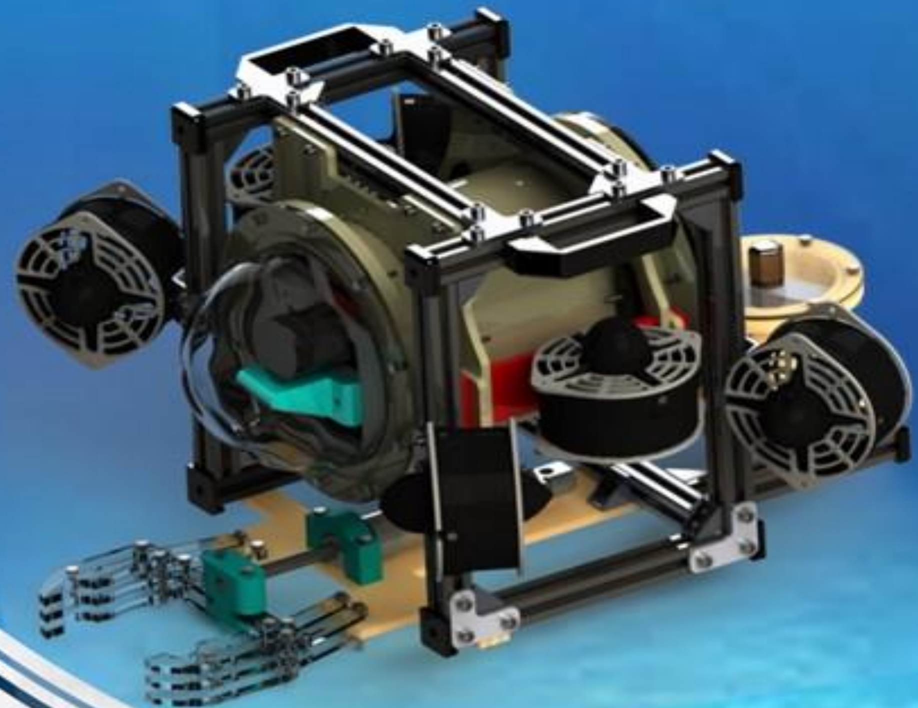

MATRIX

Matrix Team
Technical Documentation 2022
Alexandria, Egypt

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MATE ROV COMPETITION

VORTEX ACADEMY
THE ART OF THINKING

Abstract

In response to a call for proposals (RFP) from our worldwide community that aligns with one or more of the 17 UN Sustainable Development Goals, which, while not specific to the Decade of the Ocean, provide a plan for achieving a better and more sustainable future for all. Each assignment also incorporates ESG - environmental, social, and governance concerns that are increasingly being considered by businesses and organizations when making business and management decisions. Matrix team has designed and built the Square ROV which meets all requirements for the proposal to combat climate change, provide clean energy, feed our growing global population, monitor ocean health, and preserve our maritime history.

Matrix team was founded this year, by the mentoring of Vortex Company with the aim of attaining the highest quality ROV. The team is made up of ten dedicated and motivated middle and high school students who spent months learning, planning, developing, testing, and troubleshooting that eventually resulted in our ROV, Square, as a marketable product.

Square ROV is distinguished for its portability, compact size, stability, ease of assembly, and inexpensive price. It was made with a variety of techniques, including laser cutting, CNC routing, and 3D printing. A new design concept based on an Aluminum extrusion; a relatively new element employed in today's industrial underwater applications. Square has six thrusters for the required movements, a pneumatic system for the main gripper, vision cameras, custom-made printed circuit

Figure 1:Matrix team members in regional competition 2022

Contents

Design Process

A. Design Rationale

Square ROV was created with a cost-cutting mindset in mind, which our design team maintained throughout the process. Our vehicle sprints through the water, executing task after task with unparalleled speed and agility, thanks to its sleek, multi-purpose design. Our design is completely unconventional; it's based on and improves on the designs of previously manufactured rovs. A significant amount of time was spent investigating the advantages and disadvantages of previous models, as well as thinking about ways to improve their design. 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 then we simulated the water flow through our vehicle by CFD ANSYS fluent -fig (4). So, we were also able to thoroughly test our design before it went into production thanks to SOLIDWORKS and ANSYS. The mechanical design team put in a lot of effort, but the true problem was getting our vehicle to move smoothly, which our electrical team accomplished. The electrical team was able to incorporate the electronic components into our ROV through meticulous planning and close collaboration with the design team, allowing for responsive control over the ROV's path.

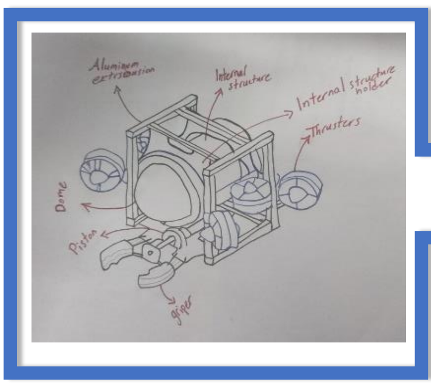


Figure 2: fee hand Sketch of Square ROV

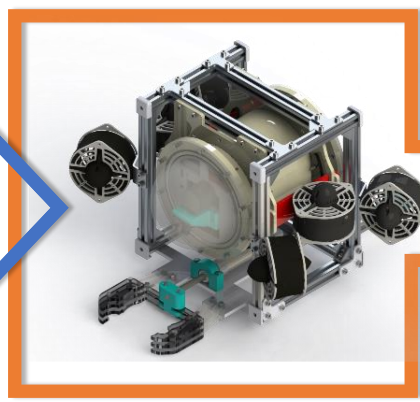


Figure 3: 3D Modelling of Square ROV by Solidworks

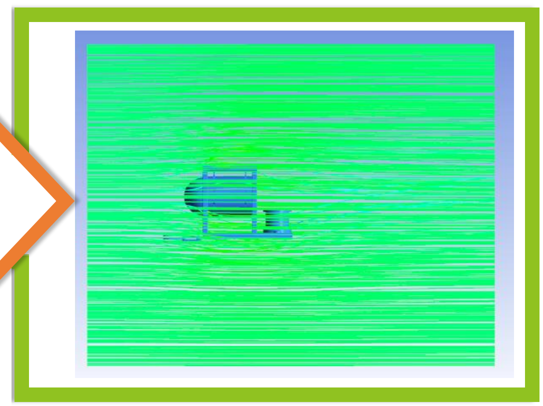


Figure 4: Simulation of water on Square ROV by Ansys fluent.

B. Vehicle structure and Size, and weight constrains

The design of Square ROV was inspired by the Yello boxfish-**Fig(5).** The opening design concept of the frame structure helps minimize the drag force and reduce eddies.

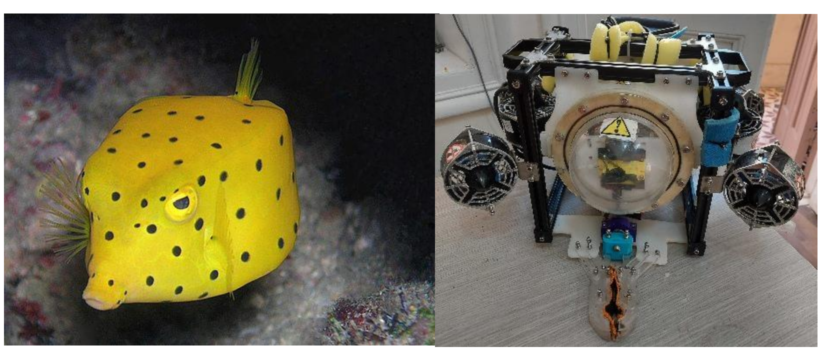


Figure 5: Yellow box fish (Left) and Our Square ROV(Right)

The Square ROV utilizes a number of innovative design features to retain excellent operational efficiency and control. For size, The vehicle was designed to fit in the ice hole so it fits in 53.5 cm of circle diameter **-fig(6)** which is smaller than the 99 cm width and length of the ice hole in task3, Antarctica Then and Now **-fig (6)**. For weight, The square rov weighs 14.5 kg in the air, with a 25-meter cable included meeting the competition's weight requirement with the maximum bonus. In freshwater, the Square ROV can carry out missions deeper than 10 meters. It operates at a voltage of 12 VDC and a current of 16 amps, which is significantly below the competition's limit of 30 amps.

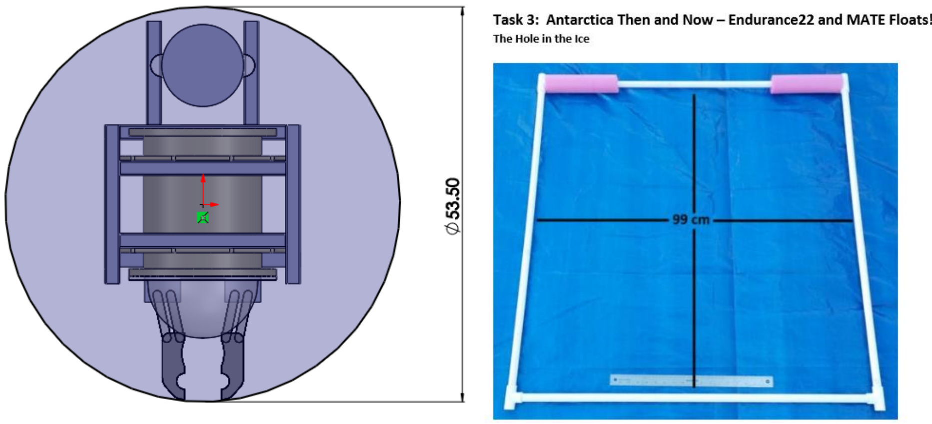


Figure 6: Square ROV fits in 53.5 cm diameter (Left) and the ice hole dims in prop building (Right)

