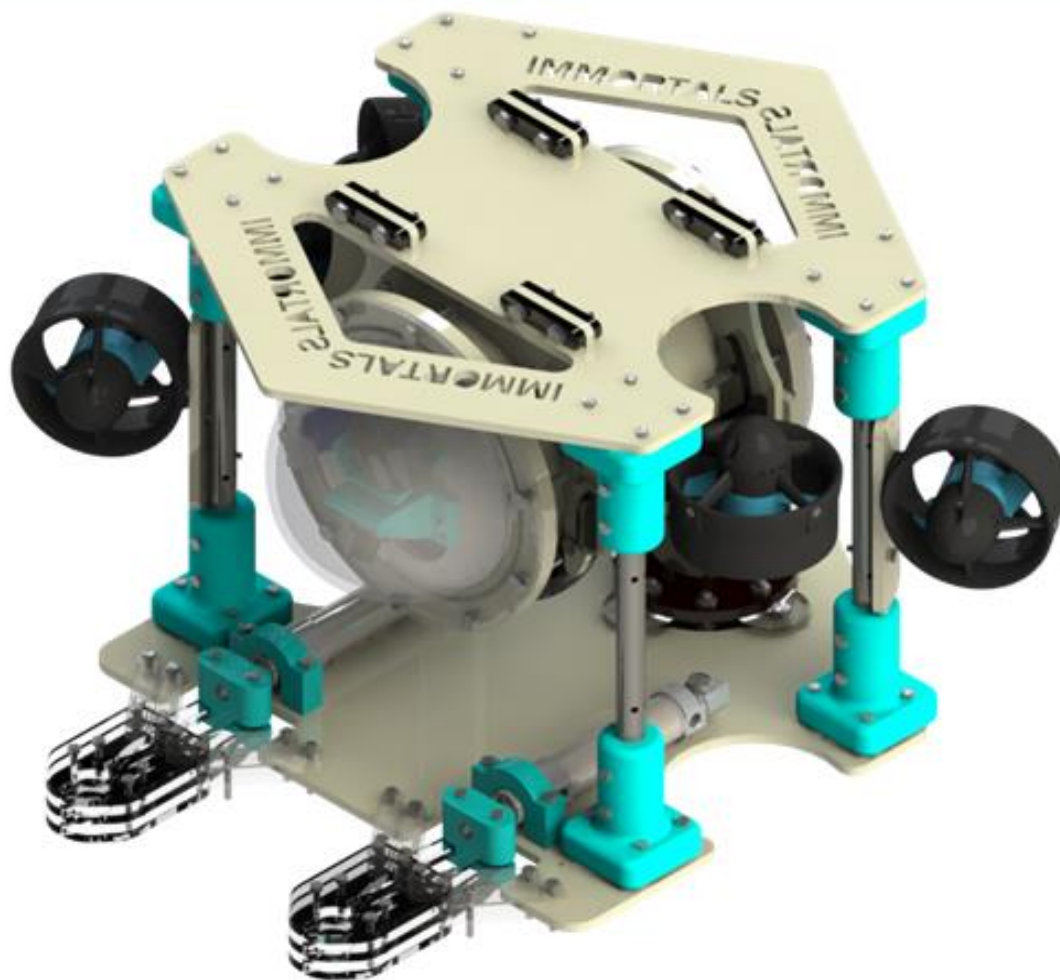




UNDERWATER ROBOTICS CHALLENGES

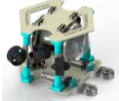
MORE THAN A CHALLENGE...



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Abdelrhaman Amr	CTO Electrical
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I- Abstract

Concerning the Underwater Robotics Research Centre's request for developing a **R**emotely **O**perated **V**ehicle (ROV), which excels in underwater excavation and revealing the artifacts. Immortals' newest creation, Blue Marlin, is an underwater ROV designed to enhance underwater excavation tasks.

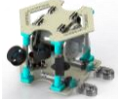
Immortals -fig(1), an eighteen-person team, has the work experience and technical skills to manufacture ROVs adapted for numerous requirements. Immortals was founded last year by Vortex Academy, and divided into interdependent departments in software, electrical, and mechanical design.

Blue Marlin is the aftermath of months of planning, research and development (R&D), manufacturing and testing in different environments. Our vehicle is characterized by a modular and lightweight frame, reliable electronics, low cost, and a new software platform that makes it work with advanced techniques. We utilized the latest cutting-edge technologies, particularly the manufacturing part, such as 3D printing, laser cutting, and CNC routing. Blue Marlin is equipped with five BlueRobotics T100 Thrusters for maneuvering, a pneumatic system for the two grippers and the lift bag, cameras for computer vision and custom-made printed circuit boards (PCBs).

This documentation explores the journey of the creation of Blue Marlin and how it was designed in order to perform all the required tasks efficiently.

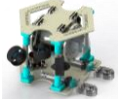


Figure 1: Immortals Team

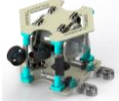


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II- Design Rationale

A- Design Process

Blue Marlin was designed with cost-efficiency in mind, an attitude that was held by our design team from start to finish. Incorporating a sleek, multi-purpose design, our vehicle darts through the water, completing task after task with peerless speed and agility. Our design isn't entirely unorthodox, as it is inspired by and improves upon the designs of previously manufactured ROVs. A lot of time was spent researching the strengths and weaknesses of older models and brainstorming ways to improve upon their design. After the design team had agreed on the schematics and developed freehand sketches -fig(2), the real work began, starting first with 3D modelling, which was done using SOLIDWORKS. Thanks to SOLIDWORKS, we were also able to extensively test our design before manufacturing began. The design team worked hard, but the real challenge was making our vehicle maneuver smoothly, a feat which we can attribute to our electrical team. Through rigorous planning and close cooperation with the design team, the electrical team were able to fit the electronic components into our ROV, allowing for the responsive control over the ROV's direction.

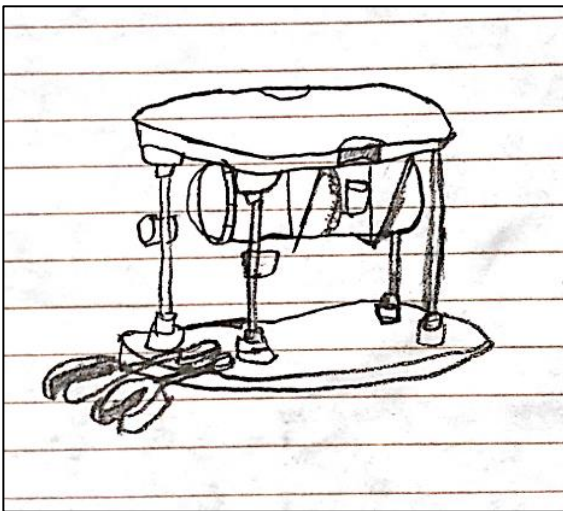


Figure 2: Blue Marlin's Freehand Sketch

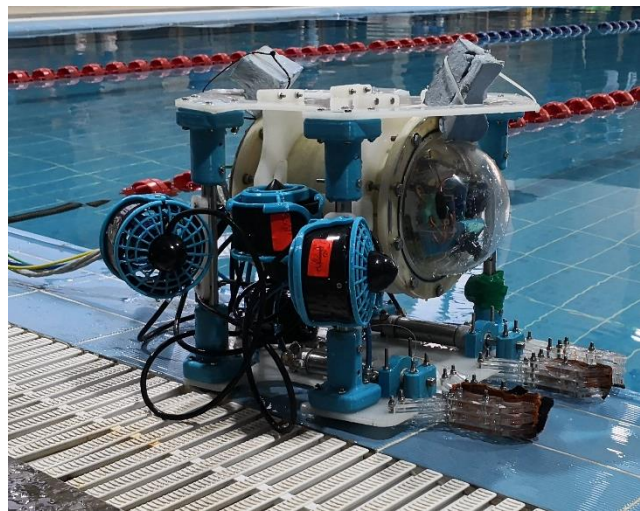


Figure 3: Fully assembled Blue Marlin

B- Design Constraints

The Blue Marlin uses many innovative design solutions to reduce its size and weight while maintaining a high level of operational efficiency and control responsiveness. It weighs 14.5 kg in air, 25m long tether included, and sports a diameter of 60 cm -fig(4), taking up a small percentage of the competition's limitations of 30 kg and 90 cm. The Blue Marlin can also perform missions deeper than 10 meters in fresh water. It operates at a voltage of 12 VDC at 16 amps, which is well within the competition constraint of 30 amps.

