# TECHNICAL REPORT

## MATE ROV COMPETITION 2022


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# Abstract

With increasing interests on ocean, the ocean health and sustainability, biodiversity of marine life has attracted lots of attentions. On the demands for ocean's health and sustainability, Glaucus team is dedicated to offer a series of solutions to ocean environmental monitoring and biodiversity protection.

Glaucus was founded in 2021, aiming at developing remotely operated vehicle and operational tools with high performance and high adaptability to various scenarios. In the past year, our team, consisted of six undergraduates with experiences in mechanical design, hardware building and software construction, put a lot of efforts on design and construction of remotely operated vehicle equipped with cameras, multiple sensors and soft grippers to complete underwater navigation and operation.

To showcase the superior capabilities, the remotely operated vehicle was preliminarily tested in the pool to complete various tasks, including ocean energy sustainability, marine life protection, ocean health maintenance and monitoring.

The technical report provided for 2022 MATE ROV Competition putting the safety rules as main preconditions, exhibits the whole process on developing robots and tools for the targeted performance. Key parameters are also given in the report. Especially, a series of solutions and methodologies for specific missions are introduced and verified, showcasing the superiority and perspective on ocean applications.



Figure 1. Team Members

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# 1. Design Rationale

## 1.1 Design Motivation

With goals on ocean health maintenance and biodiversity protection, Glaucus proposes a core concept on operational platform, i.e., a remotely operated vehicle (ROV) with high stability to navigate and high adaptability to accommodate various tools. By thoroughly analyzing the competition missions, Glaucus put forward key requirements on size, weight, cost, freedom of motion, stability, and expansibility. The overall concept model is shown in Figure 2(a). Product vehicle was manufactured and shown in Figure 2(b).

(a) (b)

Figure 2. Concept (a) and prototype (b) of ROV.

## 1.2 System Approach

Main functions of ROV are achieved by six thrusters for navigation, two cameras for monitoring, electrical housings for communication, LED lights for illumination, an aluminum alloy

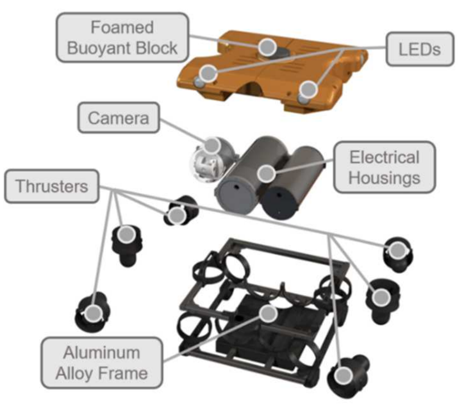



Figure 3. Explosed view of ROV

frame for high strength and stability. In addition, foamed buoyant blocks and ballast are used to balance the ROV in the water. Exploded view of ROV system is shown in Figure 3.

Considering the functionality and waterproofing, electrical housings are set in the middle of the system to carry all electrical components, which are made in a cylindrical shape and made with acrylic materials. Two cameras are separated equipped on front and back sides of ROV to give as large as broad views. Considering the high cost of waterproofed high-quality cameras, we built acrylic cover to protect the HD cameras and seal into electrical housing, ensuring the water resistance and clear vision. LED lights are utilized directly below the camera.

In this system, two main sealing methods are employed to design Water Sealing mechanisms: compressed FKM toric joints “O-rings”, marine epoxy and penetrators. The electronics and power housings are sealed with O-rings, and all cables go through penetrators which are both sealed with marine epoxy. Knob type weak current waterproof switch was chosen for its tiny and better waterproof.

### 1.2.1 Propulsion

Six thrusters are utilized to realize the actuation of five DOFs, the translation along the XYZ axes, and rotation around the yaw and roll axes as illustrated in Figure 4(a). Specifically, two thrusters in the vertical direction are mounted one at each side of the ROV, and four thrusters in the horizontal direction are mounted at four corners of the ROV, as shown in Figure 4 (b). Maximum power of RM50 thruster is 1050W for maximum 11.3kg propulsion force. The thrusters could be powered in two modes, one is high-power mode with high propulsion force and high speed. The other is low-power mode where power of motors is limited to 20%.

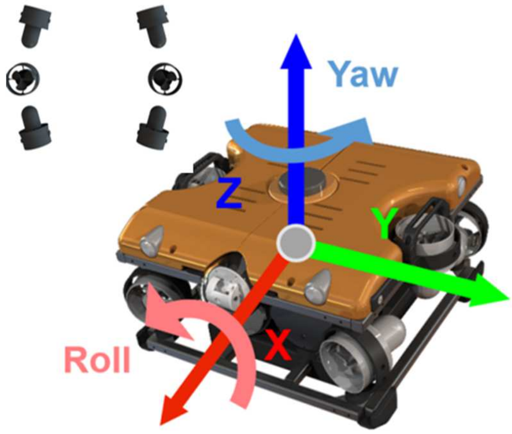



Figure 4. Thruesters settings in the vehicle.

## 1.2.2 Mechanical framework

The ROV frame consists of two layers of aluminum profiles, six cradles, and four C-brackets, as shown in Figure 5. Except for four nylon 3D-printed crash pads, all the parts that make up the frame are made of aluminum alloy for stability. The four vertical cradles support thrusters and connect two layers of aluminum profiles at the same time. An 3D-printed nylon plate is placed on the lower aluminum profile layer, which enhances the structural stability and keeps the ROV's center of mass in the center of the structure.

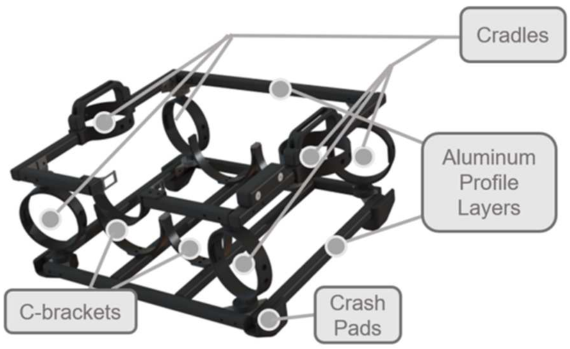



Figure 5. Aluminum framework

## 1.2.3 Control and Electrical Systems

The whole system mainly includes a topside control station and belowside electrical housings. The control system aims at safety and convenience to provide remote operation by a joystick communicating with computer in Windows 10 operational system which equipped with three screens. All components of the underwater belowside system have corresponding protective measures and devices during transportation and operation. The belowside system connects the ground repeater to zero buoyancy through USB, and then communicates with ROV through power carrier module.

### (1) Control System

For the topside (Figure 6), according to the competition rules, shore-based power supply is utilized. Transformation from 220-volt alternating current (VAC) to 48-volt direct current is completed on the shore. The topside control station (Figure 6) is consisted with DC power supply providing 48VDC to the belowside ROV by electrical wires, computers and joystick for communicating with ROV and sending commands. Electrical safety is secured by the 30A fuse connecting to the ROV. As a result, the topside control system and belowside electrical system are physically connected by signal and electrical cables. ROV control modes on the topside remote operation are divided into three modes: manual mode, steady navigation mode and fixed depth mode. Manual mode is the complete control of ROV movement under water by human operation. In the steady navigation mode, PID is used to control the ROV in the water in the front, back, left and right directions to independently walk in a straight line. Depth fixing mode fixes the depth of ROV in water on the premise of steady navigation mode.

