Warrenton Aquatic Robotics

Warrenton, Oregon

The Rays

Dwayne Wallace	CEO & Head Engineer
Adam Barbic	Graphic Design
Connor Moha	Marketing & Research
Jessica Newton	Marketing & Engineering

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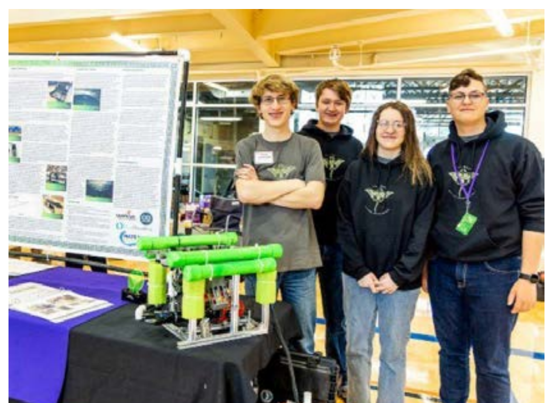
Abstract:

We are The Rays of Warrenton Aquatic Robotics (WAR), and our headquarters are in Warrenton, Oregon. This year, we fit higher-end parts on our all-new frame to ensure we can compete at a higher level of competition. Our team carefully researched and designed each part based on its price, performance, and versatility. An example of this would be our brand new claw, which solves our poor waterproofing and unreliability from last year and can improve our ability to perform underwater.

These improvements have allowed us to increase the effectiveness of our machines in the real world. Examples of these tasks would be, exploring an Antarctic shipwreck or fixing underwater cables that supply us with marine renewable energy. Overall, our company is committed to improving the machine every year to fix the global community's problems.

Warrenton Aquatic Robotics is a three-team company headquartered in Warrenton, Oregon associated with the Warrenton-Hammond School District. Our team is The Rays. We have four employees: Dwayne Wallace, a sophomore, our CEO/CTO, Electrical Design, and Software Development lead; Adam Barbic, a junior, is Co-lead with Dwayne on the Mechanical Design and lead of the Mechanical Assembly effort. He is also the corporate pizza demolition specialist, and Graphic Artist; Connor Moha, a sophomore, is head of Sales and Marketing, CFO, and worked on manipulator design studies; Jessica Newton, a sophomore, helps with writing and moral support.



Team Photo; Dwayne Wallace, Connor Moha, Jessica Newton, and Adam Barbic
Photo Credit; Heidi Lent

Team-Work:

With the small size of our team, along with the added level of competition, teamwork was a very important aspect of our company this year. The very first thing that we did at our meeting was decide what tasks we were to do throughout the year, as well as determine what roles we would have throughout the competition. These roles were agreed upon by everybody along with the dates of completion, leading to increased efficiency and teamwork on many projects.

Another thing that we do as a team is that we teach other groups. Whenever we were teaching the middle schoolers a lesson or guiding them with their machine, there was always more than one member of our team on-site ready to help out. This led to us having a very close team which increased communication and productivity, especially during the final month before the competition.

Scheduling

This year we have made a concerted effort to have, and stick to a schedule. Our goal this year was to have everything done promptly. This was crucial after our victory at regionals because suddenly, we had to make a technical document as well as mount a media effort and fundraising campaign.

For More information on the scheduling, refer to appendix D.

Resources

Our company learned to use many new resources during the development of our machine. One of the largest was the google suite, which allowed us to share, edit, and make documents with each other with ease. We also heavily used Discord, this helped us a lot with communication and working remotely. We were able to quickly contact and communicate with each other. This removed the problem of poor communication. Texting was another huge source of communication with our team, as it is small enough that all team members can be contacted over text, without the internet, very easily. All of these forms of communication led to us all being able to be contacted no matter what we were doing or where we were.

Design Rationale:

Engineering Design Rationale

The key to designing a vehicle is simplicity and size. The more simple the design the easier it is to troubleshoot and fix. The smaller the ROV the easier it is to launch, and maneuver in the water, and the tighter the spaces it can investigate. We designed our ROV by taking into account the problems we faced with last year's model. Last year we had many problems with our tether affecting the machine. The weight and stiffness limited the movement of the machine, not allowing us to function well. To combat this we have chosen to use fiber optic in our tether. Another problem was our clear acrylic tube kept cracking so we had to use a PVC tube. This year we chose to use a 3” aluminum black tube. This reduced the risk of failure yet eliminated the ability to see into the enclosure to quickly troubleshoot things like loose connections or water leakage. This tube allows us easy access to fix internal issues.

