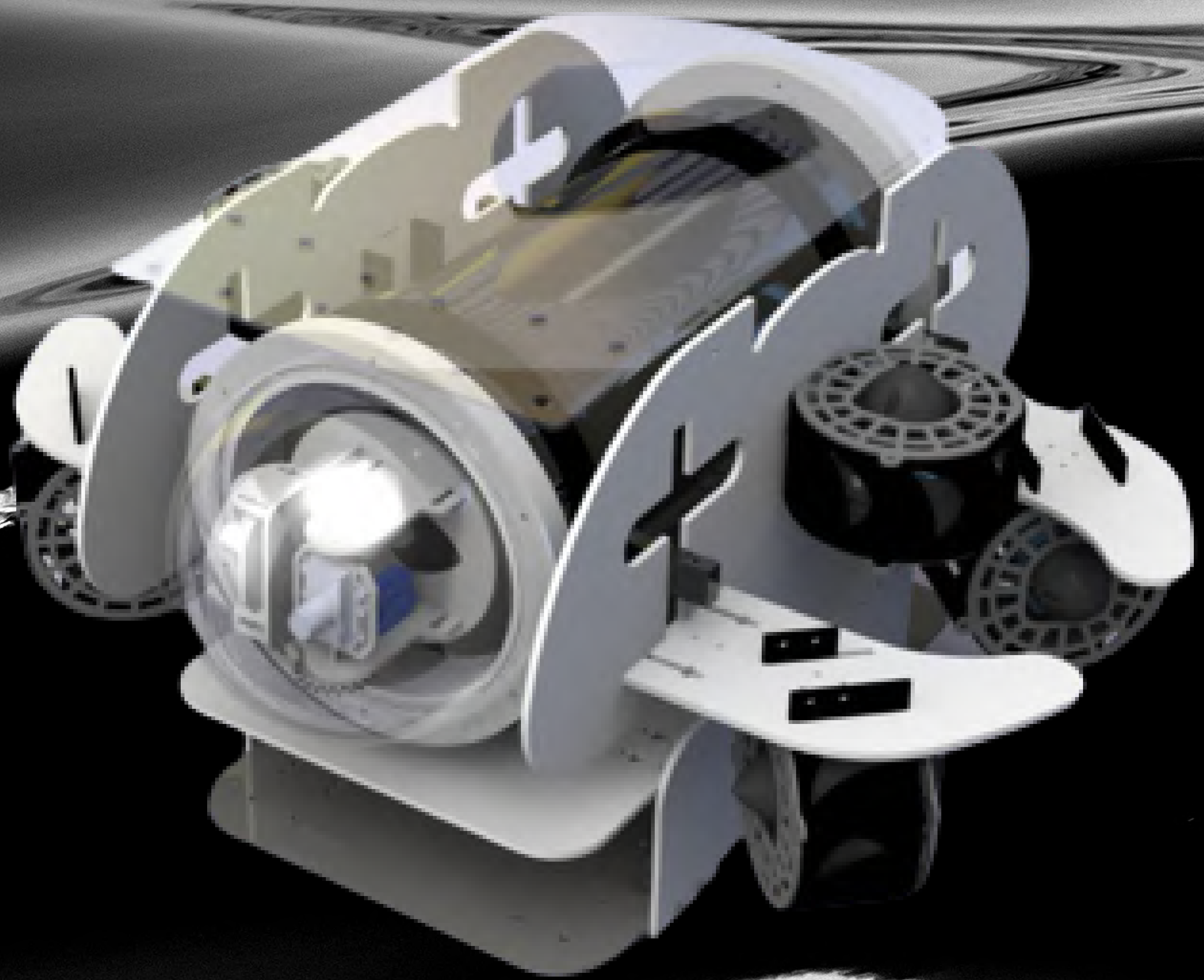
UNDERWATER ROBOTICS CHALLENGES
MORE THAN A CHALLENGE...

ORCA
Technical Report



Featuring our company employees

22'MOHAMED ABDULLAH CEO
23'ADHAM ADEL CTO
23'MOHAMED AHMED CFO
23'AHMED HAMDY MECHANICAL HEAD
22'MANAR KOTB ELECTRICAL HEAD
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23'KHALID HISHAM (MECHANICAL ENG)*
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1. ABSTRACT

In 2018 we started our journey in the Remotely Operated Viceheel industry and from this year we continue to be a forward-looking team dedicated to designing ROVs that are built to last. Robotech-ASU is a company from Ain shams university. The company has accumulated expertise in the eld of underwater robotics over the years. With a steady pace towards improving the performance of each ROV, the company devised innovative solutions to accomplish this year's tasks. Our company proudly introduces the new version of the previously prominent Dusky, ORCA. This ROV is designed for high modularity, serviceability, underwater speed, and power efficiency. Features such as modular assembly and optimum software make Britta II our most iconic product. It features a gripper and new cameras to provide an HD video system.ORCA is designed to use in Underwater Monitoring System and Search and Rescue is about being ready in case things went wrong and having the ability to intervene when needed. Moreover, we can use it in Underwater Entertainment.

This document illustrates the design, development, assembly processes, and specifications of ORCA designed idyllically to meet the global community's request for proposals (RFP).

TABLE OF CONTENTS

2. DESIGN RATIONAL

A. Design Evaluation

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, We started the year by studying previous designs to draw from our long experience participating in the ROV Competitions 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 lightweight, and what is worth 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.

Figure1: ORCA

Design Process

While designing ORCA, we aim to obtain an efficient high performing ROV and an exquisite design. Also, having an ROV capable of moving steadily in all 6 degrees of freedom underwater 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 underwater 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.

Design Constraints

While designing the ROV, we planned to follow the competition regulations of having an ROV with less than 20KG of mass and an 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.

B. Mechanical Design

Frame

ORCA is Special For its material. Our team Searched for material that is durable, light, and also easy to use, and be machined. After a lot of searching on the internet and Factories, we found it. A material called ACP or Cladding(Commercial name), ACP is a composite of two thin sheets of aluminum and a polymer between them. This composite is lightweight and is machined by CNC to get a 2D shape. ACP is available in different Thicknesses according to the application, and in ORCA we used 4mm Thickness as we see that it's the most suitable one. We use it for ORCA Side plates and Middle plates that carry the Electronic Kit. Also, we used a Steel sheet of thickness 4mm to give ORCA Extra weight and to give it stability and manipulation in Buoyancy and make ORCA easy to go down.

Figure2:frame

Sealing

Sealing was the hardest phase in making ORCA as it's the most important one, Wherewith low sealing quality, water can enter the electronic kit and burn its parts. Also worth can happen like may someone die. So our team focused on how to seal ORCA well. We used Standardized material tables as we used O-rings using Static Sealing tables. We didn't settle for one layer of O-ring so we used two layers to get more protection and sealing as shown in fig(2).

figure(3):Back plate Sealing & Inner sealing

The electrical housing sealing is incorporated in its HDPE end caps: each end cap has two radial O-rings set in grooves machined according to Parker Co. standards. The O-rings not only keep the electrical components dry at all times, but they also cut down on maintenance time, as the caps can now be easily removed by hand without having to use any tools. Silicone grease is used with the O-rings to protect them from wear, extending their lifetime. 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 had different parts. 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.

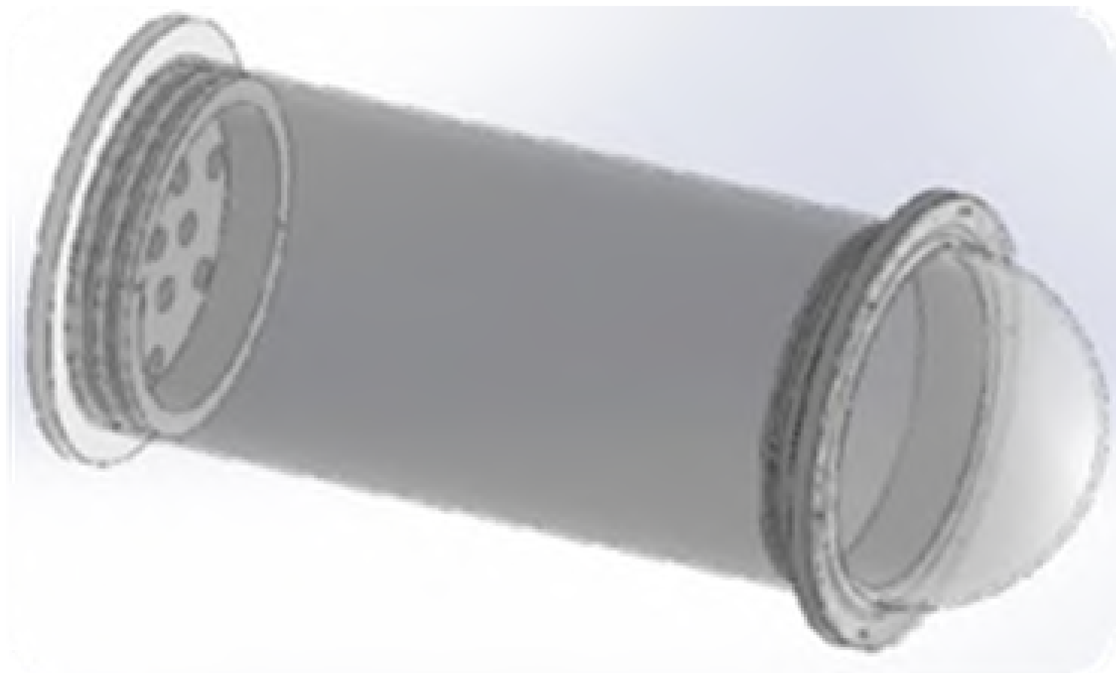


Figure (4) Electrical Kit Housing

Movement

In ORCA we used six Bluerobotics T100 motors to give us 6DOF. The upper two Motors are used for moving up and down in the Z plane. Also used for Roll Motion. The other four motors are set in the angle to be used in horizontal and vertical motion too, also for yaw and pitch motion. However, the T200 thrusters have one deficiency which is their high power consumption, yet this is only considered at high-speed operations as shown in the drag equation:

$$F_D = \frac{1}{2}\rho . u . C_D . A$$

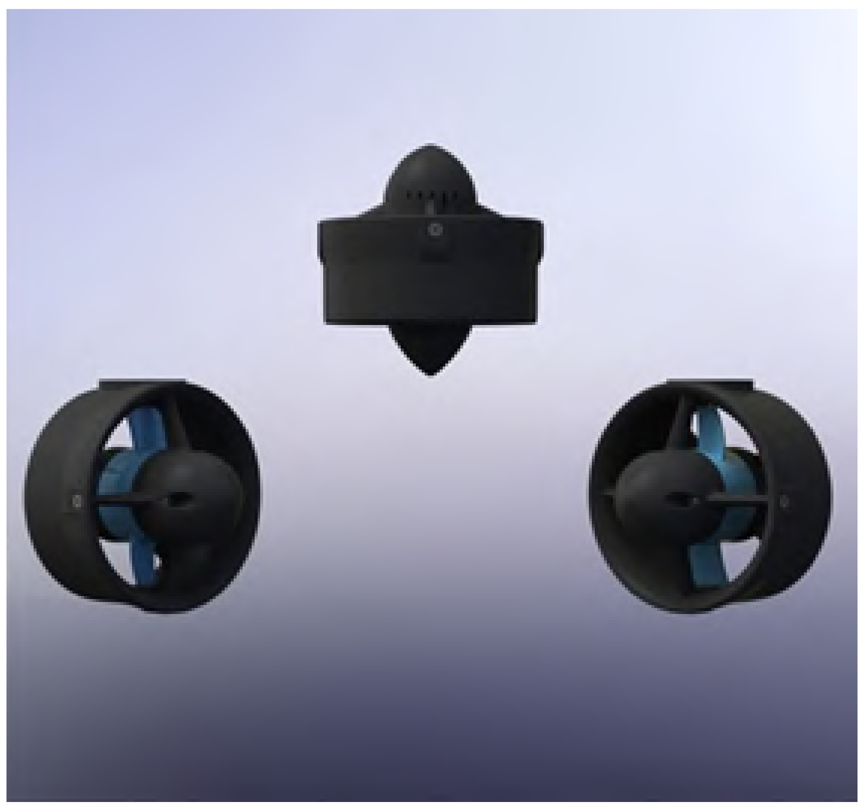
Where F_D:is drag force(N), ρ : is density of fluid(kg/m^3) , u: speed of the ROV relative to the fluid(m/s^2) , C_D : Drag Coefficient, A: Cross Section Area(m^2)

$$\rho = 1000\ kg/m^3 \ , \quad C_D = 0.45 \ ,$$
$$A = 0.05318088\ m^2$$

$$\therefore F_D(u) = \frac{1}{2} * 1000 * 0.45 * 0.05318088u$$

$$\therefore F_D(u) = 11.966u\ N$$

Figure (5) :Equations of motions



Figure(5):Thrusters Orientation Figure(6):Thrusters Distribution

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 the 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.