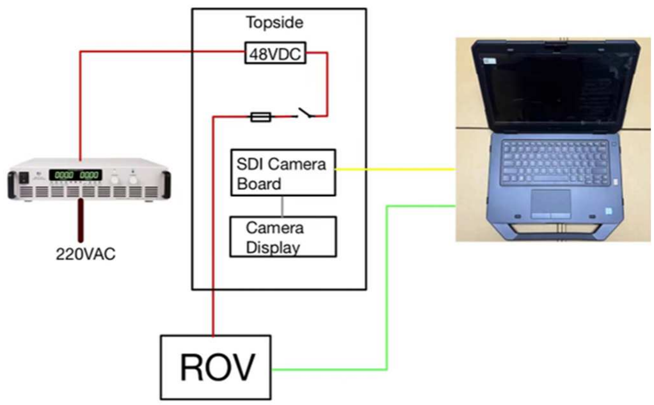



Figure 6. Topside control station

### (2) Electrical System

Components of electrical system is illustrated in Figure 7. The electrical cable to the electrical housing is with 48VDC outputs through power boards, completing transformation to 12VDC and 5VDC, six supplies power to the six brushless motors controlling the ROV attitude. One circuit of 48VDC supplies power to the light. One circuit of 48VDC is input to a power control board integrating multiple step-down modules, and 12VDC is output to supply power to the power carrier module, 12VDC is supplied to Px4, 12VDC is input to 5V step-down module, 5VDC is output to supply power to the steering gear in the camera PTZ, and 5VDC is output to the raspberry master control.

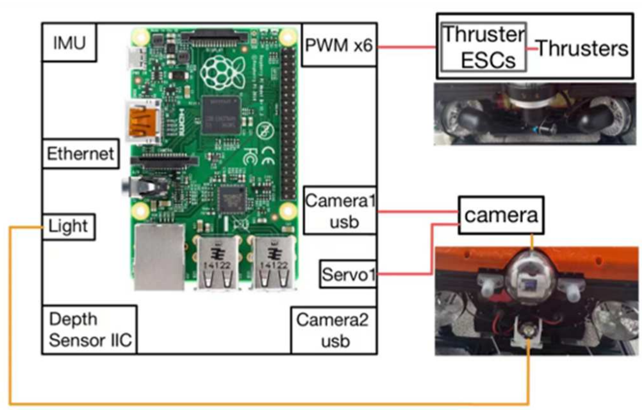



Figure 7. Belowside electrical system

The DCDC isolated power module used inside the ROV has an input of 48VDC, an output of 24VDC. The module is designed to be ultrathin, small in size, high in power density, and equipped with multiple protection functions. It is corrosion-resistant, moisture-proof and has good thermal conductivity. The typical efficiency can reach 80%, which is very reliable. At the same time, in order to meet various small voltage outputs, a PCB integrating various step-down modules is designed in ROV, which has small volume, complete voltage output interfaces and certain self-protection function to deal with some emergencies.

The video head used in the ROV front end is a USB driver free visual detection camera module, 1080p, 2 million pixels. Secondly, based on the WiFi function of raspberry pie, we adopt the method of IP camera network to indirectly call the currently used camera through web backend data transmission, so as to achieve seamless switching between cameras and provide convenience for ROV underwater operation.

ROV uses power carrier communication mode (PCL), which is a unique communication mode of power system. It uses the existing power line to transmit analog or digital signals at high speed through carrier mode. As long as there are wires, data transmission can be carried out. Secondly, we use raspberry pie 4B as the intermediate data processing system (with the picture). The reason why we choose this development board is that compared with the previous generation, this development board is equipped with Bluetooth 5.0 and USB 3.0 0 interface, which greatly improves the transmission rate of video stream. The Ethernet interface of raspberry pie is connected with the Ethernet interface of BluePLC, which is connected to the main tether line of ROV through micro cable and directly connected with the upper computer of onshore notebook to realize the communication between the upper computer and intermediate data processing system. The operator sends the control signal through the upper computer. The control signal is output through the USB to Ethernet interface module, through the communication cable, through the power carrier module to the raspberry network port, and further transmitted to the main control module for processing. At the same time, various sensor signals in ROV, including depth sensor, gyroscope, video stream and other data signals, are transmitted back to the upper computer on shore in the opposite way and fed back to the operator.

The power carrier communication mode is realized based on the BluePLC module. It is a technical product based on orthogonal frequency division multiplexing. And the maximum transmission rate is 500mbs, including RJ45 Ethernet interface. There is no need to configure, plug and play. The feedback information including video stream data and other sensors in the ROV is transmitted to the PC.

Communication between the camera and the ground PC: the main control of the raspberry pie inside the ROV and the PC at the ground end run the code at the same time to transmit the video stream content.

Raspberry pie intermediate data processing system mainly has three signal inputs and outputs. It communicates with camera through USB, Px4 through micro-USB, and Ethernet is used for total data transmission. Px4 integrates various signal interfaces, with built-in ms5611 barometer, l3gd20 gyroscope, lsm303d accelerometer / magnetometer, mpu6000 accelerometer / gyroscope, and outputs 9 channels of PWM signals. Six channels are used to control the speed of brushless motor, one channel is used to control electric regulation, one channel is used to control the opening and closing of lighting lamp, and one channel is used to control the rotation angle of steering gear to adjust the field of view of camera. Mpu6000 gyroscope is used to monitor the attitude of ROV, and ms5611 hydraulic gauge is used to monitor the horizontal position of ROV. At the same time, they can be used as a feedback signal to adjust ROV to achieve target position and balance state.

The raspberry pie 4B development board inside ROV realizes the control of each part of ROV based on QT framework. When the ROV is connected with the laptop on the water, we can quickly browse the overview of the whole ROV, including the status of sensors, power supplies, cameras and other modules, to help us quickly judge the ROV and repair the error.

### （3）Tether System

The ground repeater is used to convert the signal transmitted by the ROV from the zero-buoyancy cable to the ground into the network signal recognized by the PC to realize the relay function. The connection between ROV and the ground is established through tether cable, which is composed of two cables, one for ROV power supply and the other for communication. Except the tether cables, the electrical housing cap (Figure 8) sets one pneumatic connector for airtightness inspection before underwater operations. Additionally, there are connectors for camera signals and pressure signals entering the ROV electrical housing.

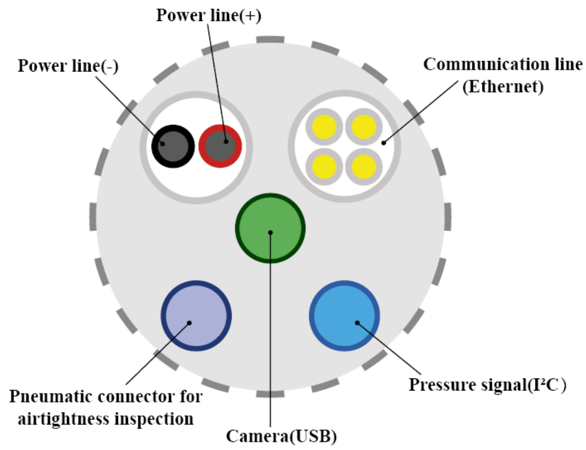



Figure 8. Electrical housing cap with tehter sysmtem illustration.

The cross-sectional area of the cable for power transmission is 0.25cm2. The cable for communication is AWG twisted pair and shielded with aluminum foil. The cable is a zero-buoyancy cable. The section connected to the ground repeater adopts a waterproof IP20 plug 4 pins, and the section connected to the ROV adopts a general cable waterproof plug 4 pins.

## 1.3 Mission Specific Features

Referring to the specific tasks, this section introduces the novel tools and algorithms used in the vehicle system, including high-adaptable soft grippers for all manipulation tasks and algorithms used in image processing for identification jobs, and novel electrical float design.