C. Mechanical Design

1. Frame

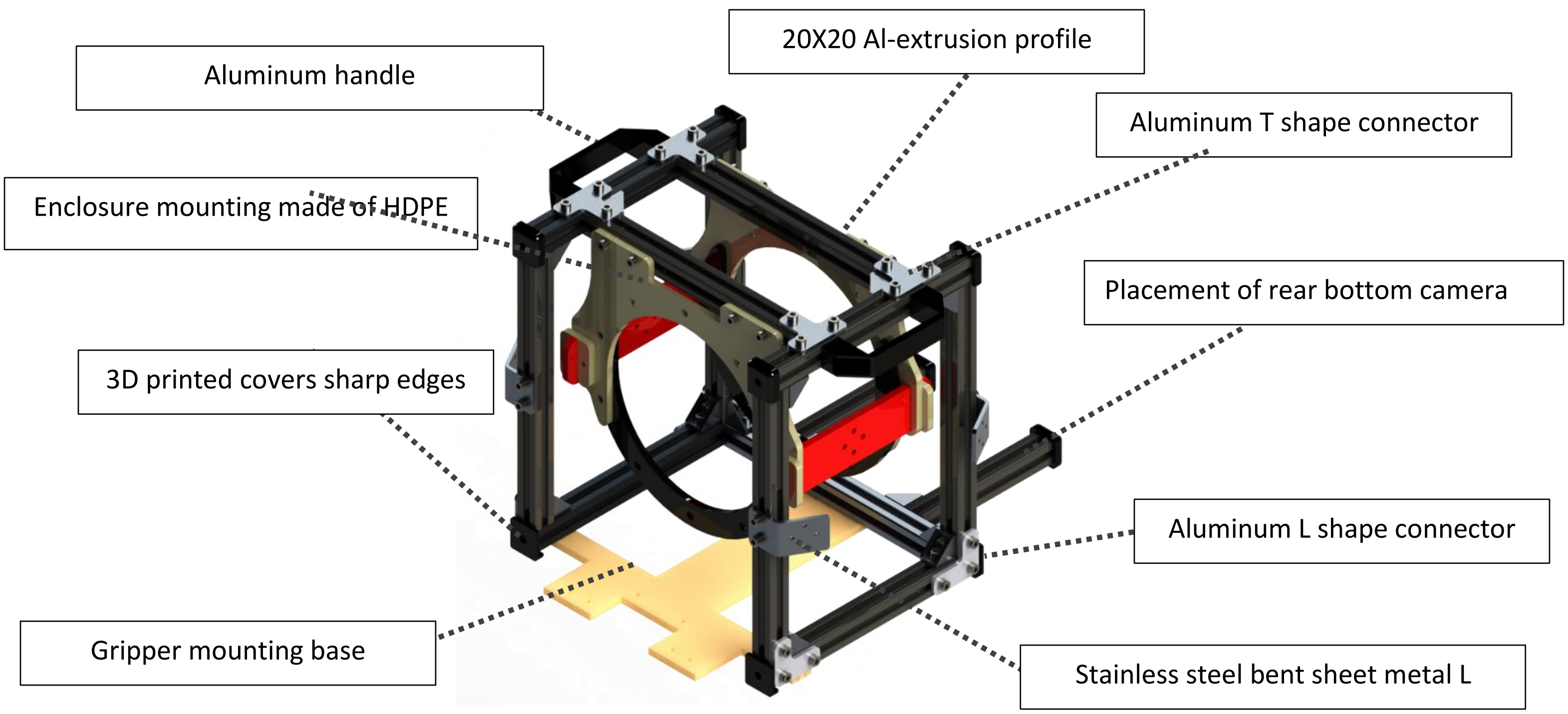


Figure 7: Square Frame

The main structure of the frame **-fig (7)** is consisted of eleven 20X20 Aluminum extrusion profile which means a width of 20 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 (8)**.

Figure 8: Al-extrusion and its accessories

Figure 9: Enclosure and its holder parts

Aluminum extrusion profile is inserted to support the enclosure holder's weight and to lock the rotation of the enclosure. The holder parts of the enclosure **-fig (9)** 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.

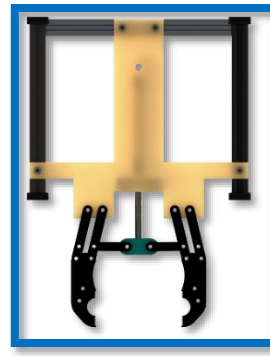


Figure 10: Gripper and its base mounting

The manipulator is held in place by a 6mm thick HDPE (High-Density Polyethylene) base that was built using a CNC (Computer Numerical Control) router and it is fixed on three profiles of 20X20 aluminum extrusion **-fig (10)**.

Figure 11: Thruster and bent L mounting

Thruster 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 60-degree angle. We preferred the bent aluminum rather than the 3d printed parts since the aluminum has more strength, and rigidity but the PLA material of the 3d printed parts is fragile and absorbs water that making it heavier.

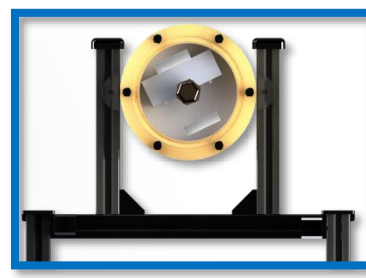


Figure 12: Bottom camera mounting

Rear bottom camera enclosure is mounted on a two 20X20 aluminum extrusion profile through T nuts and M5X8 bolts.

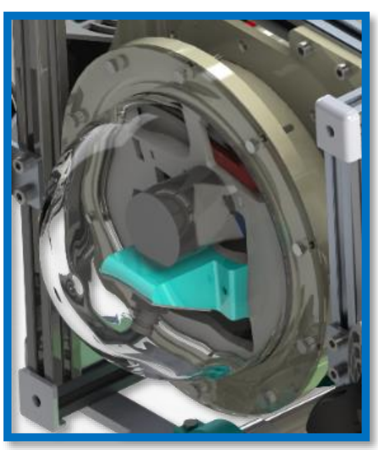


Figure 13: PMMA dome

A 6mm thick transparent polymethyl methacrylate (PMMA) dome **-fig (13)** covers the front face of the Square 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.

3D printed part -fig (14) of PLA material to cover the sharp edges of the aluminum

Figure 14: 3d printed part

Figure 15: Aluminum handle

Aluminum handle -fig (15) for easy handling of the rov

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

2. Buoyancy and stability

The enclosure on the Square ROV displaces the most water, at 664,824.2 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 Square 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 symmetry, the ROV's CB and CG are centered in the middle of the square ROV.

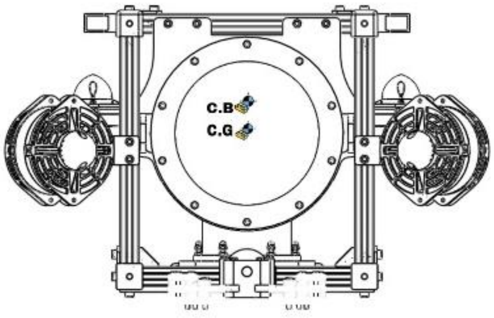


Figure 16: Centers of Buoyancy and Gravity

3. Propulsion:

Six thrusters propel Square ROV (2 T200 and 4 T100), providing it unprecedented freedom of movement while lowering drag -fig (17). Four thrusters T100 are fastened to bent sheet metal stainless steel installed at a 60-30-degree angle on an aluminum extrusion profile. The active thrusters may be swapped to cancel out the rotation, allowing movement in any direction on a 2D plane. A pair of upward-pointing T200 thrusters allow the vehicle to quickly dive or recover, as well as make moderate depth modifications. Because the thrusters are spaced closer together, there is a reduced surface area, which minimizes drag and makes transporting the ROV easier. The thrusters are Blue Robotics T100&T200 thrusters -fig (18), a high-performance variant with a rating that can endure pressures at depths of thousands of meters. It was an easy choice because of its straightforward control, Moderate cost, and mounting options.

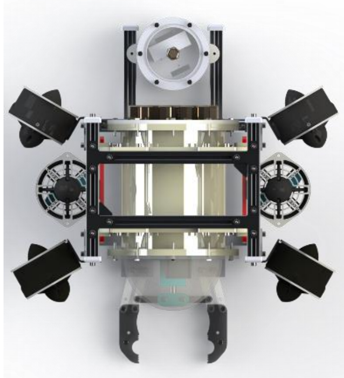


Figure 17: Square ROV's 6 Thruster Configuration

Table 2: Maximum Possible Thrust Force Calculations.

Direction	Maximum Thrust
Upward	2x36.38267= 72.76N
Downward	2x28.4393=56.87N
Forward	2 x 23.15 x sin (60) = 40.1 N
Backward	2 x 17.85 x sin (60) = 30.1 N
Lateral	(23.15 x cos 60)) + (17.85 x cos (60)) = 20.5 N


Figure 18: T-100 Thruster

4. Square 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 (19), 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 (20) Also, you will notice a low velocity down to zero as the kinetic energy is converted to the pressure energy.