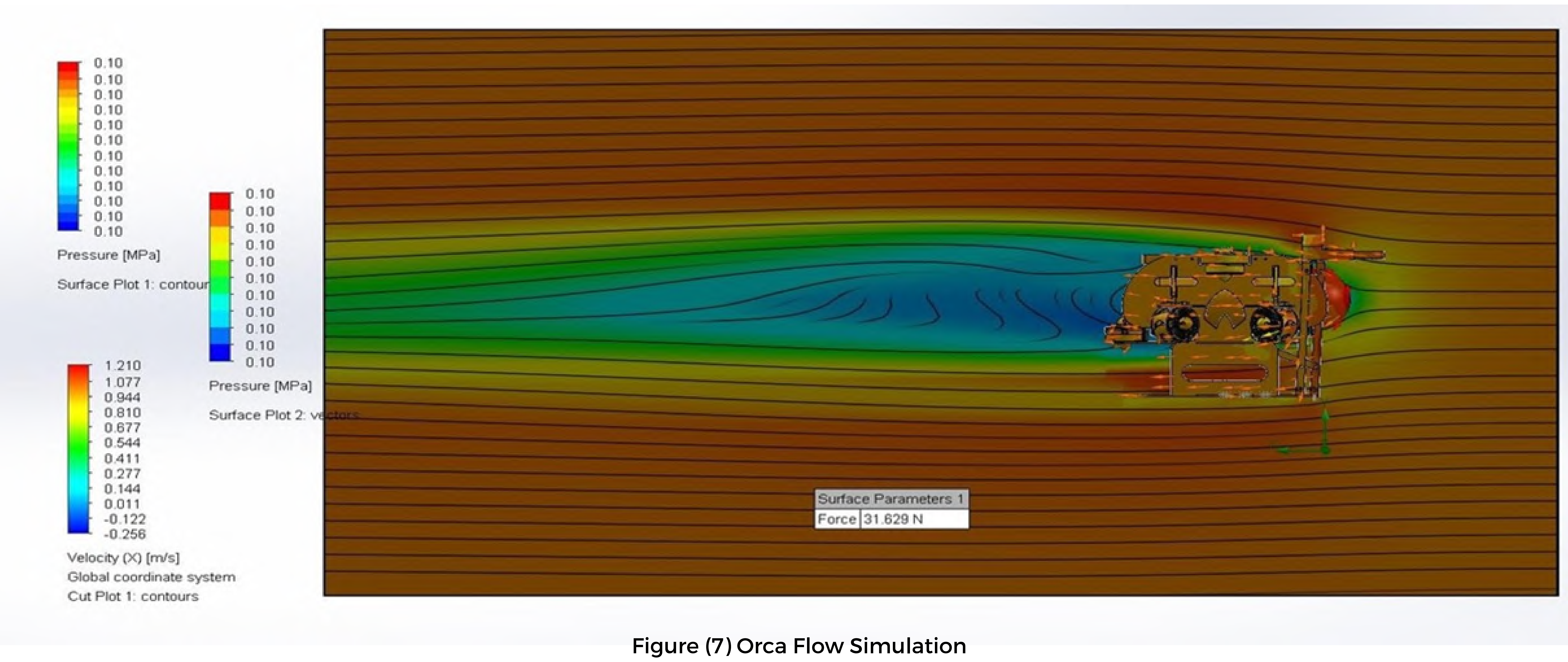
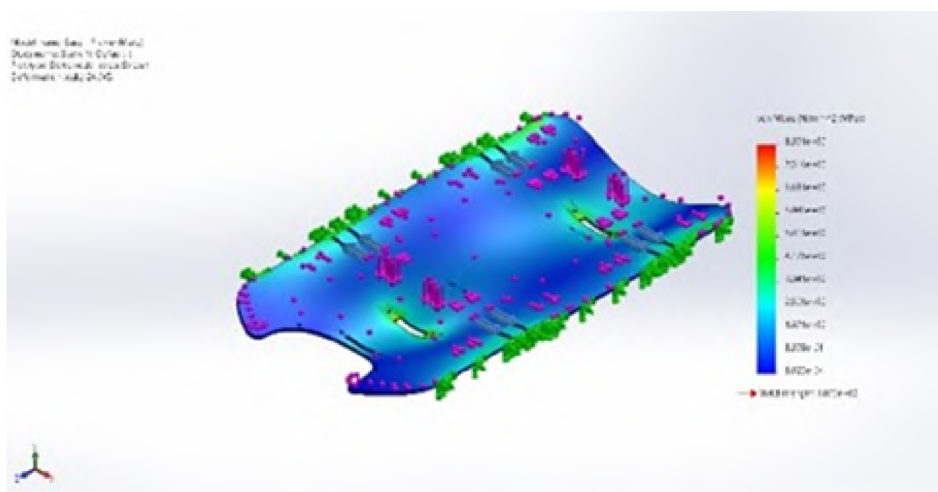


Figure (7) Orca Flow Simulation

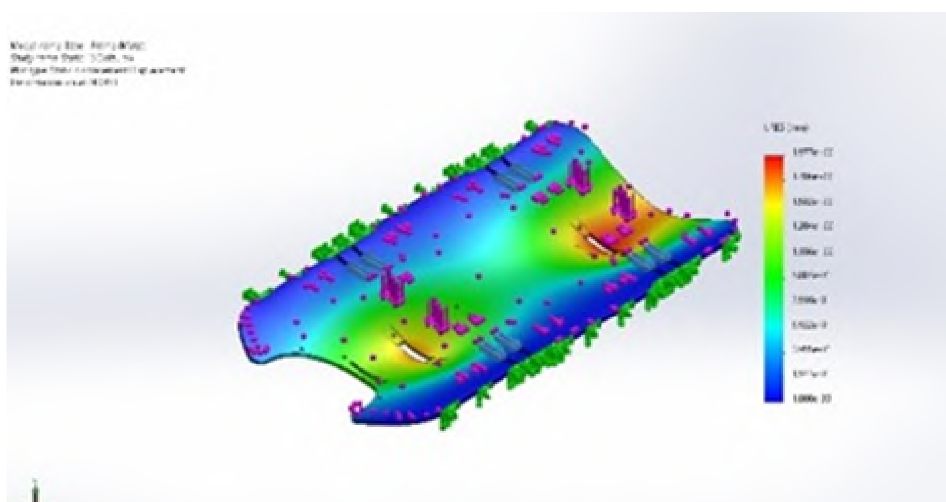
Stress analysis

Stress analysis is essential to choose suitable material that can afford the stress and the weight of an Electronic kit. At the last ROV versions, Our team used Acrylic to hold the main parts of the ROV, but it is not strong enough in low thicknesses, So we go to another material that is ACP where we can make on it the same 2D designs that we can make on Acrylic and can afford more Stress with lower thickness. This analysis shows the most critical part of ORCA that is the Middle plate where it holds Electronic kit the is the heaviest part of ORCA:

As shown in Fig(5), The maximum stress is 8.351MPA and all the body at the safe zone
As shown in Fig(6), The maximum Deflection is 1.977 mm.



Figure(8): Max stress



Figure(9):Max Deflection

Buoyancy and Stability

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

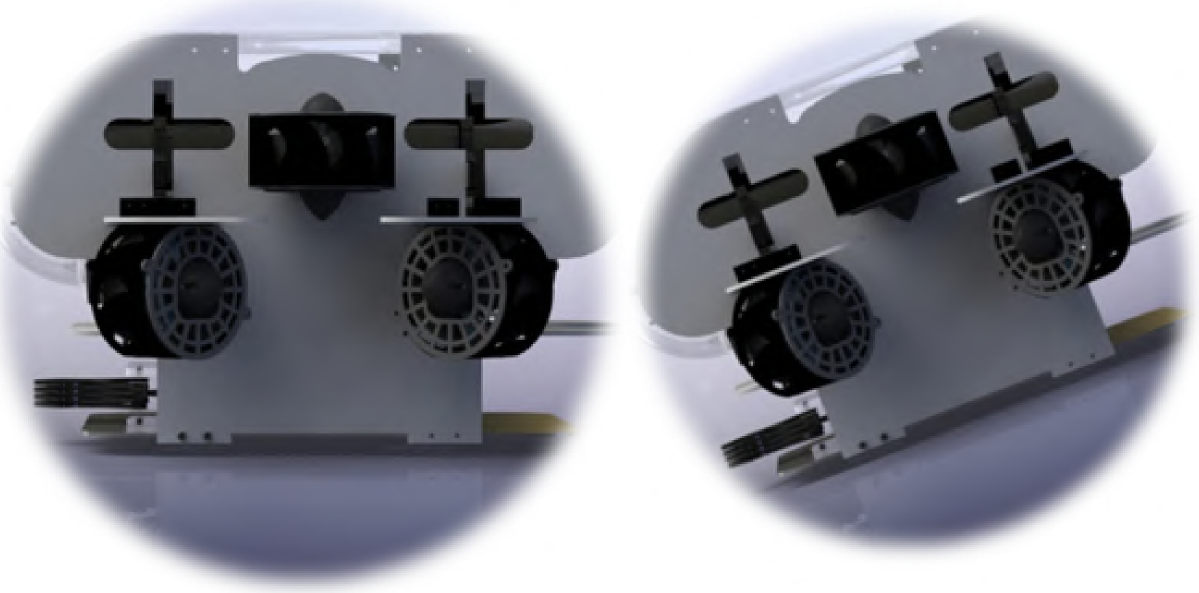
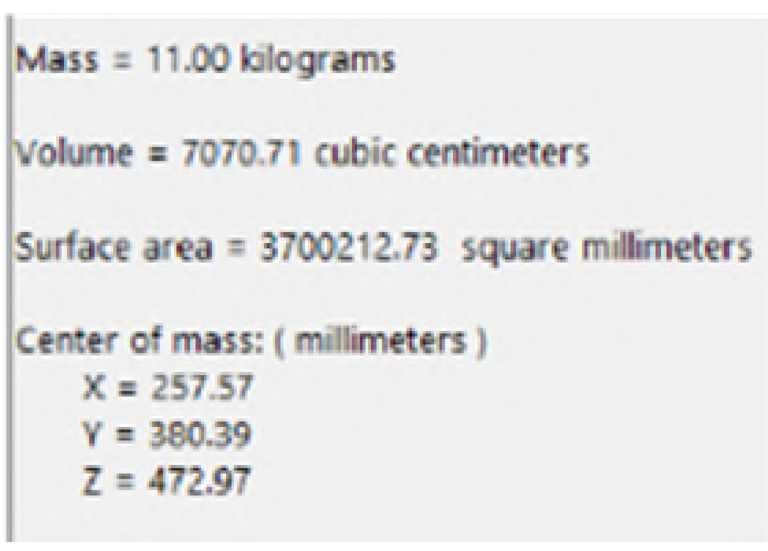


Figure (10) ORCA Buoyancy Study

The mass of ORCA in Simulation is 11KG and its center of mass in the Y-axis is 380.39. While the Center of Buoyancy in the Y-axis is 427.12. Centre of Buoyancy is above the CG by 46.73mm and that is the Required.



