The 19th IET/MATE Hong Kong Regional of the MATE ROV Competition

OBSERVING OUR OCEANS: UNDERSTANDING OUR WORLD AND CREATING OUR FUTURE

Technical Documentation

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Team number:	
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1) Abstract

Upon the request for proposals issued by MATE, our company response by designing and building a remotely operated vehicle and the necessary sensors and tools to accomplish the four missions with complementary technologies to relocate ocean observing assets by releasing the multi-function node, deploy and connect the SMART Cables for Ocean Observing, understand ecosystems and saving species from the Red Sea to Tennessee and design and construct an operational vertical profiling float for ocean data collection.

Our ROV is fully designed to process underwater missions with the following equipment.

1. Six highly efficient brushless thrusters for mobility which are directly controlled by PWM signals. Two of them are for shifting the ROV towards left and right.
2. Four high-resolution wide-angled cameras positioned in different angles of the ROV for observation of the underwater environment clearly.
3. A rotatable robotic arm with grabber (payload) for holding and grabbing objects firmly for transport and release in any orientations.
4. A monitor with split views for showing the views from the four cameras simultaneously.
5. Other devices and features:
    - A. Temperature sensor for measuring temperature.
    - B. Python image processing programs with OpenCV to measure and create a scaled 3D model of the coral restoration area autonomously
    - C. A vertical profiling float for recording the pressure and the depth of the float verse time and be able to communicate with the surface control.
6. Safety is also our major concern. We maintain all safety precautions in design, building and operating the ROV.

(248 words)

Table of Content

I. Photo of ROV

Outlook of the our ROV (KTS-WaterLoong)

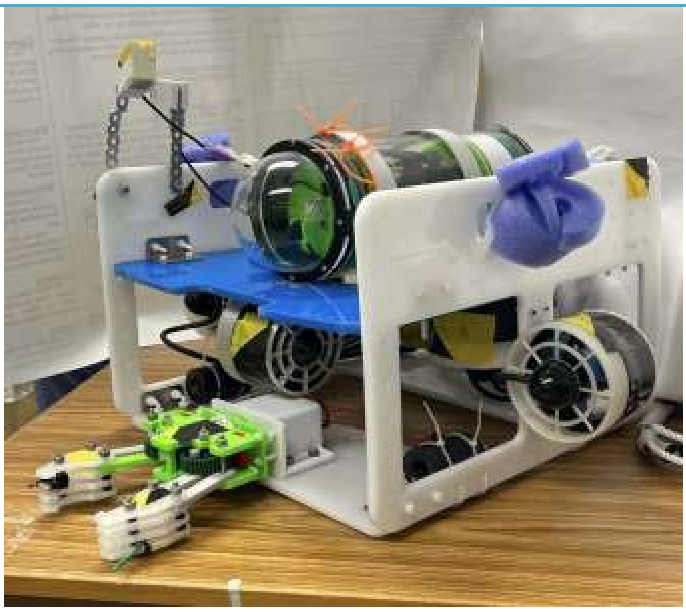

Fig 1.1 Perspective View of ROV

Fig 1.2 Top View of ROV

Fig 1.3 Front View of ROV

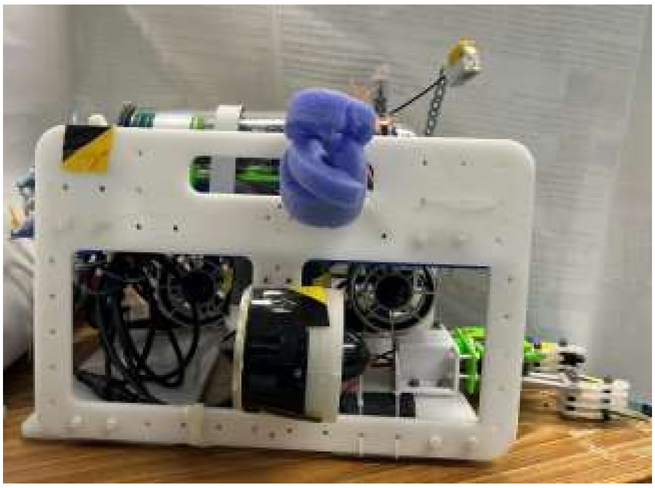

Fig 1.4 Side View of ROV (with rotated arm)

II. Design Rationale

Our team has undertaken modifications to enhance the design of our ROV by integrating innovative and recently developed components. We had several meetings and drew sketches for the design of the ROV. We also took reference of our previous ROV for the design. To achieve this, we have employed 3D-printed materials for the construction of various parts, including the fender for thrusters, camera mounts, and grabbers. Although designing the SD-models to print all by ourselves may be very time consuming, but this way we can have custom parts for our ROV and maximize the effectiveness. The utilization of these lightweight and flexible materials has enabled us to create a more compact and efficient ROV, which is of paramount importance in effectively demonstrating its capabilities in the esteemed MATE ROV Competition.

The fundamental elements of our ROV design primarily consist of a waterproof tube for housing electronic components, six waterproof thrusters, and a rotatable robotic payload tool. However, the considerable concern lies in the sluggish movement of the ROV underwater due to the resistance posed by water and power supply constraints. While these factors remain constant throughout the competition, our team has concentrated on two pivotal design rationales, namely efficient thrusters and a streamlined ROV design, to effectively address this issue.

Given the time constraint of merely 15 minutes to complete all designated tasks, our team strives to construct an underwater ROV that is highly efficient. Drawing from our past experiences, we have garnered knowledge that brushless motors outperform brushed motors in terms of efficiency, resulting in heightened speed and overall operational efficiency. For innovation, our company design and make efficient tools by own hand to reduce the cost, like the rotational robotic arms and their water proofed motors. Despite of the cost, the design of the rotational payload is highly efficient and low cost. When we build our entire ROV, we keep it within our budget.

In conclusion, our team's innovative utilization of 3D-printed materials, coupled with a focused approach towards efficient thrusters and a streamlined ROV design, serves as a critical design rationale in the creation of a high-performance ROV for the esteemed MATE ROV Competition.

III. Vehicle Core System

A. Mechanical

1. Framework

Fig 3.1 ROV body

The framework's overall performance and functionality play a crucial role in the competition. Highlighted in this report are the design and features of the ROV framework that our team has developed for the Mate ROV Competition 2023, emphasizing its two-tier design, integrated handles, and materials used.

Two-Tier Design:

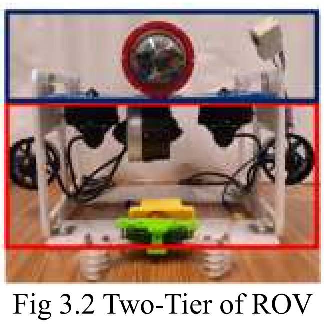

Fig 3.2 Two-Tier of ROV

To enhance serviceability and streamline repairs and maintenance, our team has implemented a two-tier design for the ROV frame. This design facilitates convenient access to the ROV's internal components, simplifying the process of conducting necessary repairs or maintenance tasks. Furthermore, the design promotes effortless mounting and repair of payloads, effectively minimizing downtime.

Integrated Handles:

Our team has integrated handles on each side of the frame to facilitate easy retrieval and launching of the ROV from any direction. This feature improves the ergonomics of the ROV and makes it easier for operators to handle the ROV when deploying or retrieving it from and to the swimming pool.

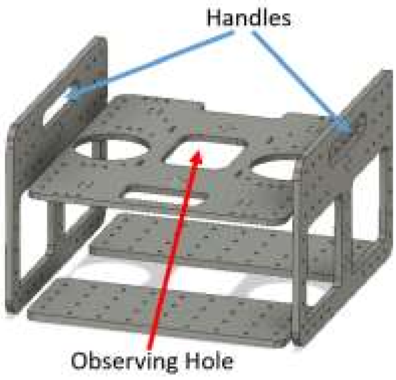

Fig 3.3 ROV frame body

Observing hole:

To ensure efficient mission completion, we have incorporated a hole at the bottom of the ROV, allowing for a wider field of vision. This feature enables us to observe the seabed clearly to perform the mission while navigating underwater .

