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Polluted waterways are a real world problem facing the environment.

1.0 ABSTRACT

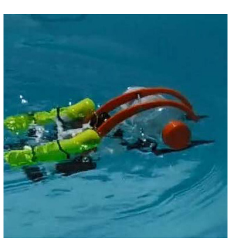
The 2021 SeaPerch Challenge is inspired by real-life environmental conditions where remotely operated vehicles (ROVs) can play a key role in assisting with cleaning up polluted waterways increasingly threatened by everything from floating garbage patches to hazardous submerged explosives.

The following Technical Design Report summarizes the engineering design process and overall approach to solving this year's **Mission Challenge: Waterway Cleanup.** It provides an overview of the engineering design process (EDP), including ROV design, construction, testing, analysis and results, modifications and future plans. Additional details and results have been recorded in a separate engineering workbook.

The team began the process with a thorough analysis and understanding of the problem, followed by the development of a clear and concise set of goals and measurable objectives to help guide the project. The design approach began by building on the strengths of the 2019 ROV, and continued with an exploration of multiple strategies and prototypes to successfully complete the mission.

The uniqueness of the Wahoo concept lies in it's apparent simplicity in design and operation. The compact and light weight vehicle attacks all challenges using a universal, retractable and remotely operated attachment that quickly and effectively collects, transports and deposits a range of floating and submerged debris.

Just like wildlife, the ROV needs to avoid being entrapped by the debris.



A key challenge for the Waterway Cleanup Mission was to design a system that's equally effective on the surface and the bottom.

2.0 TASK OVERVIEW

The team elected to compete using the optional Waterway Cleanup Mission Course challenge to demonstrate the Wahoo's capabilities. The Mini Course used is uniquely designed to replicate four waterway cleanup activities:

TASK-1 (Active Mine) consists of a simulated active mine that must be disarmed or removed and deposited in the disposal area on the vault platform.

TASK-2 (Disposal Vault) requires opening and closing of the vault gate latch where sunken waste will be deposited in Task 4.

TASK-3 (Garbage Patch) requires collection and removal of five floating objects from the containment ring.

TASK-4 (Sunken Waste) consists of an assortment of submerged debris (five pieces) to be collected and deposited on the vault platform.

Teams are provided two minutes to complete Tasks 1 and 2 (Run 1), and two minutes to complete Tasks 3 and 4 (Run 2) (SeaPerch, 2021). The following summarizes some of the key design considerations used to justify the ROV design and construction.

ROV DESIGN CONSIDERATIONS
Design a smaller adaptable ROV to navigate tight spaces.
Reduce risk of dropping objects using a secure or operable attachment.
Explore retractable attachments to be more compact and adaptable to multiple tasks.
Design an attachment to quickly and securely manipulate the active mine.
Incorporate adjustable components to fine tune the ROV during testing.
Locate attachments close to the vertical thruster for optimal lift and control.
Minimize obstructions on ROV to avoid snags on the course and debris.

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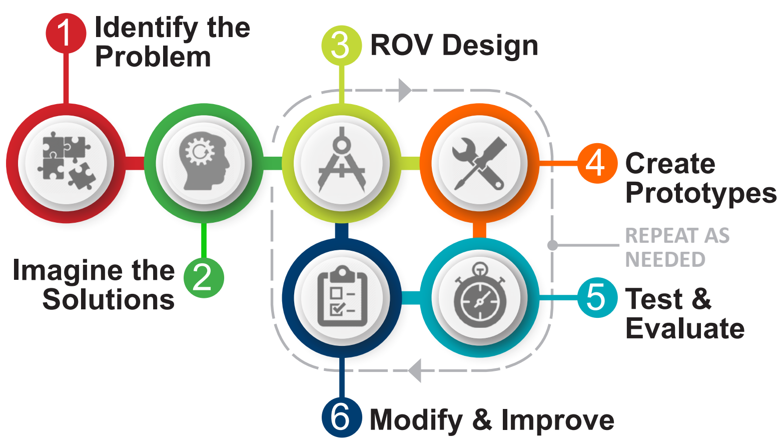
3.0 DESIGN APPROACH

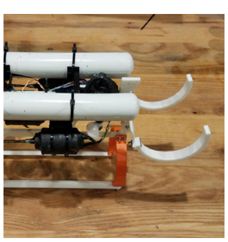
Engineering Design Process

The team's approach to the 2021 SeaPerch Challenge followed an iterative process identified in the following EDP; including design, construction, research, testing and results, as well as conclusions and future plans (Valenzuela,2019).