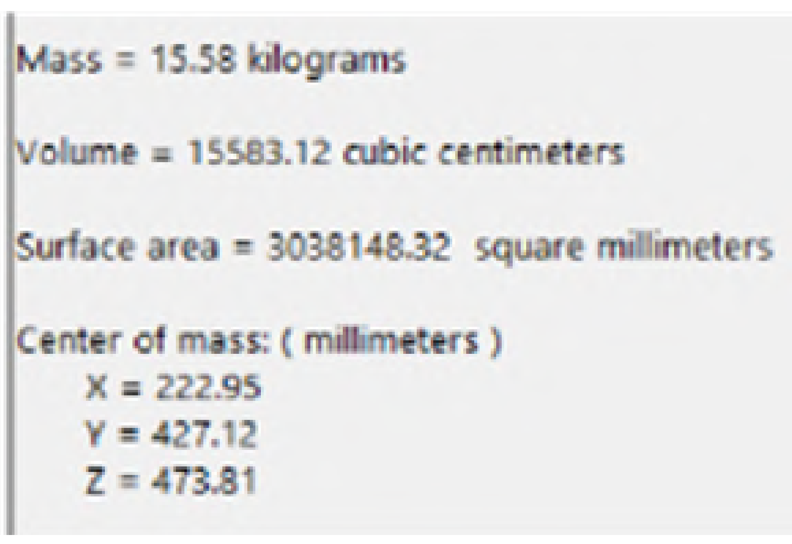
Mass = 11.00 kilograms

Volume = 7070.71 cubic centimeters

Surface area = 3700212.73 square millimeters

Center of mass: (millimeters)
X = 257.57
Y = 380.39
Z = 472.97

Figure(11):CG



Mass = 15.58 kilograms

Volume = 15583.12 cubic centimeters

Surface area = 3038148.32 square millimeters

Center of mass: (millimeters)
X = 222.95
Y = 427.12
Z = 473.81

Figure(12):Center of Buoyancy

Mobility

In ORCA we saw the easiest way to carry the ROV without damage and also can be held by one man, So we cut four slots on both sides of the ROV so one man can carry it by diagonal slots or two men carry it, each one with a slot and the opposite.

Figure(13): Holding Slots

Gripper

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 and each gripper is controlled separately with its own air cylinder. Pneumatics were used in the gripper, as it proved to be fast, efficient, easy to control, and reliable in previous years' designs. Guides are also added to eliminate the chance of any rotation of the end effector mid-mission. Acrylic is selected for the end effector, taking advantage of its transparency, lightweight, and resistance to normal stress.

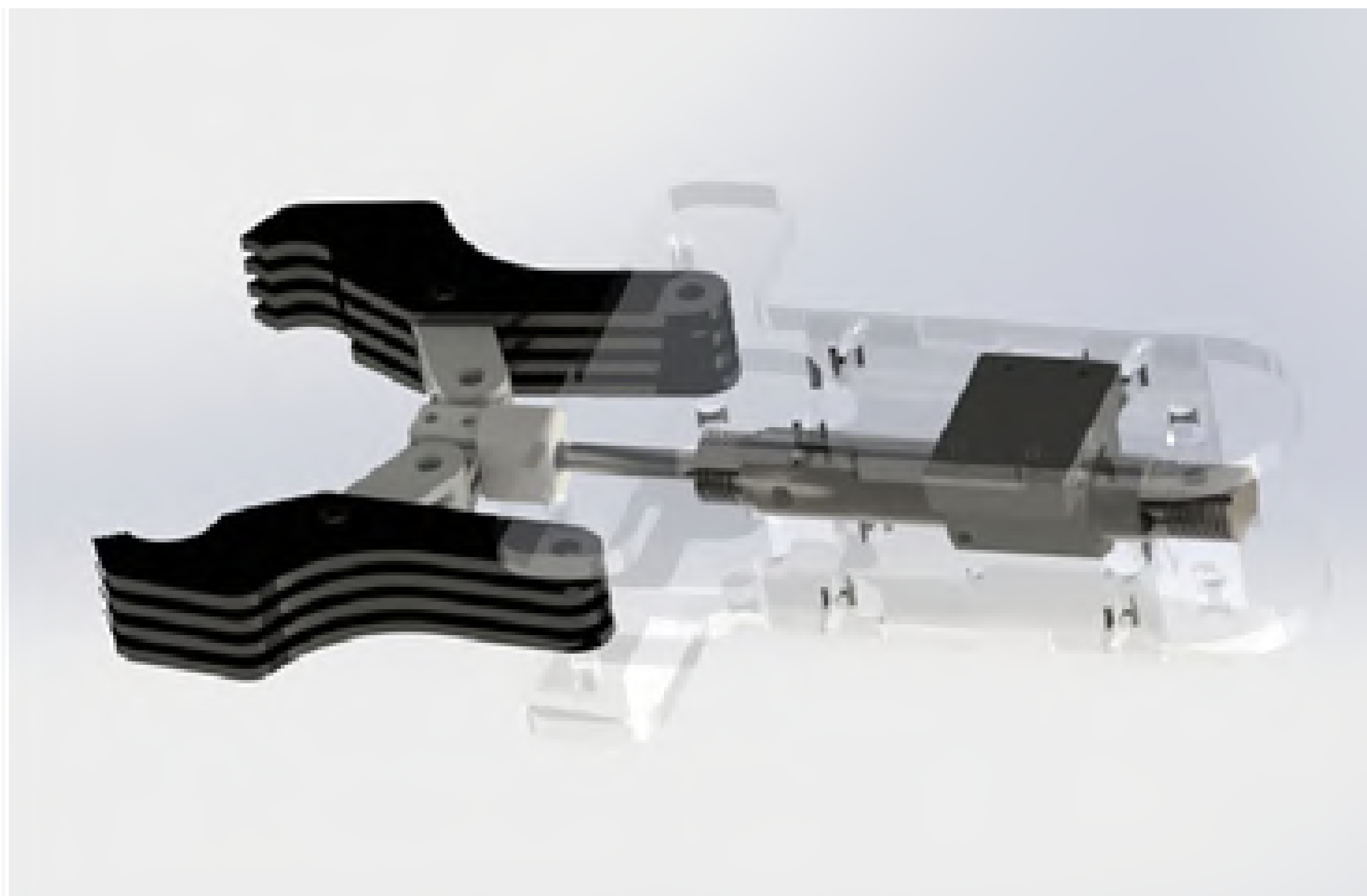


Figure (14) : Gripper

C. Electrical System

Tether

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.

The tether we are using is made up of two individual lines:

I. Power transmission

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 15), so the DC converter gets a constant DC voltage higher than the switching voltage whatever the load.

Wire type:	Copper	
Resistivity:	1.72e-8	Ω·m
Wire diameter size:	15	mm
Wire/cable length (one way):	20	meters
Current type:	AC - Single phase	
Voltage in volts:	48	V
Current in amps:	30	A
	Calculate	Reset
Voltage drop in volts:	0.116799	V
Percentage of voltage drop:	0.243330	%
Wire resistance:	0.00389328	Ω

Figure (15) Voltage drop calculations.

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 was 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. Communication

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.

Imaging 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 the challenges that we faced in the previous years.

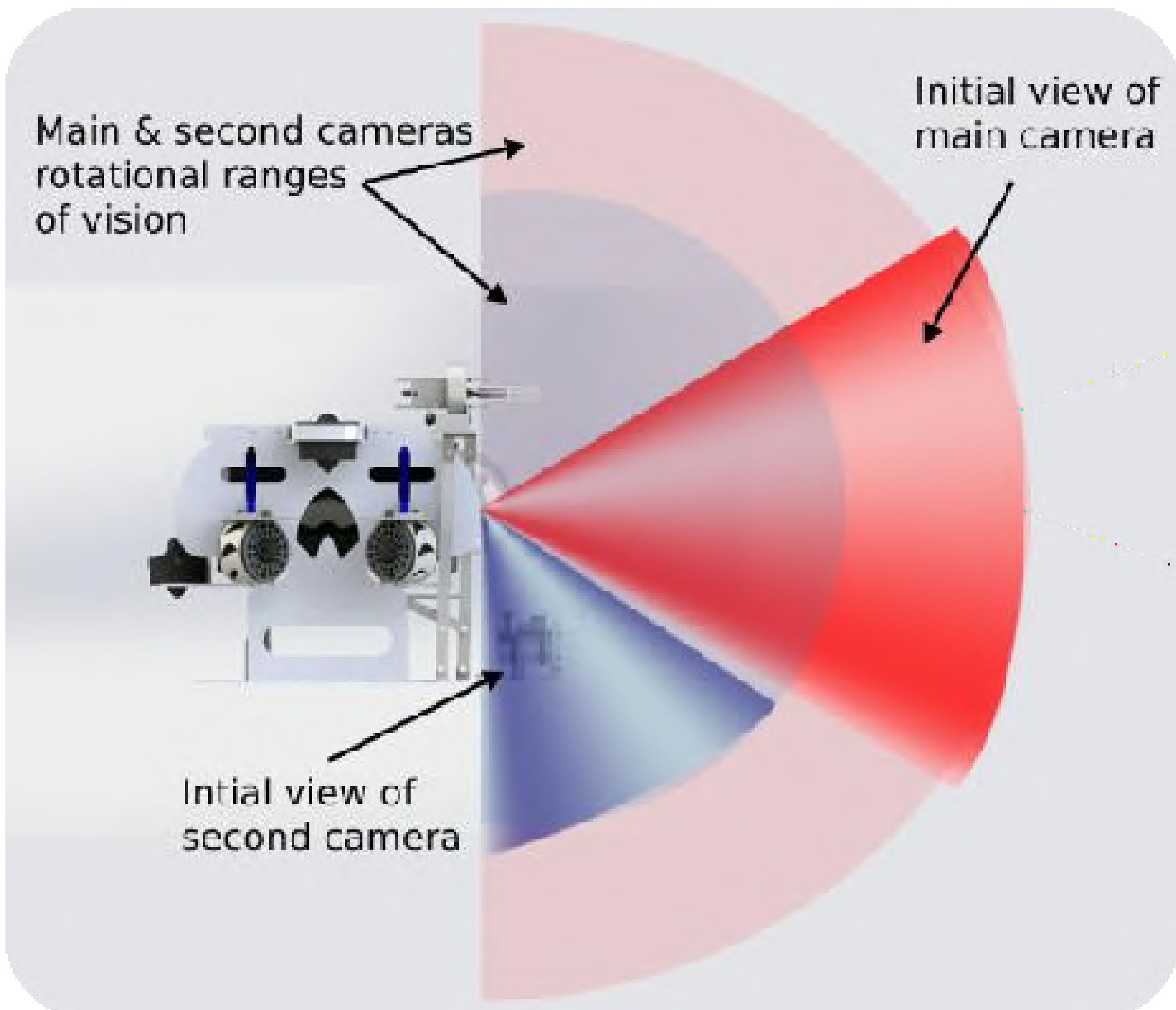


Figure (16): Field view of the 2 cameras

- ### Main Camera

The main camera used is a CCTV type (manufactured by HIKVISION) provides a 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.

- ### Second Camera

This camera is for 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 extra benefits as It could be used as a backup for the main camera in case of any breakdown to the main one. And to perform the image processing missions as accurately as possible.

Figure (17) Our HIKVISION Camera

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(17)

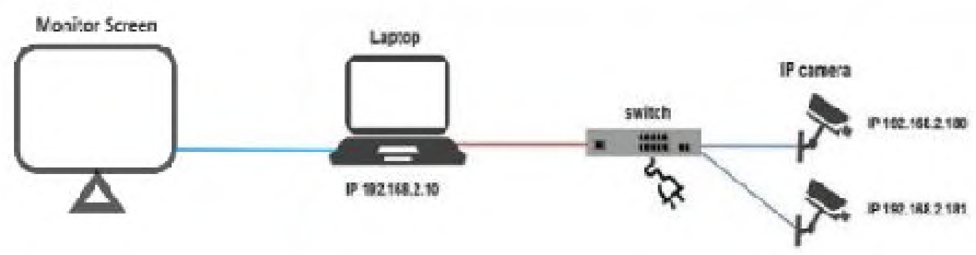


Figure (18) Camera connection diagram

Kit design

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 the figure Using din rail terminals in power connection of the components and the scattered ESCs makes the design crowded with wires and heavy in weight which is not practical enough.

