as the PVC and pool noodles obstructed the water flow for the up-and-down motor. Hence, we focused on the rectangular frame. However, after going through numerous obstacle course trials, the frame still prohibited the ROV from grabbing hanging corals from the bio-bucket. The wider frame also increased the frontal area of the ROV, making it less hydrodynamic. So, we reduced the length from 13 to 10 inches. With a shorter frame (RECTANGLE-2), the ROV now averages 85 seconds per trial and can transport samples from the buckets easily.

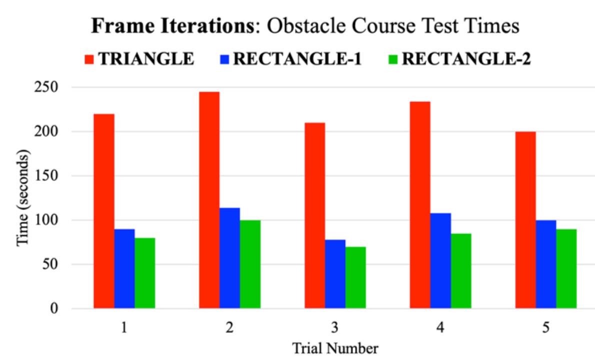

Figure 8. This bar graph shows the different times it took each frame version to complete the obstacle course.

We also calculated the speed of each frame by conducting an 8-foot distance test (see Table 1). All frames had generally fast and comparable speeds, with deviations varying from 0.3 to 0.6 ft/second. The triangular frame had the slowest speed at 1.3 ft/second. The smaller rectangular outperformed the larger by 20% time-wise and 19% speed-wise, which led us to choose it as our final design frame.

Frame Type	Time (s)	Distance (ft)	Speed (ft/s)
TRIANGLE	6.3	8	1.3
RECTANGLE-1	5.2	8	1.6
RECTANGLE-2	4.15	8	1.9

Table 1. This table contains the results from an 8 ft distance speed test for each ROV frame.

REFLECTION & NEXT STEPS

This year, the team has gained valuable insight into teamwork, effective delegation, and smooth communication. Last year, we had some issues with communication and deadlines because our schedules were not aligned. This year, we split into six groups: Vehicle Frame & Assembly, Thrusters, Tether Cable, Control Box, Courses, and 3D models. By forming these sub-teams, members could gain more personalized learning opportunities on technical skills such as soldering. This also allowed everyone to share their knowledge with new members and communicate more effectively, as we now have a larger team.

To maximize the potential of our team, we also decided to have each team member create their own design by conducting independent research and using past SeaPerch ROVs for inspiration. We found it beneficial when the team analyzed each part of different designs and worked together to combine the best into one. This year, we conducted more research on design possibilities and consulted previous ROV drivers to understand common issues with hydrodynamics. One of our main challenges was deciding on the lengths of our frame components. We wanted to make the robot smaller to increase speed but not so small that it could not pick up objects because of buoyancy issues. After consulting with the ROV drivers and testing different options, we agreed on a final design. Passing on our sketch to the CAD team, two of our team members modeled the ROV and our hook designs using Inventor (a 3D modeling software) to visualize the robot and finalize the exact measurements of the individual PVCs that make up the frame, allowing for a streamlined engineering design process.

As a whole, our team found this year's SeaPerch experience to be much more enjoyable. Because we separated our team into multiple smaller groups that focused on specific aspects of the build/design process, we could focus on and master specific engineering skills such as using drills and a metal shear brake, soldering, and sawing pipes. Although we were more efficient in our building process, we struggled to get testing time because we did not have access to a pool. With the help of one of our teammates who owns a pool, we could test our ROV in time for data collection and analysis for iterations.

For next year, we plan to keep many aspects of our design. We will continue to spray-paint the elbows of our ROV, as the neon colors made it much easier for the controllers to see underwater. The smaller frame also proved much smoother for the ROV controllers to control, which enabled faster movement and shorter run time overall. While there are positives, we have plenty of room for improvement. Understanding that everyone has a busy schedule and the uncertainty of our pool access, we should plan ahead for next year. We can organize testing dates and sites weeks in advance by creating a shared calendar of everyone's availability and active deadlines. This can reduce a lot of stress for the entire team.

At Staten Island Technical High School, there are now three SeaPerch teams. From what started as a team of confused freshmen, we have grown into a family and a large friend group. Despite the fact that this is a competition, what is truly important is sportsmanship. Our relationship with the other teams has allowed us to learn to be compassionate and supportive of each other's needs and accomplishments. Through experiencing the engineering design process together, we have also been able to expand our skill sets. Not everything works the first time in engineering. Some of our early ideas were not incorporated into our final design, while some did. What matters the most is that we persisted through these challenges together. What we accomplish is up to how we approach the problems and merge unique ideas to ensure everyone has an enjoyable SeaPerch season.

ACKNOWLEDGEMENTS

Aside from the support we have gained from each other, our team would not have been successful in the design and testing process without the valuable support of others within our community.

