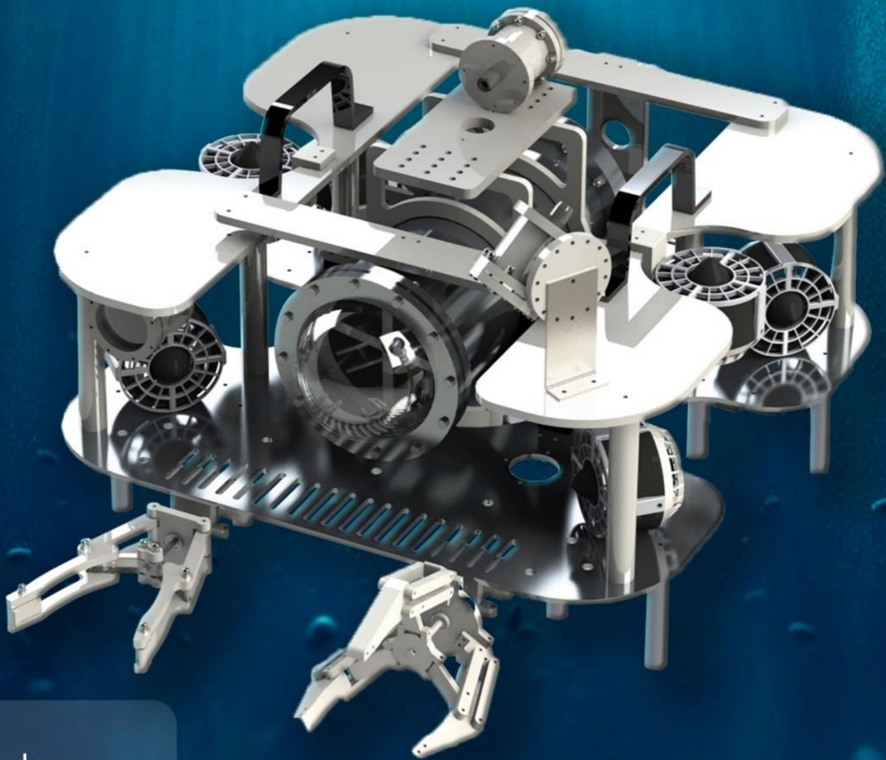
SAILFISH ROV

Your Eye inside Ocean



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NAVY

Tecnical Report ’24

Higher Technological Institute
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MATE ROV COMPETITION EGYPT

Higher Technological Institute Tenth of Ramadan City

SAILFISH ROV 2010 BORN TO DIVE

Website
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1 Introduction

1.1 Abstract

Sailfish, a company at the Higher Technological Institute on the 10th of Ramadan, Egypt, established in 2012, focuses on underwater engineering and collaboration skills by manufacturing Underwater Remotely Operated Vehicles (ROVs).

Sailfish integrates with Egypt's Vision 2030, particularly in environmental sustainability and scientific advancement within the maritime sector.

Navy is equipped with four video cameras, two lights, two grippers, and containment equipment, manufactured using advanced techniques such as CNC machining and 3D printing, built with autonomous navigation and task performance capabilities to aid in marine resource exploration and infrastructure inspection.

Sailfish's initiative addresses pressing environmental concerns such as microplastic pollution, which poses significant threats to marine life and impacts human health, as **Navy** has the capabilities to explore and remove microplastic from marine environments, which exemplifies our commitment to environmental preservation.

Through interdisciplinary cooperation and innovation, Sailfish plays crucial role in improving Egypt's maritime life, embodying excellence in engineering and environmental stewardship.

Figure 1: Sailfish ROV company members

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2 Design Rationale

2.1 Design Evolution

At the onset of the year, our focus shifted towards a thorough examination of past designs, leveraging our extensive involvement in the MATE ROV Competition. Through careful analysis of their strengths and weaknesses, we embarked on the task of refining **Navy**, aiming to deliver unparalleled performance. Our primary objective was to engineer a versatile ROV endowed with advanced functionalities, as shown in **(Figure 2)**.

Figure 2: Navy's Rendered Model

2.1.1 Mechanical System Design Evolution

- **Frame:**

The **Navy** ROV, chosen by the mechanical department for its optimal relationship with the thrusters' configuration, is designed with ease of installation and disassembly in mind. The frame consists of one aluminum plate connected by Artelon rods, resulting in a lightweight yet robust structure. This geometry offers a broader area for mounting equipment compared to alternative designs. The thrusters' mount plate, integral to the frame's geometry, enhances the propulsion system's efficiency by expanding the operating area in front of each thruster's throttle. This configuration minimizes drag force on **Navy** and ensures maximum thrust force by eliminating obstructions within the thrusters' operational perimeter.

- **The Electronics Enclosure:**

Sailfish chose the "cylindrical" shape for the design evolution of the electrical housing, emphasizing its advantages over a cuboid shape. The cylindrical design offers better underwater performance due to its reduced drag force. It facilitates well-organized wiring and creates a central gap within the frame, enhancing hydrodynamics.

- **Mechanisms:**

Our company has mounted multi-purpose mechanisms onto the platform, providing flexibility, high performance, and increasing the success rate of missions.

2.1.2 Electrical System Design Evolution

- **Arduino Mini Pro:**

The Arduino Mini Pro was the second microcontroller which was selected because of its small size, as shown in **(Figure 3)**, high integration, versatility with sensors such as temperature sensor (MAX31865 RTD), and robust community support make it a cost-effective, offering open-source flexibility and ease of programming.

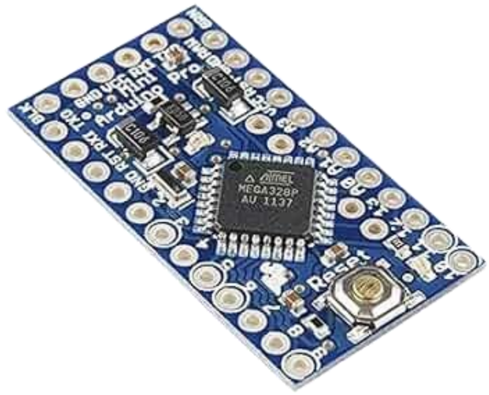

Figure 3: Arduino Mini Pro

- **Temperature Sensor:**

The decision to utilize a PT100 sensor with the MAX31865 RTD module instead of other alternatives was driven by several factors. Firstly, the PT100 sensor offers high accuracy and stability underwater. It also offers a cost-efficient solution, aligning well with budget constraints without compromising on quality. Additionally, the MAX31865 RTD module provides signal conditioning and digital conversion specifically tailored for RTD sensors like the PT100, ensuring reliable and accurate temperature readings. Furthermore, the compatibility between the PT100 sensor and the MAX31865 module simplifies integration and reduces the risk of compatibility issues. This combination of high accuracy, dedicated signal conditioning, and ease of integration makes the PT100 with MAX31865 RTD an optimal choice for demanding temperature sensing (the SMART repeater's temperature sensor).

IMU Sensor:

MPU 6050 is the preferred IMU sensor for Navy (Internal Measurement Unit), selected based on the PID controller's aims, budget constraints, lower power consumption, and simpler solution when compared to alternatives.

2.1.3 Software System Design Evolution

- **PID Controller (Proportional Integral Derivative):**

Navy achieved a unique performance this year by using the PID which is based on the IMU. The calibrated sensor data (usually roll and pitch angles) is used as feedback for the PID controller. The controller calculates the error between the desired orientation (setpoint) and the actual orientation measured by the IMU. However, this year, use the "manual tuning method "according to trial and error. Finally, PID reaches a stable ROV position even in currents or varying water conditions, allowing the pilot to drive simply and complete tasks as quickly as possible, specifically recovering a sediment sample.

- **GUI:**

Adding a logger messages label to show the state of **Navy** communication and ensure the transmission and received data are perfect without any defects (errors), PID tab to show the effect of PID gains to minimize the error that comes from varying water conditions., and Trajectory tracking tab to show the current position of ROV from the start point.

2.2 Design Process

When apps are approaching the design process, our company considers several factors. Firstly, given that our vehicle will operate in a busy port with limited space and maneuverability, we prioritize a compact and highly hydrodynamic design. Additionally, our mission to provide customers with affordable and efficient ROVs heavily influences our designs. Therefore, we carefully consider available materials in the market and various manufacturing techniques within our locality. The design addresses the **problem** of efficient navigation and operation in underwater environments. The placement of thrusters and the streamlined shape of the body are likely optimized for agility and control. The choice of materials considers the balance between strength and buoyancy.

2.2.1 2D sketch

The Mechanical department begins by thoroughly reviewing the tasks required by our vehicle, brainstorming various design ideas for the frame and thruster arrangement. They then present a mockup or mechanical drawing to engage other company departments, gathering feedback and suggestions for modifications. This iterative process continues until the design is considered optimal by all departments. To facilitate easy viewing and modification suggestions from various departments, a computer-aided design (CAD) was generated using **SolidWorks**. This CAD was then showcased at a company-wide meeting. Subsequently, the designs were converted into

Drawing Exchange Format (DXF) and Standard Tessellation Language (STL) files. These files were intended for use with our CNC router, laser cutter, and 3D printer.

3. Mechanical Design

3.1 Frame

The **Navy** ROV is designed with ease of installation and disassembly in mind. It comprises two horizontal plates at the top made of 8 mm thick polyethylene sheet. Connecting these top plates to the bottom plate, which is made of 5 mm thick aluminum, are eight vertical rods made of polyethylene with a diameter of 25 mm. Additionally, the arms are crafted from polyethylene sheet with a thickness of 20 mm, while the control box holders are made from 8 mm thick polyethylene sheets, as shown in **(Figure 4).**

Figure 4: Navy's Frame

- **Thrusters**

For better efficiency, T200 brushless thrusters are used, where two thrusters are used for vertical movement, and four brushless thrusters are used for horizontal movement. They are placed at 45 degrees from the neutral axis, allowing maximum torque, and there is a thruster in the rear of the vehicle to stabilize the vehicle.