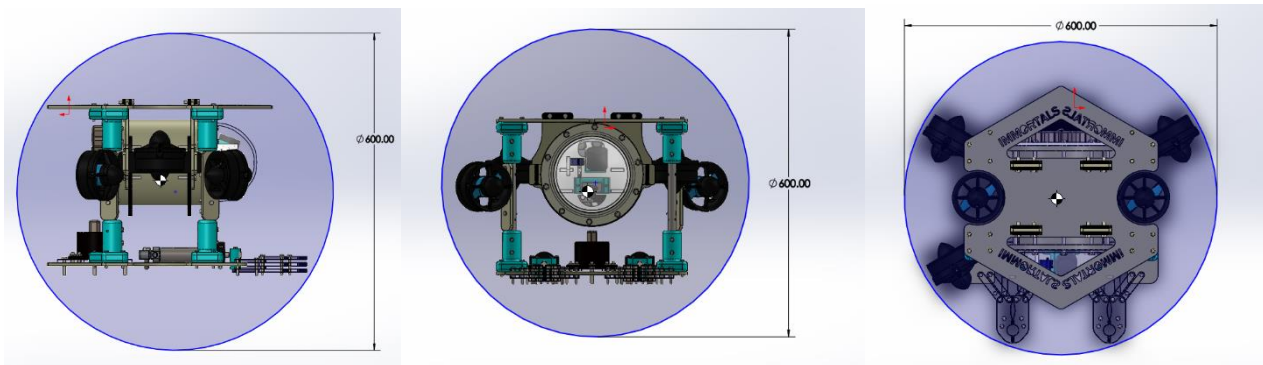
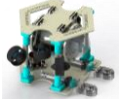


Figure 4: Blue Marlin Fitting in a 60cm Circle



C- Mechanical Design

1- Frame

Blue Marlin's frame -fig(5) is optimized to balance cost, weight, size, drag, and toughness based on its mission parameters. Its base is made of 6mm thick HDPE (High Density Polyethylene), manufactured using a CNC (Computer Numerical Control) router. It has concave grooves to make way for the flow of the vertical thrusters mounted above.

The base holds four 3D printed rod attachment platforms made of PLA (Polylactic Acid) -with 100% filling- into which stainless-steel rods, chosen for their strength -fig(6), are inserted to support the weight of the enclosure holder. Three of the rods, two in front and one in the rear, have thruster mounts attached to them at a 60-degree angle. The rods have a diameter of 16mm and a thickness of 0.5mm.

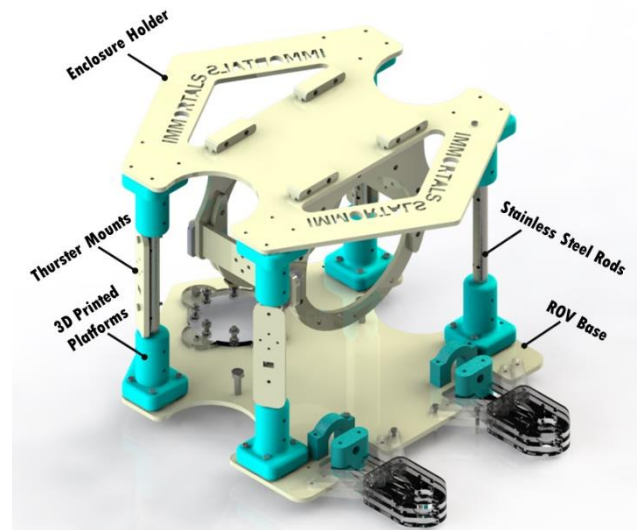


Figure 5: Blue Marlin Frame

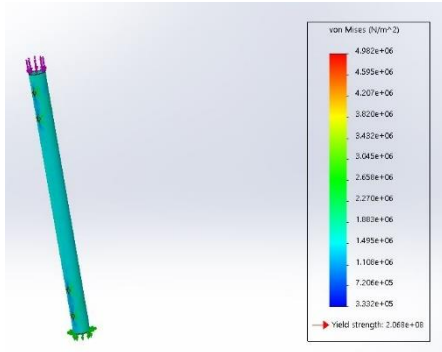


Figure 6: Stress Analysis on Rods

Atop the rods are attachment platforms connected to the enclosure holder, where the enclosure is inserted. The enclosure holder, also made of HDPE, was created specifically for securing the electrical enclosure to the top of the frame. The holder consists of a pair of rings the size of the enclosure which are secured by bolts to the top of the frame, as well as mounts for the vertical thrusters. The top of the frame integrates handles, which saves on weight and cost, while allowing the same ease of transportation as other designs.

HDPE was used for most of the vehicle's structure for its toughness, low density, and fatigue resistance, which allows it to survive most of the harshest situations it may find itself in. PLA was used in the supports due to their unique shape, which makes them very difficult to fabricate using traditional methods.

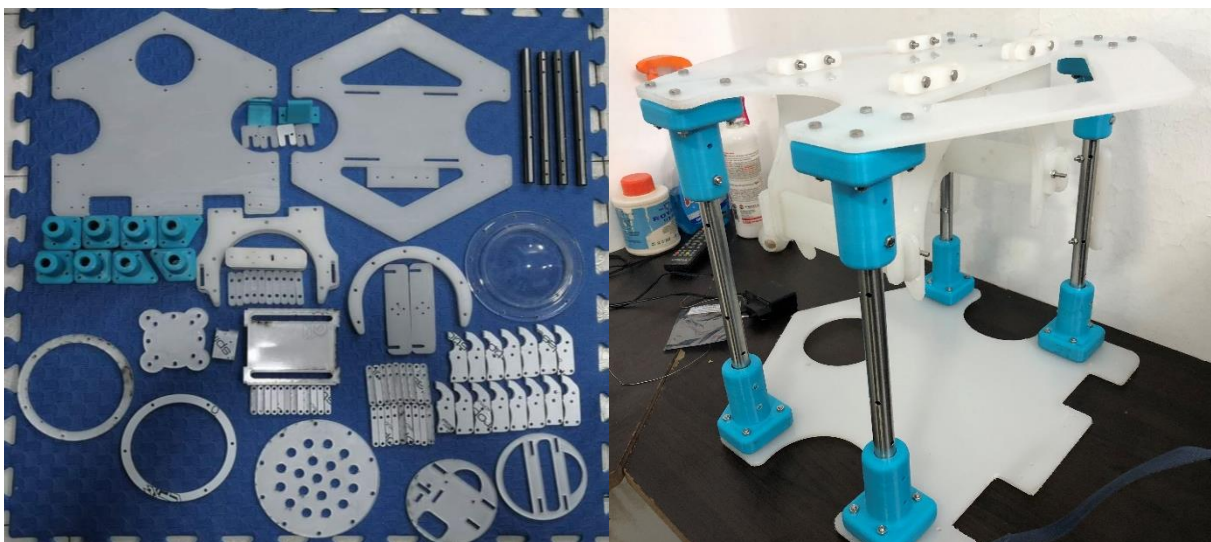
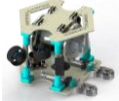


Figure 7: Frame Assembly



2- Buoyancy and stability

Blue Marlin's enclosure displaces the most water, occupying 664,824.2 cubic centimetres, which is part of the reason why it was placed at the top of the ROV. This shifts the centre of buoyancy upwards - [fig\(8\)](#), which counterbalances the overall weight of the ROV and whatever payload it might be carrying. Since the weights are placed at the bottom of the Blue Marlin, it boasts a high level of stability. The result is a slightly positively buoyant ROV when foam is added, which can easily be cancelled out by the vertical thrusters whenever needed.

