Crubotics ROV Division

Pensacola Catholic High School
Pensacola, Florida, USA

2022 MATE ROV Technical Documentation

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Grant Robertson	Lead Modeler
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Abstract

The Catholic High Crubotics Team is composed of 14 members that specialize in programming, piloting, building, and marketing. The ROV Division focuses their talents on designing and operating Remotely Operated Vehicles for the MATE ROV competition.

For this year's competition, the Crubotics team created A.R.R.E (Automated Repair Reconnaissance Explorer) to help solve the problems of ocean cleanup and underwater investigation. The A.R.R.E has a system of 6 thrusters that allow for omnidirectional movement. The frame of A.R.R.E. was built using PVC pipes in the shape of a rectangular prism. A.R.R.E also includes two claws: one static claw and one hydraulic claw which works through the use of a syringe-based pump.

A.R.R.E uses one forward-facing camera for navigation and one downward angled camera for viewing the ocean floor. Lasers are used to complete the various tasks during the competition and are able to gauge the size of an object in water.

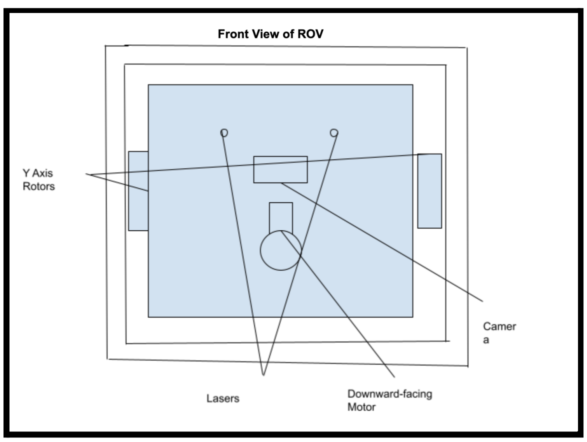
Figure 1. The image above is a group photo of the Crubotics ROV Division.

Design Rationale

The Design Process:

The initial part of the designing process required research and sketching from all members of the ROV team. Programmers, builders, designers, and documenters were all required to look at the MATE specifications for an ROV and create their own original designs. After a week passed, the designs were presented to the other club members. The design that best fit the budget, time frame, and size requirements was chosen.

The design that the Crubotics ROV team chose had a rectangular prism frame, six motors, two cameras, and two lasers. Before the building process began, 2D sketches of the ROV were made. The sketches presented show what the original design for the ROV's front and side views were going to look like (Figure 2). Shortly after the sketch was made, the design team created a 3D version of the ROV using Tinkercad. After the 3D model was created and the building team had something to base the ROV on, construction of A.R.R.E. (Automated Repair Reconnaissance Explorer) began.



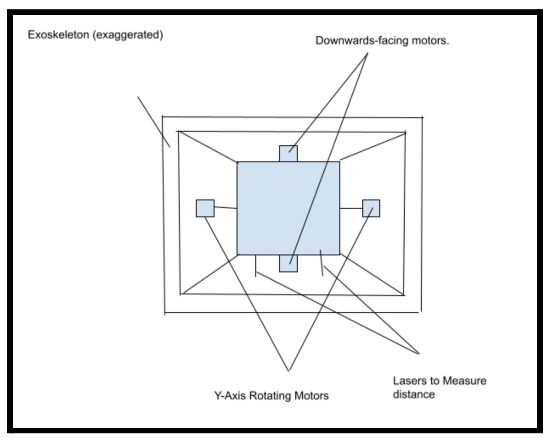
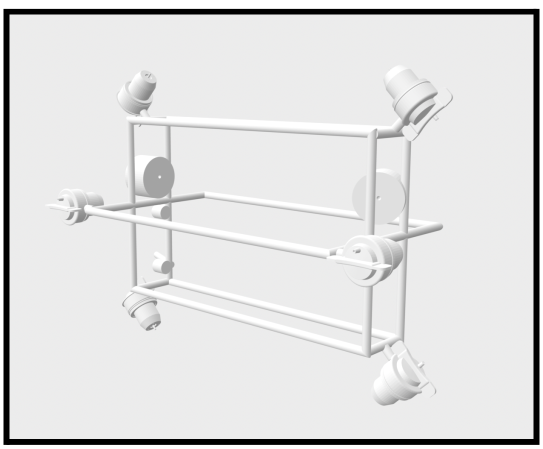


Figure 2. The images above show the initial 2D sketches for the ROV. The sketches include a front view and side view that show the original plans for the six motors, two cameras, and two laser systems.