Figure 5: T200 Thruster

As for the 3D printer machine, we used APS to manufacture part at **(Figure 6)** for use in Thruster up and down.

Figure 6:The part is made of APS

3.2 Mechanisms

The **Navy** ROV is equipped with a variety of versatile mechanisms including a double-gripper jaw and a triple-jawed gripper. These mechanisms efficiently convert pneumatic power input into customized movements, this enables the ROV to perform specific Tasks during the competition. Pneumatic systems are highly advantageous due to their simplicity, reliability, and cost-effectiveness. They offer high power-to-weight ratios, rapid response times, and safe operations. Additionally, these systems are clean, versatile, and require minimal maintenance. They are made of Artelon with 8mm thickness. Artelon typically has a low density, making it lightweight compared to many other materials. The material selection fell on using Artelon material because of its features which are cost-effectiveness, high machinability, non-corrosiveness, and high strength compared to other materials.

- **Main Gripper**

The gripper is an innovative and unconventional tool that efficiently handles multiple tasks using a pneumatic system. It can grip PVC pipes of varying diameters (12.7 mm–50.8 mm) and simply be used with the secondary gripper at the same time because of its small volume, as shown in **(Figure 7).**

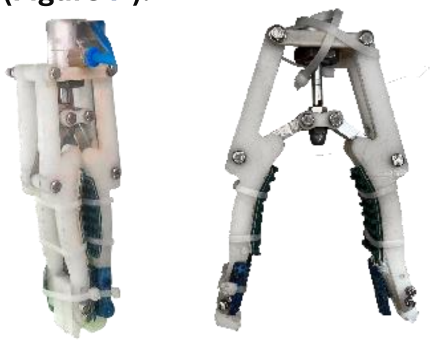

Figure 7: Main Gripper

- **Secondary Gripper**

This gripper was designed in a way that supports the simplest manufacturing methods and thus reduces cost. This gripper was manufactured using a CNC router machine using an 8 mm thick Artelon sheet. There are also some links of 1.5 mm thickness. A pneumatic system is used to control this gripper. This gripper is used to activate the irrigation system and deal with complex things easily as shown in **(Figure 8).**

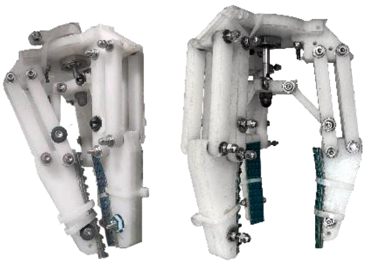

Figure 8: Secondary Gripper

- **Vertical float**

A precision-engineered vertical float system revolutionizing pool dynamics. The cutting-edge design harnesses a floating engine comprising four advanced syringes and a high-performance stepper motor. Leveraging this technology, the motor intelligently draws water into the syringes, augmenting the float's weight for seamless diving experiences. Subsequently, a precise reversal triggers the release of water, enabling the float to effortlessly ascend to the water's surface. This meticulously crafted cycle is repeated twice, ensuring unparalleled control, and enhancing the overall aquatic adventure as shown in **(Figure 9).**

Figure 9: Vertical float

3.3 sealing

- **Electronics Housing Design**

It's a brain of **Navy** ROV because it contains everything that thinks ON (thruster, gripper, and camera) and controls ROV in all directions. At the heart of our vehicle, the aluminum mold and aluminum cylinder house the electronics responsible for handling all the vehicle's operations, save the power conversion as shown in **(Figure 10).**

Figure 10: Control Box

It is 300 mm long, with a 145.5 mm internal diameter, and a 2 mm wall thickness. These components achieve complete mechanical sealing of the electronics housing while enabling incredibly effortless plug-and-play replacements. Two aluminum flanges surround our aluminum cylinder. Each flange has two radial grooves. that house O-rings, which are responsible for the sealing. between the flanges and the aluminum tube. In addition, Two aluminum end caps complete the mechanical sealing. of our electronics housing. Another two surface O-rings seal the region between the flanges and the acrylic end.

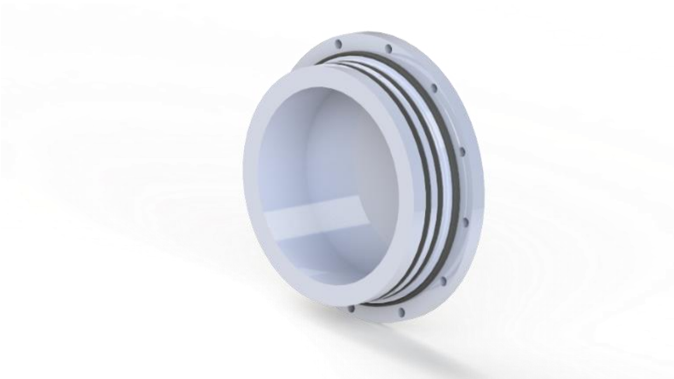

Figure 11: End-cap with O-rings

- **Dome**

The front-end cap is dome-shaped to decrease drag force. A surface O-ring was used to seal between the penetrators. and the rear aluminum cap, while Loctite Marine Silicon was cast to seal the area around the cable. Besides, there is a camera inside that rotates at certain angles for easy shooting.

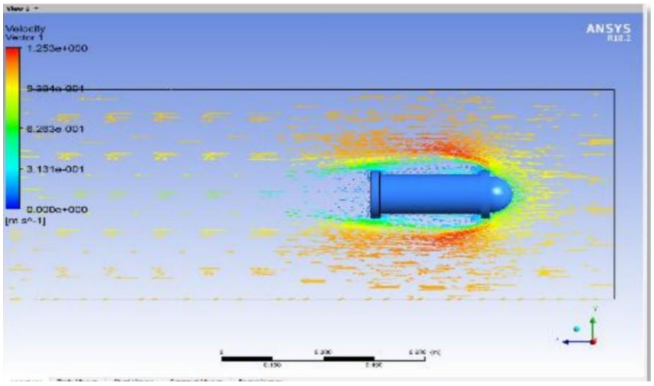

Figure 12: control box drag force

3.4 Manufacturing Process

After thoroughly reviewing the tasks required by our vehicle, the Mechanical department brainstorms different design ideas for the vehicle's frame and thruster arrangement. Next, they present a mockup or mechanical drawing **(Figure 13)** to discuss with the company's other departments and accommodate their feedback and suggested modifications. The process repeats until the design is deemed optimal by all departments.

To help the company's different departments easily view the design and suggest any beneficial modifications, a computer-aided design (CAD) was created using SolidWorks and viewed at a company-wide meeting. Finally, the designs were converted into Drawing Exchange Format (DXF) and Standard Tessellation Language (STL) files to be sent to our CNC router, laser cutter and 3D printer.

- **Manufacturing Process for Electronics Housing**

In the beginning, the manufacturing is important for us and sealing because it is related to several grooves and suitable with O-Ring'*S* dimensions **(Figure 14),** Manufacturing must be at the highest level.

Figure 13: O-rings control box

- **Steps of the manufacturing process:**

First, rolling process: We bring sheet aluminum and use the rolling machine to convert it to cylinder shape by using the equation: πD. Second, Lathe process: We bring an aluminum rod then run it by lathe machine make the cap, three flanges and grooves to all O-Rings **(Figure15)**. Third, Splitter process: We make 10 holes in three flanges and cap to prove screws by splitter device. Fourth, Welding process: after rolling

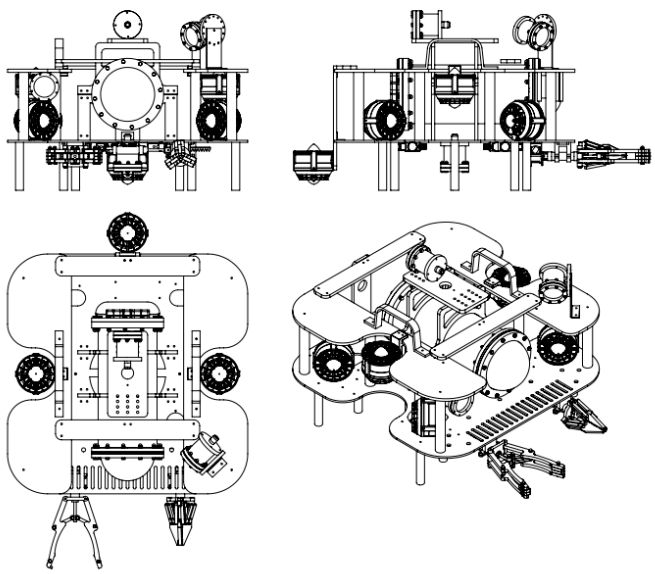

Figure 14: Mechanical Drawing of Navy

aluminum sheet to convert to cylindrical shape welding it, welding between two flanges in tube one of them in party tube and another flange in another party tube. Upon assembly, the problem of increasing the thickness of the weld appeared and we overcame it by sanding stone. Finally, Assembly of all Ingredients control box and link screws in holes.