ENGINEERING DESIGN PROCESS



Redesign efforts successfully reduced the overall ROV height by 20% (2019-top left).



2019 concept with static hook attachments to collect and maneuver objects.

This process allows the team to continuously modify the design based on key performance criteria and test outcomes. The following outlines critical action items conducted for each step in the EDP.

1 STEP 1

- ☑ Review 2021 SeaPerch Challenge events, compliance factors, team rules and rubrics
- ☑ Research the problem
- ☑ Identify real and potential constraints to overcome

2 STEP 2

- ☑ Brainstorm ideas that help to overcome the identified constraints
- ☑ Develop measurable goals and objectives to guide ROV design and development

3 STEP 3

- ☑ Conceptualize possible ROV features
- ☑ Explore and evaluate materials and methods
- ☑ Refine details and construction methods
- ☑ Prepare detailed drawings for the preferred concept

4 STEP 4

- ☑ Construct a range of ROV prototypes and attachments for pool testing

5 STEP 5

- ☑ Test ROV prototypes
- ☑ Evaluate strengths & weaknesses
- ☑ Analyze and compare test results
- ☑ Select preferred ROV design
- ☑ Retest and evaluate

6 STEP 6

- ☑ Modify ROV to improve performance
- ☑ Retest and analyze based on testing and evaluation results
- ☑ Repeat process as needed

Design Iterations

During initial brainstorming, a key design strategy was to build from the successful foundation of the 2019 ROV design. The earlier ROV frame was strong, lightweight, hydrodynamic and adaptable. The team explored various alterations and static modifications that would successfully accomplish this year's mission challenge (SeaPerch, 2021).

Design iterations began with modifications to the planar frame to streamline the overall profile and improve the vehicle's agility (Chakraborty, 2019). Attachments were developed that would accomplish the mission and were compatible with the revised frame and thruster alignment.

Early concepts employed a simple hook apparatus that was envisioned to knock the floating objects out of the containment ring. Bottom wedges were integrated into a "scoop" device that was used to both lift objects off the bottom and cradle floating objects. Hook attachments were spaced at the bow to accomplish the removal of the mine arming device. A curved scoop also served to carry objects close to the bow where maximum vertical thrust could be applied.

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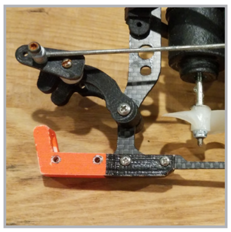
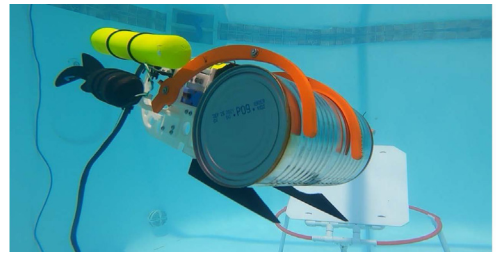
Micro servo (example).



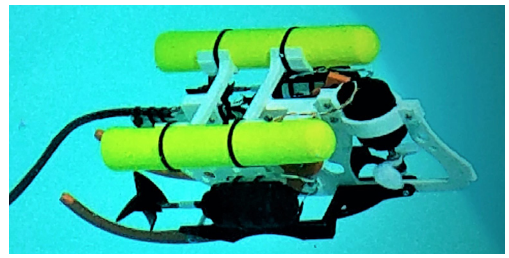
The 2019 articulating claw became the baseline for designing this year's attachment.