A.R.R.E Revision Two

After completion of the MATE regionals the team decided to switch to a more octagonal design after thoroughly testing the ROV. This led to a design similar to the first iteration but with an octagonal, rather than rectangular, outer frame. While the basic shape of the ROV has changed, most of the basic features are still incorporated smoothly into this new design. The team changed to an octagonal frame to fit the thrusters on the inside of the frame for improved safety (Figure 4). The octagon shape was chosen because it would still allow the thrusters to be mounted at 45 degree angles the same way they were mounted with the rectangular prism design (Figure 3).

For the second version of A.R.R.E. the design of the thruster shrouds were changed. The original thruster shrouds weren't as structurally sound, broke easily, and weren't as safe . The new thrusters are thicker and have thinner slits in them, and this smaller size prevents someone from sticking a finger near the thruster and sustaining an injury (Figure 5). The end of the thrusters have an attachment that resembles a waffle grid, and it is also included for user safety and safety of props in the environment.



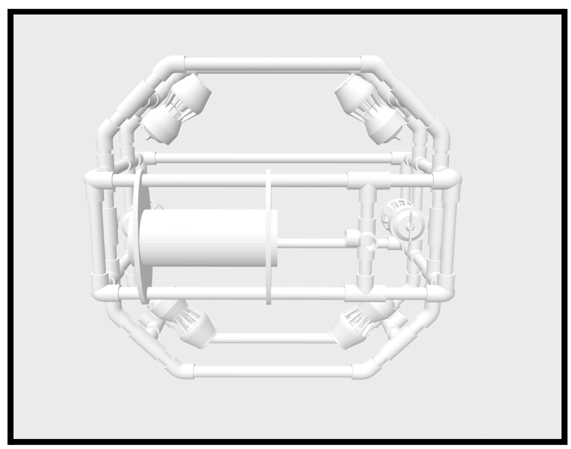


Figure 3 (LEFT). This is a 3D modeled version of A.R.R.E. version 1 that shows the 45° angled thrusters and original rectangular prism design.

Figure 4 (RIGHT) . This is a 3D model of the second iteration of A.R.R.E. with the octagonal PVC frame and inner tube for waterproofing wires.

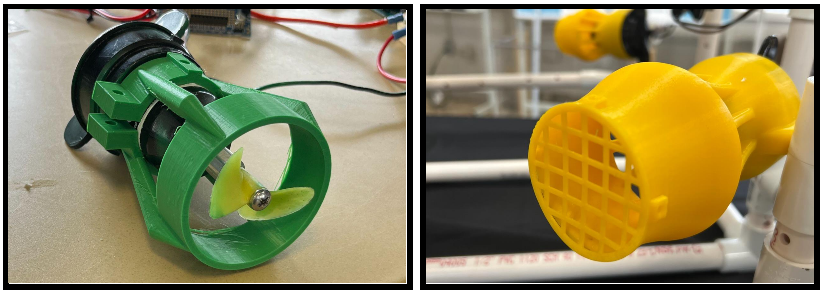


Figure 5. The following two images compare the prop guards used for A.R.R.E v1 (left) and A.R.R.E v2 (right). The new design is thicker, rounder, has a waffle safety mesh, and bars that are closer together to prevent injuries.