### 1.3.1 Manipulation

To enable the ROV to perform various tasks underwater, we designed a soft gripper for the ROV instead of conventional motors. The gripper is composed of a 3D-printed gripper front end, bellows and a gripper back end. The front end of the gripper is bolted together, and then connected to the bellows as a power structure. We use a tooth at the front of the gripper, so that the gripper can grip more tightly. At the same time, in order to make the gripper can better grasp various shapes of objects, we also add a sponge inside the front end to reduce the gap between two parts of that, and also improve the adaptability of the gripper. The soft gripper system involves an electrical circuit to the pump which tunes the water input/output to the gripper and a hydraulic circuit to the gripper for controlling the pressure in the circuit. A pressure regulator and pressure release valve are utilized between the pump and gripper for safety considerations. The concept and prototype of soft grippers are shown in Figure 9.

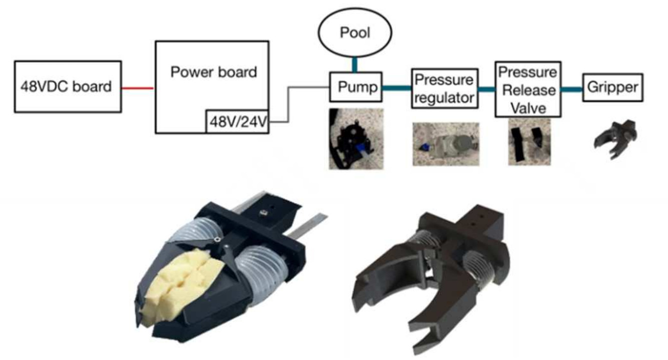



Figure 9. Soft grippers with hydraulic circuit presented.

Figure 10 shows the high effective performance in twelve tasks with only one pair of grippers. This pair is designed with one in horizontal placement and the other in vertical placement to enhance the reliability in grasping by offering two crossed forces. Take the task seagrass planting as an example showing the operation process. This part is the main test of the operability of the jaws and the convenience of the operation. Glaucus uses the soft body gripping jaws to complete the pick-up and placing of the seagrass. During the placement process, some disturbances may occur, which requires both accuracy and stability of the ROV.

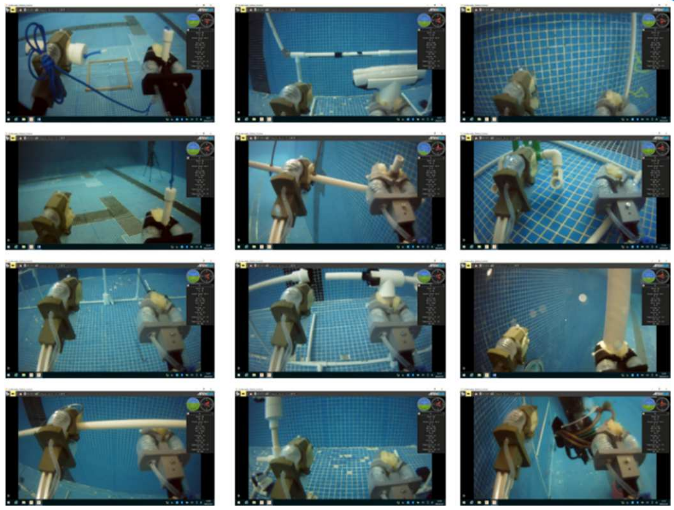


Figure 10. Operarional scenorias of soft grippers.

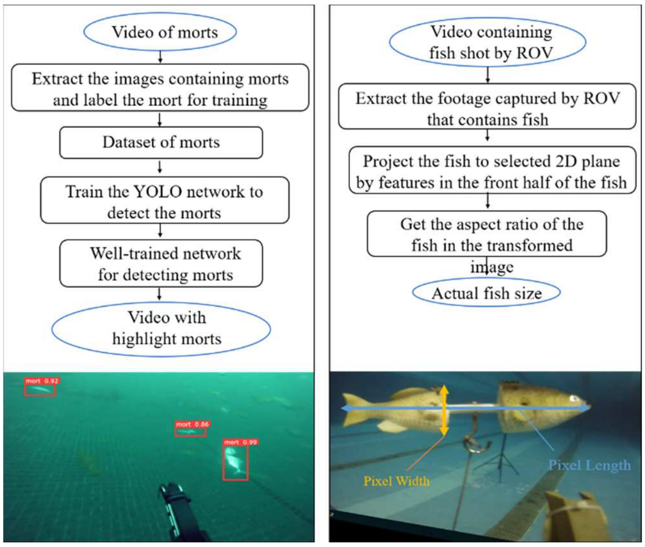
## 1.3.2 Image Processing

### （1）Inspect an offshore aquaculture fish pen

The main requirement of this part is the stability of the ROV, i.e., the ROV should complete the horizontal or vertical movement as much as possible in the patrol line part. Glaucus chose to manually inspecting, and thanks to its “fixed depth” mode, ROV can move smoothly in the horizontal direction.

During the ROV navigation, the camera will return its front scene and the damaged area will be presented. Then team member can easily identify the distribution and the number damaged net areas.

At this point the ROV needs to repair damaged section of netting by using the gripper jaws to pick up a new net, and here the task operability of the ROV was tested. Then two similar tasks of removing encrusting marine and algal marine growth were given and the same soft gripper is used to perform.




(a) (b)

Figure 11. Workflow of tasks in morts collection and size measurements.

### （2）Maintaining a healthy environment

This part can be divided into 2 different parts: one is about the AI detection and the other is about the operation of ROV.

In AI part, Glaucus used to train the neural network to detect the "morts" from the fish pen. The part of video provided consist the train dataset and test dataset.

In operation part, Glaucus used a fish hook to pick up the dead fish. This also requires precision of operation. The whole process is explained in Figure 11(a).

### （3）Measuring fish size

Due to the restricted underwater scene, glaucus used the camera as a source of image information to restore the 2d cross-section of the fish. Using the projection matrix, the distance of the actual camera position relative to the normal position is obtained to restore the captured image as much as possible. Finally, the aspect ratio of the fish is used to determine the length of the final fish. And so on, the average length of the three fish is finally obtained. Finally with the equation provided the team member could determine the biomass of the fish cohort.

In this mission, Glaucus first needs to change the camera view of the ROV so that it can get a picture of the bottom of the pool. Secondly, member of Glaucus will control the ROV to fly a transect over the area of the wreck and at the same time observe the distribution of the wreck in the corresponding area, which will be mapped on the corresponding position as shown below. The second part was to obtain a complete map of all sections, which was stitched together from eight images taken over each area. Glaucus chooses to use the feature point method to obtain the boundary locations of each area and, by homogeneous transformation, the figures will be deformed the photographs to correspond to the locations of the area in the complete image. The final results of the image stitching will be obtained automatically. The final task of measuring the length of the wreck from bow to stern is based on the previous task. On the complete top view of the area, the pixel location of the wreck is obtained, and the actual length is calculated by enlarging it to the actual scale (Figure 11(b)).

## 1.3.3Float

### （1）Vertical Profiling Float Design Overview

The vertical profiling float is designed for collecting marine information data while drifting and sinking in the ocean. As Figure 12 shown, the float is comprising seven parts: buoyancy adjustment block, safety secure interface, power module, control module, water bladder, environment interface, and hydraulic supply module.