Figure 15: Lathe Machine

3.5 Stress Analysis

Ansys CFD

CFD In our ROV application, computational fluid dynamics (CFD) is utilized to predict fluid flow, heat and mass transfer, chemical reactions, and related phenomena. This involves numerically solving the set of governing mathematical equations, including conservation of mass, momentum, and energy, as well as considering the effects of body forces. We employ CFD to determine drag and lift forces based on known pressure, velocity, and flow type. By comparing these CFD-derived forces with the actual forces generated by the motors, we can assess the ROV's smoothness and speed of diving, comparing it with the time required to accomplish tasks, as shown in **(Figure 16).**

The drag force equation used is:

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

FD: drag force (N)

ρ: density of fluid (kg/m2)

V: speed of the ROV relative to the fluid (m/s)

CD: drag coefficient.

A: cross-sectional area (m2)

The calculated drag force from CFD was found to be **13.5 N**, which proved sufficient for the **Navy** ROV to perform all tasks effectively.

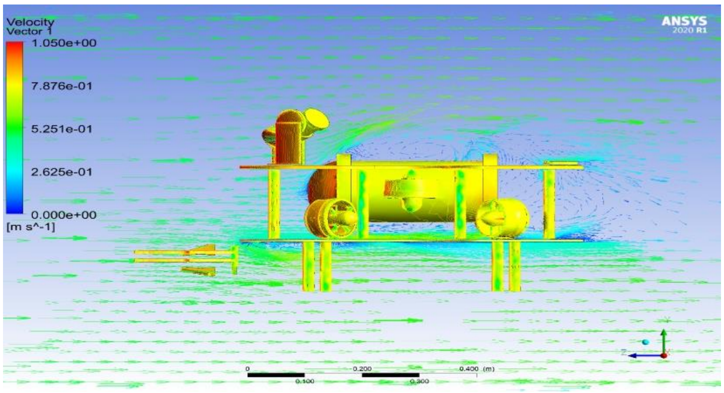

Figure 16: pressure distribution

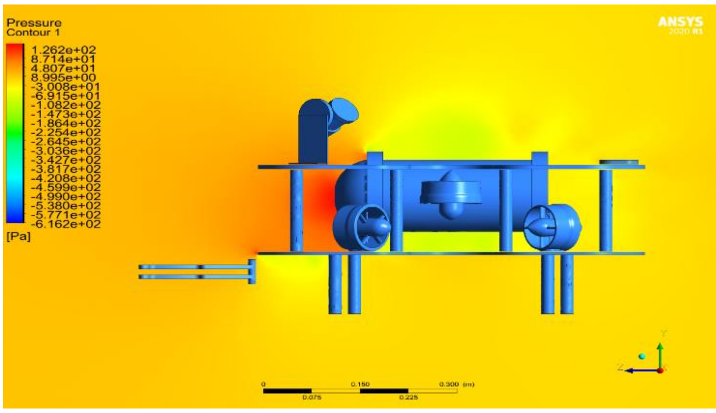

Figure 17: Velocity Streamline

3.6 Equations of motion

First, according to Newton's law the second law that states that the exerted force over a body equals the body's mass multiplied by the body's acceleration.

Using the equation of motion for constant acceleration: $V^2 = V_\circ^2 + 2ad$

We get the required acceleration for reaching the required speed at distance of 10 cm and starting from rest: $a = \frac{0.5^2}{2 * 0.1} = 1.25\ m/s^2$

Then applying the acceleration in Newton's second law to get the required force to be executed from the thrusters to produce the motion:

$$F = ma = 13.5 * 1.25 = 16.875\ N$$

This force is the net force required to move the robot with the required speed and acceleration after the effect of drag force and added mass forces.

3.7 Mobility

Mobility, defined as the degrees of freedom for vehicle motion, is crucial for maintaining stability, with the propulsion system playing a key role. The chosen **7** thrusters **(Figure 18)** vectored propulsion system is designed to ensure excellent stability, robust horizontal movement, and intuitive pilot control. Configured in this manner, the 7 thrusters grant the ROV six degrees of freedom, enabling yaw, heave, surge, roll, pitch, and sway motions.

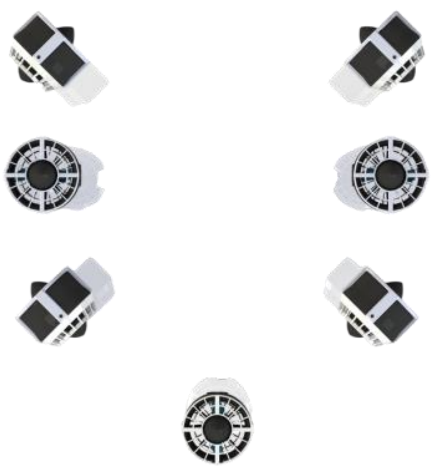

Figure 18: Six Degrees of Freedom

3.8 Buoyancy

One challenge encountered by the mechanics department was achieving smooth suspension of the vehicle in water to enhance navigation.

Additionally, obtaining neutral buoyancy underwater posed another hurdle, aiming for a balance where the buoyancy force neither becomes excessive nor insufficient. This balance ensures minimal effort required for the thrusters to maneuver vertically. Consequently, maintaining the vehicle in pristine condition is imperative for executing all required tasks effectively. After compilation, the block for the ROV weighed 20 kilograms, equivalent to 198.789N.

The weight displaced by water, causing negative buoyancy, measured 100.2N. The variation in vertical forces components tends to converge between the effect of buoyancy and the weight of the displaced water. However, the weight of the displaced water slightly outweighs buoyancy, resulting in a slight sinking of the vehicle. In response, various solutions were devised. The company opted for lightweight foam as a flotation material, chosen for its low density (30 kg/m^3) and cost-effectiveness. This foam was placed in the legs and hands of the vehicle to maintain its shape and resistance at the expected depth of occupancy, as shown in Table (1).

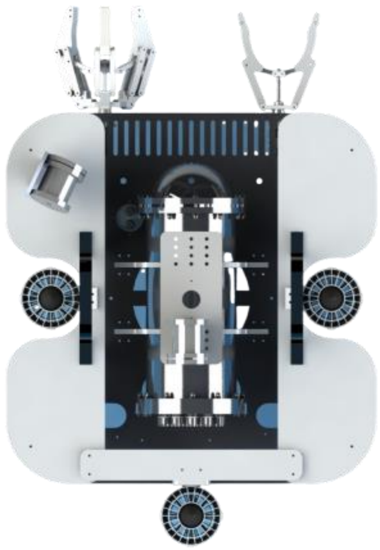

Figure 19: Navy ROV top view

Table (1): Buoyancy Effects

Part	Quantity	Total Weight Outside Water(N)	Buoyancy(N)	Total Weight Inside Water (N)
TOP plate	2	11.7266778	11.54340424	0.183273559
Bottom plate	1	35.633844	13.44672219	22.18712181
Thruster	7	26.0946	12.8627583	13.2318417
Led & Camera Housing	4	3.2031612	3.39590651	-0.19274531
Leg	4	2.2241232	1.842318	0.3818052
Control box	1	52.2873	22.30377359	29.98352641
Gripper	2	7.848	1.450797368	6.397202632
Valves	3	10.0062	2.690683072	7.315516928
Center holder	1	1.8691974	1.963430298	-0.094232898
Camera holder	2	1.4809176	1.555673528	-0.074755928
Rod	8	6.3356904	6.654751625	-0.319061225
Holder Tether	1	2.4235605	1.15418731	1.26937319
Fixed	2	0.5318982	0.521511961	0.010386239
Total		198.7899381	98.56797899	100.2219591

4 Electrical Design

Navy electrical system consists of total three PCBS, Main Board, Sensors Board and switches Board. The main board is in charge for the motion system of the ROV as it contains the Arduino UNO along with the Arduino shield and the IMU sensor. The second board contains the Arduino Mini-Pro along with the temperature sensor and the final board contains the transistors for all the switches in the ROV such as the DCV and the LEDS. Because it is very modular, the new three-board system greatly facilitates debugging, provides us with additional room, and allows us to change or develop any aspect of our system.

4.1 Main Board

The main board is in charge of the motion and the stability of the ROV as it single-handedly handles the movement of the Thrusters and the servo motor to change the orientation of the main camera as it consists of the Arduino UNO along with the Arduino Ethernet shield which is how the ROV receives commands from the station Pilot to operate the thrusters. Also, with the help of the MPU 6050 IMU sensor. PID system is implemented in this PCB which gives the ROV exceptional stability regardless of variations in water flow.

Figure 20: Main Board

4.2 Sensors Board

The Sensors Board contains the PT100 temperature sensor and Arduino Mini Pro is communicating with the Main Board through RX and TX pins (UART communication). MAX31865 kit in a 3-wire configuration also contains the Ethernet socket which makes it the PCB responsible for uploading new code to the system from the top-side control unit using an FTDI module **(Figure 21)** without having to open up the underwater control unit.

Figure 21: FTDI module

4.3 Switch Board

The switch board is very reusable and adaptable, fitting into various systems. By just connecting the signal and ground pins, it has five NPN transistors that may be used to turn on or off 3 DCVs (Directional Control Valve) to control grippers and 2 LEDs. Additionally, it has a power MOSFET and an optoelectronic isolator to protect against reverse currents that can cause malfunctions or burn system components.

Figure 22: Switches Board

4.4 Power Distribution

The ROV is powered from the top-side control box using 4 power supplies each of which is 12V. The total voltage connected in series to power up the ROV with 48V. The 48V is connected to 4 DC-DC Buck converters to convert 48V to 12V to power up the LEDS, DCVS, and cameras. A DC-DC 12V to 5V buck converter is used to feed the microcontrollers. The power is distributed as shown in Table (**2**).