ROV with control system
Photo Credit: Dwayne Wallace

The ROV is designed to be very open. We used X-rail to simplify the structure as well as make it easier to attach our many innovative tools. The LED lights can easily attach anywhere on the ROV and be easily moved. There are 3 cameras on board as well. One camera is located inside the tube and has a 180’ field of view. The other 2 cameras are attached to the X-rail on the machine and can be quickly relocated at any time.

Innovation

Every year our company strives to be on the cutting edge of technology. This year is no exception. Working with fiber optics was a huge innovation this year. With the addition of fiber optic we were able to; decrease the weight of our tether, increase the functionality and effectiveness of our machine, and increase the simplicity of the machine all at a lower cost. Another example is our shrouds. Just by coming up with an updated design, we were able to increase the efficiency and the ease of repairability without increasing the cost or difficulty of manufacturing.

Shrouded Motor
Photo Credit: Dwayne Wallace

Problem Solving

Designing an entirely new ROV with innovative systems will inherently pose some difficult challenges. Our team was up to that challenge and succeeded through perseverance and hard work. There were many problems with the development of our machine. Some of the largest issues were in the development of our control system. Most of the problems were in the fiber optic and learning how to care for it. We had to replace our tether because we cracked the fiber line by bending it too tight. Some of the other problems were in the software, we tried three different methods of communication with our motor controllers. We finally settled on the packet serial approach, which provided superior performance and better control. The Sabertooth Packet Serial library didn't work as advertised and we had to research and experiment, even contacting the manufacturer to fix some of those problems.

Systems Approach

The functionality of the many systems on the machine is crucial to how successful our machine is in the water. A great example of how we are doing this is the fact that we made our machine modular this year. All of the systems can be replaced much easier so that we can make sure that all of the components of the machine are functional and working properly without having to take apart massive parts of the machine. We also installed all of the components to the frame with buoyancy and hydrodynamics in mind. This is why most of the weight is in the center, while lighter components such as lights, cameras, and motors are the only things on the sides of the robot. This leads to us having a cohesive machine where all of their components work in tandem with each other.

Vehicle Structure

There were many tradeoffs and decisions made in the development of our machine. One of the largest was the choice of motors. We had the choice of a stronger more powerful motor but it would pull more amps. This was a hard decision on what motors we would choose but we chose the less powerful, lower current draw motors for our machine.

Vehicle Systems

Cameras

We also redesigned the way we manufacture our cameras. We potted them with epoxy into a small acrylic tube to create a camera that we can put anywhere on the machine. This decreases our weight while allowing us to have the possibility of putting the cameras wherever we want. We installed three cameras on our machine; one positioned straight down on top of the claw to let us better see what we're grabbing, and the other looking straight up to help us navigate through the ice. The third is a dry camera

Size Comparison of the cameras
Photo Credit: Heidi Lent

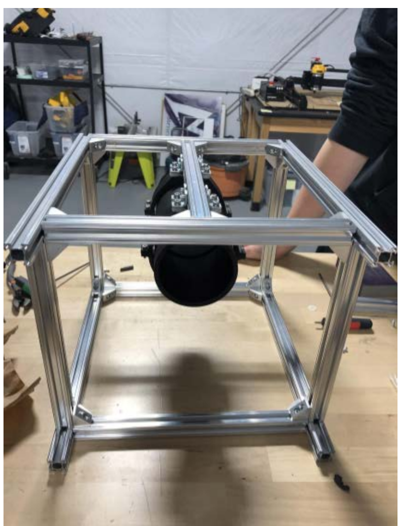
put inside our electronic canister allowing us to easily waterproof it and we can add a pan-tilt system in the future.

