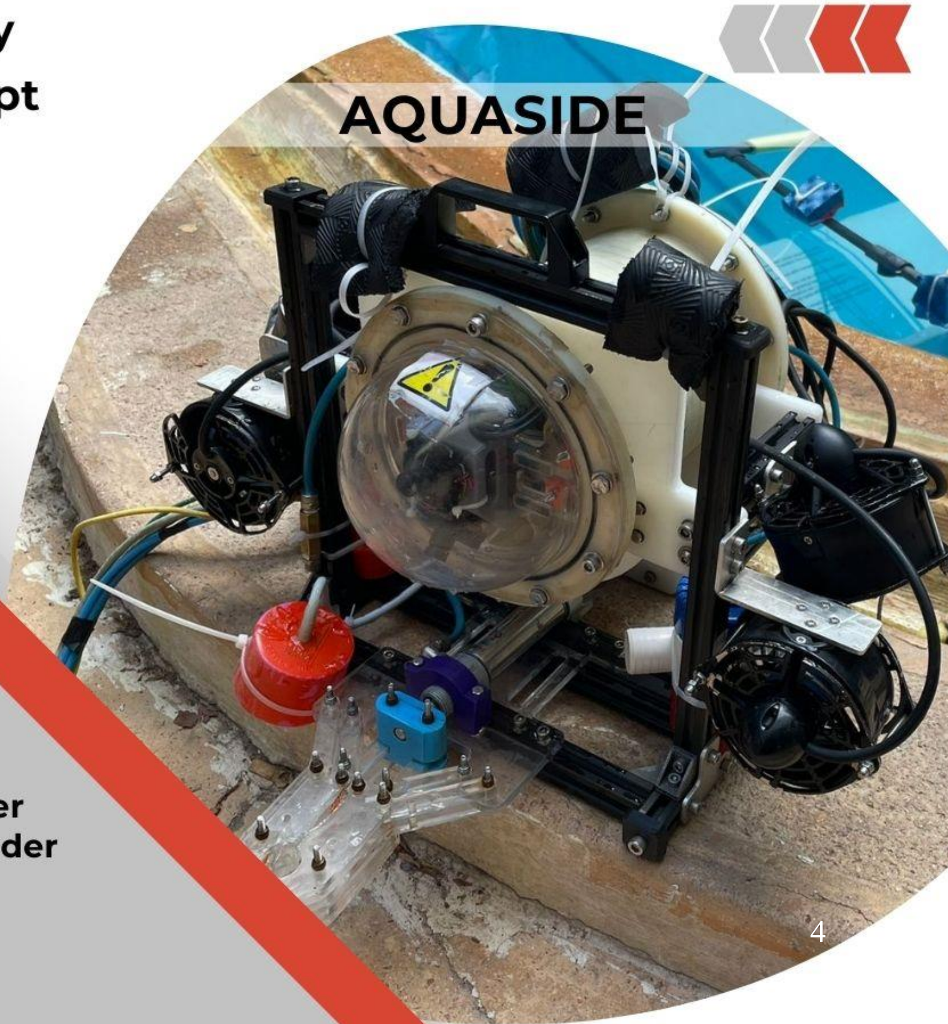
ETERNAL

TECHNICAL DOCUMENTATION

Vortex Academy
Alexandria, Egypt



MATE 23

COMPANY MEMBERS

SOFTWARE TEAM

Omar Karim | New
Eyad Ahmed | New
Fares Hossam | New
Ali Eldin Ahmed | Return
Rodayna Mohamed | Return
Ahmed Wael | New | Software Leader
Ziad Khair | New | Auto-docking Leader

ELECTRICAL TEAM

Aya El-Sayed | Return
Omar Mahmoud | New
Hana Mohamed | Return
Adham Al-Hakem | Return
Saif Tabouna | Return | Electrical Leader

MECHANICAL TEAM

Yassine Mohamed | New
Abdallah Elsherbiny | CEO
Ali Mohamed | New | CFO
Youssef Khaled | New | CTO
Isel Karim | New | Seagrass Leader
Retaj Tamer | Return | Mechanical Leader
Abdelrahman Mekky | New| Main Enclosure Leader
Hour Ahmed | New
Anas Hany | Return
Adam Ibrahim | New
Adam Ahmed | Return
Mohamed Sameh | New
Hamza Mohamed | New

MENTORS

Abdulaziz Yousry
Asmaa Bahaa
Karim El-Sayed
Aya Esam
Mai Allam
Mazen Gemeay
Aly Zaituon

I. INTRODUCTION

ABSTRACT

Eternal was founded this year with mentoring of Vortex Company and AASTMT school, with the goal of creating an ROV that fulfills the greatest quality and safety standards while adapting to developing global environmental concerns. The team consists of 24 devoted and motivated middle and high school students who spent months learning, planning, creating, testing, and debugging to produce our ROV, Aquaside, as a viable product.

Aquaside Rov is designed to achieve UN Sustainable Goals such as affordable and clean energy, responsible consumption, and production, and combating climate change, and it is fully equipped with tools to do difficult tasks such as underwater organism detection by creating full 3D models and collecting eDNA data to identify them, as well as underwater structural inspections utilizing its cameras to produce high-resolution photos that allow the operator to spot any flaws. However, it can significantly reduce the risks associated with underwater work while also improving the efficiency and accuracy of underwater operations.
Aquaside Rov is unique in its portability, compact size, stability, ease of assembly, and low cost. It was created using several processes, including laser cutting, CNC routing, and 3D printing. A novel design concept based on an Aluminum extrusion; a relatively new element employed in today's industrial underwater applications. Aquaside Rov has four thrusters for the required movements, vision cameras to visualize objects underwater, a pneumatic system for the gripper, and a custom printed circuit board.

Figure 1 : Eternal team members with our mentor, Abdulaziz Yousry in regional competition 2023 by the regional competition event photographer.

Top row (left to right): Abdelrahman Mekky, Saif Tabouna, Hamza Mohamed, Youssef Khaled, Ahmed Wael, Ziad Khair, Ali Eldin Ahmed, Mohamed Sameh, Hour Ahmed, Rodayna Mohamed, Retaj Tamer, Hana Mohamed.
Bottom row (left to right): Abdulaziz Yousry, Omar Mahmoud, Fares Hossam, Ali Mohamed, Adham Al-Hakem, Omar Karim, Eyad Ahmed, Adam Ahmed.

TABLE OF CONTENTS

II. DESIGN RATIONALE

DESIGN EVOLUTION

Our Aquaside ROV was built with a cost-cutting approach as part of our design process. Aquaside's sleek and versatile design propels it through the water with exceptional speed and agility, allowing it to complete task after task without interruption. Our software design concept, on the other hand, evolved from the divide and conquer concept, so we divided our software system into two modules; the topside module is responsible for taking joystick input, being able to take screenshots and process them in mission specified software such as 3D modelling, and displaying received data from the float engine, while the underwater module is responsible for controlling thrusters, lift bag, bilge pumps, and gripper, allotment.

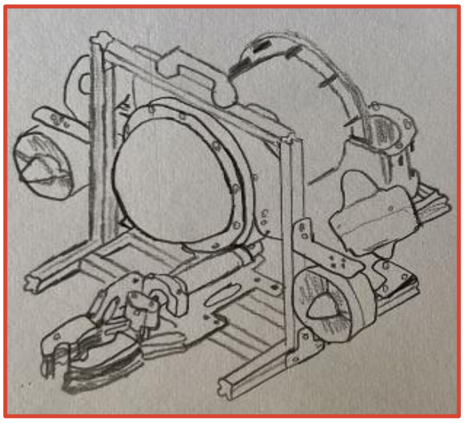


Figure 2: free hand Sketch of Aquaside ROV by Retaj Tamer

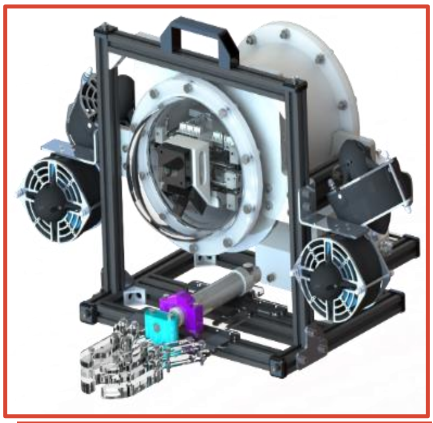


Figure 3: 3D Modelling of Aquaside ROV by Solidworks.

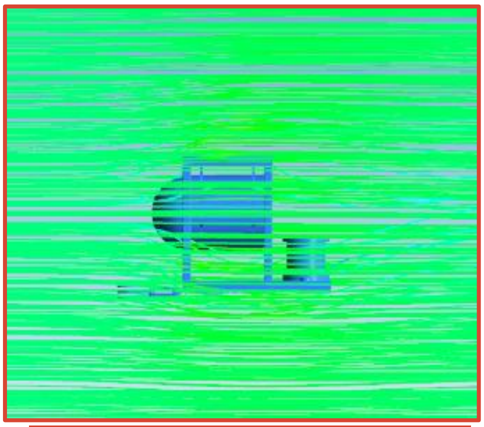


Figure 4: Simulation of water on Aquaside ROV by Ansys fluent.

A. Mechanical Design and Manufacturing Process

Aquaside design is completely unconventional; it's based on and improves on previously manufactured ROVs. A considerable amount of time has been spent researching the advantages and disadvantages of the previous models, especially the 2019 & 2022 design concepts, as well as thinking about ways in which they could be improved. Following the design team's agreement on the schematics and the creation of freehand sketches-**fig (2)**. The real work began with 3D modeling using SOLIDWORKS -**fig (3)** as a starting point. We simulated water flow through our vehicle by CFD using ANSYS fluent **fig (4)**. So, we tested our design before production thanks to SOLIDWORKS and ANSYS. The mechanical design team put in a lot of effort, but the main problem was getting our vehicle to move smoothly. This was achieved by our electrical team accomplished. The electrical team incorporated electronic components into our ROV through meticulous planning and close collaboration with the design team. This allowed for responsive control over the ROV's path.

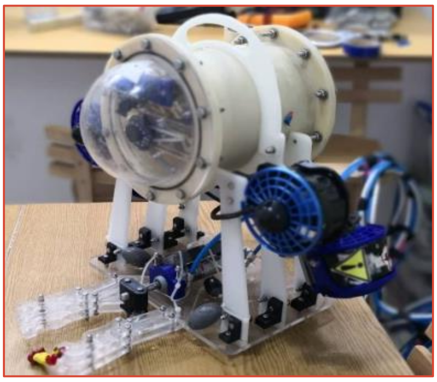


Figure 5: 2022 ROV (Left) by Retaj & 2019 ROV(Right) by Seif

B. Vehicle structure and Size, and weight constraints.

The Aquaside ROV structure was inspired by a combination of the 2019 Rov propulsion system, which is represented by four thrusters, and the previous year's design, which is primarily based on the use of Aluminum extrusion bars with an opening design concept of the frame structure, which helps minimize drag force and reduce eddies.

The Aquaside ROV utilizes several innovative design features to retain excellent operational efficiency and control. For size, the main three dimensions of the ROV is 55 cm, 35.9 cm, and 55.5 cm. the vehicle was designed to fit in the docking station so it fits in 56.5 cm of circle diameter **-fig (6)** which is smaller than the 84 cm cube docking station**-fig (7)** that the ROV must pilot through. For weight, The Aquaside ROV weighs 9.2 kg in the air, without a 25-meter cable weight meeting the competition's weight requirement with the maximum bonus. In freshwater, the Aquaside ROV can carry out missions deeper than 10 meters. It operates at a voltage of 12 VDC and a current of 20.5 Ampere, which is significantly below the competition's limit of 30 Ampere.

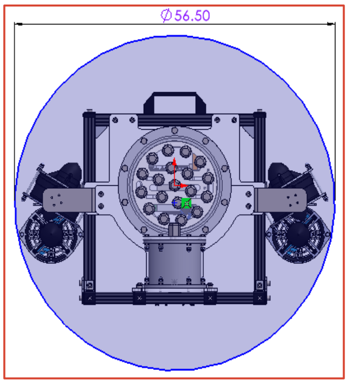


Figure 6: The Aquaside ROV fits in 56.5 cm diameter by Solidworks.

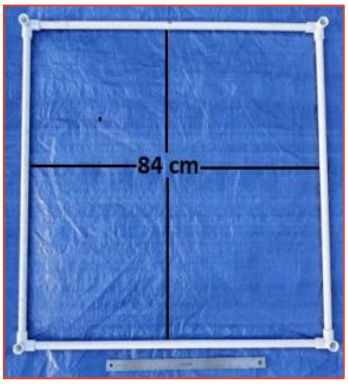


Figure 7: the base of the docking station from prop building document

C. Mechanical Components

1. Frame main structure

There are several tradeoffs of materials, and structure base to be selected So, we selected the best material for the frame structure based on the nature of the component itself and the properties of each material, such as density, impact strength, flexibility, and cost **-table 1**.

Table 1: PMMA, HDPE, Aluminum, PLA, and stainless steel 304 materials properties.

Property	HDPE	Acrylic (PMMA)	Aluminum	PLA	Stainless steel 304
Density (g/Cm^3)	1	1.2	2.7	1.24	8
Impact Strength (J/m)	260	74	294	96.1	325
Flexibility (MPa)	24	71	90	80	540
Cost	Low	Moderate	Moderate	High	Moderate

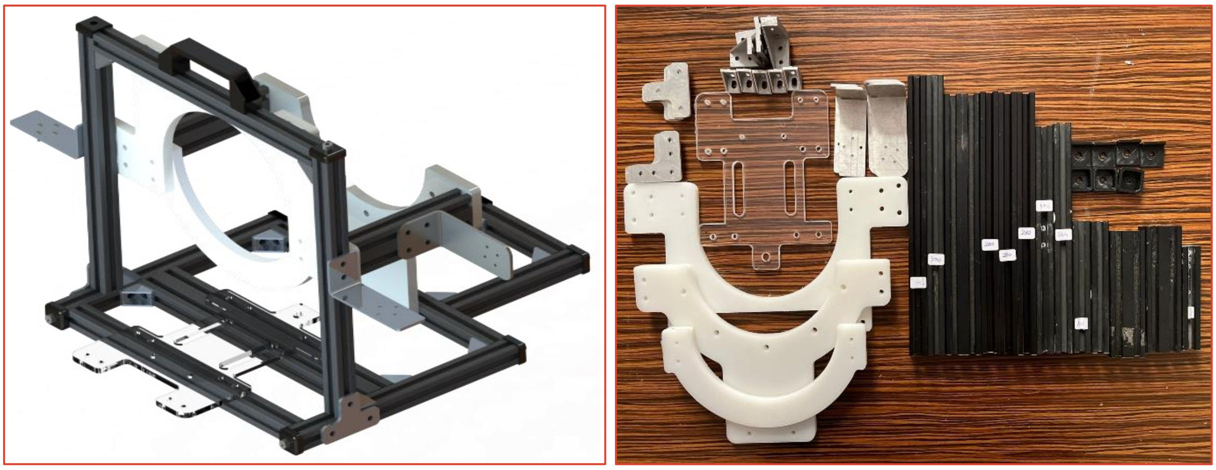


Figure 8: Aquaside ROV's main frame structure CAD design by solidworks(left) & Manufactured parts (Right) by Retaj

The main structure of the frame **-fig (8)** consists of eleven 20X20 &20X40 Aluminum extrusion profile which means a width of 20/40 mm and a thickness of 20 mm with different lengths. The easy accessibility previewed in the aluminum extrusion accessories such as aluminum corner, aluminum T shape, L shape, T nut and M5X8 bolt **-fig (9)**.

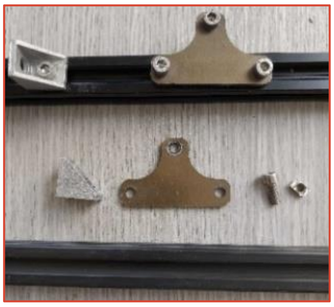


Figure 9: Al-extrusion and its accessories by Retaj

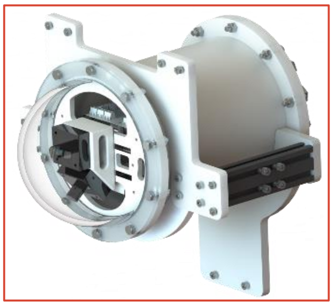


Figure 10: Enclosure and its holder parts by Solidworks.

2. Electronics Housing and its mounting

Aluminum extrusion profile is inserted to support the enclosure three holders and to lock the rotation of the enclosure. The holder parts of the enclosure **-fig (10)** are made of HDPE (High-Density Polyethylene) material that was built using a CNC (Computer Numerical Control) router for its ductility, light weight, and density.

The rear bottom camera enclosure-**fig(11)** is mounted on a two 20X20 aluminum extrusion profile through T nuts and M5X8 bolts.

3D printed part-**fig(13)** of PLA material to cover the sharp edges of the aluminum extrusion profile.

Figure 11: Bottom camera mounting by Solidworks

3. Dome

A 6mm thick transparent polymethyl methacrylate (PMMA) dome **-fig (12)** covers the front face of the ROV. The dome serves various objectives, including providing clear views of the surrounding area to the cameras, offering extra space to accommodate two cameras at different view angles, and lowering the overall drag force on the ROV, resulting in more efficient thrust power consumption. The drag coefficient of the ROV was calculated by simulating the flow across it.

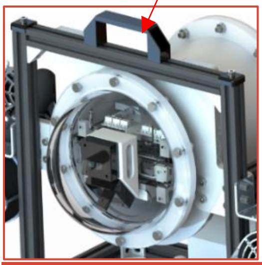


Figure 12: PMMA dome by Solidworks.

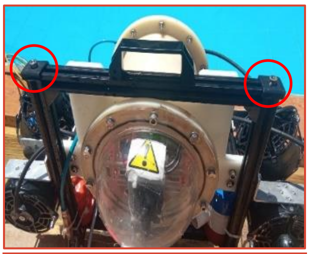


Figure 13: 3d printed part by Retaj.

4. Thruster fixation

Thruster **-fig (14)** mounts of Stainless steel 304 sheet metal bent are fastened to four of the AL-profiles, two in front and two in back, at a 90-degree angle. We preferred the bent stainless steel rather than the 3d printed parts since the stainless-steel material has more strength, and rigidity but the PLA material of the 3d printed parts is fragile and absorbs water that makes it heavier.

Figure 14: Thruster and bent L mounting by Solidworks.

5. The manipulator fixation

The manipulator is held in place by a 6mm thick PMMA (Acrylic) base that was built using a CNC (Computer Numerical Control) router and it is fixed on two profiles of 20X20 & 20X40 aluminum extrusion **-fig (15)**.

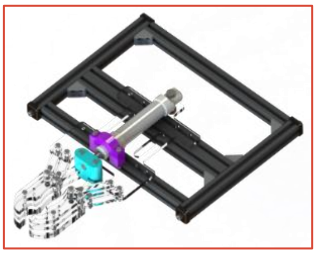


Figure 15: Thruster and bent L mounting by solidworks

D. Buoyancy and Stability

The enclosure on the Aquaside ROV displaces the most water, at 5497 cubic centimeters, which is why it was put at the top of the ROV. The center of buoyancy (CB) is shifted upwards **fig (16)**, counterbalancing the entire weight of the ROV and any payloads it may be carrying. The Aquaside ROV has a great level of stability because the weights are placed at the bottom. As the foam is added, the result is a somewhat positively buoyant ROV that can be readily canceled out by the vertical thrusters when needed. Because of the symmetrical, the ROV's CB and CG are centered in the middle of the square ROV.

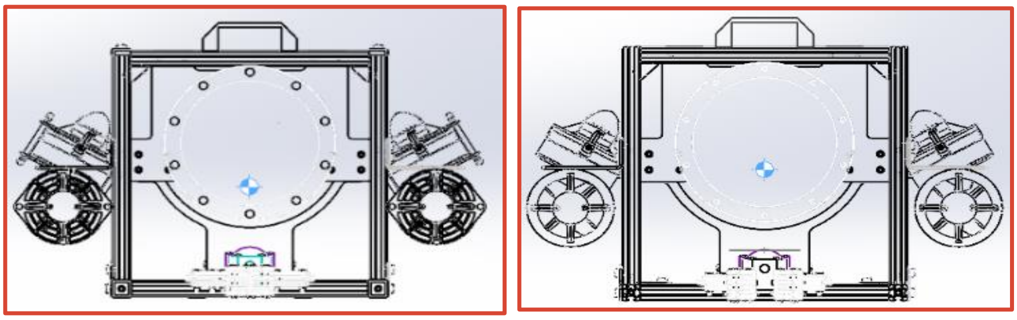


Figure 16: Centers of Gravity (Left) & Center of buoyancy (Right) by Solidworks

E. Propulsion

In Aquaside ROV, we wanted to use as few thrusters as possible while maintaining all the degrees of freedom required for maneuvering. One of our options was to use six thrusters T200, which was a very expensive solution and used excessive power. The second option was to utilize four thrusters T200, which were less costly but still consumed excessive amounts of power. Finally, a four-thruster configuration **fig (17) (2 T100 & 2 T200)** was chosen to reduce power consumption and overall costs. The ROV was driven by Blue Robotics two T-100 and two inclined T-200 thrusters, a high-performance model with a rating that can withstand pressures at depths of thousands of meters. It was an easy decision due to its simple control, moderate cost, and mounting possibilities. The angle of inclination of the inclined thrusters is 60°.

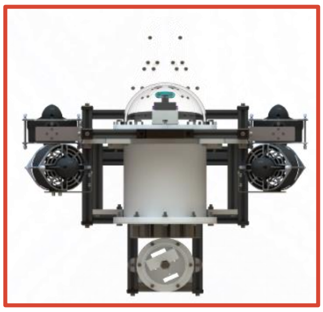


Figure 17: Aquaside ROV's top view of thruster configuration by solidworks

The four thrusters allow the vehicle to move straight sideways, known as "Crabwalk", as well as many other movements without requiring any thrusters in the center of the vehicle. Vertical and crabwalk motions are produced by adding thrust vectors. Vehicle motion is produced by vectored thrusters-**fig (18)** interacting with each other. The blue arrows indicate that both vectored thrusters are generating a force diagonally upward and towards the midline, which is equivalent to the combination of a vertical force, a red arrow, and a horizontal force, a black arrow.

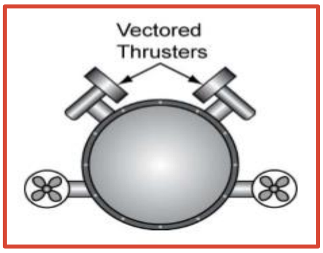


Figure 18: Aquaside's vectored thrusters from underwater robotics book

The resulting force propels the vehicle upwards and toward the surface. The vehicle will dive if both thrusters reverse their direction. As a result, this configuration enables straight-up and straight-down motion **(fig 19)**.

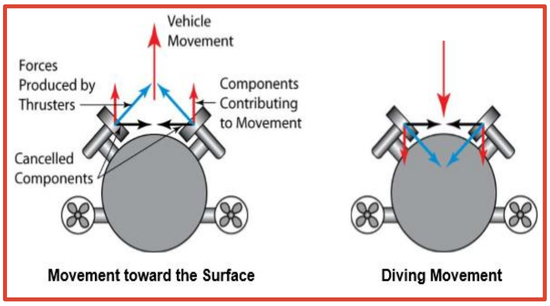


Figure 19: Aquaside's Vertical Movement from underwater robotics book

The port thruster is creating a propulsive force downward and to the left, while the starboard thruster is creating a force directed upward and to the left. In this case, the horizontal, red, components cooperate, so the vehicle is pushed sideways in a crabwalk motion to the left. And if both thrusters reverse their directions, the horizontal, red arrows, will cooperate in the opposite direction and the vehicle will crabwalk to the right **fig (20)**.

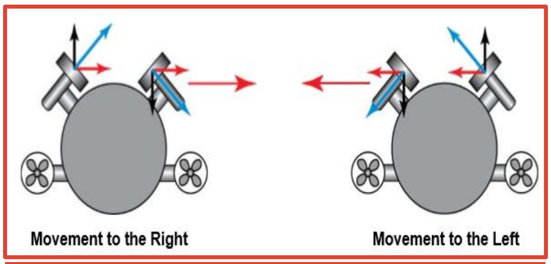


Figure 20: Aquaside's Lateral Movement from underwater robotics book

Table 2: Maximum Possible Thrust Force Calculations.

Direction	Maximum Thrust
Upward	2x1.82X sin (60) = 3.152 Kgf
Downward	2x1.02X sin (60) = 1.766 Kgf
Forward	2 x 1.3 = 2.6 Kgf
Backward	2 x 0.7 = 1.4 Kgf
Lateral	(1.02 x cos (60)) + (1.82 x sin (60)) = 1.42 kgf

1. Aquaside ROV Flow analysis

Due to the importance of the computational fluid dynamics nowadays we made a water flow simulation on our vehicle to predict the behavior of our vehicle in the maneuvering, Pressure distribution, velocity distribution, and to calculate the coefficient of drag and drag force.

In pressure distribution **-fig (21**), you can notice that the first point that meets the water flow has a high pressure due to the stagnation point effect that makes the whole kinetic energy become zero which is represented in velocity.

In velocity distribution **-fig (22)** Also, you will notice a low velocity down to zero as the kinetic energy is converted to the pressure energy.

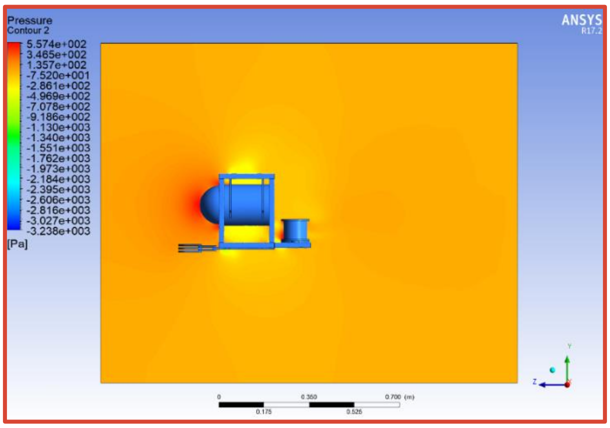


Figure 21: Pressure distribution by Ansys fluent

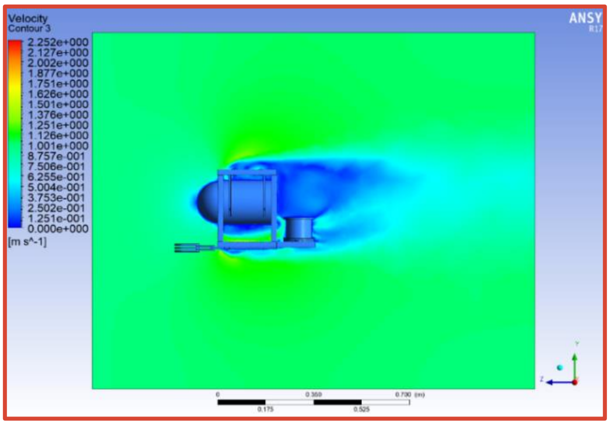


Figure 22: Velocity distribution by Ansys fluent

2. Drag force calculations:

Coefficient of drag = 0.056883267 (Calculated from Ansys fluent)
Frontal area = 131803.81 mm^2 =0.13180381 m^2
Density = 1000 kg/m^3
Velocity = 1 m/s
Drag force = 3.75 N

$$F_D = C_D A \frac{\rho V^2}{2}$$

where
F_D is the drag force
C_D is the drag coefficient
A is the reference area
ρ is the density of the fluid
V is the flow velocity relative to the object

Equation 1: Drag Force

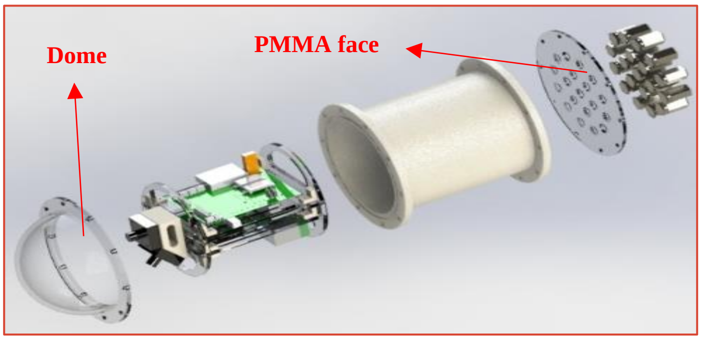


Figure 23: Aquaside ROV's Electrical Enclosure by Solidworks

F. Electrical enclosure and sealing

At the heart of our vehicle is an inclusive lathed machined pressure housing **-fig (23)** that is secured in place by a pair of rings linked to the top plate, giving it a sleek, hydrodynamic profile. PA Type 6 (Polyamide Nylon6) enclosure with integrated flanges on both sides and 158x2.5 mm O-ring fitted in 1.5 mm deep slots. Because the O-rings are made of Nitrile, they operate as a robust sealant between the enclosure and the faces and were chosen according to Parker's Sealing Handbook specifications. In the enclosure, no chemical sealant was applied. Moreover, the enclosure has a 5mm-thick laser-cut clear PMMA face from one side **-fig (23)**, and a PMMA dome **-fig (23)** from the other side, which were selected to provide clear vision for the cameras, as well as to check the compression of the O-ring. HDPE material was selected as there are no pores formed within the material, meaning that it can act as a perfectly sealed container. Stress analysis **-fig (25)** was made by solidworks static analysis to ensure that the enclosure can withstand a pressure up to 10 meters underwater with a factor of safety 1.1.

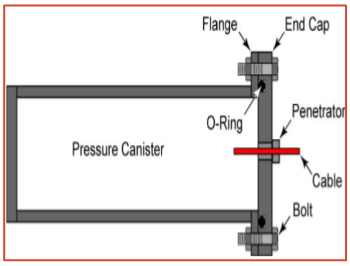


Figure 24: Cross section of the enclosure

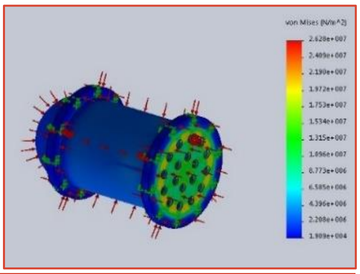


Figure 25: Stress analysis by solidworks

G. Electrical System

The electrical system of the Aquaside is meant to be robust yet simple and easily connected using pluggable wire terminations. A double-layer PCB was custom-designed and manufactured by our team to minimize the PCB size, hosting the major components such as the microcontroller and the RS485 communication module **-fig (26).** The joystick delivers signals to the microcontroller via serial communication, which controls the actuators, while the GUI displays the gripper's state, the direction of maneuvering, and speed level.

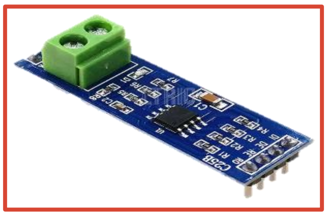


Figure 26: RS-485

1. Power Distribution and Calculations

The power supplied by the 12-VDC source passes through the 30 Ampere fuse at the surface-end of tether to reach the onboard electrical system. The power fluctuation, due to the voltage drop across the tether when the load increases, disturbs the cameras. Therefore, a reused buck-boost converter from vortex academy **-fig (27)** was integrated into the system to stabilize the voltage and eliminate this disturbance. DCVs, LEDs, ESCs, Arduino, bilge pumps, RS485, and cameras are all powered by 12 volts.

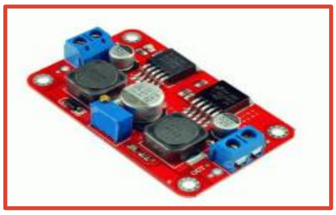


Figure 27: Buck-boost converter

Since the thrusters have the most influence on the total power consumed, there was a special attention to controlling them. This resulted in building a software interlock system, which limits the current drawn by the thrusters through limiting their speed to a -1700µs PWM input to the ESC **-fig (28)**- and only one thruster-movement may be conducted at a time. Concluding that, the maximum power consumed is **494.16 watts,** and the maximum current is **20.58 amps**. Consequently, **the required fuse is 20.58*1.3 = 26.754 amps**, **hence the fuse used is 30 amps**. A detailed power distribution is shown in table 2.

Table 2: Power Consumption Calculation

Component	Voltage (Volts)	Max current (Amperes)	Max power (Watts)	Quantity	Total max power (Watts)	Total max current (Amperes)
T100	12	5	60	2	120	10
T200	12	5	60	2	120	10
Cameras	12	0.3	3.6	3	10.8	0.9
DCV	12	0.28	3.36	1	3.36	0.56
Bilge pump	12	10	120	2	240	20

Maximum power consumed = 494.16 watts
Maximum current = 20.58 Amperes

2. Main PCB

We developed our own double-layer PCB **-fig (28)** to efficiently utilize the available space for the bottom side electrical system, without compromising any of the required components. Also, we prioritized including protection via a fuse to protect the PCB from overcurrent while powering the system. The board integrates the Arduino, ESCs, IRF540 MOSFETS, RS485 Module, and provides robust connections for the signals between all the components and delivers power to them also. To facilitate any system adjustments or upgrades, the unused Arduino pins are available for use through the PCB. Before the Gerber Files were submitted to a factory to build the final PCB used in the ROV, we made a prototype PCB **-fig (29)** just to ensure the proper functionality of our design.

Figure 28: Main PCB by Seif

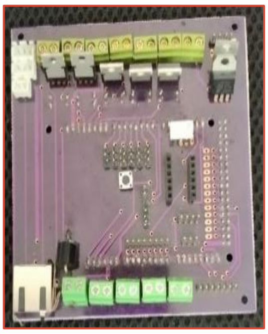


Figure 29: Prototype PCB by Seif

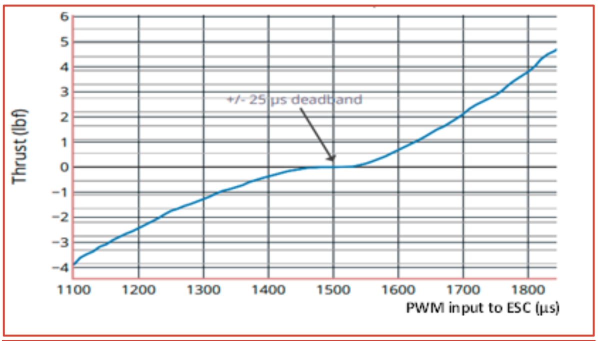


Figure 28: T100 thrust vs PWM input to ESC

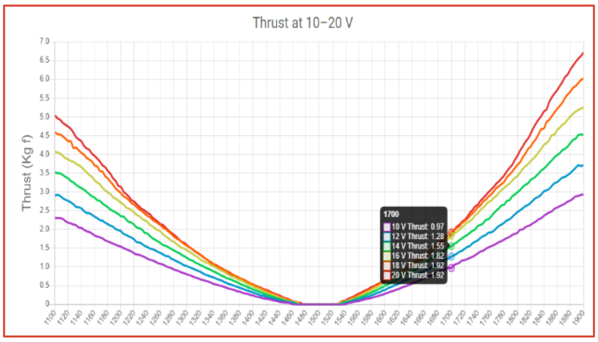


Figure 29: ESCs

3. Control System

a. Microcontroller

We reused Arduino boards **-fig (30)** from Vortex Academy since they are open-source microcontrollers that are widely available, easy to program, and cost efficient unlike other micro controllers such as raspberry pi; as we don't need its processing power. The 8-bit Arduino UNO was the best choice for our control system since it has UART serial communication port required to communicate with the RS-485A, as well as 14 digital I/O pins for operating all Aquaside's thrusters, gripper, and tools. Unlike past years we opted for an Arduino UNO over an Arduino Mega, as it the latter has too many unneeded pins and required excess space that we used more efficiently this year; so, the Uno was enough for Aquaside's system.

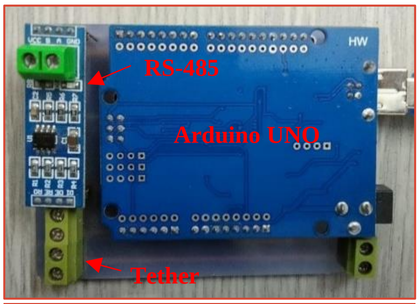


Figure 30: Topside PCB by Seif

b. Thrusters control and Thrust force.

The 2 T100 and 2 T200 thrusters **-fig (32)** are controlled by four ESCs (electronic speed controllers) **-fig (31)**, where the Arduino UNO sends PWM (pulse width modulation) signals that control the speed and direction of the thrusters. To reduce the number of wire connections in the internal structure, the ESCs were soldered onto the PCB to receive the signal and power directly from the PCB.

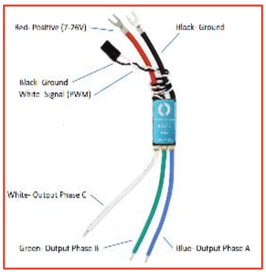


Figure 31: ESCs

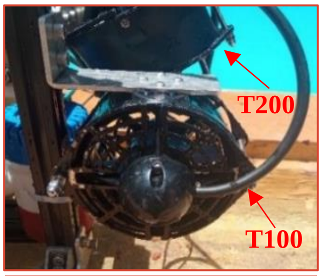


Figure 32: ESCs by Seif

c. DCV control:

We control the 5/2 DCV and the 2/2 DCV using IRF540 MOSFETs that control the high power of the loads with the 5V digital signal supplied by our Arduino UNO. The temperature of the MOSFET **-fig (33)** was deducted to ensure that there is no excessive heating. We reused a 5/2 DCV from Vortex Academy to control the air flow to the pneumatic cylinder attached to the gripper and the 2/2 DCV, that was purchased, for the lift bag.

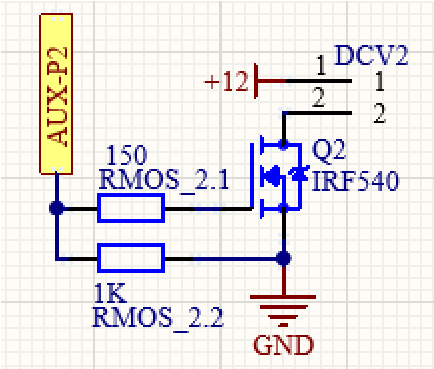


Figure 33: MOSFET Circuit

IRF640 MOSFET temperature calculations:

$I_D = 0.28$ A

$R_{DS\,(on)} = 0.18$ ohm

$P_{dissipated} = R_{DS\,(on)} \times I_D^{\,2} = 0.014$ Watt

$R_{th\ j\text{-}a} = 62$ °C/Watt

$\Delta T = T_{th\ j\text{-}a} \times P_{dissipated} = 0.87$ °C

4. Tether

a. Communication

Data is sent from the station to the ROV using two Category 6 (CAT6) Ethernet cables, that have four twisted pairs each **-fig (34).** One cable connects the USB-RJ45 adapter to the Arduino UNO and carries the signal of a camera, while the other connects to the other two cameras. We chose CAT6 cables, which has a serial transmission rate of 250 Kbps (kilobits per second).

b. Power

Based on the AWG wire sizing chart, a 6 AWG (4 mm) power cable was chosen to reduce voltage-drop across the tether ends and provide a more stable voltage to the system. Knowing that our current limit is **20.58** amps, we choose our wires based on the following calculations:

Max power Consumption = 494.16 Watt

Max Current = 20.5 Ampere

Fuse Calculations:

20.5 X 1.3 = 26.754 Ampere

Fuse used = 30 Ampere

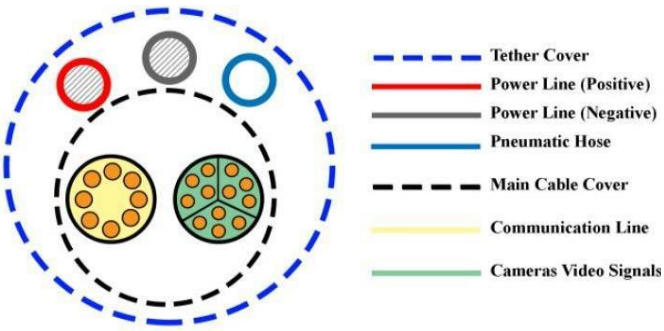


Figure 34: Tether Diagram

$$VDI = \frac{Current\ (Amperes) \times Length\ of\ wire\ (feet)}{\%voltage\ drop\ \times voltage\ (volts)}$$

Equation 2: Voltage drop index (VDI) and American wire gauge (AWG) Calculations

c. Tether management system

Our tether management system consists of a wooden cable wheel, that the tether is wound around it during transportation to eliminate tangling and any possible damages. Also, during the deployment of the ROV, it is used for lengthening and shortening of the tether.

H. Software

1. Vision system

Our system aims to maximize the pilot's field of view since different missions require different views of Aquaside **-fig (35).** It consists of three selected Reused CCTV cameras after assuring that they are working in their full functionality, each camera with a focal length of 2.8mm and an angle view of 89.9 ° horizontally and 79.8 ° vertically. The first camera was tilted at 45 ° for the gripper view used in different missions. The second facing forward for the pilot's view and its mainly used in Autonomous Docking and 3D modeling. The third viewing the bottom side of the pool for the Transect line mission to allow easy viewing while moving. We also got all the camera frames to the topside laptop for the 3D modelling and measurement mission.

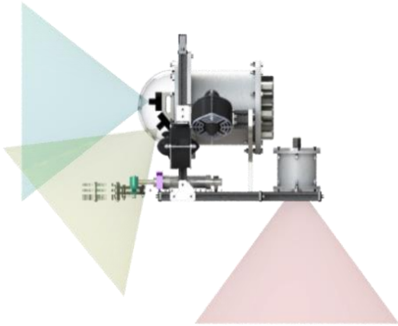


Figure 35: Vision System Camera Cones by Solidworks

2. Topside Control Unit (TCU)

The master RS-485 communication module, video baluns, DVR, and the main outlet power for all components are all housed in the ROV's control panel **-fig (36).** Our DVR was reused to be connected to the surface laptop through a local network via RJ45. While all components are effectively fastened, the AC and DC power supplies are separated and labeled, and no exposed cables are present. While all wires coming into the panel are strain relieved.

The monitor and the case were reused in order to decrease the total cost of the TCU, while the joystick was purchased to make sure that it supports pygame python library and send the right signal to the GUI.

Figure 36: TCU by Seif

3. Software and Control System

The Aquaside software performs two functions: commanding and directing the ROV using Our GUI and the vision system, as well as managing input from the joystick. Our software is separated into two major subsystems; The first subsystem is the underwater system while the second subsystem is the topside system.

a. Underwater System

Our ROV software receives commands from the topside and controls the thrusters accordingly. It is built using a very common and simplistic architecture called finite state machines, where we perform a specific action based on the input and also take into consideration our current state. For example, if the letter "f" is received, the ROV moves forward, but if it was already moving vertically before that command, we must stop that motion and move only forward as we are currently unable to operate all four thrusters at the same time to limit the over current.

b. Topside Software

Our topside software acts as a user interface and connects with the ROV through the TCU. It is composed of three distinct modules that run asynchronously to eliminate code dependencies and interact through inter-process communication to improve performance. The Topside system basically consists of:

- Control Unit.
- Graphical User Interface.

1. Control Unit

The control unit consists of an Arduino UNO connected to the pilot computer which is responsible for communication between topside Arduino and Underwater one via serial communication, this system is operated by the GUI which gives visual real time feedback so that the pilot is able to know how the Aquaside is behaving according to his/her inputs , we chose Arduino as our main controller as it is easy to use and have a wide range of supported libraries unlike other controllers PIC and AVR that require extra knowledge.

2. Graphical User Interface

Our graphical user interface **-fig (37)** is built using the pyqt5 library and talks with other scripts via the Python multiprocessing communication module, which works similarly to socket programming but on the local machine. When the GUI and other processes are up and running, they can easily communicate. For example, the GUI requires this communication to receive joystick input and update the motion indicators accordingly. We use the pygame library to take joystick input, and the GUI can launch other processes as subprocesses when necessary, such as in image processing and measurement missions. Our GUI also includes motion indicators, a timer to track mission time, a gripper indicator, labels for floating engine data, and buttons to run mission specified software.

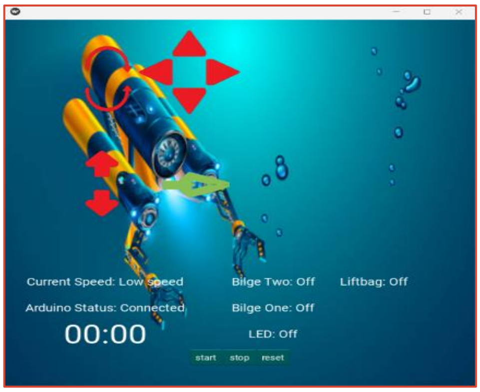


Figure 37: Aquaside GUI

4. Mission Specified Software

1. Auto Docking

We used YOLOv5 Architecture, a developed object detection model that involves building features from input images. These features are then entered into a prediction system, which draws boxes around objects and predicts their classes. Our mission can be broken down into three steps:

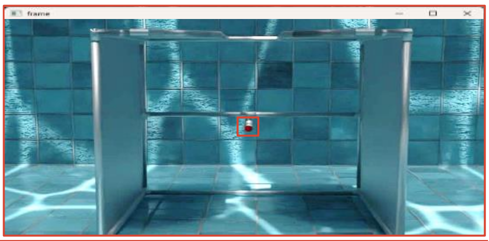


Figure 38: Detecting Auto docking button.

1. **Dataset collection:** We manually collected data and labelled it for model training. Our data was mainly obtained from Mate's Prop-Building Instructions.
2. **Model Training:** We trained our model over 250 epochs.
3. **Model testing:** To ensure that the model is not overfitting, the model prediction outputs were tested using data that did not exist in the trained dataset.

After testing the model, we loaded it into a Python script to provide a control signal to the thrusters based on the model's prediction of the red button position **-fig (38);** if the model no longer detects the button, it sends a stop signal to the thrusters.

2. 3D Modeling and Measurement

Given the importance of aquatic plants, which can collect and store huge amounts of CO_2, making them useful ecosystems for combating climate change, we worked on establishing a way to build 3D models of the coral head using Blender, which has an embedded Python interpreter that can be used to execute a Python script. Blender exposes Python modules to the embedded interpreter, such as BPY and MATHUTILS, so that they may be imported into a script and provide access to Blender's data, classes, and methods.

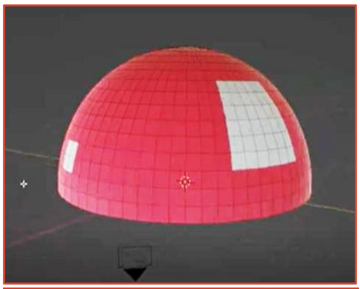


Figure 39: 3D Coral Head

Using a prewritten Python script for Blender, construct a half sphere with the measured radius using a known PVC pipes and fittings-**fig (40)** as a reference, the texture is then added using the 2D images captured from the front CCTV camera after they have been processed with the OpenCV python library for extracting the diseased areas of the coral head and the coral head itself without a background.


Figure 40: Measurement tool (Reference) by Abdallah

I. Payloads and Tools

- Cameras as a payload have been identified in the vision system section previously.

1. Gripper

Aquaside ROV is equipped with one gripper **-fig (41)** to perform the necessary tasks like picking the camera and holding the float engine, placing the tent over the diseased area of the coral, and the lift bag that holds the heavy container in the least time possible. The gripper is directly attached to a base that is made of the PMMA material (Acrylic) of the ROV through a 3D printed mount and an M8 bolt. The material chosen was a clear 6mm-thick laser-cut PMMA, to provide a clear view for the pilot of the held objects during task. We also grooved 2 holes in each gripper to attach our tools on them like the tool used to remove the Removing algal marine growth in task 1.

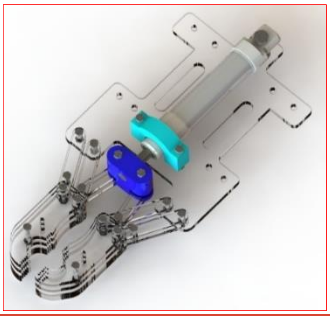


Figure 41: Aquaside's gripper by Solidworks

We used a pneumatic system because it is easy and simple to use, and efficient for our tasks. A pneumatic piston having a bore diameter of 25mm and a stroke of 50mm was selected to provide a maximum end- effector opening of 10cm, and a gripping force of 123 Newtons when a pressure of 2.5 bars is provided. The movement is transmitted from the pneumatic piston to the end-effectors through PMMA links and 3D printed part having a nut embedded inside. The end-effector has 2 curvatures with different diameters to hold objects of different sizes. The smaller opening can be used to carry small objects. The rubber was glued to the inner curves of the end effector to increase the friction force and exert a stronger grip on the held objects.

2. Payloads (fry fish tool)

This tool-**fig (42)** is designed from half cylinders from polyvinyl chloride (PVC) which will be closed by two half circles from the corrugated sheet to facilitate the process of fry fish releasing by closing the gripper. At the same time, the corrugated sheet prevents the spread of fry fish during the ROV journey to the releasing area. One PVC part is attached to the gripper by 3D printing angle and the other part is attached to specified PMMA base and these parts are fixed together with spread pins to speed up the process of fixing and removing this tool. This tool is used to eliminate the possibility of early release or taking the penalty for moving prob building in case of lifting by ROV assistant if it is a non-ROV device.

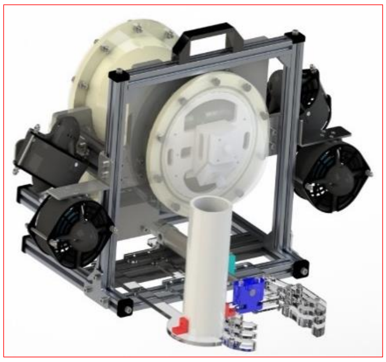


Figure 42: Fry fish tool by Solidworks

3. Payloads (E-DNA sample)

The E-DNA sample tool – **Fig (43)** consists of a bilge pump acting as a closed drive, a fixed displacement rotary piston pump and a water storage bag. The pump contains a suction tube and a discharge tube that transports the sample to the water bag.
The water bag is distinct because of its low cost, ingenuity, simplicity, virtual, adjustable closure, volumetric scale, and ease of separation from the system for sample delivery to the judge.

Figure 43: E-DNA sample tool by Abdallah

4. Payloads (The simulated UV light source)

The UV light source **-fig(44)** is made of a sealed led that is fixed in a plastic cup which the rov will position over the diseased area, then irradiate the diseased area of coral with a simulated UV light.

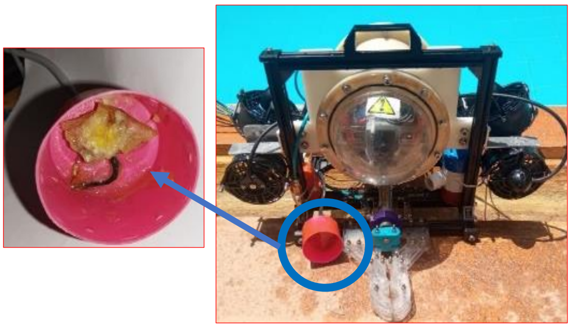


Figure 44: The UV light source by Abdallah

5. Payloads (Lift Bag)

Due to the Aquaside ROV's incapacity to lift heavy containers, we used a lift bag - **fig (45)** that uses compressed air to lift the heavy container by releasing compressed air through a non-return valve that controls the path of the compressed air and prevents any water intervention in the opposite direction, check the pneumatic circuit in the fluid power diagram Appendix A.3.

For easy attachment of the heavy container, it features a cut water bottle, rope, and hook.

Figure 45: Lift Bag by Abdallah

6. Payload (Eco-mooring tool)

This tool consists of a gear train and two wheels in a V shape to rotate the PVC pipe that will accomplish the mission. It is mounted on the frame side and motored by a sealed bilge pump for rotational motion purposes. We designed a gear train to increase the torque of the mechanism.

Figure 46: Eco mooring tool by solidworks

7. Payload (Sensors)

There was a pressure sensor in the Rov last year in order to meet the requirements of some missions, but this year there is no mission that requires the use of this sensor.

J. Non-ROV Device Vertical profiling Float: Cosmo

1. Mechanical Design

Cosmo **-fig (47)** was designed to flawlessly complete several vertical profiles. After reviewing numerous ideas and tests, the final design was created. The float consists of one enclosure made of PMMA that houses the float's brain and water storage volume that stores the water in it to increase the weight and change the buoyancy. Four syringes are activated by a nut that travels on a spinning threaded rod that functions as a power screw to suck the water in or out by a DC motor driving. The PMMA enclosure is sealed from both ends with HDPE caps and O-rings with a PMMA face. Pneumatic cables are used to help the water flow inside the float. The water tank is designed and positioned in such a way that the float remains stable while operating, allowing for successful vertical profiles with a low center of mass.
Two sets of four 4 mm diameter stainless steel rods hold and support the shelves of the electrical components.

Figure 47: Vertical float engine design by Solidworks

2. Electrical Design

Our float engine is powered mainly from 16 AA batteries (1.5V each). Eight batteries in series to be able to supply 12V. There are 2 sets of the eight batteries connected in parallel to be able to supply the demanded current. An Arduino Nano is mounted on the PCB with a 7805 regulator to supply 5V to power the Arduino. There are 4 male pin headers soldered on the PCB to connect the power and signal cables to the DC motor.

3. Software Design

The HC-12 was used to allow two Arduinos to communicate wirelessly. The first, known as the Transmitter, will be situated inside the floating engine, while the second, known as the Receiver, will be connected to the station laptop via USB. We chose the HC-12 module since it has 100 channels that can be switched between, each channel has its own frequency, and its range is 433.4 - 473.0 MHz; so, we may switch between them to minimize interference if required. However, HC-12 can communicate over a long distance (approximately 1 km). On the other hand, we control the movement of the float using a DC motor and L298 - Dual Full Bridge Driver.

a. Transmitter:

To be able to send data serially, we needed to use a battery powered RTC module with the code DS3231 on the floating engine Arduino, which provides us with the UTC time, but we need to configure it before we can send the UTC time alongside the company number to the topside Arduino.

b. Receiver:

It is made up of an HC-12 and an Arduino Uno. To receive the data being transmitted from the floating engine, the HC-12 module must be on the same channel as the transmitter. To easily visualize the data received from the floating engine, we used the threading concept to launch a thread that accepts serial data from the topside Arduino and displays it on the GUI.

The main reason for selecting the HC-12 module over the HC-05 Bluetooth module is that the HC-05 has a short-medium range and failed to transmit or receive across barriers during testing, but the HC-12 module proved otherwise.

We used a stepper motor with A4988, but it couldn't tolerate high pressure, so we had to replace it with DC motor.

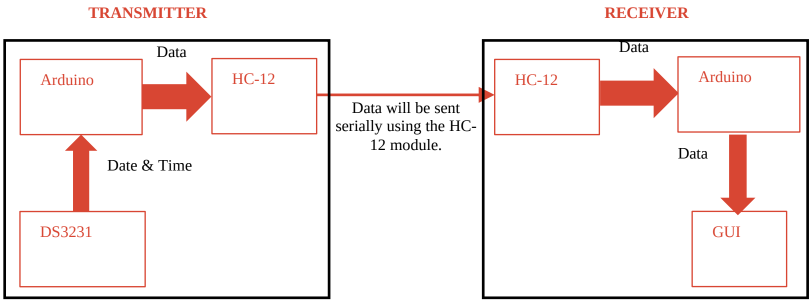


Figure 48: Float communication diagram

K. Non-ROV Device: Fry fish tool

The fry fish container -**fig (49)** is shaped like a drawer with magnetic field built into the bottom. As long as the magnetic field is active, the drawer remains closed. When the fry becomes accustomed to the local environment, the drawer opens, releasing the fry into the desired location by deactivating the magnetic field.

Figure 49: Fry fish tool

III. TROUBLESHOOTING AND TESTING TECHNIQUES

A. Troubleshooting

We followed a troubleshooting methodology each time, which allowed us to swiftly and easily discover the problematic item in our system. Since the software is the shortest route for handling a problem, we developed testing scripts that allow us to examine each component in the structure of our control system separately, allowing us to determine whether this component is working effectively. First, we run the Aquaside system script. If we don't receive a connection string from the downside control system, we then verify the compressor and power supply; the compressor's regulator must be set to 2.5 bars (2.5 x 105 Pa), and the power supply must deliver 12 volts. then attempt to send commands directly from the joystick via the Putty app without using a GUI. If the issue remains, we plug the laptop directly into the downside microcontroller to run a script that operates the thrusters to ascertain if the problem was only with the RS communication. As a final check to make sure that it's not a software problem, we continue testing the system on an external set of motors to ensure the problem is not on our main PCB. If nothing works, the electrical team starts to guarantee that the equipment is secure to be worked on; the first step with any electrical equipment is to check for electricity. When a problem arises, we examine each component independently in the internal structure. **[flowchart Shown in: Appendix D]**

B. Testing Techniques

At the beginning, remove any factor that could result in an unfair test. To test the sealing, we introduce a pneumatic hose into any enclosure or component that cannot be reached by water, then immerse Aquaside in water and use a compressor to raise the pressure in each component until any insufficiently sealed component produces bubbles inside the water. Then we ensure that the system is properly connected; if there is a problem, we examine each component individually in the internal structure and test the communications system.

IV. SAFETY

A. Company Safety Rationale

Team members are our most valuable resource, and no aspect of the business is more critical than their personal safety. We believe that all accidents can be avoided, that’s why safety has been our top priority throughout the manufacturing and operation of Aquaside Rov. We protected our team members by implementing safety standards for using tools **fig (50)**, where all members were taught the right operation before they began using them under the observation of our mentors. While testing Aquaside Rov, all our team members worked away from the pool edge except the tether man, and running on the surface of the pool was prohibited. In addition to these guidelines, we designed other safety features for Aquaside Rov to ensure the vehicle operators' safety.

Figure 50: Example of safety in our workshop by Adam

Safety Instructions

- During testing or manufacturing, at least two safety instructors must be present at the workshop.
- Using safety equipment such as goggles, gloves, and footwear while machining or using pneumatic circuits is a must.
- Members should make sure that their hands are dry when in contact with the power supply.
- picking up heavy equipment with a natural lower back to prevent spinal disc injury and lifting heavy objects together avoid lifting anything above the shoulder.
- Check overall insulation and waterproofing elements.
- It's necessary to use a holder for the welding iron while soldering the PCBs.
- A First aid kit, as well as a fire extinguisher, is provided in case of any emergency.

Figure 51: Safety instructions in our workshop by Adam

B. ROV And Float Engine Safety Features and Precautions

1. Mechanical Safety Features:

Our company prioritizes safety above all else and believes that all accidents are preventable by implementing strict safety measures. Therefore, numerous safety practices and protocols are enforced to ensure that all members are working in a suitable and safe environment as Safety instructions are always considered during designing, building, handling, and testing of the ROV and the float engine.

Our mechanical engineers ensured the presence of no sharp edges on the ROV. Also, moving parts, such as thrusters, are covered with Aluminum meshes designed by our mechanical team to meet IP20 standard. Thus, protecting the thrusters from any foreign objects of 12.5 mm diameter or greater. Cap nuts are used to eliminate any exposed threading. Our float has smooth curved edges and no sharp corners to prevent harm or injury when handled. The float engine is designed upon the principle of the piston seal of the cap that will open directly in case of a sudden increase in pressure within the housing which will act as a release container.

2. Electrical Safety Features:

A fuse-box between the 12V power supply and the tether, which has an inline two fuses of 30 Ampere was installed Polarized connectors and color-coded cables are used to prevent inverted connections for power and signal transmission across the whole system. A 30 Ampere fuse is placed on the PCB to avoid drawing more than the demanding current from the power supply. There is no exposed wiring within the float engine, and a 5 Ampere fuse is placed on the PCB of the float engine too for the same reason of safety.

3. Warning Labels:

To guarantee that anybody in contact with the ROV and the float engine is fully aware of the potential hazards, warning labels are placed on thrusters and moving parts, high-pressure parts, PMMA parts that may fracture, electrical components. You can check photos of the warning labels in the company safety review.

4. **Safety Procedures: Operational and Safety Checklists**

Throughout ROV operations, Eternal's Operational and Safety Checklists are strictly followed. Employees are also required to follow operational JSAs for ROV launch, recovery, and waterside safety. **[A detailed safety checklist in Appendix D]**

V. LOGISTICS

A. Scheduled Project Management

Eternal is divided into three major technical departments; mechanical, electrical, and software. Each department is further broken into project groups. Our mentors began each department with engineering training phases. After the training phase, the Election phase began, and we decided our CEO, CTO, and CFO, as well as the project leaders, based on their success in the training program and personal abilities. Then we had a research phase where we researched each project to determine what needed to be done, and then we moved on to the design phase where we designed the vehicle and software solutions for the tasks.

Following that is the implementation phase, in which two members of the mechanical department oversaw each of the following: designing the frame, tools and payloads, electronics enclosure and sealing, pneumatic systems, and manufacturing. Two members of the electrical department oversaw each of the following tasks: PCB, SID & power calculations, control panel, and enclosure rewiring. While two members of the Software team oversaw each of the following: ROV control system, Deep learning and vision, and float system. The final phase was the training and piloting phase to be able to train on the actual prop building and test our product to make sure it meets the tasks requirements.

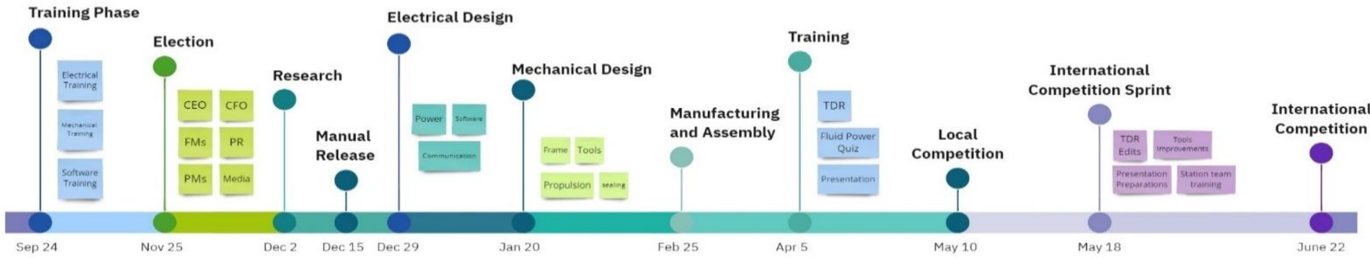


Figure 52: Team Timeline

B. Company Organization

1. Single Point of Responsibility.
2. Improve focus.
3. Improve communication among team members.
4. Improve reporting.
5. Resource flexibility

These benefits were easy to recognize while working with this organizational structure because the hierarchy was well-structured, and each member understood his or her position. On the other hand, because the CEO was the person who leads and oversees the team, as well as setting up general meetings to ensure that the three departments interacted regularly and tracked their success. The CTO met with the leaders on a regular basis to direct them and analyses their progress and the leaders had frequent meetings and constantly assigned work with deadlines to team members to ensure that we were on timeline-**fig (52).** We were able to adapt this organizational structure to our needs. Leaders were chosen for the software, mechanical, and electrical departments; each leader leads employees from the same department; additionally, we had a leader for each project in our ROV that communicates with the department leader.

C. Version Management

Our company used cutting-edge communication technologies such as the Slack application, which had a set of channels to communicate, and each channel with a purpose, project management channel, from its name it's a channel that contains the CEO, CTO, CFO, departments leaders to be able to communicate with each other and for the departments' leaders to be able to request manpower from each department if needed. A channel for each department for the members to be able to ask about tasks if there is something not clear,

finally project channel which is a channel for each project leader and his project members – **fig (53)** to be able to communicate, discuss, and finish project tasks and schedule meetings with each.
We used Trello app to distribute and handover work in the form of well-divided cards **-fig (54)** for each phase of the project; the flow of cards is strongly tied to our meetings. Team members meet with each other to distribute tasks and discuss project progress.

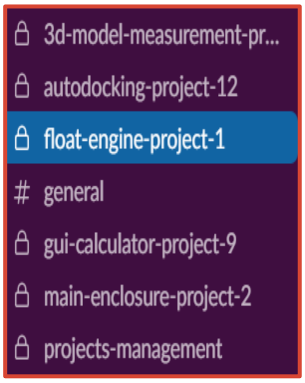


Figure 53: Eternal Slack Workspace

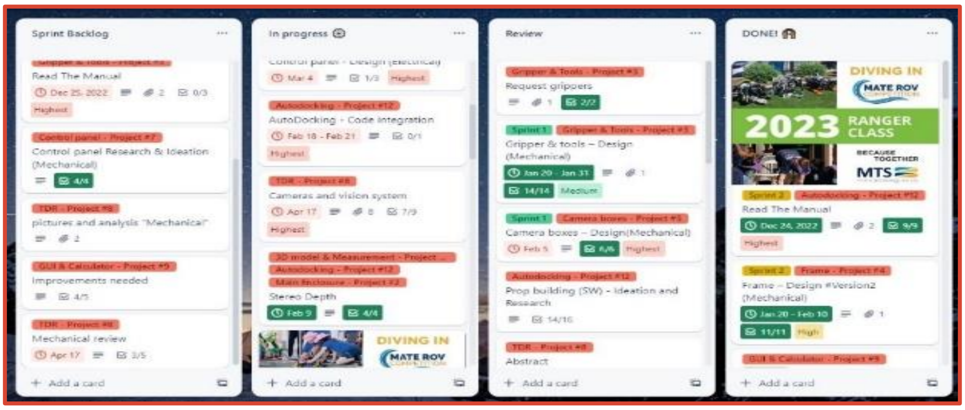


Figure 54: Eternal Trello Board

VI. BUDGET AND PROJECT COSTING

Eternal team develops a budget plan with expected expenses based on the previous years' actual costs and the main critical aspects for our ROV at the start of the project. To ensure proper purchasing, after the budget has been approved, all purchases must be confirmed by the company's CFO and our technical mentors. The company submitted purchase requests for evaluation and authorization to guarantee budget integrity. Purchase transactions were also tracked on a project budget sheet in **Appendix C** which was verified on a regular basis. Furthermore, all things were gathered from multiple sources before the purchase to confirm that the pricing was reasonable. In fact, a large percentage of the company's expenses were spent on materials and hardware that includes an Aluminum extrusion, a control panel, and all the vertical float engine's components. A detailed breakdown of costs and donations in **Table 3**.

Build vs Buy

Customized parts are cost-effective and customizable. The top-side camera enclosure this year reflects this. The aluminum extrusion profile was also machined on the miter saw equipment by members of the mechanical team.

Another custom-fabricated component of our ROV is the frame, which was milled out of sheets of High-Density Polyethylene (HDPE). It was easy for the team to develop buoyancy, tool, and propulsion mounting. The vertical float engine components were bought totally. Purchased components are sometimes important since they provide a quick and typically more reliable answer to any problem. Almost all the electronics onboard, for example, Arduino, Cameras, control panel, and the screen are purchased equipment. When compared to other options, this approach is significantly more time and cost-effective.

New vs Re-used

The team had to carefully evaluate both cost and ROV performance when deciding which parts would be purchased fresh and which parts would be reused from prior years' designs from our organization's "vortex academy" teams. The team members chose to purchase new equipment in areas that were crucial to this year's contract and overall ROV performance, while reusing what we could to save money and lessen our environmental effect. The electronics system is massively redesigned to both complete the mission tasks more effectively and improve the ROV's overall capabilities. New purchased components also include the case and the monitor of the control panel, Aluminum handle for easy lifting and handling the rov, and all the components of the float engine. Re-used components of this year's ROV include two T-100 thrusters and two T200 thrusters were reused from the previous team of vortex academy because of their relatively high cost, The tether, the video multiplexer, Arduino, cameras, pneumatic system, manipulator, and main computers, among other things. These were all high-cost items, where buying new offered no real performance advantages.

Table 3: Project Budget

Category	Income	Source		Amount(USD)
	Type	Description	Projected Cost	Budgeted value
Tether	Re-used	CAT6 cables	$101.46	
	Re-used	12 AWG Power cable	$16.33	
	Re-used	pnuematic cables	$32.66	
Electronics	Re-used	Buck boost	$20.00	
	Purchased	Anderson connector	$19.00	$19.00
	Purchased	PCBs	$20.00	$20.00
	Re-used	RS485	$35.60	
	Purchased	Terminal Blocks	$2.00	$4.00
	Purchased	Connectors	$6.00	$6.00
	Purchased	Cytron Motor (Dual Channel Driver)	$15.00	$15.00
	Purchased	MOSFETs & BJT	$2.13	$3.00
	Purchased	LEDs	$0.21	$1.00
	Purchased	Regulators	$0.22	$2.00
	Purchased	Fuse/Fuse Holders	$0.32	$1.00
	Re-used	Bilge Pumps	$40.00	
	Purchased	ESC	$144.00	$144.00
	Re-used	CCTV cameras	$69.00	
Float Engine	Purchased	Regulators	$0.24	$0.50
	Purchased	DS RTC3231 (clock module)	$3.88	$4.00
	Purchased	NEMA17 Stepper motor	$13.83	$15.00
	Purchased	A4999 (motor driver)	$6.00	$6.00
	Purchased	3A Fuse, Fuse holder	$0.10	$0.50
	Purchased	HC-12	$16.28	$17.00
	Purchased	AA Batteries, Battery holder	$46.42	$47.00
	Purchased	Power switch	$32.36	$33.00
	Purchased	Pistons	$9.00	$9.00
	Purchased	Pinheaders	$0.85	$1.00
	Re-used	Power Screw	$10.00	
Control Panel	Re-used	Monitor	$120.00	
	Purchased	Joystick	$56.00	$60.00
	Re-used	Case	$140.00	
	Re-used	DVR	$112.00	
	Purchased	HC-12	$16.28	$17.00
	Re-used	Arduino Uno	$5.66	
	Re-used	Video Baluns	$12.00	
	Purchased	Case Accessories	$35.00	
Hardware	Re-used	Materials (PMMA & PA type 6)	$190.00	
	Purchased	3D printed parts	$112.00	$115.00
	Purchased	Aluminum Extrrution&Accessories	$91.00	$91.00
	Purchased	Aluminum Handle	$12.00	$12.00
	Purchased	Aluminum sheet	$5.40	$6.00
	Purchased	Bolts & Nuts	$70.00	$70.00
	Purchased	CNC router	$146.40	$146.40
	Re-used	Compressor	$135.00	
	Re-used	DCV	$102.00	
	Re-used	Fittings	$32.00	
	Purchased	Foam sheet	$5.70	$6.00
	Purchased	Glands	$85.50	$85.50
	Purchased	laser cutting	$21.67	$21.67
	Purchased	O-Rings	$5.80	$6.00
	Purchased	PMMA dome	$47.50	$48.00
	Re-used	Pnuematic Piston	$48.00	
	Purchased	sheet metal bending	$41.60	$41.60
	Purchased	Stainless steel sheet	$12.40	$13.00
	Re-used	T100 thrusters	$290.00	
	Re-used	T200 thrusters	$400.00	
	Re-used	Thrusters' mesh	$40.00	
Logistics	Purchased	Poster Printing & Uniform	$540.00	$555.00
Travel	Purchased	Travel Expenses (Tickets & accommodations)	$23,265.00	$23,265.00
Total Expenses		$26,859		
Total Re-used		$1,987		
Total Expenses - Re-used		$24,872		
Total Fundraising Needed		$24,872		

VII. ACKNOWLEDGMENTS

MATE Centre and Marine Technology Education – for developing such a professional competition where engineers can pursue their interest in marine education.
AASTMT Arab Academy for Science Technology & Maritime Transport – for organizing the regional competition.
Vortex Academy and AASTMT School - for providing technical support throughout the competition as well as moral support and encouraging us to bring out our full potential.
Trello, Slack, Clockify and Google Drive – for assisting us in keeping track of our tasks and successfully functioning as a team.
Collab – Their faster GPUs aided us in the development of deep learning models.
Blender – to help us with generating 3D models.
Our mentors – for their continued technical support and encouragement.
Our families and friends – for their assistance in overcoming obstacles and achieving our objectives.
Ansys, SolidWorks™, VS Code Editor and Adobe photoshop - For providing us with a student license.

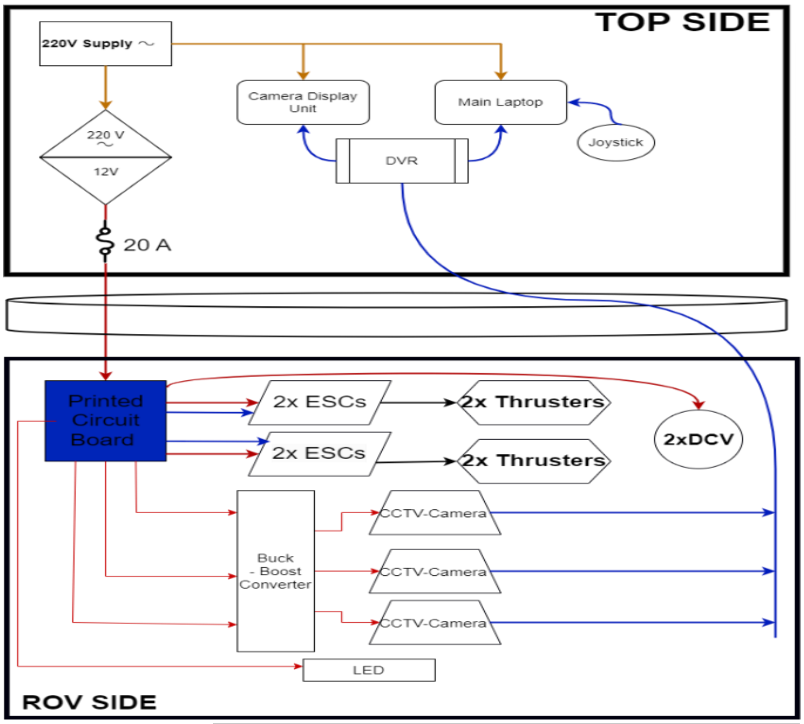
VIII. REFERENCES

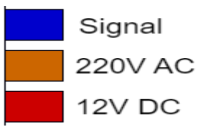
- Blue Robotics. “T100 Thruster Documentation.”: T100 Thruster Documentation
- Blue Robotics. “T200 Thruster Documentation.”: T200 Thruster Documentation
- Blue Robotics. “ESC Documentation.”: ESC Documentation
- MATE. “MATE ROV Competition Manual Rangers.”, 15 Dec. 2023.
- MATE. “MATE ROV Competition Video.”, 10 Mar. 2023.
- BLENDER. “Blender 3.5 Python API Documentation.”, 10 Apr. 2023. https://docs.blender.org
- OpenCV-Python Tutorials: https://docs.opencv.org
- Object Detection Documentation: Object Detection Documentation
- Camera Streaming Documentation: Camera Streaming Documentation
- (AI) Library Documentation: https://pytorch.org/
- Python Documentation https://www.python.org/
- Arduino home http://www.arduino.cc/
- Simple Shape OpenCV with python 3: https://pysource.com
- Parker O-ring handbook. 50th Anniversary Edition
- Fluid Mechanics Fundamentals and Applications by YunusCengel and John Cimbala 3rd edition
- IRF640 MOSFET Datasheet: http://www.alldatasheet.com
- PLA Material Properties: https://plastics.ulprospector.com
- Awg Wire Sizing Chart: https://homequicks.com
- Underwater Robotics: Science, Design and Fabrication by Steven W. Moore
- The ROV Manual: A User Guide for Observation-Class Remotely Operated Vehicles by Robert D. Christ and Robert L. Wernli Sr.
- https://www.rovplanet.com/

IX. APPENDICES

Appendix A: System interconnection diagrams

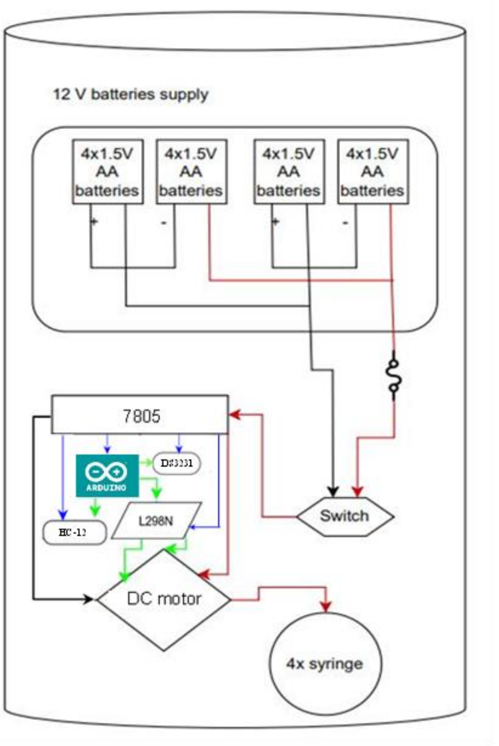
1. Electrical SID of ROV

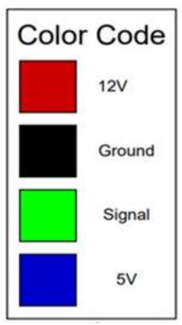


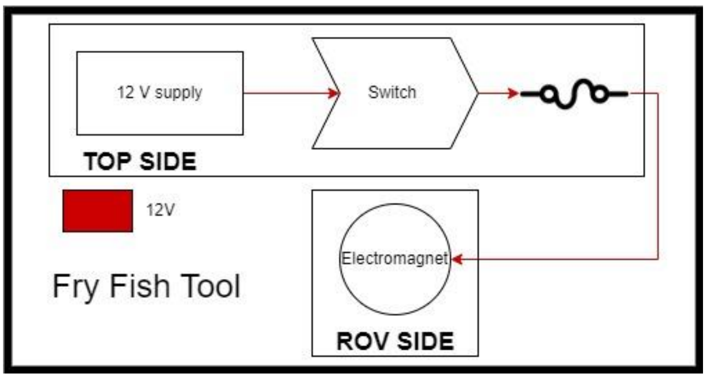


Max power Consumption = 494.16 Watt
Max Current = 20.5 Ampere
Fuse Calculations:
20.5 X 1.3 = 26.754 Ampere
Fuse used = 30 Ampere