### （2）Controller inside the float (Power, STM32)

The inner components (power module, control module, and water bladder) are sealed by the O-ring mounted on the metal caps at both ends and the acrylic cylinder. A battery pack consisting of 8 AA batteries is responsible for powering the entire system including the controller circuit with a DC

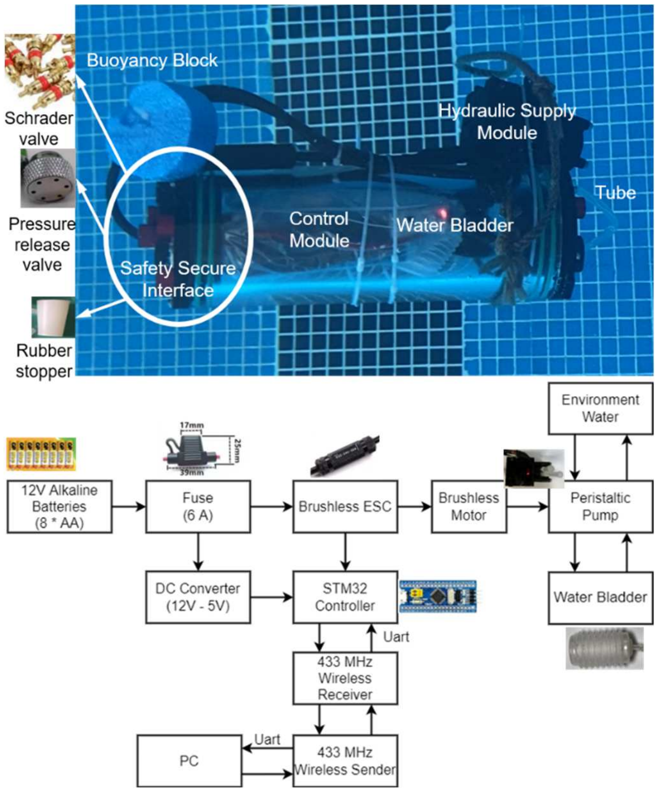



Figure 12. Electrial float design and system.

converter and motor power circuitry. The onboard STM32C8T6 controller could receive the ashore command to execute floating up or sinking down by a 433MHz wireless communication module. Wireless communication is chosen for improving reliability to avoid cables stuck in tight crevices. The SID diagram also shows the scalability of the topside controller interface designed based on the UART port. Any PC console with C340 USB-TTL driver could use this system conveniently.

### （3）Outside the float (Motor, Buoyancy Block)

The waterproof brush-less ESC and motor with a peristaltic pump head are attached outside the acrylic cylinder for the buoyancy balance and volume optimization of the internal control bin. Through the bulkhead connector, the power and signal wire are connected with the inner electrical loop. By the forward and reverse rotation of the motor, the peristaltic pump could pump into or out of the water bladder which would change the weight balance of the float. By additionally fitting an appropriate buoyancy block, the float should be neutral buoyancy when the water bladder is in the middle of the maximum size. Our company chooses to use a small water bladder to achieve smooth underwater dynamics for a better data collection quality.

### （4）Detailed Design Security Information:

Without any thruster and cameras, this device does not have a power supply connection from the surface. As Figure 12 shown, the onboard batteries are a set of 8 AA alkaline batteries whose total voltage is 12VDC and a 6A fuse is connected after the battery positive terminal within 5 cm. And the battery box is attached to the cylinder by a glued supporting structure.

After retrieving the float from the ocean, the inner pressure of the cylinder may be different from the atmosphere. Larger or smaller air pressure differentials should be considered, as the lumen may burst or suck the end cap too tightly. The O-ring sealed end cap is naturally safe for the bigger inner pressure and it would slide out the cylinder when the force caused by the pressure deviation is bigger than the friction force between the O-ring and acrylic cylinder wall. Besides, Schrader valves are settled at the left side of the cap for connecting the outside environment to the inner chamber when a large pressure deviation occurs. Apart from that, a pressure relief valve is deployed for automatically opening when the inner pressure is bigger than the outside. The pressure differential trigger has been adjusted to 3 psi by changing the innerspring length. For emergency situations, a rubber relief plug with a 26cm diameter is used to rapidly release the air in danger. Although pressure security is deployed, a comprehensive waterproof silicone rubber sealing is applied for all the electrical components for water leakage protection.

## 1.4 Buoyancy and Ballast

Glaucus has a flow chart to check if ROV is level maintained. When test start, we check the condition of ROV, if ROV is level, then we will check the depth of the ROV and judge if ROV sink underwater. The buoyancy and ballast calculations are shown in Table 1. If ROV does not sink underwater, then end test. Or, if ROV is sink under water, we tune-up thruster speed gain, and then back to beginning. Then, if ROV is not level, we will check is depth keeping mode on, if it is closed, then we adjust the buoyancy block and the counterweight. After that, back to check if ROV level maintained. And if the depth keeping is on, then we check if the thrusters work properly. If the thrusters are done, we will check the thruster condition and inspect the thruster connection, and then back to the beginning of the test. If the thrusters work properly, we will tune-up thruster speed gain and back to the beginning of the test.

| Item | Quantity | Denisty (kg/m^3) | Volume (m^3) | Buoyant Force (N) | Total Weight in Air (N) | Total Weight in Water (N) |
|---|---|---|---|---|---|---|
| Buoyancy block PVC | 1 | 1398 | 0.00228 | 22.42 | 31.35 | 8.92 |
| Power Box Acrylic | 1 | 1200 | 0.00054 | 5.38 | 6.46 | 1.07 |
| Electronics Box Acrylic | 1 | 1200 | 0.00054 | 5.38 | 6.46 | 1.07 |
| Electronics Enclosure Aluminium | 1 | 2700 | 0.00083 | 8.15 | 22.03 | 13.87 |
| Frame Aluminium | 1 | 2700 | 0.00154 | 15.09 | 40.74 | 25.65 |
| Gripper PLA | 2 | 1240 | 0.00016 | 1.60 | 1.99 | 0.38 |
| Thruster ESCs Aluminium | 6 | 2700 | 0.00054 | 5.35 | 14.44 | 9.09 |
| Screw and Nuts Stainless steal | 1 | | | | 27.96 | 20.56 |
| Thrusters | 6 | | | | 16.75 | 10.58 |
| Camera components PLA | 1 | | | | 20.45 | 9.47 |
| Total | | | | | 188.67 | 100.71 |

Table 1. Buoyancy and ballast calculations.

## 1.5 Vehicle Structure

The appearance of ROV is cuboid as shown in Figure 13, which is 49cm in width, 53cm in length and 28cm in height. Total weight of the system including ROV, soft grippers is 26.5kg.

## 1.6 Innovation

Glaucus focuses on remotely operated vehicle and operational tools research and development (R&D). Comparing to the state of the art, high performance and adaptation are shown in our developed products.

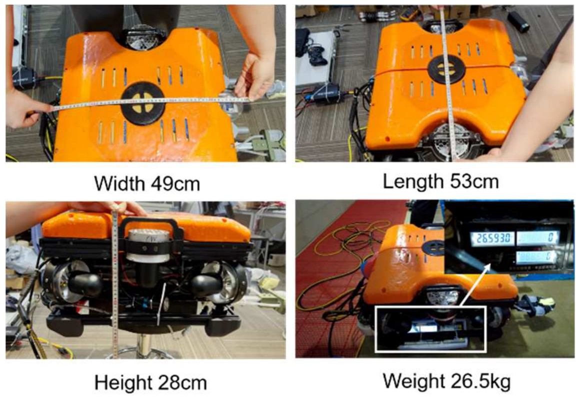



Figure 13. Vehicle structure illustration.

Our vehicle shows high performance in propulsion force and speed by adapting high-performance thrusters. Limited 20% power is used for safety considerations. Additionally, the aluminum-made mechanical frame provides high materials strength and accommodation to diverse tools.