Core System and the Frame:

As mentioned above, the design team initially decided on a rectangular prism frame for A.R.R.E and then opted for the Octogonal design. This shape was chosen because it would protect the internal wirings and electronics of the ROV if A.R.R.E. hit the sides or the bottoms of the task pool. The chosen material for the frame was a 12.70 mm outside-diameter PVC pipe. PVC was chosen over alternative materials like aluminum because of PVC's lighter weight and structural integrity.

There are six total thrusters on A.R.R.E., with four thrusters on the inside of the octagonal frame and two on the upper parts of the frame near the protective wiring tube. This configuration was chosen to maximize movement in multiple directions. The thrusters on the four inside corners of the octagon allow for lateral movement, diagonal movement, and strafing. The thrusters are positioned at 45-degree angles from the PVC attachments to minimize prop wash from the thruster force. The other two thrusters are used for elevational movement (Figure 4). These two thrusters will be responsible for lowering A.R.R.E. to the depths of the ocean floor and all the way back up to the surface. The thrusters have a length of 13.5mm and a diameter of 6.5mm.

Also attached to the mainframe of the ROV are two cameras. The cameras are 85mm long, 3.75mm in diameter, and the monitors for viewing the camera input are 180mm wide. The specific camera model being used is the Eyoyo Fish Camera which allows for underwater use. One of the cameras on the ROV is facing the forward direction to view the ROV's direct surroundings, aid the driver in directing A.R.R.E.'s motion, and to direct the lasers that are also attached to the mainframe. The lasers are used to gauge the ROV's relative distance from other objects in the testing pool. The bottom camera on the ROV is used to view the "ocean floor." This camera is placed at a 25-degree angle from the PVC attachment. Along with gauging seafloor surroundings, these bottom cameras are going to be used to aid with docking the ROV and watching the altitude of the ROV as it travels through the pool. The wirings on A.R.R.E. are secured inside a tube on the top of the frame to keep the wires away from water.

Marketable Features and their Benefits:

The position of the thrusters and the protections placed on the thrusters themselves make them an efficient and environmentally safe option. The four thrusters on the outer four corners of A.R.R.E. are placed at a 45-degree angle, which minimizes prop wash as much as possible. By minimizing the prop wash from the thrusters, A.R.R.E. runs a much lower risk of disturbing wildlife in the environments in which A.R.R.E. operates. Forward and backward movement would minimize the disruption of the water's current.

Additionally, the thrusters are protected with a 3D printed shroud that acts as a safety measure for both the ROV itself and objects within its operating environment (Figure 5, right). The first function of the shroud is to protect the thrusters from any net entanglement that might come from any nets present in the underwater environment. This makes A.R.R.E. optimal for use in fishing and environmental cleanups in places near offshore wind farms or tidal force farms. These protections allow for A.R.R.E. to remove debris that would otherwise be damaging.

Another external feature of the ROV is the tether management system that is used to manage communication between A.R.R.E. and the controller. One challenge that comes with creating an ROV is creating something that can operate over long distances. The tether helps to communicate information from the laser systems and the cameras to the drivers that are controlling the robot from a distant location. This tether houses the electrical power and can break away if necessary. Tether management also includes a relief system that is on A.R.R.E. that prevents the tether from being disconnected from the ROV during demonstrations (Figure 7).

Figure 7. The image above shows the relief system for A.R.R.E.'s tether. This relief prevents the tether disconnecting from the ROV.

To complete retrieval and reconnaissance tasks, A.R.R.E has a dual claw system attached to the PVC mainframe. One claw is a static claw with hooked teeth that can latch onto different items in the pool area. The second claw is a hydraulic claw that can open and close through the use of a syringe pump system. Water is inside the pump system to regulate the claw movement. This hydraulic pump system will be controlled in the control box, and a long tube allows for the syringe's effects to reach the claw even from long distances.