Materials Used:

The ROV frame's top and side plates are constructed using High-Density Polyethylene (HDPE), a polymer selected for its cost-effectiveness and rigidity in comparison to other polymers like Delrin. HDPE also exhibits superior fatigue resistance, ensuring increased durability for the ROV framework.

To minimize costs, material usage, and weight, the bottom plates of the ROV frame were designed as thin strips instead of a single plate. This design choice enhances serviceability by simplifying the process of mounting and repairing payloads. Furthermore, the frame features regularly spaced M5 holes throughout, providing ample options for component placement and weight distribution adjustments, thereby enhancing the ROV's versatility.

2. Buoyancy

i) Water-proofed plastic Cylinder and foams for ROV buoyancy

Achieving neutral buoyancy is crucial for ensuring efficient maneuverability of an ROV. The frame and tether of the ROV are constructed using waterproofed plastic material and foam, which aid in maintaining neutral buoyancy by balancing the ROV's weight. Upthrust is generated by water proved cylindrical chamber at the top of the ROV and foams, counteracting its weight of the ROV. The pair of opposite forces, therefore the resultant vertical forces balance up and down, and the resultant force is zero.

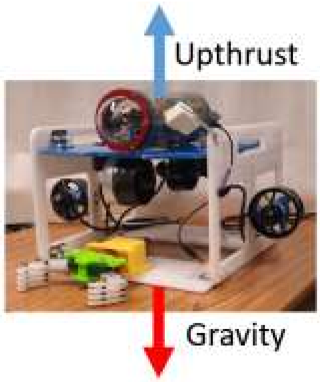

Fig 3.4 Buoyancy supported by cylinder

Additional foam is added to achieve balance on the left and right sides of the ROV. This maintenance of neutral buoyancy enables the ROV to maneuver with greater effectiveness. Swimming foam, an affordable and readily available material, is utilized to maintain buoyancy in the ROV. This allows for the attainment of neutral buoyancy, ensuring the ROV remains at the correct water level by balancing the net force acting upon it. To maintain the center of buoyancy below the center of gravity of the ROV, the main control box is installed at the upper center of the ROV body and positioned behind two thrusters. This arrangement minimizes additional water resistance caused by the thrusters while preventing uneven torque and tilting of the ROV. To test the ROV's buoyancy, it is submerged underwater, and various amounts of foam are added through repeated tests until neutral buoyancy is achieved, allowing the ROV to maintain its position underwater. Overall, the attainment of neutral buoyancy is vital for optimal performance of the ROV, necessitating careful consideration of the materials used.

ii) Buoyancy on the Tether

Furthermore, there is a 16-meter long cable connecting the ROV to our other devices, accompanied by additional wires. The weight of the cable also affects the buoyancy of the ROV. To ensure that the ROV's cable maintains neutral buoyancy, we have punctured it and inserted foam. The foam, being less dense than water, generates upthrust and offsets the weight of the cable. Testing is conducted to determine the neutral buoyancy, which occurs when the average density of the cable matches the density of the surrounding fluid in which it is submerged. We tie the tether in a circle neatly in order to deploy it more conveniently.

Fig 3.5 Tether wrapping by foams

(photo credit: Ben)

3. Propulsion

The propulsion system of the ROV for the Mate ROV Competition 2024 is a critical component that plays a significant role in achieving high levels of efficiency and maneuverability in water.

The T200 brushless thrusters are known for their high efficiency and reliability. Although T200 brushless thrusters are relatively expensive, they are known for their high efficiency and reliability making them an ideal choice for our ROV. They offer higher maximum thrust of 7.8lbf (34.696N) with a low current drawn, which results in consuming less power, and are designed to operate underwater. Moreover, the thrusters have an integrated speed controller, enabling precise control over the ROV's movements.

In previous year, we had been using 6 thrusters to control the movement of ROV, two for float and sink, four OMNI arrangement thrusters for a 360 degree directions of movement. However, the efficiency of the 360 degree of movement is lowered to about 70% only. To solve this problem, we focus on the panning movement of the ROV (shifting left and right).

3.1 Position of propulsion system

Building upon our previous experiences and feedback, we have made an improvement in the design of our ROV. In our latest iteration, we have incorporated two additional thrusters strategically positioned in the middle of the ROV. This innovative configuration provides a crucial ability for horizontal panning, allowing our ROV to navigate effortlessly in both left and right directions.

The introduction of these extra thrusters has revolutionized the flexibility and maneuverability of our ROV compared to its predecessor. In the previous design, the ROV was limited to rotational movements only, which posed challenges in certain scenarios. However, with the incorporation of these new thrusters, we have overcome this limitation and opened up a world of possibilities.

After discussion, our team has decided to use six T200 thrusters from Blue Robotics to power our ROV instead of only four. It is due to its highly efficient, superior performance and reliability. For convenience and a better movement with different directions, the propulsion system of this year will be supported by six Blue Robotics T200 thrusters.

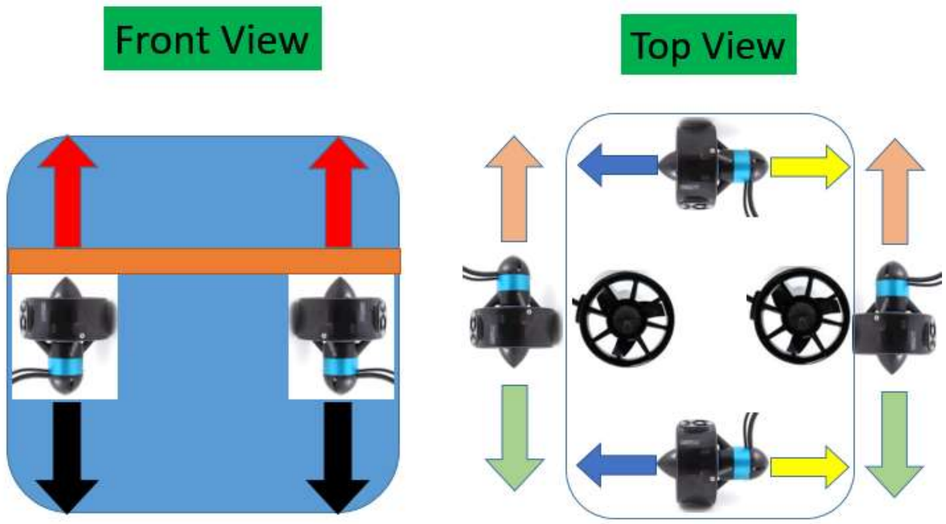

Fig 3.7 Position of the six Thruster (by Karel)

We continue to allocate two thrusters for float and sink movement of the ROV. We put 2 thrusters to control forward, backward, left-turn and right-turn. To achieve left-right shifting, we reposition the two thrusters in the lower deck which facing horizontal toward left hand side such that it can provide a net force to either left or right. The diagrams below illustrate how the movements are being controlled by thrusters.