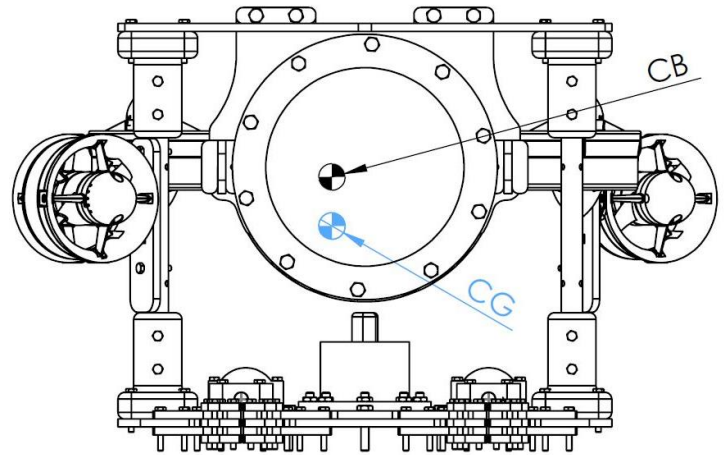


Figure 8: CG and CB of Blue Marlin

3- Propulsion:

Blue Marlin is propelled by five thrusters - [fig\(9\)](#), allowing for unprecedented freedom of movement while reducing drag. Three thrusters are attached to metal poles in as many corners at a 60-30 degrees angle. This allows for movement in every direction on a 2D plane, as the active thrusters can be alternated to cancel out rotation. A pair of thrusters are pointed upwards, enabling the vehicle to quickly dive or resurface, as well as make minor adjustments to its depth. The spacing of the thrusters creates a smaller surface area, which reduces drag and makes transportation of the ROV easier by reducing its width. The thrusters are BlueRobotics T100 thrusters - [fig\(10\)](#), a high-performance model rated to 5 pounds of thrust and durable enough to withstand pressures deep in the ocean. Its simple control and ease of mounting options made it an easy pick.

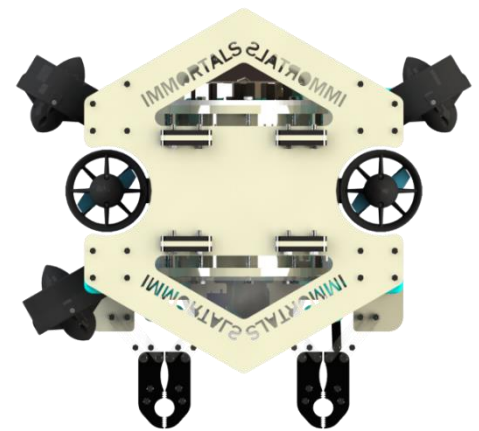


Figure 9: Blue Marlin's 5 Thruster Configuration

Direction	Maximum Thrust
Upward	$2 \times 23.15 = 46.3 \text{ N}$
Downward	$2 \times 17.85 = 35.7 \text{ N}$
Forward	$2 \times 23.15 \times \sin(60) = 40.1 \text{ N}$
Backward	$2 \times 17.85 \times \sin(60) = 30.1 \text{ N}$
Lateral	$(23.15 \times \cos(60)) + (17.85 \times \cos(60)) = 20.5 \text{ N}$

Table1: Thrust force calculations [Max. forward thrust force of one T100 thruster is 23.15 N, and max. reverse thrust is 17.85]



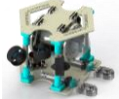
Figure 10: T100 Thruster

4- Drag Analysis:

To minimize the drag force acting on the ROV during forward motion, a PMMA (Polymethyl Methacrylate) dome is attached to the front face of the electronics enclosure, reducing the coefficient of drag.

$$F_D = C_D \frac{1}{2} \rho V^2 A$$

Where F_D is the drag force in Newtons, C_D is the coefficient of drag, ρ is the density in kg/m^3 , V is the vehicle velocity in m/s and A is the frontal area in m^2 .



5- Electrical Enclosure and Sealing

Blue Marlin's electrical enclosure -fig(11) is inserted in a pair of rings attached to the top plate, giving it a sleek, hydrodynamic profile while securing the enclosure in place. The enclosure is made of PA Type 6 (Polyamide Nylon6), with integrated flanges on both sides with 158x2.5 mm O-rings, inserted in 1.5 mm deep grooves. The O-rings act as a tough sealant between the enclosure and the faces, as they are made of Nitrile, and were selected as per the standards provided in Parker's Sealing Handbook. No chemical sealant was used in the enclosure. The enclosure has a 6mm-thick laser-cut clear PMMA face from one side, and a PMMA dome from the other side; which were selected to provide clear vision for the cameras, as well as 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 perfectly sealed container.

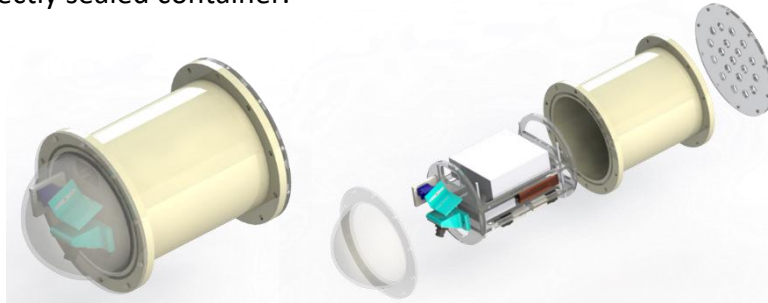


Figure 11: Blue Marlin's Electrical Enclosures

The vehicle's power and control are delivered through an array of glands mounted on the PMMA face -fig(12). The chosen glands are Nickel-Plated Brass Cable Glands; 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 in order to match the diameter of the cables going into and out of the electrical enclosure.

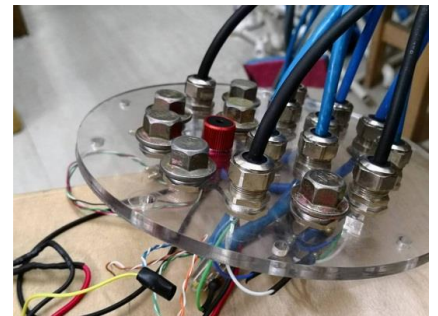


Figure 11: Cable Glands Attachment

The internal structure of the enclosure is made of PMMA 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- Tools

Metal Detection

To inspect the artifacts and retrieve the golden ones, a metal detection device is needed. A magnet is placed inside a balloon -fig(12) which is attached to the base and allowed to move freely. If the ROV goes near the artifacts, the balloon starts to move towards it, indicating that the artifact is metallic.



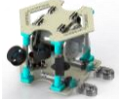
Figure 12: The balloon with the magnet inside



Figure 13: Water Bottle Used for the Lift Bag

Lift Bag

A lift bag is used to retrieve the granite block to the surface and inspect the engraved readings. The lift bag consists of an 8 litres plastic water bottle -fig(13) attached to a hook through multiple ropes. The lift bag is inflated by using a solenoid pneumatic valve receiving its signal from a MOSFET switch.



7- Grippers

Blue Marlin is equipped with two grippers-[fig\(14\)](#); to perform the necessary tasks in the least time possible. The two grippers are 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.

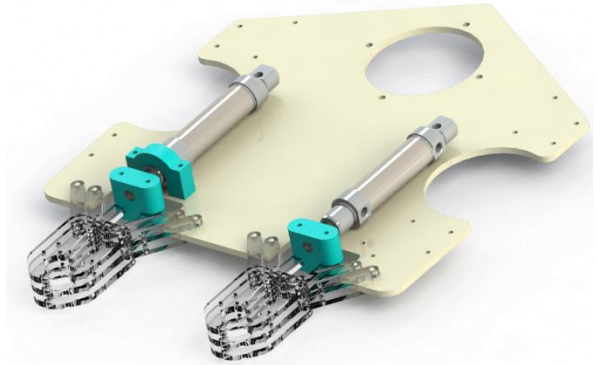


Figure 14: Blue Marlin's Grippers



Figure 15: The Gripper's End Effectors

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 as the labels used in task 2.3, while the larger curves can be used to carry larger objects as the artifacts in task 3.2. Rubber was glued to the inner curves of the end effector -[fig\(15\)](#) to increase the friction force and exert a stronger grip on the held objects.

D- Electrical Design:

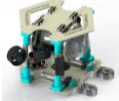
1- Electric Power

The 220 VAC voltage supplied from the socket is converted to 12 VDC by means of a power supply rated at 30 amperes. The current is transmitted to the ROV by a 4.17 mm² power cable after passing by a 25 Amps fuse for short circuit protection. The 12 volts is used to supply the Arduino Mega, 5 T100 Thrusters, the 3 cameras and the 2 DCVs. The 12 volts is stepped down to 5 volts using a 7805 voltage regulator to supply the servo motor.

Components	Volt	A/unit	NO.Of..Units	No.of units at the same time	Max current
Thrusters	12V	7	5	2	14
DCV	12V	0.4	2	2	0.8
CCTV	12V	0.3	1	1	0.3
Low Light Camera	12V	0.12	2	2	0.44
Total	12V				15.54
Fuse					15.54*1.5 = 23.31

Table 1: Maximum Power Consumption

Although the ROV is equipped with 5 thrusters, only two thrusters work at the same time and they're interlocked at a maximum current of 7 amperes by supplying them with a PWM signal of 1800 microseconds -[fig\(16\)](#).