Safety Features of A.R.R.E:

The Crubotics team has implemented many safety features into the body and components of A.R.R.E. As mentioned above, a prop shroud is being used to protect the propellers from net entanglement. The internal camera allows for the controller to view the inside of the ROV to ensure that internal components are intact. Foreign components from the PVC frame have been removed to reduce the risk of the frame introducing unsafe elements into the ocean. A.R.R.E.'s control box and electronics have also been waterproofed to avoid damaging the electronics. Wiring in the control box has quick disconnects in between the controls and the thrusters so that power can be disconnected in case of emergency. There is also a killswitch to the power supply in case of internal damage.
Another safety measure that the team has taken to ensure the safe use of A.R.R.E. is the setup of the fuse. To prevent the ROV from overheating, the fuse is placed 15cm away from the battery terminal (Figure 8). All electronics have been deemed safe by the team safety officer.

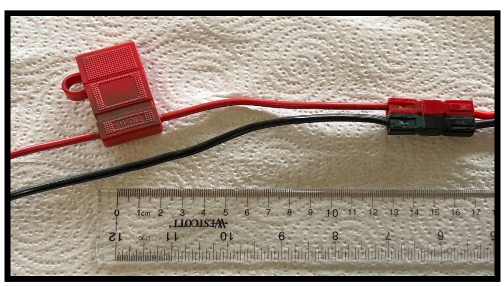


Figure 8. The image above shows the short 15cm distance between the fuse and the battery terminal that prevents the ROV from overheating during the competition. Also shown are the Anderson Pole connections to the terminal.

Vehicle Structure:

A.R.R.E. weighs a total of 7.05kg and the ROV's dimensions are 580mm x 582.5mm x 375mm. A.R.R.E. required a total of 68 student hours to build, and the estimated cost excluding reused items is $476.39.

Vehicle Systems:

The different features of the ROV were selected to carry out the MATE ROV competition tasks more efficiently. For the first task of replacing an underwater cable, A.R.R.E. has a hydraulic claw that can open and close to accommodate for the thickness of the power cable. The claw can open and close by the use of a water fueled syringe pump system. To determine the broken cable, which is marked by the brown spot), the dual camera system on A.R.R.E. can locate the spot from multiple angles. The lasers on the sides of A.R.R.E. can also help the drivers visualize the distance between the ROV and the cable. The six thrusters on A.R.R.E. will also allow for the drivers to turn the failed buoyancy module 180 degrees. The different thrusters allow for omnidirectional movement to make this possible (see Appendix B.) To assist with docking, the multiple cameras and protective rectangular prism can make this operation safe and more efficient.

For the second task of aquaculture inspection, A.R.R.E. uses some of the same features that were required for completion of task one. To inspect the netting of the pen, identify holes in the net, and scout for morts, A.R.R.E. uses two underwater Eyoyo cameras with two separate monitors the drivers can see. Algal growths can be removed with both the hydraulic claw and the static claw with hooked teeth. Measuring the size of the fish can be used with the dual laser system.

To create a photomosaic, the Eyoyo underwater fishing camera will be used. The controllers will be able to piece together the photomosaic remotely using input from both of the camera feeds. The Crubotics team has also crafted a GO-BCG float that will be able to conduct diagnostics while the robot is performing tasks one and two. The float has a buoyancy bladder that uses water to control the buoyancy. The float is also able to move up and down at specific time intervals using code input from Arduino.

Propulsion:

The thrusters that are used for A.R.R.E.'s movement are the Johnson-pump 500 GPH Motor Model 2855. These motors have a length of 13.5mm and a diameter of 6.5mm. A.R.R.E. utilizes 6 thrusters. 4 of the 6 thrusters are used to direct the horizontal motion of the ROV and allow for strafing. The other 2 thrusters are used for vertical motion.

Payload and Tools:

A.R.R.E. uses two cameras to monitor the ROV's surroundings. The Crubotics team uses the Eyoyo Fish Camera that has a length of 85mm and a diameter of 3.75mm. One camera is forward-facing in order to view what is in front of the ROV, direct the ROV motion, and direct the lasers to measure objects. One camera is angled downward on the bottom of the PVC frame to view the "ocean floor" and help with docking. The downward camera is also able to monitor the altitude of the ROV and see if the robot is getting too close to the ocean floor.