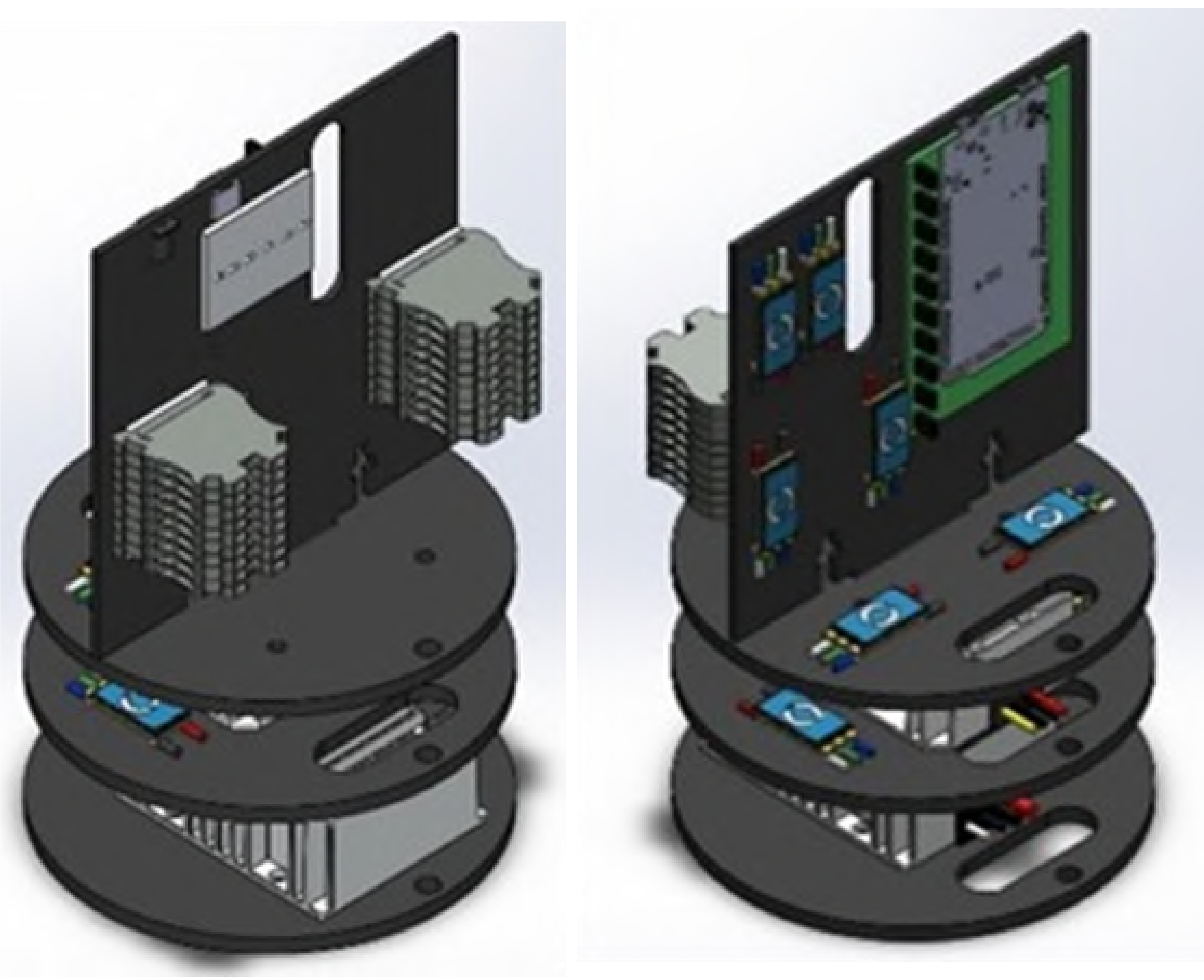


Figure (19): Previous Kit design in an isometric view

As shown in figure(19): All the components are placed together on the top side of the kit and the converters on the bottom side which facilitate the connection between the components and our PCBs. Also, all the wires coming from the tether will take their path on the bottom side of the kit to reduce the crowds of wiring and make our kit more visible and maintainable.

Electrical Housing

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

- Power Board:

This board is designed to take power from the 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%

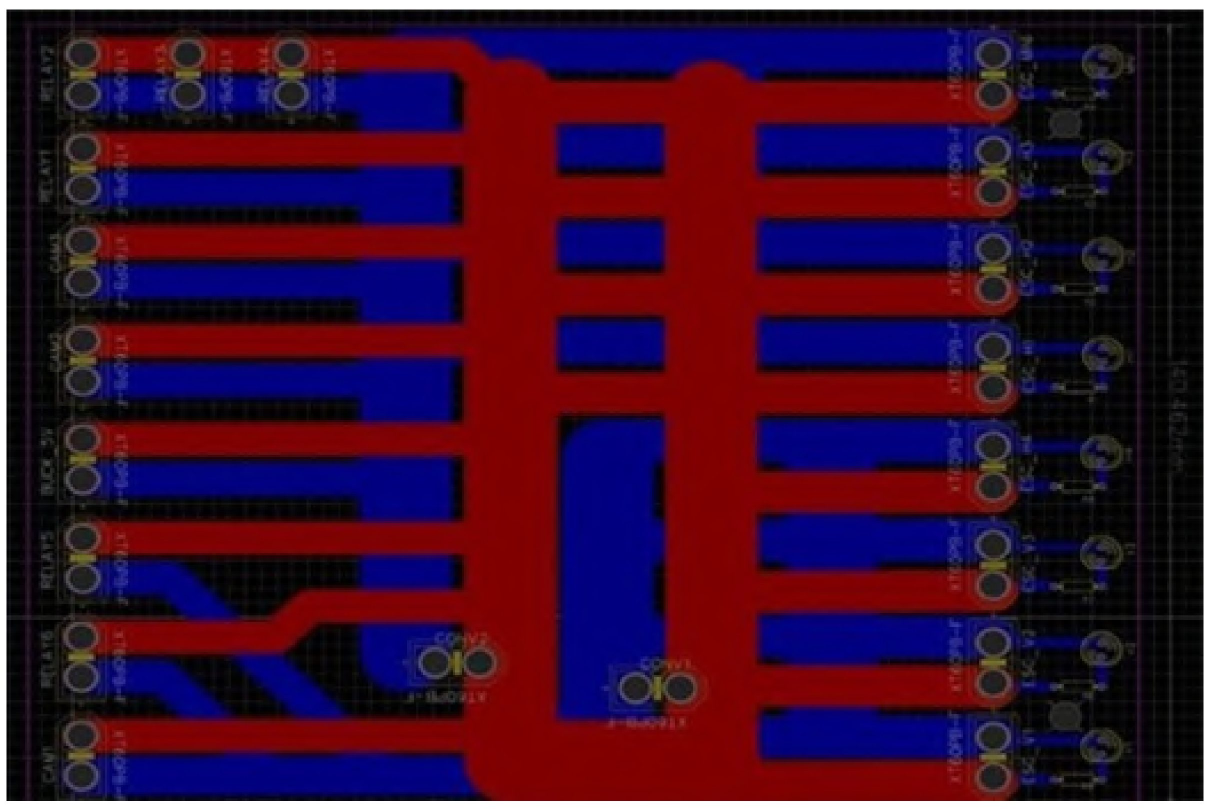


Figure (20) Power PCB

All routes are ended with XT-60 connectors to assure that the power will be delivered to the components efficiently and it will bear the high power.

- Control Board:

This board is designed to communicate with the Topside (TCU) and control all the other components, it is connected with:

1. Microcontroller:

We used Arduino Mega2560 because of 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 process it and send it to the top side, besides sending signals to the relay modules to control the pneumatic valves of our grippers and our servos.

2. Relay Modules:

Our 6 relay modules are divided as the following: 2 Relays for the grippers to open and close the valves of each gripper, 2 Relays for our lifting mechanism to obtain more control over it, and the last 2 Relays is a plus in case one of the modules has an error.

3. Sensors:

It mainly consists of depth and IMU sensors to measure the balance, movement, and rotation of the ROV. Also, a leakage sensor is installed to alert the pilot in case water enters the tube, providing protection against water leaks. Also, we have a Temperature Sensor to measure the heat inside the electronic kit.

4. FT232RL FTDI Serial Adapter Module:

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

5. ESCs & 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).

6. Servo motors:

We use micro metal-geared servos to control the position of our cameras as they are mounted on our servos to give 180 degrees 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.

