ORCA

Technical Report

RoboTech ASU
Mate 2021
International Competition

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I-Abstract

For successfully exploring oceans all around the globe, RoboTech ASU proudly introduces the new version of the previously prominent Dusky, **ORCA**. Designed and tested to improve on previous flaws in older designs, **ORCA** is a capable Remotely Operated Vehicle (ROV) that can swiftly dive and maneuver in deep waters with the ability of visual feedback and environment manipulation using powerful pneumatic grippers. The designing and construction procedure is done by the cooperative teams that compose the RoboTech ROV corporation. The basic goal of the designing procedure is to maintain the public safety of both end-users and testing engineers with easy maintenance procedures in consideration. All the systems present in the ROV are synergic to provide convenient pilot operations with multiple degrees of freedom.

ORCA, which is manufactured using the latest and advanced techniques such as Computer Numerical Control (CNC) mill, 3D printing and Laser-cutting, comes in a unique design, compact dimensions, and light weight, and what is worth to mention that it is fully equipped with the needed sensors, cameras, controllers, thrusters, and custom-designed grippers. This technical documentation shows in detail the whole development process that **ORCA** passed through and eventually made it the best match for the requirements.

Figure (1) RoboTech Company Members

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II-Design Rationale

A- Design Process

While designing ORCA, we aim to obtain an efficient high performing ROV and an exquisite design. Also, having a ROV capable of moving steadily in all 6 degrees of freedom under water in an average depth of 7 meters. Equipping the vehicle with actuators able to grab and move objects either at the surface of the water or at the bottom, with a frame that easy to manufacture using high quality material, also we tried to make assembling and disassembling the vehicle must be easy especially for the electronic kit that must be removed easily from the entire assembly; this is to ensure easy maintenance and to fix any problem either electrical or mechanical as fast and easy as possible. ORCA must be equipped with 2 cameras one at the top of the frame for water surface missions and another camera for under water navigation and missions, equipping the vehicle with a micro ROV that can move independently from the mother ROV to do missions in tight places that the mother ROV cannot enter.

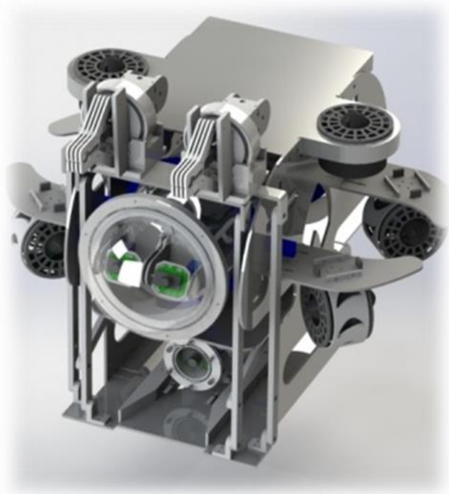


Figure (2) Fully assembled ORCA

B- Design constraints

While designing the ROV, we planned to follow the competition regulations of having an ROV with less than 20KG of mass and a ROV dimension fitting in a 64cm Diameter sphere without any of the non ROV accessories used by the ROV for extra functionality. With a moveable platform that can carry any type of payload based on the mission of the ROV, we successfully made accessories that can be added to the ROV like grippers, and Micro-ROV to fit in hard-to-reach places.

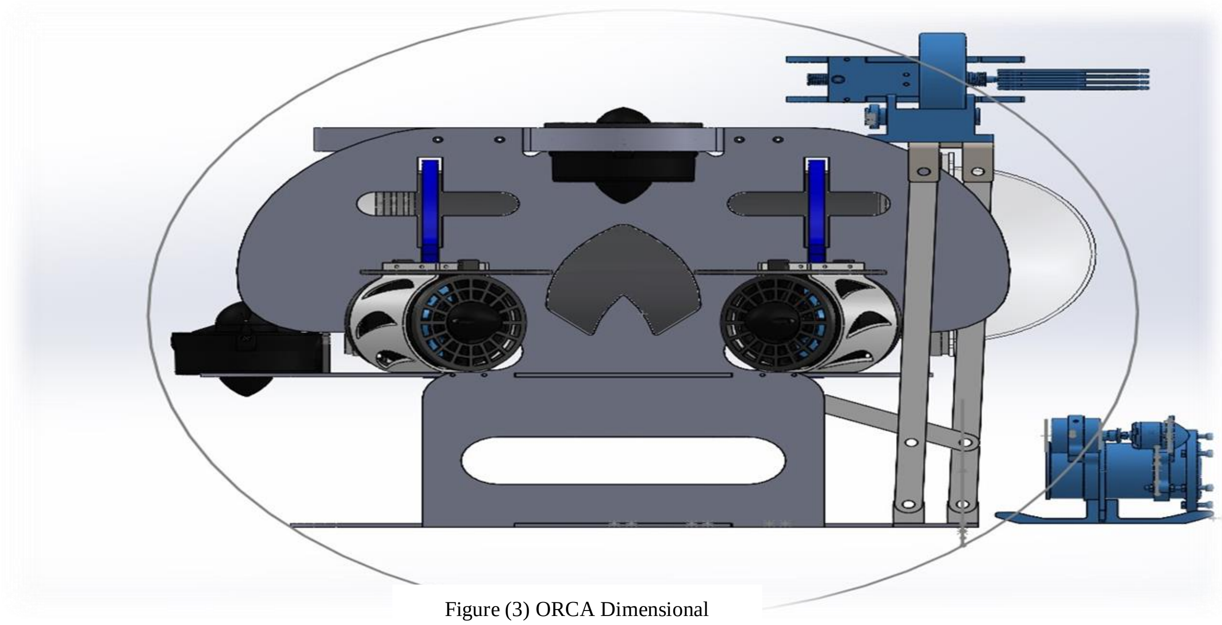


Figure (3) ORCA Dimensional Constraints

As seen in the picture above, the ROV is within the stated 64cm Sphere, excluding the non-ROV devices. To qualify as non-ROV devices, a device should be easily detachable from the ROV – within 20 seconds. So, we made sure that the movable platform is modular to accommodate different payloads and end effectors that are easily swappable.

C- Mechanical Design

1. Movements and Degrees of Freedom:

ORCA uses 7 thrusters for movement and manoeuvring. Our company decided to use T-100 & T-200 thrusters by Blue Robotics as these thrusters can produce thrust up to 23.14N in forward operation and 18.14N in the reverse operation. We designed and equipped the thrusters with shrouds for safety. The thrusters are distributed across the frame to provide the 6 degrees of freedom as shown in Figure (3) & Figure (4). The 4 horizontal thrusters mounted on the ORCA wings are aligned at a 45-degree angle to provide both surge and sway motion.

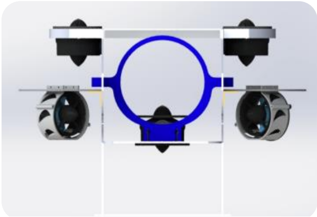


Figure (4) Thruster Omni Configuration

This alignment also provides a stable yaw motion. There are also 3 vertical thrusters, 2 of them are mounted ad the centerline of the ORCA to provide heave & roll motion while the last thruster mounted at the back of the vehicle provides pitch motion, also it work as a counterweight at the back in case that the vehicle was grabbing a heavy object at its front; to ensure steady movement.

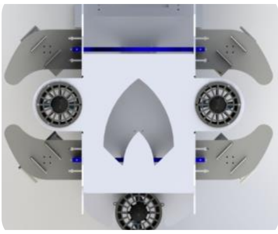


Figure (4) Thruster Omni Configuration

2. Frame:

Most of the Orca'21 frame is made of 4 mm thick Aluminum Composite Plates (ACP). This material combines the strength of aluminum alloys and the light weight of plastics. Also having a slightly higher density than water made it an excellent choice for manufacturing an under water ROV.

The plates were bought locally by our company and manufactured using CNC milling machines. Other parts of the frame are made of stainless-steel sheets like the pneumatic cylinder holders while other parts are made of "Acrylic" plates as in the kit holders.

Figure (5) Electric Kit Holder

As shown in figure (7) the frame of the ORCA is designed for to make installing and un-installing the electronic kit as easy and as fast as possible. This can be done by just unscrewing the bolts that connect the upper part of the kit holder to the lower part then disconnecting the kit from the tether and finally pulling the kit out of the frame and just like that, the kit is ready for maintenance. As the electronic kit, both the thrusters and their shrouds are easy to be installed and uninstalled.

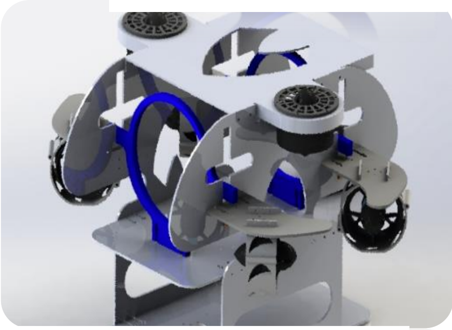


Figure (6) Electric Kit Fixation in Frame

As its name, the design of the ORCA is inspired from the killer whale or the " ORCA ", hence it is called by the same name, for it to show dominance in the sea.

Figure (7) ORCA the killer whale

3. Actuators:

<u>i- The grippers:</u>

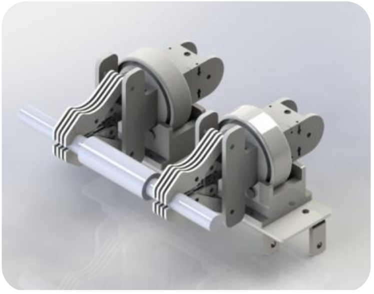


Figure (8) Gripper Vertical Orientation

Controlled by 25mm stroke air cylinders, these grippers are designed to hold objects up to 80mm in width. Furthermore, this pair of gripers can be easily fastened and removed easily from the Orca'21 and each gripper is controlled separately with its own air cylinder. These grippers can also be oriented manually in horizontal or vertical position or any angle in between these 2 positions with and each gripper is controlled separately with its own air cylinder.
The outer faces of the grippers are designed to act as a third gripper when the pair of grippers is oriented vertically.

As shown in Figure (9) this "third" gripper works when the 2 main grippers open their jaws. This third gripper can grip objects up to 94 mm in width.

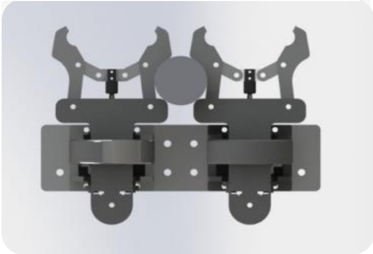


Figure (9) Gripper Horizontal Orientation

<u>ii- The lifting mechanism:</u>

One the most recognisable features of the Orca'21 is the lifting mechanism at its front. Controlled by an air cylinder, this 4-bar mechanism enables the pilot to change the position of the grippers between the top of the Orca'21 (for collecting floating objects) or its bottom (for grabbing objects under the water surface).
When the grippers are at the bottom of the Orca'21 they are also 300mm away its body giving the pilot a clear view of the grippers without having to use another camera for them. This feature will also come in handy if the object is deep inside a smaller opening than the ROV's body; the pilot can just position the grippers inside that opening without having the ROV to enter it. Moving the grippers without having to move the entire ROV will help the pilot in various tasks.

Figure (10) Four bar Mechanism limits stroke

4. Fluid Dynamics and Analysis:

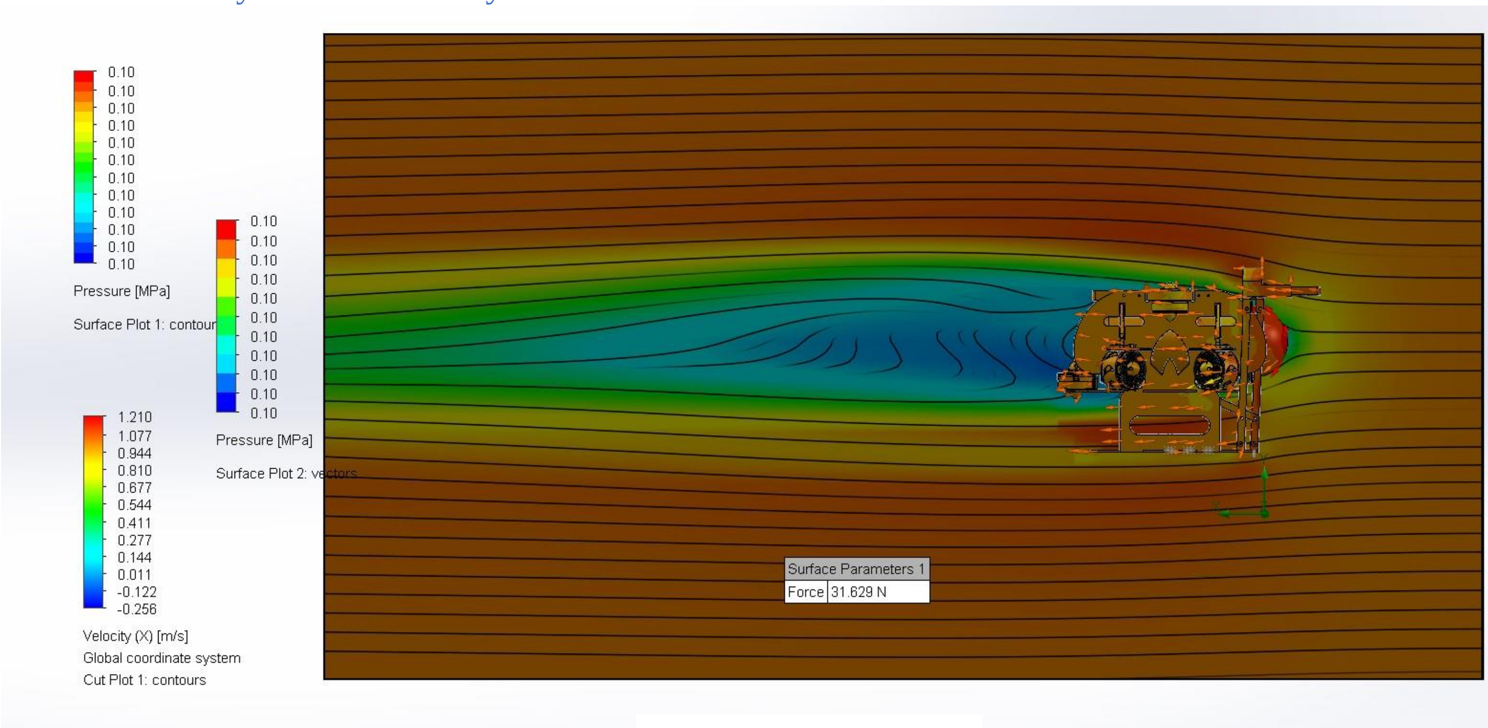
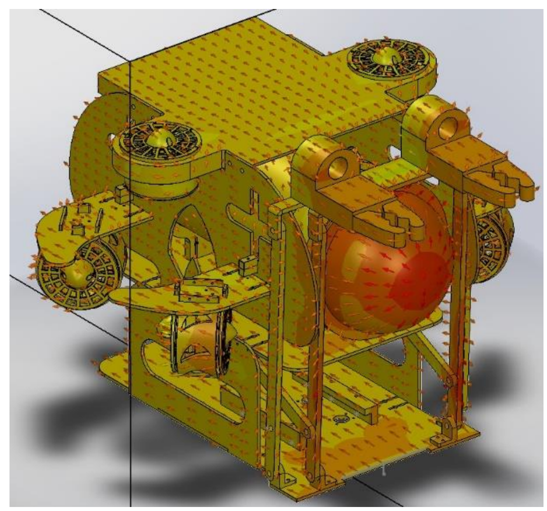


Figure (11) Orca Flow Simulation



The Fluid Simulation is used to verify the pressure stagnation points as well as the drag forces acting on the ROV as it moves through the water. As seen from the picture above, the stagnation point is acting on the dome protecting the camera, and because no sharp points are in the ROV frontier, the adverse effect of sudden pressure change on fluid dynamics is reduced.

By measuring all the normal forces on surfaces that cause drag as the ROV moves through water, we found that with a speed of 1m/s, the ROV is handling drag forces of 31N, which is more than sufficient by the T100 motors to overcome.

5. Buoyancy:

The study of vertical forces acting on the ROV is crucial for determining the required thrust force to submerge the ROV under water and keep a stable level as it makes its critical missions. For stability under water, the center of buoyancy should be higher than the center of mass to naturally overcome any disturbances tilting the ROV. In the designing process, we made sure that components with high buoyancy forces, like the electronic kit, to be physically placed higher in the ROV frame. After studying the mass properties of the ROV and comparing it to the volume of water displaced by submerging the ROV under water – to get the buoyancy force, we verified our initial design goals of a statically stable ROV under water with a slightly positive buoyancy that acts as a safety mechanism preventing the ROV from drowning if power is suddenly cut from the thrusters.

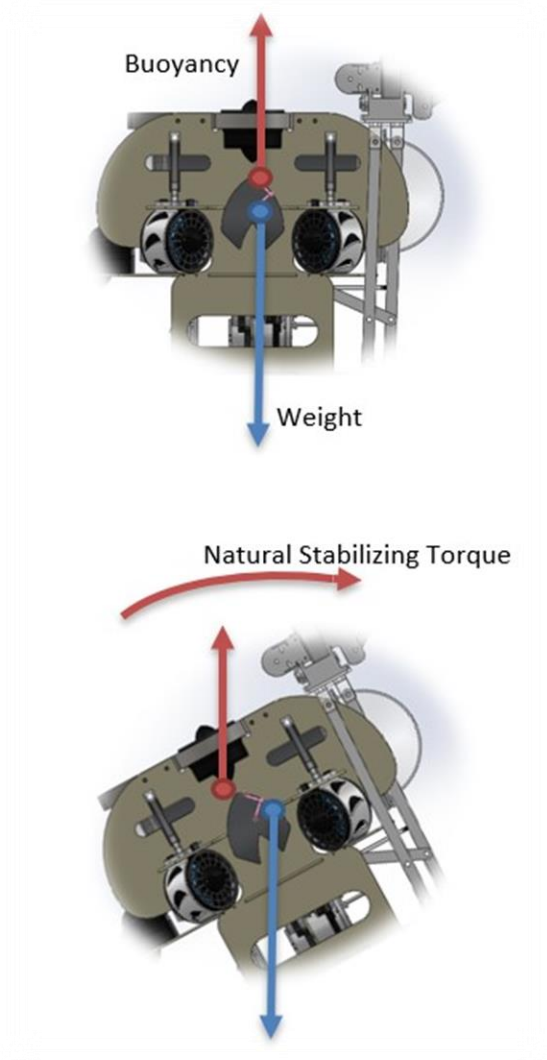


Figure (12) ORCA Buoyancy Study

Mass = 17579.62 grams

Volume = 17569663.06 cubic millimeters

Surface area = 3599060.51 square millimeters

Center of mass: (millimeters)
X = 197.01
Y = 436.27
Z = 473.00

ROV mass of 17.5KG and a CG lower than
The Centre of Buoyancy.

Mass = 11956.81 grams

Volume = 7919158.23 cubic millimeters

Surface area = 3776719.30 square millimeters

Center of mass: (millimeters)
X = 218.00
Y = 451.87
Z = 473.02

Centre of Buoyancy is above the CG by 15mm.

6. Electronics Kit Sealing:

Like the main compartment in ORCA, the hardware kit should be as compact as possible with valid waterproofing to keep safe operation. Housing the main electronics and converters powering ORCA, the Hardware Kit is directly connected to other modules to power and control sensors and actuators.

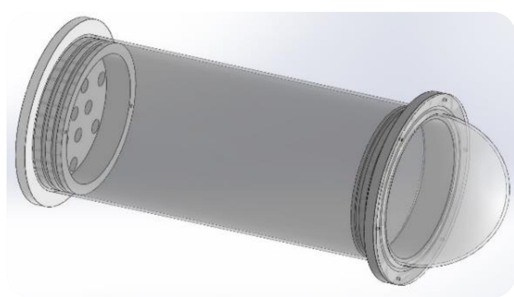


Figure (13) Electrical Kit Housing

Many designs were taken into consideration before settling on the final design of an Acrylic Cylinder as the mainframe for the kit. For instance, a design using flat acrylic panels connected using L Hinges and 3D printed
connectors were so close to being implemented but having different parts
with more connections meant more possible areas of waterproof failure even if it is more aesthetically

pleasing and unique in design. Functions were considered before form and the decision was made to use the acrylic cylinder.

Sealing is done by standardized O-rings following the Parker O-ring Guide Handbook. With an internal diameter of 170mm, the tube is sealed by adding O-rings to the front and backward caps. Submersible glands are used to seal the cables entering the kit to make sure all the electronics are waterproof.

The front of the kit is the home of two cameras that have a wide vision because of the servo operated control system. Both cameras are independent from each other and only one camera can be used to perform missions, but the second camera is added as a redundant feature to make sure that the ROV will not lose vision if any failure happened to the main camera.

D- Micro ROV (Nemo)

Having a micro ROV that can be detached from the mother ROV at the will of the pilot has many advantages. It can enter deep inside a tube which the mother ROV cannot enter and where its gripper cannot reach.
Using only 2 propellers Nemo can move in 2 degrees of freedom (heave and yaw motion) which is more than enough to finish its task in the competition.
We could not use the T100 thrusters for Nemo as they are expensive and relatively big in size, so knowing that some blushless DC motors can work under water we decided to use EMAX - XA2212/1200kv as our propellers.
The mother ROV "ORCA" is designed to contain Nemo and detach is at will.

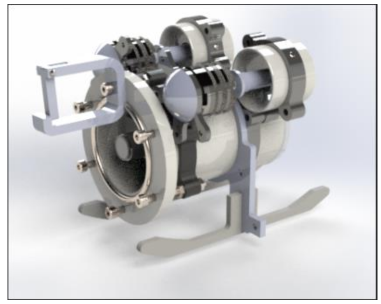


Figure (14) Micro ROV

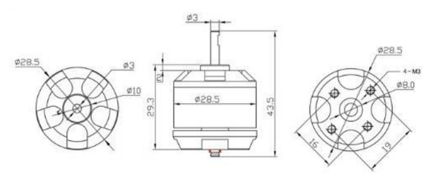


Figure (15) Micro ROV brushless motor

Nemo is fixed in its position using slots that constrain 5 degrees of freedom leaving Nemo to move only forwards and backwards. Nemo is then hooked in its position using a controlled rack and pinion - detach mechanism. When detaching Nemo, the pilot unhooks using his controller then he moves her forward until it gets out of the constraining slots and Nemo is ready to go.
Due to the size constrains when designing Nemo Our team could not afford using a mechanical gripper for the micro ROV mission knowing that this gripper will need another pneumatic cylinder. So, our company decided to go with a carabineer mechanism.
As shown in figure (18) this mechanism has a one way free joint that hooks objects when they are in position. This mechanism is very useful for the micro ROV's mission especially being small and easy to manufacture.

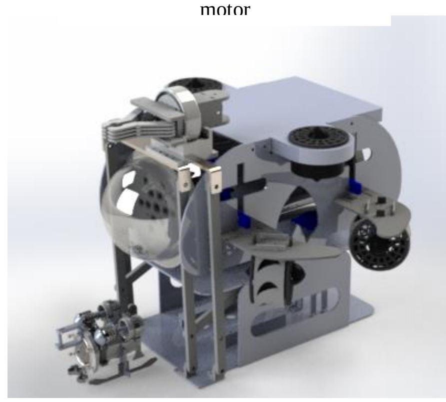


Figure (16) Micro ROV Housing in ORCA

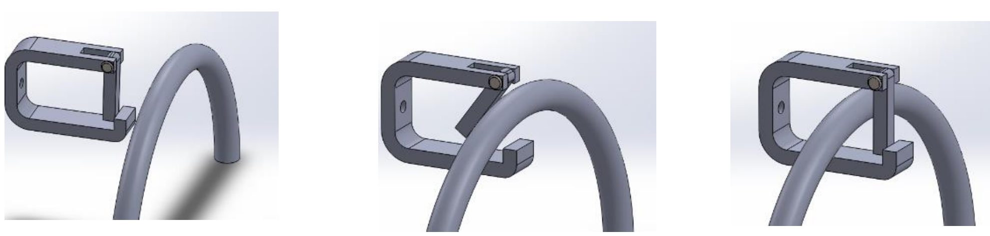


Figure (17) Mechanical latch gripping mechanism

E- Electrical Design

1. Kit Design:

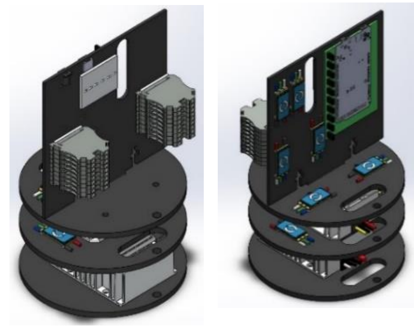


Figure (18) Previous Kit design in an isometric view

Our company's goal in designing our electrical kit is to improve the design and try to solve the problems of the previous designs.
As shown in figure 18:
Using Din-rail terminals in power connection of the components and the scattered ESCs makes the design crowded with wires and heavy which is not practical enough.

As shown in figure 19:
All the components are placed together on the top side of the kit and the conve facilitates the connection between the components and our PCBs. Also, all the wires came from the tether will take its path on the bottom side of the kit to reduce crowding of wires and make our kit more visible, maintainable, and easy to handle.

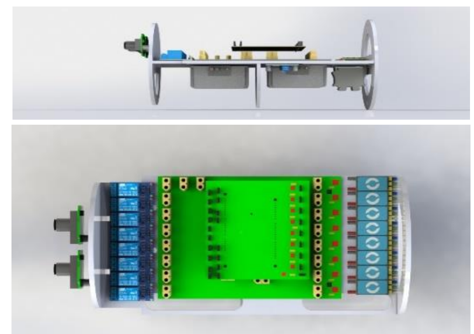


Figure (19): Our improved Kit design in both Side and Top View

2. Electrical House

1. Microcontroller

We used Arduino Mega2560 Microcontroller as its affordable price as well as their open source AVR microcontroller-based development which can be programmed easily, also the number of pins and features it provides. We used it to control our eight thrusters according to data given from the joystick, receive the data from both temperature and leakage sensors, then processing it and send it to the co-pilot on the control unit laptop, besides sending signals to the relay mod control the pneumatic valves of our grippers and our servos.

Figure (20) Arduino Mega Microcontroller

2. Mother board

In our design we aim to avoid wiring because of its fatal problems such as (voltage drop, wire chocking, volume, and appearance it includes terminal connectors to feed power to circuits to protect our circuits from high current, it is divided to:

- <u>**Control PCB**</u>:
  Our control PCB is designed to connect our microcontroller with the other components using its routes as in Figure 20, these components are:

  - **Relay Module**
    Our 6 relays modules (Figure 21) are divided as the following:
    - 2 Relays for the grippers to open and close the valves of each gripper.

Figure (21) Relay Module 1 channel

- 2 Relays for our lifting mechanism to obtain more controlling on it.
- the last 2 Relays is a plus in case one of the modules has an error.

- **Leakage Sensor**

  The Leakage Sensor can detect water leakage into an improperly sealed watertight enclosure quickly and reliably before any major damage can occur.

Figure (22) Temperature and Leakage sensor

- **Temperature Sensor**

  This high-accuracy, fast-response temperature sensor comes sealed and ready to use for temperature profiling, lab measurements.

- **Connectors**

  Using XT-60 connector manufactured with high specifications to bear the high current moving through its routes and the components.

Figure (23) XT-60 connector

- **LEDs**

  Using LEDs for each ESC to check whether working properly or not.

Figure (24) 5V Buck Converter

- **Buck converter**

  To convert 12v from the DC-DC converters to 5v.

- **FT232RL FTDI Serial Adapter Module:**

  Using for communication between the Arduino board and a computer or other devices. Serial communication on pins TX/RX use TTL logic levels (5V or 3.3V depending on the board).

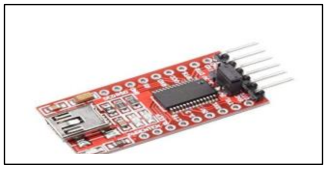


Figure (25) FT232RL FTDI USB to TTL module

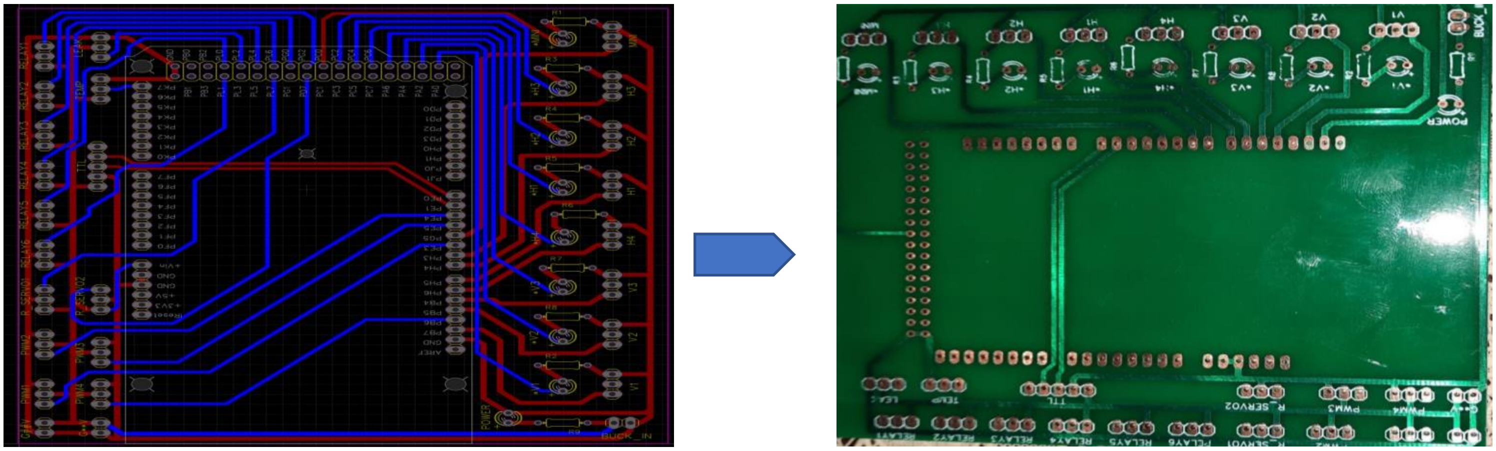


Figure (26) Control PCB (From designing to manufacturing)

- **<u>Power PCB:</u>**
  Our power PCB is designed to take power from power supply, provide converters, then distribute the power from the two DC-DC converters to all the components using its routes which are designed considering the trace width calculations. Under normal conditions, it has high efficiency with more than 95%.

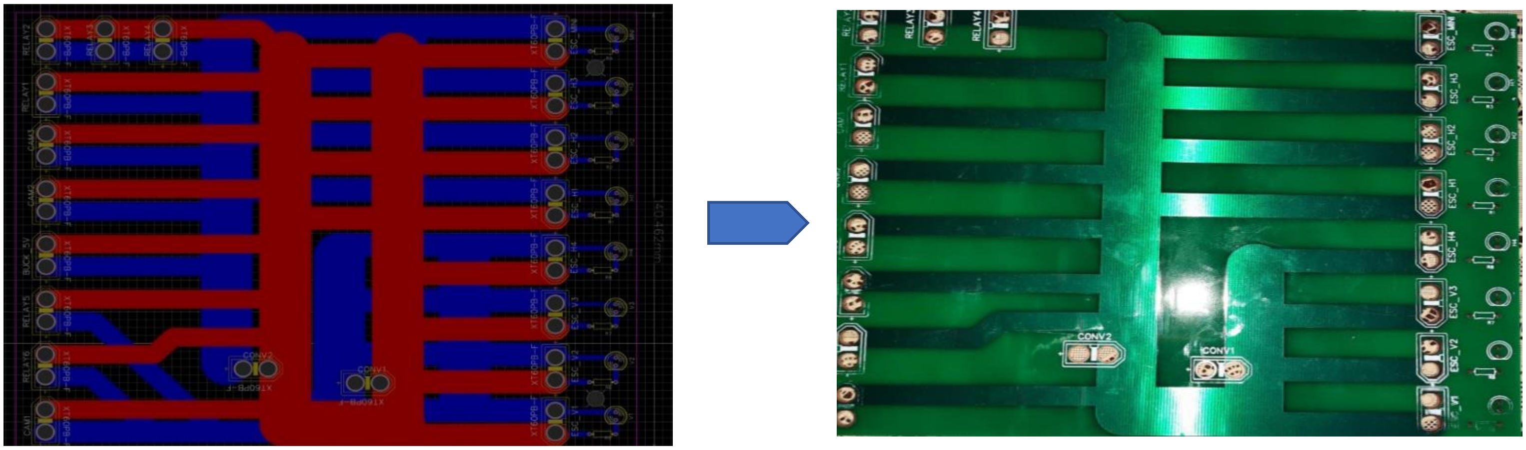


Figure (27) Power PCB (From designing to manufacturing)

3. ESCs and Thrusters

We preferred to use Blue Robotics Electronic Speed Controller (ESC) as it is compatible with both Blue Robotics T100 and T200 thrusters, high-efficiency, low-heat design optimized for minimal cooling environments and an easy-to-use interface as well as its feature to control the direction of the thrusters (i.e., clockwise, and anticlockwise).

This year, we added three T200 thrusters to our propulsion system. Its patented flooded motor design makes it powerful, efficient, compact, and affordable. It is optimized to run at a voltage of 16v (such as a 4s lithium-ion battery pack), but also can run at some ranges of voltage.

Figure (28) Blue Robotics ESC and Thruster

4. Brushless Motor

We use brushless motors to move our Micro-ROV forward and backward directions using EMAX ESC 20A, Simon series. This ESC (electronic speed controller) firmware is optimized for best performance of brushless motor. As it has over-heat protection and self-checking function.

Figure (29) EMAX ESC and Brushless Motor

5. Servo

We use micro metal geared servos to control the position of our cameras as they are mounted on our servos to give 180 degree of vision to our pilot.
Our relays are used to switch between the two servos making our pilot able to choose which camera he wants to adjust its position to have better vision.

Figure (30) Micro metal geared servo

6. Tether

The tether we are using is made up of three individual lines.

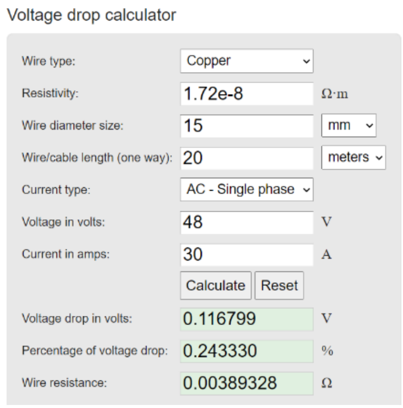


Figure (31) Voltage drop calculations.

I. <u>Power transmission</u>

It is important to determine whether the wires in the power cord or wiring array will provide acceptable efficiency when considering the length of the power. Long sets of wires may present potential safety hazards due to the voltage drop resulting from this length.
Consequently, some specifications were taken into consideration before selecting the permissible cable,
the permissible voltage drop cannot exceed 0.11% (Figure 14), so that the DC converter get a constant DC voltage higher than the switching voltage whatever the load.
The cable must bear a constant current of 30A to reduce the pulling force generated by the cable considering a factor of safety of 1.5.
Our electrical design department were easily able to choose our tether with the best specification to meet our needs, so we chose to use a cable of 15mm equals 348.55018 kcmil.

II. <u>Communication</u>

We incorporated an Ethernet CAT6 cable for the communication tether. We preferred the CAT6 type over CAT5e because of the greater transmission performance and better immunity from external noise. CAT6 is also more robust in terms of malleability and can handle harsh conditions and it can provide serial communication at a rate of 250 Kbps which is considered the best choice for our IP cameras.

3. Power System:

The design of our power system takes into consideration protective measures to avoid electrical faults in our components or the main power supply.

The current passes through 20A fuse going to the main terminal box which distributes the current to the 2 parallel DC- DC converters. Two converters are connected in parallel to avoid tripping of propulsion system. So, if something went wrong to one of them that may lead to increase the redundancy of the electric system.

Figure (32) 48v ~ 12v converter

Our power board is designed with maximized compactness and effectiveness as the input 48v is converted to 12v by two converters to obtain the high current necessary to derive:

- Three T200 vertical motor, one T100 horizontal motor via ESC drivers and camera.
- Three T100 horizontal motor via ESC drivers, camera and micro ROV.

Furthermore, the 12v is converted to 5v by the buck converter, which is used in providing our microcontroller and sensors with the required power to be able to operate successfully.

- **Power Calculations**

Name	Quantity	Max input current	Max Input volt	Max input power	Max used current	Max used volt	Max used Power	Total Ampere	Total power
T100 motor	4	12.5A	16V	135watt	7A	12V	84watt	28A	336watt
T200 motor	3	32A	20V	645watt	7A	12V	84watt	21A	252watt
Brushless Motor	2	6.5A	12V	80watt	3.25A	12V	40watt	6.5A	80watt
Camera	3	.5A	12v	6watt	.5A	12V	6watt	1.5A	18watt
Buck converter	1	3A	12v	36watt	.83A	12V	10watt	.83A	10watt
Gripper's Coils	5	-	-	3watt	-	12V	2.5watt	-	6watt

I. Total maximum power consumption = 702 watts **(never reached).**

II. Worst case scenario:

Forward motion use four T100 thrusters = 336 watts
Two cameras = 6 watts
Two sensors = .15 watts
Gripper = 4.5 watts
Arduino = 1 watts
Servo motors = .3 watts
Total = 348 watts
Total Ampere = **348/48 = 7.25 A**

7.25x1.5 (Safety factor) = 10.9 A

Used Fuse =20A

4. Vision System:

This year, RoboTech ASU decided to improve our vision system and change the previous system used in the previous years. This modification will provide more clearance and fast communication with the top side which is one of challenges that we faced in the previous years.

- Main Camera

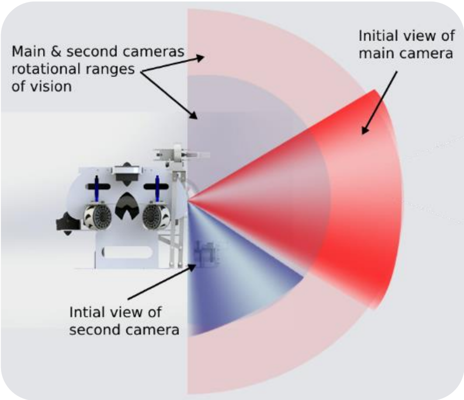


Figure (34) Field view of the 2 cameras

The main camera used is a CCTV type (manufactured by HIKVISION) provides frontal view of the ROV, the camera is horizontally oriented for pilot navigation, for the best piloting experience it is mounted on a 180° servo motor to give the pilot a full field of vision, including the pool's bottom and surface.

Our new camera has a night vision system using IR cut filter, water, and dust resistant, Fixed Bullet, 2MP and the most importantly that it is an IP camera (network camera). So, it will be connected directly to the top side using ethernet cables without using DVR which will provide fast and stable connection.

- Secondary camera

Figure (34) Our HIKVISION Camera

This camera is for the image processing missions, initially it was fixed to have a view of the bottom of the pool. Later, it was mounted on a 180° servo motor to have three extra benefits:

1. It could be used as a backup for the main camera in case of any break down to the main one.
2. To perform the image processing missions as accurately as possible.
3. To have a capture of the micro ROV getting out of the ROV as additional safety as shown in Figure 35.

- Camera Connection
  To achieve the best vision and fast connection, both cameras are connected through CAT6 cables to a switch to collect and send the video signal of both connected cameras to the pilot laptop through a single CAT6 cable as shown in Figure 36.

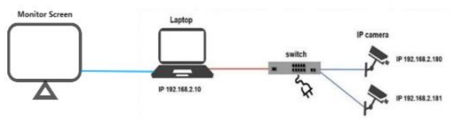


Figure (35) Camera connection diagram

F- Software Design

The ROV software consists of two main layers: a top side high-level layer, and a bottom side low-level one. Together, the two layers create a powerful software system which meets our requirements of readability, efficiency, reliability, and maintainability. The code is written in Python and C++. GitHub was used to facilitate collaboration and version control. The system's components were tested individually and after integration to ensure proper functionality.

1. Top side:

Our software team developed a graphical user interface, written in python using the Qt Framework. The GUI runs on the pilot's laptop during navigation and acts as the heart of the software system by performing the following operations:

- Displays a detailed status of the ROV and all the system components.
- Receives and displays the readings from the mounted sensors.
- Collects and transmits the desired movement and speed commands from the joystick.

Additionally, it allows the pilot to perform the ROV's main functionality such as manually flying the ROV (via a joystick) or executing its image processing tasks.

2. Bottom side:

The Bottom side was developed using C++ to run on an Arduino Mega board. The Bottom-Side is responsible for receiving the commands sent by the top side and controlling the ROV motorized motion and speed. It is also responsible for sending sensors readings to the Top-Side layer.

3. Image Processing:

- **Task 1: Transect Line and Mapping**

In this task, we aim to have the ROV autonomously fly over a specific path while maintaining a constant depth and steering angle. We achieved this by extracting just the blue pipes and dividing the image into four vertical sections and ensuring that the blue pipes remain in the first and fourth ones. When the blue pipes are at the edges of the screen, the ROV dives upwards, and when the blue pipes are close to the 50% of the center of the screen, the ROV dives downwards to remain at a certain height over the reef during the transect.

Additionally, the ROV creates a grid map of certain points of interest along the transect by finding the contours of the colored shapes, then using a shape detection algorithm to identify the shape of each contour. At this point, we map its coordinates to our created grid and place the corresponding symbol.

- **Task 2: Coral Colony Health**

This task requires comparing the old given image of the coral colony with the live feed coming from the ROV's camera. Therefore, the two images must first be perfectly aligned (using feature-based image alignment) to be able to identify areas of change. Once the images are aligned, the specified color ranges are then used to obtain the binary masks needed to compare the images and identify areas of change.

- **Task 3: Photomosaic**

We aim to create a photomosaic of a subway car submerged to create an artificial reef. To perform this task as quickly as possible, we have designed a program that is able to extract all five sides of the car using only 2 (diagonal) images. Once extracted, the five images are compared to determine the correct ordering so they can be stitched together as a single image.

4. Graphical User Interface (GUI):

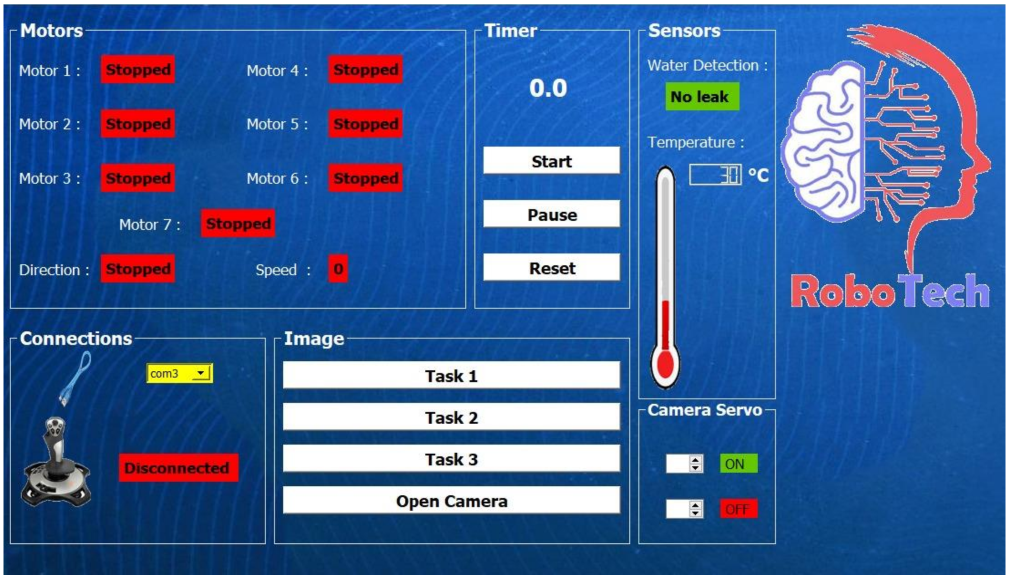


Figure (36) ORCA GUI

The graphical user interface is one of the ways of communicating and viewing feedback from the ROV, providing a high-level interface for the pilot. The application is written in python and is designed to:

- Show motors status from the feedback signal as well as the ROV direction and speed.
- Stopwatch to keep track of time spent on tasks.
- Display the readings of leakage and temperature sensors.
- Spin boxes to control the direction of view of the Main camera and Secondary camera (if the main camera is disconnected)
- Execute the image processing tasks.
- Display and configure the Arduino board connection.

5. Communication and Motorized Movement:

The communication between the top and bottom sides are done through a “USB to TTL” UART module. UART communication was chosen as it requires only two wires for full duplex data transmission (apart from the power lines). Additionally, it does not need a clock or any other timing signal, and a parity bit, which ensures basic error checking, is integrated into the data packet frame.

Figure (37) ORCA Controller

The pilot can control the ROV via a joystick connected to the pilot's laptop by 2 libraries: pygame and pyserial. A python script processes the joystick input and sends the corresponding command to the Arduino board to move the ROV or cameras' sensors. It is comfortable for the pilot and enables him to have complete control over the ROV direction and speed. The joystick consists of three axes, each controlling a specific direction of the ROV movement to give the best control experience. There is also a joystick slider for variable ROV speed. As well as additional buttons to perform other custom tasks.

G- Mission specified tools and payloads

Controlled by 25mm stroke air cylinders, ORCA's grippers are designed to hold objects up to 80mm in width. Furthermore, this pair of gripers can be easily fastened and removed easily from the ORCA and each gripper is controlled separately with its own air cylinder. These grippers can also be oriented manually in horizontal or vertical position or any angle in between these 2 positions to easily and accurately to accomplish the any task with minimum time.

➔ Design requirements of the gripper end effector include:

- Can grip objects with specified dimensions in the competition.
- Can exert enough force to lift the heaviest object in the competition.
- Is compliant with all the mechanical and electrical safety regulations applied by the competition.

III- Safety

A- Safety philosophy

To keep the electronics in a safe compartment away from water and debris, the electronic kit should be sealed deliberately and tested to determine how long and under what pressure will it keep its seal shut, apart from that, Fuses and regulators are added with water detectors to ensure extra safety. The Handling of ORCA is easily done by multiple holding points found around the ROV frame. During the design and construction of ORCA, team designers made sure no sharp edges might be visible or cause injuries to ORCA's carrier. Capped nuts are used where bolts are visible, and all edges are deburred.

B- Mechanical Safety

Thruster Safety and ROV Frame Precautions:

The prominent T100 off the shelf bluerobotics thrusters are used to provide the ROV with the needed thrust to make fast maneuvers with high reliability. This type of brushless DC Motors is isolated from water by being embedded in a waterproof layer of marine epoxy that protects the motor internals from the water. To protect ROV operators and unattentive personnel found around the ROV, 3D printed shrouds are placed on the thrusters to prevent human hands from reaching the thruster blades

Tether safety

The tether is connected to the ROV frame using a stress relief mechanism to prevent failure in the tether. Also, all cables entering the kit are coated in an insulating material and heat shrink to prevent any short circuits caused by water.

The tether is surrounded by insulating coats to keep it floating and protect the tether from marine hazards. Handling the tether is done by trained operators during any ROV missions to make sure nothing is blocking the tether or stopping ORCA's movement.

A- Electrical Safety:

Robotech ASU Company pays the greatest attention concerning all safety aspects. Safety is a priority for all Robotech ASU engineers since any injury is considered a failure for our team in handling our product.

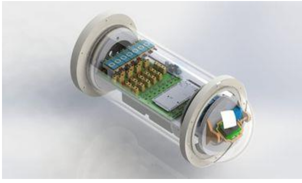


Figure (38) Sealed Housing

Figure (39) Fuse 20A

1. All electrical equipment has been enclosed in a sealed housing with padded insulating material.
2. It uses a 20A fuse with an isolated casing and color-coded cables for power and signal transmission across the electronics housing. Moreover, the software interlocking system is designed to protect thrusters from reaching full power at the same time.
3. Concerning our sealing techniques, we take safety factors to prevent any chance for water leakage in our electronic units onboard. Water detector sensor alarms the operators in case of leakage and trips the power immediately.
4. Our company engineers use 7 LEDs to check power connection for each motor and 1 LED to check if power PCB operated successfully.
5. In case of an emergency, our TCU is fitted with an emergency switch.

IV- Logistics

A- Company Organization and Teamwork

Robotech ASU company is managed by CEO and three heads for each team, it consists of three technical teams which are mechanical team, electrical team, and software team. There are 7 members in the software team,6 members in the mechanical team and 4 members in the electrical team.

First each head gave tasks for team members with deadlines to make sure that they can apply everything they had learned during the learning phase. The CEO held general meetings such that the three teams communicated regularly and well and to let each team know the work of other teams.

Tasks were assigned such that each member had a specific role to play. For the electrical team 2 members were assigned for designing the PCB, 2 members for power calculations and distribution, for the mechanical team 2 members were responsible for designing frame, 1 member for actuators, 1 member for sealing, 2 members were designing specialists, for the software team 2 members were communication specialists, 2 members were image processing specialists, 1 member were mapping specialists and 2 members were control specialists. Also, some members from the software team helped the electrical team and some members from the mechanical team helped the electrical team on their work and vice versa The team also included a non-technical department which is human resources to make sure that each and every member were accomplishing his/her tasks on time.

B- Project Management

We started working on ORCA 5 months ago, we plan to know when we should end the designing process, manufacturing process and building process.

We have made a mini competition between the team by dividing the whole team into two Sub teams. our aim from the mini competition was to train team on old missions provided by the mate, to know the ability of the team to design new ROV and to make good communication and teamwork between whole team.

C- Estimated budget

a) Direct Material

Category	Description/Use	Quantity	Total Price	Condition		
Acrylic Dome	3mm thickness, 16 cm diameter	1	$11.50	Reused		
ACP Manufacturing	4mm thickness	3	$83.09	Purchased		
Acrylic Tube	3mm, 18 cm radius	32 cm	$15.98	Reused		
Artelon Manufacturing	250 diameters	10kg	$145.00	Purchased		
3D Filament	For manufacturing	800	$50.00	Purchased		
steel Sheet	4mm thickness	4.5kg	$28.76	Purchased	Total:	$334.33

b) Electronics / Components

Category	Description/Use	Quantity	Total Price	Condition		
ESC	Brushless Motors ESC 30A	8	$200	Reused		
5-axis Joystick	For controlling ROV	1	$25	Reused		
DC-DC Buck converter	converter 48v to 12V, 30A Max	1	$35	Reused		
DC-DC Buck converter	converter 48v to 12V, 30A Max	1	$35	Reused		
DC-DC Buck converter	converter 12V to 5V, 5A Max	1	$6.39	Purchased		
USB to TTL	For communication with Arduino	1	$3.52	Purchased		
Relay Module	To control Air Valve	5	$7.99	Purchased		
IP Cameras	2 MP 1080p HD	3	$90.00	Reused		
Arduino Mega	Microcontroller	1	$16.60	Purchased		
Tether	Ethernet Cable Cat6	40m	$36.96	Purchased		
Wires & Connectors	Jumper wires and High current connectors	50	$40.57	Purchased		
T100	BlueRobotics brushless thrusters	7	$833	Reused		
A2212	Brushless motor for Micro ROV	2	$20	Reused		
Servo	For moving camera module	2	$8	Reused	Total:	$1,356.50

b) Pneumatic system components

Category	Description/Use	Quantity	Total Price	Condition
Pneumatic Connectors	For connection between valves and cylinder	10	$4.24	Purchased
T Connectors	Size 4 mm	1	$0.65	Purchased
Teflon Tape	For pneumatic sealing	1	$1.28	Purchased

Needle Valve	Flow control valve	2	$2.07	Purchased		
Pneumatic Hose	4 mm, 10 bar maximum pressure	120m	$20.00	Purchased		
Pressure Regulator	To limit the output pressure for 40 dsi	1	$5.11	Purchased		
Compressor	To charge the air tank	1	$67.11	Purchased		
5/3 Direction Control Valve	Controls ROV gripper	3	$29.20	Purchased		
Pneumatic Cylinder	Pore Diameter 16mm, Stroke 25mm	3	$24.00	Purchased	Total:	$154.00

d) Direct Labor

Category	Description/Use	Quantity	Total Price	Condition		
Laser Cutting	For frame and grippers	3 hrs	$14.06	Purchased		
PCB	For hardware kit	2	$40.62	Purchased		
TCU	Control Box		$19.17	Purchased	Total:	$74.00

e) Manufacturing Overhead Indirect Material

Category	Description/Use	Quantity	Total Price	Condition		
O-rings	For sealing	2	$4	Purchased		
Bolts and Nuts	For fixations		$4.47	Purchased		
Glands	For sealing	13	$25.00	Purchased		
Lead screws	For fixation	4	$5.11	Purchased	Total:	$39.00

2- Period Cost

Category	Description/Use	Quantity	Total Price	Condition		
Co-Working Space Rent	Renting a suitable place to work on the ROV	1	$100	Paid		
Registration Fees	Needed to enter the competition	1	$400	Paid	Total:	$500.00

Total Purchased	$684.00
Total Paid	$500
Total Reused	$1,261.98
Total Cost	$2,445.98

V- Conclusion

A- Challenges

1. Technical challenges

At the beginning of designing process, we faced some experience leakage which led us to learn about some topics, understanding it well and then getting our optimum solutions, although, we had have some problems every time which we tried to fix again and again, but by time we noticed that the problems decreases gradually, which was a good thing to us. The main problem we faced was that a very well sealing led us to another problem which made the cabs on both sides very hard to be opened again, and this made it hard to reopen it for any maintenance in the future, the best solution we put silicone grease as a lubricant, so it became easily opened. While we were working our software, team faced a few technical issues, these issues were that there were some errors at the code which control motors then we tried to change many things to make the code simpler and change some criteria into object oriented.

2. Non-Technical challenges

Our team combated to find a sponsor, so most of the expenses was paid by the team members. We also had many troubles with the imported components from abroad as they were very expensive and arrived in a long time. Due to the current conditions of COVID-19 we weren't able to do many meetings, and this affected our work in a bad way and this also affected the testing phase and pilot's training.

B- Testing and Troubleshooting

Each time we test and troubleshoot our ROV, we follow the same strategy. First, we finish sealing and electronic kit together, then we test sealing without an electronic kit by putting ROV in the pool to check that there is no problem with ROV sealing after that we put the electronic kit and test again. We checked the communication board and the printed circuit boards (PCB) inside the enclosure using an AVO meter. We also check the voltage as we want it to be and reach all the electronic components and motors, then we try all components with a micro controller and integrate all circuits together. After that we integrate all ROV components together and try to perform the required missions. At the software level, first we will do a test to the motors and check if signals reach the motors and work well or not. At image processing we test photos before putting ROV in the pool and apply a blue filter on it and check that there are no errors on the software application.

C- Lessons learned and skills gained

1-Technical skills

Our members learned CAD modelling programs as SOLIDWORKS, in order to be able to design the electric kit components. Not only that, but also learned EAGLE, and PROTEUS and manufactured our power and control PCBs. New methods of housing electronics were explored, studied, and tested, giving our young and senior members more experience. This year, our company was able to gain a new skill by trying mechanical sealing for the first time, this was especially challenging as no member in our company has tried any type but chemical sealing before.

2-Non-Technical skills

The ability to work remotely without knowing each other were the best test for the candidates to gain his/her position in the team, the team were able to select members that worked well with each other. This allowed for a more enjoyable experience for all the members and gaining the soft skills needed for each member to accomplish tasks on his own or in a teamwork. We have built our ROV not just to compete in the competition but also to be a marketable product. We have gained a lot of non-technical experiences.

D- Future Improvement

1. Adding sensors to help in stabilizing the vehicle (ROV) automatically in water using our thrusters.
2. Establish a cooling system for the electrical kit to reduce the temperature to eliminate the condensing problem on the dome.
3. TMS (Tether Management System) can be made to serve the vehicle's need of the tether length automatically by an electrically motorized system.

E- Reflections

Omar Taha (Vice Electrical Head)

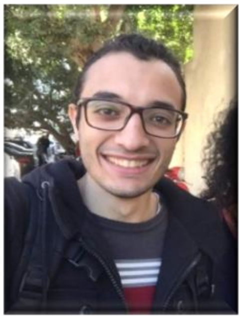
"My Journey was full of experience, I have learned many skills not just technical but how to manage my time and to work with my team and this year when I became one of the team leaders, I have learned to manage the team and to teach them what I have learned. Really, this journey I will never forget"

Salem Majed (Mechanical Engineer)

"For an Engineer, his passion is focused on Robotics field, being a mechanical member in Robotech company has enhanced my technical skills to a very good level and the non-technical skills which helped my self-confidence and widened my horizon for what I truly desire in my career. I am lucky that I was a valuable member in such experience. The Journey is Just Beginning"

Yomna Abdelhamid (Software Engineer)

"I think participating in real life projects is really important to apply the knowledge, that we gain in lectures, in a real application and pass through the experience to make it work satisfyingly. I 've gained a lot of skills during participating with the software sub-team & I am excited for the competition phases."