Lights

Waterproofing the lights
Photo Credit: Heidi Lent

We have designed a new lighting system for our machine, which replaces two 12v backup lights with four more reliable 3W cool white (6000K - 7000K) LED's encapsulated in epoxy resin. They are less expensive since 5 LED's only cost $8.95. The lights are more reliable with better waterproofing. The light from the LEDs is diffused, making the lighting more even and giving us better visibility. In the future, the intensity can be controlled by a pulse width modulated signal, allowing us to tailor the lighting for a variety of missions. The addition of lights allows us to see in the dark conditions of deep-sea exploration and under arctic ice.

Frame



Frame with aluminium tube
Photo Credit: Heidi Lent

We have designed our machine using an aluminum x-rail from Actobotics. This material was chosen because of its repairability and adaptability. In previous years we have used PVC or HDPE (high-density polyethylene). The problem with these materials is if adjustments need to be made you have to recut a new piece, which in the long run would cost more than the one-time purchase for the x-rails. Another pro of using the aluminum x-rail is the fact that with the way we have put our tether together, everything is very modular so we can take the same tether and motors and change the frame design for the client's specific needs. This year's machine is a little heavier than last year's machine even though it is smaller, this is partly because of the aluminum canister in the middle that waterproofs our electronics instead of an acrylic tube that continued to crack multiple times.

Control/Electrical System

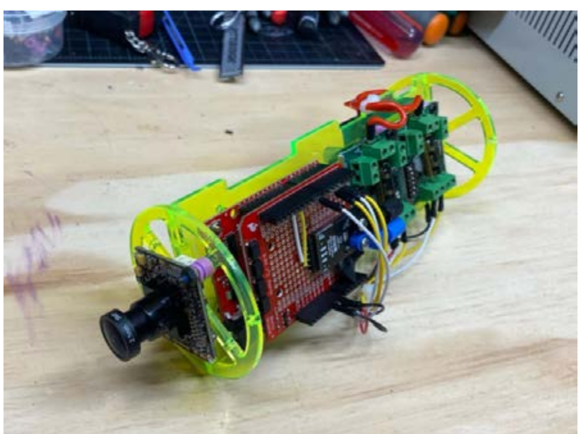
Control Box

Most of the controls and calculations are inside the control box. Two *Qwiic* Joysticks are connected via I2C to a Mega2560. The Mega reads the joysticks and maps them to usable values for our Electronic Speed Controllers (ESC). Once the values are ready, they are sent to our fiber emitter. The fiber emitter takes the serial commands from the Mega and turns them into modulated light. That light is then read by a fiber detector. The fiber detector takes that light signal and turns it back into an electrical signal. That electrical signal goes to a Sparkfun RedBoard and Arduino Uno. The Redboard and Mega2560 are talking to each other using the Serial Transfer library, which includes safety features like Cyclic Redundancy Checking (CRC), this checks for single-bit errors and testing for stale information packets.

Control box in action
Photo Credit: Dwayne Wallace

For our camera system, we're still using an analog system. Our two secondary cameras are hooked up to a single monitor that we switch inputs on depending on what camera we want to see. Our primary camera is hooked up to BOB-4. What BOB-4 does is give us an OSD overlay of whatever we want to put on there. In the future, we can take sensor data and put it on our display.

Enclosure



Finished Brain of Omicorvis
Photo Credit: Dwayne Wallace

Once the RedBoard receives the signal it relays those commands to all of our components. For ESCs we're using two Sabertooth 2x5 amp units in packet serial mode. Each Sabertooth is sent signals to be mixed for each of its two motors. One Sabertooth controls fore and aft thrust and turns left or right. The other Sabertooth controls a pair of vectored thrusters, which support vertical thrust, roll, and crabbing motions.

The claw is controlled with standard servo commands, which are available using the Arduino Servo library. 0 is set to full close and 180 is open, there are no in-between settings.