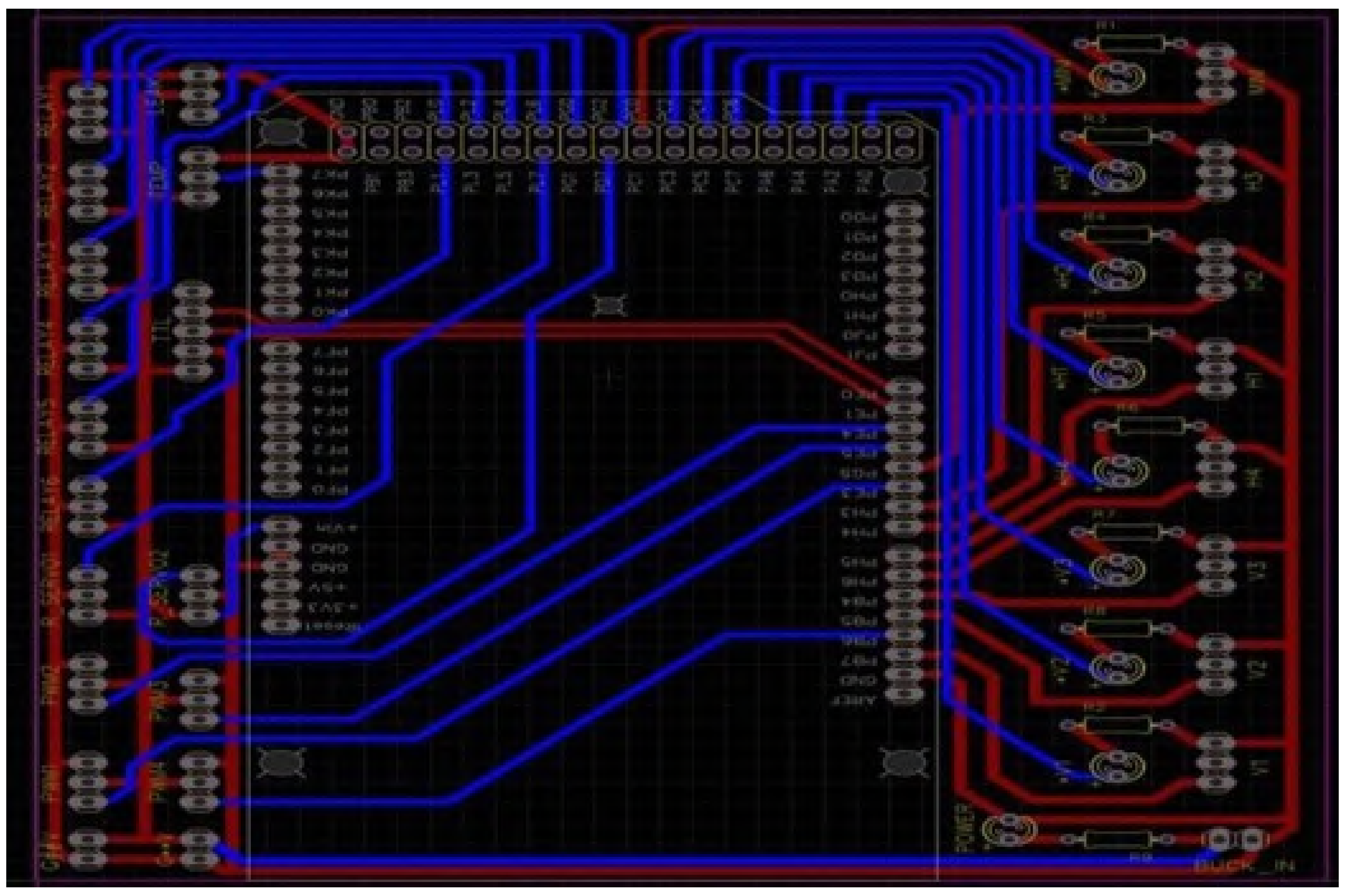


Figure (21) Control PCB

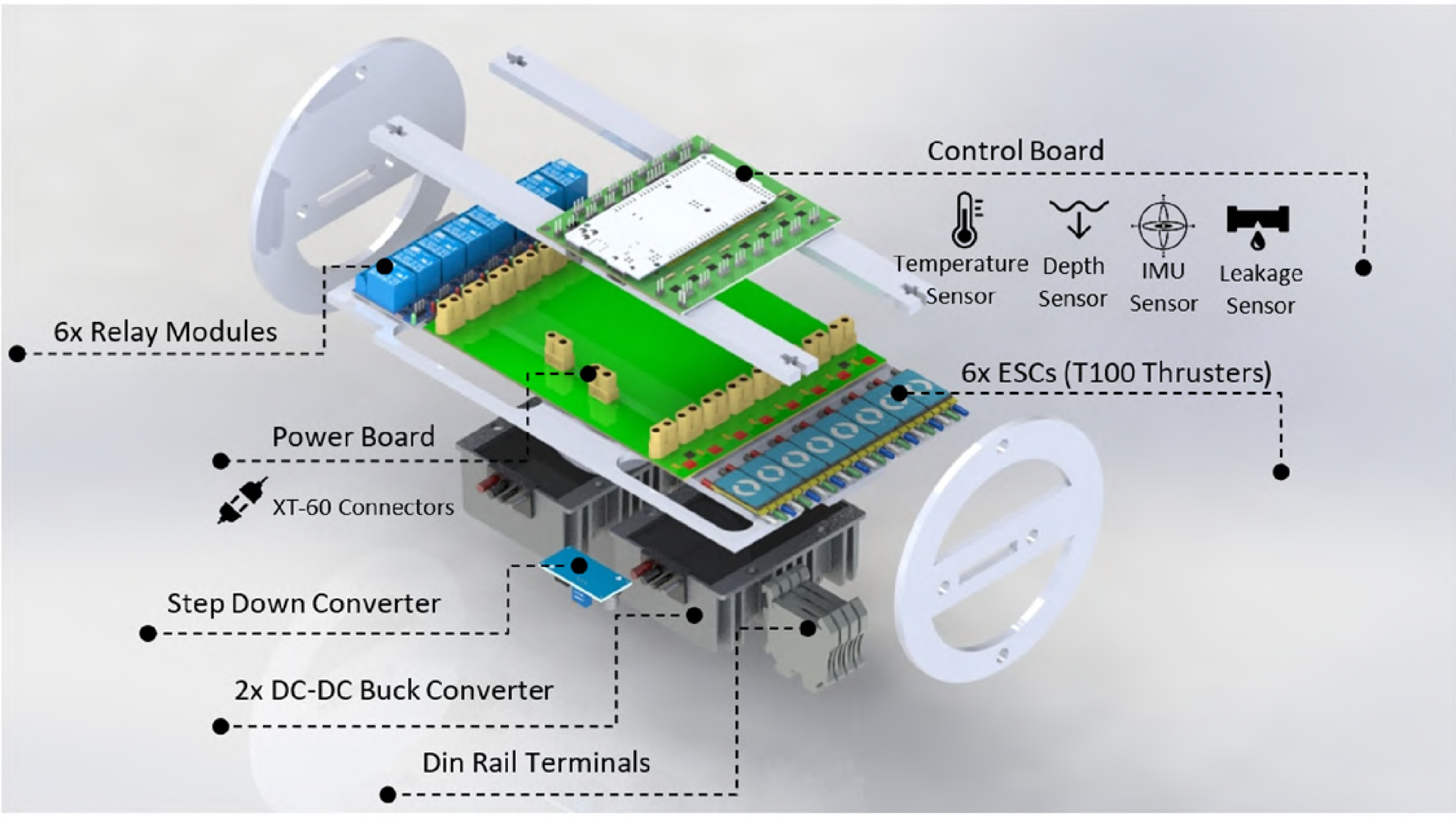


Figure (22) Exploded View of Electrical Kit

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 the 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 the propulsion system. So, if something went wrong with one of them that may lead to increased redundancy of the electric system.

Figure 23: 48-12 DC Buck 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 T100 vertical motors, one T100 horizontal motor via ESC drivers and camera. - Three T100 horizontal motors 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. After conversion, the 12V bus is distributed with another in-house manufactured PCB to thruster electronic speed controllers (ESCs) and other power-demanding components using 12 AWG & 16 AWG cables as detailed in (Figure 24).

ESCs are needed to power the thrusters as they require three-phase power as opposed to regularly brushed motors that require simple H-bridges. Each ESC powers one thruster with high efficiency for optimal throttle response. Each thruster is programmed with an ID number and has its input and output cables numbered as per our in-house standards.

Wire Size (AWG)	Current Rating
24 Gauge	5.1 amps
22 Gauge	6.3 amps
20 Gauge	8.9 amps
18 Gauge	11.4 amps
16 Gauge	13.9 amps
14 Gauge	17.7 amps
12 Gauge	24.0 amps
10 Gauge	32.9 amps

Figure 24:AWG

Power Budget

Components	Quantity	Voltage (V)	Current (I)	Power/Component (W)	Total Power (W)
Thruster (Horizontal)	4	12	7	84	336
Thruster (Vertical)	2	12	10	120	240
Basic ESC	6	12	0.3	3.6	21.6
Camera	2	12	0.5	6	12
Arduino	1	5	1	5	5
IMU Sensor	1	5	0.01	0.05	0.05
Depth Sensor	1	5	0.01	0.05	0.05
Leakage Sensor	1	3.3	0.01	0.033	0.03
Temperature Sensor	1	5	0.01	0.05	0.05

Total Power Consumption 614.72 W.
Current drawn from Power Supply = 614.72/48 = 12.806 A.
Fuse value = (150%) x12.806= 19.468A ≈ 20 A.

D. Software

Top-Side Control Unit (TCU)

The software staff at ORCA created a sophisticated graphical user interface in Python using the Qt framework to guarantee fast and smooth execution regardless of the operating system. During navigation, the GUI runs on the pilot's laptop and serves as the software system's heart, performing numerous functionalities, such as the ability to display a detailed status of the ROV and all the system components. Furthermore, the readings from the installed sensors are received and displayed. Not only that but also, the joystick is used to collect and deliver the desired movement and speed commands. It moreover allows the pilot to control the ROV's principal functions, such as manually controlling it (using a joystick) or performing image processing duties.

Graphical User Interface (GUI)

The graphical user interface (GUI) provides a high-level interface for the pilot that allows it to communicate with the ROV and view its input. The application is developed in Python and is intended to perform the following functions:

- Shows the motors' status as well as the ROV's direction and speed based on the feedback signal.
- Use a stopwatch to keep track of how much time you spend on each task.
- Display the temperature and leakage sensor readings.
- Control the view of the primary camera and secondary camera (if the main camera is detached) using spin boxes.
- Carry out the tasks related to image processing.
- The Arduino board connection is displayed and configured.

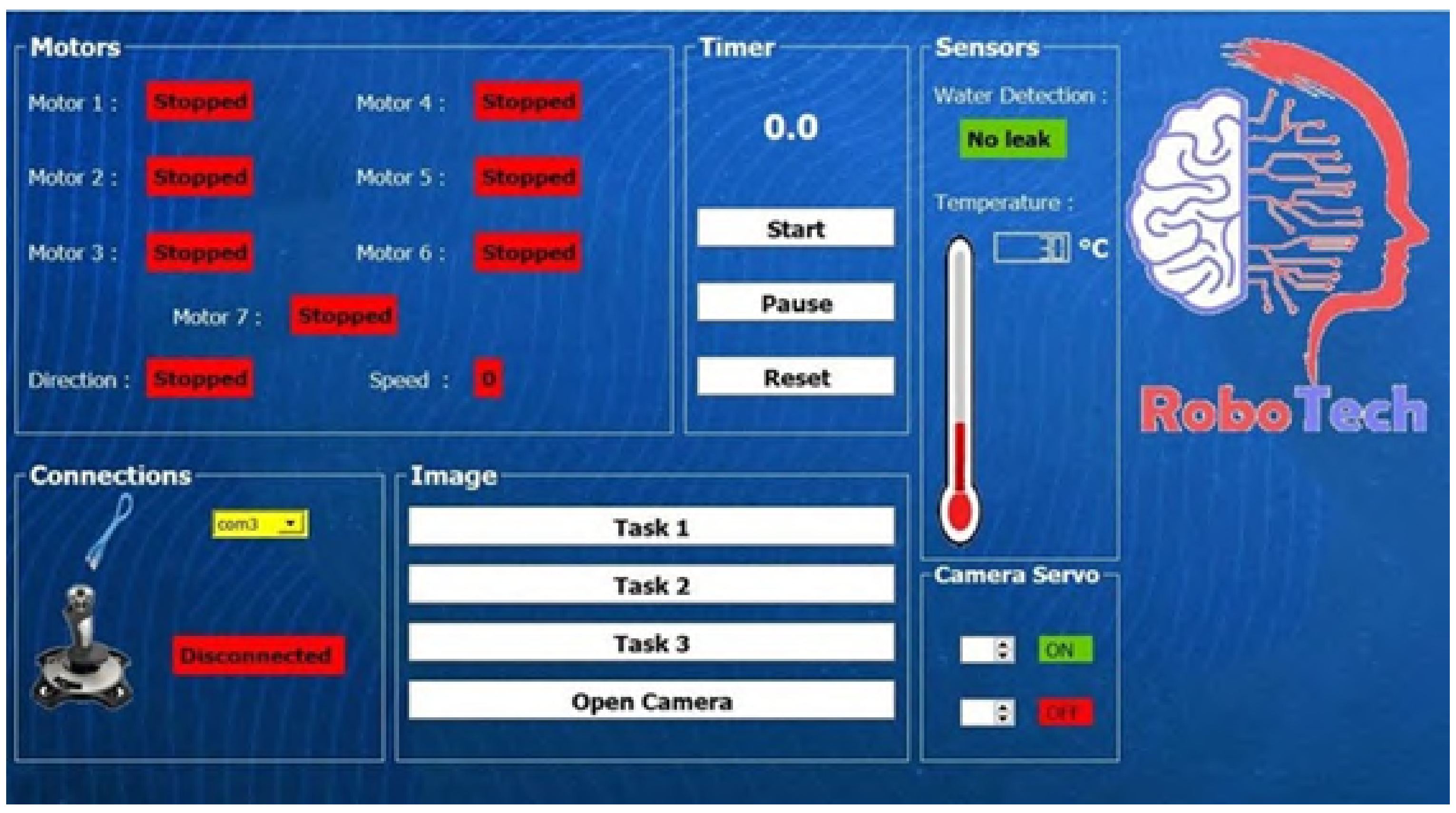


Figure 25:GUI

Serial Managing and Data Handling

Data and commands are communicated between boards in packets, which begin with an indication header and then text data sent over UART. The master board, also known as the communication board, is in charge of interpreting directives and assisting in data switching. It also makes it easy to send, poll, and replicate data losslessly, which helps to avoid multiple bytes loss.

To make communication more robust, the Cyclic Redundancy Check (CRC) checksum technique is employed to discard or resend faulty-received packets. These functions are translated into software by the "Serial Manager" class, which allows the software to be uploaded to additional boards through UART by resetting them to trigger the bootloader and act as a bridge for data transferred from the PC. This bridge functionality allows for easier debugging on a specific board, and the uploading capability saves time because it allows us to upload and update the code of any specific board without having to take the ROV out of the water or remove a specific board to update its software and reinstall it. Data is transferred between the TCU and the microcontrollers using the Universal Serial Bus (USB) to Universal Asynchronous Receiver and Transmitter module (TTL UART). It also allows you to upload Arduino code without having to replace the microcontrollers every time the firmware has to be updated.

Figure 26:TTL

Thrusters Navigation and Validation

Our ROV will use vector-based navigation to ensure that motion is aligned with the axis of a certain camera view. Precision has also been increased by constantly operating all thrusters and applying opposing moments to create zero net motion and moment, allowing ORCA to change the speeds of certain thrusters to achieve steady motion in the desired direction. This improves response time and allows for a net speed that is lower than the minimum speed possible when running together in a simple configuration. Allowing ORCA to move in 3D space at any speed and angle. It can, for example, rotate, move laterally in any direction, move upward, and roll all at the same time, giving it a great level of maneuverability.

E. Features

Scene optimization

Underwater filming is a challenging task to ORCA, because of the underwater noise and darkness. By pre-processing phase, the image was optimized to be ready for the tasks and tracking the image easily and smoothly for the Pilot Image passes through Noise suppression, Filtering and morphological operations, such that noise reduction is pre-processing step to improve the results of later processing “Edge detection on image ”, then images go into saturation correction to make ORCA be able to get clearer images from underwater dark Situations.

Smoothly follow the trajectory

In this task, ORCA detects the circle at the start of the line, then detect the line as a vector determining its direction and angle, then moving ORCA autonomously in that vector direction by splitting the direction of the line into two velocities horizontally and vertically making it move as close as possible to the line, all the way through the line until it stops in the square. To make ORCA detect the line easily and accurately we fill the gaps of the line to prevent any problems with detecting the line.