The voltage reaching the ROV is not 12V due to voltage drop in the tether, we decided to use a 4.17mm² cable for minimal losses.

The voltage drop is calculated with the following equations:

$$R = \rho \frac{l}{A} = 1.7 \times 10^{-8} \times \frac{25}{4.17 \times 10^{-6}} = 0.1019 \Omega$$

$$V_{loss} = I \times R = 0.1019 \times 15.54 = 1.59 V$$

$$V_{ROV} = 12 - 1.59 = 10.41 V$$

A boost convertor **-fig(17)**. was used to amplify the voltage reaching the cameras to be 12V to prevent noise and flickering of images.

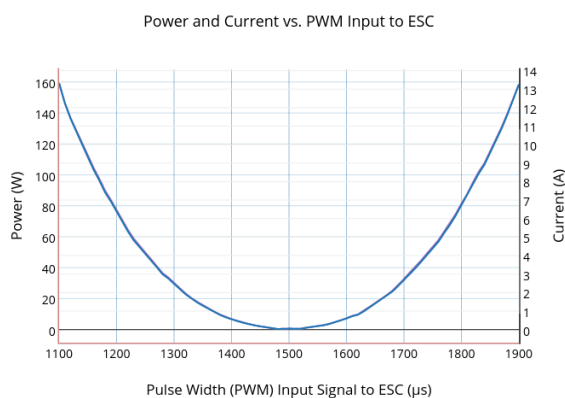


Figure 16: PWM Thruster



Figure 17: Boost/Buck Converter

2- Communication

We used USB to RJ45 **-fig(18)**. after a lot of research because the D+ and D- data lines of the USB port of the laptop are directly connected to the TX and RX terminals of the Ethernet cable. The Ethernet protocol is a full-duplex communication- protocol. The USB extension enables the control the ROV from a considerable distance from the station. The USB to RJ45 offers an easy access to the Arduino directly to upload codes without the need to open the electronics enclosure. Additionally, its price and availability in local stores encouraged us to use it.



Figure 18: RJ to USB converter

3- Control system

Controller (Micro-Controller)

We researched on what to use as our control system and we chose to use Arduino Mega **-fig(19)** since they are available and open source and easy to program also the Arduino mega2560 32-bit board that we used has a lot of I/O pins 14 of the are PWM (pulse width modulation) also it has 12 analogue ports the Arduino Mega are supported by a lot of library's that makes programming it easy and practical.

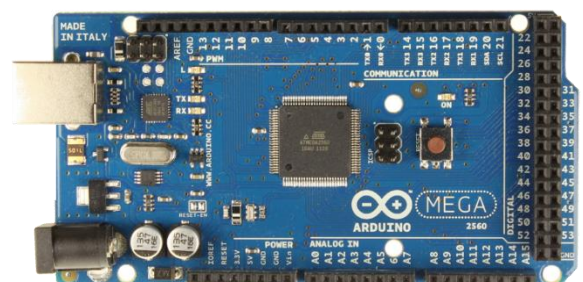
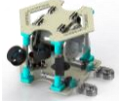


Figure 19: Arduino Mega



Actuators

5 ESCs -fig(20) are used for controlling the speed of the T100 BlueRobotics Thrusters by our microcontroller using PWM.



Figure 20: ESC

IRF640 (MOSFETS)

To control the two DCVs and the 10W LEDs we used IRF 640 MOSFETs that allows us to control the high power with the 5v supplied by our Arduino mega, we also calculated the temperature of the MOSFET -fig(21) with the power supplied to it to make sure everything works well without any damages.

IRF640 MOSFET temperature calculations:

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

Figure 21: MOSFET Calculation

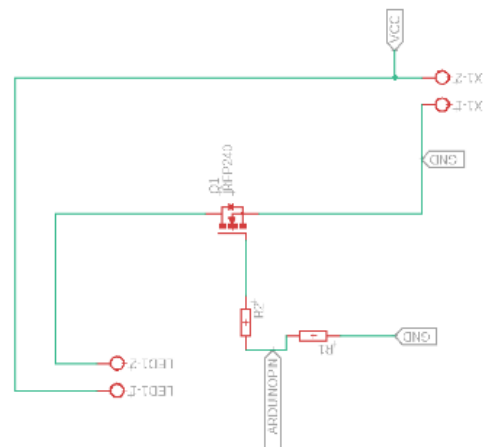


Figure 22: MOSFET Circuit

System onboard

This year we used a double layer PCB -fig(23) to allow us to minimize the size and use as much components as we want. We also put a 6- amp diode to protect us from reverse voltage connections. The board is used as an Arduino shield to make the connections inside the internal structure of our ROV. Also we made all the connection that we may need like the DCVS, LEDs, the ESCs and the analogue pins so that we can get the readings of the sensors to our Arduino.

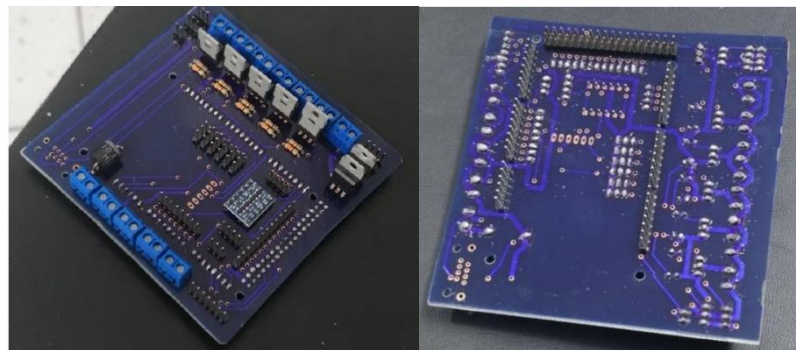
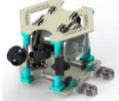


Figure 23: Mother Board

We also put the unused pins out in case we needed them We manufactured a prototype PCB by printing both layers on glossy papers and then heating it over the PCB to get printed over it and the put the PCB in acid until all the copper is gone except that has printed tracks on it and the we start the soldering process which was a challenge to solder all these pins. Track width was selected to prevent voltage drop or overheating of the board, in case the tracks are too thin.

$$\text{Width(mils)} = \frac{\text{Area}}{\text{Thickness (oz.)}} \times 1.3$$



4- Tether

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).

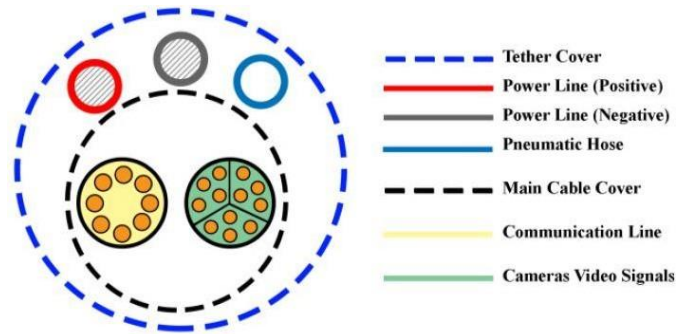


Figure 24: Tether Diagram

Power:

Based on the AWG wire sizing chart, we decided to use a 6 AWG (4 mm) power cable in order to decrease the voltage-drop (across the tether terminals providing the system with a more stable voltage. Knowing that our current limit is 23.31 amps so our wire selection was based on this calculation.

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

$$VDI(12) \rightarrow \text{AWG (6)}$$

Figure 25: Voltage drop index (VDI) and American wire gauge (AWG) calculations

5- Vision system

Main camera:

An analogue CCTV camera having a focal length of 2.8mm with an angle view of 89.9° horizontally and 79.8° vertically. Another feature in terms of flexibility, we installed a servo motor attached to the CCTV camera; indeed, the pilot can change the view of the camera from 90° to 180°.

Secondary camera:

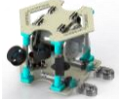
Low light analogue, Blue robotics camera, with focal length of 2.1 mm and an angle of view 128° horizontally and 96° vertically. For instance, in the statue inspection mission we used the camera to identify the largest part of the statue.

Computer Vision Reinforce Camera:

Another low light camera is used for enhancing the Computer Vision Algorithms from different aspects and for safety insurance.



Figure 26: Vision Cameras



6- Station

Main laptop

A pilot is controlling the ROV using our main laptop; in the meantime, a Graphical User Interface (GUI) demonstrates the ROV readings to the pilot, such as thrusters speed and manipulators indication.