To ensure objects stayed on the scoop attachment, the articulating arm was modified from the 2019 concept. The servo-operated arm attachment was designed to rotate from a centrally mounted pivot point and reach beyond the largest object and hook downward to hold debris in place. The servo was later oriented horizontally to help reduce drag and stabilize performance.

To operate the on-board micro-servo, a common inexpensive servo tester was used to control the claw attachment from shore. This is a similar setup that was used on the 2019 ROV. A waterproofed high torque, digital mini-servo was wired using the fourth channel in the tether. A third signal wire was routed from the servo to the tester and connected it to the outside of the tether.

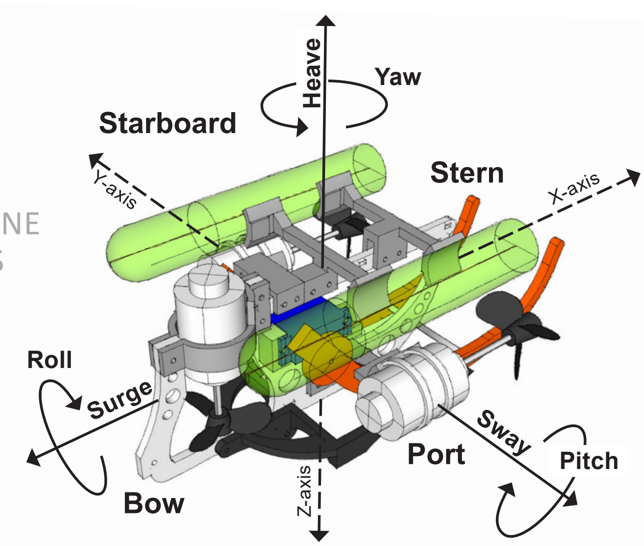


The Wahoo utilizes a remotely operated articulating arm to collect both floating and sunken debris.



The Wahoo ROV has the ability to retract both grasping attachments (upper and lower) for unobstructed navigation, reduced drag and improve speed.

SUBMARINE MOTIONS



For the final concept, the team devised a means of bridging the frame "around" the bow-mounted vertical thruster rather than "over" it, as in 2019. By moving the pontoon floats outward, the vertical height of the ROV was successfully reduced from five inches to four inches (or 20%). The float system is adjustable using zip ties which helps to fine tune its buoyancy and reduce pitch and roll motions (Mraz, 2014).

MODIFICATIONS & DESIGN FEATURES

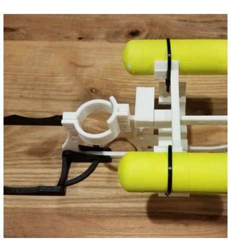
- ☑ 3D frame and mounting brackets are lightweight and easy to modify
- ☑ Adjustable motor and float mounts allow for quick repositioning or replacement
- ☑ Counter-rotating horizontal thruster propellers provide stability and reduce roll (Reichow, 2019)
- ☑ Retracted size: 6" L x 5" W x 4"H
- ☑ Hollow tube floats reduce drag and mass and maintain buoyancy at any pool depth

What makes the Wahoo design unique is the two simple attachments that work together. The ROVs ability to completely retract these attachments 180 degrees during the obstacle course, results in a compact maneuverable vehicle that is both adaptive and agile.

The servo tester operates separate from the ROV controller. This setup works well in this scenario as it allows the driver and the cord manager to work independently. This is important as it gives the ability to navigate the ROV and operate the servo at the same time.

Final Concept

The final 2021 ROV concept is a simple, compact, lightweight and adaptable vehicle that is both effective and efficient in completing the Waterway Cleanup mission.



Bridging the frame around the thruster allowed the profile to be reduced by 20%.

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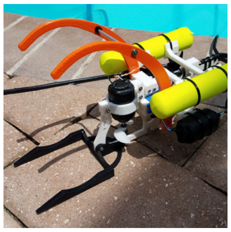


Coating the upper and lower articulating arms provided additional grip and reduced drops.

OBSTACLE COURSE

10% Reduction in Course Time

Fastest Time: 23.70 sec.