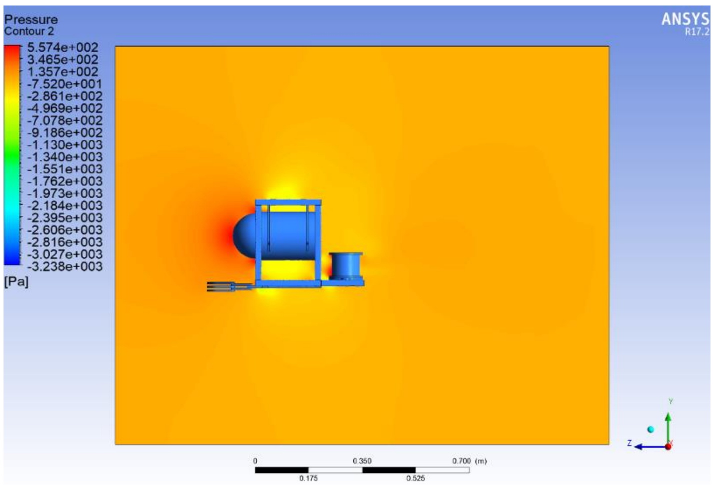


Figure 19: Pressure distribution

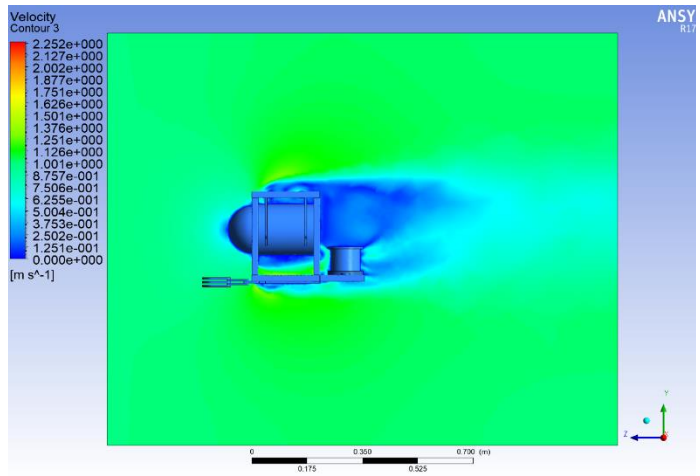


Figure 20: Velocity distribution

Drag force calculations

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

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

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

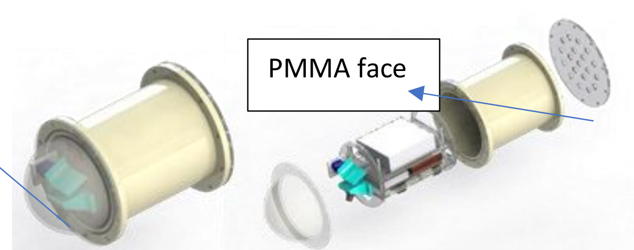


Figure 21: Square ROV's Electrical Enclosure

5. Electrical enclosure and sealing:

At the heart of our vehicle, is an inclusive lathed machined pressure housing -fig (21) 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-rings -fig (22) 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 (21), and a PMMA dome -fig (21) 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. PA Type 6 was selected as there are no pores formed within the material, meaning that it can act as a perfectly sealed container.

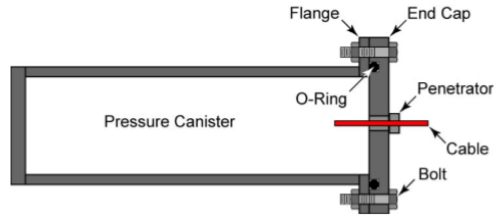


Figure 22: Cross section of the electrical Enclosure

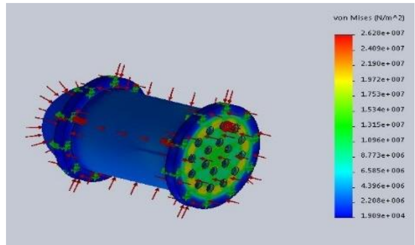


Figure 23: Stress analysis by solidworks

A stress analysis -fig (23) 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.

The vehicle's power and control are delivered through an array of glands mounted on the PMMA face. The chosen glands are Nickel-Plated Brass Cable Glands –fig (24) as they have an IP rating of 68, can withstand a pressure difference of 8 bars, and are characterized by rust and corrosion resistance. Some modifications were made on the gland; custom made rubber fittings were made to match the diameter of the cables going into and out of the electrical enclosure.

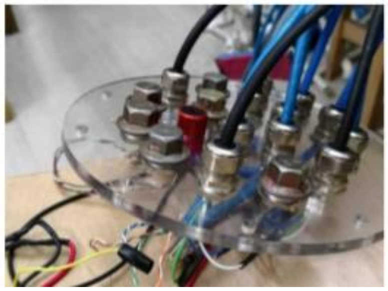


Figure 24: Cable Glands Attachment

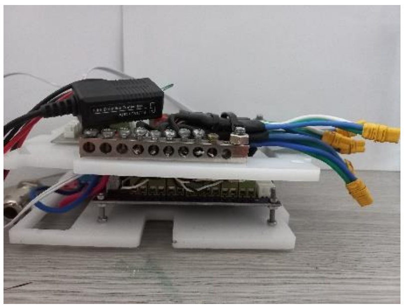


Figure 25: Internal Structure

The internal structure -fig (25) of the enclosure is made of HDPE (High-Density Polyethylene shelves. The power electronics and distributors are placed at the top of enclosure; to protect them in case a leakage occurs. The DCVs are placed at the bottom of the internal structure; as they're heavy, shifting the CG of the vehicle downwards and increasing the stability. Two cameras are placed within the acrylic dome, one is held by a 3D printed mount, and the other is attached to a servo allowing for free rotation within the dome.

6. Payload (Gripper)

Square ROV is equipped with one gripper -fig (26) to perform the necessary tasks like picking the mort and holding the float engine to and from it place in the least time possible. The gripper is directly attached to the HDPE base of the ROV through a 3D printed mount and an M8 bolt. The material chosen was clear 6mm-thick laser-cut PMMA, to provide a clear view for the pilot of the held objects during task performance like pulling the pins in task 1.1. 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 2.

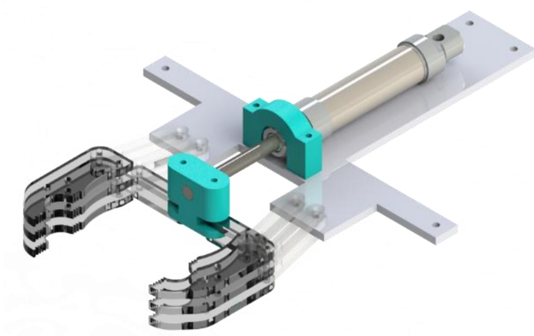


Figure 26: Square ROV's gripper

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 in order 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. 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.

7. Actuation method of the gripper: Pneumatic system

When we first thought about using electric motors or actuators for the manipulators, we found that the load that can be lifted is limited and requires a high current. Besides, the sealing of such motors and actuators will be complicated and causes an increase in their size. When we considered the fluid power systems option, we realized that the pneumatic components' water the tightness can endure high depths and withstand high loads depending on the pressure inside it. Although hydraulic systems' rated pressure is higher and use incompressible fluids, we chose pneumatic systems because their components are lighter, cheaper, and smaller in size. The air is supplied from the station to Square ROV through a pneumatic hose that has an inner diameter of 4 mm and an outer diameter of 6 mm. It's able to withstand pressure up to 10 bars (10^6 Pa), It is attached to the tether and then distributed to the two-directional control valves after entering the rear cover of the inclusive housing. Solenoid directional control valve of the type 5/2 for the gripper cylinder.

D. Electrical Design:

The ROV's electrical system is designed to be easily assembled, with pluggable accessible wire terminations. An onboard double layered PCB was customized to accommodate the microcontroller and most of the components. The joystick sends signals to the microcontroller through the RS485 communication module which controls the actuators, and a C# based GUI displays the readings of sensors, direction of maneuvering and speed level. The ROV uses a 12-volts external power supply which feeds the ROV through a fused tether.

1. Power Distribution

The current supplied from the 12volt source passes through the 25Amp fuse, to supply the electric system onboard. Because a sudden voltage drop may occur across the tether and consequently the electromagnetic interference (EMI) and noise can disturb the cameras due to the high rate of voltage change. Accordingly, a buck-boost converter -fig (27) was used to stabilize this disturbance.

Figure 27: Buck-Boost Converter

Component	Voltage (Volts)	Max current (Amperes)	Max power (Watts)	Quantity	Total max power (Watts)	Total max current (Amperes)
T100	12	10	120	4	480	40
T200	12	16	200	2	400	32
Camera	12	0.3	2.4	3	7.2	0.6
DCV	12	0.28	3.36	1	3.36	0.56

Table 3:Maximum Power Consumption Calculation

Maximum power consumed = 930.56 watts **Maximum current = 76.52 Amperes**

Maximum power is limited by a software interlocking system that prevents the speed from exceeding a certain speed -1720 µs PWM input to the ESC -fig (28), and only one thruster movement can be executed. Therefore, the actual maximum power is **190 Watts**, and the maximum current is **14.8 Amperes**.

Fuse needed: 14.8*1.5 = 22.2

Fuse used: 25Apms.

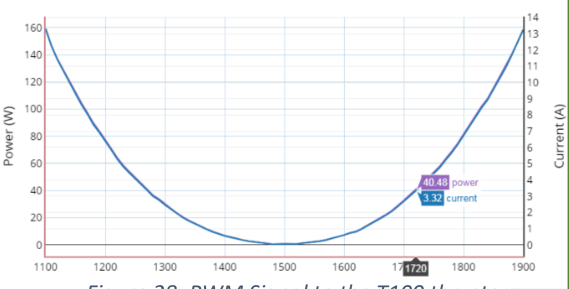


Figure 28: PWM Signal to the T100 thrusters

2. Communication modules onboard:

The communication system is dependent on the RS-485 communication module which is half-duplex UART communication system. The control panel is equipped with a PCB-fig (29) on which the master Arduino UNO microcontroller is responsible for the communication bridge with the slave Arduino Mega microcontroller in the ROV. The RS485 has a signal noise immunity and is known to sustain long distance communication up to 1200 meters.

Figure 29: Top Surface Communication Board

3. System onboard

We designed our own double layer PCB-fig (30) to minimize the size of the electrical system without compromising any components we need, with protection through a diode to protect the PCB from reverse voltage connections. The board houses the Arduino to connect the digital pins of the Arduino to the IRF640 MOSFETS to control the DCV and provide sufficient power to the Arduino. The excess pins of the Arduino are outputted as pin headers to accommodate any modifications to the system. We tested first using a prototype made by us and after testing the prototype and making sure that it works properly, the Gerber Files were sent to a factory to build the final PCB which is used in the ROV.

Figure 30: System PCB

4. Control system:

a- Microcontroller:

We used Arduino boards-fig (31) as they are open-source microcontrollers and available at hand. Arduino MEGA (2560) 32-bit was the most suitable for our control system as it has the serial communication (UART) port needed to communicate with the RS-485A and it has 54 digital input/output pins to be able to control all the ROV's thrusters and 12 analog input pins to read sensors' date.

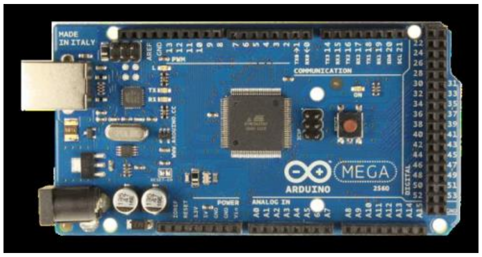


Figure 31: Arduino Mega

b- Thrusters control:

All the T100 and T200 thrusters are controlled using 6 ESCs -fig (32) (electronic speed controllers), where the Arduino Mega sends PWM (Pulse width modulation) signals to control the speed and direction of the thrusters.

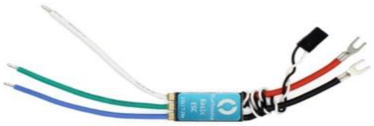


Figure 32: ESC

c- DCV control:

We control the 5/2 DCV using IRF640 MOSFETs -fig (34), that control the high power of the loads with the 5V digital signal supplied by our Arduino mega. The temperature of the MOSFET was deducted -fig (33) to ensure that there is no excessive heating.

IRF640 MOSFET temperature calculations:

$$I_D = 0.28\ A$$
$$R_{DS(on)} = 0.18\ \Omega$$
$$P_{dissipated} = R_{DS(on)} \times I_D{}^2 = 0.014 watt$$
$$R_{th\ j-a} = 62\ ^{\circ}C/watt$$
$$\Delta T = R_{th\ j-a} \times P_{dissipated} = 0.87^{\circ}C$$

Figure 33: MOSFET Calculation

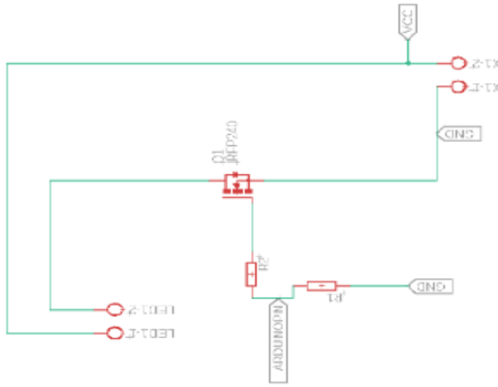


Figure 34: MOSFET Circuit

5. Tether

a- Communication:

The data is transmitted from the station to the ROV through two Category6 (CAT6) Ethernet cables which have 4 twisted pairs each. One cable is for the USB –RJ45 adapter to transfer the commands to the Arduino mega and the other is for the cameras. The CAT6 that we used can provide serial communication at a rate of 250 Kbps (kilobits per second).

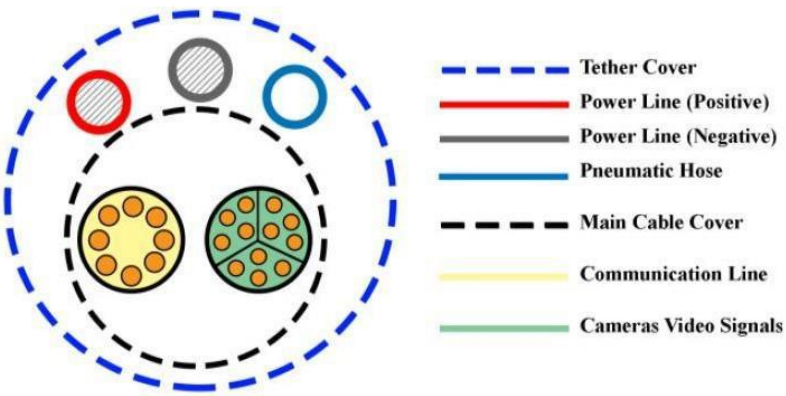


Figure 35: Tether Diagram

b- Power:

Based on the AWG wire sizing chart, a 6 AWG (4 mm) power cable was selected in to decrease the voltage-drop across the tether terminals providing the system with a more stable voltage. Knowing that our current limit is 16amps, our wire selection was based on this calculation:

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

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

6. Vision system

Our system utilizes 3 CCTV cameras that have a focal length of 2.8mm with an angle view of 89.9° horizontally and 79.8° vertically. 3 cameras were used; one for the gripper view tilted 45°, the other is facing forward for pilot's front view and the third viewing the bottom side of the ROV for the photomosaic mission and mapping the wreck. We also managed to get all the camera frames on our surface computer for any needed image processing in the wreck measurement mission and the fish measurement.

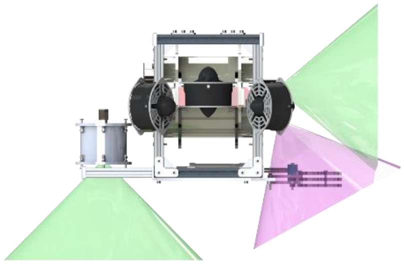


Figure 36: Cameras' Vision Cones

7. Station

a- Main laptop

Our pilot controls the ROV using a PlayStation Joystick, connected to our main laptop. A Graphical User Interface (GUI) demonstrates the ROV readings to the pilot, such as thrusters speed and manipulators indication.

b- Control Panel:

The ROV's control panel hosts the master RS-485 communication module, video baluns, DVR, for live streaming from the cameras to the LCD screen and serves as the main outlet power for all components. All components are secured thoroughly, and AC and DC powers are separated and labeled. Our DVR is connected to the surface computer via RJ45 through a local network between the DVR and the computer.

Figure 37: Our Topside Control Panel

E. Software Design

1. Onboard software:

Our software engineers designed the onboard software using the most flexible architecture: the Round-Robin architecture which is considered to be one of the simplest techniques; because there are no interrupts, no shared data and no latency concerns. Our main loop checks each I/O devices in order, services any device requests and returns data from the sensors to the top-side Arduino if needed. Therefore, our onboard software is characterized by its ease of modification & debugging allowing for accomplishing a wide variety of mission with minimal changes in the core system.

2. Surface-Side software:

Our surface system is broken down into 3 main independent processes; Control unit, Graphical User Interface and the Mission specific software (Image processing, measurements, etc. All processes are running asynchronously to prevent any code dependency between different codes and allowing them to access any needed data throw an inter-process communication system that boosts the performance of all 3 modules.

i. Control unit:

The control consists of an Arduino connected to the pilot computer and it is responsible for the communication between the pilot commands and the onboard Arduino via Serial communication, this system is operated by the GUI for real time Visual feedback to the pilot on how the ROV is operating, we preferred the Arduino as our main controller since it is easy to use and is supported by many libraries and forums unlike other controllers like PIC and AVR which requires extra knowledge of the hardware with less support than the used Arduino.

ii. Graphical User Interface (GUI):

Our Graphical user interface is developed using pyqt5 library, we have 2 main windows:
Pilot UI: it has labels that indicate direction of movement, also we included a timer within this window as not to lose track of time within each trial as shown.
Co-pilot UI: this is just like the pilot UI in addition to the ability to activate Mission specific software; calculation missions, autonomous missions, and image processing missions.

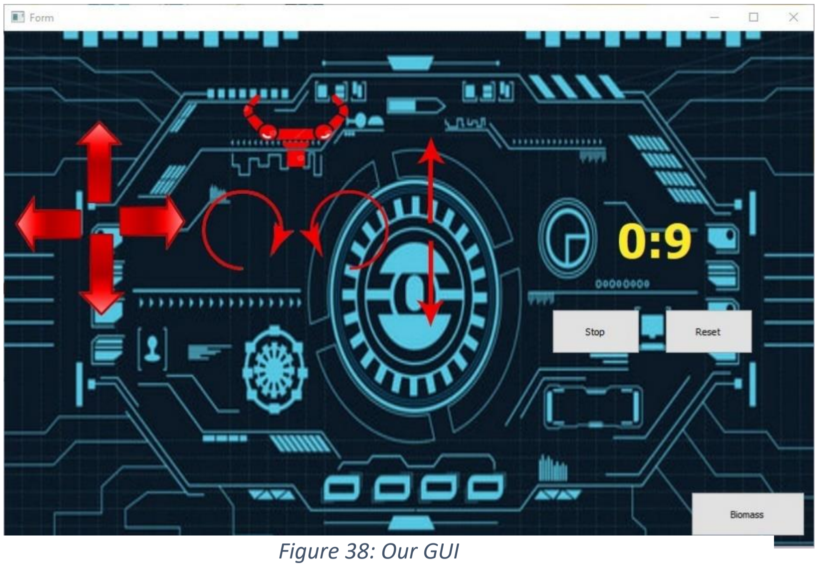


Figure 38: Our GUI

iii. Mission specific software:

BIO mass and fish size:

our approach for this mission is to get the fish size using a reference attached to the ROV's gripper and send the taken picture to a GUI window for calculating the relative length of the fish with respect to the known length of the reference. Then enter the given data into our Co-pilot UI to get the BIO mass of the fish as shown in fig(37)

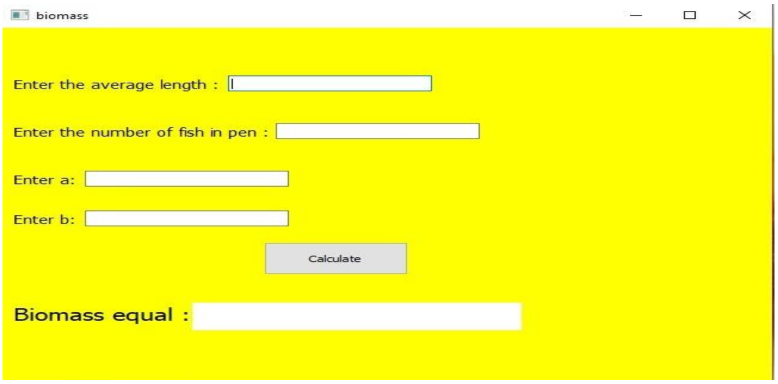


Figure 39: Biomass calculator

Inspecting an offshore aquaculture fish pen:

in this mission our software team decided to use color masking to isolate the red rope from the green net and the based on a color histogram we managed to get the exact position where the ROV should follow the red rope to its end mapping our visual data to directions; and the pass them on to the controlling Arduino operate the ROV autonomously. The code logic is shown in the flow chart-appendices.