Buoyancy and Ballast:

To control the buoyancy of A.R.R.E., pool noodles are placed on the outer rectangle of the PVC frame. Pool noodles were chosen to follow the MATE rule that states that there can only be a set amount of contained air on the ROV. Pool noodles were the buoyancy module of choice because they can be easily cut and manipulated to change the way the ROV sits on top of the water. The pool noodles on the ROV are not a standardized size, and placement all depends on the weight distribution of the ROV.

For the Go-BCG float, this buoyancy engine is going to be housed via a custom built deploy module inside the mainframe of A.R.R.E. The module is going to traverse different water columns in the ocean to monitor temperatures and contaminants. The buoyancy engine uses 8 12ml syringes that are moved up and down via a motor and screw system. Upward motion of the motor pours liquid out of the syringes and pulls the float upwards. Water is pushed out of the syringes into an outside bladder to control buoyancy.

Electrical System

SID Diagrams:

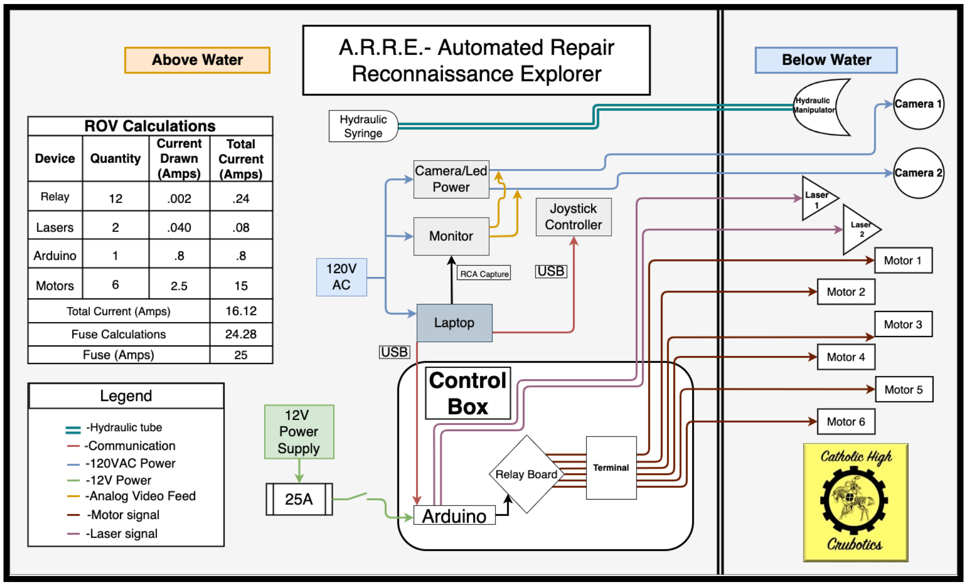


Figure 9. The image above is a SID diagram for A.R.R.E. which includes calculations for total current, overcurrent protection, and fuse calculations in amps.

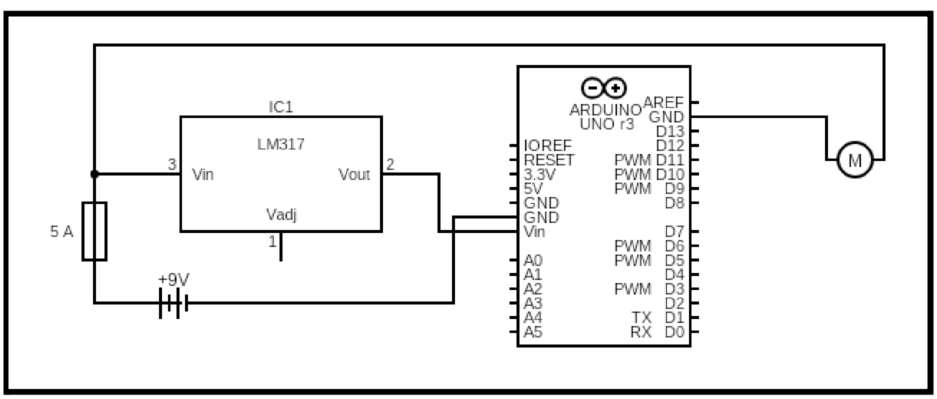


Figure 10. The image above is a SID diagram for the GO-BCG float that is to be used for task 3.