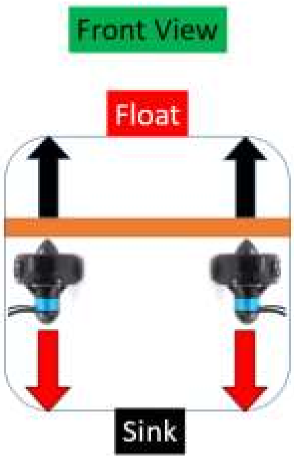

Fig 3.8 Float and sink movement

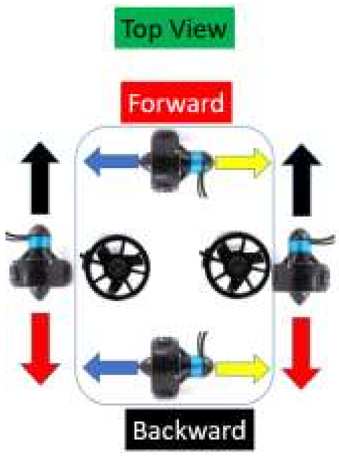

Fig 3.9 Forward and backward movement

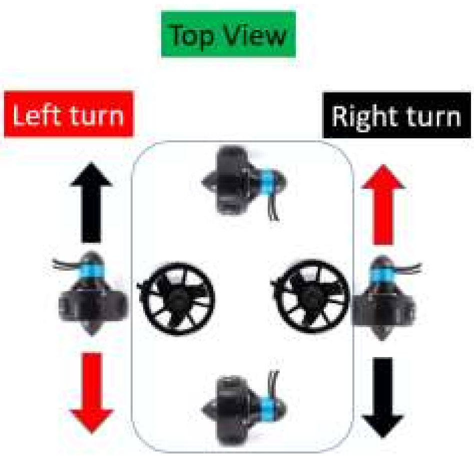

Fig 3.10 Left and right turn movement

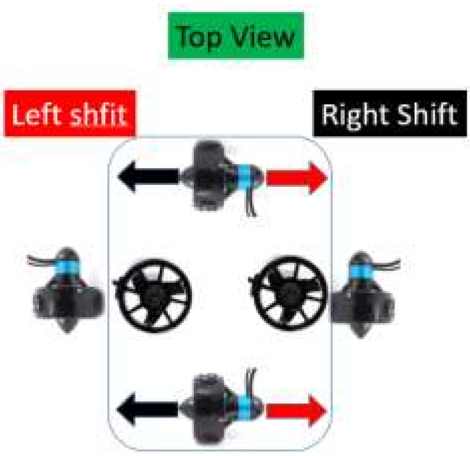

Fig 3.11 Left shift and right shift movement

One notable advantage of our current design is the enhanced efficiency it offers. Unlike the previous omni movement design, where energy from the thrusters could be wasted in non-optimal directions, our new configuration ensures that every thruster contributes directly to the intended movement. This optimized energy usage translates into longer operational periods and increased overall efficiency.

Moreover, the stability of our ROV has been significantly improved with this new design. Previously, even slight differences in the power output of individual thrusters could impact the direction of movement. However, our current configuration mitigates this issue by distributing the thrust across multiple thrusters, reducing the influence of minor variations in their performance. As a result, our ROV maintains a more consistent and predictable movement pattern, enabling precise navigation and control. Thrusters are controlled by program by accepting joystick input and convert to PWM signals.

The core of the T200 thruster is sealed and protected with an epoxy coating and it uses high-performance plastic bearings in place of steel bearings that rust in saltwater. This guarantees a better performance in the ocean.

Fig 3.12 3D-printed protective cover for both sides. (photo credit: Karel)

4. Payload with rotating Arm

The ROV's payload is made to pick up items and snag its equipment. The original of the design is excellent to grab and hold any objects. It is because when using the gripper, it cannot securely grasp an item with a servo motor. This is due to the fact that servo motors must continuously supply an electrical force in order to maintain the force necessary to securely grip an object. To push the arm forth or backward in accordance with the assessment, we designed a **worm gear system** that is powered by a motor and provides extremely high strength. So, depending on how the worm gear and motor are moving, the arms can be opened or closed.

Fig 3.13 3D design of the payload with worm gear system (Photo Credit: Cheung)

This design is difficult to alter the condition of the arm without manipulating the motor since the gear ratio is greatly enhanced by the worm gear. As a result, even in the absence of electricity, the gripper can securely hold an object. A screw cap with two joints and a long screw is used to operate the gripper. Two fixed joints pull down as the gripper tightens up as the screw turns clockwise. The two fixed joints raise and the gripper opens when the screw spins counterclockwise. These enable the gripper to grasp and release things in order to carry out various duties. This is an obvious advantage. Our payload has a very high strength to push the arm outward or backward accordingly. Hence the arms can be opened or closed tightly.

Furthermore, grabbing objects in different orientation is also essential. We design to position a smaller motor to adjacent to the main grabber with gears which forms a gear system. in the system, the driver gear has 12 teeth whereas the driven gear has 36 teeth. It makes the rotation slower but stronger. So that we can control the grabber to grab vertically or horizontally. The difference is 90 degrees. If the rotation speed is too fast, it will be difficult to adjust to 90 degrees.

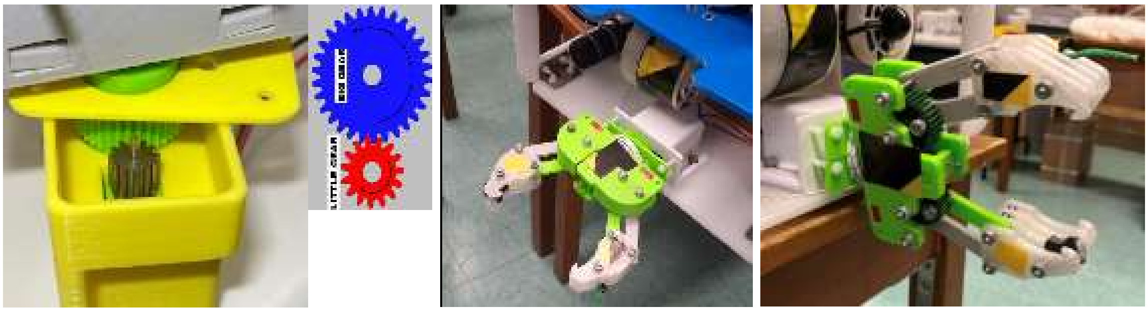

Fig 3.14 Rotatable grabber design (photo by CKH)

As the motor rotated more slowly, which helped it change to the appropriate angle. As a result, the gripper can grab an object both vertically and horizontally, giving us the benefit of easily picking up objects while considerably reducing the system's size and weight. Finally, all components are fastened in a 3D-printed platform. The design makes it simpler for the ROV to take up objects. Making a gripper system that works properly takes a lot of effort since even a small error may wreck the entire system and even influence the operations.

Since the motor needed to be water-proofed, we make by our own. The cylindrical tubing is then filled with petroleum jelly, epoxy is added, and the tube is sealed to guarantee that no water can flow into the engine. This makes the motors waterproof. They are done by putting epoxy into the cylindrical tubing, filling the tubing with petroleum jelly and sealing the tube with epoxy to ensure that no water could leak into the motor. The rotating system's motor is waterproofed using a similar process to how the gripper system's motor is. The cables were linked to the ROV's control unit using a watertight plug. The wires are connected to the control unit in the ROV via a waterproofed plug.

B. Electronics

1. Electronic speed control (ESC)

To control brushless motors effectively, an Electronic Speed Controller (ESC) is essential. This device serves as an electrical circuit that enables dynamic braking of the motor and allows for precise control over its speed and direction. In our project, we incorporated an ESC to facilitate the control of the brushless motors in our ROV, specifically the KTS-WaterLoong.

Fig 3.15 Blue Robotics Basic ESC

The ESC acts as an intermediary between the thruster commander and the motor. It receives the Pulse Width Modulation (PWM) signal from the thruster commander, which contains information about the desired speed and direction of the motor. Based on this input, the ESC adjusts the timing of transistor switches within its circuitry to regulate the flow of current to the motor windings. By precisely timing these transistor flips, the ESC can control the rotation of the motor. Depending on the desired direction, the ESC adjusts the timing to facilitate either clockwise or anti-clockwise rotation of the motor. This capability allows for versatile maneuvering of the ROV in various directions.

Furthermore, the ESC provides dynamic braking functionality, which allows for quick deceleration and stopping of the motor when needed. This feature is particularly useful in scenarios where rapid changes in speed or direction are required. By incorporating an ESC into our ROV's propulsion system, we have gained fine-grained control over the brushless motors, enabling us to navigate and maneuver the ROV with precision and responsiveness.