Novel soft grippers are developed to offer high adaptability for handling various task without needs to adjust tools in the period of full tasks. Soft robotics is a new trending in designing and manufacturing robots. Soft materials could provide high adaptability for interacting with unstructured environments, while provide smaller forces comparing to the conventional motors. Our developed soft grippers employed soft-rigid hybrid design to provide large force and high adaptability simultaneously, showing the great perspective on the underwater applications.

# 2.Testing and Trouble-shooting

Testing and troubleshooting are the most important process to verify the capabilities of our products.

The precious experiences should be recorded as references to build systems. Our testing and troubleshooting process are mainly conducted on the overall ROV systems, soft grippers, algorithms of image processing and non-ROV device float. All these tests are carried out according to our safety technical document, and only when the requirements in the safety technical document are met can we proceed with these steps.

## 2.1 Remotely Operated Vehicle of Trouble-shooting

### （1）Mechanical design testing

For mechanical structure, every part is modeled in SolidWorks to check the design idea and ensure that all parts are correct before purchasing and processing. All sealed enclosures are subject to different hours of waterproof testing according to the safety specification, to ensure effective protection of electronic components under water.

### （2）ROV system testing:

After the unit test passes, the units are integrated into a system, and the system is then tested. When testing, you need to input specific values to the system to verify the corresponding output and ensure that the system works as expected. At the same time, to avoid accidents and device damage during system testing, all systems are added with debugging LED lights, and added fuse and emergency stop devices. The LED will indicate when the output value of the system differs greatly from the theoretical input, the fuse protects the system in the event of an electrical problem. If there is any emergency problem, there is a manual emergency switch.

The ROV was first tested in a good environment on shore to ensure that all parts of the ROV were working properly. Conduct underwater test when there is no breakdown in shore test. The ROV is first subjected to underwater pressure tests to ensure that the ROV is sealed. After passing the pressure test, test the ROV’s functions one by one according to the test procedure in the safety technical manual. When there is a breakdown, we will gather all members to discuss the solution. If there is no breakdown, we will test it completely and execute all tasks at last. When the task is complete and no breakdown are found, the testing and troubleshooting phase is complete. It should be noted that any component should be tested in an isolated environment, and protective measures should be taken to avoid major accidents.

One example of troubleshooting process is listed in Figure 14 showing the analysis and methods on solving problems on testing vehicle.

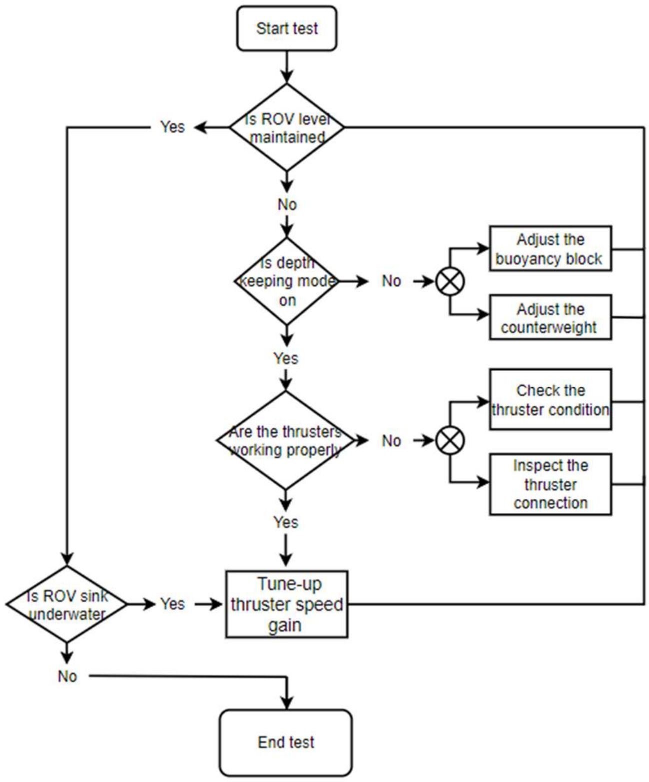



Figure 14. The analysis and methods on solving problems on testing vehicle.

## 2.2 Tools of Trouble-shooting

### 2.2.1 Gripper

Key performance of soft gripper mainly involves the relations between angles of gripper joint and hydraulic pressure. The higher hydraulic pressure, the larger grasping force would be offered by the gripper. We recorded its testing and troubleshooting process as in Figure 15. This process exhibits minds on the lack of grasping forces. To solve this problem, we checked the fluid circuit in case of any leakage and increased hydraulic pressure to enhance the grasping forces.

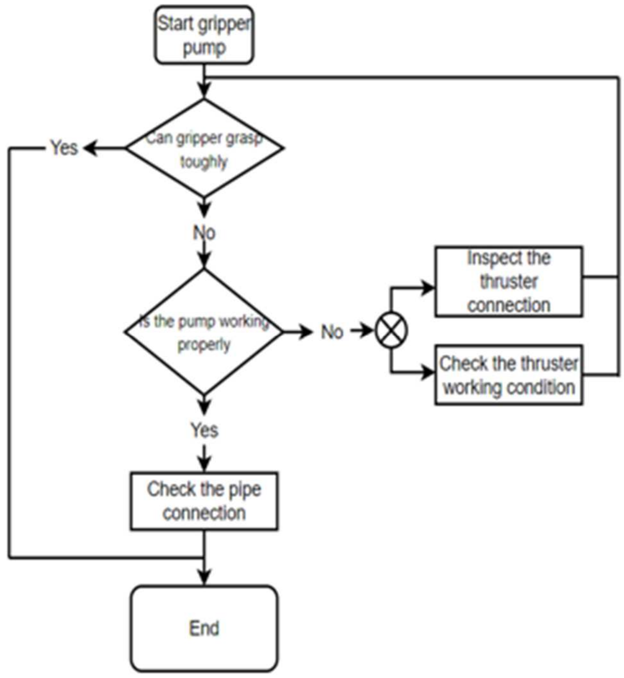



Figure 15. The analysis and methods on solving problems on testing gripper.

### 2.2.2 Algorithm

Algorithms on image processing are developed for multiple tasks. Take Task 3 as an example illustrated in Figure 16. The key to this task is finding features and descriptors of two images to estimate the effectiveness of descriptors. The troubleshooting process underwent means by manually selection and algorithms-based recognition.

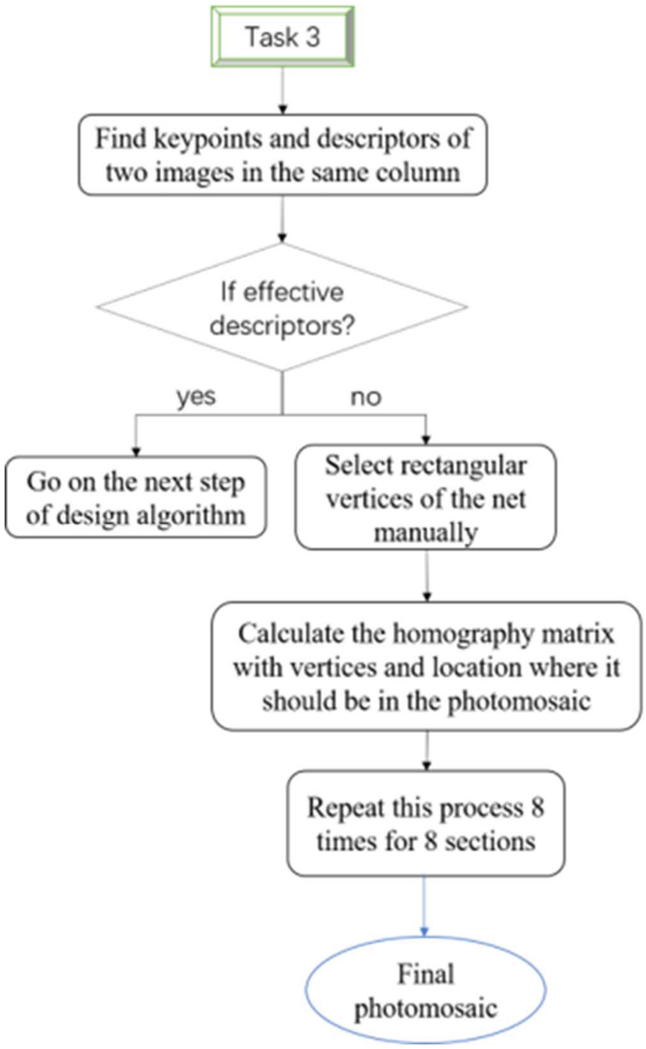



Figure 16. The analysis and methods on solving problems on testing algorithms.