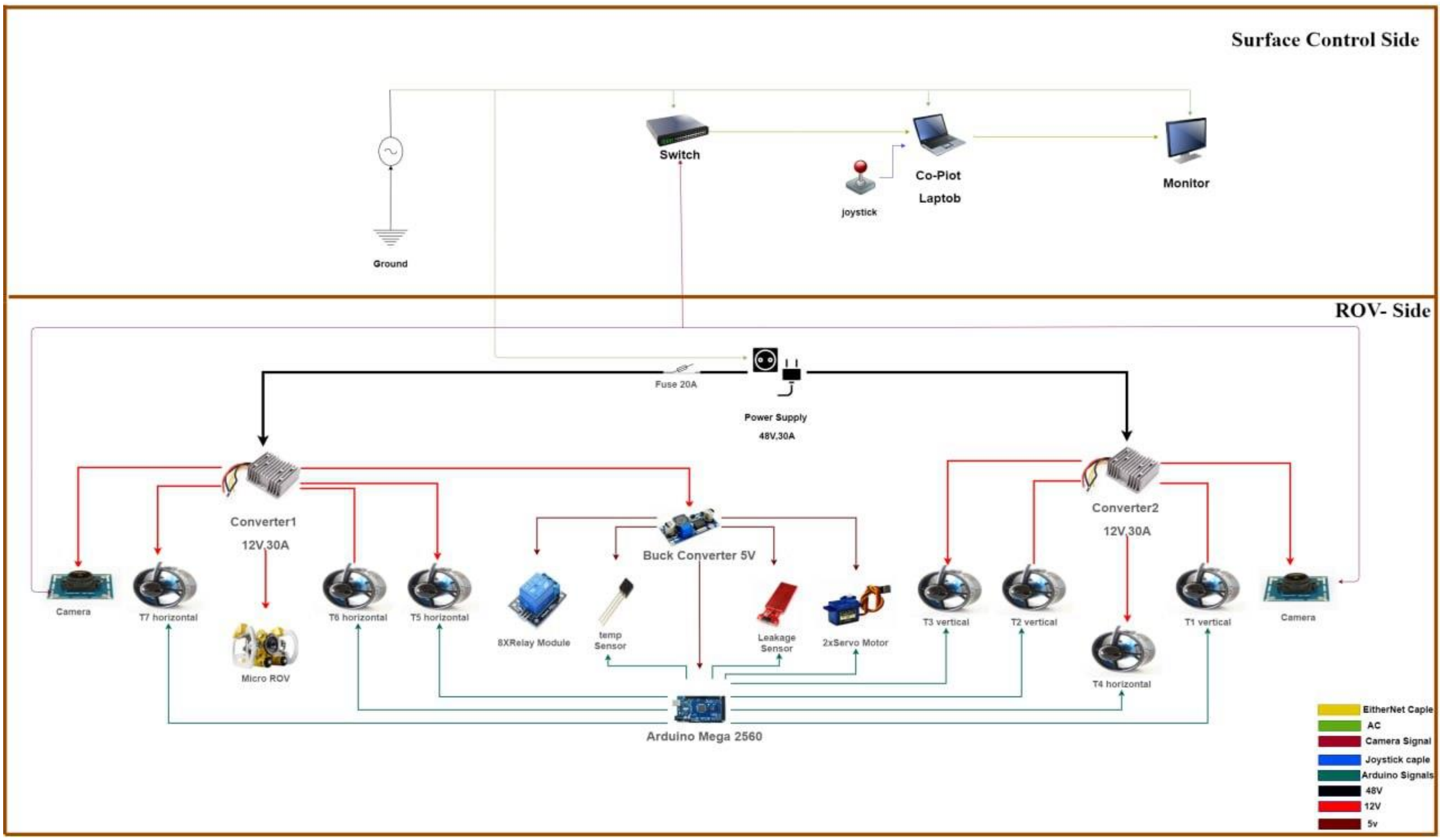


Michael Magdy (Software Engineer)

“In just a span of a few months, I’ve gained invaluable technical and non-technical skills. I have also gained extremely important experience about working as part of a team. I am certain that this learned knowledge will aid me in any future projects I embark on. Additionally, working on the image processing module of the project sparked my interest in computer vision and motivated me to pursue it further. I am glad I was able to give and learn so much.”

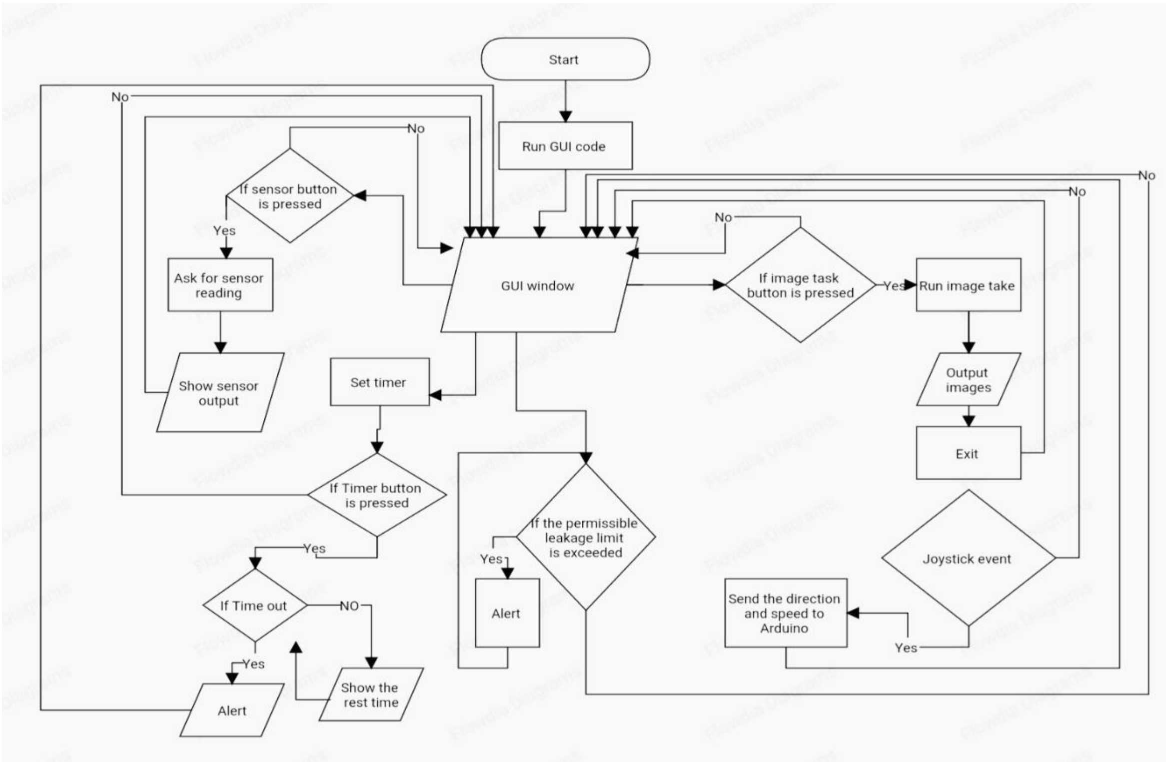
VI- Appendices

Appendix A: System Interconnection Diagram

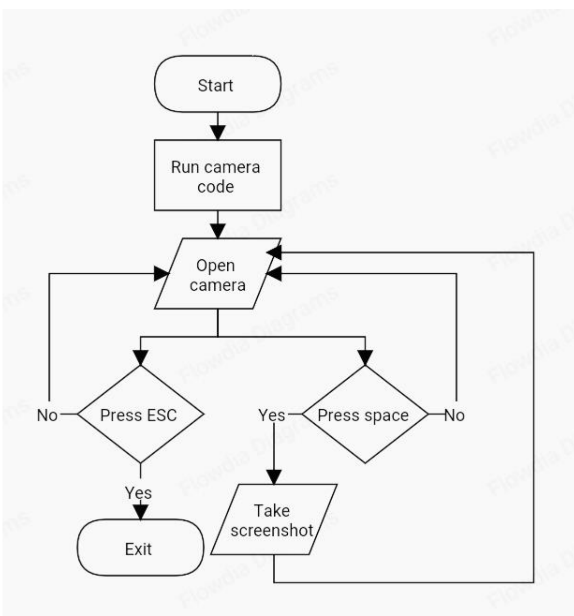


Appendix B: Flowcharts:

1. GUI



2. Arduino



3. CAM .