2. Main Control box of ROV

To control the movement of our ROV, we opted to use an Arduino board for programming. It is capable of generating PWM signals, which are used to control the ESC. We chose the Arduino board because it is programmable compared to the thruster commander of bluerobotics. To operate the ROV, we incorporated PS2 gamepad into Arduino for controlling its movements by sending out PWM Signals.

Different features of the ROV, like the Payload, robotic arm rotation, are controlled using electrical buttons that respond quickly. So that the pilot can focus on controlling the ROV movement and co-pilot responsible to other operations.

Fig 3.16 PS2 gamepad for controlling of ROV.

In terms of design, we divided the monitor box into two boards: the electronic part and the main control part. This way, we avoided stacking all the electronic components on a single board. The electronic part, located at the bottom, consists of components like the Arduino board, ammeter, and cable connections. On top, the main control part includes buttons to power on the ROV, control the grabber motor, and manage the thruster. By employing these techniques and organizing the components in a clear manner, we have created a user-friendly control system for our ROV, enabling precise and efficient operation in various underwater tasks.

Fig 3.17 Main ROV Control panel

3. Camera

3.1 Positions and mechanism

Fig 3.18 Water-proofed Camera

The ROV is equipped with three cameras and one USB camera to enhance vision for accomplish different missions and imaging processing. Two cameras are positioned inside the waterproofed cylindrical closure. One offers front view for navigation, another one provides a bottom view for observation. The third camera is positioned on the left-hand side of the ROV, focusing on the gripper, which helps the pilot estimate the destination of objects.

All cameras are connected to a monitor, which is divided into four sections using a video splitter. This setup allows real-time images captured by the cameras to be displayed simultaneously. The four-camera configuration not only facilitates product demonstration but also enables the pilot to effectively operate the ROV for specific tasks in real-world dam restoration work.

The USB the camera is dedicated to piloting as well as examine and measure the dimension of the coral. The USB camera also provides the vision for image processing program to generate the 3D model of the Coral.

3.2 Interference reduction and Voltage stabilization

To address the issue of current interference, a capacitor has been incorporated into the system. The rapid changing of the thruster current cause sudden fluctuations of the current, leading to an unstable power supply to the camera. This instability often results in signal interference and a blurry image.

Fig 3.20 Image displayed in LED monitor

Last year, by utilizing a capacitor and a VBS-Diode, the excessive voltage generated by the thrusters is promptly stored. This helps stabilize the current flow and ensures a consistent and reliable power supply to the camera. As a result, the interference is minimized, and a clearer image is maintained throughout the operation. The capacitor and VBS-Diode act as a safeguards, preserving the image quality and enhancing the overall performance of the system.

Fig 3.19 TVS-Diode

However, we want to further improve the quality and stability of the video signals this year by a separated power connection to the camera in minimize the interference caused by thrusters.

Instead of connecting the wire to the main power supply, we connect an additional power source for the camera by a voltage regulator which acts as a stabilizer to step down the 12V power to a constant 5V voltage level despite any fluctuations in the main power supply caused by the operation of the thrusters. This helps prevent sudden voltage spikes or drops that could impact the camera's performance. With a stable power supply provided by the voltage stabilizer, the camera can function optimally, ensuring a continuous and clear image feed. This is crucial for piloting the ROV effectively and obtaining accurate visual information from its surroundings. We got a prominent result after testing.

Fig 3.20 12V to 5V DC regulator

We have a voltage regulator to ensure that our voltage is stable. In order to be prepared for any accidents, we have a spare voltage regulator ready to replace it if broken.

4. Waterproofed electronic components and plugs

We use waterproof plugs (waterproof performance of IP65 (International Protection Code) to connect wires from the ROV to the surface control box. The 4-pin waterproof plug is also easy for replacement.

The waterproof cylindrical closure is used to contain all electronic components, like ESC and the voltage convertor and camera. It is useful for protecting the electrical circuit and avoiding electric shock. The closure is designed for easy components replacement. A broken part can be replaced in a short time. Or if there is a main issue for the circuit inside the box, it can be replaced with a new one without disassembling other components. That makes repairs easier and more user friendly.

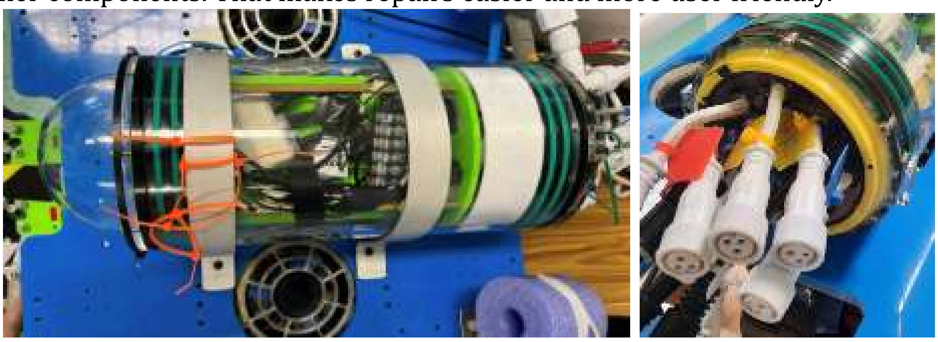

Fig 3.21 ROV waterproof cylindrical closure (Photo by Javen)

In addition, the waterproof cylindrical closure and plug also avoids potential human error caused by incorrect wiring (mismatched the corresponding pins). The dull edge on the plug helps ensure the correct pin connections. This is useful for us since there are many wires we need to use for different aspects, and they may twist together and get tied up. We wasted much time in the past fixing such a problem. Regarding the holes for cable connection in and out of the box, we also sealed them with an AB Proxy agent to make them waterproof.

We also poured epoxy into our electronics. Epoxy resins are a class of reactive prepolymers and polymers which contain epoxide groups. They are ideal for waterproofness. This ensures a better insulation between the devices and water and allows the ROV to function in a more stable way.

Fig 3.22 Waterproof plug (cross section)

Fig 3.23 Waterproof plug

To ensure the motor remains protected from water ingress, a waterproofing process is implemented for each camera. This involves placing the camera inside a specially designed rectangular 3D-printed container and completely sealing it by filling the container with epoxy. The chosen epoxy is transparent, minimizing any impact on the camera's visibility compared to other materials. Moreover, a waterproof plug securely connects the camera's wires to the control unit within the ROV. This setup enables the gripper to grab objects in both vertical and horizontal orientations while maintaining a clear image.

5. Mission Specifics

Missions of this year involved a lot of transferring objects from one place to another for "Global Ocean Observing System" and "Protect and restore ecosystems and biodiversity". We highly depend on the mobility of the ROV and the rotation payload. The skills of pilot and copilot are needed to be well trained for the missions. For "Unlock ocean-based solutions to climate change", the vertical float is built from scratch on paper to prototyping and to final the design. A number of programs are must needed to fulfilled the task requirements. The following tools or actions summarized our mission specifics.