## 2.3Float of Trouble-shooting

The prototype version of the float is operating by a timer that the whole equipment would run the scheduled program as time goes by. By settling desired vertical movement with certain time integration, the float could run automatically after being released by the ROV. After several pool tests, two major problems have been found: the mistake of ROV operation would influence the vertical movement time sequence of the float and the time-dependent strategy could not equally balance the water volume of the water bladder after a certain time of up and down procedure. Water imbalance of the bladder may cause severe water leakage problems as it is allocated inside the electrical cylinder.

To solve this problem, the motor should be controlled under flexible manual operation to avoid the previous issue caused by the unchangeable time sequence method. Based on that, the 433MHz wireless communication module is selected for two main reasons. First, wireless communication could lightweight both the onboard and the onshore hardware design and deploy easily for most situations without wire stuck issues. Second, 433MHz microwave could work underwater as usual 2.4G would be easily influenced. Our company builds a simple but effective command protocol for the interaction between the float and deck operation station. The revolution of the motor would directly influence the floating and sinking behavior of the buoy. Based on that, we build the universal command which consists of three parts: the speed of rotation, the direction of rotation, and the running time for the motor. It could effectively describe the needed motor behavior for vertical profiling operation. This communication protocol could be suitable for any other motor-based hydraulic system with only a few moderate modifications for different KV and torque-current characteristics (Figure 17).

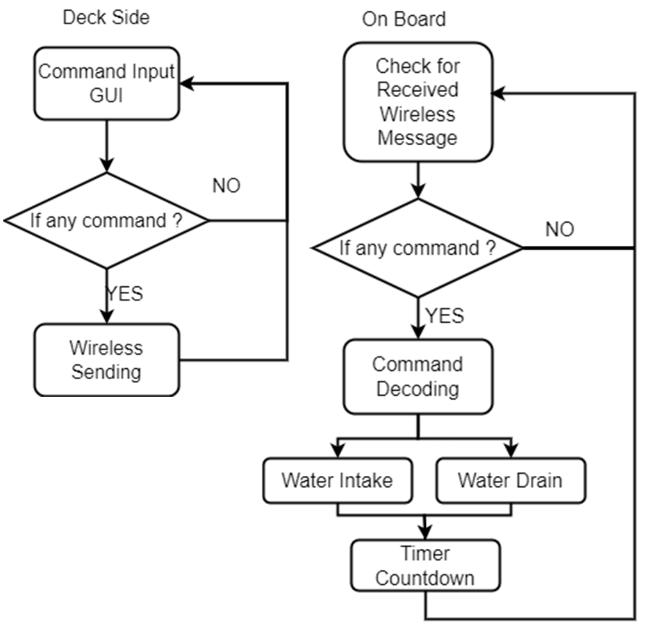



Figure 17. The analysis and methods on solving problems on testing float.

# 3.Safety

Safety has the top priority in the competition MATE 2022, and all members in our team all have this knowledge. In the design and installation of the machine, the factor of safety was set as the highest priority in order to achieve security of subsequent operation. Any member must be trained and given permission before operating or modifying the ROV. The environment during the preparation process also meets safety standards.

## 3.1 Personal Protection

New members must be trained before operating the ROV, and asked to watch the operation process of the permitted operator at least once. And the first operation of new members must be supervised by an experienced person. After completing the above requirements, the new member will be allowed to complete the operation independently (Figure 18).

New members must also be trained prior to making internal inspections or changes to the ROV. A dedicated person is responsible for a dedicated area and changes need to be announced to prevent adverse effects on other parts.

Figure 18. Safety education and shop/tool safety.

## 3.2 Workplace Safety Management

Any member must complete technical and safety training before using the relevant equipment and ROVs to prevent unnecessary damage. For more complex or safety hazard related tasks, a minimum of two members need to be present, of which one to perform the operation and the other to collaborate the task and pay attention to safety. When ongoing installations and other work in the laboratory, the safety manual for the specified place must be followed and operations. And dismantling the machine in a place where it is not permitted is strictly prohibited.

Gloves are required when using reagents that may be harmful to the skin, and masks are required when working in public places due to the epidemic. For various emergency situations, the team has formulated related measures and responses, and each member must be familiar with the measures while conducting rehearsals.

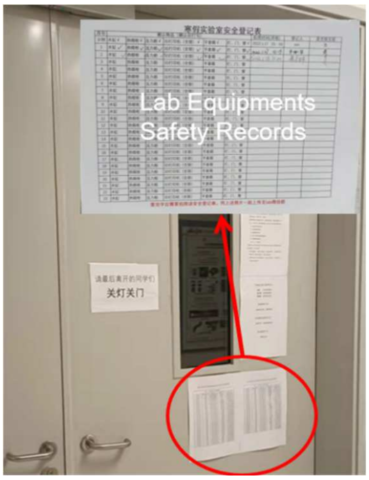


Figure 19. Workplace Safety Management.

## 3.3 Safety Features of ROV

Strictly following the safety rules, the ROV are designed and manufactured without any sharp edges (Figure 20). All thrusters are shrouded with IP20 standard mesh. Strain reliefs are designed on both sides entering the ROV and control stations. Eligible fuse and Anderson connectors are employed to secure the electrical safety.

Figure 20. Six sides appearance of ROV for safety considerations.

## 3.4 Operational Safety

The ROV circuit and the power supply part are potted to get a chamber that can be sealed underwater, thus avoiding the direct exposure of the circuit part to the water. And the airtightness test must be performed before each entry into the water to ensure the safety of the testers as well as the machine.

Packing the ROV part of the propeller (easily accessible) to prevent the operator from being scratched before and after entering the water, in line with the requirements of IP20; regulating the cables of the ROV linkage so that they are arranged in a reasonable way to ensure that the cables of communication and power supply will not be tangled and cause damage.

Strain relief devices are added to the ROV cable connections and surface control box to prevent damage to the internal cables.

The collision-prone areas of the ROV are protected to prevent damage and dropping of important components.

Silica desiccant is added to the electrical cabin for condensation prevention, so that there are no problems such as short circuits.

To ensure operational safety, self-established testing protocol would need to be followed strictly by all members. To protect the members and ROV machine, airtightness test must need to be performed on shore before testing underwater. Also, an operation checklist was designed to avoid any possible injury by accidental activation of manipulators and thrusters.

In the event of an emergency, any crew member in proximity of the power supply must cut off power immediately to avoid or minimize casualty by both the crew and the electronics on the ROV.