Figure 23: Step-down Converter 48to 12 volt

Figure 24: DC-DC Buck converters

4.5 Tether

The tether of **Navy** consists of 2 power cables (48v and ground), 3 pneumatic cables 1 for controlling mechanisms 1 for sealing test and 1 for exhausting the air outside, 3 CAT6 cables, 1 used for communication, 1 for bootloader and for connection between bottom-side video baluns and top-side video baluns. All 8 cables are wrapped in a protective sheathe which makes it more convenient for the tether-man attach foam pieces to make it more buoyant and have better control over it. The tether is shielded from excessive tension by being attached between two strain reliefs, as shown in **(Figure 25)**.

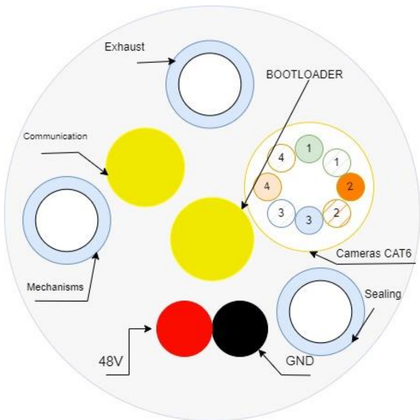

Figure 25:The Tether of Navy

Sailfish's Tether Management Protocol, the product of many years of experience, gives crew safety, mission effectiveness, and practical application first emphasis. The tether is always under human control while operating, under the observation of the ROV. In order to avoid twists and connector damage, a post-mission maintenance process makes sure the tether is rolled and stowed correctly. Two on-deck staff members oversee an operational routine that guarantees safe mission utilization.

4.6 Top side control Unit

Sailfish company's TCU is custom made from wood. It is designed to have all the space required to fit our power supply unit, camera's video baluns, router for communication, DVR, wires, cables and the Pilot screen along with a space for placing the joystick. Sailfish ROV's station also contains an on/off switch and an emergency shut-off button which decreases any electrical risks.

Figure 26:Top side control Unit

4.7 Vision System

Navy's vision system consists of 4 CCTV cameras in different positions, as shown in **(Figure 27)** that are connected to DVR. A CAT6 cable is used to transfer the signals from the cameras to DVR in the top control side. The camera signal transfers a long distance, so video baluns are used to make the camera signal better to overcome any noise.

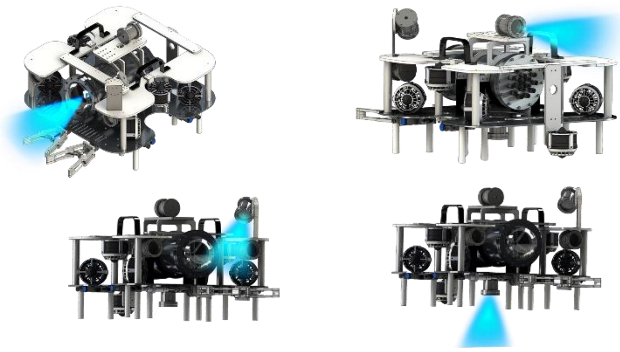

Figure 27: Navy's vision system

Figure 28: Video Baluns

Table (2): Power Distribution

Component	Quantity	Voltage(v)	Current(A)	Power/component	Total power
T100 thruster	1	12	6	72	72
Arduino UNO	1	5	0.2	1	1
DCV (solenoid)	3	12	0.4	4.8	14.4
T200 thruster	6	12	9	108	648
ESCs	7	12	0.5	6	42
Camera	4	12	5	2.7	10.8
PT100 Temperature sensor	1	5	5×10^{-6}	25×10^{-6}	25×10^{-6}
IMU sensor	1	5	0.0039	0.018	0.018
Arduino mini pro	1	5	16×10^{-3}	0.08	0.08
Total power consumption			788.298		
Peak power available at top of tether (watt)			1182.447		
Fuse Calculations			788.298*1.5/48V=24.634A So, we use a fuse 25 A		

5 Software

5.1 Graphical User Interface (GUI)

The GUI is written with PyQt5 and comprises a pilot GUI used by the driver and a co-pilot GUI with ancillary information. The pilot GUI shows the state of all components (thrusters, grippers, IMU reads, and logger messages). There are two tabs in the pilot GUI. The primary tab is trajectory tracking tab, which helps the pilot reach the immediate position of ROV from the start point of movement in the pool. The secondary tab contains a PID graph. The co-pilot GUI is divided into multiple tabs which makes all tasks easy to finish.

Figure 29: Pilot GUI

Figure 30: Co-pilot GUI

5.2 Stability

Last year, the mechanical department was responsible for handling the stability of ROV. But this year, after adding IMU that add a big chance to get the first step to solving one of the biggest **problems** in the last few years. **Navy's** stability is controlled by using software with PID controller (manual tuning) was based on finding the constants by trial and error which was a tedious and time-consuming procedure that achieved outstanding performance in terms of robustness and flexibility of control.

5.3 3D Modelling

Capturing images from all angles based on restoration area and applying some traditional ML algorithms to enhance images. Then, upload the dataset to COLMAP (Photogrammetry Software) which applies Structure from Motion (SFM) to coral reconstruct 3D structures from a collection of 2D images, these steps are shown in **(Figure 31)**.

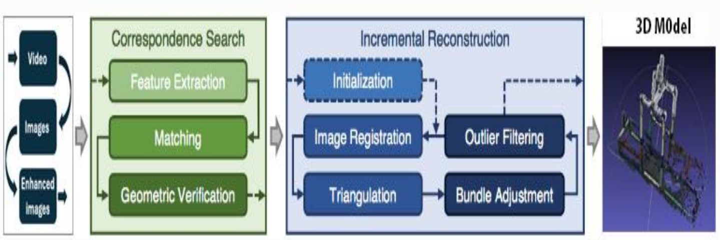

Figure 31: The steps of creating a 3D model

Then, measure the length of coral restoration area with image processing and use MeshLab to show a 3D model with the length and estimate the height, as shown in (**Figure 32**).

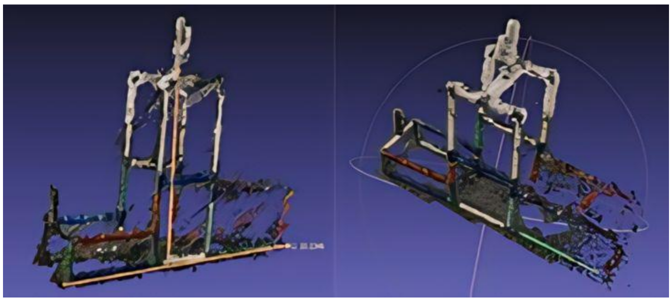

Figure 32: Coral Restoration Area 3D Model

5.4 Autonomous Task

By merging all data that is given from sensors (IMU, front camera, and gripper camera) IMU gives the current position of **Navy**, both of cameras look for the required area by using color detection, and gripper camera gives order to open and close grippers that how **Navy** can catch the coral and put it in required area.

6 Safety

6.1 Safety Principles

Safety is the cornerstone of operations at Sailfish ROV. "Injuries harm, safety preserves," underscores the critical importance of maintaining a secure working environment conducive to effective design, manufacturing, and testing. We are unwavering in our commitment to meeting MATE's safety standards, ensuring that all Sailfish personnel strictly adhere to safety protocols and heed warning labels. Our commitment to employee safety always comes before machinery safety because it is the foundation of our company's well-being. During the manufacturing and pre-launch phases, we implement comprehensive workplace guidelines and protocols to ensure compliance with MATE's safety regulations.

6.2 Safety Training

New hires receive safety training from our seasoned staff. In addition to technical training, new employees undergo safety training to learn about the necessary safety measures and protocols. By participating in rigorous safety training and gaining hands-on experience through supervised tasks, all employees become well-versed in the procedures that promote safety at all times.

6.3 Safety Features

6.3.1 Power Supply

Navy has introduced a power supply unit capable of delivering DC voltages up to 48V. This unit is designed to safeguard against overload currents and reverse polarity. Additionally, a kill switch is included for emergency shut down situations.

6.3.2 SBS-50 Anderson Connector

To perform MATE safety standards, Anderson Power pole connectors are provided by the ROV.

Anderson connectors are utilized to firmly secure the two power terminals in place, thus preventing any potential mishaps while making a connection.

6.3.3 Fuses

Calculations of the power consumption are used to add a suitable standard 30-A fuse to the power cable.

6.3.4 Sheathed Tether

It is essential to create a procedure to prevent slipping around the pool area, which is why all tether cables are securely fastened and coated with polymers derived from tether.

6.3.5 Shrouded Thrusters

The fundamental aim of workplace safety programs is to proactively minimize workplace injuries. This is accomplished by utilizing shrouds as protective enclosures for the intake and exhaust of the thrusters.

6.3.6 Smoothed edges

The presence of sharp edges in engineering workplaces can lead to a significant number of accidents. Therefore, it is essential to prioritize safety by smoothing out all edges and corners.

6.3.7 Non-Return Valve

Preventing Fluid Backflow: In systems where backflow could lead to dangerous situations, such as in hydraulic systems, check valves prevent the reversal of flow. This prevents potential hazards like explosions and equipment damage that could result from unexpected flow direction changes.

6.4 Safety checklist

Sailfish ROV prioritizes safety and adheres to a stringent protocol for all staff members prior to, during, and after the deployment of the **Navy**. Regular inspections are carried out, and a comprehensive set of operational safety guidelines is available in **Appendices 11.1**. Although employees are responsible for diligently following the safety checklist, a safety director guarantees its rigorous implementation.

7 Testing and Troubleshooting

7.1 Mechanical Testing

The **Navy** mechanical system underwent extensive mechanical testing to enhance its reliability, efficiency, and durability. This optimization not only reduces the risk of failures and eliminates safety hazards in the **Navy**, but also guarantees its effective performance in demanding underwater conditions.