Improvements in Obstacle Course times were attributed to a 20% decrease in the vehicle's profile and retractable attachments that reduce course conflicts.

MISSION COURSE RUN 1

56% Reduction in Course Time

Fastest Time: 24 sec.

Improvements in Mission course times were the result of developing the right-sized attachment and lots of practice.

MISSION COURSE RUN 2

47% Reduction in Course Time

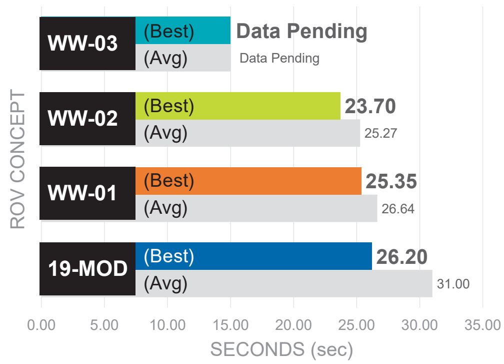
Fastest Time: 1 min. 33 sec.

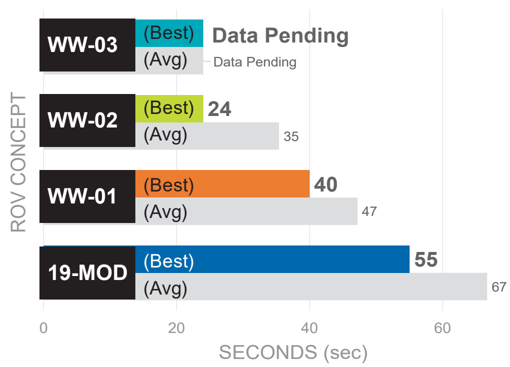
Improvements in Mission course times were the result of incorporating an operable attachment, modifications to the float assembly and even more practice.

4.0 EXPERIMENTAL RESULTS

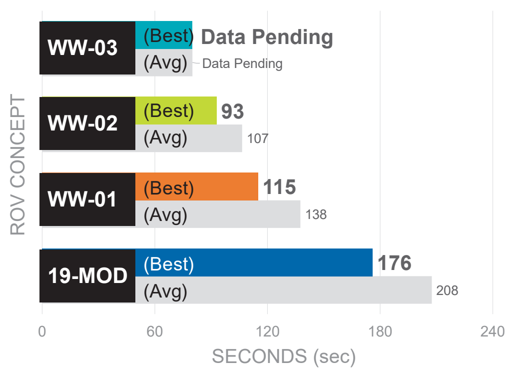
Testing Analysis

ROV concepts were pool tested in three categories; Mission Course Run 1 and 2 and the Obstacle Course. While the obstacle course will not be included in the 2021 International SeaPerch Competition, the team felt it was a good measure of the Wahoo's performance and adaptability, as well as the possibility that this course may be used at some regional events.





Mission Course RUN 1 includes Tasks 1 & 2



Mission Course RUN 2 includes Tasks 3 & 4

ROV CONCEPTS TESTED

(1) **2019 Modified ROV:** This concept incorporated the basic 2019 chassis utilizing a range of static attachments.

(2) **WW-01:** This ROV added fixed remotely operated attachments to test its functionality. The attachments did not retract.

(3) **WW-02:** The current concept incorporates modifications to the horizontal thruster mounts, servo position and upper arm configuration. This model also includes retractable attachments.

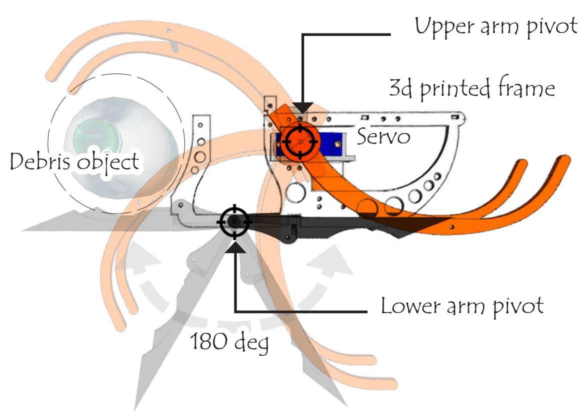
(4) **WW-03:** Under construction.