# 4. Project Management

## 4.1 Company Profile

Glaucus was founded in 2021, aiming at developing remotely operated vehicle and operational tools with high performance and high adaptability to various scenarios. In the past year, our team, consisted of six undergraduates with experiences in mechanical design, hardware building and software construction, put a lot of efforts on design and construction of remotely

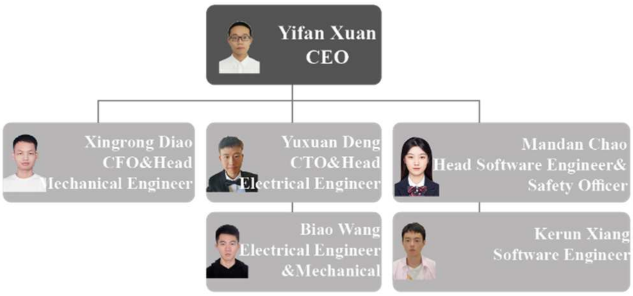



Figure 21. Team members and positions.

operated vehicle equipped with cameras, multiple sensors and soft grippers to complete underwater navigation and operation. Company organization is exhibited in Figure 20 with the following positions and duties,

*Chief Executive Officer (CEO)*

Yifan Xuan, 3rd year robotic engineer, with 3 years' experience in Robotics.

*Chief Financial Officer (CFO) and Head of Mechanical Team*

Xingrong Diao, 3rd year robotic engineer, interested in mechanical design and project management, with 3 years' experience in robots as well as managing technical problems and daily progress.

*Chief Technical Officer (CTO) and Head of Electrical Team*

Yuxuan Deng, 2nd year electronic circuit design engineer, with enriching experience in managements of several robotic projects, responsible for managing daily progress and tracking technical problems.

*Head of Software Team and Safety Officer*

Mandan Chao, 4th year software engineer, professional in image process and AI image recognition algorithms, experienced in managements of underwater robotic projects.

*Electrical Engineer*

Biao Wang, 4th year electrical engineer, interested in Underwater Robots.

*Software Engineer*

Kerun Xiang, 2nd year software engineer, interested in AI image recognition algorithms and robotics programming

## 4.2Project Schedule

After we knew the competition was about to begin, the CEO and other team leaders of our company made a detailed schedule of the progress. Not only does the schedule give us specific direction of our daily jobs, but also it helps us to arrange our time optimally and make sure we can reach the goal ahead of time. Following the schedule, we will have enough time left testing our product and training our pilot to be totally familiar with our vehicle, then we can successfully execute the required missions efficiently within the limited time, and made the best decision of tasks that we will accomplish to get ourselves a good score in the competition. The details are in the Gantt chart(Figure 1).


Figure 22. Process management.

## 4.3 Process Management

Glaucus has a complete testing and training process, and these makes us work more targeted. At the beginning of the test, Glaucus will check the ROV working condition and gas tightness. Then we test ROV in the tank in our laboratory, so that we can debugging ROV when the problems arise. After that, we go to the pool and build the prop for the training of the tasks. Next, we test ROV in the pool and train our operators. Finally, we go back to laboratory to reanalyze the test in the pool and propose improvement plan. Then, the process back to testing ROV in the tank, which creates a cycle. After practice, this process management is very suitable for us to promote the task (Figure 21).

## 4.4 Code Management

After compared plenty of Version Control System (VCS) websites, Glaucus software team uses GitHub for code storage and update. GitHub allows people to code online, which reduces the time spent in offline face-to-face communication. Thus, with GitHub, we can know how other members update the code immediately and communicate more effectively. Finally, GitHub makes Glaucus easier to work remotely.

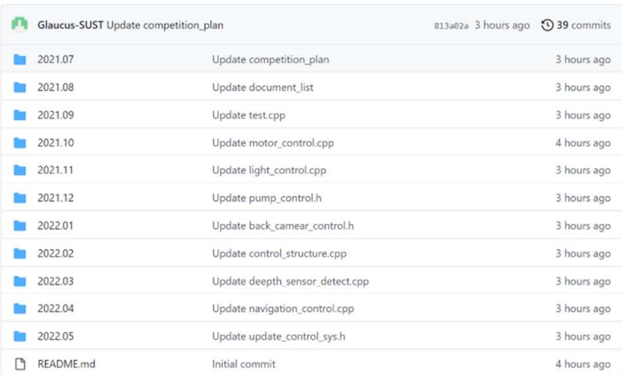



Figure 23. GitHub code management.

## 4.5 Budget and Cost Accounting

Glaucus received sponsorships from the university funding and research group funding. The majority of cost are the development of ROV system. For ROV mechanical framework, to develop a stable and responsive mechanical system, a large portion was spent on the ROV frame and Sealed Cabin. For electronical system, a large portion was spent on thrusters to develop task-oriented manipulators. With a limited budget, review of effective purchase is done continuously to ensure efficient cost budgeting and working progress. In addition, cost of soft grippers, float and other auxiliaries are listed. USD 4137 was spent for the Glaucus's development which is within the proposed budget of USD 4600. The budget projections and cost breakdown of Glaucus are attached in Appendix B and Appendix C.

# 5. Conclusion

## 5.1 Challenges

### 5.1.1 Technical challenges

When we try our best to design and debug the ROV in order to make it work more smoothly and reliably, lots of challenges arise that require urgent attention.

One of the challenges is the connection of the camera is unstable which means that the pilot may lost the view under the water. It is fatal when ROV work under the water. Finally, we found out that it was because the raspberry pie inventory is too small that when we control ROV, camera may be squeezed out of operating space. Thus, improve the control board is necessary. And it also affects the depth sensor that may let ROV sink to the bottom sometimes.

Another challenge we faced was the sealing problem. If water enter the housing, then our work is done. At many times, we had to stop training as the sealing tests were not pass. The situation improved when we resealed it, but it still exists. To solve this, we need to take more to do the sealing test.

### 5.1.2 Non-technical challenges

As the COVID-19 become serious again, the greatest challenge we faced was how to conduct offline experiments. This delays our processing on testing ROV, as well as decline the time the training of control ROV. And the COVID-19 also limits the space we can check the ROV and practice on the task. Also, as we must finish the tasks offline, it spends plenty of time on manufacturing the site props and decorating venues.

However, not only have we managed the training mission successfully, but also recorded this process for the next competition.

## 5.2 Future Improvements

After going through the process from research and development to debugging equipment, we increasingly understand the importance of persistent learning. Basing on the challenge we met, we plan to make the following upgrades for future releases. At first, we decided to do more software testing since errors are often generate when we are going to add more tools on ROV. The reasons of that are because the operation and storage of the panel is too small. Thus, we decide to improve the panel and the control structure. Besides, we plan to add some popular machine learning frameworks like TensorFlow. Then, we are willing to change the Arrangement of electronic housing, as the arrangement now is preventing us from removing the panel, which wasted plenty of time on scaling circuit.

# Acknowledgement

Glaucus would thank the following supporters for their efforts and helps on the development of Glaucus.

[1] Southern University of Science and Technology (SUSTech) for providing educational support and sponsorship.

[2] Department of Mechanical and Energy, SUSTech, for providing workspace and sponsorship.

[3] BioRobotics and Control Laboratory supervised by Prof. Zheng Wang for providing the technical guidance on design and construction.

[4] International League of Underwater Robot (ILUR) as organizers providing opportunities for competition.

[5] MATE Center for organizing the international underwater ROV competition and educating the public on marine technology.