The mechanical system's components were initially prototyped for safety testing and to verify the effectiveness and efficiency of the design. Every prototype underwent meticulous refinement and testing prior to advancing to the final design and assembly stage in order to prevent any issues Integration into **Navy** presented challenges. The frame's stability was confirmed through rigorous testing under high vibrations to ensure the security of all attachments. Additionally, pneumatic manipulators and their DCVs were tested to ensure optimal end effector mobility. The sealing mechanisms were also validated.

7.2 Electrical Testing

Sailfish ROV puts great emphasis on testing and troubleshooting the electrical system. We always make sure the system's components are protected and functional. Throughout the season, we have come up with different testing mechanisms to find the most reliable, efficient, and fastest testing plan. Finally we came up with the best testing plan that is designed to validate components performance and functions, check over or under voltages, and check the communication system, as shown in **(Figure 33)**.

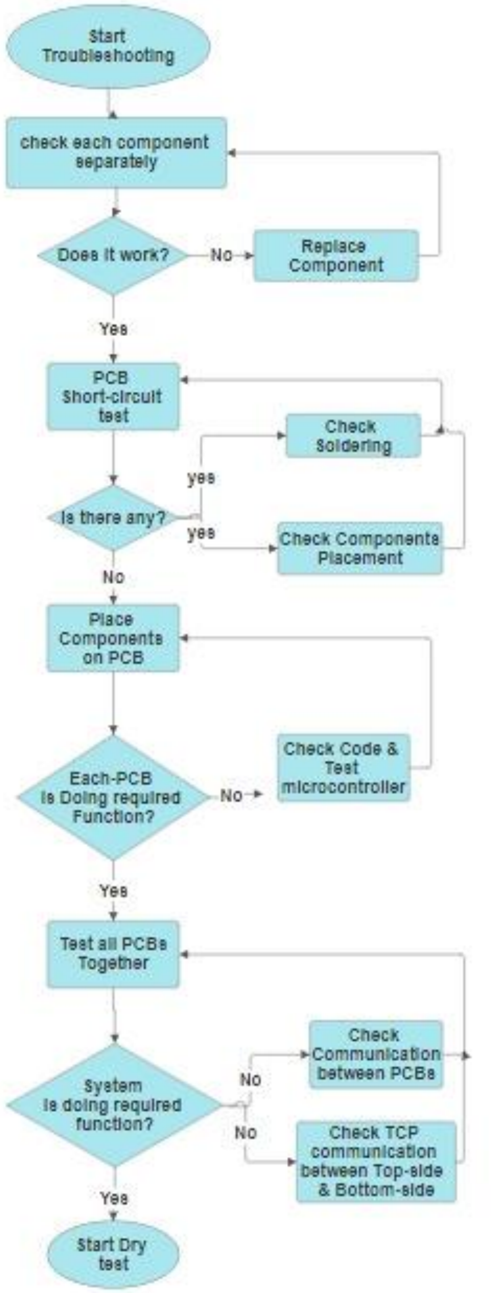

Figure 33: Electrical Testing for Navy ROV

8 Logistics

8.1 Company History

Sailfish ROV Company was established in 2012 at the Higher Technological Institute (10th of Ramadan City). Sailfish ROV is the first ROV company and one of the most successful ROV companies in Egypt. Sailfish have now taken part in the MATE ROV Competition for the previous 10 years. Sailfish has demonstrated impressive performance in the Egypt Regional MATE ROV Competition, placing fourth three times in the Mate ROV Competition, with the most recent one being in 2023.

- Mate ROV competition's Best Pilot award (twice).
- Mate ROV competition's Best Poster Design ward (two times).
- The Mate ROV competition's Best Manoeuvrable in 2023.

Sailfish is a business that offers a variety of services and goods associated with underwater engineering and robotics. Sailfish ROV expands its collection with a new cutting-edge ROV each year, starting in 2012 with the newest.

Figure 34:Sailfish ROV last ROVs

8.2 Company structure

Sailfish ROV focuses on underwater robotics and engineering. There are 45 employees in the company, split between the technical and non-technical departments. The three departments that make up the technical department are hardware, software, and mechanical. Every department is responsible for planning, constructing, testing, and running a particular **Navy** ROV subsystem. Four departments make up the non-technical department: public relations (PR), media, human resources (HR), and business plan. Each department is in charge of publicizing, recording, and showcasing the accomplishments, goods, and services provided by the business. The Chief Executive Officer (CEO) is in charge of the company's management, strategy, and overarching vision. Three of the head technical officers (head), who oversee the technical department, as shown in (**Figure 42**).

8.3 Company Management

The company has competed in numerous national and international tournaments and has received numerous honors for its superior performance, engineering, and design.

The management hierarchy of the company is divided into three tiers:

The CEO and the heads of the hardware department, software department, and mechanical department make up the executive board. They are in charge of establishing the company's vision, objectives, and goals, in addition to managing the projects' finances and administrative details. In addition, they work with sponsors, mentors, and the media. The project company is made up of the deputies of the mechanical, hardware, and software heads. They are in charge of carrying out the projects' technical requirements, which include creating, assembling, testing, and running the ROV. In order to guarantee the caliber and effectiveness of the work, they also collaborate with the advisory committee and the executive board. The advisory committee is made up of mentors and a supervisor who advise, critique, and assist the company. Experts in a range of domains, including electronics, mechanical, software, marketing, and education, they are involved in underwater robots. They support the group's outreach and networking initiatives as well.

8.4 Project Scheduling

The four primary phases of the project timeline design, development, testing, and deployment will be created by the sailfish ROV company using a digital project management platform. Each phase's scope, duration, and dependencies will be specified by the project manager and the technical leads, who will also periodically update the project timeline. The group will meet in a variety of ways to plan, communicate, update members on the project's progress, and present their work.

The group will get together on a regular basis to plan, discuss, and update each other on the project's progress. There will be meetings of the following kinds:

Daily stand-ups are brief, targeted meetings in which company members discuss their goals for the day, their accomplishments from the previous day, and any obstacles they may be facing.

Weekly reviews: lenger, more thorough sessions where company members discuss any issues or dangers that need to be addressed, show their work, and receive feedback.

Monthly retrospectives are thoughtful and productive gatherings when the company assesses each other's performance, decides what worked and what needs to be improved, and sets goals for the following month's tasks.

Quarterly demos are structured, interactive sessions in which the company presents their work to members, walks them through the sailfish ROV's features and capabilities, and gets input and ideas for the following quarter.

8.5 Workspace Management

Workplace Administration The sailfish ROV crew works out of a large, well-appointed studio with distinct areas for diverse uses, like a SolidWorks s, a 3D printing space, and a water testing facility, a storage closet, a testing pool, and a metalworking area. Before, during, and after each task, the work environment must be kept orderly and secure. A workshop manager is in charge of making sure everything is in working order and is maintained, as well as doing any repairs or improvements to improve the workspace.

8.6 Shared Files and Libraries

Sailfish ROV company holds weekly meetings as part of our project management process to go over the tasks that need to be completed on Microsoft Teams. These sessions are crucial for monitoring our development, settling any conflicts, and guaranteeing that company members are working well together. Additionally, we communicate, share files, and have video calls using Microsoft Teams.

In addition,We have also made a drive where each member can turn in their tasks. This motivation aids in work organization, duplicate prevention, and mutual feedback. We can improve the effectiveness and professionalism of our project by utilizing this drive.

We are proud of our company and our project, and we are looking forward to presenting **Navy** ROV at the upcoming competition. We believe that it has the potential to make a positive impact on the world of underwater exploration and research.

9 Budget planning

Full budget is ($9,000) in addition to ($1000) for risk support, knowing that Sailfish ROV is sold for ($3800).

The budget divided into 3 main parts:

1. Manufacture costs: manufacturing 3 ROVs ($2520 cost for each).
2. Implementation of marketing plan:

- Participate in collaboration with tech store to have special corner for Sailfish that gives demo use for ROV and for maintaining products.
- Awareness campaign by making events in schools and clubs to present ROV and how it can help us.
- For PR field, Sailfish increased their public exposure by participating in different interviews in TV, we presented the ROV in long interview in ETC channel, and quick report in MBC channel.

- Making social media campaign that depends on content marketing to increase knowledge of ROV field.