Task #1: Coastal Pioneer Array The action included are trigger the nodes, pull the pin, grab and return the recovery float. We will mainly use the rotatable grabber to achieve the tasks.	 Grabber
Task #2: SMART Cables for Ocean Observing: "Undersea cables connect the planet – what if they could help save it?" The action involved are hold, deploy, return the SMART cable and place the SMART repeater in the designed area. We will again mainly use the rotatable grabber to achieve the tasks. For the water temperature measurement, a high precise temperature sensor is equipped on the ROV to take the measurement. It is affixed in front of the gripper so that the sensor can extend to the specific area and record a more accurate temperature.	 Grabber  Fig 3.24 Temperature sensor

<table>
<tr>
<td>Task #3: From the Red Sea to Tennessee: Understanding ecosystems and saving species
We will use the rotatable grabber to accomplish the following tasks.
3.1 Place and deploy probiotic irrigation system and
3.2 Transplant branching coral and brain coral

For task 3.3 - 3D Coral Modelling, at the beginning of our plan, we use python with OpenCV to recognize and measurement of the coral automatically. The measuring process is done by analyzing the images collected and use computational program to calculate the dimension. Lastly, we will use computer program simulation to regenerate the model. However, we are still trying hard to make is work. A lot of programming skills are included. In case we cannot have enough time to do it automatically, we will take a picture of the coral. After that, the co-pilot will use the python program to measure the length and the height of the coral by calculating the ratio between the coral and the cube. Then, the collected data will be sent to another program, which generate the 3D model based on the data.
For task 3.4 - Determine the location of sturgeon spawning grounds, we create a program that allow the pilot to enter the data provided by the judge, which can generate the graph automaticity by python or excel
Either way is efficient.

Lastly, we will collect a sediment sample (stone) by fish net.</td>
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Fig 3.25
USBCamera
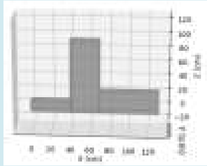
Fig 3.26
Sample 3D model generated

Fig 3.27
Sample Data graph

Fig 3.28 Fish net</td>
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<td>Task #4: MATE Floats!
Deploy the MTAE float, measuring depth and communication between station. The detail design and mechanism will be discussed at the next section.</td>
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C. System Integration Diagram

System Integration Diagram – Electrical

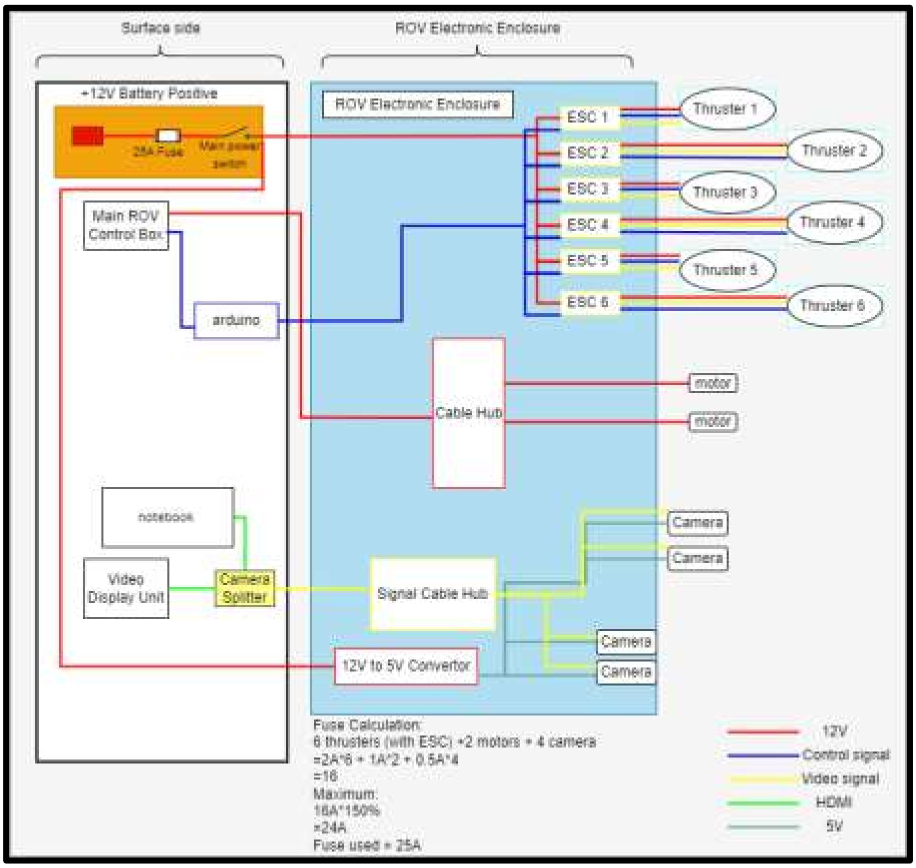


Fig 3.29 SID of the Main ROV system

D. 3D Design Software

Autodesk Fusion 360

We continue to use Autodesk Fusion 360 Education License to design the ROV structure and all the components that are intended to be build or mounted to it. The software helps us to design parts more efficiently and accurately by providing the actual distance. The 3D design software helps us design the ROV framework joins, thruster protect cover, the rotatable grabber, internal frame of the vertical float and attached parts of the camera. Waterproof cables junction containers waterproof ring container for putting eproxy are created by the 3D design. This software provides accurate measurements and allows us to create detailed, precise designs that are essential for the successful operation of the ROV. It reduces the time for the crew to build various parts of the ROV.

Fig 3.30 Use of 3D design software – Fusion 360(Photo Credit: Hormann)

<u>Prototype design</u>

We use the 3D design software to sketch out the design of the ROV structure and all components which will be mounted to the ROV. By creating a simulation of the ROV and prototyping our design, we can improve the positioning of the major components which increase the safety and performance of the ROV.

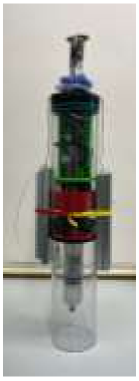


Fig 3.31 Vertical float

IV.Non-ROV device

A. Devices-vertical profiling float

Our company's aim is to establish a worldwide network of chemical and biological sensors to monitor the health of the oceans. We make a platform for oceanographic instruments that can take measurements in the ocean without requiring a ship, propeller, or human operator.

B. How we make the device

A PVC tube was used as the body of the float last time. However, we think that using the PVC tube as the body was too large. Therefore, we have made an improvement by using a cylinder tube as the main body this time. There is still a combination of a linear actuator and a syringe inside which can push water out or suck water into the syringe. It is used to control the density of the whole device by changing the amount of water in the syringe. Also, epoxy was filled in to prevent the device from getting wet and short circuit due to the inflow of water.

Fig 3.32 Vertical Float

(i) buoyancy engine

We use buoyance engine to make the vertical float and sink. The mechanism of of the buoyancy engine is that we have large syringe built inside the float. The piston of the syringe is attched with a linear motion actuator which can be extend or retract for controlling the inhale or exhale of the water in and out of the float. This will alter the overall density of the float.

When the linear motion actuator extends, it pushes the piston of the syringe. Water is exhaled out of the vertical float, hence it become less dense than water. Consequentially. it floats towards surface. (Fig 3.33A)

Fig 3.33A (Vertical Float floats)

Fig 3.33B (Vertical Float sinks)

On the contrast, when the linear motion actuator retracts, it retracts the piston of the syringe. Water is inhaled out of the vertical float, hence it become denser than water. Consequentially. it sinks to the bottom of the pool (Fig 3.33B)

(ii) electronic and communication

We made a holder to hold all the electrical components inside the cylinder, so that all electronic components can be placed inside of the body neatly. The Arduino serves three functions:

1. detecting the depth of water by MS5837 depth sensor
2. controlling the positive and negative poles of the H-bridge to regulate the movement of the actuator
3. communicating with and sending data pack to the surface control unit by HC-05 (bluetooth communication component)

There is a water proof on/off plug which when is tighted, the circuit will bed closed and the vertical strts operating. On the other hand, when the plug is loosen, the circuit wwill be opened ehcih turn off the vertical float.

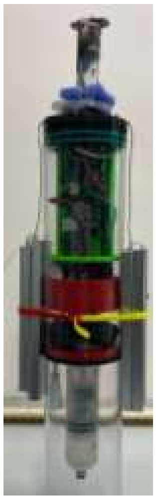


Fig 3.34
Vertical Float

(iii) Waterproof

To create a waterproof cylindrical closure is used. It is done by double O-ring to prevent water to get in the vertical float. Additionally, we fill the cap of the tube with epoxy to ensure no water flows in the tube.