Manipulators control monitor

The control monitor shows the captured stream from the manipulators' camera.

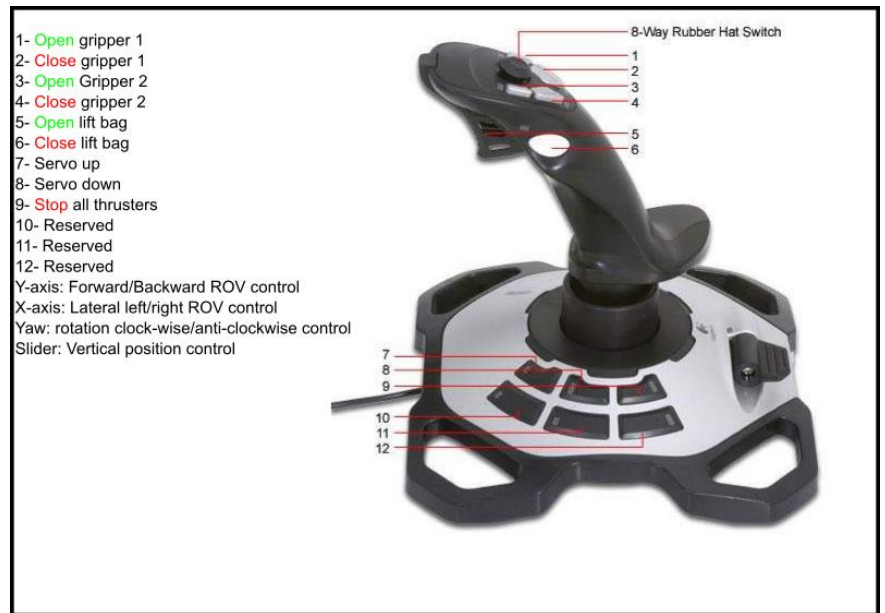


Figure 27: ROV controls using Logitech 3D pro joystick



Figure 28: Control Panel

Control Panel:

The ROV is controlled from the surface by an adaptable box -fig(28); moreover, we prefer cable management in our box to prevent cables and wires losses and for obvious troubleshooting, if needed. Logitech 3D Pro Joystick -fig(27) , which is responsible for controlling the ROV, as well as the DVR ,for live streaming from the cameras to the LCD screen ,are placed inside the control panel.

E- Software

1- Onboard Software

Blue Marlin is controlled using a master Arduino Mega hooked up to a laptop and a joystick (3D Logitech pro), the Master takes the input from the joystick, concatenates it into chars to be sent through our communication system. The goal during development was to give the pilot and co-pilot complete and intuitive control over the Blue Marlin.

2- Topside GUI

Immortals developed a new Software -fig(29) built on Python 3 equipped with thrusters testing module; in fact, it can help us in testing ROV movements. The improved topside software sends data to our joystick, 3D Pro Joystick, to the Arduino (onboard software); furthermore, the Arduino receives the software's data as character formation, then the output will be shown on the ROV.

In planning the software design, a large emphasis was placed on object-oriented programming (OOP), leading to more organized, readable, and modular code. All controllers programmed in Python 3. While Python is a less efficient alternative to compiled languages such as C#, its benefits lie in its popularity, readability, and small learning curve for beginners to allow them to learn about the ROV's software.

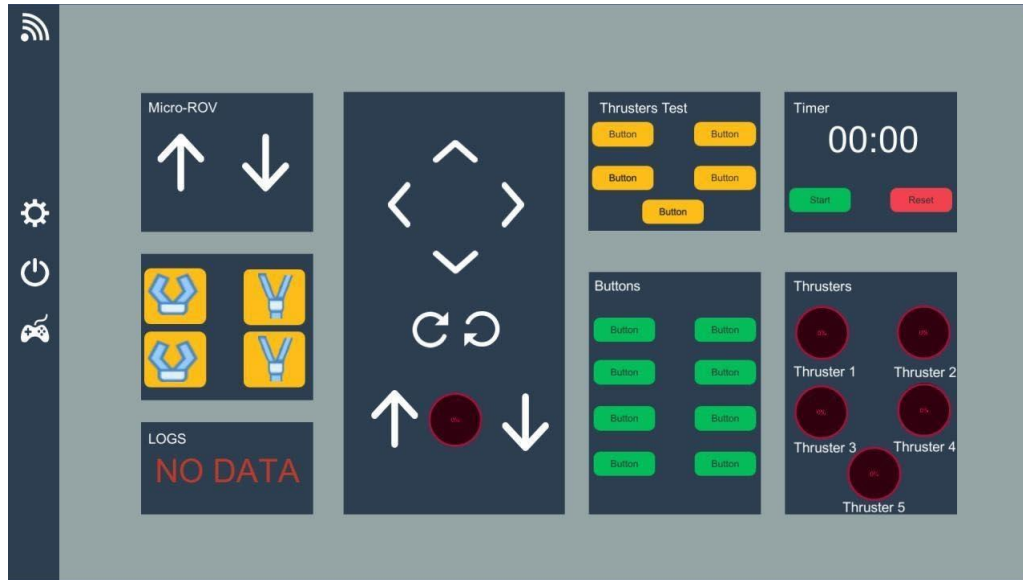
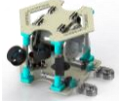


Figure 29: Graphical User Interface (GUI)

3- Mission Specified Software

Mission specified Graphical user interface (GUI) - [fig\(30\)](#) developed using Python3 and Qt library. So, the software is responsible for calculating the area of the underwater excavation area. Consequently, the software can plot the vector representation of the temple on this 20x20 grid.

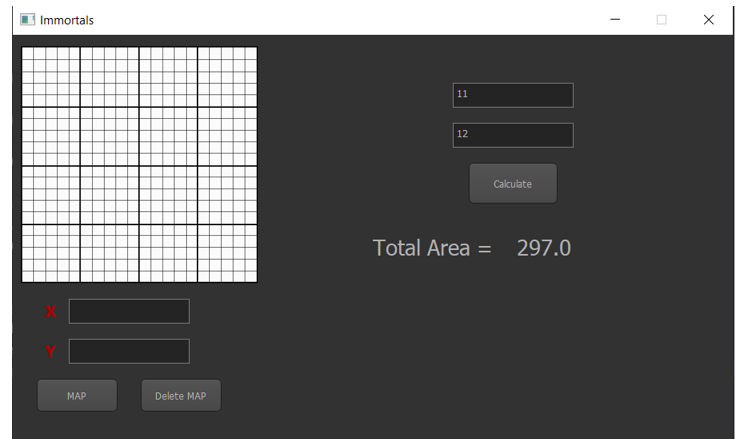


Figure 30: Plotting the temple

4- Computer Vision

The first task was for us to get the depth of the temple, so we utilized Open-CV libraries for python. As a result, we detected the brown contours of the temple by using a green PVC pipe as a reference for scaling and detecting its contours to. Since, the PVC will be at the bottom of the pool, we measure the perpendicular distance between them, and this is the height of the pool from the bottom. So, the depth will be total pool depth-height of temple from bottom of the pool

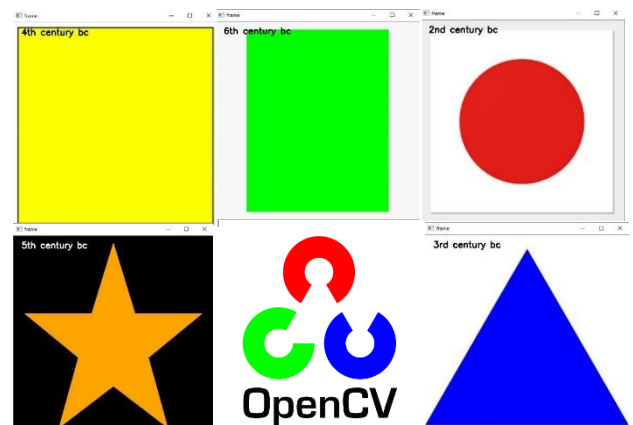
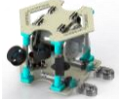


Figure 31: Computer Vision output

The second task was to identify the era of sunken ships from the shapes and colors drawn on it [fig\(31\)](#) . Through our computer vision algorithm, we can detect the shape and the color of the targeted underwater sunken ship by identifying its shape and color. Consequently, the algorithm will make a label, for the century of the sunken ship, for each shape and its own color.