2. Electrical SID of Non-ROV Device

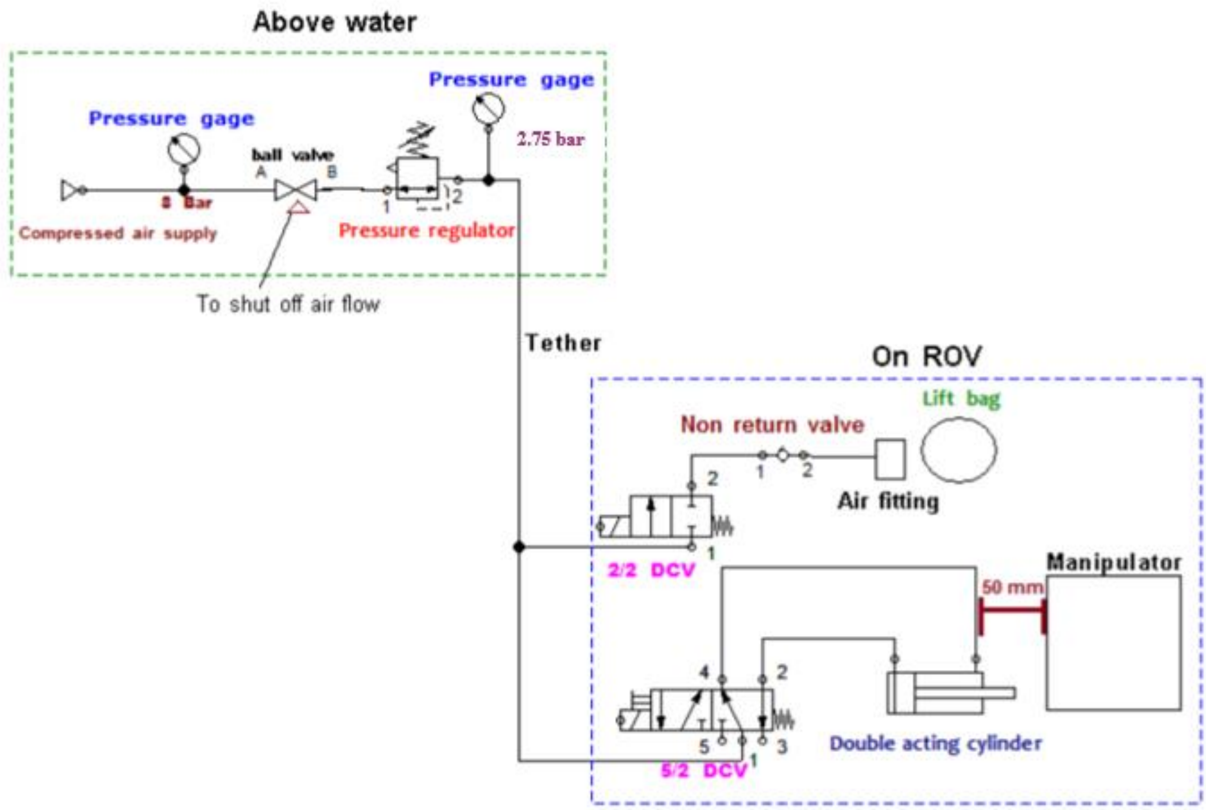




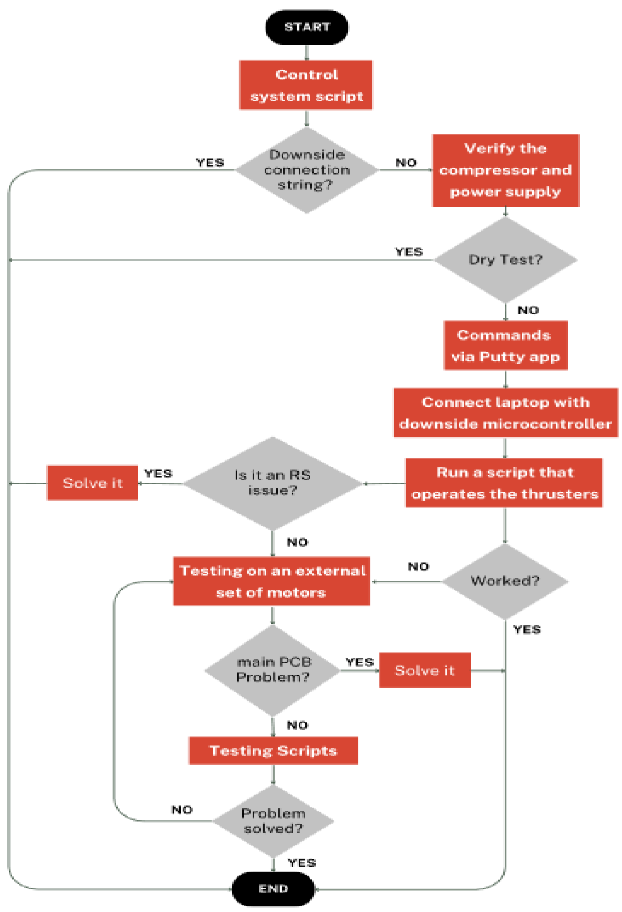


Fuse Calculations:
Max Current = 3.269 Ampere
3.269 X 1.5 = 4.9 Ampere
Fuse used = 5 Ampere

3. Pneumatic SID of ROV



Appendix B: Testing Techniques



Appendix C: Project Costing

Date	Type	Category	Descrption	Sources/Notes	Amount	Running Balance
Cash donated		General	Self-Funds from Team Members	Used for general veicle construction		$2,000
28/2/2023	Re-used	Electronics	Buck boost	Vortex Company	$20.00	$2,000.00
28/2/2023	Purchased	Electronics	Anderson connector	Saftey	$19.00	$1,981.00
2/3/2023	Purchased	Electronics	MOSFETs & BJT	Vortex Company	$2.13	$1,978.88
2/3/2023	Purchased	Electronics	Regulators	Vortex Company	$0.22	$1,978.66
3/2/2023	Purchased	Electronics	PCBs	Signal & power distribution	$20.00	$1,958.66
4/2/2023	Purchased	Electronics	Terminal Blocks	Signal & power distribution	$2.00	$1,956.66
4/2/2023	Purchased	Electronics	Connectors	Signal & power distribution	$6.00	$1,950.66
5/4/2023	Purchased	Electronics	Cytron Motor	Signal & power distribution	$15.00	$1,935.66
5/4/2023	Re-used	Electronics	Bilge Pumps	Vortex Company	$40.00	$1,935.66
6/4/2023	Purchased	Electronics	LEDs	Vortex Company	$0.21	$1,935.45
12/12/2023	Re-used	Electronics	RS485	Vortex Company	$35.60	$1,935.45
18/2/2023	Re-used	Electronics	CCTV cameras	Signal	$69.00	$1,935.45
25/3/2023	Purchased	Electronics	ESC	Controlling	$144.00	$1,791.45
28/2/2023	Purchased	Electronics	Fuse/Fuse Holders	Vortex Company	$0.32	$1,791.13
18/2/2023	Purchased	Float Engine	Regulators	Signal & power distribution	$0.24	$1,790.89
2/4/2023	Purchased	Float Engine	Pistons	Fastners	$9.00	$1,781.89
8/3/2023	Purchased	Float Engine	HC-12	Signal	$32.36	$1,749.53
18/2023	Purchased	Float Engine	Power switch	Initialize the float	$46.42	$1,703.11
20/2/2023	Purchased	Float Engine	DS RTC3231 (clock module)	Clock provider	$3.88	$1,699.23
20/3/2023	Purchased	Float Engine	NEMA17 Stepper motor	Controlling	$13.83	$1,685.40
20/3/2023	Purchased	Float Engine	A4999 (motor driver)	Controlling	$6.00	$1,679.40
20/3/2023	Purchased	Float Engine	3A Fuse, Fuse holder	Saftey	$0.10	$1,679.30
22/3/2023	Purchased	Float Engine	Pinheaders	Holders	$0.85	$1,678.45
23/3/2023	Re-used	Float Engine	Power Screw	Vortex Company	$10.00	$1,678.45
28/3/2023	Purchased	Float Engine	AA Batteries, Battery holder	Signal & power distribution	$16.28	$1,662.17
15/3/2023	Re-used	Hardware	Materials (PMMA & PA type 6)	Frame	$190.00	$1,662.17
5/3/2023	Purchased	Hardware	Aluminum Extrrution&Accessories	Frame	$91.00	$1,571.17
14/2/2023	Re-used	Hardware	DCV	Sealing	$102.00	$1,571.17
14/2/2023	Re-used	Hardware	Fittings	Sealing	$32.00	$1,571.17
14/4/2023	Purchased	Hardware	laser cutting	Vortex Company	$21.67	$1,549.50
17/3/2023	Purchased	Hardware	3D printed parts	Frame structure	$112.00	$1,437.50
18/4/2023	Re-used	Hardware	Compressor	Sealing	$135.00	$1,437.50
19/4/2023	Purchased	Hardware	PMMA dome	Vortex Company	$47.50	$1,390.00
23/3/2023	Purchased	Hardware	Aluminum Handle	Frame handling	$12.00	$1,378.00
23/3/2023	Purchased	Hardware	Aluminum sheet	Frame buoyance	$5.40	$1,372.60
23/3/2023	Purchased	Hardware	CNC router	Machining	$146.40	$1,226.20
23/3/2023	Re-used	Hardware	Pnuematic Piston	Vortex Company	$48.00	$1,226.20
23/3/2023	Purchased	Hardware	sheet metal bending	Vortex Company	$41.60	$1,184.60
23/3/2024	Purchased	Hardware	Stainless steel sheet	Vortex Company	$12.40	$1,172.20
24//2023	Purchased	Hardware	O-Rings	Sealing	$5.80	$1,166.40
24/3/2023	Purchased	Hardware	Bolts & Nuts	Saftey	$70.00	$1,096.40
24/4/2023	Purchased	Hardware	Glands	Sealing	$85.50	$1,010.90
25/3/2023	Re-used	Hardware	T100 thrusters	Vortex Company	$290.00	$1,010.90
25/3/2023	Re-used	Hardware	T200 thrusters	Vortex Company	$400.00	$1,010.90
25/4/2023	Purchased	Hardware	Foam sheet	buoyance	$5.70	$1,005.20
26/3/2023	Re-used	Hardware	Thrusters' mesh	Vortex Company	$40.00	$1,005.20
4/2/2023	Re-used	Tether	Cat 6	Signal	$44.00	$1,005.20
4/2/2023	Re-used	Tether	12 AWG Power cable	power	$16.33	$1,005.20
4/2/2023	Re-used	Tether	Pneumatic Cables	Vortex Company	$8.25	$1,005.20
28/4/2023	Re-used	Control Panel	Monitor	TCU	$120.00	$1,005.20
8/2/2023	Purchased	Control Panel	HC-12	Signal	$16.28	$988.92
8/3/2023	Re-used	Control Panel	Arduino Uno	Vortex Company	$5.66	$988.92
19/3/2023	Re-used	Control Panel	Case	Vortex Company	$140.00	$988.92
25/3/2023	Purchased	Control Panel	Case Accessories	Vortex Company	$35.00	$988.92
27/4/2023	Purchased	Control Panel	Joystick	Controlling	$56.00	$932.92
28/4/2023	Re-used	Control Panel	DVR	TCU	$112.00	$932.92
28/4/2023	Re-used	Control Panel	Video Baluns	Vortex Company	$12.00	$932.92
15/4/2023	Purchased	Logistics	Poster, Uniform, Mate fees	Marketing $ fees	$555.00	$377.92
		General	Self-Funds from Team Members	For travel and accommodation	$23,200	$23,200
5/5/2023	Purchased	Travel	Purchased	Travel Expenses (Tickets & accommodations)	$23,365.00	$212.92
Total Raised				**$25,200**		
Total Spent				**$24,987**		
Final Balance				**$213**		

Appendix D: Operations and Safety Checklist

PROCEDURE	CHECK MARK
Pre-Power Checks	
Station members are wearing safety gear	
Check that Thrusters and Manipulators are not obstructed by anything	
No running at the pool	
Before conducting the safety check, power is turned off	
Make sure the fuse isn't blown.	
Clear obstructions from propellers, shafts, and manipulators.	
Electrical connections are waterproofed, and cables are tied down.	
Make sure the working environment is clear of obstructions	
"Safe" say it loudly.	
Pre-Water Checks	
Connect tether to the control panel	
Test the video system	
Compress the electronics enclosure to the called dive's rated depth.	
Check that compressor pressure is below 2.75 bars	
Lower the ROV into the pool by two team members and the tether man	
"In Water," say it loudly.	
In-Water Checks	
Check the warning lights after turning on the system.	
Verify that the internal pressure is steady at the surface.	
Check for air bubbles and look for leaks visually.	
"Pilot in Command," say it loudly.	
Communication breakdown	
Restart the ROV	
Send another test package.	
If there is no communication, turn off the ROV.	
Bring the ROV to the surface with the tether and inspect it for damage or leakage.	
Recovery Checks	
Make sure the ROV is at the surface and looking away from the pool wall.	
Turn off the system and say, "Crew in Command."	
Lift the ROV from the pool onto land by two crew members and a tether guy.	
Rearrange the tether neatly	
Safety Keeper Signature:	
ENTERING THE LAB OR WORKSHOP	
Wear the facemask and PPE provided by the company	
Sign and timestamp the Signing Sheet for Employees	
Operating Power tools	
Wear all PPE necessary for the tools	
Always keep your hands away from the tool's head	
Keep long hair tied back and spinning sections free of strings, ropes, and flexible fabrics/materials.	
Working with Electrical Components and Soldering.	
Use a solder fume extractor	
keep the soldering iron or hot air hand tool in its holder, When not in use.	
Check all electrical connections to ensure they are not in contact with liquids	
Employee Signature:	