(iv) Security

The enclosure housing is also designed with a 3cm diameter hole and affixed with a syringe so that it will open if the pressure inside the housing is greater than the outside pressure. And under no condition housing will be built with fasteners to hold the device together if there is no pressure release valve.

Fig 3.35
Pressure release

V. Build Vs buy, New Vs Used

In discussing the “build or buy” issue, our team firmly believes in the principle of building as much as possible when it comes to the "build or buy" issue. While purchasing a complete tool from the market may save time, it would also cost considerably more and provide less enjoyment. We are convinced that through the process of designing and building, we can gain a deeper understanding of the product's mechanisms, develop a greater appreciation for the product in the market, and most importantly, evaluate ready-made market products. After carefully evaluating both the ready-made product and our own craftsmanship skills, we made the decision to proceed with building the product ourselves. The following items are too expensive to purchase from the market.


Fig 5.1 ROV body


Fig 5.2 Payload (Gripper)


Fig 5.3 Water proofed camera

Here are tables capered in the commercial product and self-made tool of the ROV. KWOK TAK SENG INC. found that the commercial products are generally more expensive than homemade. The design of commercial products requires further modification before adapting to KTS-WaterLoong. Therefore, our company decided to make a self-made gripper for various missions in different tasks and camera for our ROV for better vision during the competition.

	Pay load (Gripper)	
	Ready-made product	Self-made
Cost($)	HK$ 6000	HK$200
Time use(days)	About 10 days(including shipping)	About 5
Modification difficulties	High	Low
Maintainability	Low	High

	Water proofed camera	
	Ready-made product	Self-made
Cost($)	$800	$300
Time use(days)	About 10	About 5
Modification difficulties	High	Low
Maintainability	Low	High

As for the thrusters, camera and ESC (electronic speed controller), it is too difficult for high school students to build them. The self-made thruster performance was under our expectation the thrust power is not large enough. Also building a thruster from raw material may be higher than the commercial price. After a series of research in the commercial product from the market, KWOK TAK SENG INC. found that Blue-motor has a high efficiency of power and is most suitable for our ROV. In conclusion, we are going to purchase these items from commercials.

As the body and the gripper of ROV, we draw a 3D graph ourselves. We can custom make the part to fit in the ROV and more suitable for us to create and design the ROV. Modifying part by part, we can build some components that cannot be found in the market. It is also easy for downsizing as this provides a higher performance of the ROV. In addition, we also found two re-used items which are temperature sensors from previous years for Task 2 mission to measure the temperature under water accurately. They are suitable for us to use this year.

VI.Safety

The safety of every team member is highly valued, and as such, safety is always given top priority in every domain of work. To minimize the likelihood of accidents, we have created a safety checklist.

Safety precautions

Safety is a top priority in the workshop, and several measures are taken to minimize accidents. The team places great emphasis on personal appearance, with shoes being tied neatly and safety glasses being worn at all times. The workspace is kept clean and tidy, with waste removed promptly to prevent tripping hazards and fire risks. Wires are arranged neatly to avoid overloading circuits, and the workspace is divided into sections to minimize distractions and reduce the risk of injury from nearby tools. When handling hazardous materials, such as corrosive fluids and high-temperature objects like epoxy and chloroform, gloves and masks are worn to prevent exposure to toxic substances or skin irritation. Glasses are worn during soldering to avoid burning the skin. Before leaving the workshop, all dangerous tools are turned off and returned to their proper positions.

These measures help to ensure that the workshop is a safe place to work, and that team members are protected from potential hazards. By prioritizing safety and taking proactive steps to minimize risks, the team is able to create a productive and fulfilling work environment. The emphasis on personal appearance and workspace organization helps to prevent accidents such as tripping or wire overloading, while the use of protective gear and careful handling of hazardous materials minimizes the risk of exposure to toxic substances or skin irritation. Overall, the team's focus on safety helps to create a safe and productive workplace for everyone involved.

Safety feature of ROV

- ✓ To prevent injuries caused by people putting their fingers or other body parts into the motor, the propeller is enclosed by a plastic case and covered with red warning tape to indicate the danger. In addition, sharp edges are either rounded or protected by plastic tubing or adhesive tape, or rubbed off to minimize the risk of injury further.
- ✓ Accessories are waterproofed inside the waterproof boxes.
- ✓ Fuses are used to protect the circuit, the same as the output devices.
- ✓ Plugs are kept away from the water source and dry to prevent electric shock.
- ✓ To prevent accidents from the wrong connection of plugs and unauthorized operation of the ROV. The operation must be authorized by Chief Operator or CEO who will double check the all connections. This process helps to increase safety and prevent accidents from unauthorized access and incorrect connections.

The following table (Table 6.1) shows some of our adoptive safety measures:

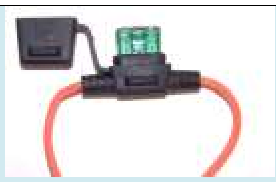
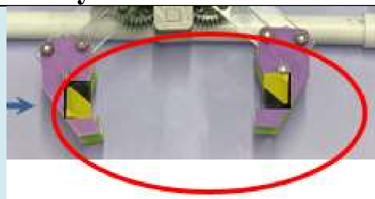
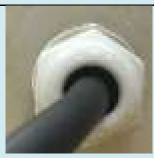
 Use of Anderson power plug	 In line 25A fuse within 30cm	 Sharp edges are label by yellow and black
 Thrusters are shrouded and guarded	 Use of strain relief	**We will not use pneumatic system this year.**

Table 6.1

VII. Challenges and Troubleshooting Techniques

Making a ROV is very challenging as it requires creativity, knowledge and cautiousness. While we were building KTS-WaterLoong, we encountered many difficulties.

A) Vehicle testing methodology

A small pool built up for the testing of the movement of the ROV and the vision of the camera underwater, the performance of waterproofing etc.

B) troubleshooting strategies and techniques used

Thoroughly inspecting the ROV's components, wiring, and connections to pinpoint the problem. In addition, referring to technical documentation and manuals can provide valuable insights. Employing diagnostic tools, such as multimeters or oscilloscopes, can aid in identifying electrical issues. make a group discussion for sharing knowledge and ideas. Testing and prototyping regularly during the building process Keep a record of the steps you take to fix problems and what results you get.

C) use of prototyping and testing to evaluate design options

During the construction of the grabber for our underwater ROV we employ a systematic approach of designing and testing multiple iterations. Through the use of simulations, we evaluate the performance of each design in various tasks, with a particular focus on the grabber's ability to securely grasp objects. By subjecting the designs to simulated scenarios, we can identify strengths, weaknesses, and areas for improvement. Any design that falls short undergoes modifications and is retested until an optimal solution is achieved. This iterative process ensures that the final grabber design is well-suited for its intended underwater tasks, delivering reliable and efficient performance.

D) Some of the probelmthat we encoutnered and solve.

A)	**Unstable voltage:** We discovered a problem that the voltage isn't stable. Unstable voltage can also damage the power supply. Voltage spikes or surges can overload the power supply circuitry, causing components to fail or even leading to permanent damage.
Solution:	After a few discussions, we decided it would be best to add a 12V to 5V transformer in order to stabilize the voltage. Now with stable voltage, the rov can operate at its optimum energy efficiency.
B)	**Power and signal supply for USB camera:** We found out that the power and signal supply for the USB camera must be separate and we cannot take those from the computer. Even if the camera manages to power on without proper supply, it might not operate at its full capacity or resolution.
Solution:	We got the power from the waterproof storage and got the signal from the computer. This way we have a stable power and signal supply. When the camera has consistent power and signal supply , it becomes more reliable, experiencing fewer malfunctions, disconnections or errors.
C)	**Programming issues:** As we have to use our camera to generate a 3D model, we have to add many camera libraries like OPENCV and NUMPY. Their attributes may differ from different python versions; this will cause attribute error.
Solution:	To fix that, we have searched many websites and studies that use the latest code which allows us to run the program successfully. Now that the program can run smoothly, we can continue with other tasks.