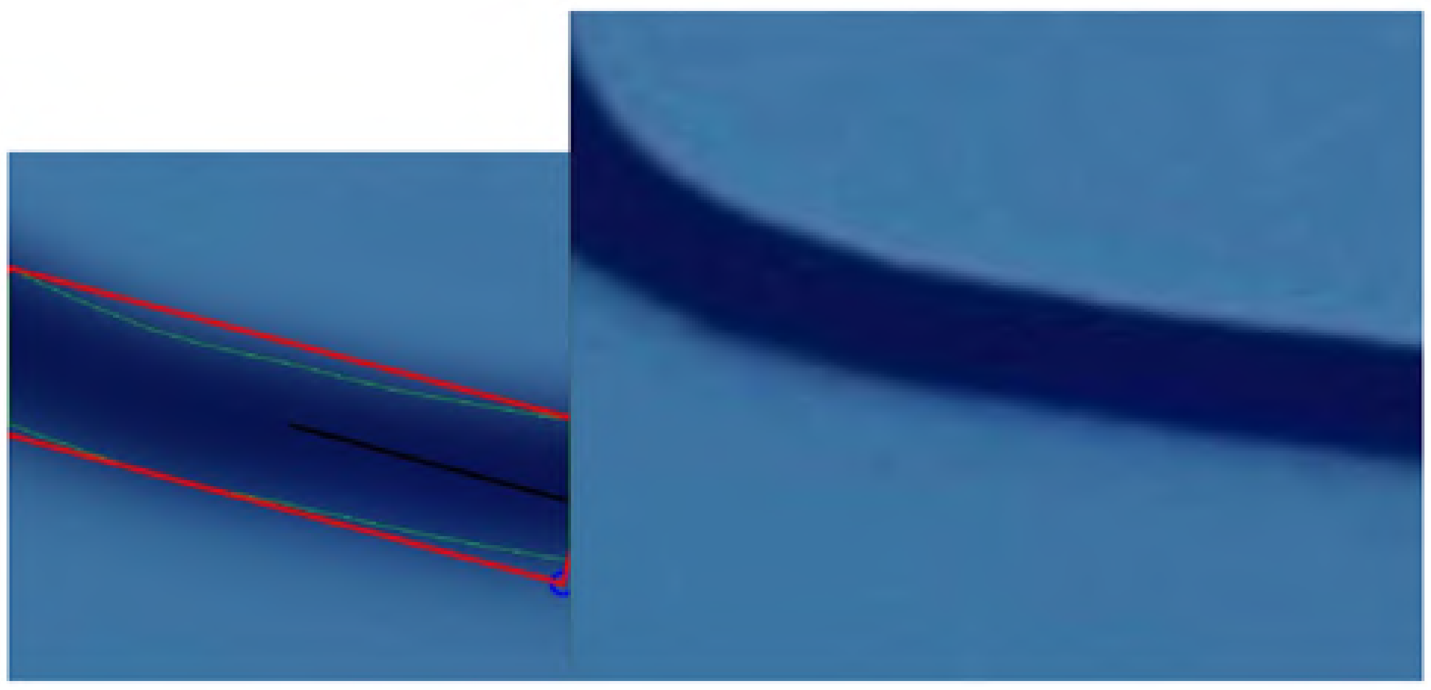


Figure 27: segment line and getting contours angel

Smoothly follow the trajectory

In this task, ORCA detects the circle at the start of the line, then detect the line as a vector determining its direction and angle, then moving ORCA autonomously in that vector direction by splitting the direction of the line into two velocities horizontally and vertically making it move as close as possible to the line, all the way through the line until it stops in the square. To make ORCA detect the line easily and accurately we fill the gaps of the line to prevent any problems with detecting the line.

Calculate the dimensions

For the best accuracy in calculating area, ORCA scans its environment and shoots a scene where a known dimensions object exists.

Instead of depending on varying conditions, ORCA processes the scene with a grid view and considers the grid pixels as its measuring unit. ORCA extracts the contours of the objects in the scene and creates a precise ratio between the defined length and the object’s dimensions with the grid scale. We used the tiles in the background as a fixed reference to measure any required length at any location and ORCA can easily calculate any length afterward.

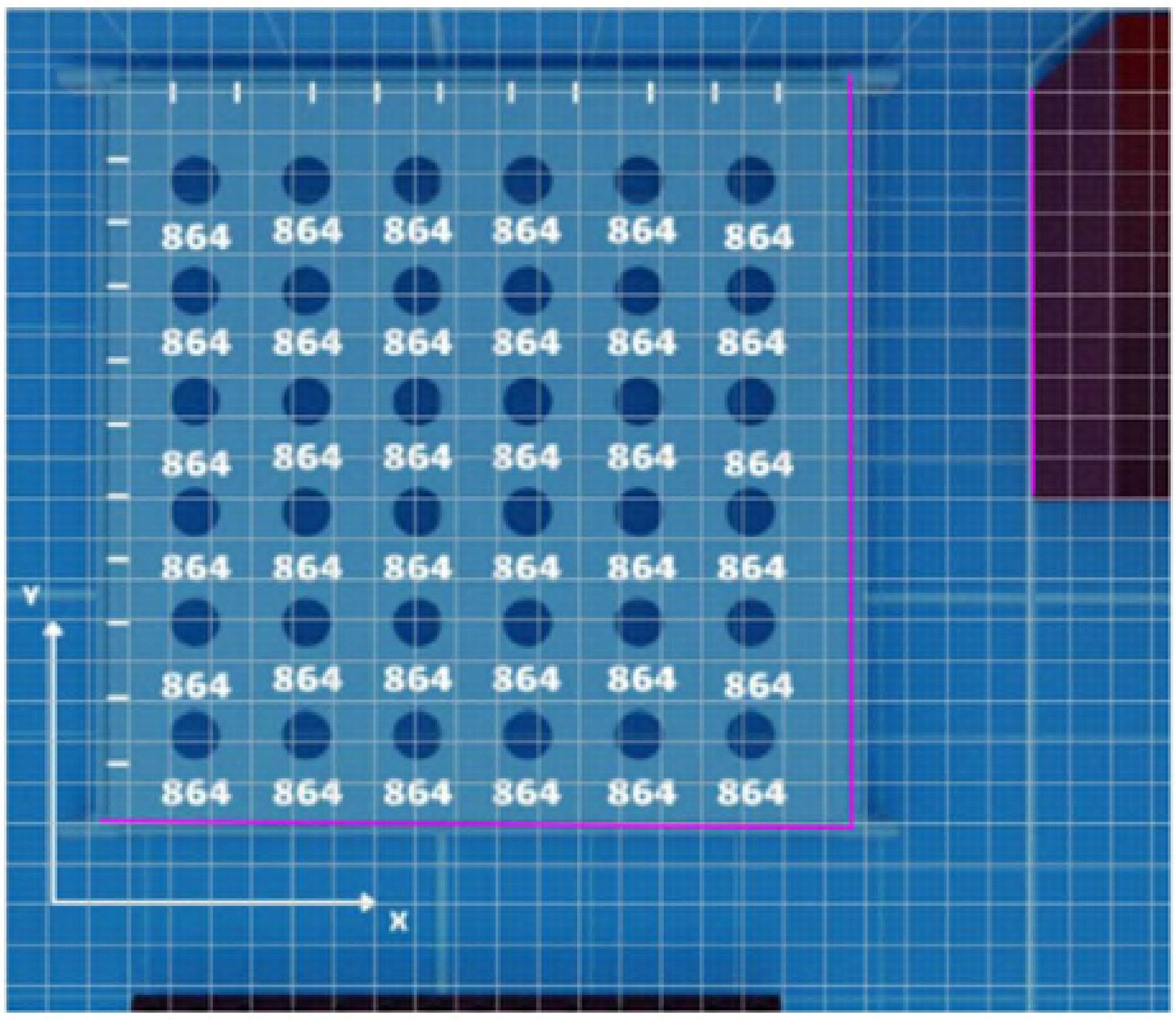


Figure 28 calculate unknown distance from the ratio between already known distance and fixed gird

IMU Sensor

IMU is a Micro-Electro-Mechanical System accelerometer and gyroscope sensor that measures and reports ORCA’s angular rate, and acceleration (providing 6 degrees of freedom measurements). It provides the feedback signal to the PID controllers. A major disadvantage of using the IMU is that it typically suffers from accumulated error. The accelerometer and gyroscope readings are fused for ultimate accuracy. Moreover, a head-start PID calibration is applied to get the appropriate accelerometer and gyro constants and a periodic calibration is used for further optimization.

Figure 29: IMU Sensor

Depth Sensor

Depth sensors are a form of three-dimensional (3D) range finder, which means they acquire multi-point distance information across a wide Field-of-View (FoV). Standard distance sensing technologies typically measure distance using one or more sensors with comparatively narrow Fields-of-View. For example, Lidar (light detection and ranging) distance sensors emit a laser or infrared signal with Fields-of-View of up to 2° which offers accurate information regarding a single distance but limited depth data. To obtain an accurate picture with full 3D depth perception, sensors must be able to output a matrix of multiple distance readings over a Field-of-View.

Figure 30: Depth Sensor

Temperature Sensor

This high-accuracy, fast-response temperature sensor comes sealed and ready to use for temperature profiling, lab measurements. the sensor is the voltage across the diode terminals. If the voltage increases, the temperature also rises, followed by a voltage drop between the transistor terminals of the base and emitter in a diode.

Leakage Sensor

The Leakage Sensor can detect water leakage into an improperly sealed watertight enclosure quickly and reliably before any major damage can occur.is high and a leak is unlikely to occur, the SOS Leak Sensor acts as a secondary shield to ensure the safety of the electronics.

3. SAFETY

A. Safety Philosophy

From the concept of employee safety before the machine, Robotech-ASU believes that a safe working environment is important to produce a suitable atmosphere to design, manufacture and test. We always strive to meet global standards of safety by ensuring all company employees Adhere to safety protocols. Our safety philosophy is centered around the safety of personnel In order to comply with Underwater Safety standards, putting warning labels to guide employees, and protocols are carried out during manufacturing and Troubleshooting.

B. Safety Protocol Standards

- Provide proper personal protective equipment (e.g. gloves, goggles, and earmuffs) when performing any Task.
- Testing all equipment before using.
- Use proper technique when using any sharp tools.
- Sharp Tools are handled carefully when not in use. they are stored in racks and boxes, and their sharp edges are covered with a cap -if available.
- Hazardous materials are clearly marked and stored separately to ensure they're handled carefully.
- Using insulated electrical tools including insulated fuse pullers, hand tools, and drills.
- doing a pressure test of all equipment
- Stop work when an unsafe condition or act could occur during operation.
- Sealing test of electrical housing before adding an electrical kit
- Any in-water tests are performed far away from the Electrical Team's work area.
- Systematic safety checks are performed before every test.

C. Safety Features

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. As required by safety protocols a suitable-sized fuse is connected 30 cm from the Anderson Power-pole connectors. Strain-relief is applied to the tether on both ends to prevent strain on the connectors. 3D printed shrouds are placed on the thrusters to prevent human hands from reaching the thruster blades. 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. Concerning our sealing techniques, we take safety factors to prevent any chance for water leakage in our electronic units onboard. The water detector sensor alarms the operators in case of leakage and trips the power immediately. Our company engineers use 7 LEDs to check the power connection for each motor and 1 LED to check if the power PCB operated successfully.

Kill-switches are present on the main power supply unit on the TCU. The camera compartment is physically isolated from the electronics housing with the use of O-rings. The clear acrylic dome housing the camera allows for visual inspection in case of any leaks by searching for water droplets.

4. TESTING AND TROUBLESHOOTING

4.1 Mechanical

Separate tests were done on each component before being assembled, effectively eliminating compounded problems that are harder to troubleshoot once the ROV is fully assembled. The frame is first tested for stability by loading and subjecting it to high vibrations to ensure that all fixations are sound.

Gripper test

After choosing material for our gripper we did a stress analysis test to achieve our goal is to maximize the gripper efficiency while minimizing power losses due to friction or any other form of power loss.

Pneumatic test

Robotech ASU put great attention to ensuring proper connectivity regarding pneumatic circuits by testing them several times to enhance the safety and performance of the pneumatic system

4.2 Electrical

ORCA'S systems are designed in a modular way that makes troubleshooting much easier From the design phase we tested our PCB. We always ensured to have spare connections and parts such as the Motors, Sensors, Cameras, and power sources. Each PCB is tested separately before connecting it to the system, making troubleshooting a much easier and more time-effective process.