Safety Rationale

All members of the Crubotics team were required to take a safety quiz, regardless of whether their job required use of shop machinery. The safety quiz went over procedures on what safety equipment to use in different situations, the appropriate attire to wear in the shop, and how to handle accidents like electrical fires or minor cuts. Along with the safety quiz, all members must have their parents sign a safety agreement that acknowledges Pensacola Catholic High School's lab rules. While shop tools are used, protective safety glasses are used, and oftentimes, members will use headphones to protect their ears from machinery noises. When team members are testing the lasers, protective glasses and a safety shield are used to prevent eye damage.

Testing and Troubleshooting

The Crubotics team followed the engineering process when it came to creating and testing A.R.R.E. for the competition. The engineering process includes forming ideas, implementing the ideas, and testing them. Testing for the ROVs happened with every department, from testing the code, testing the wire safety, testing the GO-BCG float, and testing the movement of the ROV's thrusters. Code testing happened throughout the preparation time for the competition. Code was tested through the arduino, and a lot of time went into tweaking communications between the controller and the ROV mainframe. The GO-BCG float was tested for its buoyancy, efficiency of the syringe-pump system, and its timing intervals that were made possible through code. The mainframe of the ROV endured a lot of testing as well. The size of the frame was constantly adjusted, pool noodles were added and moved around to allow for buoyancy, and the position of the motors was determined through trial and error. Whenever the team came into a problem, the strategy was to identify one cause of the error at a time and brainstorm an alternative solution.

Project Management

Company Overview:

The 2021-2022 Crubotics team is composed of 14 student team members which includes 3 freshmen, 2 sophomores, 8 juniors, and 1 senior. 13 of the team members are male and 1 team member is female. The team met 2-3 times a week with meeting times lasting from 30 minutes to 1 hour and 30 minutes. The team's main objective for the 2021-2022 season was to build a functional ROV and compete in the MATE ROV Competition.

Schedule and Planning:

At the beginning of the building period, the Crubotics team met together and discussed a progress timeline that would be followed until the competition date. A copy of the schedule was presented at the first meeting. Additional meetings were planned to get the company back on schedule. The Crubotics team met biweekly on Tuesdays and Thursdays. As the timeline advanced, the team started meeting weekly.

Team Organization:

As the team members specialized, a leadership structure emerged. The CEO of our company had the most experience on the ROV team and was actively involved in multiple areas of A.R.R.E.'s production. Our team CFO was in charge of managing the budget and keeping track of expenses. Within different departments, leaders emerged and these leaders helped delegate work with other department members and their assistants.

Job Title and Name	Description of the Job
CEO - Kush Wells	Kush oversaw all of the different departments of the ROV division. Executive decisions, including structural, electrical, and mechanical decisions were made by him.
CFO - Logan O'Hanlon	Logan was in charge of managing the budgetary expenses for the company. He also documented all of the different parts used for the ROV and documented if parts were reused or bought.
Head of Media - Maggie Johnson	Maggie was responsible for technical documentation and the marketing presentations for the Crubotics team. She worked with other department members to compile all information necessary for the engineering report.
Team Electrician - Tyler Ruble	As team electrician, Tyler was responsible for ensuring that all wires were waterproof. Tyler was responsible for wires in the control box and wires that feed input from cameras and lasers to the monitors that the

	drivers see.
Programmers - Quentin Wright, Porter Hanley, Alex Che, and Luke Junck	The programmers were responsible for connecting the controlling device to the different thrusters on the ROV. Raspberry pi and arduino helped label commands and control the ROV's range of motion.
Safety Officer - Gavin Strickland	As safety officer, Gavin was responsible for providing documentation on the different safety features of A.R.R.E. and any safety measures the team took when creating the ROV. Gavin is also responsible for the safety checklists that are filled out before the competition.
Float Engineer - Brandon Hoppe	Brandon was responsible for the building and engineering of the GO-BCG float which is to be used for task 3. Brandon helped build the float, engineer the buoyancy bladder system, and work with programmers to get the timing of the movement correct.
Prop Builder - Finley Holmes	Finley was responsible for building any of the props that the team needed for the competition, including props to use in pool tests.
Lead Modeler - Grant Robertson	As the lead modeler for the team, Grant made different sketches of the ROV using 2D and 3D applications. Grant created the 3D imaging of the ROV using Fusion360.
Designers and Builders - Aloysius London and Luke Foster	The designers and builders were responsible for the physical construction of the ROV. These team members cut PVC pipes and pool noodles and attached the thrusters and cameras to the frame.

Accounting

Budget:

The team CFO, Logan O'Hanlon created the budget. The budget accounted for how much money could go into purchasing each component of the ROV needed. To prevent unnecessary spending, parts that could be reused were listed. The budget stayed within the sponsorship income of $16,300.

	Amount	Type	Price	Est. Price
Adafruit Motor Shield V2	1	Purchased	$19.95	$20.00
Aluminum Heat Sink 10 pack	1	Purchased	$4.95	$10.00
arduino Nano 22 BLE	1	Purchased	$22.50	$30.00
Lasers	2	Purchased	$9.49	$18.98
T100Thrusters	6	Purchased	$45	$270
Thermal Tape	1	Purchased	$5.99	$6.00
zipties	1 pack of 100	Purchased	$5.99	$6.00
Arduino Uno R3	1	Reused	$21.58	$20.00
cameras	2	Reused	Reused	
Claw material (Hyrdrolics)	1	Reused	Reused	
electrical wire (?gauge)		Reused	Reused	
epoxy		Reused	$9.76	$10.00
Logitech F310	1	Donated	$16.69	$20.00
Power Supply (Cen-Tech)	1	Reused	$45	$45
propellers	6	Reused	Reused	
PVC Pipe		Reused	Reused	$8.69/In
raspberry pi 3 Model B	1	Reused	$35.00	$35.00
Registration			$200	
Travel: Regional Competition			$300	
Travel: World Championships			$17,605	
INCOME: SPONSORSHIP FUNDING			$18,400	

Figure 11. The image above shows the team budget which was created by the CFO. The budget includes expenses that the team could use towards different components of the ROV. Reused items and donated items were also listed to prevent unnecessary spending.

Build vs Buy and Old vs Used:

The parts that were reused included the Arduino Uno R3, Eyoyo fish cameras, claw materials, electrical wire, epoxy, power supply, thrusters, Raspberry pi 3 Model B, and PVC pipes. These components were taken from last year's ROV, Echo. A logitech F310 was donated from a team member and is one of the controlling devices for the ROV. Everything else, like the motor shield, heat sink packs, thermal tape, etc., were used to accommodate for new design principles that team members introduced for this year's ROV.

Acknowledgements

A.R.R.E.'s development was supported by a number of sponsors for the Crubotics ROV Division. Mentors for the 2021-2022 Robotics season were Mrs. Dana Lupton and Mrs. Andrea Whitson. Sponsors for the 2022 world championships include Catalyst Fishing, Wetland Sciences, Dauphin Island Sea Lab, Raxis, Zoo Fan Photography, Harry and Bella Play, The O'Hanlon Family, The Marshall Family, The Young Family, The Smith Family, and the Pensacola Catholic High School Robotics Department. Thanks to the generosity of the sponsors listed above, the Crubotics team received $18,400 in sponsorship money.