3. Creating a website: To deal with customer requests for purchasing and renting.

Here are cost details:

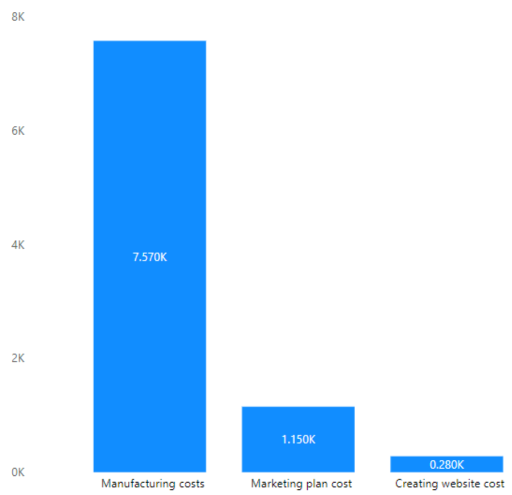

Figure 35: Type of costs

- **Profit percentage**

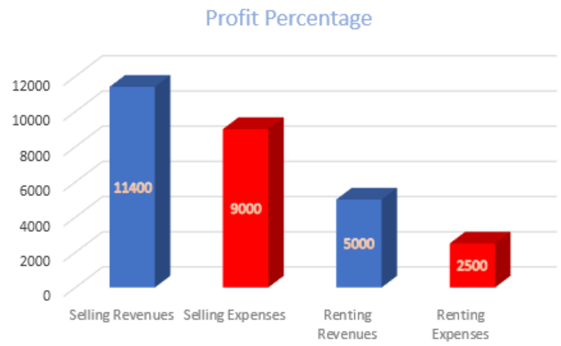

Figure 36: Sailfish Profit percentage

- **Cost accounting**

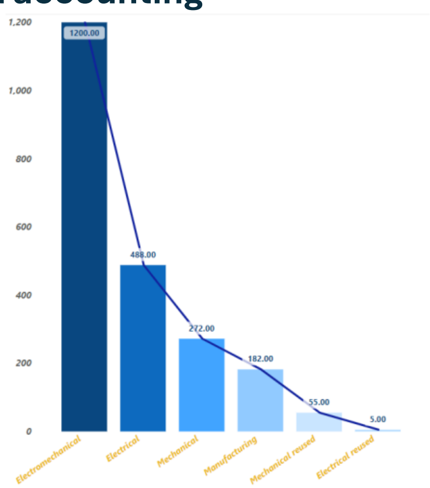

Figure 37: Navy ROV Cost accounting

- **Cost pie chart**

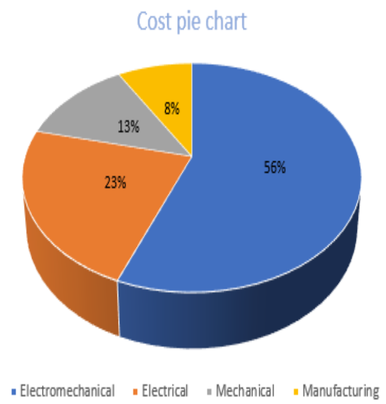

Figure 38: Cost pie chart for Navy ROV

- **Income sources and allocations**

Selling	$11,400
Renting	$5,000
Donations	$880
Partnership	$667
Total	$17,947

- **Funds sources:**

Higher Technological Institute	$370
Educational sessions in schools	$360
Youth Leaders Foundation	$150

- The donations reached $880.
- The ROV is sold for ($3800).
- ESC and Artelon sheet purchased by funds and donations (301$).
- Engineers wages paid by funds and donations ($500).
- Travel costs to the competition covered by funds ($61).

10 Conclusion

10.1 Future Improvements

- **Control System:**

Implementing automatic tuning of PID gains to reach high level performance for stability and path planning. Using ROS as a communication architecture handler to implement great features that would have been much harder to achieve using normal serial communication protocols.

- **Vision System:**

The vision system of **Navy** ROV needs to add a depth camera to provide depth estimation. So that will enhance the accuracy of object detection and length estimation.

- **Navigation System:**

Using more cameras and sensors (ZED cameras, IP cameras, 360-degree cameras, depth sensors, etc..) will help ROV implement different localization and mapping algorithms to achive smooth autonomous movement.

- **Power Conversion System:**

Adding more converters to reach the full power of the T200 thrusters.

10.2 Lessons learned

The Sailfish ROV provides its members with the opportunity to learn and develop new skills. Through a variety of training programs and hands-on experience, the company helps its members grow their knowledge and expertise in a variety of areas.

- **Mechanical Department**

The mechanical department is responsible for the design and construction of the **Navy** ROV. The department's members have gained a variety of skills in the following areas: SolidWorks, 3D printing, CNC machining, automated manufacturing.

Gained strong skills in the process and knowledge of manufacturing processes and determining the type of machinery required to make a particular part.

- **Hardware Department**

The hardware department is responsible for the maintenance and repair of the **Navy** ROV. The company's members have gained a variety of skills in the following areas: Electronics, Troubleshooting. Hardware Department members have acquired strong abilities and raised their understanding of components selection based on availability in our market, PCB Design, Creative Wiring Documenting and presenting their work in a clear and understandable manner.

Software Development

The software department is responsible for the development of the Sailfish ROV's software. The company's members have gained a variety of skills in the following areas: C++, Python and have a high awareness of interfacing with different microcontrollers and frameworks.

- **Non-technical Department**

Public Relations (PR):

The PR members excels in effective communication, outreach, and brand representation. Members learn to craft compelling narratives, engage with stakeholders, and promote Sailfish's mission. Skills acquired as Communication, Networking, and Strategic Messaging.

Human Resources (HR):

Sailfish recognizes the importance of company dynamics and member well-being.HR members gain insights into company management, conflict resolution, and fostering a positive environment. Skills acquired as Leadership, Conflict Resolution, and company Building.

Business Plan:

The Business Plan members strategizes for Sailfish's sustainability and growth. Members delve into market analysis, financial planning, and organizational strategy. Skills acquired as Business Acumen, Strategic Planning, and Financial Literacy.

Media:

The Media members plays a crucial role in documenting Sailfish's journey and promoting its achievements. Members learn photography, videography, content creation, and storytelling. Skills acquired as Visual Storytelling, Content Creation, and Digital Marketing.

10.3 Acknowledgement

As Sailfish ROV, we would like to express our heartfelt gratitude to:

- Dr. Hossam Ramadan for his continuous guidance throughout the season.
- The Higher Technological Institute in the 10th of Ramadan City, our affiliated college, for their fund support.
- Mate competition for providing us with the opportunity to showcase our work and talents.
- The Arab Academy for Science, Technology, and Maritime Transport for hosting.
- YLF for their support.

10.4 References

- MATE ROV Competition Manual 2024
- Blue Robotics' T100. and T200 Thrusters Documentation.
- Nave, Rod. "Buoyancy." Hyper Physics. Georgia State University.
- Blue Robotics
- Arduino UNO
- Arduino-PID-Library-V2
- Texas Instrument TPS54561 buck
- Motion Tracking Sensor (IMU) MPU-6050
- OpenCV Python Documentation
- COLMAP Documentation

11 Appendices

Construction Checklist

- Any testing conducted in the water is done distant from the Electrical Team's workspace.
- Any task requires the use of sanitized appropriate personal protective equipment (PPE), such as goggles, earmuffs, and gloves.
- The workspace is adequately aired, and supplementary fume extractors are employed to prevent the inhalation of hazardous vapors during the soldering or handling of glass fiber, epoxy, etc.
- To guarantee safe handling, hazardous products are stored apart and are properly labeled.
- Sharp tools are handled carefully, kept in racks and boxes when not in use, and, if accessible, have caps placed over their sharp edges.

Figure 40: Construction Checklist

11.1 Sailfish safety checklist

Launching and In Water

- ☐ Fuse and circuit protection against overvoltage built into power supply to avoid overvoltage.
- ☐ Test thrusters, manipulators, and payloads.
- ☐ Make that the tether is being held in place by the strain release on the ROV's side.

Pre-Launch

- ☐ Make that the tether is being held in place by the strain release on the ROV's side.
- ☐ Use strain relief to prevent cable pull on connectors.
- ☐ Invest in robust, high-quality seals for critical components.
- ☐ Shroud propellers adequately.

Developing the ROV

- ☐ Optimize power management systems to extend operational endurance.
- ☐ Powerful lights and high-resolution cameras are essential for navigation and operation.
- ☐ Use similar metals throughout the structure to avoid galvanic corrosion.

Figure 39:Sailfish safety checklist

11.2 Sailfish Expenses Table

Direct materials

Electrical costs	
7 Pluggable terminal block 2-pin	0.8$
2Electrolytic Capacitor 0.1uF 50v	0.1$
4*2N2222 NPN POWER	0.1$
4PIN HEADER FEMALE	0.5$
PIN HEADER MALE	1.7$
RJ45 ETHARNET PLUG CONNECTOR	0.7$
Soldering wire 0.6mm	2.5$
TIP120 NPN	0.3$
PCB SINGLE LAYER FR4	1.2$
Fixed resistor	0.1$
4.7KOhm resistor	0.1$
200MM GT2 CLOSED BELT	0.1$
160MM GT2 CLOSED BELT	0.1$
2FEMALE RJ45 SOCKET	0.6$
2Desoldering pump CJ	2$
48~12converter (4)	5.3$
7 Spring lever connector 4way	2.3$
7Quick terminal block 3 way	2.6$
2Spring lever connector 2way	0.4$
Electrical insulation tape, 19mm	0.4$
65pcs flexible breadboard	1.5$
Arduino UNO	9.2$
LM2596 DC-DC BUCKET	1.7$
1M CABLE 2MM	1.5$
4 Cameras	47$
Endless wire	0.7$
4 video balon	8.3$
DRV8825 STEPPER MOTOR	2$
IMU MPU 6050	14$
6 ESC	216$
4 Power Supply	47.2$
Etharnet Cable 28m	19.5$
12~5 DC Conv	Reused
Anderson power connector 30A	4.7$
Leds	3$
PT100 Temperature Sensor	4.05$
MAX31865 AMP. For Temperature Sensor	13.59$
BMP Pressure Sensor	2.75$
PCB Fabrication	23.01$
TIP122 Transisors	4$
Wooden Plate	2.1$
Wago Connector	1.62$
Terminal Block	3.3$
PC817 Optocoupler	0.78$
Wires	2.59$
Pin Headers	1.10$
Arduino mini pro	10.95$
JST connectors	2.75$
Total	**470.8$**

