IOTA

HONG KONG

TECHNICAL DOCUMENTATION

2021 MATE INTERNATIONAL ROV WORLD CHAMPIONSHIP

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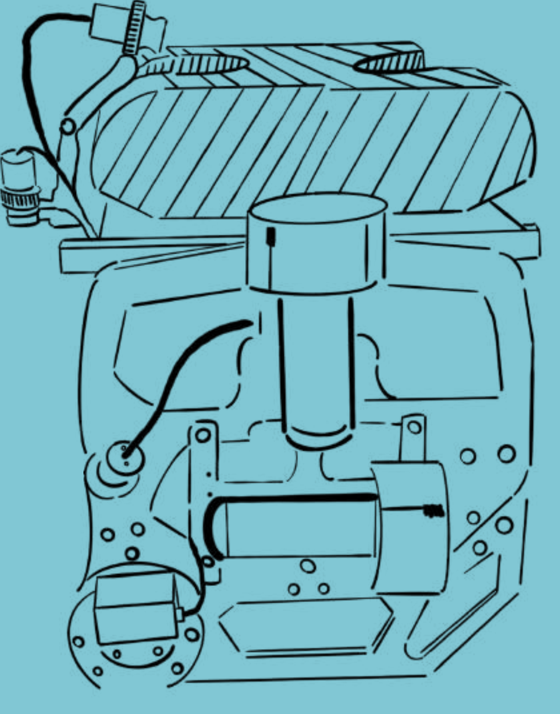

CMA UNDERWATER EXPERT LTD.

CMA SECONDARY SCHOOL, CMASS ROBOTICS TEAM

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Abstract

CMA Underwater Expert Limited consists of 4 dedicated and highly creative engineers. Based on the Eastman's Request For Proposal (RFP), they have developed a Remotely Operated Vehicle (ROV) named ***Iota*** to tackle real-world plastics pollution in oceans, reduce the negative impacts of climate change on coral reefs, and eliminate the consequences of poor environmental practices on our inland waterways.

Iota is built with valuable experiences from the previous 12 years of experience with an emphasis on increased speed, maneuverability, and power efficiency. It has incorporated features such as a HDPE frame, a small buoyancy device, and Seabotix thrusters that ease the general operability. To meet the desired functionalities, ***Iota*** is also equipped with mission-specific components, such as a plastic debris collector specially catered to remove floating plastic debris and manipulators that are capable of gripping small parts precisely.

The resulting design has a flexible configuration, a small profile, with its reliability optimized through simplicity. It is the result of the collaboration and dedication of Mechanical, Electronic, and Software engineers for over 400 hours since April 2021. The following technical documentation presents the design rationale and development process of the creation of ***Iota***.

Figure 1: Team photo *(Listed from left to right)*
Jacky MA, Samuel HUI, Terry AU, Candy LEE

A. Aim

This year, CMA Underwater Expert Ltd. focuses on achieving three objectives.

First, build an integrated ROV which is compact while being lightweight and flexible. Iota was designed to maximize maneuverability and power efficiency by reducing the diameter to less than 60cm.

Second, widen Iota's voltage adaptability, making it less vulnerable to the unstable power supply and adapt to various load situations. A DC-to-DC voltage regulator is added to the Electrical Distribution Control Panel (EDCP) and a degree of flexibility is considered in the calculation.

Thirdly, design innovative mission-specific components that can perform tasks in a cost-effective way. For example, a plastic debris collector is specially designed for Task 1.

B. Design Process

Suspension of face-to-face classes in schools during the COVID-19 pandemic has seriously affected the development of the ROV project.

In pursuit of an ROV which is compatible with our company's standard and the requirements of MATE 2021, we started our ROV project right after we knew the MATE International ROV Competition would continue this year. We listed all the deficiencies and potential problems in our previous year's design, followed by modifying the mission-specific tools and buoyancy as well. In the meantime, we arranged intensive training for both new and experienced members to familiarize themselves with the competition rules and boost their confidence.