VIII. Lesson Learned

8.1) Technical skills

During our latest lesson, we delved into the subject of waterproofing, as well as the intricacies of connecting various electronic components and designing 3D models for use in 3D printing. This year marked the first time we utilized 3D models to create and build our ROV, which presented some challenges in terms of fitting different parts together. Despite utilizing Fusion 360 to measure gap sizes and modify our 3D graph, we still encountered some difficulties. Additionally, we incorporated a new system from BLUE ROBOTICS to control the ROV, which required us to figure out how to connect all the different parts together to ensure proper functionality. Through this experience, we gained valuable skills in waterproofing, electronic connections, and 3D modeling, but we acknowledge that there are still some challenges to be faced in utilizing Fusion 360 effectively.

8.2) Interpersonal skills

Lessons about interpersonal relationships. Effective communication is essential for successful teamwork, and participants must be able to convey their ideas clearly and receive feedback constructively. Conflict resolution is also crucial for maintaining positive relationships within the team. By addressing conflicts directly and finding mutually agreeable solutions, participants can avoid long-term damage to their relationships. Trust is another essential factor in effective teamwork, and participants must trust that their team members will complete their tasks on time and to the required standard. Embracing diversity and valuing different perspectives can lead to more creative solutions and stronger relationships within the team. Overall, the MATE ROV competition provides an excellent opportunity to develop interpersonal relationships and learn valuable skills that can be applied in various contexts. By practicing communication, conflict resolution, trust, and diversity, participants can build stronger relationships with their team members and work more effectively towards a common goal.

IX.Further improvement

9.1 A clear working schedule

Since each member's schedule is different, sometimes some members do not have spare time to work. That means much work is delayed, which affects teamwork and working efficiency. To ensure efficiency and improve teamwork, a clear arrangement of members' working schedules is needed.

9.2 Teamwork

In order to enhance our workflow, we have implemented distinct working departments to handle various aspects of our tasks. However, we have encountered challenges arising from a lack of effective communication between these departments, leading to frequent conflicts in design. As a consequence, a significant amount of time is wasted on redesigning. Recognizing this issue, we sought guidance from our advisor and subsequently organized multiple meetings to facilitate discussions on design and progress. The outcome of these efforts was a marked improvement in efficiency and productivity. Moving forward, it is imperative that we enhance our teamwork by engaging in more thorough discussions prior to finalizing the design for future projects, such as the ROV project.

9.3 The build up of specific strength

Our team has faced difficulties in programming and 3D designing tasks due to a lack of knowledge in certain modules, compounded by a limited number of skilled members. This has hindered our progress. To address these challenges, we need to recruit more software engineering skilled members and provide basic training for all team members. These measures will enhance our capabilities, minimize knowledge gaps, and promote a more efficient working environment. Our goal is to empower the team to tackle programming and 3D design tasks with confidence and proficiency.

X. Team Work

As we lacked experience in building ROVs, we conducted extensive research and sought guidance from our team advisor. Through studying the work of our graduates, we gained a basic understanding of constructing an ROV and available resources. We began by holding a briefing to discuss our missions and requirements before brainstorming ideas to complete the tasks. We drew mind maps and wrote ideas in point form during meetings in order to brainstorm ideas together effectively. Each member was assigned a suitable job based on their skills, such as 3D designing for those experienced in the software and electronic part connections for those studying physics. The report team was responsible for writing the report and other documents, but everyone contributed to the content.

Each member wrote the content for their respective ROV part, while the report team proofread. Despite facing numerous challenges, we encouraged each other and worked collaboratively to overcome difficulties. This approach enabled us to track progress and maintain the project's momentum. We also sought advice from former team members who had more experience building ROVs. Additionally, we bonded through social activities like meals to strengthen team spirit and cooperation when operating the ROV.

Resources, procedures, and protocols were managed to meet mission objectives and solve day-to-day operational problems. Remaining flexible and adaptable in response to evolving circumstances enabled us to overcome unexpected challenges effectively.

Encouraging innovation and creative thinking within the team facilitated the development of novel solutions to complex problems. Effective management of resources, procedures, and protocols is essential for the successful execution of ROV operations. By prioritizing resource allocation, adhering to standardized procedures, and fostering a culture of problem-solving and continuous improvement, our team has been able to meet mission objectives and address day-to-day operational challenges effectively. Moving forward, we remain committed to refining our practices and embracing innovation to further enhance our capabilities in the field of ROV operations.

Reflections

ROV competition is quite different from the events that I joined before as we have to build all stuff from scratch instead of making modifications based on a well-designed machine. This year I am in charge of the MATE Floats! task together with other team members. I am glad to have them to guide me what to do and how to do it. I learnt developers pay intensive effort in researching, designing and reviewing for their final product. (Ben’s reflection)

It’s the first time to join the ROV event, this must be an unforgettable experience for me. In this activities, I have learnt many things during the event such as problem solving skills and cooperate with teammate, which cannot be learnt in textbook.I am pleased that I can join this competition and enjoy all the process of designing and making the ROV. (Donald′s reflection)

XI.Project Management:

Managing the requests from MATE is a challenging task that requires effective management skills. To ensure successful project completion, four departments were formed: Hardware ROV, Mechanics, Electronics and Software, and Safety. Each department is headed by a selected student who supervises their team members. Weekly progress reports are presented during meetings where a log book is also discussed. The team evaluates and justifies different solutions to any problems faced during the project. The work schedule is subject to change depending on the situation after thorough discussion. Each department head records their team's progress in a log book for inspection by the CEO and team advisor to ensure that goals are achieved according to schedule. This process involves planning, organizing, motivating, and controlling resources, procedures, and protocols. The CEO and financial secretary oversee the budget planning and usage.

Company History: Kwok Tak Seng Inc. (Hong Kong) had 19 years of experience in participating in MATE ROV competition since 2006. We are always in the top five of the Hong Kong regional ROV competition. We have been qualified to the international competition in 2009, 2010, 2017 and 2019. , LEUNG TO, CHEUNG KAREL, CHEUNG MAN HO, LEE JAIVEN joined the ROV competition in 2022. All other members join the competition for the first time this year.

Personnel:

Name	Post	Grade	New/Return
CHEUNG KAREL	Pilot, Chief Executive Officer, Chief ROV Designer	10	RETURN
CHEUNG MAN HO	ROV Designer, Safety manager, 3D-Graphic Designer	10	RETURN
LEUNG TO	Co-pilot, Software engineer	10	NEW
LEUNG SHEK MAN	Chief Secretary, Software engineer assistant	10	NEW
LAW PAK CHUN	Financial Officer	10	NEW
LEE JAIVEN	Mechanical Engineer	10	RETURN
DAI ZHOUXIAN	Programmer	10	NEW

Schedule of works

Remaining flexible and adaptable in response to evolving circumstances enabled us to overcome unexpected challenges effectively. Encouraging innovation and creative thinking within the team facilitated the development of novel solutions to complex problems. Effective management of resources, procedures, and protocols is essential for the successful execution of ROV operations. By prioritizing resource allocation, adhering to standardized procedures, and fostering a culture of problem-solving and continuous improvement, our team has been able to meet mission objectives and address day-to-day operational challenges effectively. Moving forward, we remain committed to refining our practices and embracing innovation to further enhance our capabilities in the field of ROV operations.