Appendices

Appendix A: Company Schedule

Start Date	Target Date	Activities
Oct 14	Nov 18	Team sign-up and Initial Meeting
Nov 29	Dec 10	Safety training · Mechanical/tools · Electrical
Dec 13	Jan 4	EXAMS and Winter Break
Jan 5	Jan 21	Theme Orientation Brainstorming
Jan 25	Feb 28	Build · 3D Modeling · Frame · Control Box · Wiring
Mar 1	April 4	Video Processing & Programming · Design · Implementation · Test/troubleshoot Marketing Poster/presentation
April 5	April 27	Testing, Troubleshooting & Training · Buoyancy and Motors · Camera Feed · Programming · Pilot and Co-Pilot tryouts Marketing Poster/Presentation
April 29	May 1	**Regional Competition**
May 2	May 6	DeBrief and Redesign

May 9	May 23	Acquire Supplies & Rebuild
May 24	May 27	EXAMS
May 30	Jun 16	Testing, Troubleshooting & Training · Buoyancy and Motors · Camera Feed · Programming
June 21	June 25	**World Championship – Long Beach, CA**

Appendix B: Photographs of ROV

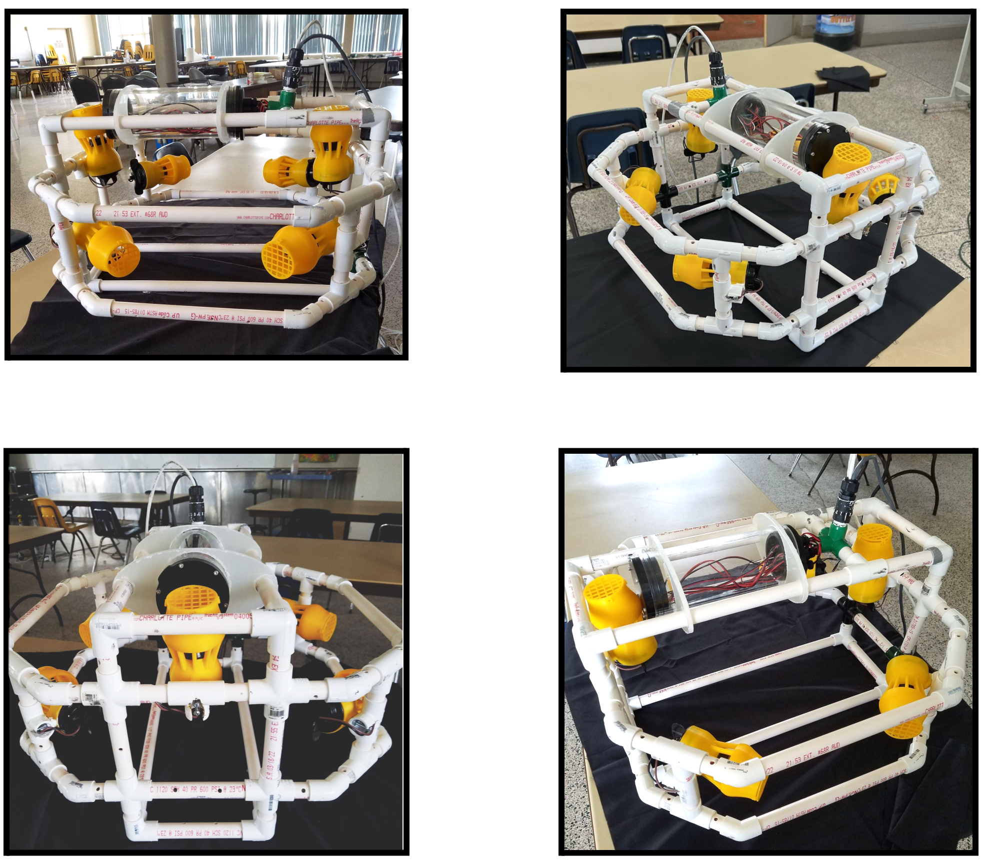


Figure 13. These are photographs of A.R.R.E. showing the completed octagonal frame, thrusters, relief system, and waterproof wiring tube.