4.3 Full System Testing

Each time we test and troubleshoot our ROV, we follow the same strategy. First, we finish sealing an 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 tested it again. We checked the communication board and the printed circuit boards (PCB) inside the enclosure using an Avometer. 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 microcontroller 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 on 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.

5.FUTURE IMPROVEMENTS

Cooling System

We aim to Establish a cooling system for the electrical kit to reduce the temperature to eliminate the condensing problem on the dome.

Electrical System

We aim to improve our electrical kit design by adding more PCBs for control and validation and using T200 motors in our new version.

Control System

We want to use the PID control system to implement a higher level of control for path planning and the ability to dynamically load and execute new mission scripts based upon commands.

Image Processing

Our company wants to use it in its next creation, the Jetson Nano board. It can run a wide variety of advanced deep learning models, including the full native versions of popular machine learning frameworks like TensorFlow, PyTorch, Keras, and others.

6.CHALLENGES

Technical challenges

At the beginning of the designing process, we faced some experience leakage which led us to learn about some topics, understand them well, and then get our optimum solutions, although, we had had some problems every time which we tried to fix again and again, by the time we noticed that the problems decrease 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 open 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 on our software, the team faced a few technical issues. These issues were that there were some errors in the code that controlled the motors.

Non-Technical challenges

Our team fought to find a sponsor, so most of the expenses were 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.

7.LESSONS LEARNED

Technical Skills

Our members learned CAD modeling 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.

Non-Technical Skills

The ability to work remotely without knowing each other was the best test for the candidates to gain his/her position in the team, the team was able to select members that worked well with each other. This allowed for a more enjoyable experience for all the members and gained the soft skills needed for each member to accomplish tasks on his own or in 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.

8.LOGISTICS

A. Company Structure

Robotech ASU company is managed by a CEO under whom CTO & CFO and three heads for each team, it consists of three technical teams which are mechanical team, electrical & control team, and software team. There are 5 members in the software team,6 members in the mechanical team, and 6 members in the electrical & control 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 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 power PCB, 2 members for power calculations and distribution, and 2 members for control system and communication for the mechanical team 2 members were responsible for designing the frame, 1 member for actuators, 1 member for sealing,

2 members were designing specialists, for the software team, 4 members were image processing & computer vision specialists. Also, some members from the electrical team helped the mechanical team and some members from the mechanical team helped the electrical team with 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, PR to write technical documentation and media for graphic designs.

B. Scheduled 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. and with believing in time management, the company put a strategy to assign milestones periodically. With the guidance of experienced company mentors, a timeline was laid down to schedule work in real-time.

C. Budget

CFO handles all of ORCA's finances. They set the budget, collect payments, and act as a bookkeeper. ORCA is self-funded, its budget is limited and must be utilized carefully, avoiding frivolous purchases. An excel sheet is used to document all ORCA's future purchases based on the previous year's purchases and the improvements the company plans to implement. This sheet is used to estimate the budget, and payments from staff are then requested accordingly. Another excel sheet is used to record all purchases made and transactions completed, all confirmed by receipts.

9. EVENTS

Our company participated in ROV competitions science 2018, we took part in MATE ROV regional competition, underwater robotics challenge, and Ebdaa festival. with ORCA we took part in the MATE ROV regional competition and got 9th place.

Figure 31: Mate ROV Ragional Competition

10.REFLECTIONS

Mohamed Abdullah
CEO

"In all of my life, I haven't gained more experiences like this journey. With such a great team, we passed through visually impossible situations that we thought we couldn't do. But with diligence, hope and willingness we did much more than we had expected. I really appreciate my team and colleagues that the journey wouldn't be complete without them."

Adham Adel
CTO

"The enjoyment of the journey is not in reaching but in the people you knew, Skills you gained. This experience has a special place in my heart. I was working on a lot of projects with several teams but this one still has a special feeling for me."

Omar Taha
Electrical Vice-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."

Mohamed Wael
Control-Head

"This has been a once-in-a-lifetime opportunity. It has not only taught me the value of programming and the practical applications of all of my math and programming lessons throughout the years, but it has also provided me with the opportunity to establish lasting friendships. I'm disappointed that this will be my final year competing with this incredible bunch. I am optimistic that fresh prospects will arise in the future."

11.ACKNOWLEDGEMENTS

Robotech ASU would like to extend a special thank you to: -
- Underwater Robotics Challenge
- Alamein Robotics Championship
- Arab Academy for Science and Technology (AAST)
- Faculty of Computer & Information Science Ain Shams university
- AIM learning Center for their support

12. REFERENCES

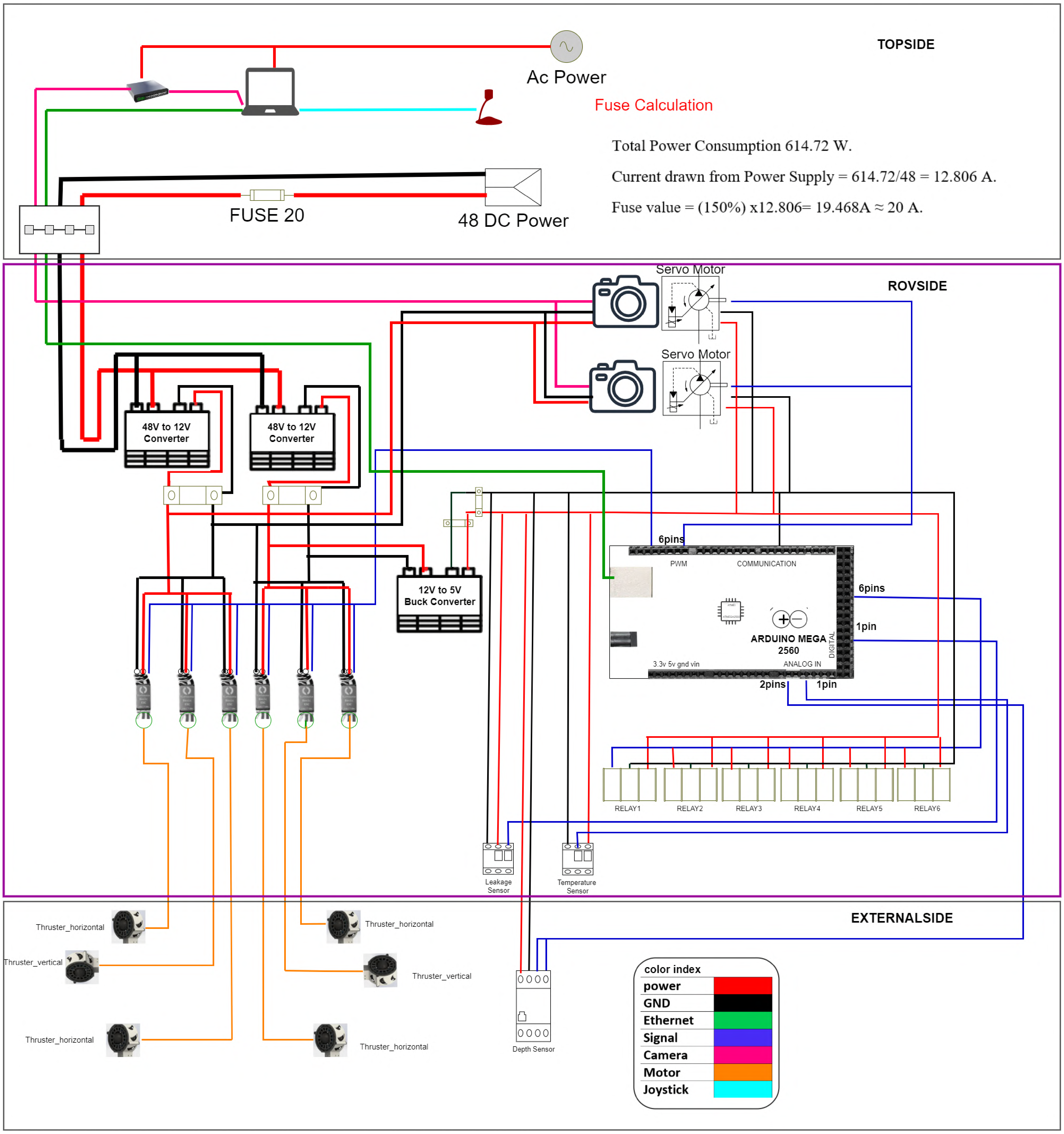
- The ROV Manual: A User Guide for Remotely Operated Vehicles: Second Edition (2014), Robert D. Christ and Robert L. Wanli
- J. Sahili, A. E. Hamoud and A. Jammoul, "ROV Design Optimization: Eect on Stability and Drag force,"
- Blue Robotics Blue Robotics' T100 Thruster Documentation.
- OpenCV documentation (https://docs.opencv.org/3.4.5/)

13.APPENDICES

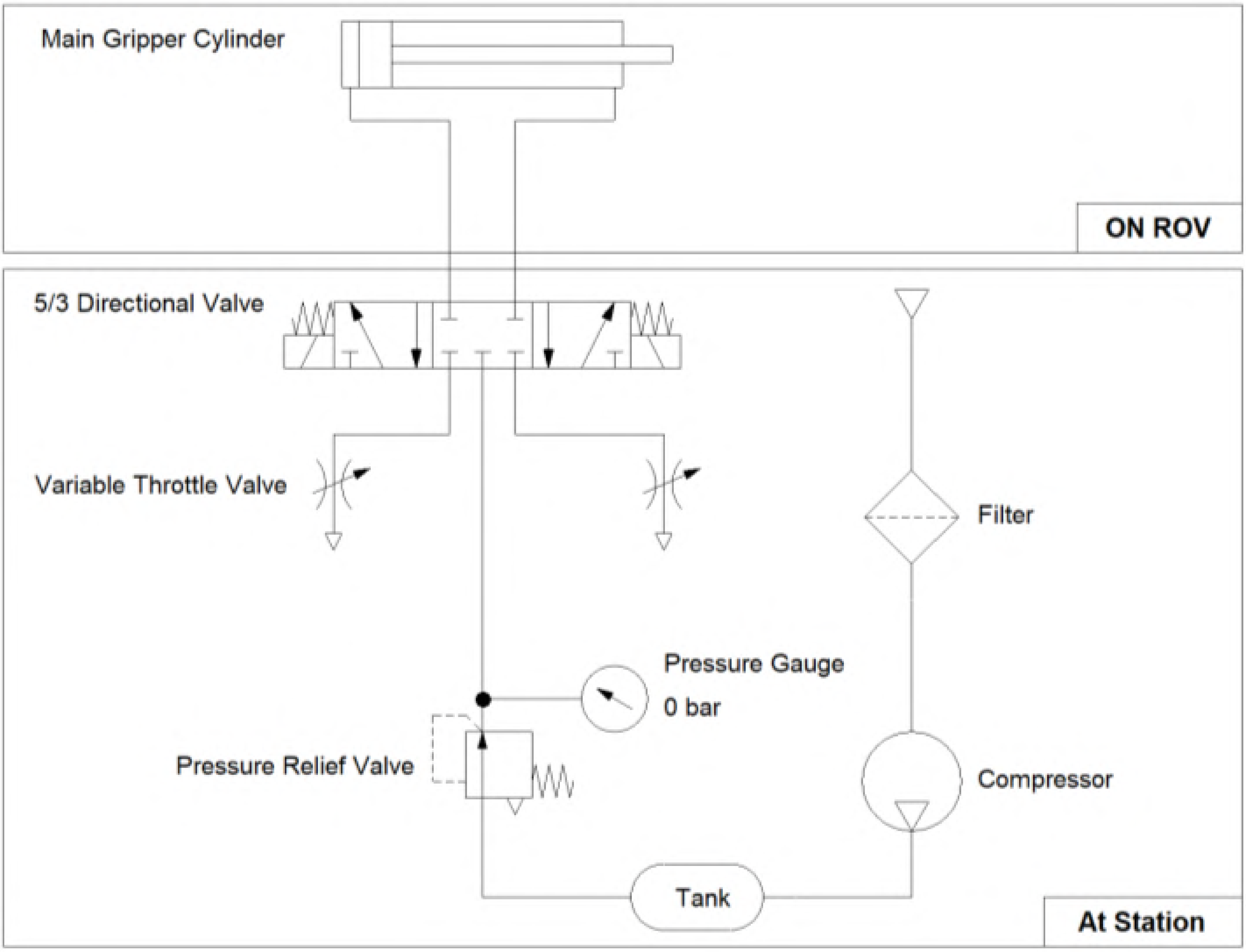
A. Safety Checklist

- Area is safe.
- Poolside is clear of obstructions.
- Only Crew members on site.
- Power switches are off.
- Connector is connected in the right way.
- Tether connected from Source and secured.
- Tether connected and secured to ROV.
- Cables are tied down and electrical connections are waterproofed.
- Electronics housing sealed.
- No exposed wires or loose connections.
- Control Unit receives 48 V/30A
- Set compressor output to 2.75 bar.
- Dry test thrusters, manipulators, and payloads.
- Check Cameras connections.
- Power down the system and call out "Water Ready".
- Two crew members and a tether man lift the ROV from the water onto land.
- Visually inspect for leakage, check for air bubbles.