Key Modifications

During testing the servo would on occasion rotate slightly causing it to bind with the float mounts and scoop attachment. To eliminate this condition, the team redesigned the support platform to contact the servo on five of the six sides and incorporated two additional mounting screws.

In the retracted position the collapsed arm and scoop attachment would occasionally get caught on the course. The team redesigned the parts to rotate 180 degrees between courses. By narrowing the thruster supports, and moving them forward and up, the team was also able to elevate the position and improve responsiveness.

RETRACTABLE ARM ASSEMBLY



Summary

Overall WW-02 has performed consistently and meets the established performance goals for the project. The team plans to continue to test and modify WW-02 to optimize it's performance, including the addition of a fourth motor, reconfiguration of the arm assemblies and a carbon fiber frame.

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5.0 REFLECTION & NEXT STEPS

The first competition in 2016 at LSU.

Looking Back

Reflecting on the team's experiences during the 2021 SeaPerch season to this point, it has been one of many challenges and uncertainty compared to previous seasons. While the team was not able to practice very much or compete in any pool events in the current environment, it has allowed time to focus on other aspects of the project such as research and presentation.

This is also a time for reflection on the team's four years of participating in SeaPerch, beginning in 2016. Today, as seniors in high school, the team has gained a lot of knowledge and experience through involvement in the SeaPerch underwater robotics program. Participation has provided the opportunity to create, problem solve and compete at an international level, as well as network and be surrounded by many like-minded students, professionals, mentors, and supporters from across the country and around the world.

A particular challenge for the team this year was designing a vehicle that was equally adept at capturing both floating and sunken objects of various sizes and shapes. The team tested a number of concepts to find the most effective solution, and they aren't done yet. While the overall results are positive, they are not quite where they want to be with the vehicle's capabilities. What four years of competing has taught the team is that there is always room for improvement and more ideas, testing and redesign to be done.

The WW-03 replaces the heavier .01" diameter CAT6 cable with the much thinner .01" diameter Cat6A tether.

Going Forward

Looking ahead, the Wahoos plan to use the next few months leading up to the International SeaPerch Competition to continue to **explore new concepts and take new risks**. The plan is to take their project into the "Open Class" to allow the flexibility and resources to push ourselves and open up new options.

The WW-03 operates using a fully on-board power source.

WW-03 utilizes an stick-type controller

The team is currently competing with the WW-02 ROV. The goal for the next generation vehicle (WW-03) will be to minimize what is perceived as one of the greatest hindrances to the vehicle's handling and performance, the 50 foot CAT6 tether. The objective is to transition from pool side to onboard power. The practicality, both in terms of reliability and latency associated with the available frequencies, power consumption and likewise safety, has put realistic considerations for true wireless on pause.

This limitation however, still leaves much of the tethered inconvenience to be mitigated through other methods. Due to the advancement of battery technology, and the development of small, lightweight, and inexpensive motor and battery management systems available to the hobby and remote control community, expectations are for it to be possible to house the necessary equipment onboard the ROV. To optimally interact with these new electronics the original SeaSwitch controller will be replaced with an RC stick-type controller, giving it variable speed control.

The new onboard infrastructure will allow it to utilize a tether with constituent wires of much smaller gauge, without the need to transmit sufficient power to move the ROV (REDARC Electronics). The proposed slimmer and much lighter cable should provide a fundamental competitive advantage in handling and speed. This approach is not novel in the realm of industrial surveying ROVs, but is believed to be an under appreciated approach to lessening the supportive equipment to power and pilot these smaller systems.

STAY TUNED!

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Cooling off on a hot day at the pool.

6.0 ACKNOWLEDGEMENTS

The team would like to take this opportunity to acknowledge all of the support received this year.

First of all much appreciation needs to go out for **coach Jim**. This year was full of challenges that required a lot of planning and coordination for building and testing the ROV. Mr. Hughes made sure time was used wisely, especially pool practice time and meeting deadlines for regional competitions. Coach Jim also purchased a 3D printer and filament for the team, enabling the team to design and produce parts in-house.

