Aquabot Technicians

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Diego Gonzalez: Chief Operating Officer & Tether Specialist
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<u>2022 MATE ROV Competition</u>
Aquabot Technicians
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Corpus Christi, Texas, USA

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Abstract

Our company, Aquabot Technicians, consists of five student employees and two interns all working toward the goal of creating the best ROV possible. This year, our company worked together to create *TR2-Seahorse*, which we will be using for the 2022 MATE ROV Competition. It is the result of hours upon hours of research and software testing. We have constructed and designed *TR2-Seahorse* to be nimble, strong, flexible, and aesthetically pleasing. Its two cameras, one digital and one analog, allow us to see the environment around it underwater, helping us to perform inspections of offshore wind turbines and aquaculture fish pens, as well as find and map the location of the *Endurance*. Its claw allows it to perform maintenance and repair tasks on offshore wind turbines and aquaculture fish pens. Its thrusters allow it to efficiently navigate through the water. We are confident that *TR2-Seahorse* will be capable of facing and completing the challenges posed by this year's competition.

Company Sustainability

Although our company has managed to be successful, it does have challenges that will need to be confronted in the future. Most of our current employees are Seniors and will be graduating from our school and leaving our company after this year. Only one of our company's current employees will be employed next year, meaning Aquabot Technicians will have to find a way to attract more students to the Underwater Robotics program. Without new members, the company will be unable to survive. A step that the company has recently taken toward sustainability is the adoption of internships for Freshmen. The purpose of these internships is to allow Freshmen to become familiar with the Underwater Robotics program prior to them becoming Sophomores, which gives them robotics experience and hopefully encourages them to continue with the program. Aquabot Technicians currently has two spring interns and five more interns lined up for the summer. Both spring interns have prior experience in Underwater Robotics from middle school. One of our spring interns, Christian Estrada, was given the position of co-pilot due to his prior experience in piloting during middle school for the Scout competition and piloted for the company during the 2022 MATE Regional Competition. Below is an image of the company's employees and interns competing in the 2022 MATE Regional Competition:

Figure 1: Company's Employees and Interns

Production

Project Management

Aquabot Technicians is a company that consists of brilliant high school students looking forward to becoming diligent engineers. Unfortunately, the team this year had taken a drastic hit from seniors graduating from the previous year. The classroom was once full and now it consists of merely eight people. However, we are even more dedicated and driven to make this year our best year. Even though our team is stretched thin, we keep up with our assigned tasks based on our skills and specialties.

Engineering Design Rationale

When our team first began production of our ROV in fall of 2021, the 2022 MATE ROV Ranger Competition Manual had not been released. We looked to our predecessors' designs for inspiration and planned to adjust once we knew the constraints set by the manual. We set out to create a frame design which improved upon the design of *TR1-Poseidon*. We created several cardboard prototype designs, one of which is shown in **Figure 2.**

Figure 2: Cardboard Prototype

This prototype frame helped us to realize a mistake that we had been making: the inclusion of sharp edges. Sharp edges are a safety hazard, and so we redesigned our frame to include only smooth edges. Once we were satisfied, we created a CAD drawing of our design on a program called Inventor, which we then uploaded to V-Carve, a program which programs cutting paths for CNC machines. Our plan was to transfer the V-Carve file to our CNC machine, the ShopBot, and then create a prototype using plywood. However, this plan proved to be very difficult, as the ShopBot was at first very hard for us to navigate. Our company had never operated the ShopBot before. The manual which we had for the ShopBot was not even connected to the model which we owned, and so we had to learn via the internet and a process of trial and error. Eventually, we were able to create a plywood prototype of our frame using the ShopBot, shown in **Figure 3**.