B. Electrical SID

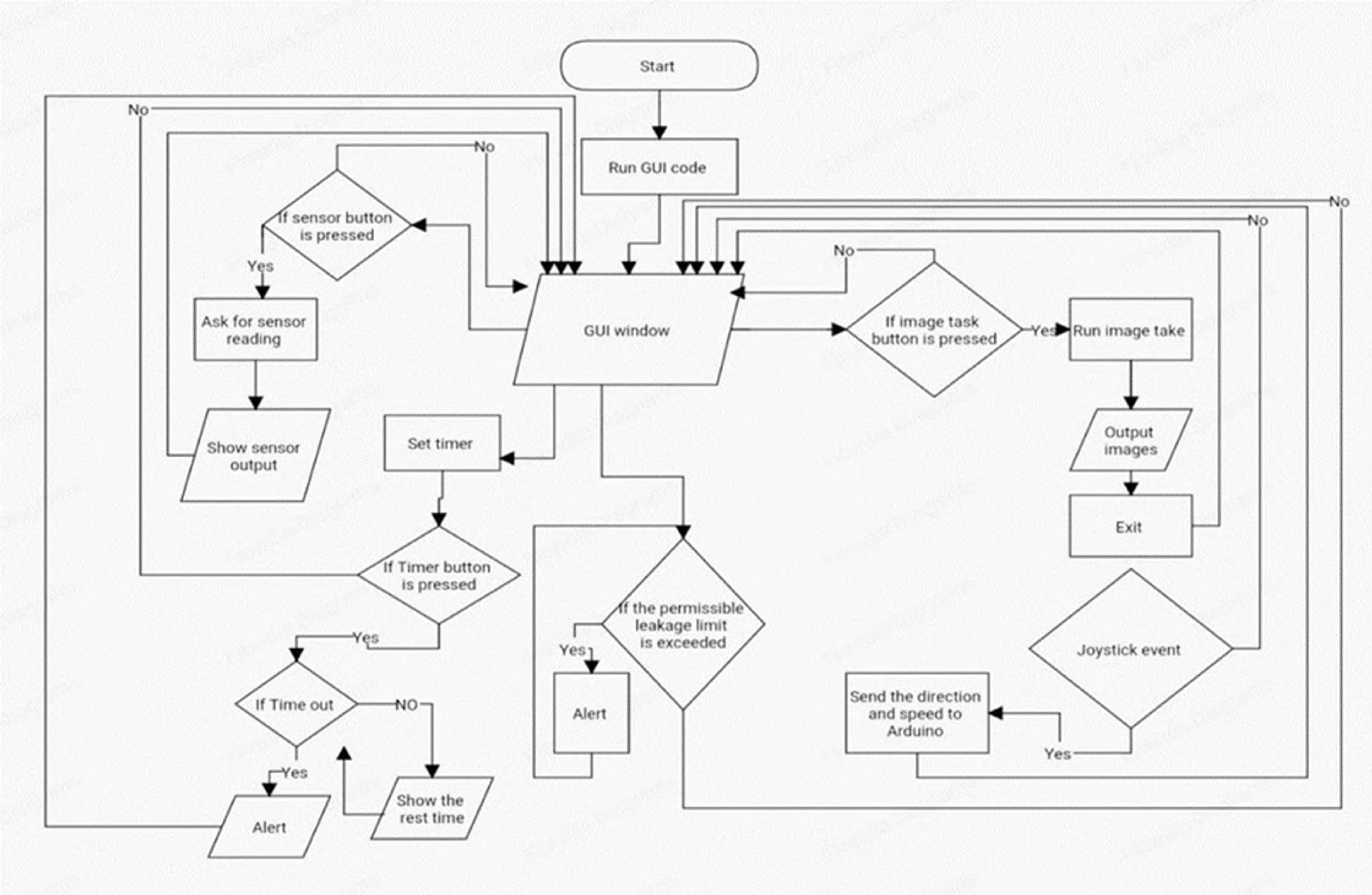


C. Pneumatic SID

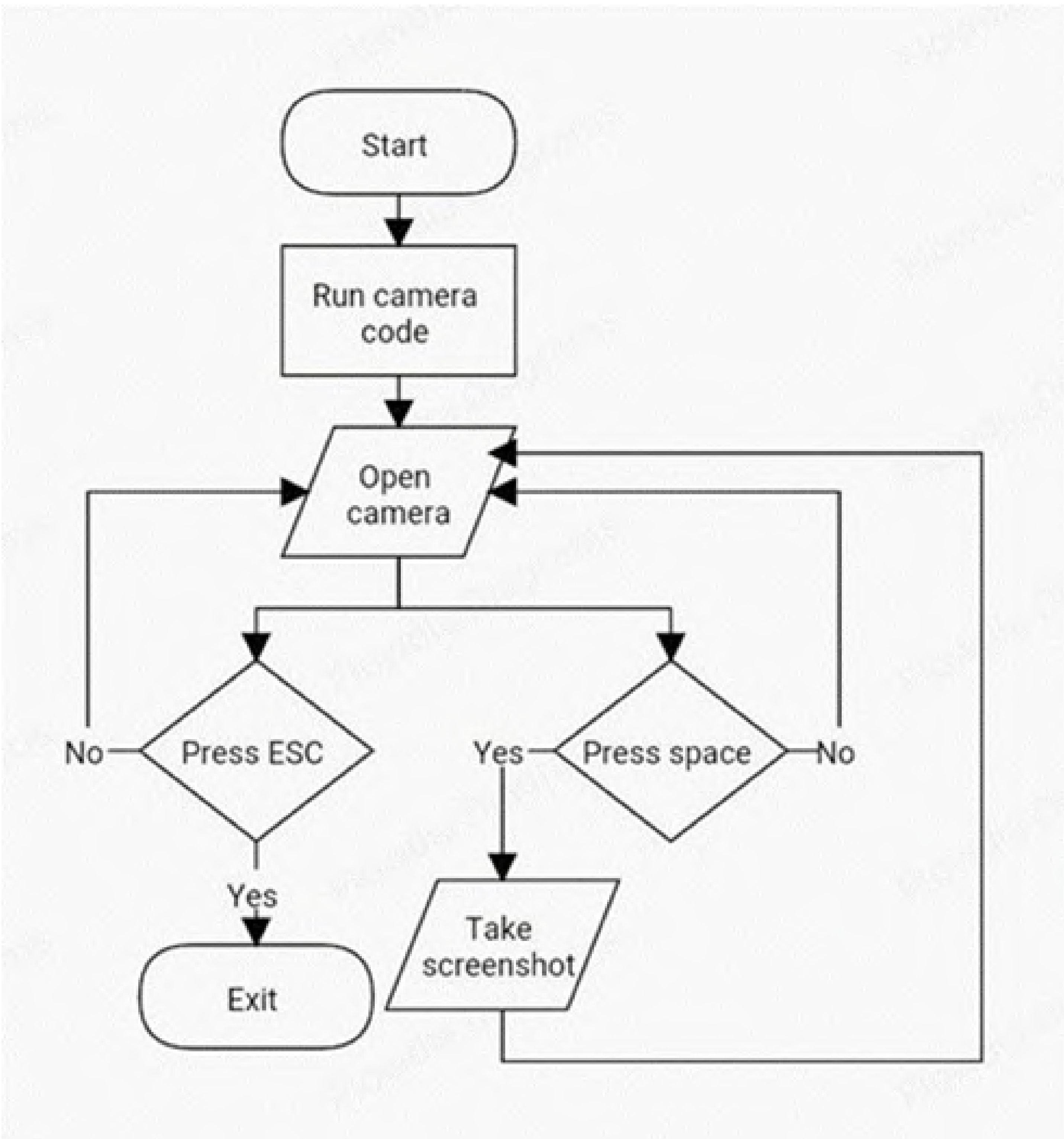


D. Flowcharts

1.GUI



2. Camera



E. Budget

Money sources	Source	Income($)			
	Self-fund	$636.45			
	FCIS ASU	$1,310.00			
	Aim Learning Center (Sponser)	$250.00			
	Total	$2,196.45			
Product Cost	Direct Material	Budget($)	Type	Cost($)	Difference($)
	Acrylic tube	$20.00	Production	$15.98	$4.02
	Acrylic dome	$15.00	Production	$11.50	$3.50
	Steel sheet 4mm	$28.00	Production	$28.76	($0.76)
	Acrylic Kit holder	$150.00	Production	$139.99	$10.01
	Acrylic top cover	$65.00	Production	$66.00	($1.00)
	ACP 4mm	$10.00	Production	$9.50	$0.50
	Stainless steel base	$55.00	Production	$57.81	($2.81)
	Acrylic shrouds	$13.00	Production	$12.98	$0.02
	ESC(X8)	$200.00	Production	$200.00	$0.00
	Connector(X50)	$31.50	Production	$30.00	$1.50
	led(X16)	$1.50	Production	$1.27	$0.23
	Temp sensor	$2.00	Production	$1.59	$0.41
	leakage sensor	$1.00	Production	$0.95	$0.05
	MPU	$15.00	Production	$19.75	($4.75)
	DC-DC Buck converter 48V to 12V, 20V Max	$25.00	Production	$25.00	$0.00
	DC-DC Buck converter 48V to 12V, 30V Max	$30.00	Production	$35.00	($5.00)
	DC-DC Buck converter 12V to 5V, 5A Max	$7.00	Production	$6.39	$0.61
	USB to TTL	$3.50	Production	$3.52	($0.02)
	Relay Module(x5)	$10.00	Production	$7.99	$2.01
	Hikvision 2 mb ip camera(X2)	$80.00	Production	$67.11	$12.89
	Arduino Mega	$15.00	Production	$16.60	($1.60)
	Tether	$34.00	Production	$31.96	$2.04
	T100(X7)	$870.00	Production	$833.00	$37.00
	Servo	$5.00	Production	$4.00	$1.00
	PCB(X2)	$40.00	Production	$40.00	$0.00
	5-axis Joystick	$20.00	Production	$25.00	($5.00)
	Pneumatic cylinders	$10.00	Production	$8.82	$1.18
	Direction control valvs	$10.00	Production	$9.45	$0.55
	Compressor	$65.00	Production	$67.00	($2.00)
	Total	$1,831.50	Total	$1,776.92	$54.58
	Direct labours	Budget($)	Type	Cost($)	Difference($)
	3mm laser cut	$10.00	Manufacturing	$14.06	($4.06)
	3d printed parts	$10.00	Manufacturing	$6.39	$3.61
	Total	$20.00	Total	$20.45	($0.45)
	Indirect materials	Budget($)	Type	Cost($)	Difference($)
	O-rings	$4.00	Production	$4.00	$0.00
	Glands	$10.00	Production	$8.95	$1.05
	Bolts and Nuts	$5.00	Production	$4.47	$0.53
	M6 hexbolts head	$15.00	Production	$7.99	$7.01
	M4 alan key	$0.50	Production	$0.12	$0.38
	Belts	$3.00	Production	$4.00	($1.00)
	Lead screws	$5.00	Production	$11.50	($6.50)
	Grey Duct Tape(x2)	$6.00	Production	$5.00	$1.00
	Total	$48.50	Total	$46.03	($1.00)
Period Costs (2 months)	Type	Description	Budget($)	Cost($)	Difference($)
	Co-Working Space Rent	Renting a suitable place to assemble the ROV	$115.00	$100.00	$15.00
	Registration fees	Needed to enter the competition	$250.00	$250.00	$0.00
	Total		$365.00	$350.00	$15.00
Project Cost	Total Budget & Cost	Project Cost($)			
	Income	$2,196.45			
	Direct Material	($1,776.92)			
	Direct labours	($20.45)			
	Indirect materials	($46.03)			
	Period Cost	($350.00)			
	Total Project Cost	$2,193.40			
	Available funds	$3.05			