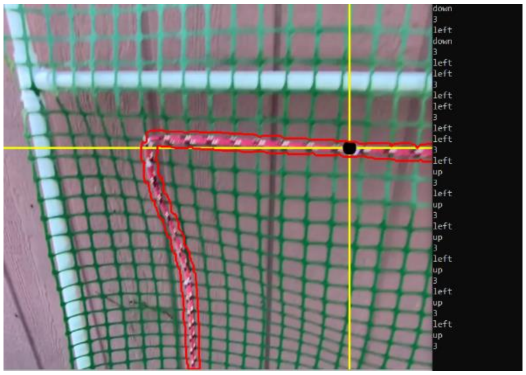


Figure 40: Rope Detection

Photomosaic:

Our team used the openCV library in python to attach the taken images using our lower cctv camera using the Stitcher function, this is done without the need for any editing tools or cropping in advance.

Figure 41: Mosaic Completion

Determining the location where the flo

In this mission we decided to make a software for easy entry of all floats initial states and we determine the initial position of the float by indicating the square directly on the grid to simplify the process of picking the first block.

```
D:\Omar\python\ROV\Ready to use\GO FLOAT>FLOAT_final.py
Enter current speed in ms^-1: 0.143
Enter current direction in degrees: 85
Enter time taken until resurface in hours: 144
The float moved a distance of 74.13 km at 85 degrees, which means it moved 37 blocks east and 4 blocks north
```

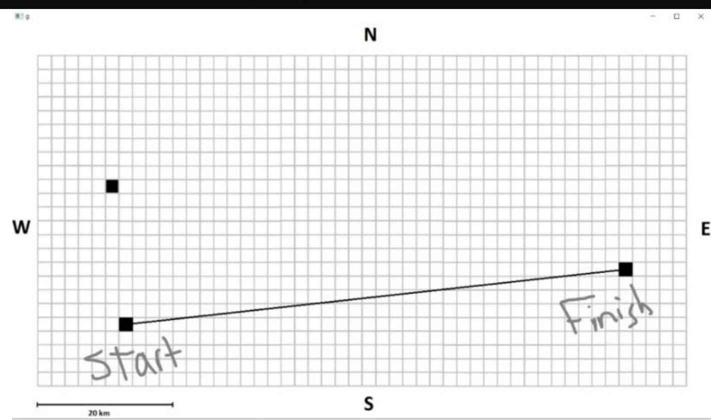


Figure 42: Picking the First Block

Using AI to differentiate "morts" from live fish

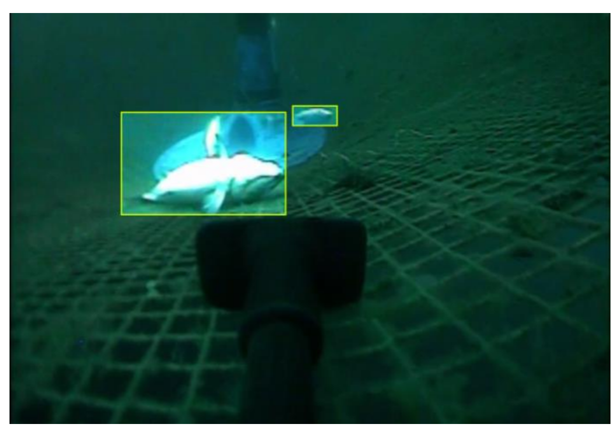


Figure 43: Identifying the Mort

Our team used A neutral network model to identify the morts.
We used a dataset consists of morts , living fish and neutral frames.

Software Troubleshooting:

We followed a troubleshooting methodology that allowed us to identify the defective part in our system in short time and with little to no effort. First when the ROV is not responsive malfunctioning, we start by sending commands directly from the Putty app without the use of GUI, then if the problem persists, we start by plugging the laptop directly to the internal Arduino to test if the problem was in the RS communication between the 2 Arduinos. And as a final check if nothing is working, we start to test the internal Arduino on an external prototype of set of motors to make sure that the problem is not in our main PCB.

F. Vertical profiling Float

A-Mechanical Design

The Float engine is designed to flawlessly complete several Vertical profiles. The float consists of two separate enclosures: an electric enclosure that houses the float's brain and a small water tank that holds 600 CCs. An HDPE connector connects the two enclosures. The float is powered by a buoyancy engine that employs two R385 water pumps with a 3/2 DCV connected in series. When the float is activated, the pumps begin filling and emptying the water tank, while the DCV directs the flow of water in the proper direction. As the tank fills with water, the float sinks, and when the tank is empty, the float rises again. The PMMA electrical enclosure is sealed from both ends with HDPE caps and O-rings, and the HDPE water tank is sealed from the top with a PMMA face. Pneumatic cables are used to help the water flow inside the float. After reviewing numerous ideas and tests, the final design was created. 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.

Figure 44: Vertical float engine design

B-Electrical Design

To protect the float, the electric components are also housed in a separate container from the water. To achieve 12V from the series connection and increase the mAmpH usage from the parallel connection, we use a set of 8-in series 1.5V alkaline batteries in parallel with the same set. A 4 Amp fuse is installed within 5 cm of the positive terminal of the battery. The float is made up of an H-bridge, a pump, a solenoid-actuated valve, and an Arduino nano to provide the necessary signal. After being deployed, the float would try to complete vertical profiles by touching the bottom and returning to the surface, and so on.

Component	Max current	Max voltage	max power	Quantity	Max power
Pump	0.3A	12V	3.6w	2	7.2W
solenoid actuated valve	0.4A	12V	4.8w	1	4.8W
Arduino nano	0.019A	5V	0.095w	1	0.095W
L298N	-	-	20w	1	32w
Total power					8.496W

Table 4: Float Power Calculation

Safety

Figure 45: Our CTO Omar Tabouna Truman working safely in the workshop

A. Safety Philosophy

Throughout the construction and operation of our ROV, safety has been our highest priority. By employing safety protocols for using tools and requiring adult oversight during meetings, we worked efficiently and ensured the safety of our team members. All members were taught the proper operation of each power tool before they began using them with the supervision of one of our mentors. We are required to wear safety goggles, gloves, masks, and close-toed shoes when working with power tools. Also, to prevent accidents during fabrication, we cleaned all floors and organized all surfaces after every meeting. While testing, running on the pool deck was prohibited and all members (except the tether man) worked away from the pool edge. In addition to safety precautions taken during fabrication and testing, we developed many safety features onboard our ROV to ensure the safety of vehicle operators.

B. Safety Instructions

- During testing or manufacturing, at least two safety instructors must be present at the workshop.
- Using safety equipment 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.
- When loading or unloading heavy components, slightly bend your body forward to prevent back injury.
- It's necessary to use a holder for the welding iron while soldering the PCBs.
- Use flux to clean the soldering iron after soldering.
- A First aid kit, as well as a fire extinguisher, is provided in case of any emergency.

Figure 46: Safety instructions in our workshop

C. ROV Safety Features:

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 under a suitable and safe environment as Safety instructions are always considered during designing, building, handling, and testing of the ROV.

Our mechanical engineers ensured the presence of no sharp edges on the ROV. Also, moving parts, such as thrusters, are covered with 3D-printed 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.

2. Pneumatic Safety Features:

A pressure relief valve is added to the compressor and is set to 10 bars (106 Pa), which is the maximum allowable pressure for the tank, and the pressure regulator is adjusted to 2 bars (2x105Pa) at all times. Pneumatic fittings either have O-rings, or Teflon tape is wrapped to prevent leakage. Also, all the pneumatic hoses are rated up to 10 bars (106 Pa) of pressure.

3. Electrical Safety Features:

A fuse-box between the 12V power supply and the tether, which has an inline two fuses of 25 Amp was installed Polarized connectors and color-coded cables are used to prevent inverted connections for power and signal transmission across the whole system. ROV's static sealing was tested against a pressure up to 2 bars and confirmed its potential for tolerance, and a water detection sensor is placed to detect any leakage. Glands work as strain relief for electrical wires.

4. Warning Labels:

Warning labels are placed on thrusters and moving parts, high-pressure parts, PMMA parts that maybe subjected to fractures, electrical components and close to the high brightness LEDs to ensure that anyone in contact with the ROV is fully aware of the possible hazards.
Safety checklist pre, through and after the mission

Phase	Topic to check	✓
Pre-launch	The power supply is placed on a dry location	
	Anderson connectors of tether are connected to power supply	
	Micro-ROV is completely docked	
	Fuse of main ROV and micro-ROV are not blown	
	All bolts are well tight	
	All of the thruster shrouds are well installed	
	Dry test for the thrusters to check on the control	
	Check cameras and vision system	
	Dry testing the micro-ROV system (DC motor, LED and Camera)	
	Checking on the compressor's regulator (less than 2.75 bars)	
	No one is touching any moving parts	
	Safety labels are all placed properly	
	All seals are installed correctly	
	Members are wearing safety gears	
In-water checks	Check for bubbles	
	Constantly check on the readings of the water-detection sensor	
Retrieval	Switching the power off	
	Compressor is discharged	
	ROV is retrieved by at least two members	
	Ensure that the micro-ROV is docked	
	Quick visual inspection for any cracks or damages	
	Tether is neatly rearranged	

Table 5: Safety Checklist

Build vs Buy

Cost-effectiveness and customizability are two advantages of creating custom parts. This is evident in the design of the top-side camera enclosure this year. Our mechanical team members also used the miter saw equipment to machine the aluminum extrusion profile.
The frame, which was milled out of sheets of High-Density Polyethylene (HDPE) using a CNC router, is another custom-fabricated component of our ROV. When it came to developing buoyancy, tool, and propulsion mounting, the team had a lot of flexibility. The vertical float engine components were bought totally.
Commercial components are sometimes important since they provide a quick and typically more reliable answer to any problem. Almost all of the electronics onboard, for example, Arduino, Cameras, control panel, and the screen are commercial 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 crew 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. 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 handles for easy lifting and handling the rov, and all the components of the float engine.

Re-used components of this year’s ROV include Six T-100 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.

Accounting

A. Project budget

All team members met at the start of the project to discuss and develop a rough budget-Appendix (C). Following the budget's approval, all team members followed it during the ROV's construction phase. All purchases must be approved by the company's CFO and our technical mentor to ensure fair spending. Furthermore, all parts were sourced from numerous sources before being purchased to guarantee that all pricing was reasonable.