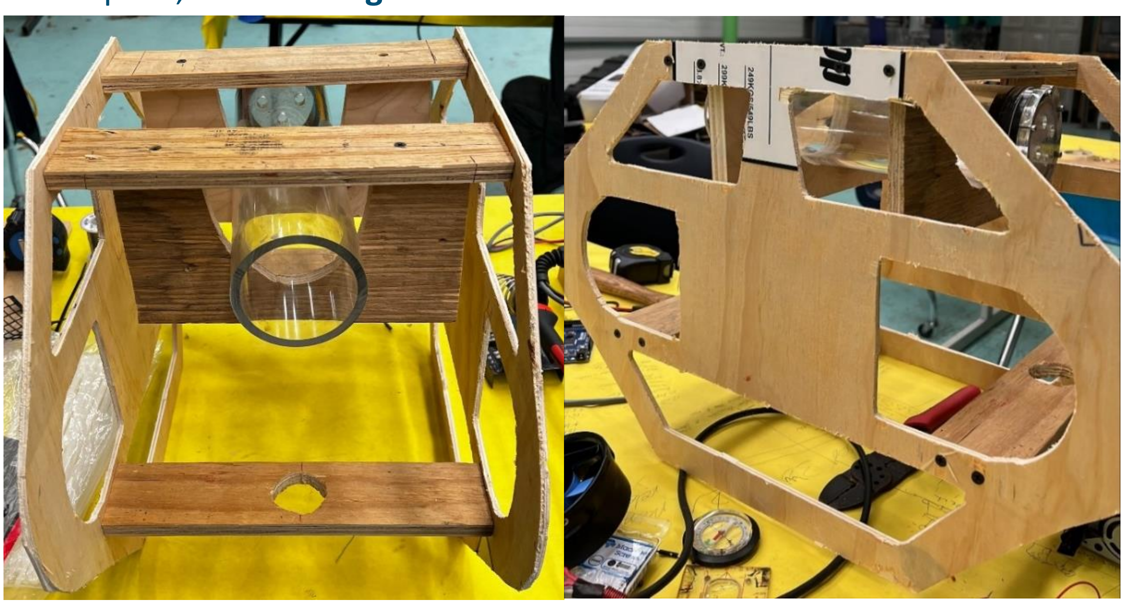


Figure 3: Final Wood Prototype

Once we accomplished this, we moved on to creating a prototype of our frame using Lexan plastic, which went on to be the final frame we would take with us to our 2022 MATE ROV Regional Competition.

Figure 4: CNC Machine cutting out the ROV's frame

Another challenging aspect of designing *TR2-Seahorse* was figuring out how to set up the control system. At first, we planned to make use of an Arduino microcontroller. Several weeks were spent trying to incorporate it into our system. Eventually, however, we decided to instead use a Fathom X in place of the Arduino. Once the manual was released, our company began to meet every day after school from 16:30 to 17:30 in order to complete our ROV. We also met on Saturdays from 9:00 to 14:00. Both during and outside of class time, our company amassed a total of 770 man-hours before our regional competition. The Gantt chart below portrays what exactly the company was working on throughout the year.

Gantt Chart

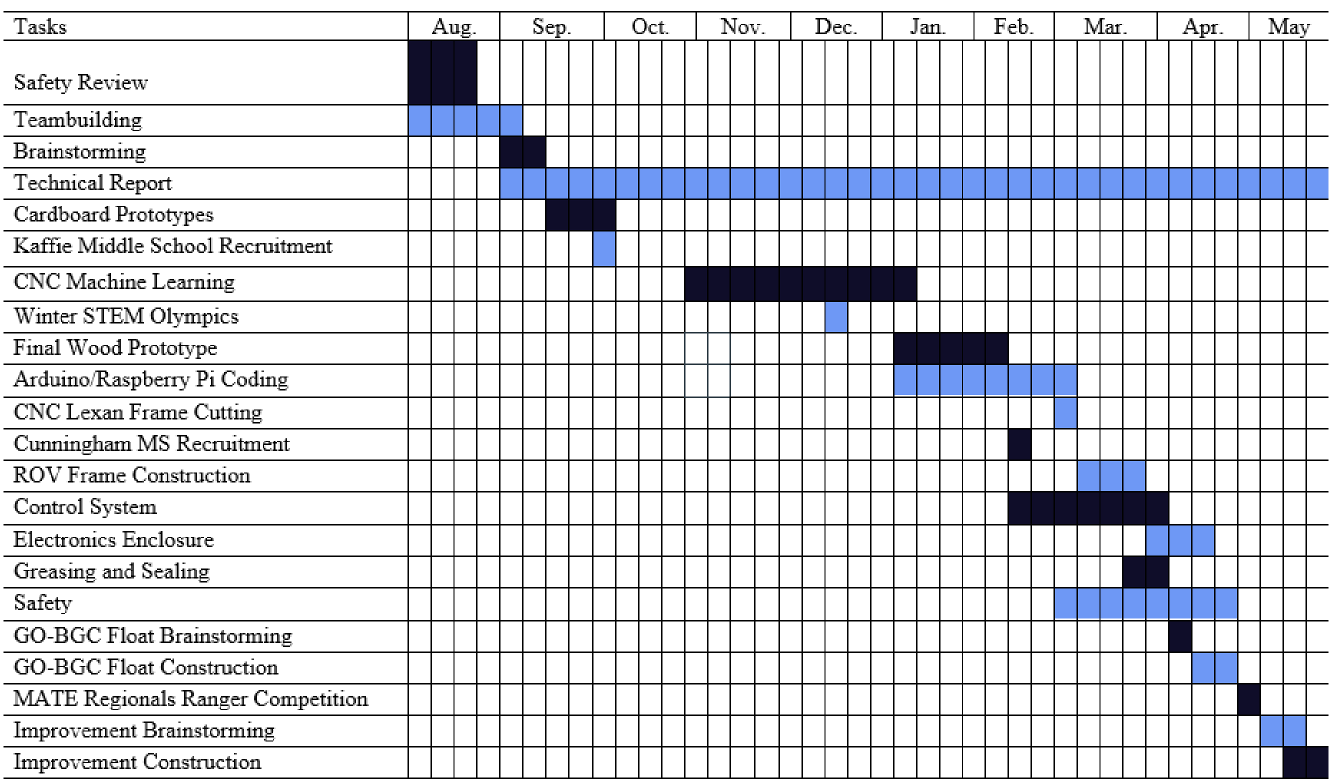


Figure 5: Timeline

Problem Solving

An abundant number of problems occurred while working on this year's ROV. In fact, there were too many to count on two hands. The reason being that at the start of the company's journey, there were big dreams and goals. However, they were too big for the company to handle due to the lack of employees. Despite this challenge, the company implemented ways to properly deal with these problems.