Tether

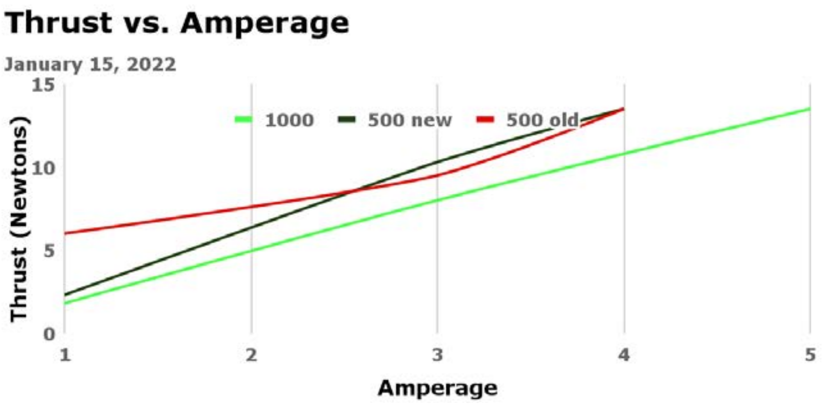
Our tether consists of a set of power lines, a fiber optic cable, and 3 coax cables. The power lines bring 12V power down to the machine which is then distributed and regulated inside the enclosure. The fiber optic line sends down the commands. The three coax lines are for our analog camera signals.

Propulsion

Our team has extensively tested different motors and shrouds to find the best-performing option. We tested a new bilge pump thruster from SeaMATE (500 Gph) to an aftermarket 1,000 Gph thruster. We placed the thrusters in a fish tank measuring thrust in Newtons using a Vernier wireless force sensor mounted to a custom-designed test rig. We then tested the motors at different Voltages while measuring the current draw. The conclusion that we came to is that if you graph force to Amperage, you see that they are very similar. This means that both motors produce the same force for the amperage but the 1,000 Gph thruster takes less voltage to do so. Because of the higher price and the higher current draw of the 1,000 Gph thruster, we decided not to use it. We designed a custom shroud for the SeaMATE thrusters to protect the users and the environment from the spinning propellers. Our company has designed a multipart shroud that is easier to manufacture and increases repairability.

Thrust Test in Progress
Photo Credit: Heidi Lent

Once we had chosen the thrusters that we would be using we started working on where we were going to put them. We settled with four motors because it would be easier to create a control system and we would end up pulling less current. Our Vertical/Crawl thrusters we have decided to vector and our Fore/Aft thrusters are running like tank tracks. Running it like this gives us four axes to move which is enough to do all the tasks needed.



Buoyancy and Ballast

It was extremely difficult this year to get the Buoyancy just right. We started by calculating the length of a 1½” PVC pipe to get our machine close to buoyant but still positive. We would then weigh and trim it via washers on the bottom. This lowers the center of gravity and raises the center of buoyancy to increase the stability of the machine.

We were off with our calculations and had to go back and increase the buoyancy. We added a second set of pipes hoping that that would help but it was still too negatively buoyant. At our regionals, we had to improvise and install pool noodles in a crunch. This was a bad idea because the pool noodles compressed at the depths of the competition which changes the buoyancy of the machine as we go up and down.

Three different tube materials
Photo Credit: Dwayne Wallace

We tested three different tube materials; PVC, CPVC, and ABS; to find the one that had the lowest density. We cut three identical tubes out of the three materials and then glued the caps on, to then test in the pool. We found that the ABS was by far the least dense material allowing us to make smaller tubes to get the same buoyant force. This saves us money by using less material.

Finally, we bought bigger 3” ABS tubes to then use. We finally got it positively buoyant and therefore ballast it properly to get a more stable and usable machine. However, 2-3” tubes provided way too much buoyancy so we reduced it to one 3” tube centered on the machine. This too caused other issues. Our upward-facing camera and LED lights were blocked. Finally, we calculated the water weight of the final machine and recalculated the 2” tube weight and volume displacement to come up with a length that is perfect for our ROV. This was a very tricky task.

Payload and Tools

On our machine, we have three cameras, one of the cameras is placed inside our canister. It's a Lowlight 1080p Analog camera. We chose it for its clarity but mainly for its low-light qualities. For the other two cameras, we have potted backup cameras in epoxy resin to waterproof them. We chose the backup cameras because of their small size and ease of manufacturing. Together the cameras give us wide ranges of view that allow us to easily perform the tasks.

For our claw, we bought a BlueRobotics Newton Subsea Gripper. The gripper was easy to implement into our design and use with our machine. Plus all the claw specifications fit the tasks we needed to do perfectly. Another bonus that the gripper had was that it had a force limiting system that prevented it from squeezing some of the objects too hard.