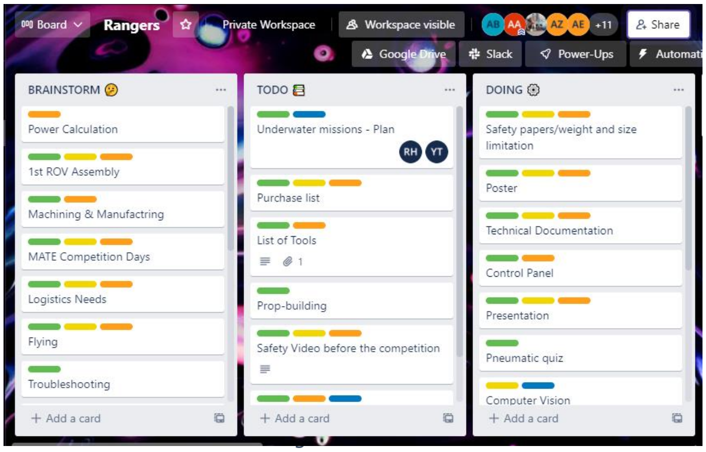
B. Total project cost

Most of the company’s costs came in the form of purchased materials and hardware for the construction of the frame which mainly consists of an Aluminum extrusion profile and its accessories, A unique control panel, a new screen and all the components of the vertical float engine. To cut off the budget we reused the T100 thrusters, Cameras, and Most of the electric components due to their high cost. To keep track of purchases, a Google Sheet was used and regularly updated with each purchase made. A comprehensive chart of costs and donations can be found in Appendices -Appendix (D).

Planning and Project Management

All members of the Matrix team strive to achieve new heights by utilizing cutting-edge technologies. This year, the company grew dramatically, with several members from the previous year returning, as well as new members with similar goals. The Matrix crew takes pleasure in being incredibly organized. The team's design and manufacturing timetable, which was set in December 2021, demonstrates this. Appendix (...), the team's Gantt planning chart, shows a graphical representation of this.

This year, because of the effects of the pandemic, we changed our way of communication from going to meetings in our office to online meetings and online chat groups. To ease the submission of tasks we used "Trello" which is a popular, simple, and easy-to-use collaboration tool that enables the team to organize their work, and everything related to them into boards. With Trello, you can find all kinds of information, such as: What’s being worked on? Who’s working on what? What progress the project is making?



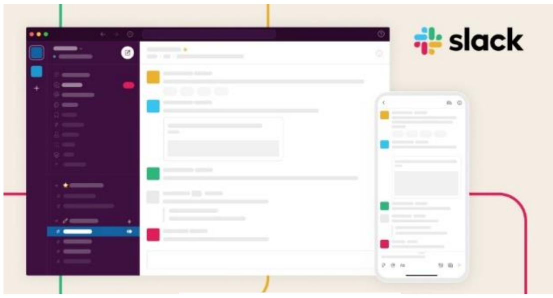


Figure 48: Slack

We also used "Slack" which is a messaging program designed specifically for the workplace for daily communication. What distinguishes slack is that it offers many IRC-style features, including persistent chat rooms (channels) organized by topic, private groups, and direct messaging.

Company Organization and Teamwork

Matrix Team is made up of three main technical departments: electrical, mechanical, and software. Each department is broken down into project groups. Our mentors formed the team as an engineering training program so that each member could choose whatever department and project group, he wanted to work in. Following the completion of the course, the CEO, CTOs of each department, and CFO were chosen based on their success in the training program and personal skills. The CTOs held frequent meetings and constantly assigned assignments to team members with deadlines to ensure that we stayed on track. The CEO arranged general meetings so that the two departments could communicate and track each other's success. The CFO estimated the budget and devised a financial strategy to be followed until the desired product was delivered. Tasks were provided such that each team member had a distinct role to play.

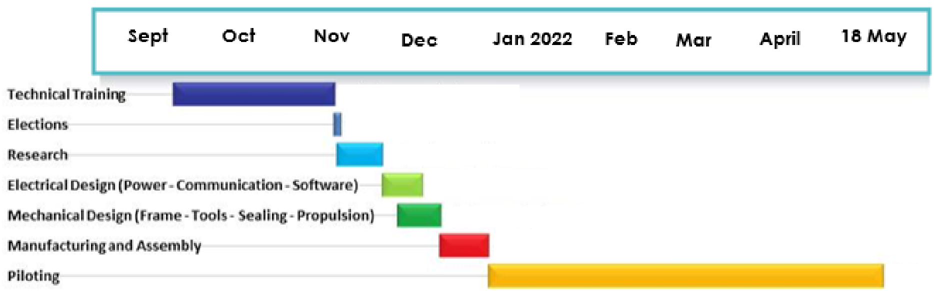


Figure 48: Timeline Gantt Chart

Conclusion

1. Testing and troubleshooting

Before any runs were tried, several tests were done to ensure that the ROV can perform the tasks safely and efficiently. These are some of the tests done:

Test	***Description***
Waterproofing Test	All components of the ROV were tested to be waterproof over an extended period of time, both separately and together in depths of 10 meters (Pressure Chamber).
Power-On and Power-Off Tests	This test ensures that all controllers boot upon power-up and that all components of the ROV are powered on. After power-off, all components should return to a safe state, and should be OK to power-on once again.
Max Current Draw Test	All five thrusters operate simultaneously for an extended period of time, to create a large current draw. This test ensures that all electrical components can handle that amount of current, and that other components in the system continue to receive enough power.
Control box	We used a multimeter to test the current at different points in the control box. We did this to minimize voltage drop and to make sure that there are no voltage spikes.
Grippers	We tested the grippers with all the possible components the ROV will hold ,to ensure that it can hold firmly and easily any component
PCB test	We tested the PCB with all the components before assembling anything in the ROV to make sure that no errors occurred during the simulation on the PCB

Table 6: Performance Tests

If any of the tests above show that there is a problem, we start performing the following steps:

1. Eliminate any possible factor that could result in an unfair test. Then start identifying the problem.
2. Innovate possible fixes and implement the best depending on cost, efficiency, time, and simplicity.
3. Test the solution more than 1 time.
4. Monitor the solution to ensure it is fully resolved

Acknowledgements

We would like to thank with our appreciation and gratitude to all those who provided us with the environment to develop and complete this product and those who helped us to overcome the obstacles we faced along our journey from day zero:

- MATE "Marine Advanced Technology Education" – for
- creating such a professional competition where engineers from all over the world explore their passion for marine education and develop technical and non-technical skills.
- Delta Square – for organizing the regional competition.
- AASTMT Arab Academy for Science Technology & Maritime Transport– for organizing the regional competition.
- Vortex Co. and our mentors –for providing technical support throughout the competition as well as moral support and encouraging us to bring out our full potential.
- SolidWorks™ - For providing us with a student license.
- Ansys -For providing us with a student license.
- PyCharm Code Editor – For using student license.
- Air Technology Company – for providing us with discounted pneumatic components.
- Our beloved families and friends for support.

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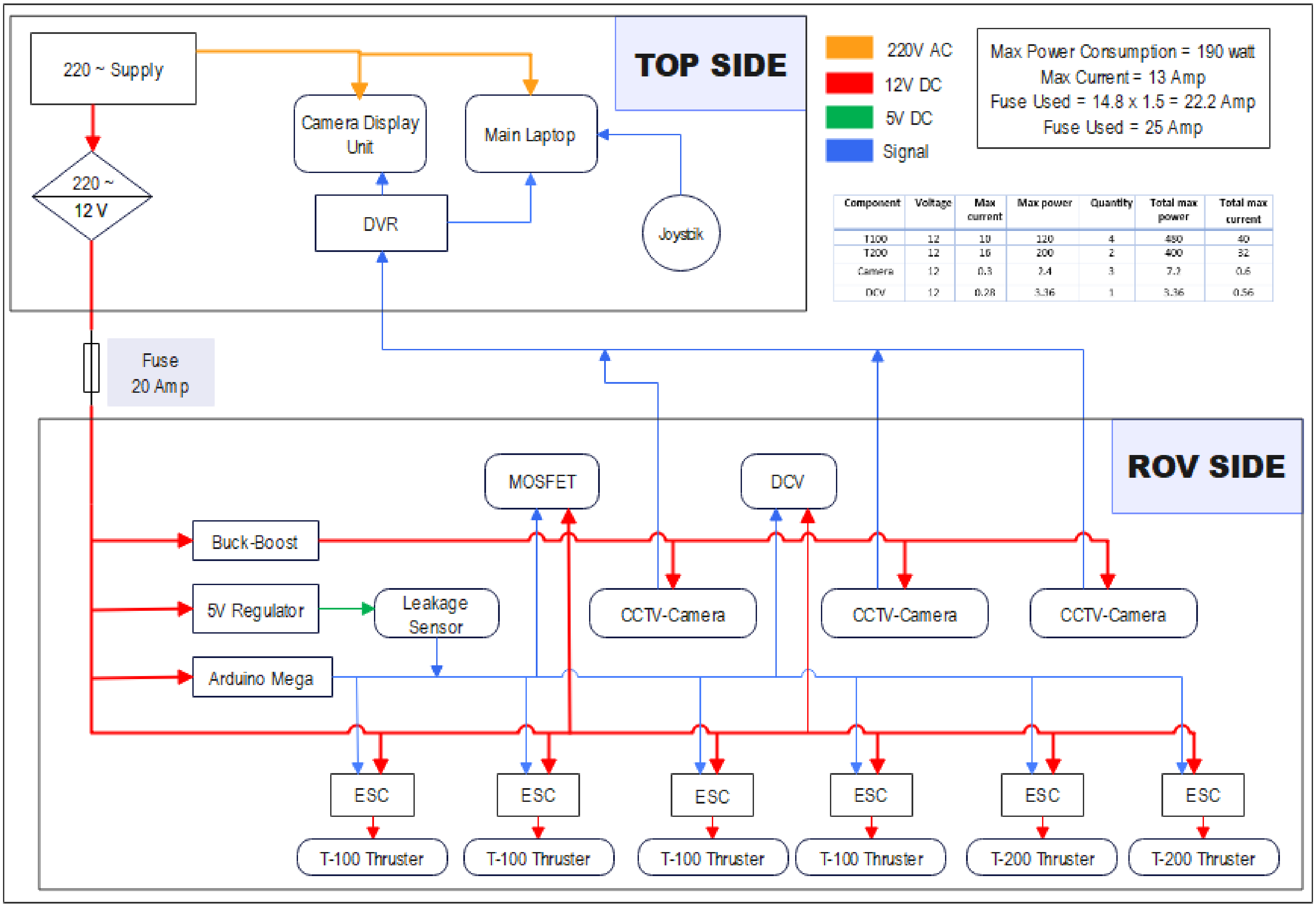
- Blue Robotics ESC Documentation < https://docs.bluerobotics.com/bescr3/>
- Arduino home https: www.arduino.cc
- IRF640 MOSFET Datasheet < http://www.alldatasheet.com/datasheet-pdf/pdf/17801/PHILIPS/IRF640.html>
- Interface Logitech 3D Joystick with Python https://pygame-gui.readthedocs.io/en/latest/quick_start.html
- Simple Shape OpenCV with python 3 <https://pysource.com/2018/09/25/simple-shape-detection-opencv-with-python-3/>
- PLA Material Properties <https://plastics.ulprospector.com/generics/34/c/t/polylactic-acid-pla-properties-processing>
- AWG wire sizing chart https://homequicks.com/electrical-wire-sizing-chart
- Competition manual https://files.materovcompetition.org/2022/2022_RANGER_Manual_21_JAN_2022.pdf
- Competition Video https://vimeo.com/679544035
- Parker O-ring handbook. 50th Anniversary Edition