When a problem occurred, the first plan of action was to properly identify what exactly the problem was. For instance, while a group was working on coding an Arduino to control the thrusters, the code would not compile. The first question asked was, "Why?" Then a list would be constructed of all the objects that could be causing the problems, such as the thrusters being burnt out, the Arduino board being fried, a line in the code was wrong, etc. Then the troubleshooting process would begin, and solutions are tested until the working result is shown.

Innovation

We have integrated many unique innovations into our TR2-SEAHORSE. For instance, we used Lexan plastic for the frame compared to last year's Plexiglas. Although Lexan costs more than Plexiglas, it makes up in strength. Lexan plastic is 250 times stronger than Plexiglas. Lexan is also less rigid than Plexiglas, which means that Lexan does not crack or break upon drilling, and it is easily bendable. In addition, it is just as light as Plexiglas. As a result, the robot can move swiftly in the water. Moreover, the ShopBot was a great tool for the company to create a versatile design. Once the team learned how to properly utilize the ShopBot, it was easy to cut the Lexan plastic into the wanted shape. It also only took about ten minutes for the entire frame to be cut out from the ShopBot.

The control system was also encased in a 4.5-inch diameter clear tube that would serve as a waterproof casing for the electronics. An implementation of plastic mesh was also put above the thrusters so that fishes do not mess with the thrusters. An attempt was made to 3D print a mesh design and place it onto the TR2-SEAHORSE above the thrusters, but it could not be done as the team could not figure out what was wrong with the program, and it was taking too much time.

Design Rationale

The photo below shows our ROV, *TR2-Seahorse*, as it appeared prior to our regional competition:

Figure 6: TR2-Seahorse

Vehicle Systems

Frame

Our frame is made from Lexan plastic. We used this material because it is flexible and lightweight, allowing for swift ROV motion in the water. It has no sharp edges. The four holes in its sides allow for easy access to the thrusters and facilitate the flow of water. A rubber door guard with internal aluminum shells covers our Lexan plastic frame to create a smooth surface.

Figure 7: Completed Frame-photo by Jaziel Gonzalez

Thrusters

We used four T100 Thrusters to serve as our motors. The thrusters are vital to traverse the TR2-Seahorse throughout the water and complete all the mission requirements. The company deemed the T100 Thrusters as the best thrusters for this mission. The thrusters are extremely cost-efficient with only being $100 and having 5 lbs. of thrust. A power supply box gives the thrusters 12 V of DC power. The thrusters are also lightweight and compact, making it easy to mount them upon the TR2-Seahorse. The company adjusted them so that one side goes clockwise and the other goes counterclockwise, which ensures steady and accurate movement. The orientation of the thrusters can be seen in **Figure 8**. There are two thrusters facing upwards on top of the ROV and two other thrusters facing forwards on the inside of the ROV.

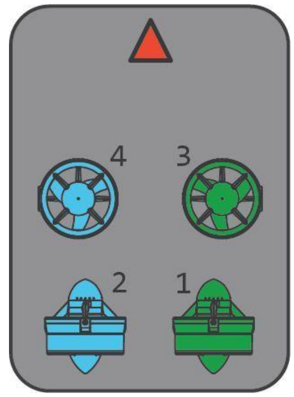


Figure 8: Thruster Orientation

Figure 9 : T100 Thruster-photo from Blue Robotics

Claw

This year, the company reused a previously burnt-out Blue Robotics claw dubbed the Newton Subsea Gripper (AKA: Pincer). Through some research, the company bought a new motor for the claw from Amazon for restoration. According to BlueRobotics, the Pincer can open as wide as 62 mm, and the prongs have aluminum screws that are corrosion resistant and lubricated. The Pincer also holds 18 volts, which allows the motor inside the claw more protection from the motor burning out.

Figure 10: Newton Sea Gripper-photo from Blue Robotics

Cameras

We made use of a Low-Light HD USB camera, which is inserted into a waterproof cylindrical case. Its high-quality digital HS-5055MG tilting servo allows the camera to tilt up and down. We placed it directly above the claw so that the team can precisely execute any tasks that involve the claw. A photo of our digital camera, from the Blue Robotics website, is shown below:

Figure 11: Low-Light HD USB camera-photo from Blue Robotics

We also made use of an analog car-reverse camera, which is placed facing downward. This allows us to see objects, such as the *Endurance* shipwreck, below the ROV.

Figure 12: Analog Camera-photo by Daniel Cantu

Control System

The surface section of our control system is encased in a yellow control box, as shown in **Figure 12**, and includes a Fathom-X (**Figure 13**), Pixhawk (**Figure 15**), and Raspberry Pi **(Figure 16)**. Our thrusters and digital camera are maneuvered using a Logitech Gamepad F310 (**Figure 14**). Signal travels from the controller to the Fathom X, which sends and receives signal from the Pixhawk and Raspberry Pi. The Pixhawk controls our thrusters (it is essentially an underwater drone system) and the Raspberry Pi controls our digital camera.