III- Logistics

A- Company Organization and Teamwork

Our company, IMMORTALS, has grown significantly in terms of knowledge and skill since last year. We have built a bigger, better, and more sophisticated ROV with several new components that were built with low costs and high efficiency. The best thing about our company is how we have been able to come together and work as a team to solve problems we have faced with relatively low amounts of experience. Since we are only a second-year team, we have not been together for that long and have already had team members come and go. Throughout the process of learning and growing through competition and building experiences, we have learned to put our minds together to brainstorm a solution when solving problems in a short time. In the future, we want to perfect our team's ROV and experiment with more efficient solutions to the problems we are trying to solve. The most rewarding part of our entire building experience was learning how to solve real-life problems as teens. As students, we don't always feel like we have much power in terms of change. MATE Underwater Robotics has shown us that it is possible to produce change as young people and that we truly are the future.

B- Project management

This year, Immortals moved over to a digital platform for assignments management. The cloud-based project management software, Trello [fig\(32\)](#), was used to keep track departments tasks and dates. The digital card consists of assignment, dependencies, mentioned team member, due date, and maintained across all the departments. The digital system is more intuitive than simple sidenotes for the team, and especially in the lockdown time. A Gantt chart was established to track the timeline of the team's workflow [fig\(33\)](#).

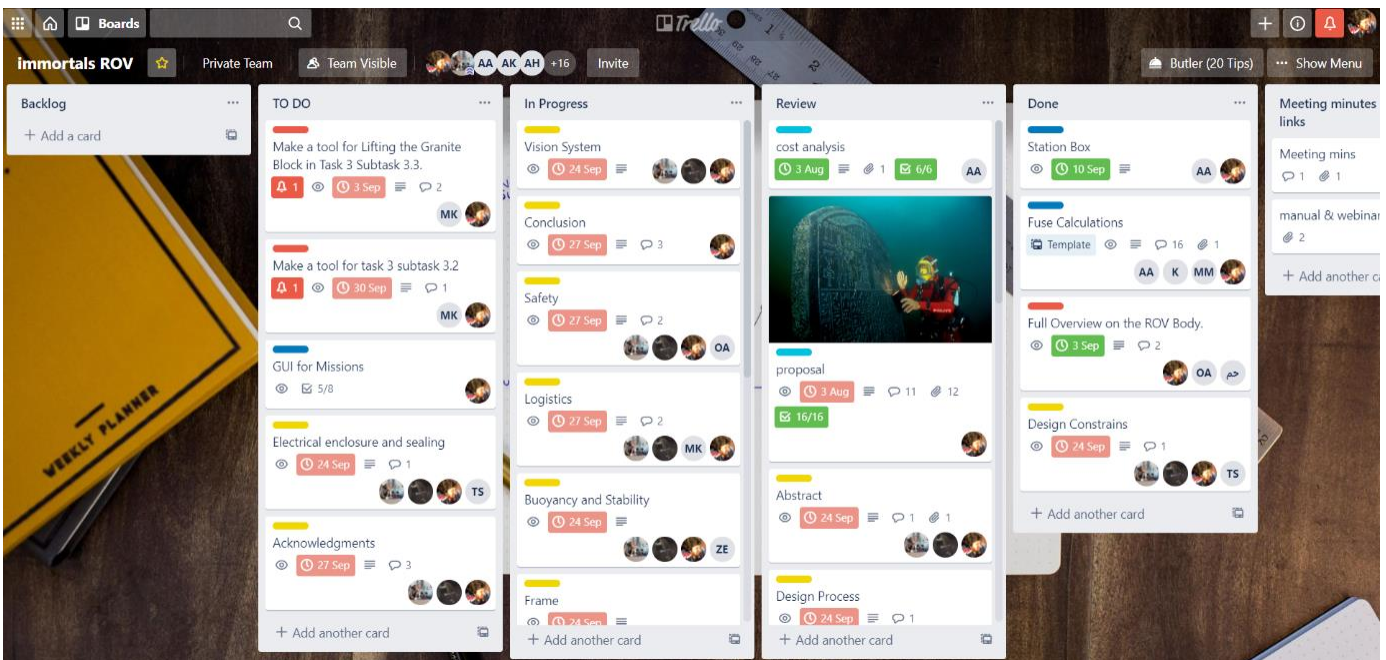


Figure 32: Team tasks dashboard

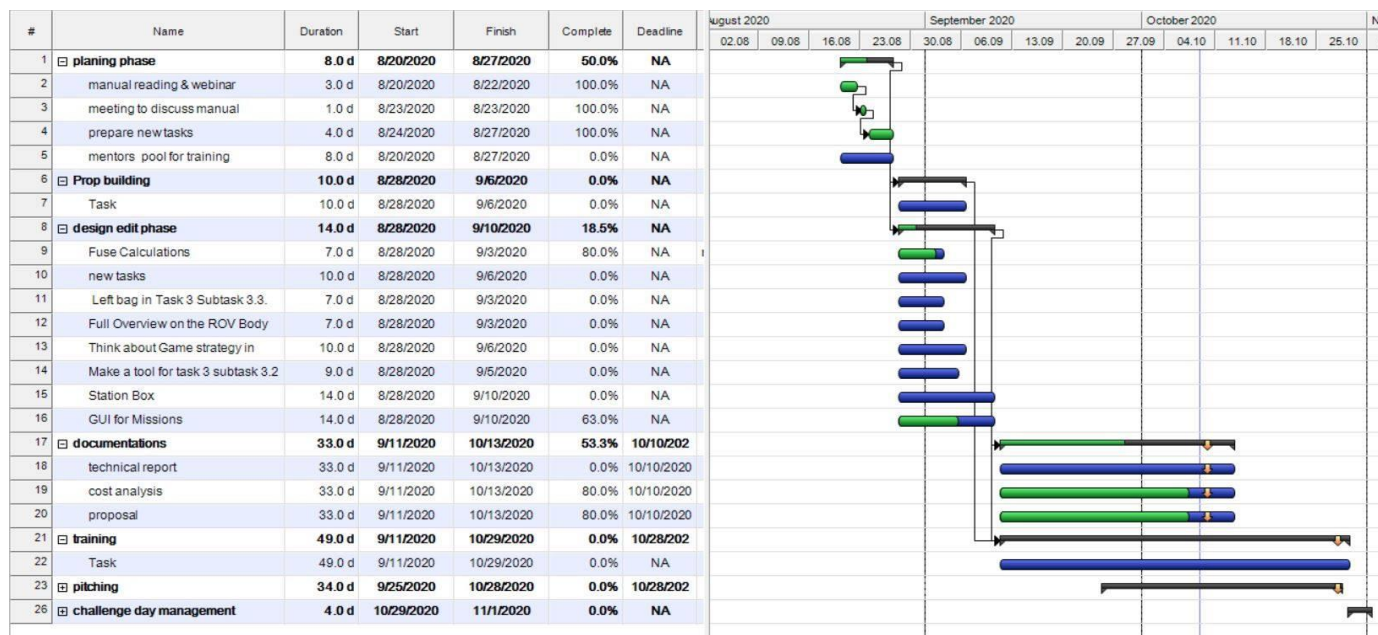
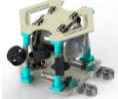


Figure 33: Project Timeline

IV- Conclusion

A- Challenges

1- Technical

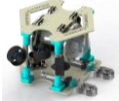
The electrical department got hands-on practice on how to manufacture double layer PCB for smaller size and instead of the single ones, while the members had previous experiences with single layer PCB. Likewise, when designing the motherboard, the upper and lower tracks had to be traced which was the actual challenge.

2- Non-Technical

Most of us don't live in the same city, so we implemented a straightforward way of communication between the team division. Through weekly meetings, technical/non-technical writing and follow-up sessions, and weekly tasks using Trello dashboard, we were able to continue specially in the pandemic time.

3- Testing and troubleshooting

All the team members must to pursue vital guidelines in troubleshooting to prevent any injurious action. We check if the compressor's regulator is 2.5 bars, while the tether cable is disconnected and check the supplying of the power supply is 12 volts. After connecting the tether, if the power is not working, if the fuse is damaged, we will replace it. Subsequently, we must check the grippers and thrusters that they are working properly before starting our mission. For further troubleshooting, if we noticed a damaged component, we would detach it for testing.



B- Lessons learned and skills gained

1- Technical skills

We are taking the pride in helping each other to boost our outcome in any task, whether it is perfecting their new forehand or nailing their next speech. Before working with the ROV, the team participated in three-month training, which contains all the valuable information and hands-on experiences for manufacturing the ROV from A to Z, hence the skills we gained not only for ROV manufacturing process, but also for any STEM project involve research and technical parts. The training was divided into two divisions, Electrical and Mechanical. The electrical training taught us, electronics, coding, vision system, and communication. The mechanical, CAD design, sealing techniques, propulsion system, manufacturing methods, and materials and their properties.