First, we want to thank our coach, Mr. Henriques, for his unwavering support every season in the last four years. Despite his busy schedule—teaching our school's engineering class and helping us get licensed in Amateur Radio—he was always there to help and encourage us to fully embrace the SeaPerch challenge, utilize the Engineering Design Process to overcome our failures, and step out of our comfort zone. Our season could not have succeeded without him, and we are very grateful for the advice he has taught us.

Next, we would like to extend our gratitude to our school's Career and Technical Education Coordinator, Dr. Jax. Because of him, we have been able to jumpstart this school program. Dr. Jax has helped us secure funds for our four seasons thus far. Without him, we would have been unable to create three teams and expand our engineering outreach to more students within our school.

Furthermore, we would like to graciously thank our school's First Tech Challenge Coach/ Physics teacher, Mr. Colangelo, for always inspiring us to explore different types of engineering tools, one of which we capitalized on this year— 3D printing. He generously provided us with essential access to a 3D printer, allowing us to print our hook designs as we iterated through the "Improve" stage of the Engineering Design Process. We used quite a lot of filament, but Mr. Colangelo has never complained!

We are also very fortunate to have our principal, Mr. Erlenwein, who enthusiastically supports us and our robotics program, and our school's Makerspace teacher, Mrs. Stefanese, for her valuable recommendations on material uses and willingness to provide us with equipment.

Last but not least, our team would like to graciously thank one of our team members for always providing us with access to their pool to test our SeaPerch ROV. This has allowed us to collect and analyze data for design iterations. Without the help of our mentors and school officials, we would not have been able to complete our mission.

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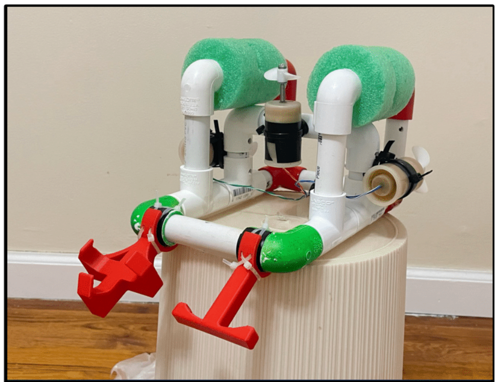
Appendix A: BUDGET

Component	Vendor	How was the component used?	Cost (in USD)
Krylon Fusion All-In One Spray Paint (2)	Amazon	Visibility Underwater	$5.97 (Split Cost With 2nd Team)
Polylactic Acid Filaments (PLA)	Amazon	Hooks	$0.75
Aleene's Acrylic Matte Spray Sealer (1)	Walmart	Setting Agent for Spray Paint	$2.99 (Split Cost With 2nd Team)
Regular Length Zip Ties (50 ct.)	Amazon	Fastening ROV parts	$3.49
Small Length Zip Ties (50 ct.)	Amazon	Fastening ROV parts	$2.49
TOTAL COST OF SEAPERCH COMPONENTS			**$15.69**

Appendix B: FACT SHEET

SITHS Special Operations Team

Staten Island Technical High School, Staten Island, NY, USA



HS-STOCK

4 Years participating in SeaPerch

1 Times at the International SeaPerch Challenge

Our SeaPerch is unique because: (100 words MAX)

Our SeaPerch is unique because of its specialized hooks and colored elbows. With three inward curvatures, the Cross hook increases our chances of grabbing and transporting sensors, marine life, hanging corals, and octopuses. The T hook is designed to open the bio-bucket hatch despite imprecise movements. Both hooks use durable, lightweight PLA filaments, reducing the risk of breakage during competition. They are tilted downward, allowing the ROV to pick up samples without descending far, which reduces runtime. We also spray-painted the front and back PVC connectors with different neon colors for high visibility underwater to help controllers operate the ROV.

SeaPerch Design Overview: (100 words MAX)

Through robust research, we decided on specific design features to ensure efficient maneuverability and precision. We reduced the size of the ROV by 25% to minimize drag force and increase the speed. We also used polylactic acid (PLA) filaments to construct our Cross and T hooks, which are lightweight and enable us to maneuver rapidly with an improved hydrodynamic nature. Each hook also specializes in completing specific tasks: transporting sensors, hanging corals and marine life, and opening the bio-hatch. Ultimately, our design enhances the ROV's maneuverability and efficiency in completing the mission and obstacle courses.

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

Our biggest takeaway is the opportunity to improve and teach others about technical and interpersonal skills. Following the engineering design process, we were able to familiarize new members with universal tools such as drills and soldering, cultivating technical abilities most could not have gained in a conventional learning setting. Understanding former challenges, we have learned to embrace and apply them to construct a more efficient ROV, fostering a positive mindset applicable to all aspects of life. Despite everyone's busy schedule and the unavailability of a pool in our school, we have learned to persevere, communicate, and understand sportsmanship.

Instagram: @siths_seaperch