Appendices

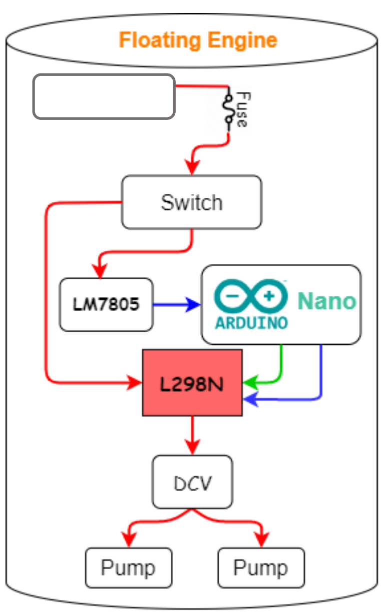
Appendix A: System interconnection diagrams

1. Electrical SID of ROV



Component	Voltage	Max current	Max power	Quantity	Total max power	Total max current
T100	12	10	120	4	480	40
T200	12	16	200	2	400	32
Camera	12	0.3	2.4	3	7.2	0.6
DCV	12	0.28	3.36	1	3.36	0.56

2. Electrical SID of Non-ROV Device



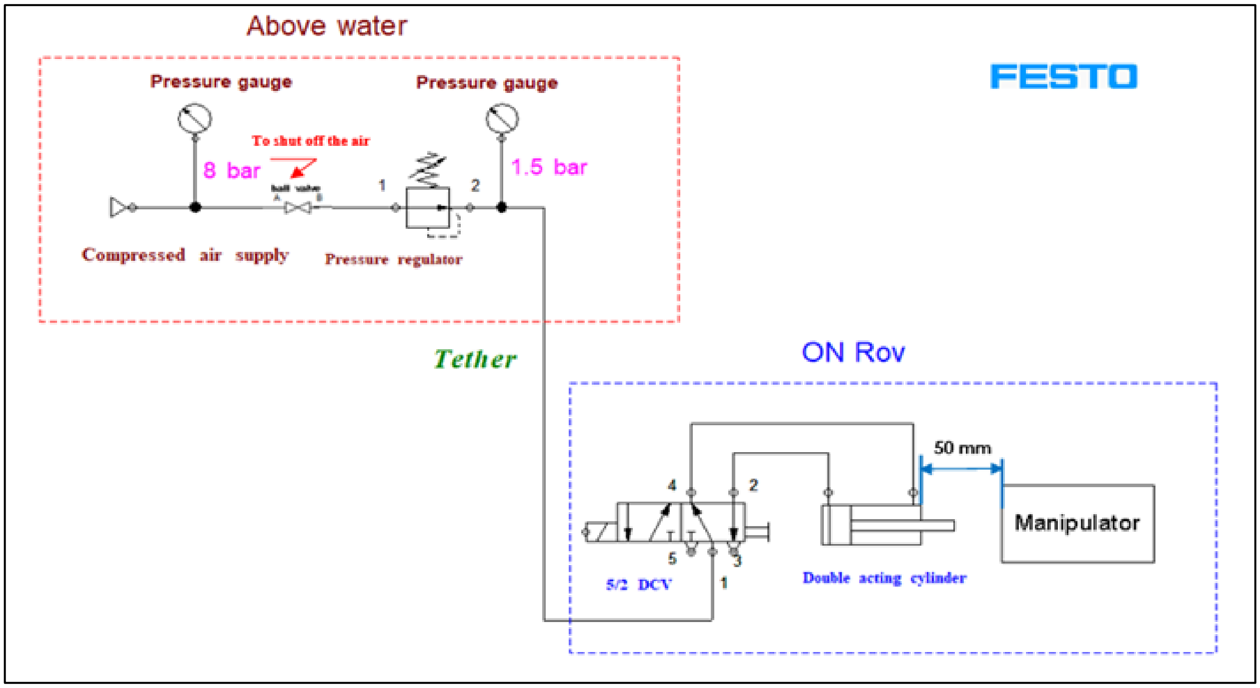
Color code
5v DC
12v DC
Signal

Fuse calculations

Max current= 2.6A
Fuse= 2.6 x 1.5 = 4A

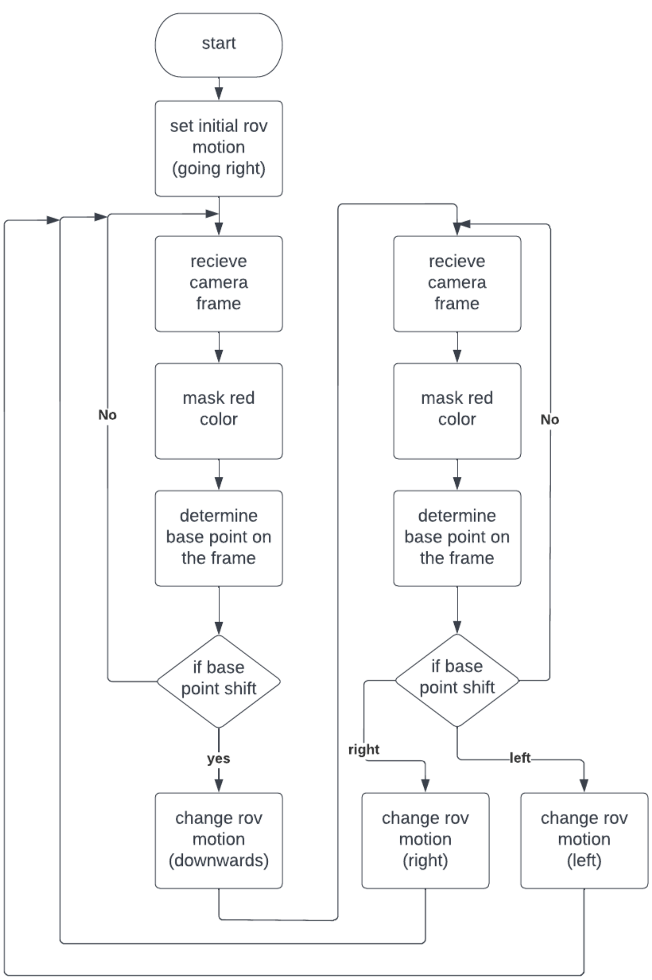
Component	Max current	Max voltage	max power	Quantity	Max power
Pump	0.3A	12V	3.6w	2	7.2W
solenoid actuated valve	0.4A	12V	4.8w	1	4.8W
Arduino nano	0.019A	5V	0.095w	1	0.095W
L298N	-	-	20w	1	20w
Total power					32W