Mr. Herren provided the team with much needed technical expertise. Mr. Herren built the 3D printer that was purchased and he is called on regularly to help troubleshoot during the learning process. He also served as a sounding board for bouncing off electrical and mechanical ideas and questions. Mr. Herren also provided CNC support to prepare carbon fiber frames. The team certainly would not have been able to accomplish as much as it has without his generous support and time.

The team would like to thank **Uncle Rick** for allowing use of his swimming pool to practice and test ROV concepts. There have been plenty of concepts and modifications to test and Mr. Hughes was kind enough to accommodate a schedule which included evenings and weekends. In exchange for using his pool, the team offered to do the pool cleaning throughout the season.

The team is continuously looking at new and different ways to meet the challenges. They are constantly researching different fabrication techniques and materials. The friends at **ACE Hardware** were an invaluable resource in helping find unique and specialized hardware, tools, materials as well as a source of basic knowledge and alternative or more cost effective methodologies to achieve the objectives.

The Wahoos are fortunate to have had the experience and knowledge of Richard Hughes (**Grandpa**) to turn to for the tough questions. Mr. Hughes is a retired electrical engineer who worked for the Naval Surface Warfare Center Carderock Division. Mr. Hughes' background includes computer design and electronic testing and support for submarine and hovercraft platforms, as well as the research and development of stealth propulsion operation for naval ships and submarines.

Of course the team owes a huge debt of gratitude to **Mrs. Lawless**, who was the team's robotics teacher and coach in 7th grade. Mrs. Lawless introduced the team to underwater robotics and led the team to its first national competition appearance at LSU. She had to leave the program the following year, but her confidence inspired the team to start their own team, and with the exception of the 2020 season, they have participated every year since.

To meet a challenging schedule and travel constraints this year, the team had to reach out to multiple SeaPerch organizers to find the best opportunity for the team. A broad reaching thank you is also extended out to all of the **Regional and National SeaPerch staff and volunteers** that answered all of the questions and helped to plan and prepare for competition. There are too many to mention, but each one deserves recognition.

Finally, the Wahoos would like to extend their appreciation to the staff at **Florida RC Outlet**, the local hobby shop. They helped out numerous times with tough questions, hard to find parts and last minute ideas to keep things going.

One page is not nearly enough to thank all of those who have supported and inspired the team over the years. Once again, acknowledgement goes out to all those who generously provided their much appreciated time, support and encouragement received this year. Waterway Wahoos couldn't have made it this far without all of you.

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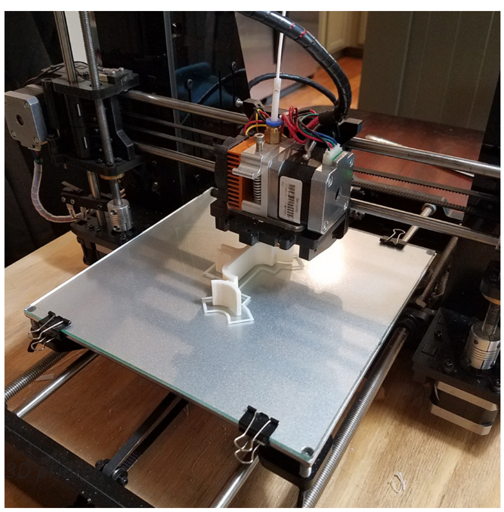
A APPENDIX A BUDGET

Materials included in the stock SeaPerch kit are not counted towards the budget and not shown in below. Material receipts for cost verification are available upon request.