Figure 13:Control Box-photo by Araceli Orozco

Figure 14:Fathom X-photo from Aquabots

Figure 15: Logitech Controller-photo from Amazon

Figure 16: Pixhawk-photo from BlueRobotics

Figure 17:Raspberry Pi-photo from RaspberryPi.com

Electronics Enclosure

We used a Blue Robotics ROV Watertight Enclosure (4” Series) and Blue Robotics Electronics Tray (4” Series) to hold all the wiring for our thrusters, claw, and cameras. The size of the electronics tray increased this year because of our utilization of the Fathom X and Pixhawk. We fit the power, ground, and thruster wires through the back holes of the capsule into a 12-meter tether. The team then filled the back holes of the capsule with a 24-hour cure epoxy to guarantee maximum security against water. The clear capsule allows us to easily observe any problems with the wiring inside and to detect any leaks. **Figure 17** portrays the watertight enclosure (left) and our electronics tray (right).

Figure 18: Electronics Enclosure and Electronics Tray-photo from BlueRobotics

Tether

The tether is specially designed for deep-sea exploration. It is naturally buoyant and has a high breaking point (160kg). It is very light, containing only four wires. The tether is roughly 12 meters to provide plenty of room for maneuvering. When the ROV is not in use, the tether is neatly coiled around a blue pedestal as shown in **Figure 19**.

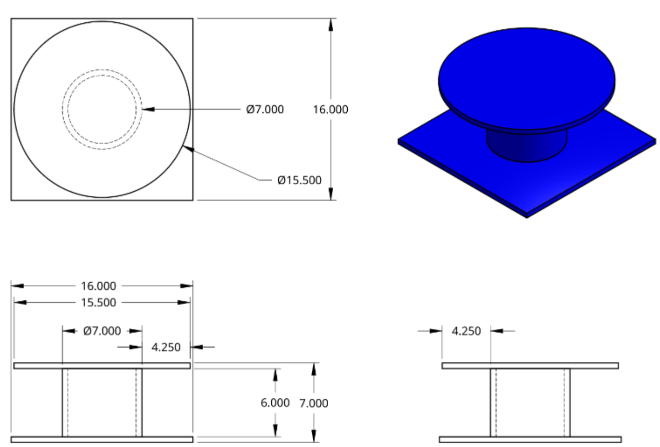


Figure 19: ROV Stand Orthographic Drawing

Buoyancy and Ballast

To calculate the buoyancy of the *TR2-Seahorse*, the company used Archimedes' Principle. Archimedes' Principles states that when an object is submerged in fluid, there is an upward force acting upon the object, called the buoyancy force that equals the weight of the displaced fluid. The company calculated the buoyancy force by submerging the ROV into a full bucket of water and catching the displaced water with two other buckets placed on the side (Refer to **Figure 18**). The company then poured the water that was displaced into a beaker and observed the weight of the water. The calculations are shown in **Table 1**.

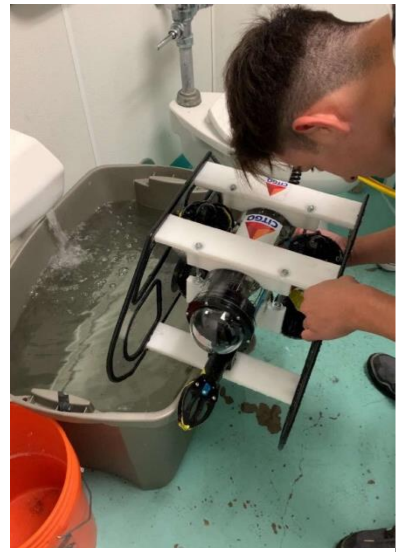


Figure 20: Setup of measuring the buoyancy- photo by Jaziel Gonzalez

Table 1: Buoyancy Calculation

Weight of the beaker	Weight of the displaced water + the beaker	Beaker weight – the weight of the beaker with the displaced water	Buoyancy Force
0.29 kg	1.205 kg	0.915 kg	**0.915 kg**

Build vs. Buy

As seen within the expense report, many parts of the *TR2-Seahorse* have been purchased in the pursuit of an effective ROV. With having an effective ROV as our main objective, many parts were bought from reputable companies such as Blue Robotics. Buying trustworthy materials allowed the team to be confident in the building process of the ROV. Throughout the building process, it was made clear that the option to buy parts and pre coded programs were available. To truly understand every concept within the competition, building and programming it on our own was crucial.

New vs. Used

Although the ROV does use multiple new parts, many re-used parts were included onto the ROV. Due to the COVID-19 pandemic many parts that were purchased last year went unused and our sister company, Gulf Coast Robotics, had extra electronics that turned out to be extremely helpful. For instance, the company utilized a control system purchased last year. However, this control system is now discontinued on the BlueRobotics website. Since the re-used parts are crucial to the ROV, buying new parts made the ROV become effective. These new and reliable parts, such as cameras and enclosures, has given the *TR2-Seahorse* the ability to complete all tasks without worry.