	Event	2023			2024											
		DEC			JAN				FEB				MAR			
1	Evaluation of last year competition and Fund Raising															
2	Learned the mission and research the information															
3	Discuss the idea of solving the task and planning the post of each member															
4	Study the feasibility for whole system															
5	Comparing & Discuss different designs															
6	Finalize the Design															
7	Hardware Purchases (Thrusters, ESC, Thruster Commander, Camera, motors, PP board ,etc)															
8	Design, implementation and unit test:															
	a) Building framework b) Thruster Assemble Integration with ESC c) Connection and Testing Thruster Commander d) Integration of Cables into The Main Control Box e) Design Payload with Rotating Arm f) Making Water Proofed Camera g) Waterproofed Electronic Components And Plugs															
9	Waterproofed test															
10	System integration and testing															
11	Submitting Report															
12	Documentation (Poster, Writing Report, JSA, etc)															

XII. Budget Sheet and Costing

One of our design rationale id to build our entire ROV within our budget. So we design the budget sheet to monitor the money.

Budget

School Name: Kwok Tak Seng Catholic Secondary School (KTS-WaterLoong)
Instructor/Sponsor: MR. LEE SIU FUNG

From: 1/9/2023
To: 20/5/2024

Income	Source	Amount (US)
	School's Grant	$ 2,600
	Students' Donations	$ -
	Parents' Donations	$ -
	Kwok's Foundation Sponsor	$ -

Expenses

Category	Type	Description	Projected Cost	Budgeted Value
Registration free	Purchased	Registration free	$ 250	$ 250
Electronics	Purchased	HD Camera	$ 120	$ 120
Electronics	Purchased	Video Spliiter	$ 94	$ 94
Electronics	Purchased	6 x Thruster	$ 1,125	$ 1,125
Electronics	Purchased	6 x Electric Speed Controller	$ 150	$ 150
Electronics	Purchased	Arduino board, H-bridge, blue tooth elctronics	$ 50	$ 50
Electronics	Purchased	Motors	$ 45	$ 45
Hardware	Reuse	Suit case	$ 50	
Hardware	Purchased	Cylinderical enclosure x 2 (Water proofed Tube)	$ 75	$ 75
Hardware	Purchased	3D printer Filament	$ 63	$ 63
Hardware	Purchased	Actualler (Linear motion)	$ 19	$ 19
Hardware	Purchased	Cables	$ 60	$ 60
Hardware	Purchased	Sucking Pump	$ 93	$ 93
Hardware	Purchased	Water proof plug	$ 50	$ 50
Hardware	Purchased	ROV body - PVC board	$ 70	$ 70
Hardware	Purchased	Snake web	$ 13	$ 13
Hardware	Reuse	Monitor	$ 124	

Items must fall into ont of the following:
Purchased - defined as items that are purchased new or service paid for.
Re-used - defined as items that were purchased in previous years. Amount listed as the current market value.
Parts donated - defined as equipment, materials, and time that were contributed to you company. School for general use excluded.
Cash donated - defined as funds contributed to your company. Do not include funds given to your school for general use.

Total Income	$ 2,600
Total Expenses	$ 2,450
Total Expenses - Re-use/Donations:	$ 2,276
Total Fundraising Needed/**Surplus**:	$ 324

Project costing

School Name: Kwok Tak Seng Catholic Secondary School (KTS-WaterLoong)
Instructor/Sponsor: MR. LEE SIU FUNG

From: 1/9/2023
To: 20/5/2024

Income	Source	Amount (US)
	School's Grant	$ 2,600
	Students' Donations	$ -
	Parents' Donations	$ -
	Kwok's Foundation Sponsor	$ -

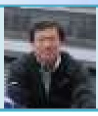
Expenses

Category	Type	Description	Amount	Running Balance
Registration free	Purchased	Registration free	$ (250)	$ 2,350
Electronics	Purchased	HD Camera	$ (120)	$ 2,230
Electronics	Purchased	Video Spliiter	$ (94)	$ 2,136
Electronics	Purchased	6 x Thruster	$ (1,125)	$ 1,011
Electronics	Purchased	6 x Electric Speed Controller	$ (150)	$ 861
Electronics	Purchased	Arduino board, H-bridge, blue tooth elctronics	$ (50)	$ 811
Electronics	Purchased	Motors	$ (45)	$ 766
Hardware	Reuse	Suit case	$ (50)	$ 716
Hardware	Purchased	Cylinderical enclosure x 2 (Water proofed Tube)	$ (75)	$ 641
Hardware	Purchased	3D printer Filament	$ (63)	$ 578
Hardware	Purchased	Actualler (Linear motion)	$ (19)	$ 559
Hardware	Purchased	Cables	$ (60)	$ 499
Hardware	Purchased	Sucking Pump	$ (93)	$ 406
Hardware	Purchased	Water proof plug	$ (50)	$ 356
Hardware	Purchased	ROV body - PVC board	$ (70)	$ 286
Hardware	Purchased	Snake web	$ (13)	$ 273
Hardware	Reuse	Monitor	$ (124)	$ 150

Items must fall into ont of the following:
Purchased - defined as items that are purchased new or service paid for.
Re-used - defined as items that were purchased in previous years. Amount listed as the current market value.
Parts donated - defined as equipment, materials, and time that were contributed to you company. School for general use excluded.
Cash donated - defined as funds contributed to your company. Do not include funds given to your school for general use.

Total Raised	$ 2,600
Total Spent	$ (2,450)
Final Balance:	$ 150

XIII. Acknowledgement

IET The Institution of Engineering and Technology	IET Hong Kong Branch – Competition organizer
YOUTH COLLEGE INTERNATIONAL / IVE Engineering	Youth College - International IVE Engineering
MATE ROV COMPETITION	Marine Advanced Technology Education Centre – Competition organizer
天主教郭得勝中學 Kwok Tak Seng Catholic	Kwok Tak Seng Catholic Secondary School – Funding
	Mr. Lee Siu Fung – Our team advisor

XIV. Reference

1. "MATE - Marine Advanced Technology Education: Home" https://www.marinetech.org/
2. "Blue Robotics - ROV and Marine Robotics Systems and Components" https://www.bluerobotics.com/
3. Build Your Own Underwater Robot and Other Wet Projects by Harry Bohm and Viclie Jensen
4. https://pysource.com/2018/09/25/simple-shape-detection-opencv-with-python-3/

XV. Appendix

I) Safety Checklist Form (Printed on separated file)

I) Safety Checklist Form

Safety of checklist is compiled by mechanical engineering and Electrical engineering and manager.

Safety checklist items	☑	Double check / Remarks
Pilots and ROV tether controllers at all times:		
1. All people wears accurately tied or closed toed shoes	☐	☐
2. All people wears safety glasses	☐	☐
Before the ROV deport to the water: (Mechanical inspection)		
1. All components and cables are attached firmly	☐	☐
2. All danger parts are identified and protected	☐	☐
3. All danger parts are identified and labeled as danger	☐	☐
4. Sharp edges are rounded off	☐	☐
5. Propellers are attached securely and with protection shield	☐	☐
6. Tether and waterproof plug neatly coiled	☐	☐
7. Motors function properly	☐	☐
8. Camera is focused and securely attached	☐	☐
9. No exposed thruster are found	☐	☐
10. All wires and devices for controlling on the surface of the water are securely attached in a control box	☐	☐
Before the ROV deport to the water: (Electrical inspection)		
1. 25A fuse is presented in the control unit and in good condition	☐	☐
2. 25A Fuse is attached within 30cm from the power supply	☐	☐
3. Check the connection of main power supply	☐	☐
4. All Plugs are dry and secure attached	☐	☐
5. Unused plugs should also be shielded	☐	☐
6. All connection are labelled	☐	☐
7. No wires are exposed / No open end wire	☐	☐
8. Ensure the input voltage matches the expected	☐	☐
9. Checking of RS485 communication signal	☐	☐
10. Check Pressure reading	☐	☐
Overall System Checklist		
1. Ensure all thrusters function properly (UP,DOWN,LEFT,RIGHT)	☐	☐
2. Payload function properly (Open, Close)	☐	☐
3. Checking the normal function of air compressor and tubing are securely attached	☐	☐

Sign of the first Staff:	
Name of the staff:	
Date and Time:	
Sign of the Second Staff:	
Name of the staff:	
Date and Time:	