DESCRIPTION	VENDOR	PURPOSE	QTY	UNIT	COST
Controller					
Signal Wire	Adafruit	Servo operation	60	feet	$2.00
Servo Tester	Hobby Lobby	Servo operation	1	ea	$3.99
Voltage Regulator 6.0V	Digikey	Servo operation	1	ea	$2.54
ROV					
Micro Servo	Hobby Lobby	Operable attachment	1	ea	$9.98
ABS 3D Print Filament	ebay	ROV frame	28	gram	$1.40
Speed Propeller (L & R)	ebay	Propulsion	2	ea	$1.24
Stainless Steel Screw 2-56	Ace Hardware	Parts assembly	16	ea	$1.28
Float (plastic tube)	Michaels	Buoyancy	2	ea	$0.30
4-40 Slip Proof Nut	RC Outlet	Propeller attachment	2	ea	$0.28
Female wire Connector	ebay	Battery connector	2	ea	$0.26

Note: All costs are shown in US dollars.

TOTAL COST OF 2021 ROV COMPONENTS $24.61



Some components or materials were purchased in larger quantities to reduce individual cost per item

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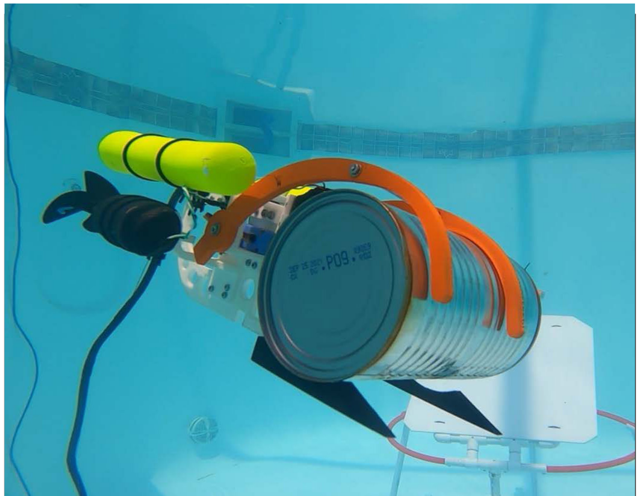
B APPENDIX B FACT SHEET

WATERWAY WAHOOS

Fleming Island, Florida US



HIGH SCHOOL CLASS

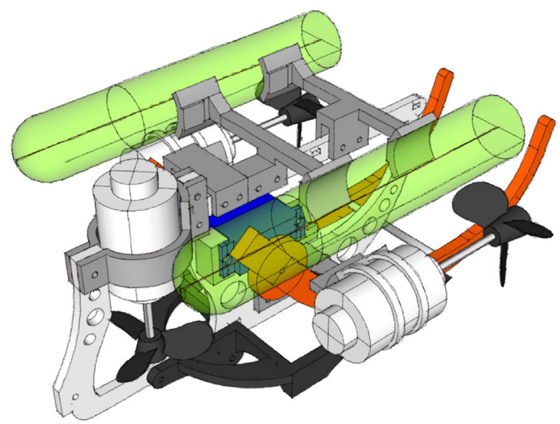
5 Years participating in SeaPerch

5 Times at the International SeaPerch Challenge

Our SeaPerch is unique because: (50 words MAX)

The Wahoo ROV (WW-03) incorporates a unique CNC cut carbon fiber body plate that is lightweight, strong, and reduces drag. 3D printed attachments support modularity and rigid construction for consistent performance characteristics. A retractable remotely operated attachment effectively collects, transports and deposits debris, while retracting 180 degrees for streamlined agility.

Our biggest takeaway this season is: (50 words MAX)



The biggest takeaway this past year has been learning to overcome adversity. The team focused on staying flexible, planning ahead and having contingency plans in place in case things went a little sideways. Detailed notes documenting the design process was instrumental in allowing the team to pick up where it left off.

SeaPerch Design Overview: (100 words MAX)

The Wahoo design is as complex as it is simple. The customizable frame builds off the success of the 2019 concept, with added agility and capability to manipulate both floating and sunken debris. It's compact size allows it to navigate tight spaces with ease and is made possible by it's rotating attachments which effectively reduce the overall length to just seven inches. Added versatility comes from remotely operable grasping arms that securely collect, retrieve and deposit objects. Other design achievements include a low profile, rigid planar frame, 3D ABS printed mounting brackets, adjustable tubular float system and repositionable motor mounts.