Non-ROV Device

Along with the TR2-Seahorse, Aquabot Technicians developed a GO-BGC Profiling Float. The company named the device, "La Anguila." **Figure 19** portrays an open tube design that houses the electronics sealed enclosure, thruster motor, and ballast. An SPST toggle switch activates a timer relay countdown for 60 seconds. When the countdown is complete, the timer relay closes the normally open switch and activates the Bilge pump motor cartridge thruster for 20 seconds. The thruster motor will draw water from the lower end of the AFD and push water through the top and side holes, descending the AFD to the pool's floor. The thruster motor then deactivates in 20 seconds and the AFD will ascend due to its positive buoyancy to the pool's surface.

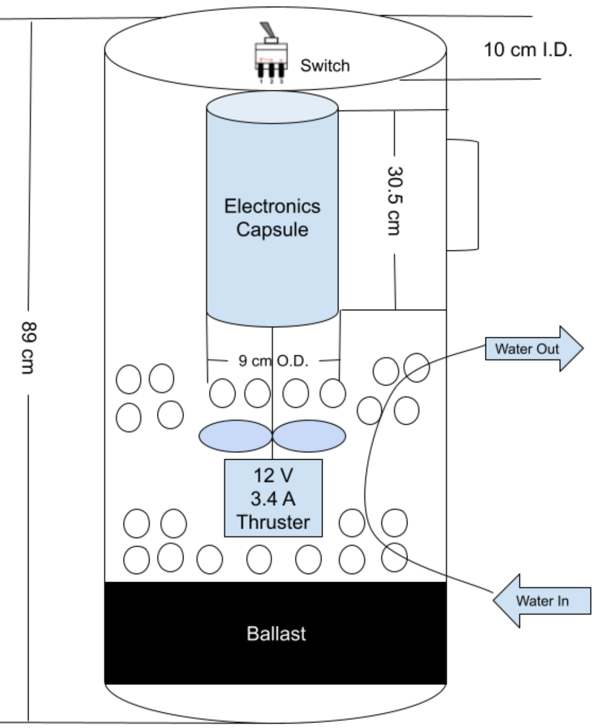


Figure 21: Diagram of GO-BGC Float

After 20 seconds, the timer relay reactivates the thruster motor for 60 seconds, descending the AFD to the floor of the pool. After the 60 seconds, the timer relay will deactivate the thruster motor, allowing the AFD to ascend to the pool's surface.

Figure 22: GO-BGC Float

Adjustments

Our experience at our regional competition helped us realize that we had to make several changes to our ROV if we were to be successful. In our first round at the competition, we realized that the bottom of our frame was preventing us from picking objects off the ocean floor, and so we had to remove it (**Figure 21**). After we removed it (and developed a much more efficient flight plan), we were able to score much higher than we had before. However, we were unable to come up with a method to determine the average size and biomass of the fish in the aquaculture fish pen (part of Task 2). After we came back from the regional competition, we realized that we could implement a laser for accurate and precise measurements of marine life. We chose the SB10 Sea Beam Underwater Laser because of its small size, easy attachment, waterproof nature, DC power, and brightness. **Figure 18** portrays a labeled image of the laser. We also decided to add an extra T100 Thruster to help our ROV sway from side to side.