BlueRobotics Newton Subsea Gripper
Photo Credit: Dwayne Wallace

Build vs. Buy

This year we have purchased our Blue Robotics Newton Subsea Gripper to use on the number of machines in our fleet. We chose to buy this component since it would take too much time to research and design an effective claw. Instead, we needed the time to learn about fiber optics. We chose it because of its compatibility with our canister and extensive waterproofing. The claw allows us to carefully interact with the objects underwater and make repairs if needed. Most importantly we will use this claw on our BlueROV2 to do community outreach projects. This helped us easily justify the decision.

New vs. Used

Our goal this year was to use as many used parts as possible to lower the cost. We reused our control box container and a lot of our small parts and tools. Doing this has decreased the cost of the machine by ~$300. All of this comes at a cost though, the more used parts you add the less reliable your machine becomes. We tried to balance this by buying a new claw and by installing new motors.

Safety:

Our company's highest priority is safety. Everything we do on the machine or deck is always with safety in mind. This year we have taken many safety precautions on the machine, on deck, and even in the attire that we wear while competing.

The clothing that we wear on deck consists of a neon-green construction vest, and always some form of a hard hat no matter what role we serve there. The hard hats will prevent anybody from hitting their head and offers overall protection from the various things that could happen on a deck. The safety vests let us stick out allowing each of the team members to be seen with just a moment's glance.

The whole team in their safety gear
Photo credit: Heidi Lent

Our ROV complies with, and exceeds, all safety standards of MATE. For safety checklists, refer to appendix E.

Critical Analysis:

Our company has created many tests for the development of our machine. Most noticeable of which is the thruster test. We tested different motors old and new to find the amount of thrust they put out at certain voltages. With the same apparatus, we tested all of our shroud prototypes and in total, we went through 5 prototypes to find the best solution for us.

Camera Tests
Photo Credit: Heidi Lent

We also tested different visual qualities of different cameras. We tested different low-light cameras by seeing how tight of lines we can see and the color accuracy with and without light. We also tested different backup cameras to use as secondary cameras. We tested LED lights in the same way.

With our buoyancy, we tested different plastics to use as our buoyancy tubes. We tried PVC, CPVC, and ABS. we found that ABS was the least dense so it would produce the most buoyant force per length. We have also used many different diameters of pipes to determine the best size of tube to buoyancy our machine with.

Our company developed a unique ballast system for our machine. The system consists of 4 bolts attached to the bottom X-rails where washers can be added or removed easily. The washers are secured with a wing nut. The goal is to get it positively buoyant and weigh it down with some washers. What this does is gives us finer control on how buoyant the machine is and be able to easily balance the front to the back, etc.

Accounting:

This year we have tried our best to build a budget-friendly machine. Our control system was built around simplicity. Doing this has made it very cost-effective making the whole control box come to ~$500.

What took the largest chunk out of our budget was the claw that we purchased. We spent ~$450 hoping that the claw will be used on many machines and be used far into the future.

For more details on the budgeting, refer to appendix B and C.

Acknowledgments:

Craig Battles, mega mentor in action
Photo Credit: Heidi Lent

We want to give a huge thanks to our coach, Heidi Lent, for money, food, supplies, knowledge, and vast amounts of time and supervision; Craig Battles, a retired Boeing Physicist and Robotics engineer for his time, tools, money, demonstrations, and priceless knowledge and advice to continue with this competition; Dusty Wallace for various supplies, food, rides, in pool helper, and overall support for all teams that take part in this company; Saysha Breitmeyer for refining our logos and helping with the graphic design and merchandise; Warrenton Middle and High School for providing workspaces for our company to create ROVs and for letting us use their resources; Sea MATE for continuing to hold this competition and providing us with knowledge about ROVs; Josh Jannusch for writing grants, and for buying the Blue Robotics ROV for us to put together and use; Lincoln City Community Center for holding the event on their campus; The Columbia River Maritime Museum for allowing us to use their pool to conduct tests on our frames; Astoria Aquatics Center for allowing us to test our machine in their pool, Northwest STEM Hub for funding a grant to help build our frame; LBCC for hosting World Championships; and lastly Arduino and Sparkfun for open source software and helpful community resources.

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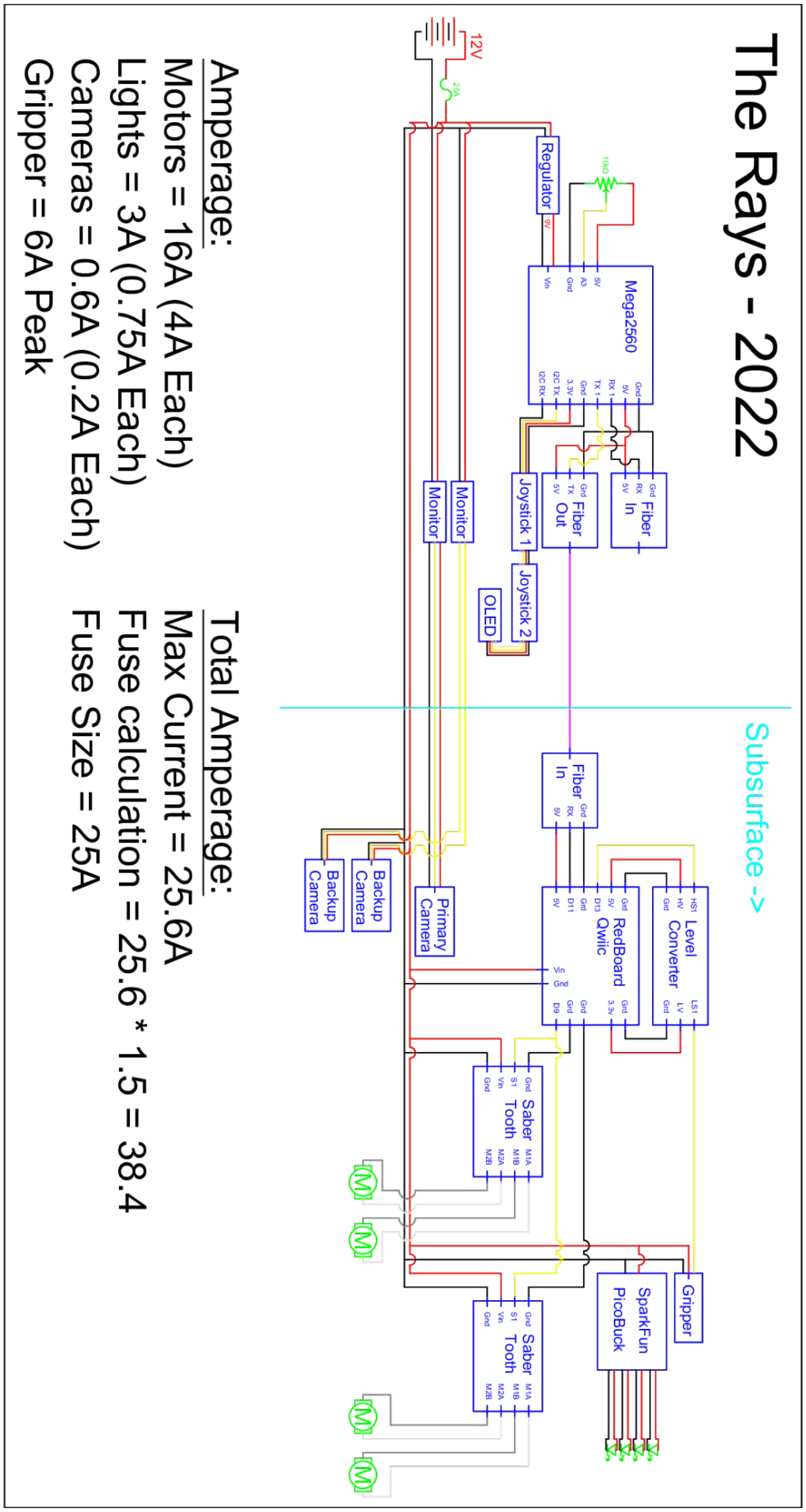
Appendices

Appendix A:



Appendix B:

ROV Budget

Category	Part	Amount	Retailer	Cost (each)	Cost (total)	Links
Frame	0.84 inch bore clamping mount	4	Servo City	$5.99	$23.96	https://www.servocity.co
Actobotics	X-Rail T-Bracket	3	Servo City	$1.99	$5.97	https://www.servocity.co
	3/8 inch by 3/8 inch 90 degree X-Rail Gusset	14	Servo City	$3.99	$55.86	https://www.servocity.co
	1x1 X-Rail Nut	5	Servo City	$9.99	$49.95	https://www.servocity.co
	6-32 Steel Socket Head screw 1/4 inch	5	Servo City	$1.89	$9.45	https://www.servocity.co
	1x2 Hole Pattern Plate	2	Servo City	$1.99	$3.98	https://www.servocity.co
	13.5 inch X-Rail	4	Servo City	$5.71	$22.84	https://www.servocity.co
	10.5 inch X-Rail	6	Servo City	$5.16	$30.96	https://www.servocity.co
$231.29	9 inch X-Rail	6	Servo City	$4.72	$28.32	https://www.servocity.co
Propulsion	Three Motor Kit (500gpm)	2	SeaMATE	$99.99	$199.98	https://seamate.org/produ
$319.96	SaberTooth 2x5	2	Dimension Engineering	$59.99	$119.98	https://www.dimensioner
Control Box	3" Series Watertight Enclosure	1	BlueRobotics	$180.00	$180.00	https://bluerobotics.com/s
	3" Enclosure Clamp	2	BlueRobotics	$40.00	$80.00	https://bluerobotics.com/s
	SparkFun RedBoard Qwiic	1	SparkFun	$21.50	$21.50	https://www.sparkfun.co
	SparkFun SAMD51	1	SparkFun	$21.50	$21.50	SparkFun Thing Plus - SA
	SparkFun Qwiic Shield	1	SparkFun	$7.50	$7.50	SparkFun Qwiic Shield fo
	SparkFun Solder-able Breadboard	1	SparkFun	$5.50	$5.50	SparkFun Solder-able Br
	BOB-4 OSD	1	Decade Engineering	$99.00	$99.00	BOB-4H (decade-engine
	BOB-4 OSD SIS	1	Decade Engineering	$50.00	$50.00	SIS (decade-engineering.
	Voltage Regulators	1	Amazon	$10.99	$10.99	Amazon.com: Valefod 6 P
	SparkFun Qwiic Joystick	2	SparkFun	$11.50	$23.00	SparkFun Qwiic Joystick -
	OLED graphic display	1	Ardufruit	$19.95	$19.95	Monochrome 1.3 128x64
$547.94	Control Box	1	Home Depot	$29.00	$29.00	
Cameras	RAAYOO Reverse Backup Camera	2	Amazon	$22.49	$45.98	https://www.amazon.com
	BlueRobotics Analog Camera	1	BlueRobotics	$29.99	$29.99	
$155.95	TFT Color Monitor	2	Amazon	$39.99	$79.98	https://www.amazon.com
Lights	3W LED (Cool White)	2	SparkFun	$8.90	$17.90	https://www.sparkfun.co
$52.90	PicoBuck LED Driver	2	SparkFun	$17.50	$35.00	https://www.sparkfun.co
Tools	Newton Subsea Gripper	1	BlueRobotics	$435.00	$435.00	https://bluerobotics.com/s
Tether	25 meters Fibre Optic Cable	25	Sure Controls	$1.95	$48.75	
	Power Cable	25	NAPA Autos	$0.50	$12.50	

Total Cost	Each	Total
Used (Everything)	$1,254.17	$1,804.29
Reused (Amount Saved)	$169.96	$310.93

Key
Reused

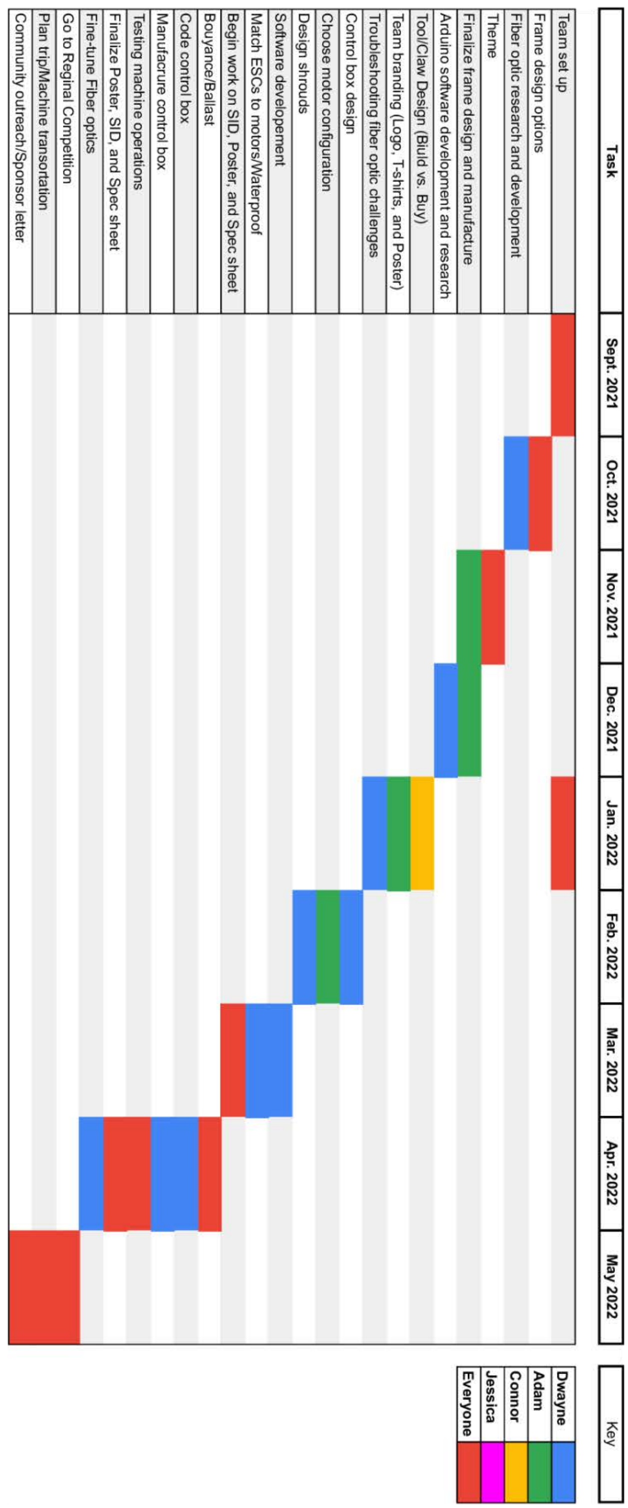
Appendix C:

Project Costing

Category	Description	Cost
Food	Snacks and meals throughout the year	$500.00
Miscellaneous	Unexpected expenses or random purchases	$250.00
Frame	X-rail and Actobotics	$500.00
Propulsion	Motors and Shrouds	$350.00
Cameras	Waterproofing cameras and the cameras themselves	$200.00
Tether	Fibre optics and the cover for the tether	$100.00
Claw	Fix old claw issues, maybe new claw	$250.00
Control Box	New control box from scratch	$500.00
Lights	Find a good light solution	$50.00
Reused	Parts from last year	$300
		$2,700

Appendix D:

Schedule



Appendix E:

SAFETY CHECKLISTS

Physical safety checklist

- All propellers are completely shrouded.
- All hazardous materials are identified and covered.
- All items are securely attached to the ROV.
- Proper waterproof o-rings and penetrates are in place on the electronic canister.
- All electrical components are within a water-tight enclosure.

Electrical safety checklist

- All wires are attached and waterproofed with no exposed wires.
- Tether has strain relief at the machine and control box.
- Motors were sealed after purchase.
- No exposed wires anywhere in the system.
- All penetrators are sealed with marine-grade sealant.

Control Box system safety checklist

- Safety Sheet inside the control box to remind the pilot to check that the vent penetrator is in place before launch.
- Anderson power plugs are used for electrical connections.
- Attached to a single power source.
- Fuse within 30cm of the power supply.
- Electrical systems are covered.
- Proper strain relief at the control box.