2- Non-technical skills

We gained a lot of non-technical skills including the following, how to do a proper research, marketing methods, problem solving techniques, and to think as entrepreneur.

3- Future Improvements

We are working on an Augmented Reality Application (AR) using Unity 3D [fig\(34\)](#) for developing full product demonstration from any mobile application with a cross-platform feature. Hence, new team members can learn more about the ROV from their smartphones and even for anyone who is interested in building ROV and wants to see the ROV specifications.

Using UNITY 3D, we were able to develop Augmented reality (AR) Application with C# coding. We integrated mobile sensors with our ROV 3D CAD model for demonstrating our vehicle.

We are also working on PID for improving our vehicle movements during computer vision tasks.



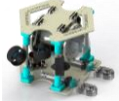
Figure 34: Augmented reality Application using UNITY 3D

C- Events

Team immortals participated in U-Tech Day gathering event which took place in the Egyptian Japanese University and Silicon Waha. We got the chance to test our vehicle inside the swimming pool of the university.



Figure 35: Immortals Participating in U-Tech



V- Safety

A- Overview (Philosophy):

It is required to use sophisticated machines in the ROV specially in construction and manufacturing parts, hence safety our number one priority while we are working. Team members are committed to a general meeting, which discusses safety guidelines; subsequently, the team has the right-hand to work in safe environment by practicing the safety fundamentals, such as safety goggles, gloves, masks, and close-toed shoes when working with power tools, and all bad coincidences are preventable.

B-Safety instructions:

- In case of any emergency case, a first aid kit and fire extinguisher are provided.
- While soldering the PCBs, it is crucial to use holder for the soldering iron.
- After soldering your circuit or wire, you can use flux for cleaning the soldering iron.
- Members should make sure that their hands are dry when in contact with the power supply
- Using safety equipment as goggles, gloves and footwear while machining or using pneumatic circuits is a must.



Figure 36: Safety Instructions

C-ROV safety features:

1- Mechanical Safety features

Safety measures are essential practice for the team while manufacturing, testing, and troubleshooting with hardware. There are abundant safety measures that every member must fulfil it to work in safe environment. Our Mechanical Department ensured the existence of the sharp edges on the ROV; accordingly, Mechanical Department designed 3D printed meshes for the ROV thrusters to meet IP20 standard. Indeed, protecting the thrusters from any foreign objects.



Figure 37: Our ROV's meshes

2- Pneumatic Safety features

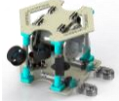
A pressure relief valve is added to the compressor and is set to 10 bars (10^6 Pa), which is the maximum allowable pressure for the tank, and the pressure regulator is adjusted to 2 bars (2×10^5 Pa) at all times. Pneumatic fittings either have O-rings, or Teflon tape is wrapped to prevent leakage. Also, all the pneumatic hoses are rated up to 10 bars (10^6 Pa) of pressure.



Figure 38: Pressure Regulator

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. The micro-ROV has a 6 amp fuse.



VI- Acknowledgments

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.

Underwater Robotics Research Center (UWRRC) – for establishing the national competition, providing services for teams, such as PCB manufacturing, and 3D printers with the highest quality.

AASTMT - Arab Academy for Science, Technology & Maritime Transport – For organizing the local and regional competitions in Egypt.

SolidWorks™ - For using SolidWorks student licenses

Pycharm Code Editor – For using student license.

Vortex Co. – for offering technical courses in electrical and mechanical

Delta Square - for organizing the local competition

Global innovation – for sponsoring the competition.

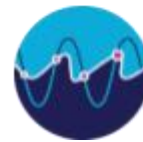
Ocean Community Challenge – for sponsoring the local competition

Robonation – for sponsoring the local competition

NTRA (RD) – for research support in the local competition

NilePreneurs – for sponsoring the local competition

Banque Misr – for sponsoring the local competition



UNDERWATER ROBOTICS CHALLENGES
MORE THAN A CHALLENGE...



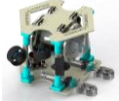
Global Innovation & Entrepreneurship
no better innovation will shape our future



OCEAN COMMUNITY CHALLENGE

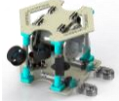


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VII- References

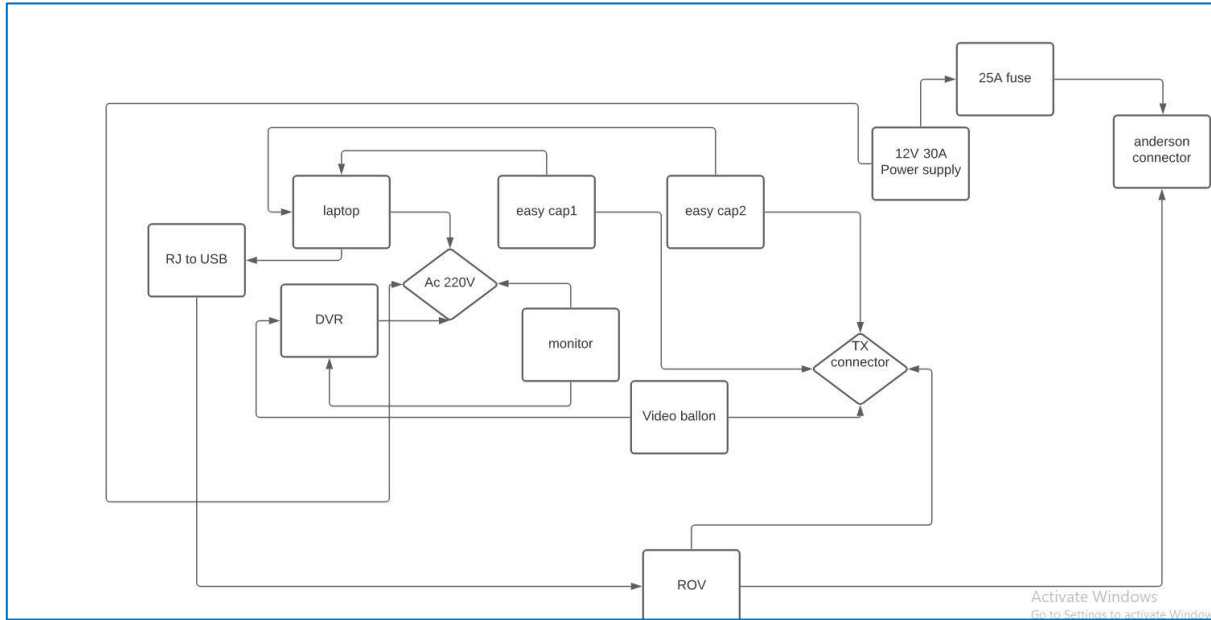
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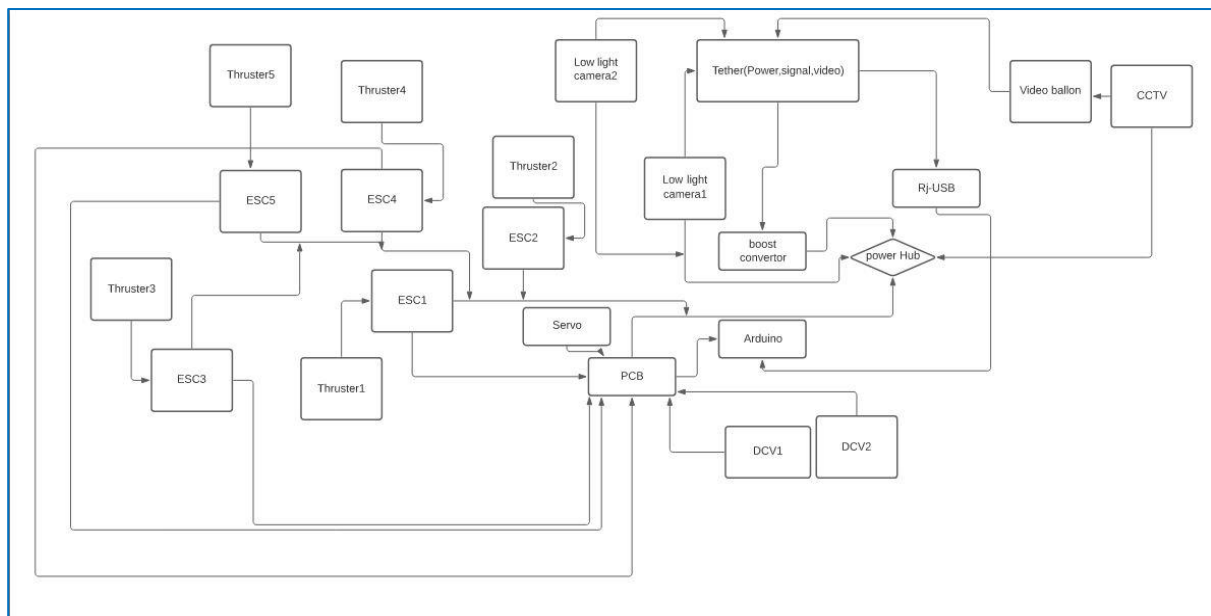
VIII-Appendices