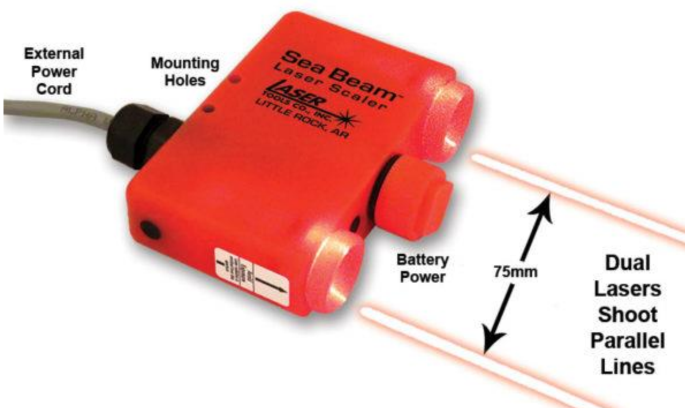
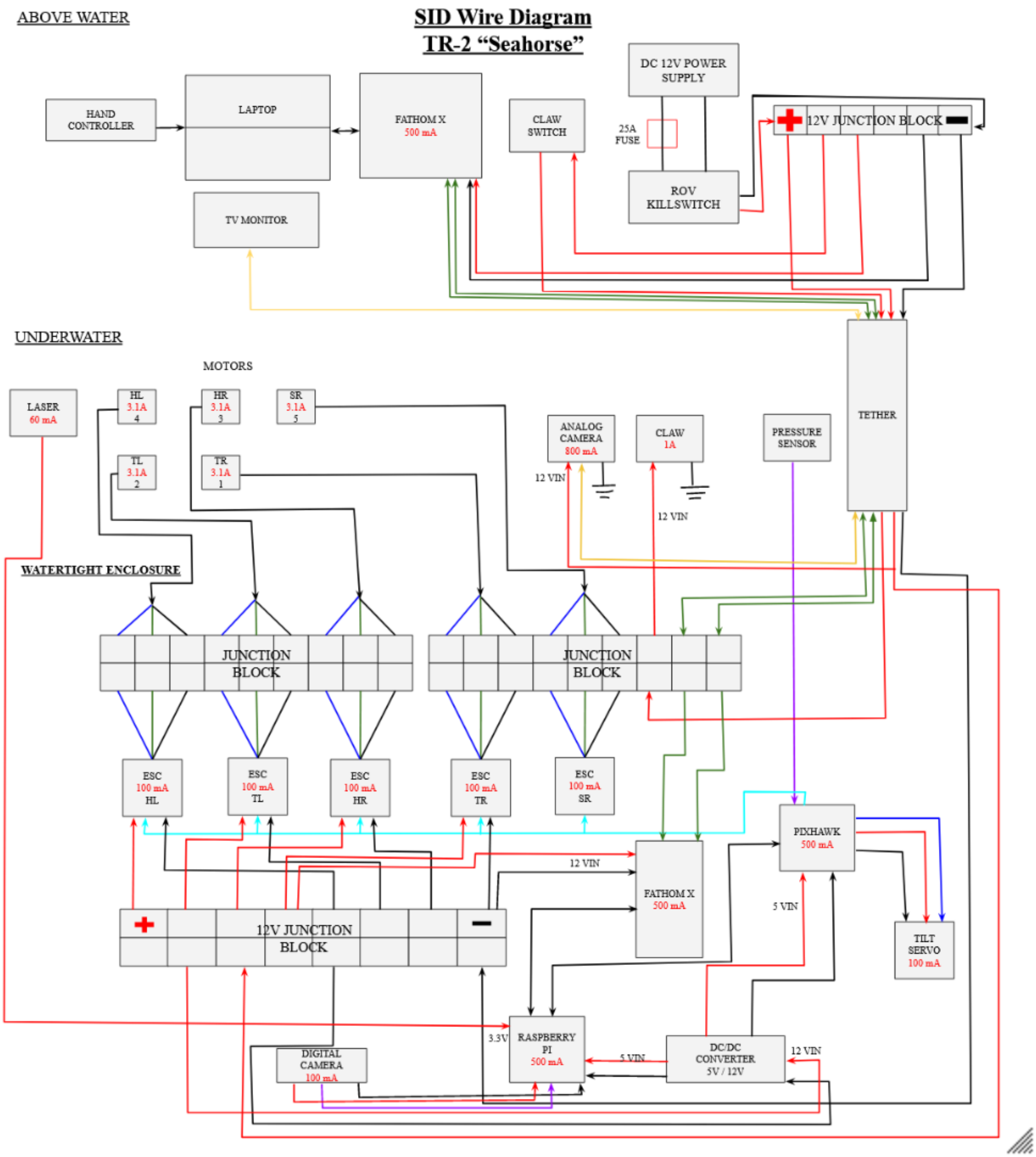


Figure 23: Sea Beam Laser™-photo from Laser Tools Co., Inc.

Figure 24: TR2 Seahorse after the Regionals Competition

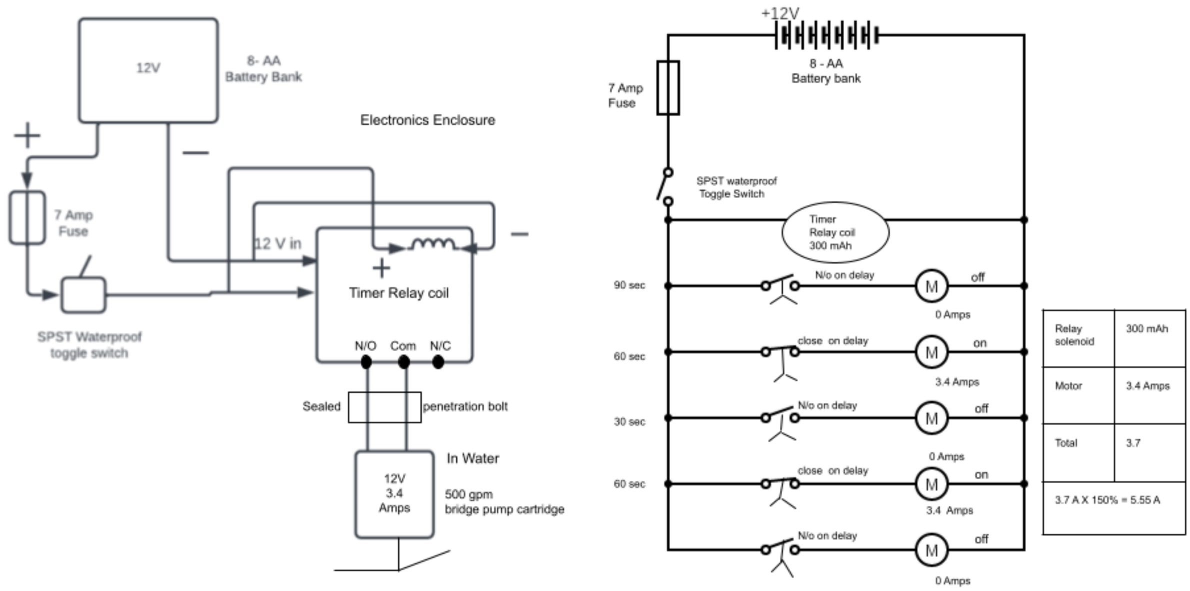
SID

Below is the System Integration Diagram (SID) for *TR2-Seahorse*:



Amperage Calculations

	AMPS
HL	3.1
HR	3.1
SR	3.1
TL	3.1
TR	3.1
CLAW	1
ANALOG CAMERA	800 mA
FATHOM X	500 mA
PIXHAWK	500 mA
RASPBERRY PI	500 mA
DIGITAL CAMERA	100 mA
ESC HL	100 mA
ESC HR	100 mA
ESC SR	100 mA
ESC TL	100 mA
ESC TR	100 mA
TILT SERVO	100 mA
LASER	60 mA
TOTAL:	19.65
	19.65 x 150% = 29.48



Above is the SID for the GO-BGC Float ("La Anguila")

Accounting:

<u>Budget:</u>

This year's budget for the company was approved to fully cover the costs of all parts and travel expenses but was contingent on winning first place in the regional event. Due to COVID-19 the company was not allowed to produce fundraising events and was very limited onto how funding would be produced. However the Corpus Christi Independent School District decided to fully fund the company's expenses. With CCISD's support the company has been allowed to purchase reliable parts and not worry about travel expenses. Since COVID-19 hindered many companies in within the CCISD districts, CCISD has created a "winners fund" and guarantees any team paid travel to a national competition.

Aquabot Technicians

Expense Report

08/16/21 - 05/26/22

Name	Employee ID	Department
Jaziel Gonzalez	#6959162	Finance

Date	Category	Description	Notes	Amount
	Electronics	Dell Laptop	Donated	$349.00
1/12	**Material**	Lexan Sheet	Donated	$63.99
9/5	**Material**	Camera Enclosure		$97.00
8/23	**Electronics**	Power Switch		$5.08
8/30	**Material**	Power Wire		$40.24
9/8	**Material**	Tether		$30.24
2/17	**Hardware**	SD Micro Card		$8.94
3/10	**Hardware**	Electronics Tray		$55.00
3/15	**Electronics**	120 RPM 12 Volt DC Motor		$12.67
3/15	**Electronics**	Digital Camera Servo		$64.00
4/4	**Material**	Control Box		$41.56
4/4	**Material**	4" Acrylic Tube		$90.00
4/4	**Material**	Penetrating Bolts		$31.75
4/4	**Material**	Nut/Bolt/Screws		$41.69
4/4	**Sealant**	Marine Grade Epoxy		$43.21
4/4	**Electronics**	SOS Leak Sensor		$32.00
4/4	**Electronics**	Thruster Commander		$60.00
4/7	**Material**	Electronics Tray Terminal Blocks and Hardware		$45.00
4/7	**Material**	Wet Link Penetrator		$95.00
4/7	**Hardware**	Waterproof Adjustable NPT Cable Gland		$17.30
4/7	**Material**	Double Sided Duct Tape		$4.78
4/7	**Material**	Gutter Guard		$7.17
4/10	**Electronics**	DC/DC Converter		$11.99

5/17	**Electronics**	Timer Module DC		$19.35
5/17	**Material**	Seal Wire Connectors		$39.99
5/17	**Material**	Switch		$20.00
5/17	**Material**	M10 Enclosure Vent		$9.00
5/17	**Hardware**	Hand Operated Vacuum Pump		$98.00
5/17	**Material**	Vacuum Plug		$8.00
5/17	**sealant**	Molykote Glue		$32.00
5/17	**Hardware**	Pressure Relief Valve x4		$84.00
5/17	**Hardware**	Pressure Relief Valve Backfill Adapter x2		$22.00
5/17	**Material**	Moisture Indicating Silica Gel Desiccant Bags		$10.00
5/17	**Electronics**	Sea BEAM Laser SB20		$2,652.92
5/17	**Electronics**	T100 Thruster	Added Thruster	$138.99
5/17	**Material**	Double A Batteries		$18.10
	Electronics	Claw Switch	Re-Used	$7.99
	Electronics	Logitech Hand Controller	Re-Used	$16.69
	Electronics	Tv Monitor	Re-Used	$169.99
	Electronics	Phathom X	Re-Used	$196.00
	Hardware	Power Supply	Re-Used	$68.99
	Electronics	Low-Light HD USB Camera	Re-Used	$99.00
	Material	Analog Camera Wire	Re-Used	$78.00
	Electronics	Gripper (Claw)	Re-Used	$439.00
	Electronics	Digital Camera	Re-Used	$19.99
	Electronics	ESC x4	Re-Used	$210.00
	Electronics	T100 Thruster x4	Re-Used	$555.96
	Material	White HDPE	Re-Used	$52.71
	Material	Roller Transport Cart	Re-Used	$267.27

$6,232.55

Safety

Figure 25: Jaziel tightening materials to the CNC machine-photo by Araceli Orozco

During the creation of *TR2-Seahorse*, Aquabot Technicians made safety our top priority. We made sure that our ROV has no sharp edges. When cutting materials, employees always made sure to wear safety glasses. Shop tools were used with the utmost care, and only after the employee fully understood the function of the tool and the safety precautions that need to be taken when using it. Each employee was required to pass a safety test in order to even be allowed entrance into our shop. A requirement was made that only close-toed shoes were to be worn while in the shop in order to prevent harm that may occur to an employee if they were to accidentally drop a heavy object on their feet. Our safety rules were strictly enforced by our Chief Safety Officer, Araceli Orozco.