Mechanical costs	
6 O-Ring	5$
Screws	2$
Nuts	1$
3 Glands	5$
Inner control Box	Reused
3 Valves	15$
3 Fittings	0.5$
Epoxy	75$
Non Return Valve	Reused
Servo Motor	3$
4 Glands	10$
Acrylic Dome	Reused
Aluminum Sheet	Reused
Aluminum Angle	Reused
Aluminum Rod	3.5$
Regulator Taiwan	Reused
Artelon Sheet	85$
Artelon Rod	27$
Tools	40$
Total	**272$**

Electromechanical costs	
1 Thruster T100	Reused
6 Thrusters T200	1200$
Total	**1200$**

Manufacturing costs	
3d Printing	67$
Turning	40$
Welding	10$
Milling	5$
Laser Cutting	15$
CNC Router	25$
CNC PCB	20$
Total	**182$**

Total direct materials	**2142$**

Direct labours	
Engineers	500$
Accountant	107$
Marketeer	117$
Total	**724$**

Indirect labours	
Security guard	83$
Supervisor	133$
Total	**216$**

Period costs	
Marketing costs	33$
Pool renting	61$
Working space renting	49$
Transportation	61$
Total	**204$**

Product cost	**2523.33$**
3 ROVs	**7569.99$**

Figure 41: Sailfish Expenses

11.3 Sailfish company Timeline

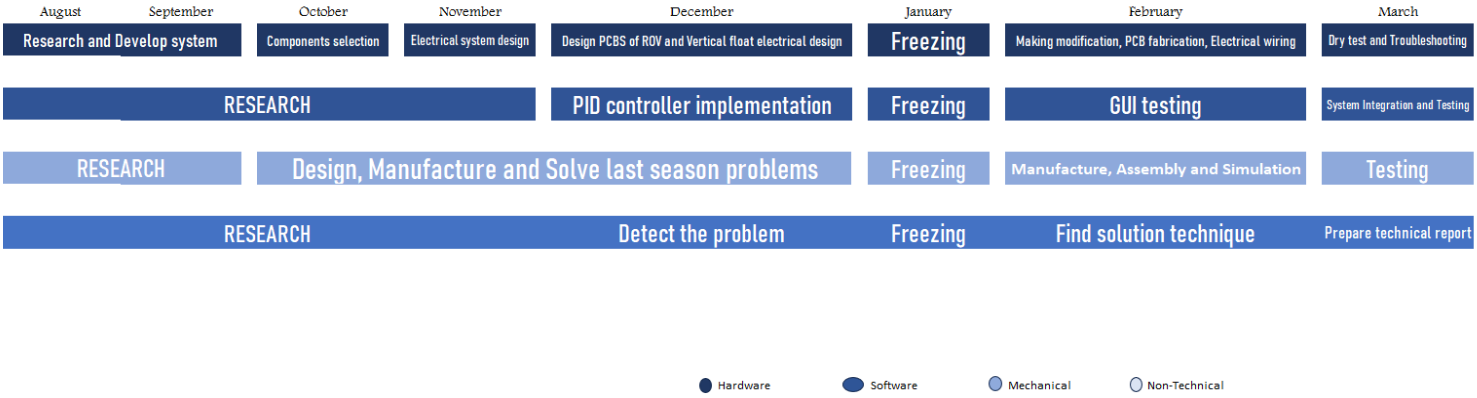

Figure 42: company Timeline

11.4 Sailfish company structure

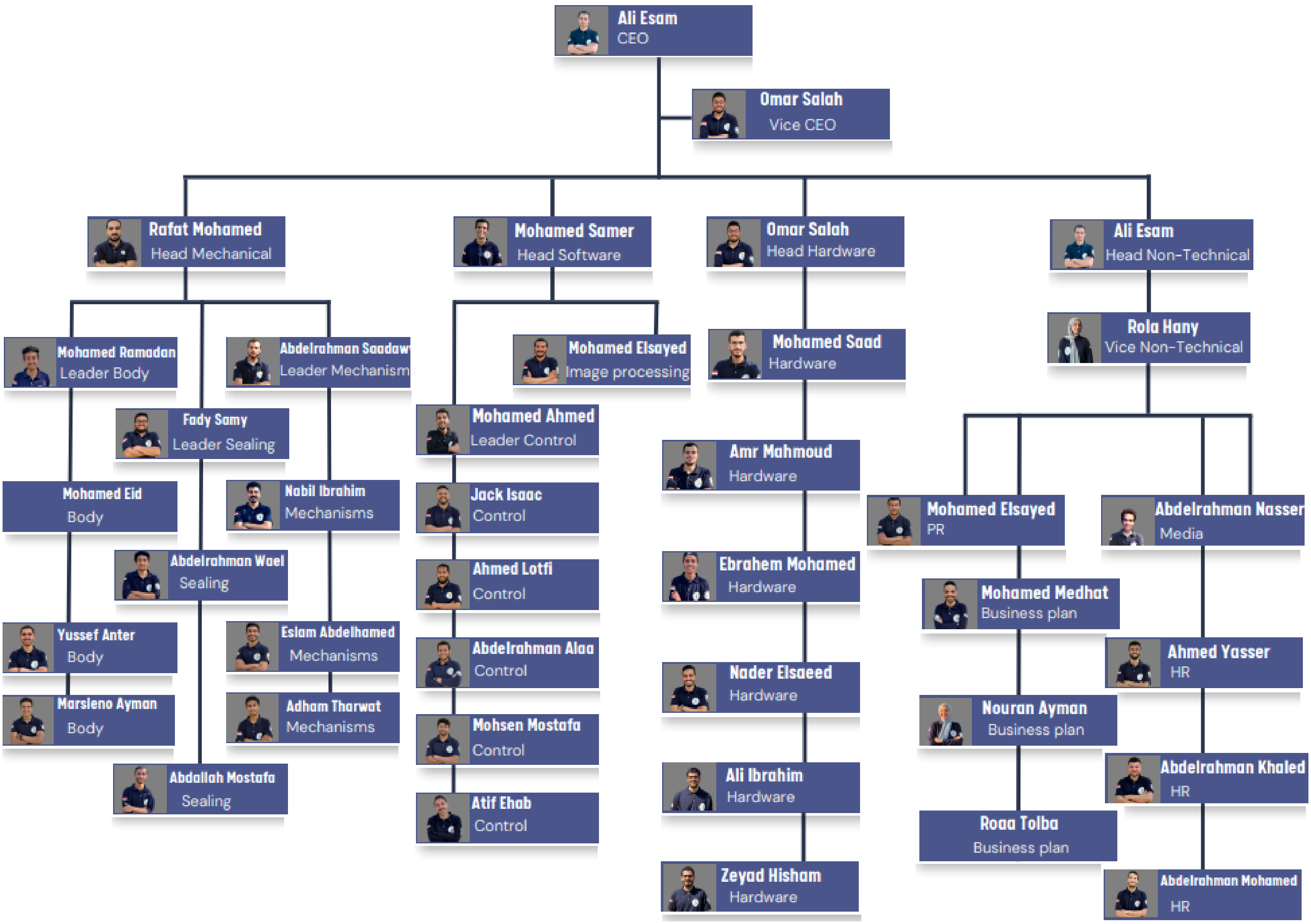

Figure 43: company Structure

11.5 SIDs

11.5.1 Software SID

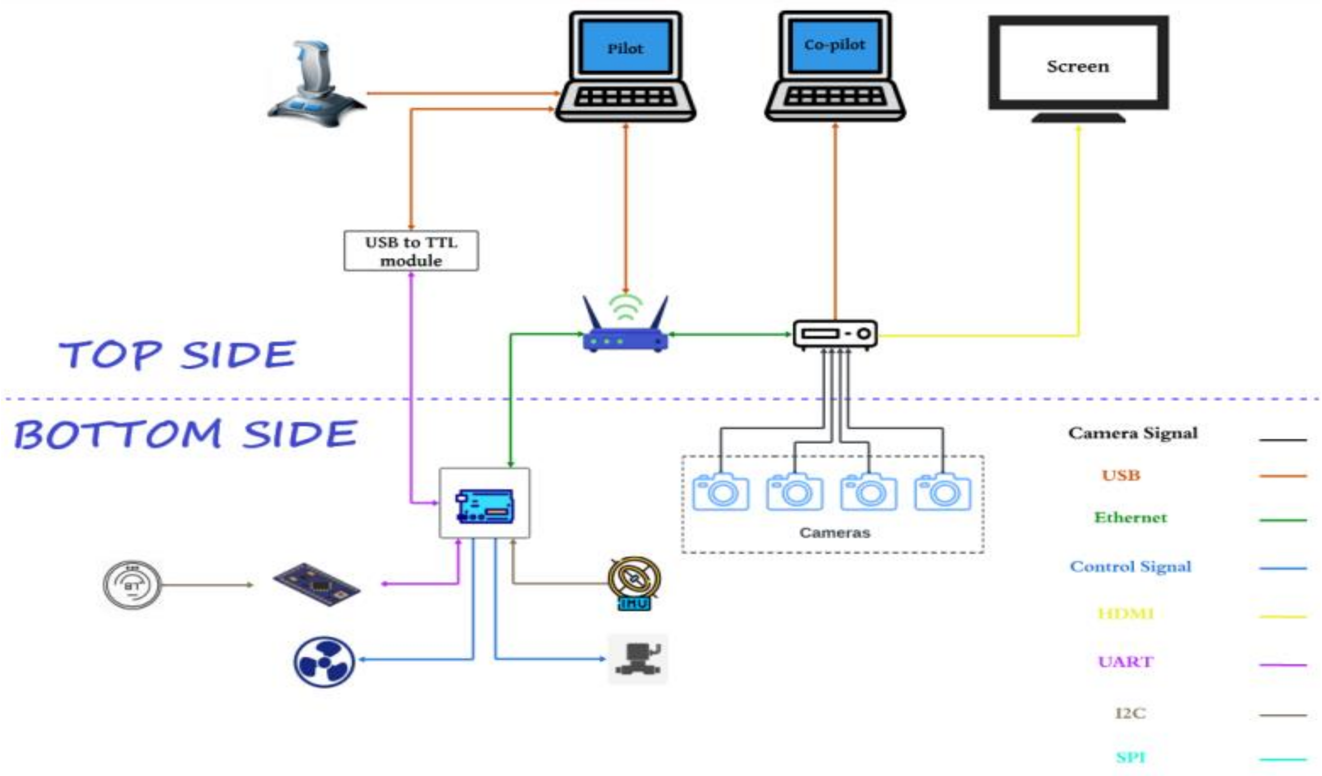

Figure 44: Software SID

11.5.2 Hardware SID

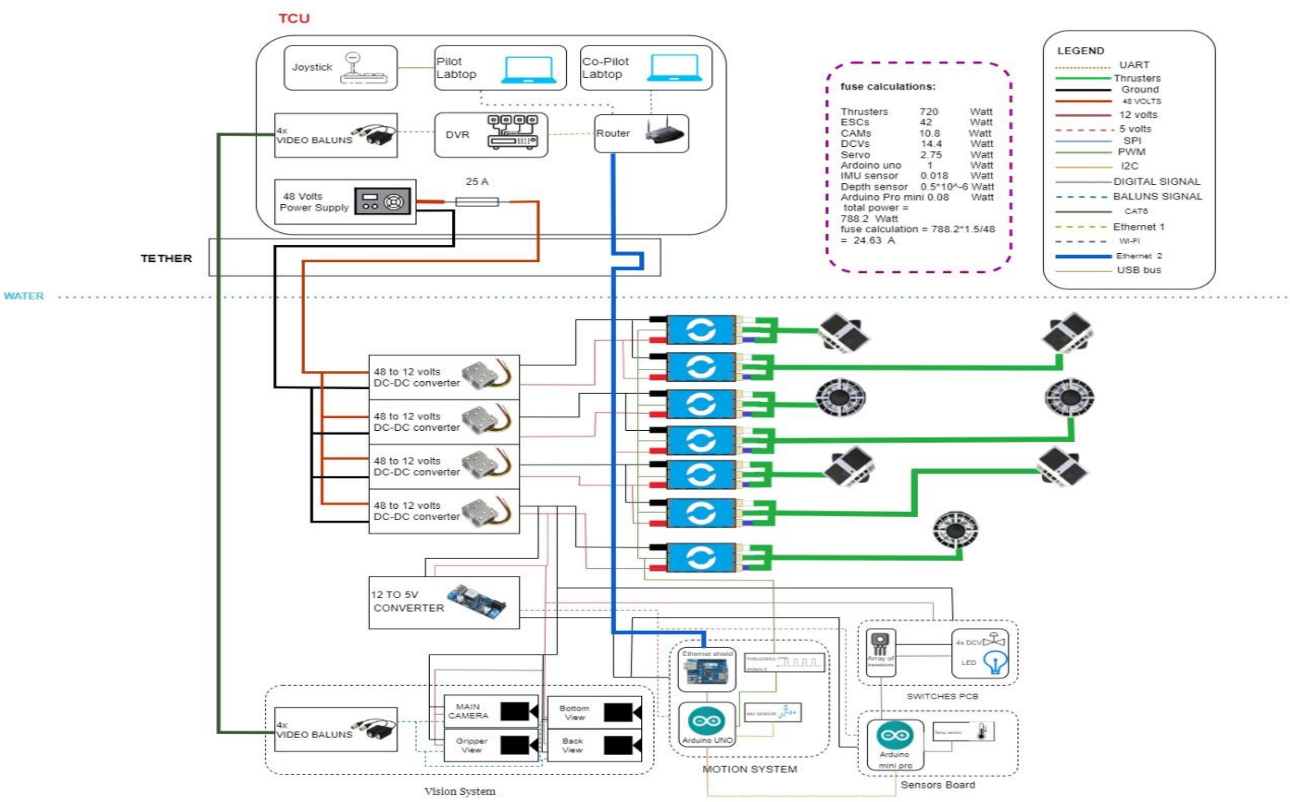

Figure 45: Hardware SID

11.5.3 Vertical float SID

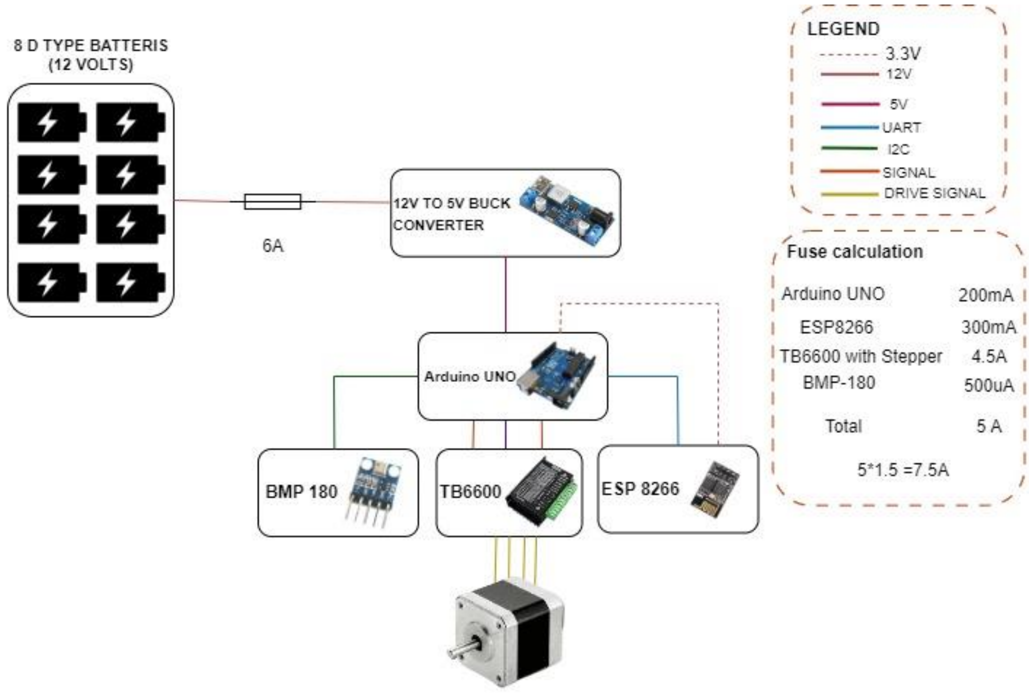

Figure 46: Vertical float SID

11.5.4 Pneumatic SID

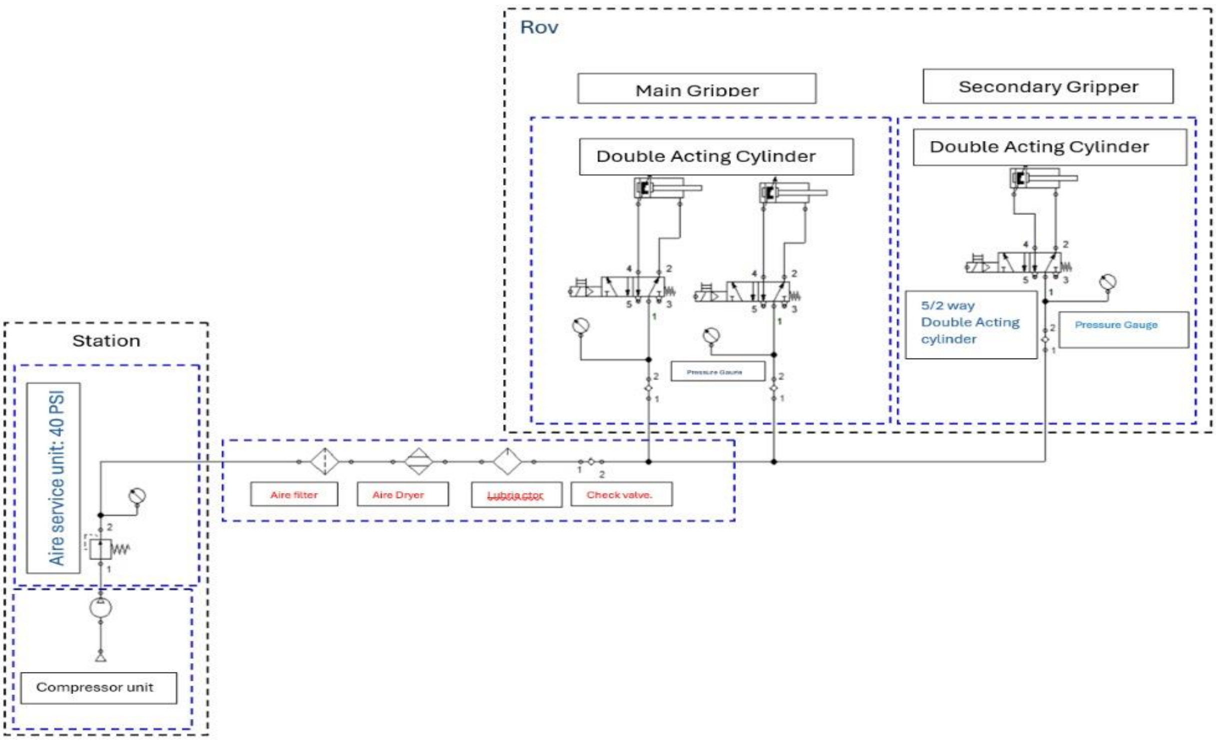

Figure 47:Pneumatic SID