# References

[1] Solidworks, Solidworks Forum. https://my.solidworks.com/forums?lang=cn

[2] Blue Robotics, Blue Robotics store. https://bluerobotics.com/store/

[3] MATE Center, Competition information. https://www.materovcompetition.org/archiveshome

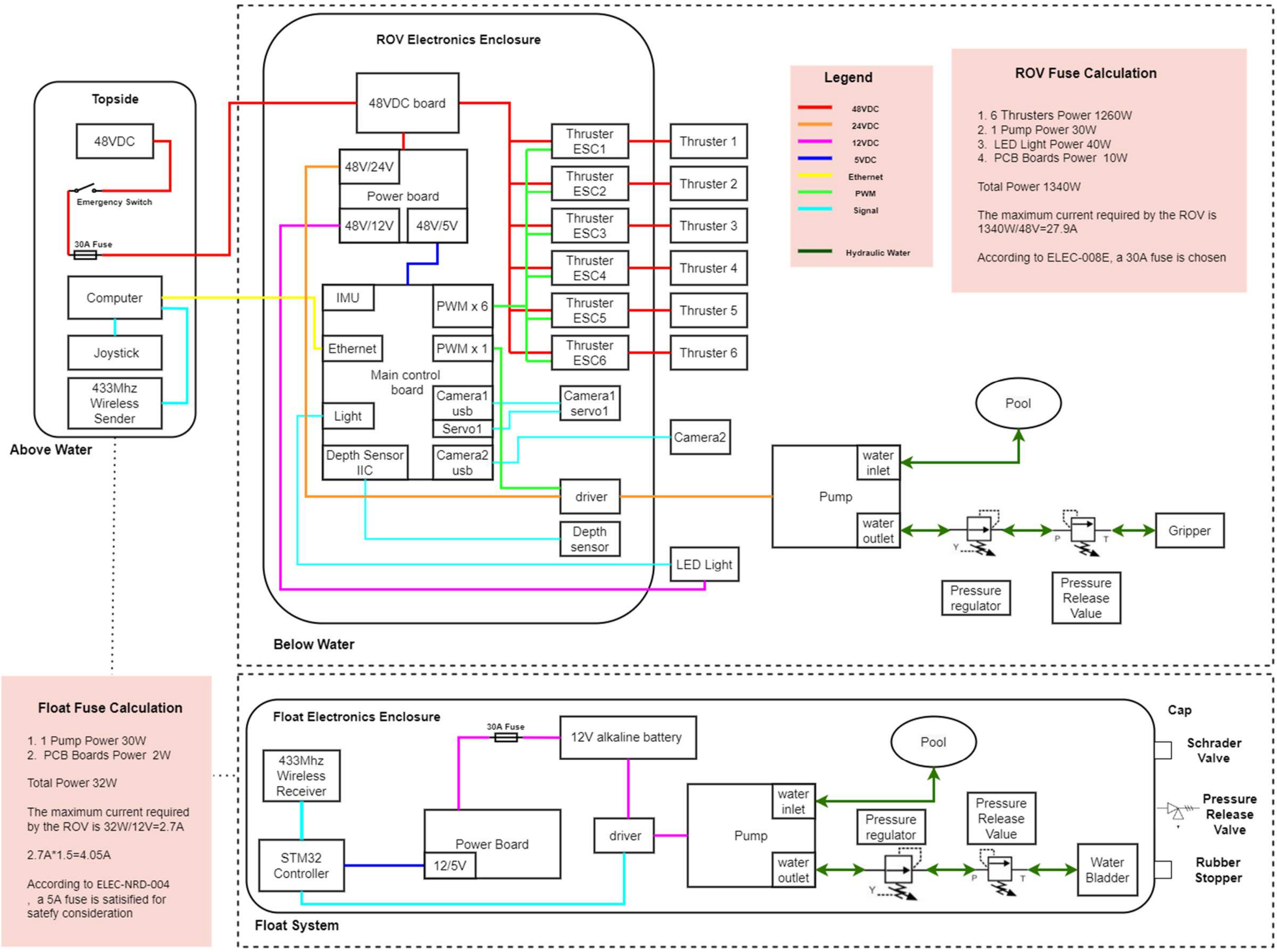
[4] JSAS Documentation. www.safetyworksmaine.com/safe_workplace/safety_management/ hazard analysis.html

[5] OpenCV, Opencv Documentation, 2021. https://docs.opencv.org/4.x/d9/df8/tutorial_root.html

[6] Govinda L, Salgado-Jimenez T, Bandala-Sanchez M,et al.Modelling, Design and Robust Control of a Remotely Operated Underwater Vehicle[J]. International Journal of Advanced Robotic Systems, 2014, 11(1):1.

# Appendix

## APPENDIX A: SID



# APPENDIX B: Budget

**Projected Budget**

| Category | Status | Total(USD) |
|---|---|---|
| University Funding | Southern University of Science and Technology | 3100 |
| Research Group Funding | BioRobotics & Control LAB | 1500 |
| | | Total Income: 4600 |
| Estimation | ROV Mechanical System | 500 |
| | ROV Electronical System | 1600 |
| | Grippers | 20 |
| | Float | 80 |
| | Surface Control and Power | 570 |
| | Public Outreach | 1050 |
| | Human and Material Resources | 500 |
| | Total Estimation: | 4320 |

# APPENDIX C: Cost Accounting

**Cost Breakdown**

| Category | Description/Example | Amount(USD) | Number | Total(USD) |
|---|---|---|---|---|
| **ROV Mechanical System** | ROV Frame | 132 | 1 | 132 |
| | Sealed Cabin | 129 | 1 | 129 |
| | Buoyancy | 91 | 1 | 91 |
| | Ballast | 70 | 1 | 70 |
| | 3D Printed Materials | 32 | 1 | 32 |
| **ROV Electronical System** | Cameras | 73 | 2 | 146 |
| | Raspberry Pi | 190 | 1 | 190 |
| | Light | 55 | 1 | 55 |
| | Sensor(Depth) | 88 | 1 | 88 |
| | Thruster | 171 | 6 | 1026 |
| **Grippers** | Soft Muscles | 10 | 1 | 10 |
| | 3D Printed Materials | 15 | 1 | 15 |
| **Float** | Sealed Cabin | 74 | 1 | 74 |
| | Ballast | 7 | 1 | 7 |
| | Battery and Cases | 14 | 1 | 14 |
| **Surface Control and Power** | DCAC Transform | 257 | 1 | 257 |
| | Main Control Unit | 216 | 1 | 216 |
| **Public Outreach** | Props | 34 | 1 | 34 |
| | Poster Printing | 13 | 5 | 85 |
| | Venue Rental | 95 | 5 | 475 |
| **Human and Material Resources** | Pool Rental | 287 | 3 | 861 |
| | Props | 130 | 1 | 130 |
| | | | Total Cost: | 4137 |

# APPENDIX D: Safety Checklists

**Procedure**

1. Before Mission

☑ Ensure the integrity and connection of all parts of the ROV
☑ Check the airtightness of the ROV by air-pump
☑ Check if the transformer power supply stably
☑ All cables are properly connected and protected with strain relief
☑ Ensure the continuous and clear communication
☑ Ensure that emergency stop is operational

2. During Mission

☑ Do not have anyone present in the pool
☑ The operator remains in control of the ROV at all times
☑ Dedicated person should take care of task of cable releasing and collection
☑ Dedicated person should observe the ROV from the shore
☑ Avoid collision between ROV and wall or bottom of the pool

3. After Mission

☑ Check the ROV body for dislodged parts or damaged areas
☑ Close the all functions of ROV
☑ Stop the power supply to prevent accidental touch finally
☑ Recycle and sort cables to keep tidy environment

Safety Officer Signature:

1. Entering the Workshop

☑ Sign the Workshop Safety Sheet
☑ Wear a mask
☑ Make sure PPE is well looked after and properly stored

2. Striking or Using Power tools

☑ Wear eye and face protection
☑ Drill bits should be kept sharp, not dull, chipped on rounded
☑ Make sure all the electrical connection are distant from Liquids

3. Operating Hand Tools

☑ Use tool holders
☑ Use tool belts designed for carrying tools
☑ Pay attention to the soldering iron or hot air hand tools

Employee Signature: