# TECHNICAL DOCUMENTATION 2023

Arab Academy for Science, Technology, & Maritime Transport
Alexandria, Egypt

STINGRAY

Wall-E

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MATE ROV COMPETITION

VORTEX ACADEMY
THE ART OF THINKING

# 1. Introduction

## 1.1 Abstract

Stingray is a 38-personnel company of collaborative and diverse engineers, founded in 2023, and mentored by Vortex Academy (*Figure 1*). The main company objective is to respond to the request for proposal focusing on solving several problems including the treatment of sick corals, protection of endangered species, monitoring the ocean's health, and prioritizing guiding organizations to embrace environmental health with the help of Wall-E.

Wall-E is a remotely operating vehicle designed to operate at considerable depths. It is equipped with scientific instruments that help in collecting data from the underwater environment. This data can provide insights into the health of the underwater ecosystems and help researchers understand the conditions met to release predatory and domestic fish species.

The primary function of "Wall-E" is using its various sensors, cameras, and manipulators to perform complex tasks such as detecting underwater organisms by making full 3D models and collecting eDNA data to identify them, in addition to performing inspections of underwater structures using its cameras to provide high-resolution images that enable the operator to identify any issues. After the tasks are successfully completed, these cameras help the ROV to be piloted into the docking station autonomously. Its manipulators are utilized to carry out a wide range of tasks, such as lifting suitable weights.

Overall, "Wall-E" is an ROV with advanced capabilities which makes it an indispensable and essential tool in underwater exploration, and operation. Using Wall-E can highly reduce risks associated with underwater work and improve the efficiency and accuracy of underwater operations.

*Figure 1-Stingray Team*

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# 2. Design Rationale

## 2.1 Design Overview

At Stingray a discussion between our mechanical, electrical, and software engineers took place to cover all the aspects needed for the design's requests.

Several ROV designs were debated among the team, upon which the members drew a freehand sketch of their preferred design and determined all the features to be included in the ROV. Also, electrical and electronic components needed were chosen after determining the general contours of the design.

Afterward, each team kicked off its design process. To ensure the quality of the design, computer-aided design (CAD) and computer-aided engineering (CAE) programs such as SolidWorks and Altium were used to design and simulate the ROV. Integration meetings occurred frequently so dependencies between teams were delivered. Lastly, after optimizing the design in simulation and revising the costs in several meetings, the assembly process took place after purchasing all the needed components.

During the brainstorming phase, a scanning process for the needed components was conducted to analyze the resources available for reuse at Vortex Academy, considering certain criteria including usability, efficiency, and cost if purchased. Ending this process, all our ROV's components' status whether to be reused or purchased was known, followed by budget planning (*Figure 2*).

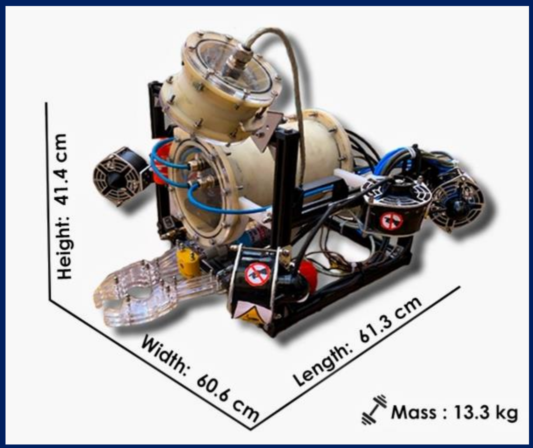


*Figure 2- Wall-E's dimensions*

## 2.2 Mechanical Components

### 2.2.1 Frame

During our early design process stages, our mechanical team was looking at the available materials to construct Wall-E's frame. Those brainstorming sessions ended up having several potential ideas for the frame. PA Type 6 and aluminum extrusions were favored among the other choices, yet the mechanical team concluded that using aluminum extrusions was ideal for Wall-E's structure due to its greater strength and lighter weight.

Aluminum extrusions are renowned for their low cost, simplicity of manufacturing, adaptability to quick changes, and a vast range of fastening options with respect to their high quality and functionality. The mechanical team agreed on aluminum extrusion bars (20mmx20mm) with T slots. They were cut to the desired length for the frame, which was then assembled using brackets, screws, and sliding nuts. This allows for plenty of inner space for various components due to its rectangular shape (*Figure 3*). The main enclosure is mounted on top of the frame with the aid of three nylon (PA Type 6) parts cut with a CNC router machine. For slippage prevention, a rubber layer is positioned between the mounting component and the main enclosure. With the main enclosure having the most buoyant force, its placement at the top increases Wall-E's stability.

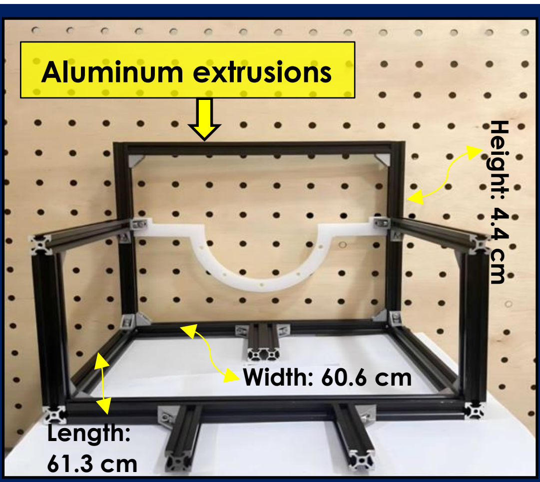

*Figure 4-Frame*

As for the camera enclosures, an aluminum bracket of 3 mm thickness, with a 75° bend was used to fix the grippers' camera enclosure, it also has two inclination options (30° & 45°), thus inclining the camera to allow visibility of the gripper. The position of this camera box is at the front-right of the frame, with the ability to slide on the aluminum extrusion bar to alter its mounting location in case needed (*Figure 4*). The image processing camera is affixed between two metal extrusion bars at the end of the ROV facing downwards to provide a clear view under the ROV.

Four horizontal thrusters were placed at the corners of the frame with stainless steel brackets bent at 45°, which provide vector drive, in addition to two vertical thrusters mounted by two flat aluminum pieces fixed to the frame on either side of the ROV for vertical and roll motions.

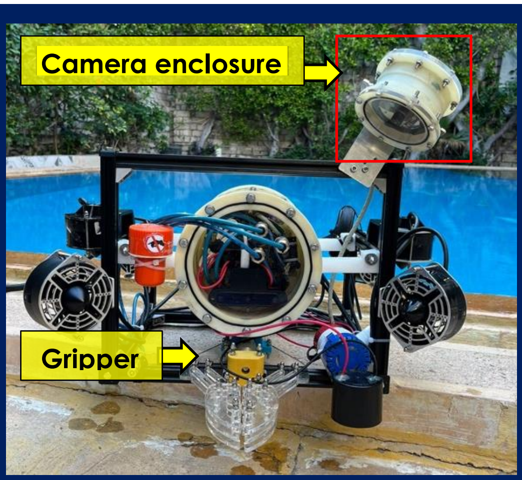

***Figure 3**- Front-view of Wall-E*

### 2.2.2 Main Enclosure

After the components required for the ROV's power and communication systems were chosen by the team, Stingray's mechanical and electrical sub-teams teamed up to design the internal structure. Components were added on SolidWorks as CAD parts, to visualize the space and arrange the components efficiently inside the enclosure. This produced the requirements for the electrical enclosure needed, like its dimensions and material. The team then reviewed enclosures that were available to reuse and selected one that met the requirements of the cylindrical housing of 15 cm inner diameter by 25 cm long.

The enclosure's construction material was nylon (PA Type 6) (*Figure 5*). Nylon's low-cost, high strength, durability, and excellent customizability led to its recommendation. Additionally, the cylinder's round shape evenly distributes the tension, minimizing shear stress at the corners. The computational and electrical components are housed within the enclosure on PMMA shelves. The shelves are held in place in the enclosure by two PMMA rings, allowing the entire interior structure to slide in and out in the event of an emergency or necessary service. The distance between the shelves is kept constant by using copper spacers to provide the strength required for the whole design.

Figure 5- Nylon Enclosure

All PMMA parts are custom designed according to the layout required (*Figure 6*). Heavier components are positioned at the bottom for the stability of the vehicle. To cool and dissipate the heat generated by the electrical components, an aluminum face is installed at the rear of the enclosure. Moreover, as one of our main concerns is securing the sealing for electronic equipment, the enclosure is sealed with a facial O-ring at both end caps that withstand a pressure of difference up to $5x10^5$ Pa (5 bars). The O-ring used is 158 mm by 2.5 mm in size, chosen

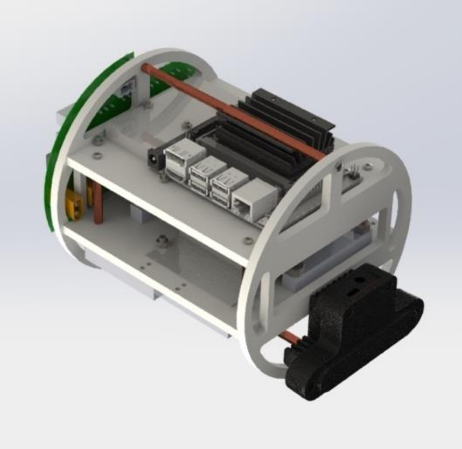

Figure 6- Main enclosure's internal structure

according to the Parker sealing manual. The O-rings are protected from wear by lubricating grease, prolonging their lifespan.

To prevent contaminating the undersea environment, no chemicals, such as silicon or epoxy, were used for sealing. For closing the gaps between the cables and the cable holes through the enclosure, nickel-plated brass cable glands with an IP-68 rating are used. The cables enter the body of the gland through a Neoprene gasket which tightly seals the cable when the gland is fastened. The nut of the gland has a Nitrile O-ring to prevent water from entering through the cable holes (*Figure 7*). The glands can relieve cables of stress and endure pressure differences of up to $5x10^5$ Pa (5 bars). Maximizing the number of glands is achieved by optimizing the distance between the glands allowing for equipping the vehicle with the thrusters, cameras, and tools needed (*Stress Analysis Figure 8)*.

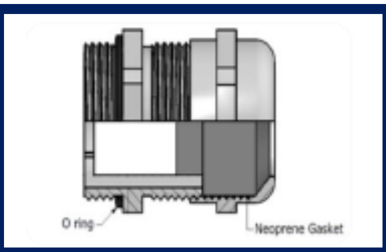


Figure 7- Internal structure of Nickel-plated Brass cable glands

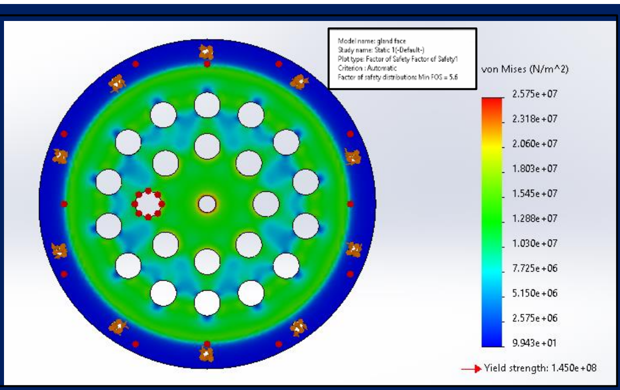


Figure 8- Stress Analysis

### 2.2.3 Propulsion

Wall-E is outfitted with six brand-new T200 Blue Robotics thrusters (*Figure 9*). This type of thruster was chosen after considering other options, as it provides the vehicle with an effective and reliable underwater propulsion system, as demonstrated by earlier Vortex prototypes. The T500 thruster, on the other hand, was too expensive, too heavy, and designed for high power requirements. Bilge pumps were also considered when looking for the optimum thruster, but it was discovered that they are rated only up to 3 meters, and did not have enough thrust to make maneuverability smooth or stable while carrying objects.


*Figure 9- Wall-E's thrusters' configuration*

Our configuration consists of two vertical T200 thrusters used for heaving motion, and four T200 thrusters are mounted at 45° angles at the 4 corners of the vehicle, to minimize flow interference with the main enclosure and gripper in the middle of the vehicle. The vectored alignment allows each thruster to contribute to the overall propulsion of the cardinal directions. 18.2N of forward thrust and 15.3N of reverse thrust are generated by the T200 thruster at its maximum operating power of 205 watts.

This propulsion configuration allows for 5° of freedom so the ROV can easily flee across the water which makes performing the tasks more efficient, and also falls within the financial, weight, and power budgets for Wall-E. (*Table 1*).

| Direction | Maximum Thrust |
|---|---|
| Forward/Backward | (2*17.8481cos(45)) + (2* 15.00417cos(45)) = 46.46N |
| Lateral/Rotation | (2*17.8481cos(45)) + (2* 15.00417cos(45)) = 46.46N |
| Upward | 2*17.8481 = 35.696N |
| Downward | 2* 15.00417 = 30.0083N |
| Roll | 17.8481 + 15.00417 = 32.852N |

*Table 1- Thrust calculation*

To cancel the spin effect caused by the thrusters on the ROV, each two corresponding thrusters have opposite propellers: one (clockwise) and the other (counterclockwise), resulting in a stable fly.

Lastly, with an IP-20 classification, the thrusters are shielded from items larger than 12.5 mm. Aluminum mesh covers are used on both sides of the thrusters to provide this protection. The aluminum mesh covers have several functions: they shield the rotating blades from accidental contact with people or the environment, they keep foreign objects from entering or harming the propellers, and they allow enough water flow and air circulation for the thrusters to function properly. The aluminum mesh covers are also resistant to rust, and simple to attach and detach.

### 2.2.4 Buoyancy

Buoyant force magnitude and its line of action are key factors in ROV stability. The design of Wall-E was focused on achieving a slightly positive buoyant vehicle force and maintaining CB and CG on the same line of action in the Y-axis direction as much as possible. The main enclosure is the primary component that causes water displacement; hence, it is located at the top, which moves the center of buoyancy up. To create stability, heavy payloads, and weights are positioned near the bottom, pushing the center of gravity downward. SolidWorks was

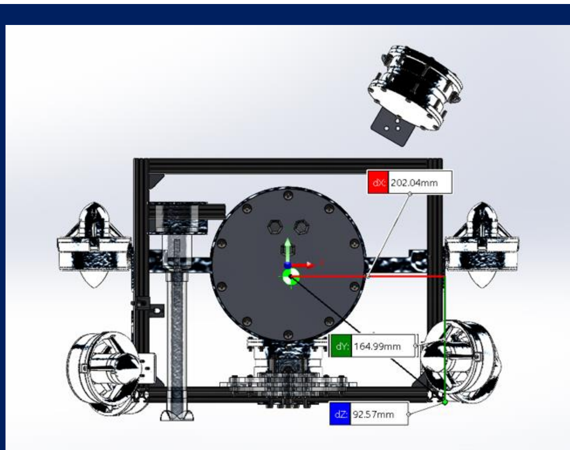

*Figure 10- Central Buoyancy*

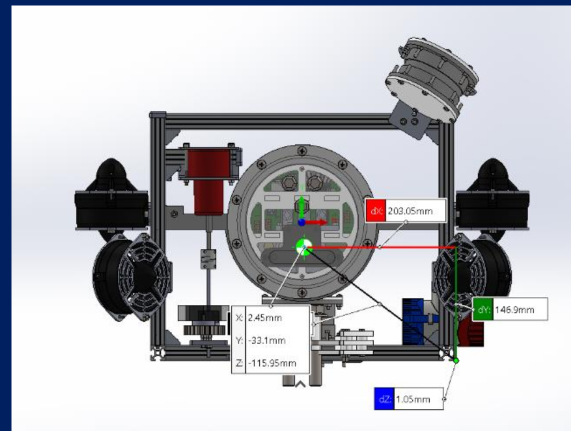

*Figure 11- Central Gravity*

used to estimate the weight of the vehicle, buoyant force, and CB (*Figure 10*) and CG (*Figure 11*) locations. After getting this information from

SolidWorks, using Archimedes' Principle and taking into account the fact that water has a density of 1 gm/cm3, it can be determined that the vehicle's weight in water is 1528.73 grams. So to achieve a slightly positive buoyancy, the foam was used to overcome the excess weight in the water.

### 2.2.5 Camera Boxes

Wall-E's vision is one of the most crucial factors when it comes to maneuverability and carrying out duties, such as installing a floating solar panel array or inspecting a space.

Despite having a great ability to settle Wall-E's camera in any position, this position must be selected in a highly effective way for much more suitable observation angles for better piloting causing the tasks to be accomplished in a highly efficient way. Therefore we installed two CCTV cameras, one viewing the gripper as mentioned in section 2.2.1 ,and the other is placed at the bottom of Wall-E, giving the pilot and co-pilots a better vision on what's below Wall-E (*Figure 12)*. The cameras are sealed by mounting them inside brand-new nylon (PA Type 6) enclosures with PMMA faceplates on each end and facial O-rings (*Figure 13*).

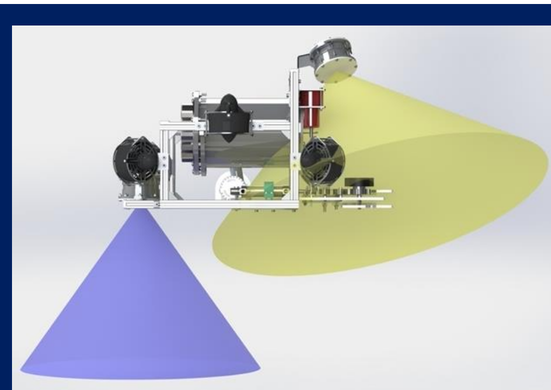
*Figure 12- CCTV camera vision cone*


*Figure 13- Camera Box*

### 2.2.6 Gripper

Wall-E utilizes a multifunctional parallel jaw manipulator that is pneumatically operated (*Figure 14*). The manipulator was designed with the purpose of decreasing the number of required tools for the missions, hence decreasing the ROV's overall size and weight.

Figure 14- Gripper

Throughout the missions, the manipulator is utilized to grasp objects as well as inflate the lift bag. For clear visibility of what the manipulator is holding, the manipulator is manufactured of laser cut transparent PMMA. An embedded nut in a 3D-printed component attached to the pneumatic piston's rod connects the end effector to the piston. The piston is controlled by a 5/2 DCV. For the convenience of handling circular objects like PVC pipes, the end effector possesses numerous curves. Curves are lined with rubber to create friction between it and the objects that need to be grasped for a firmer grip.

One of the pneumatic gripper's key features is that it offers a significant amount of gripping force compared to its compact size. They are also utterly simple to maintain and operate for elongated periods before needing to be repaired, unlike electrical grippers, which require frequent maintenance due to their complexity. The pneumatic piston has a bore diameter of 25 mm and a stroke length of 50 mm, and it operates at a pressure of 2.5*$10^5$ Pa (2.5 bars). From this equation, it is possible to determine the piston's maximum force (*Equation 1*):

$$F = P\,A = 25 \times 10^4 \times \frac{\pi}{4} \times (25 \times 10^{-3})^2 = 122.7\ \mathrm{N}$$

Equation 1- Piston's maximum force

Although the mooring connector (which has an outside diameter of 3.25 cm/1 inch PVC) is the largest mission object, the manipulator opens to a width of 10 cm, giving the pilot enough room to pick up the mission's objects with ease. Since there would be no requirement for a neutral (hold) position, a 5/2 DCV is used to operate the pneumatic cylinder.

## 2.3 Electrical System

### 2.3.1 Electrical Top-side Control Unit (TCU)

An electrical power distributor supplies an LCD and a DVR with 220 VAC. A power supply of 48VDC and 30A is connected to Wall-E's electrical system through the power cable. A CAT6 cable transfers the camera streams to the DVR through camera baluns, which are then streamed on the LCD screen (*Figure 15*) (*Electric SID Appendix 3*).


Figure 15- Control Panel

## 2.3.2 Tether

The tether consists of five cables, 25 meters long each (*Figure 16*). A power cable (14 AWG) is directly connected to Wall-E to supply it with the needed amount of electrical power with a 30Amp fuse placed at distance of 25 cm from the power supply for protection. Two pneumatic hoses are used to supply air to the DCVs for controlling the gripper and the lift bag inflation tool. Two CAT-6 communication cables, each with eight cores: one for camera stream and one for top side communication with Wall-E. To be able to determine the appropriate power cable diameter according to the American Wire Gauge (AWG) standard (*Equation 3), calculate* the voltage drop index (VDI) for Stingray's power cables (*Equation 2*).

Figure 16- Tether

**Voltage drop index (VDI) calculations:**

$$VDI = \frac{AMPS\ X\ FEET}{\%\ VOLT\ DROP\ X\ VOLTAGE}$$

VDI = 30A X 82FEET / 48V X 2= 25.626

Equation 2- Four 12 DC-DC Buck Convertor

**American Wire Gauge (AWG) calculation:**

$$0.012668\ mm^2 * 92^{(36-n)/19.5}\ [mm^2].$$

N=14 AWG

$$: 0.012668\ mm^2 * 92^{(36-14)/19.5}\ [mm^2] = 2\ mm^2 .$$

Equation 3- Four 12 DC-DC Buck Convertor

## 2.3.3 Tether management system

The Tether Management System (TMS) makes the ROV more maneuverable and extends its range without requiring the vessel or rig to be moved. It's main purpose is to extend and shorten the tether to reduce the of cable drag during underwater currents. We devised a protocol that is mostly dependent on the tether man, in which he must ensure correct handling and wrapping of the tether to minimize damage and entanglement, as well as be prepared to manage crises.

## 2.3.4 Electrical Bottom-side System

The main objective of WALL-E's electrical system is to power all the sensors, cameras, and actuators through the power distribution and control system.

## 2.3.5 Power Distribution

Four 12V DC-DC buck converters receive power from the bus bar located within Wall-E, which is linked directly to the 48 VDC power supply. The main PCB is powered by 12 volts produced from four power channels (*Figure 17).* Four buck converters connected to PCB through four power channels to let PCB distribute power to the needed components.

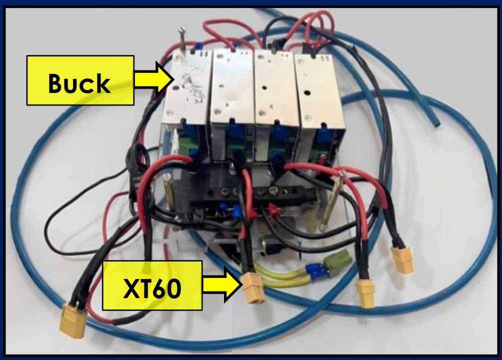


Figure 17- Four 12 DC-DC Buck Convertor

## 2.3.6 PCB

Stingray landed at the conclusion that designing the PCB in a circular shape will maximize the space for the other components inserted in the enclosure after considering several options (*Figure 18*). The power required for the six ESCs is provided by the three XT60s, since each XT60 can power two ESCs. Each ESC powers and controls each of the 6 thrusters mounted on Wall-E. The remaining XT60 is used to power three MOSFETs that regulate three DCVs (2 3/2 DCVs and 1 2/2 DCV), LED, and Cytron motor driver through terminal blocks, as well as a 5V buck converter that supplies NVIDIA with needed power.

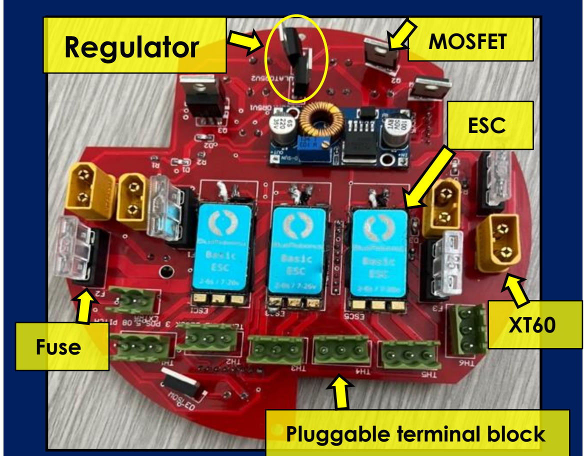


Figure 18- Main PCB

## 2.3.7 Power Calculations

The current supplied from the 48VDC power supply passes through a 30Amp to reach the main enclosure (242.76 watts).

Maximum power is never reached since our software interlocking system limits the speed of each thruster. It also prevents the four thrusters from operating at their full speed simultaneously (*Table 2*).

| Component | Voltage (Volts) | Max current (Amperes) | Max power (Watts) | Quantity | Total max power (Watts) |
|---|---|---|---|---|---|
| T200 | 12V | 7.5A | 90W | 6 | 540W |
| Bilge pump | 12V | 10 A | 120W | 2 | 240W |
| OAK-D camera | 5V | 2A | 10W | 1 | 10W |
| DCV (2/3) | 12V | 0.42A | 5W | 2 | 10W |
| DCV (2/2) | 12V | 0.4A | 4.8W | 1 | 4.8W |
| LED | 12V | 0.84 A | 10 W | 6 | 60 W |
| Jetson | 12V | 7A | 84W | 1 | 84W |
| CCTV | 12V | 0.5A | 6W | 2 | 12w |
| Sensors | | | | | 10W |
| TOTAL | | | | | 970.8W |

Table 2- Power Calculations Table

Therefore, the resulting maximum current is **20.23 Amperes**, and the fuse calculation is as follows (*Equation 4*):

$$\text{Fuse calculation} = 1.4 \times 20.23 = 28.3A$$

Equation 4- Fuse calculation

## 2.3.8 Control System

### 2.3.8.1 Actuator Control

N-channel MOSFETs are utilized instead of relays for low current loads like DCVs because of their smaller size and quicker switching capabilities. The main manipulator and lift bag inflation tool are controlled by these valves.

The rotary manipulator can be controlled by Cytron motor driver, which enables full speed when Cytron is connected to it.

## 2.4 Pneumatics

The main enclosure contains two DCVs (Directional Control Valves) that control the airflow to Wall-E's gripper and lift bag. Air is pressured at 2.75 bar (40 psi) and applied to hoses having an inner diameter of 4 mm and an outer diameter of 6 mm, which can resist pressure of up to $1x10^6$ Pa (10 bars) (*Pneumatics SID Appendix 4*).

A 5/2 solenoid pilot operated-spring returned DCV controls the gripper, while the lift bag inflation tool is controlled by a 2/2 solenoid pilot operated-spring returned DCV.

## 2.5 Software

### 2.5.1 Software Overview

Our main goal as a Software Department is to represent the entire system in a manageable way (*Software Flowchart Appendix 5*). Our simple graphical user interface is an ideal interface for controlling Wall-E. It is supported by a highly maintainable backend to send and receive signals and control mechanical components such as pumps, thrusters, and manipulators. Frames captured by cameras installed in Wall-E's main enclosure are received and displayed through the it to facilitate processing in 3D Modeling.

The GUI team faced a great challenge to integrate all the software features to plug and play the ROV through it while considering the balance between the number of parallel processes and their functionality.

### 2.5.2 Top-side Control System

Topside is the subsystem that allows the pilot and co-pilot to control and monitor Wall-E. It consists of a screen that shows two views; one from the bottom camera of the ROV and one from the gripper, a joystick to maneuver the ROV and perform tasks, and a laptop that runs a GUI that communicates with Wall-E through a CAT6 cable (*Figure 19*).


Figure 19- GUI

### 2.5.3 Bottom-side Control System

The Bottom-side subsystem manages the hardware components of Wall- E:

**a. *NVIDIA – Jetson Xavier NX:***

Amongst the many microcontrollers on the market including Raspberry Pi, Arduino, and NVIDIA, our software team concluded that the NVIDIA – Jetson Xavier NX was an ideal option for the Bottom-side control system for its high performance, and its great integration with the OAK-D camera and the Pixhawk (*Figure 20*).

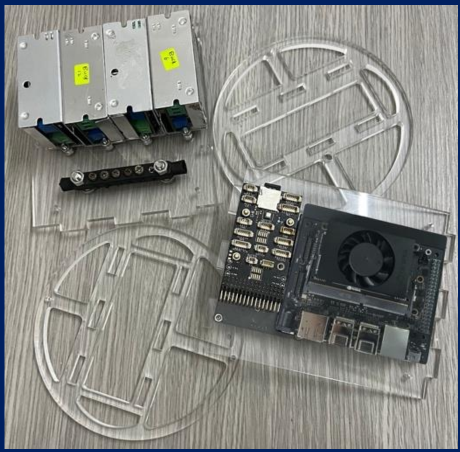

Figure 20- NVIDIA – Jetson Xavier NX

The NVIDIA - Jetson Xavier NX board acts as the main processor and communication hub between the top-side control system and the ROV. It communicates with the topside subsystem through the CAT6 cable using socket programming. It receives commands from the top-side control system to control the ROV's motion and its modes through a Pixhawk controller. It also sends data from the ROV's sensors and cameras to the top-side control system for monitoring and analysis.

***b. Pixhawk:***

To control Wall-E's thrusters, it was best suited to use the Pixhawk. It is known for being an open-source autopilot platform that allows for easy modification. The Pixhawk has exceptional features including GPS navigation to guide the vehicle to a specific location, depth hold and altitude control that automatically adjusts the thrusters to maintain a fixed depth, which is essential for some of the tasks, and numerous built-in sensors utilized in our product, such as a gyroscope, accelerometer, and magnetometer. Additionally, it allows the configuration of other sensors, such as the bar30, which is used instead of the built-in barometer.

***c. OAK-D Camera:***

When choosing a camera for Wall-E, the choice was between the OAK-D camera and the Stereo labs ZED camera; however, our software team decided that the OAK-D camera was the preferable option for multiple reasons (*Figure 21*). The OAK-D camera is known for its low cost, uses OpenCV which makes it an open source platform, has a wide field of view of 120° , and is SDK compatible. It also produces a great depth map, enabling the ROV to obtain real-life coordinates and generate accurate 3D models of the objects in its vicinity.

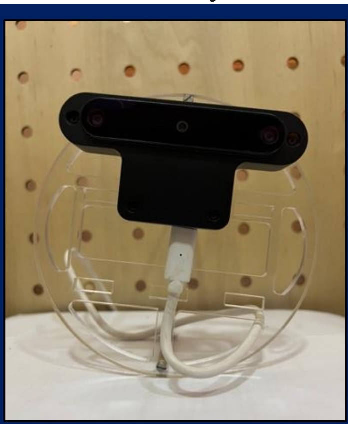

Figure 21- OAK-D Camera

## 2.6 Non ROV Device

### 2.6.1 Float

Stingray company aims to develop a global network of profiling floats that can monitor the ocean's state. To achieve this goal, its employees have designed and tested Pearl, a fast, accurate, and autonomous float that can perform multiple vertical profiles and communicate with the station from underwater (*Figure 22*).

To change its density, Pearl uses six 60-ml syringes that push or pull water in and out. A DC-motor coupled with a lead screw, moves


Figure 22- Pearl

the plungers of the syringes that slide on two rods acting as linear guides with two limit switches toggling the direction of motion when clicked. A setup adjustment was made after experiencing slippage with the NEMA_17 stepper motor. The motor’s torque couldn’t overcome a depth exceeding 2m which is not sufficient. Using the DC-motor and flipping the syringe outlet to be at the top of the float to decrease the water head by nearly 70cm resolved the issue. Pearl can reach its maximum density in just 13 seconds. The syringes and the electrical system are fixed inside a PMMA tube that is 15 cm diameter and 65 cm long. Two threaded rods, and 3D printed and PMMA plates hold the structure. The communication module is placed at the top of the tube to perform better communication with the station (*Float SID Appendix 2*).

The tube has custom-made HDPE end caps on both ends, each with two radial O-rings. These end caps allow the pressure to be released from the housing if it exceeds the external pressure, complying with Mate safety regulations. Moreover, an O-ring face seal connects the faceplate to the end cap. Faceplates make it easier to test, troubleshoot and are more convenient than removing the whole end caps because they can be attached and detached more easily and provide better access to the entire system. The system is activated manually using a Blue Robotics switch placed on top of the faceplate.

Pearl uses several components to send data to the station. These components (Arduino Nano, motor driver, sender module) are integrated on a PCB. The components are powered through the PCB using a set of 8-in series AA alkaline batteries placed in parallel with a similar set and setting the voltage to 12 VDC. A 5 Amp fuse is positioned within 5 cm from the positive terminal of the battery. This allows the entire system to function as required (*Table 3*).

| components | Max current | Max voltage | Max power | Quantity | Max power |
|---|---|---|---|---|---|
| DC motor | 2.8 A | 24 V | 43.2W | 1 | 43.2W |
| Alkaline batteries | _ | 1.5 V | _ | 2 sets 8 battery per set | _ |
| fuse | 3 A | _ | _ | _ | _ |
| Arduino nano | 20mA | 5V | 0.1w | 1 | 0.1W |
| HC12 | 100mA | 5.5v | 0.55W | 1 | 0.55W |
| Motor driver L298N | 2A | 46V | 92W | 1 | 92W |
| Voltage regulator | _ | 12 V | _ | 2 | _ |
| DS3231 | 200uA | 5.5v | 1.1mW | 1 | 1.1mW |

| | | | |
|---|---|---|---|
| Fuse Calculation | Max current 3A | Fuse 3 x 1.5 = 4.5A | Fuse used ≈ 5 |

Table 3- Pearl’s Power and Fuse Calculations

Pearl communicates with the station using the HC-12 module, which was selected based on a trade-off analysis between HC-12 and NRF24L01. The HC-12 module has the lowest SNR among the modules that can transmit up to 1 km and does not need any extra libraries to establish the connection. It also has a 10-times longer range than the NRF24L01 module. Two HC-12 modules are installed, one as a sender and the other as a receiver. The sender module delivers the company number and the current UTC to the receiver after deployment. The receiver passes the data to the station via Arduino UNO to be displayed directly on the GUI. To avoid interference from other sender modules on the same frequency, the software team changed the default frequency of the module to ensure reliable data transmission.

## 2.6.2 Fry Fish Container

The fry-fish container is made of PMMA sheets containing a magnetic field integrated into its gate (*Figure 23*). The container remains closed as long as the magnetic field is active. When the fry acclimates to local conditions, the container opens, releasing the fry in the desired spot by deactivating the magnetic field.
(*Fry Fish Container SID Appendix 1*).

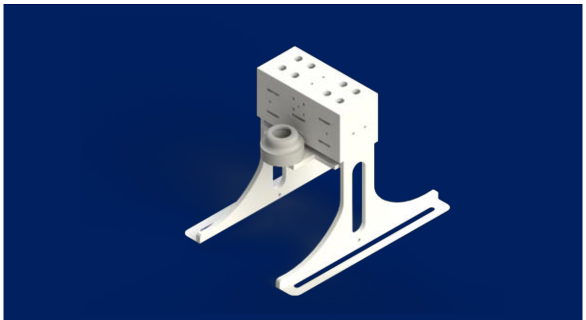

Figure 23- Fry Fish Container

# 2.7 Tools

## 2.7.1 Mechanical Tools

### 2.7.1.1 Payloads

***a. Suction retrieving mechanism:***

To identify reef organisms, collecting a water sample from above the coral head was required. This is achieved by using a pump as a suction tool that is connected to a syringe that penetrates the soft bottle and collects the sample to be retrieved by the ROV assistant (*Figure 24*).

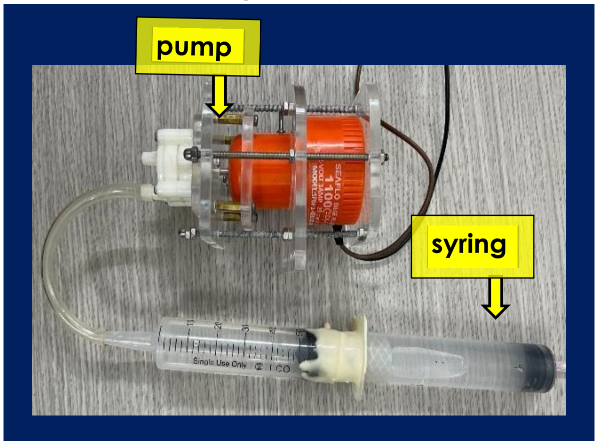


Figure 24- Suction tool

***b. UV light source:***

To successfully irradiate the diseased area of coral, a LED was installed to represents a source of UV light, illuminates the photoresistor and is fixed inside a spray cap and sealed with epoxy. The spray cap acts as a cover to block external light from entering the coupling and illuminating the photoresistor.

***c. Rotating Tool:***

The Eco-Mooring should rotate 720 ° to be secured into the sediment. Stingray's solution for this consists of a bilge pump, which is used as a motor for its compatibility to work underwater without the need to be sealed, paired with power transmission components, which are gears and a shaft. A wheel is fixed on the last gear and in contact with the Eco-Mooring, which is required to be rotated. An extension fixed to the gripper is in contact with the other side of the Eco-Mooring to hold it in place and make it rotate with the wheel rotation (*Figure 25*).

Figure 25- Rotating Tool

***d. Lift bag:***

Due to the lifting capability of Wall-E being 35.696N as mentioned in (*Table 1*), a lift bag with the ability to lift up to 120 Newtons in the water had to be thought of. Initially, a nylon lift bag was the main suggestion, but due to its large size, it blocked vision and caused a lot of difficulties during the maneuvering of the ROV. Rather than using an opaque object, a transparent plastic bottle was used instead to provide a clear vision for the pilot. Due to its rigidity, it didn't disturb the motion of the ROV as much as the nylon bag did (*Figure 26*).

Figure 26- Lift Bag

***e. Fry Fish Tool:***

A tool was designed and attached to the gripper's piston with the aid of a rod that is fixed to it. It is designed to have a drawer at its bottom that opens when the gripper opens to let go of the fry in the desired location. The ROV assistant can insert the fish into it with ease via a hinged door at the top (*Figure 27*).

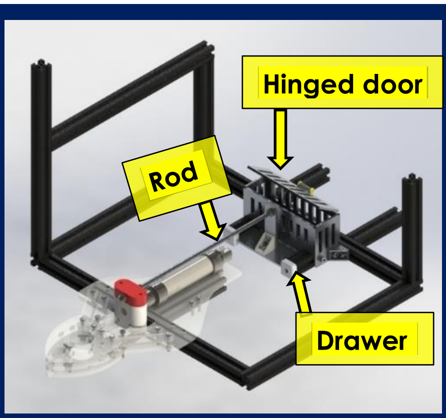


Figure 27- Fry Fish Tool

### 2.7.2 Software Tools

#### 2.7.2.1 Autodocking

The software team of Stingray created a script for Wall-E to locate and press the button by using YOLOv5l to train a model on bottle caps as it resembled the button shape and size. The model outperformed color and shape detection as YOLOv5l can learn more features of the objects than just their color. Color detection relies on the hue, saturation, and value of the pixels, which can be affected by lighting, shadows, reflections, and other factors. YOLOv5l, on the other hand, uses a deep neural network to extract features such as shape, texture, edges, and patterns from the images, which can be more robust and discriminative for object detection to estimate the depth, a stereo camera was used instead of a mono camera with deep learning algorithms, which were too computationally expensive. A stereo camera relies on the disparity between two views with a constant baseline between both cameras. The script follows these steps to move the ROV and press the button autonomously:

1. Receive the camera frame from the ROV.
2. Detect the button with the trained model.
3. Center the button on the screen within a margin of error.
4. Maintain the depth using the pressure sensor.
5. If the button's x-axis is close to the center's x-axis, move forward. Otherwise, move left or right depending on the button's position.
6. Repeat steps 1,2 and 5 until the distance between ROV and the button is less than 30 cm.
7. Move forward for 30cm to press the button.

### 2.7.2.2 3D-Modeling

Knowing the importance of the seagrasses as they are aquatic plants that can capture and store large amounts of $CO_2$, making them valuable ecosystems for mitigating climate change, the software team made an effort in developing a method to generate 3D models of the coral head using Agi soft capturing 360 ° frames of the coral head with the OAK-D camera and a USB camera installed within the enclosure, importing the images into the software, and running a script that automates the generation process of the mesh. Furthermore, the spatial location feature is used to calculate the diameter of the coral head by importing it to Agisoft to scale the generated model according to the corresponding calculations. Hence, the 3D model can be used for monitoring and analyzing the health and growth of coral reefs (*Figure 28*).

*Figure 28- Coral head 3D-modeling*

# 3. Safety

## 3.1 Company Safety Philosophy

Stingray's Safety Philosophy is simple to ensure that the safety, health, and well-being of our most precious assets are always top priorities and are everyone's responsibility within this command. Stingray employees are committed to following all MATE-published safety guidelines. Accidents or fatal injuries are always a possibility when manually handling heavy loads, hazardous machinery, toxic substances, or electrical hazards. That is why a safe workspace is offered by Stingray to create a suitable environment for designing, manufacturing, and testing and to prevent any accidents by adhering to safety protocols and regulations**.** In addition, safety instructions are hung all over the workshop.

## 3.2 Lab Protocols

The company enforced a strict safety protocol for all onsite operations to ensure the safety of its employees. A safety induction was performed prior to any task to identify the risks and create a Job Safety Analysis (JSA). Safety checklists were utilized to verify adherence to all guidelines (*Figure 29*). PPE - Personal protective equipment – is required for any hazardous task. Moreover, any team that worked in the lab had to book a session beforehand and specify the team members and the hardware components they requested . This was done to monitor all users and equipment in case of an emergency.


*Figure 29- Safety Protocols*

## 3.3 Training

For training our employees, on and off-job training was provided. The beginning of the training phase was solely online as our employees were introduced to their potentially assigned roles. Then they were brought on-site on one-on-one training sessions as they were taught how to safely use the equipment, under the management and supervision of the company's mentors. As soon as the employees denoted proper and careful working practices, they were allowed to work independently among each other to provide a helping hand, but most importantly, to ensure that the lab's safety protocols were strictly followed. The company continues to constantly update the lab safety rules and regulations as well as assign qualified employees to use such tools and equipment.

## 3.4 Vehicle Safety Features

Safety has always been a priority since the training phase, so safety was inherited by the Stingray team in every single aspect, including ROV safety according to Wall-E's safety checklist, no sharp edges or corners exist on the ROV, and any exposed bolt threads are covered with cap nuts to prevent injuries. To stop the entry of foreign objects or the contact of human hands with the thruster blades, thruster guards were added to the thrusters and have a mesh size that complies with IP-20 specifications.

The pressure regulator is set at 2.75 bar (40 psi), and a pressure release valve is connected to the compressor and set to $10^6$ Pa (10 bars), which is the tank's maximum permissible pressure. To stop leaks, Teflon tape and O-rings are used on pneumatic fittings. Chosen O-rings with vacuum-tested glands are used to seal the enclosure against water leakage.

All DC-DC converters are powered individually, and each has a short circuit and overcurrent protection, with a 20-amp fuse on an isolated housing for the protection of the hardware components. Color-coded cables are used to separate the signal and power. The power cable and the buck converters are connected to the system through the XT60 connectors to avoid short circuits and system failure. In addition, the fuse is used to protect the tether cable as it bursts as soon as the system draws more than 30 Amperes.

To ensure that everyone who comes into contact with the ROV is fully aware of the potential risks, warning labels are placed on thrusters and moving parts, high-pressure parts, PMMA parts that are susceptible to fractures, electrical components, and close to the high-brightness LEDs.

## 3.5 Safety Checklist and Operations

The Safety Checklist ( *Safety Checklist Appendix 6*) reduces errors and oversights and enhances quality and consistency by highlighting the essential steps and details that might be forgotten or overlooked.

# 4. Testing and Troubleshooting

## 4.1 Mechanical

Since subsystem simulation is an important part of producing a minimal-error vehicle, multiple CAD programs were used before manufacturing any component to ensure that everything works properly. After the design runs smoothly and all the calculations needed are done on the software, each component is then manufactured and tested independently. Then, all the subsystems are dry-tested together before submerging Wall-E in the water to adjust the thrusters' directions and the functionality of each component. If no errors occur, then the assembly process takes place. Troubleshooting is achieved by first analyzing each stage and identifying the issue's location. Then a traceback method is used to identify the reasons that can cause that issue. These are the steps to help identify and resolve problems:

1. Identifying the problem.
2. Isolate the malfunctioning system and component.
3. Repair the error.
4. Test the system and/or component independently.
5. Re-launch the vehicle and repeat the process if the problem still occurs.

A perfect example of implementing these steps is when a leakage is detected after the vehicle was submerged in water. We start by connecting the compressor to the pneumatic hose inserted in the main enclosure. Then, when the pressure inside the enclosures steadily rises, air begins to escape in the form of bubbles from the leakage point that is improperly sealed. Following the identification of the leakage point, the O-rings and glands in this defected region are examined and repaired and the process is redone until no leakage is detected.

## 4.2 Electrical

Solution approaches vary regarding the problem detected. When an issue with a certain functionality arises, its sub-system will be isolated from the whole system to be tested and tracked separately. It is necessary to verify the incoming voltage to an electrical component if it is discovered to be operating improperly. The gripper wasn't functioning, and after reviewing and inspecting the PCB, it was discovered that no signal was being delivered to the associated Mosfet. Reinserting the Mosfet with its inverted version into the PCB provided the solution. Jetson shuts down as a result of the voltage drop created by connecting Oak, and Jetson to the same source of power. To power the Jetson separately, an extra power channel is added.

Due to the weight constraint, the team had to minimize the size of the main enclosure that restricted the number of components used, that's why a circular PCB design was chosen to be put on the ring so the team can replace the rest of the components in the remaining space inside the shelves instead of a regular rectangular PCB.

## 4.3 Software

The software sub-team followed the term "shift-left testing"- conducting more software testing during the development phase to reduce defects, save the business from costly bugs, and detect the obvious bugs that jump out immediately in the code. These tests are divided into several steps: basic functionality testing, code review, static code analysis, and unit testing.

- **Basic functionality testing**: checks that every button on every screen functions properly.
- **Code review**: states that at least another pair of eyes should look at the source code, uncovering unnoticed problems.
- **Static code analysis**: To enforce coding standards, this process includes searching for several flaws in the source code, such as potential concurrency problems.

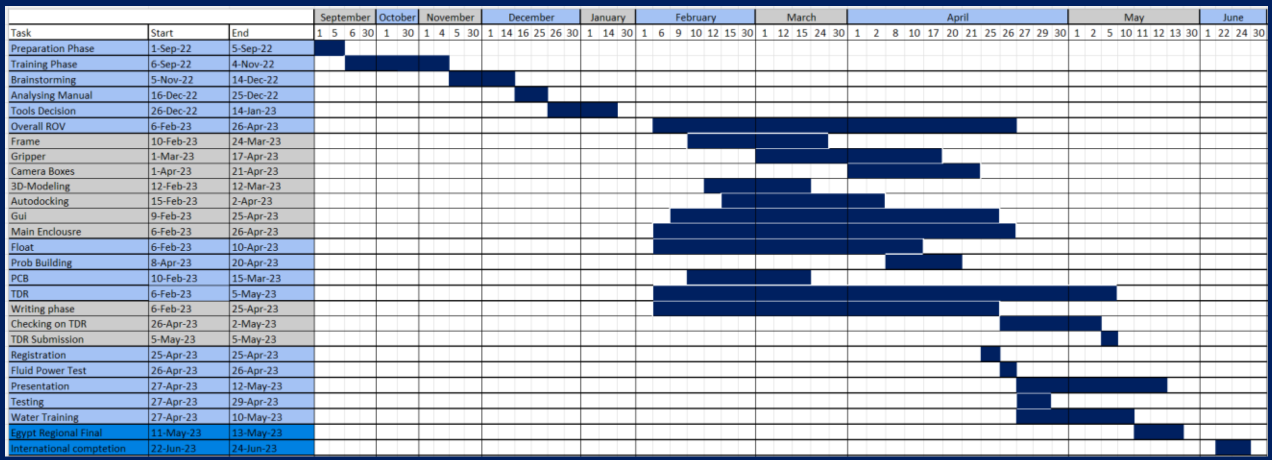


*Figure 30- GANTT Chart*

- **Unit testing**: unit tests run every time we commit a change to the source code repository.

Eventually, the software department managed to run as many tests as possible before handing the codes over to be tested on the components.

One of the tests made is choosing photogrammetry using Agisoft to create the 3D model of the coral head. However, a challenge was faced in capturing the curvature of the rounded object with the forward-facing Oak-D camera. Two possible solutions were considered: adding two more thrusters to enable Wall-E to tilt up and down or adding a USB camera with a 35° downward angle. The team opted for the second solution as it was more cost-effective and provided a better angle for taking photos.

# 5. Logistics

## 5.1 Scheduled Project Management

Our ROV's design process was broken down into phases. Starting with the preparation phase, the budget and project management were planned. The employees were then disrupted into sub-teams (mechanical, electrical, and software) to begin the training phase. To proceed to the following phase, each sub-team fulfilled four milestones which prepared employees to start designing our ROV(WALL-E). Our project plan was to divide the ROV construction into projects that were completed concurrently (frame, gripper, camera-boxes, 3D-Modeling, auto-docking, GUI, main enclosure, float, and prop-building) and their progress was documented. Each project was independently tested before being added to the main system. To prepare for training underwater, ROV was put through a ceiling test. This ensured that the ROV could perform any required task (*Figure 30*).

## 5.2 Company Organization and Assessment

Stingray followed an Agile project management approach to build an efficiently organised team structure. The company divided the process of building the vehicle into small manageable parts to facilitate tracking the progress and performance of employees. The system mainly depends on three applications: Trello, Slack, and Clockify.

Firstly, it’s essential to manage our time to get higher levels of productivity and that was the aim of using the Trello board. It consists of a group of helpful lists: backlogs, in progress, review, and done. Each card on the list has an accountable member that manages the card to make sure the work is submitted by the deadline and for providing the FM of the department in each scrum meeting with the latest updates. The deliverables are either added on the company’s drive or GitHub where all company members can access this data to enhance the working process.

Secondly, Slack platform is used for communication between team members. It was chosen as it consists of a group of channels for each department, and each department has sub-channels for each project.

Finally, Clockify is used to keep track of time spent performing tasks for each member to ease monitoring for the mentors and FMs and motivate the members to finish their tasks as fast as possible.

A discussion with the FMs is made to gain maximum knowledge. To reduce the number of working hours and save time for other projects, a strict system was obligated using the previously mentioned applications helping a lot in maintaining the good work.

## 5.3 Team Structure

The company’s management team is responsible for the company's day-to-day operations and progress. Our company is following a team-based hierarchy, as shown in (*Figure 31*). The top-level management comprises the Chief Executive Officer (CEO). The CEO plans the company's overall

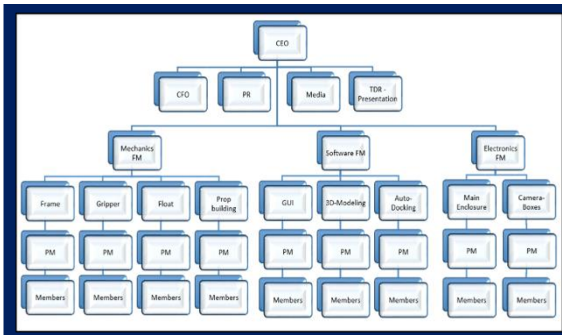

*Figure 31- Team Structure*

strategies, implements proposed plans, and tracks the company’s performance.

The next level of the management team consists of four main management positions: CFO, PR, Media and TDR-Presentation. The Chief Financial officer (CFO) deals with the financials of the company. The Public Relations (PR) is in charge of proposals and sponsors. Also, PR create and maintain a positive public image for the company representation and co-ordinate all team’s relations. The Media team is responsible for building brand awareness and creating social media content for the company. TDR-Presentation’s team controls Stingray’s document retrieval and express the features and functionality of Wall-E.

The last level of management is represented by the Functional Manager (FM) for each department. A group of projects is assigned to each FM according to the department. The FM’s main role is to support his/her team(s), fix technical issues being faced during the projects, and assist the team(s) with resources and guidance along the projects.

For each project assigned by the FM, there is a project manager (PM) who is chosen according to his/her performance. The PM is responsible for assigning tasks to the project members and informing the FM of the detailed progress of the project during a weekly scrum meeting.

## 5.4 Collaborative Workspace

A representative reservation clerk has access to organizing the company's reservations, aiding the assigned team members to take their time testing and simulating their work.

The company's office consists of three completely prepared rooms. Firstly, the Assembly-Testing room is well equipped to meet the standard technical needs as tool boards, well-assembled tables, and essential components/equipment are provided.

Secondly, the Meeting room is used for conducting emergency meetings, discussions, and finalizing plans and decisions. Thirdly, the Lecture room is used for delivering information and making interactive discussions.

## 5.5 Budget

| Company Name: | Stingray | | | | 12/1/2022 |
|---|---|---|---|---|---|
| | | | | | 5/5/2023 |
| fund | | | | | $17,000.00 |
| **Expenses** | | | | | |
| **Date** | **type** | **Category** | **Description/Examples** | **Amount** | **Running Balance** |
| **Electronical Components** | | | | | |
| 4/2/2023 | Purchased | Tether | Cat6 Cable | $55.00 | $55.00 |
| 5/4/2023 | Purchased | Payloads | DC-Pump | $70.00 | $125.00 |
| 4/5/2023 | Purchased | Payloads | Epoxy | $20.00 | $145.00 |
| 1/17/2023 | Purchased | Cables | Pneumatic Cables | $28.00 | $173.00 |
| 2/28/2021 | Re-used | Power | DC-DC Conveters | $103.00 | $276.00 |
| 3/1/2023 | Purchased | PCB | Main PCB,Prototype PCB | $61.00 | $337.00 |
| 3/5/2023 | Purchased | Nvidia Jetson | Jetson Nano | $129.00 | $466.00 |
| 12/12/2020 | Re-used | Controllers | Pix Hawk, Arduino Nano | $140.72 | $606.72 |
| 2/12/2021 | Re-used | Cameras | OAK-D Camera,CCTV Cameras,Low Light Camera | $461.00 | $1067.72 |
| 3/16/2021 | Re-used | Power | Power Supply | $28.00 | $1095.72 |
| 3/18/2023 | Purchased | Sensor | Pressure Sensor | $40.00 | $1,135.72 |
| **Propulsion Expenses** | | | | | |
| 3/25/2023 | Purchased | | Thrusters' Mesh | $40.00 | $1,175.72 |
| 3/25/2023 | Purchased | Thrusters | T200 Thrusters | $1,200.00 | $2,375.72 |
| 3/25/2023 | Purchased | | Basic ESC | $216.00 | $2,591.72 |
| **Pneumatics Expenses** | | | | | |
| 2/14/2023 | Purchased | | Fittings,DCVs | $83.00 | $2,674.72 |
| 2/14/2022 | Re-used | Gripper | Pneumatic Cylinders | $21.00 | $2,695.72 |
| 4/18/2020 | Re-used | | Compressor | $150.00 | $2,845.72 |
| 4/18/2023 | Purchased | | Pneumatic Hoses | $5.00 | $2,850.72 |
| **Safety** | | | | | |
| 3/6/2022 | Re-used | | Gloves | $9.00 | $2,859.72 |
| 4/26/2022 | Re-used | Safety Equipment | life Jackets | $12.00 | $2,871.72 |
| 3/6/2022 | Re-used | | Safety Goggles | $13.00 | $2,884.72 |
| **Manufacturing Expenses** | | | | | |
| 3/3/2023 | Purchased | | 3D-Printed Parts | $112.00 | $2,996.72 |
| 3/6/2022 | Re-used | | Hammer, and Saw | $35.00 | $3,031.72 |
| 3/24/2022 | Re-used | | Cable Glands | $28.00 | $3,059.72 |
| 3/24/2023 | Purchased | | Alumnium Extrusions | $112.00 | $3,171.72 |
| 12/3/2022 | Re-used | Mechanical Tools | Main Enclousure Material (PMMA & PA type6) | $190.00 | $3,361.72 |
| 4/21/2022 | Re-used | | Camera box (Face Seal) | $80.00 | $3,441.72 |
| 4/17/2023 | Purchased | | Grippers Material (PMMA) | $41.00 | $3,482.72 |
| 4/17/2023 | Purchased | | Grippers Manufacturing (Laser-Cutting) | $29.00 | $3,511.72 |
| 4/24/2023 | Purchased | | O-Rings | $10.11 | $3,521.83 |
| 3/24/2022 | Purchased | | Bolts & Nuts | $70.65 | $3,592.48 |
| 3/20/2023 | Purchased | Frame | PA Type 6,PMMA,Aluminium Extrusions | $302.00 | $3,894.48 |
| 5/1/2021 | Re-used | | Screen | $120.00 | $4,014.48 |
| 4/13/2023 | Purchased | | Joystick | $74.00 | $4,088.48 |
| 3/12/2013 | Purchased | Control Station | Case | $134.00 | $4,222.48 |
| 4/26/2021 | Re-used | | DVR | $40.00 | $4,262.48 |
| 4/26/2023 | Purchased | | Video Baluns | $36.00 | $4,298.48 |
| 3/18/2023 | Purchased | | Case Accessories | $35.00 | $4,333.48 |
| **Operation Expenses** | | | | | |
| 4/10/2023 | Purchased | Mission Props | total prop building | $569.96 | $4,903.44 |
| 5/1/2023 | Purchased | T-shirts | Uniform for team members | $323.59 | $5,227.03 |
| 4/26/2023 | Purchased | Mate Competition fees | Competition fees | $295.00 | $5,522.03 |
| **Non-ROV Device Expenses** | | | | | |
| 2/8/2023 | Purchased | Electrical components | Arduino UNO,Arduino Nano,HC-12 module | $48.47 | $5,570.50 |
| 2/8/2023 | Purchased | | L298N motor driver,stepper motor (nema17) | $22.62 | $5,593.12 |
| 3/8/2023 | Purchased | Manufacturing | Materials & Fabrication | $96.94 | $5,690.06 |
| **Travelling Expenses** | | | | | |
| 23/5/2022 | Purchased | Accomodation | hotel reservation | $2,708.00 | $8,398.06 |
| 23/5/2023 | Purchased | Flight | flight tickets, Travel insurance, ROV transport | $14,004.97 | $22,403.03 |
| 24/5/2023 | Cash donated | General | Funds donated by AAST | $17,000.00 | $5,403.03 |
| | | | | **Total Purchased Expenses** | $20,972.31 |
| | | | | **Total Reused Expenses** | $1,430.72 |
| | | | | **Total ROV Expenses** | $5,522.03 |
| | | | | **Total Non-ROV Devices Expenses** | $168.03 |
| | | | | **Total Raised** | $17,000.00 |
| | | | | **Total Spent** | $22,403.03 |
| | | | | **Final Balance** | $5,403.03 |

*Figure 32- Actual Cost*

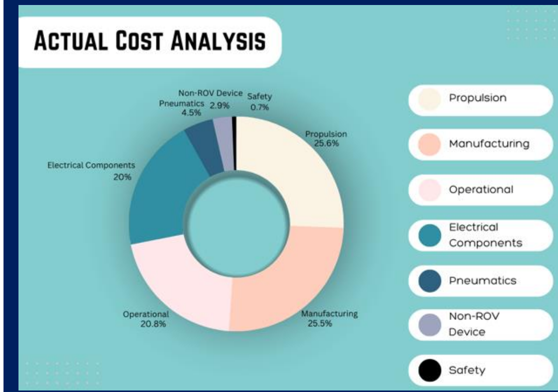


*Figure 32- Actual Cost Analysis*



STINGRAY

| | | | | Reporting period |
|---|---|---|---|---|
| **Company Name:** | Stingray | | | 12/1/2022 |
| | | | | 5/7/2023 |
| **Income** | | | | |
| **Source** | | | | **Amount** |
| **Stingray's Employees** | | | | **$5,600.00** |
| **Expenses** | | | | |
| **Category** | **type** | **Description/Examples** | **Amount** | **Running Balance** |
| **Electrical Components** | | | | |
| Tether | Purchased | Cat6 Cable | $60.00 | $60.00 |
| Payloads | Purchased | DC-Pump | $70.00 | $70.00 |
| Payloads | Purchased | Epoxy | $20.00 | $20.00 |
| Cables | Purchased | Pneumatic Cables | $30.00 | $30.00 |
| Power | Re-used | DC-DC Conveters | $110.00 | – |
| PCB | Purchased | Main PCB,Prototype PCB | $65.00 | $65.00 |
| Nvidia Jetson | Re-used | Jetson Xavier NX | $399.00 | – |
| Controllers | Re-used | Pix Hawk, Arduino Nano | $145.00 | – |
| Cameras | Re-used | OAK-D Camera,CCTV Cameras,Low Light Camera | $470.00 | – |
| Power | Re-used | Power Supply | $30.00 | – |
| Sensor | Purchased | Pressure Sensor | $40.00 | $40.00 |
| **Propulsion Expenses** | | | | |
| Thrusters | Purchased | Thrusters' Mesh | $45.00 | $45.00 |
| | Purchased | T200 Thrusters | $1,200.00 | $1,200.00 |
| | Purchased | Basic ESC | $220.00 | $220.00 |
| **Pneumatics Expenses** | | | | |
| Gripper | Purchased | Fittings,DCVs | $85.00 | $85.00 |
| | Re-used | Pneumatic Cylinders | $25.00 | – |
| | Re-used | Compressor | $150.00 | – |
| | Purchased | Pneumatic Hoses | $10.00 | $10.00 |
| **Safety** | | | | |
| Safety Equipment | Re-used | Gloves | $10.00 | – |
| | Re-used | life Jackets | $15.00 | – |
| | Re-used | Safety Goggles | $20.00 | – |
| **Manufacturing Expenses** | | | | |
| Mechanical Tools | Purchased | 3D-Printed Parts | $115.00 | $115.00 |
| | Re-used | Hammer, and Saw | $35.00 | – |
| | Re-used | Cable Glands | $30.00 | – |
| | Purchased | Alumnium Extrusions | $115.00 | $115.00 |
| | Re-used | Main Enclousure Material (PMMA & PA type6) | $190.00 | – |
| | Re-used | Camera box (Face Seal) | $85.00 | – |
| | Purchased | Grippers Material (PMMA) | $45.00 | $45.00 |
| | Purchased | Grippers Manufacturing (Laser-Cutting) | $30.00 | $30.00 |
| | Purchased | O-Rings | $15.00 | $15.00 |
| | Purchased | Bolts & Nuts | $75.00 | $75.00 |
| Frame | Purchased | PA Type 6,PMMA,Aluminium Extrusions | $305.00 | $305.00 |
| Control Station | Re-used | Screen | $120.00 | – |
| | Purchased | Joystick | $75.00 | $75.00 |
| | Purchased | Case | $135.00 | $135.00 |
| | Re-used | DVR | $40.00 | – |
| | Purchased | Video Baluns | $40.00 | $40.00 |
| | Purchased | Case Accessories | $35.00 | $35.00 |
| **Operation Expenses** | | | | |
| Mission Props | Purchased | total prop building | $570.00 | $570.00 |
| T-shirts | Purchased | Uniform for team members | $325.00 | $325.00 |
| Mate Competition fees | Purchased | Competition fees | $295.00 | $295.00 |
| **Non-ROV Device Expenses** | | | | |
| Electrical components | Purchased | Arduino UNO,Arduino Nano,HC-12 module | $50.00 | $50.00 |
| | Purchased | L298N motor driver,DC motor,ElectroMagnets | $25.00 | $25.00 |
| Manufacturing | Purchased | Materials & Fabrication | $100.00 | $100.00 |
| Accomodation | Purchased | hotel reservation | $2,708.00 | $2,708.00 |
| Flight | Purchased | flight tickets, Travel insurance, ROV transport | $14,004.97 | $14,004.97 |
| | | | **Total Income** | **$5,600.00** |
| | | | **Total Expenses** | **$22,781.97** |
| | | | **Total Expenses-Reused** | **$20,907.97** |
| | | | **Total Fund Raising needed** | **$15,307.97** |
| | | | **Total Expected ROV Expenses** | **$5,894.00** |

*Figure 34- Expected Cost*

# 6. Acknowledgments

We would like to give an immense thank you to those who helped and assisted us to reach where we are today:

- **MATE Center and Marine Technology Society** – Organizing and sponsoring the Mate ROV competition, and their great efforts in advancing the technical and non-technical skills of engineers worldwide.
- **Vortex Co.** - Creating a supportive environment and community that enables our skills to flourish.
- **FMs** - Their constant motivation and inspiration.
- **Arab Academy for science and technology**- Organizing the regional competition, supporting us students to reach our full potential, and sponsoring us in our journey to the world championships.
- **Family and Friends**- Their love, support, and encouragement.
- **Agisoft** – demo 3D-Modeling application.

# 7. References


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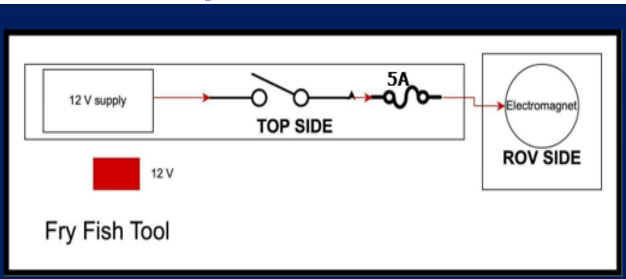
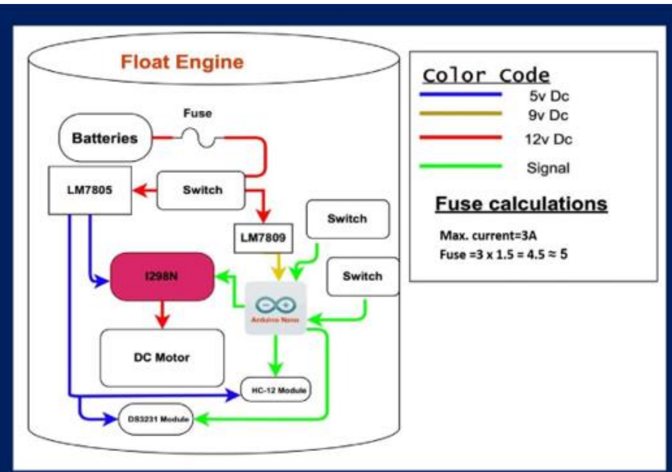
# 8. Appendix

## 1. Fry Fish Container SID



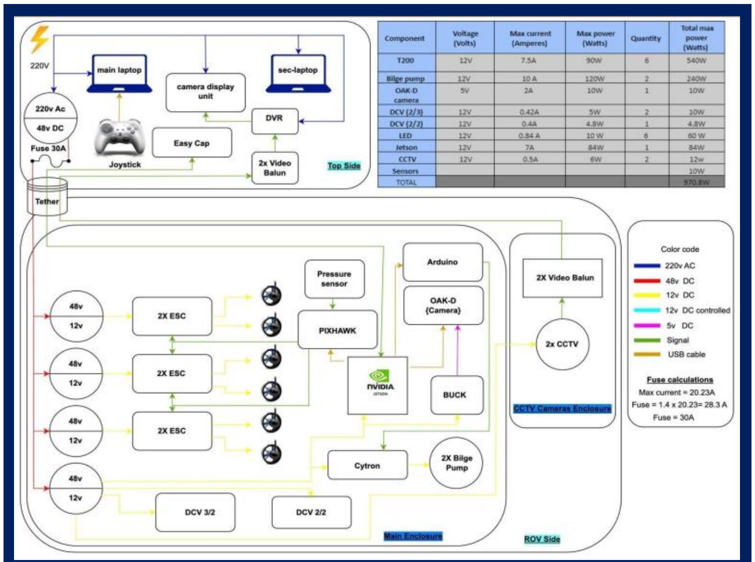

Appendix 1- Fry Fish Container SID

## 2. Float SID



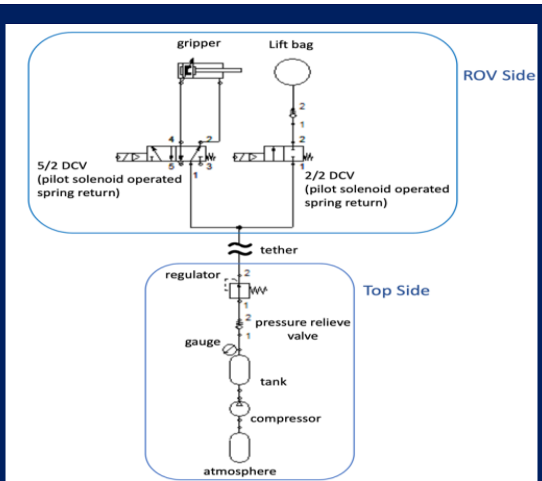

Appendix 2- Float SID

## 3. Electric SID




Appendix 3- Electric SID

## 4. Pneumatics SID

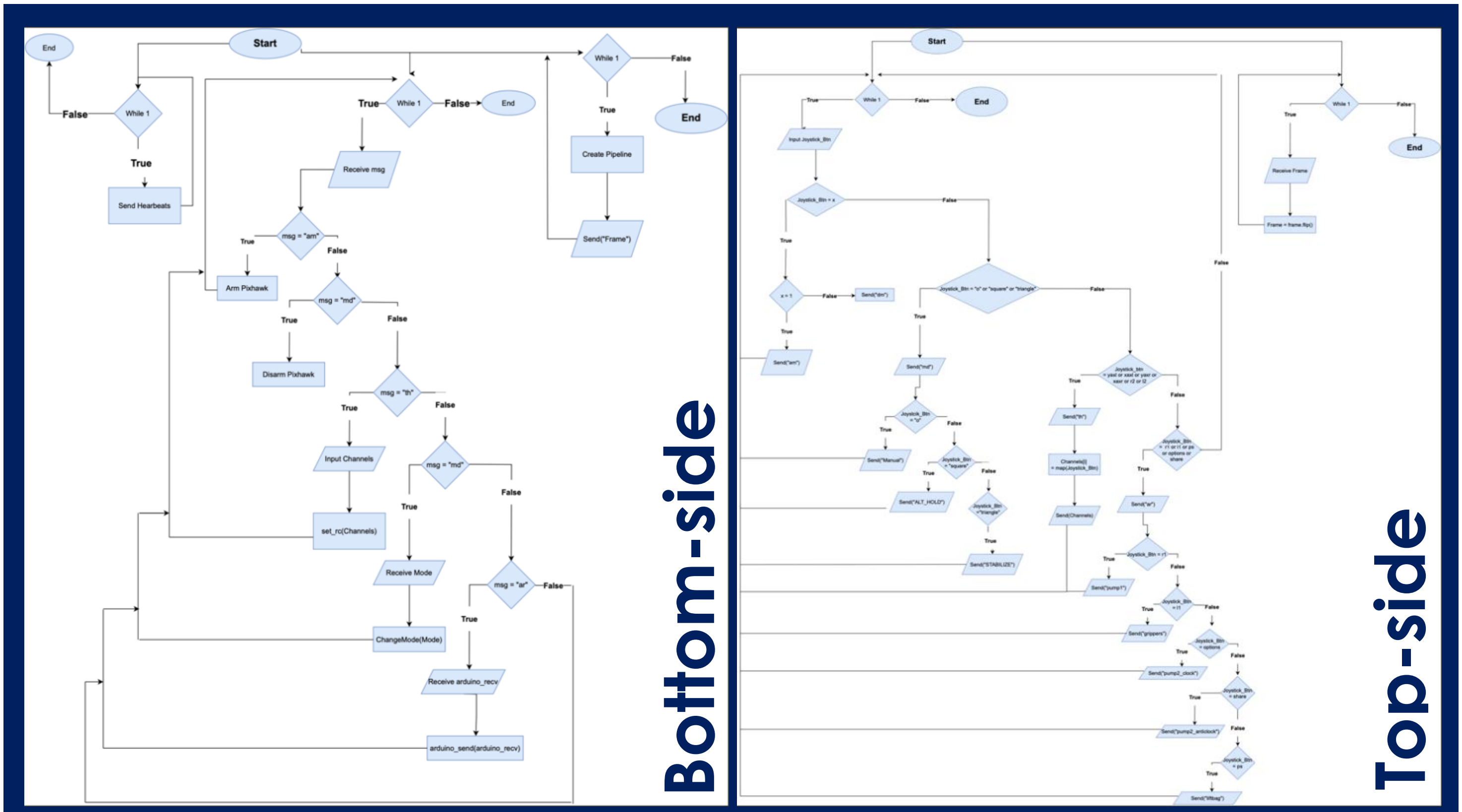



Appendix 4- Pneumatics SID



STINGRAY

# 5. **Software Flowchart**




*Appendix 5- Software Flowchart*

# 6. **Safety Checklist**

### Pre-Power test

- ☐ Area clear (no tripping hazards, items in the way).
- ☐ Verify power switches on TCU are off.
- ☐ Tether connected and secured to ROV.
- ☐ Tether connected to TCU and secured.
- ☐ Thrusters free from obstructions.
- ☐ Verify that the electronics enclosures are appropriately sealed.
- ☐ Visual inspection of electronics for damaged wires, loose connections.
- ☐ Electrical connections are waterproofed, and cables are tied down.
- ☐ Power source connected to TCU.
- ☐ Dry testing the thrusters.
- ☐ Check vacuum port is securely capped.
- ☐ Checking on the compressor's regulator (less than 2.75 bars)
- ☐ Checking on all the fittings and dry testing the manipulator to avoid any leakage.
- ☐ "Safe" should notified.

### Pre-Water Checks

- ☐ Connect tether to control station and power the system.
- ☐ Check video system in TCU.
- ☐ Verify that the internal pressure reading at the control station corresponds to the descent.
- ☐ Turn off the system and say, "Water Ready."
- ☐ Lower the ROV into the pool.
- ☐ "In Water," should be shouted.

### Power-Up

- ☐ The power supplying 48 volts nominal.
- ☐ Laptops are up and running.
- ☐ Ensure all team members are attentive and in their positions.
- ☐ "Power On" should be shouted.
- ☐ Perform thruster test.
- ☐ Perform pneumatics test.

### In Water

- ☐ Check for bubbles.
- ☐ Verify that the internal pressure is steady at the surface.
- ☐ Test thrusters, manipulators, and payloads.
- ☐ Pilot or co-pilot should shout out which task is performed.

### ROV Retrieval

- ☐ The pilot shout out "ROV surfacing".
- ☐ "Hands On", thrusters disabled.
- ☐ After securing the ROV on deck, the deck crew shout out "ROV secured on deck".

### Loss of Communication

- ☐ Pilot should shout out "Communication lost".
- ☐ Retrieve ROV via the tether's strain relief.
- ☐ Cycle power on TCU to reboot ROV.
- ☐ Take ROV completely out of water.
- ☐ If communication restored, confirm there are no leaks, resume operations.
- ☐ notify when the connection is back.

### Pit Maintenance

- ☐ Verify thrusters are free of foreign objects and spin freely.
- ☐ Visual inspection for any damage.
- ☐ All cables are neatly secured.
- ☐ Verify tether is free of kinks.
- ☐ Test onboard tools.
- ☐ Verify camera positions.