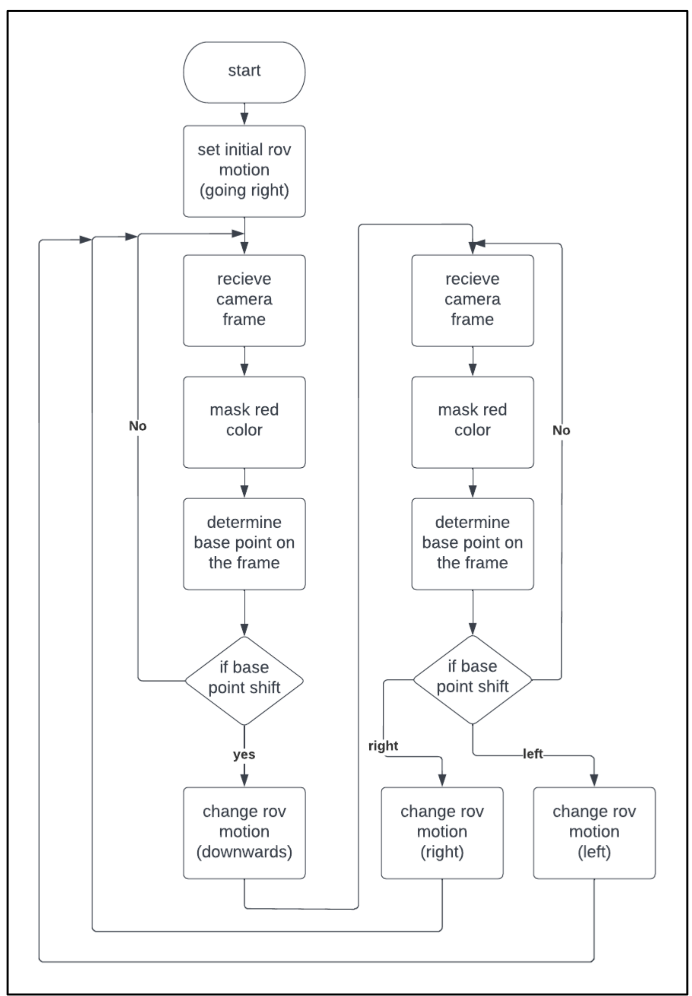
3. Pneumatic SID of ROV



Appendix B: Flow Charts

1. Top-side software





Appendix C: Budget

	Income	Income	Income	
		Self-Funds from Team Members	$3,097	
	Type	Description	Projected Cost	Budgeted value
Tether	Re-used	Cat 6	$44	
	Re-used	Power	$3.10	
	Re-used	Pneumatic Cables	$8.25	
Electronics	Re-used	Buck boost	$20.00	
	Re-used	Connectors,Fuses,Wires	$38.30	
	Re-used	ESCs	$270.00	
	Purchased	Anderson connector	$19	$19
	Purchased	PCBS	$57.50	$57.50
	Re-used	Arduino Mega	$15.30	
	Re-used	CCTV Cameras	$69.00	
	Re-used	12 V Power Supply	$41.65	
	Purchased	RS485	$35.60	$35.60
Float Engine	Purchased	Materials & Fabrication	$63.50	
	Re-used	Arduino Nano	$11.60	
	Purchased	Water Pump	$16.60	$16.60
	Purchased	PCB	$15.00	$15.00
	Purchased	Batteries	$55.00	$55.00
	Purchased	Switch	$10	$10
	Re-used	DCV	$25.50	
Control Panel	Purchased	Monitor	$92	$92
	Re-used	Joystick	$85.30	
	Purchased	Case	$134.00	$134.00
	Re-used	DVR	$112.00	
	Re-used	Video Baluns	$36.00	
	Re-used	Easy cap	$8.00	
	Purchased	Case Accessories	$35.00	$35.00
Hardware	Re-used	PMMA sheet	$66.70	
	Re-used	HDPE cylinder for main enclosure	$41.40	
	Re-used	HDPE cylinder for camera enclosure	$13.80	
	Re-used	HDPE sheet	$38	
	Purchased	PMMA dome	$47.50	$47.50
	Purchased	Stainless steel sheet	$12.40	$12.40
	Purchased	Aluminum sheet	$5.40	$5.40
	Purchased	Aluminum Extrution&Accessories	$91.00	$91.00
	Purchased	Aluminum Handle	$12.00	$12.00
	Purchased	Foam sheet	$5.70	$5.70
	Purchased	Laser cutting	$21.67	$21.67
	Purchased	CNC router	$146.40	$146.40
	Purchased	Sheet metal bending	$41.60	$41.60
	Purchased	Glands	$85.50	$85.50
	Purchased	O-Rings	$5.80	$5.80
	Re-used	DCV	$44.00	
	Re-used	Pneumatic cylinder 20X50	$21.00	
	Re-used	Fittings	$22.40	
	Purchased	Bolts & Nuts	$34	$34
	Purchased	3D Printed Parts	$65.04	$65.04
	Re-used	Thrusters T100	$580	
	Re-used	Thrusters T200	$420	
	Purchased	Thrusters' Mesh	$76.56	$76.56
	Re-used	Compressor	$166	
Logistics	Purchased	Poster printing	$50	$50
Travel	Purchased	Round-trip to long beach california	$19,630.00	$19,630.00
	Purchased	Travlling in the country	$405.00	$405.00
Accommodation	Purchased	7 days in Long beach california	$3,244	$3,244
	purchased	$2,000		
	Total Expenses	$24,449		
	Total Re-used	$2,201		
	Total Expenses - Re-used	$22,247.77		
	Total Fundraising Needed	$22,247.77		

Appendix D: Total Project Cost

Date	Type	Category	Descrption	Sources/Notes	Amount	Project Cost	Running Balance
15/3/2022	Cash donated	General	Self-Funds from Team Members	Used for general veicle construction			$2,000
	Re-used	Electronics	ESCs	Vortex Company	$270.00	$270.00	$2,000
5/4/2022	Purchased	Electronics	PCBs	Signal & Power distribution	$57.50	$327.50	$1,943
	Re-used	Electronics	Arduino Mega	Vortex Company	$15.30	$343	$1,943
	Re-used	Electronics	CCTV Cameras	Vortex Company	$69.00	$412	$1,943
	Re-used	Electronics	Buck boost	Vortex Company	$20.00	$432	$1,943
5/4/2022	Purchased	Electronics	Rs-485	internal structure	$35.60	$467.40	1906.9
5/4/2022	Purchased	Electronics	Anderson connector	safety	$19	$486.40	1887.9
	Re-used	Electronics	Connectors,fuses,wires	Vortex Company	$38.30	$525	1887.9
	Re-used	Electronics	Power Supply	Vortex Company	$41.65	$566	1887.9
9/4/2022	Purchased	Float Engine	Materials & Fabrication	Float fabrication	$63.50	$629.85	$1,824.40
	Re-used	Float Engine	Arduino Nano	Vortex Company	$11.60	$641.45	$1,824.40
9/4/2022	Purchased	Float Engine	Water Pump	Profiling	$16.60	$658.05	$1,807.80
9/4/2022	Purchased	Float Engine	PCB(float engine)	Controlling float	$15.00	$673.05	$1,792.80
9/4/2022	Purchased	Float Engine	Batteries	Float power	$55.00	$728.00	$1,737.80
9/4/2022	Purchased	Float Engine	Switch	Initialize the float	$10	$738.00	$1,727.80
	Re-used	Float Engine	DCV	Vortex Company	$25.50	$763.55	$1,727.80
	Re-used	Hardware	PMMA sheet	Vortex Company	$190.00	$953.55	$1,727.80
	Re-used	Hardware	HDPE for main enclosure	Vortex Company	$80.00	$1,033.55	$1,727.80
	Re-used	Hardware	HDPE for camera enclosure	Vortex Company	$41	$1,074.55	$1,727.80
	Re-used	Hardware	HDPE sheet	Vortex Company	$29	$1,103.55	$1,727.80
10/4/2022	Purchased	Hardware	PMMA Dome	Enclosure	$47.50	$1,151.05	$1,680.30
10/4/2022	Purchased	Hardware	Stainless steel sheet	Frame	$12.40	$1,163.45	$1,668.30
10/4/2022	Purchased	Hardware	Aluminum sheet	Frame	$5.40	$1,168.85	$1,662.90
10/4/2022	Purchased	Hardware	Aluminum Extrution&Accessories	Frame structure	$91.00	$1,259.85	$1,571.90
10/4/2022	Purchased	Hardware	Aluminum handle	Frame handling	$12.00	$1,271.85	$1,559.90
10/4/2022	Purchased	Hardware	Foam sheet	Frame buoyance	$5.70	$1,277.55	$1,554.20
10/4/2022	Purchased	Hardware	Laser cutting	Machining	$21.67	$1,299.22	$1,532.53
10/4/2022	Purchased	Hardware	CNC router	Machining	$146.40	$1,445.62	$1,386.13
10/4/2022	Purchased	Hardware	Sheet metal bending	Machining	$41.60	$1,487.22	$1,344.53
10/4/2022	Purchased	Hardware	Glands	Sealing	$85.50	$1,572.72	1259.03
10/4/2022	Purchased	Hardware	O-Rings	Sealing	$5.80	$1,578.52	$1,253.23
	Re-used	Hardware	DCV	Vortex Company	$44.00	$1,622.52	$1,253.23
	Re-used	Hardware	Pneumatic Cylinder	Vortex Company	$21.00	$1,643.52	$1,253.23
	Re-used	Hardware	Fittings	Vortex Company	$22.40	$1,665.92	$1,253.23
11/4/2022	Purchased	Hardware	Bolts & Nuts	fastners	$34	$1,699.92	$1,219.23
11/4/2022	Purchased	Hardware	3D Printed Parts	Holders	$65.04	$1,764.96	$1,154.19
	Re-used	Hardware	Thrusters T100	Vortex Company	$580	$2,344.96	$1,154.19
	Re-used	Hardware	Thrusters T200	Vortex Company	$420	$2,764.96	$1,154.19
11/4/2022	Purchased	Hardware	Thrusters' Mesh	Vortex Company	$76.56	$2,841.52	$1,077.63
	Re-used	Hardware	Compressor	Pneumatic system	$166	$3,007.52	$1,077.63
	Re-used	Tether	Cat 6	Signal	$44	$3,051.52	$1,077.63
	Re-used	Tether	Power	Power	$3.10	$3,054.62	$1,077.63
	Re-used	Tether	Pneumatic Cables	Vortex Company	$8.25	$3,062.87	$1,077.63
	Re-used	Control Panel	Monitor	Vortex Company	$120.00	$3,182.87	$1,077.63
11/4/2022	Purchased	Control Panel	Joystick	Controlling	$115.00	$3,297.87	$962.63
11/4/2022	Purchased	Control Panel	Case	TCU	$134.00	$3,431.87	$828.63
	Re-used	Control Panel	DVR	Vortex Company	$112.00	$3,543.87	$828.63
	Re-used	Control Panel	Video Baluns	Vortex Company	$36.00	$3,579.87	$828.63
	Re-used	Control Panel	Easy cap	Vortex Company	$8.00	$3,587.87	$828.63
11/4/2022	Purchased	Control Panel	Case Accessories	TCU	$35.00	$3,622.87	$793.63
11/4/2022	Purchased	Logistics	Poster printing	Marketing	$50.00	$3,672.87	$743.63
22/5/2022	Cash donated	General	Self-Funds from Team Members	For travel and accommodation	$23,000		$23,744
25/5/2022	Purchased	Travel	Round-trip to long beach california	Tickets	$19,630.00	$47,802.87	$4,114.00
25/5/2022	Purchased	Travel	Travlling in the country	Car gas	$405.00	$48,207.87	$3,709.00
25/5/2022	Purchased	Accommodation	7 days in Long beach california	Hotel	$3,244	$51,451.87	$465.00
			Total Raised	**$25,000**			
			Total Spent	**$23,639**			
			Final Balance	**$1,361**			