1- Electrical SID of ROV

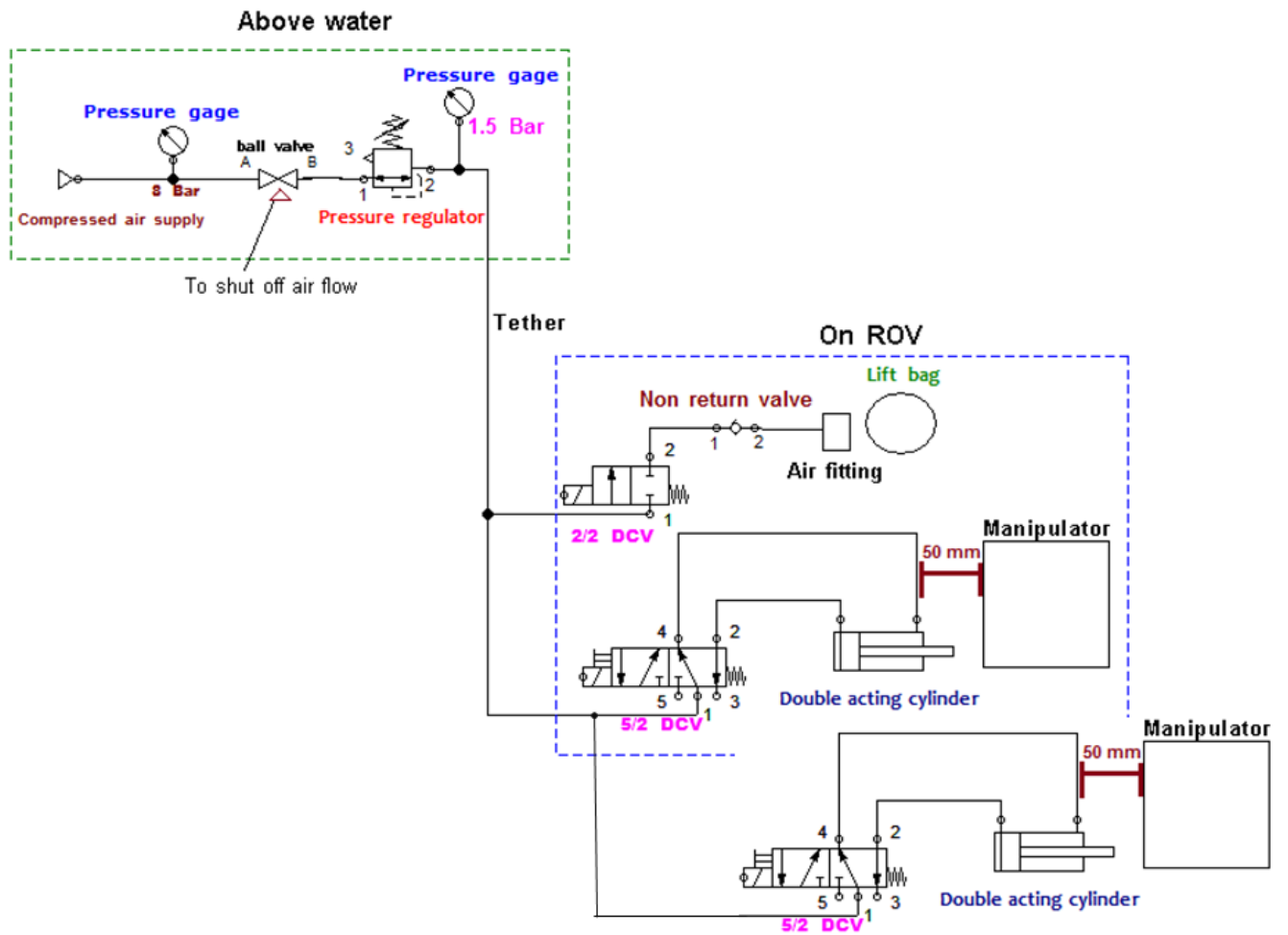
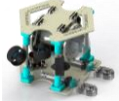
Appendix A: System interconnection diagrams



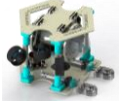
TOPSIDE SID



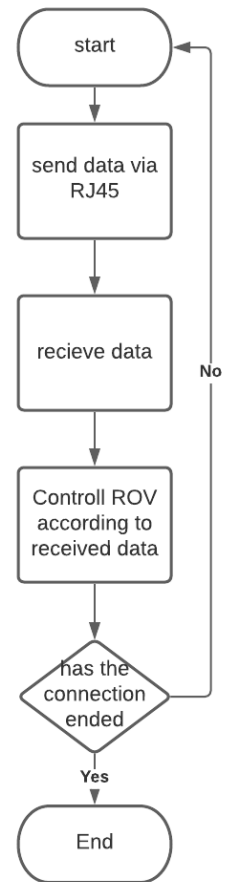
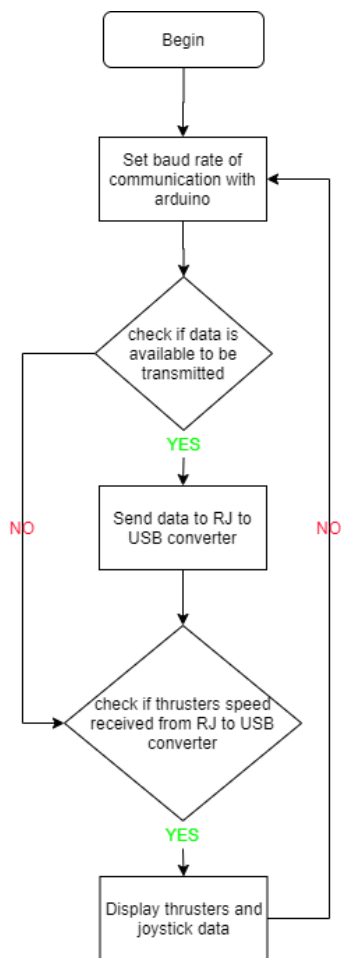
ONBOARD SYSTEM SID

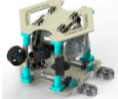


PNEUMATIC SYSTEM SID



Appendix B: Flowcharts





Appendix B: Total project Cost

Direct Materials			
Material	Price/Unit (dollars)	Quant	Price (dollars)
PMMA Sheets	30	1	30
PLA (3D-Printed parts)	129	1	129
PA Type6(Cylinder)	100	1	100
Stainless Steel Rods	1.5	1	1.5
Polyethylene Sheets	25	1	25
Arduino Mega	16	1	16
PCB(Sheild for arduino)	18	1	18
T100 Thrusters	119	5	595
ESC	27	5	135
PMMA Dome	15	1	15
Pneumatic Cylinders	37	2	74
Sealing Glands	6.1	18	110
Tether	60	1	60
DVR	65	1	65
CCTV	10	1	10
Low-Light Cameras	23	2	46
Boost-Converter	6.5	1	6.5
RJ-USB	3	1	3
12v-Power-Supply	16	1	16
DCV	20	2	40
Logitech JoyStick	50	1	50
Power-Hub	2	1	2
Sealing O-rings	0.16	18	3
Easy Caps	8	2	16
Compressor	80	1	80
Screen	45	1	45
Indirect Materials			
Name	Price/unit	Quant	Price
Bolts&Nuts	31	1	31
RJs	0.125	4	0.5
Mechanical Fittings	5	1	5
Pneumatic Fittings	10	1	10
Internal Wires	10	1	10
Heat shrinks	1	1	1
Zip ties	5	1	5
Glue	3	1	3
Screen	45	1	45
Direct Labor			
Laser Cutting	13	1	13
CNC Routing	20	1	20
Total		1834.5 Dollars	