Safety Features	
Lab Safety	• Safety Goggles when cutting or soldering • Closed-Toed Shoes • No Baggy Clothing • No Jewelry • No Horse playing • Always unplug devices after they are finished being used
ROV Safety	• The thrusters and claw are equipped with hazard tape to discourage people from putting their hands near them. • The thrusters have plastic shrouds above and below them to avoid any hand or marine life injuries. • All sharp edges are filed down or covered with hot glue to round it out. • All wires are labeled • Electronics are tightly sealed and waterproof • Lexan frame is surrounded with rubber guarding to round out sharp edges.

Table 2: Description of Safety Features

Table 3: Construction and Operation Checklist

Safety Procedures	
Construction: • Declare a proper plan with all employees to ensure everyone is on task. • Having everyone on task results in maximum efficiency and decreases recklessness. • Before everyone starts their tasks after the briefing, the safety officer makes sure all employees are practicing proper safety protocols. • After all safety protocols are checked, the list of tools needed for the task are acquired. • Upon completing each task another employee needs to present to ensure no mistakes are made and a second opinion is present if needed.	**Operation:** • Whenever working with electricity the safety officer checks the voltage currents as a precaution and to check if the power source is operating. • If power were to be lost the fuses will be checked to make sure it is working. • All power cables are effectively covered and out of sight with no wet surfaces nearby. • An effective system check is demonstrated in order to prepare for any tasks.

Figure 26: Employee Julio cutting PVC Pipe

Testing

Before sending the ROV in the water, the company had to test the thrusters to see if they properly responded to the Logitech controller. The results were a success, however, some of the employees decided to change two blades of the thrusters to counterclockwise blades. The two thrusters that changed blades were diagonal from each other. As a result, the *TR2-Seahorse* now creates thrust and the ROV now has the ability to yaw in both directions as opposed to one.

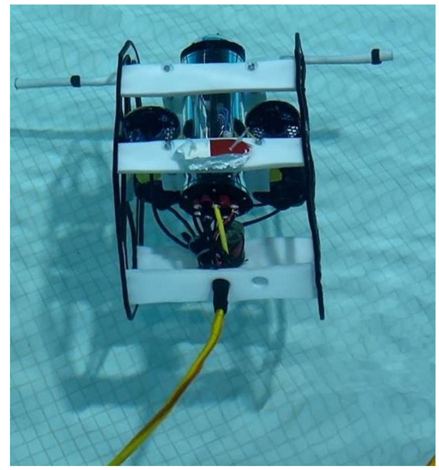


Figure 28: Testing the TR2-Seahorse in local pool

After the thrusters were tested, the company took the *TR2-Seahorse* to the local natatorium, where the buoyancy was tested. At first, before any adjustments were made, the ROV was negatively buoyant. To counteract the negative buoyancy, a tiny floaty was zip tied onto the ROV and that made the ROV positively buoyant. However, during the team's regionals competition, the *TR2-Seahorse* would not fully submerge into the water. As a result, an employee removed the floaty. Additionally, the company ran into another issue of not being able to pick up objects located on the pool floor. Thus, a group of employees cut off the bottom section of the *TR2-Seahorse* so objects placed on the pool floor could be picked up. Once the team removed the bottom section, the buoyancy force was tested, which can be seen in **Table 2**.

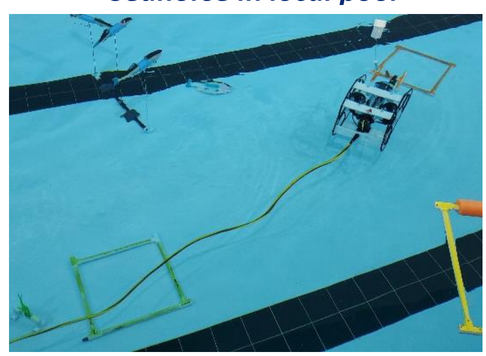


Figure 27: TR2-Seahorse at Regionals

Figure 27: Piloting the ROV

Acknowledgements

We at Aquabot Technicians would like to express our extreme gratitude to those who made the development of *TR2-Seahorse* possible. We would like to thank Corpus Christi Independent School District (CCISD) for providing us with most of our funding. We would like to thank Foy H. Moody High School, our home campus, for providing us with caring instructors and diligent employees. We would like to thank Blue Robotics for providing us with most of the components for our ROV. We would like to thank Citgo for making our program possible as part of Project Lead the Way. Finally, we would like to thank MATE for providing us with valuable learning experiences that will benefit us for the rest of our lives. We are looking forward to attending the 2022 MATE ROV International Ranger Competition in Long Beach, California, and look forward to attending MATE ROV competitions for many years to come

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