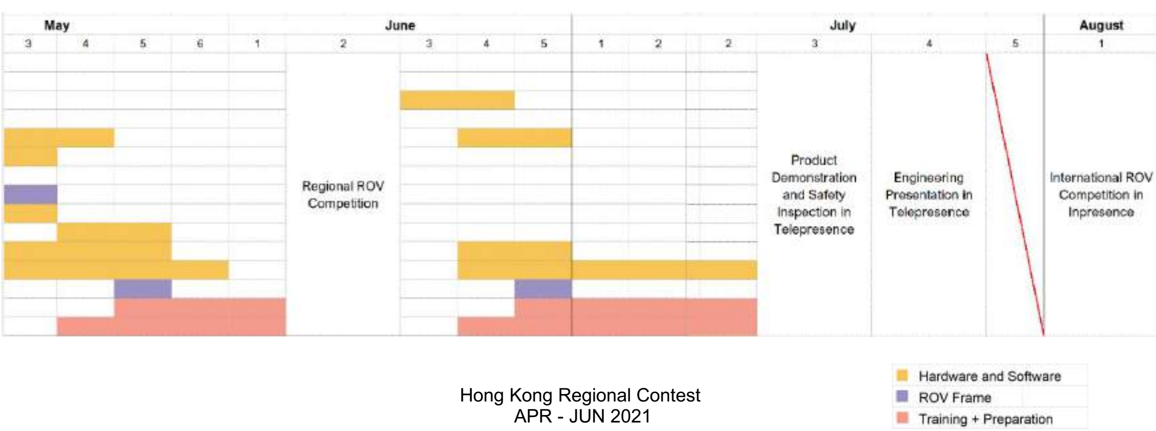


Figure 2: The development timeline
(Diagram by Terry AU)

C. Design Philosophy

We always strive to develop the most efficient ROV with improved functionality and higher performance from year to year. This year, ***Iota***'s design philosophy focuses on increased speed, manoeuvrability, and power efficiency. Equipped with a robust HDPE chassis, most components are made in-house to cater to the mission-specific, while some of them are purchased to enhance quality control. The all-in-one control panel of ***Iota*** is specially designed for a quick and convenient setup for maximum accessibility.

D. Overview (Sketches and Drafts of *Iota*)

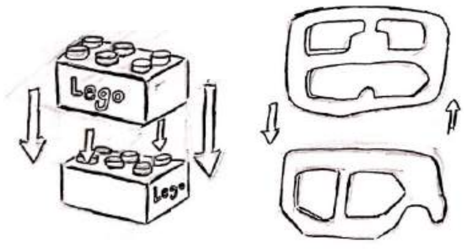


Figure 3: Concept drawing of ***Iota****'s frame*
(Drawing by Candy LEE)

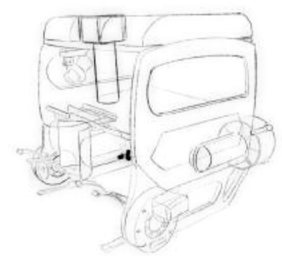


Figure 4: Concept drawing of ***Iota***
(Drawing by Candy LEE)

Once we validated the concepts through sketches (as shown in Figures 3 & 4), a 3D Computer-Aided Design and Drafting (CAD) model was used to simulate our initial design, helping us visualize and estimate the frame size, locations of different core components, and weight balance. This provides an efficient and accurate estimation on potential problems, showing us insights in making corresponding improvements. Lastly, we used Autodesk Fusion 360 to combine all the components together.

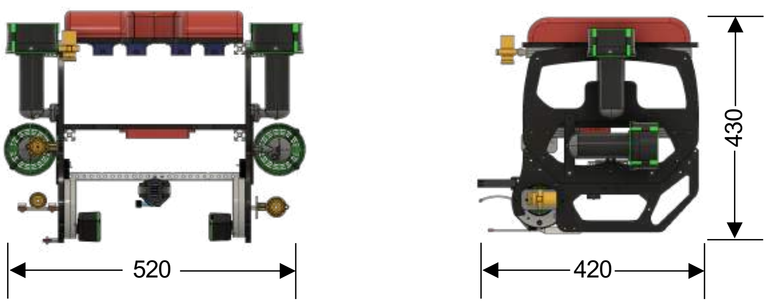
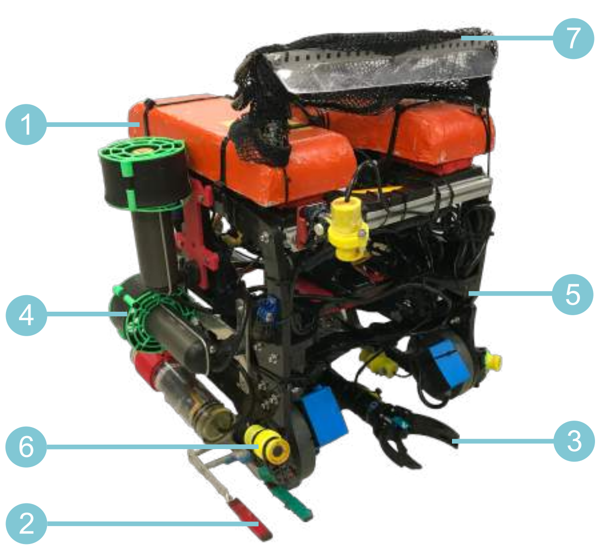


Figure 5: CAD model of ***Iota*** *with Autodesk Fusion 360*
(CAD Drawing by Jacky MA)

Throughout the design process, company members are encouraged to share and discuss innovative ideas, helping the ROV to improve as much as possible.

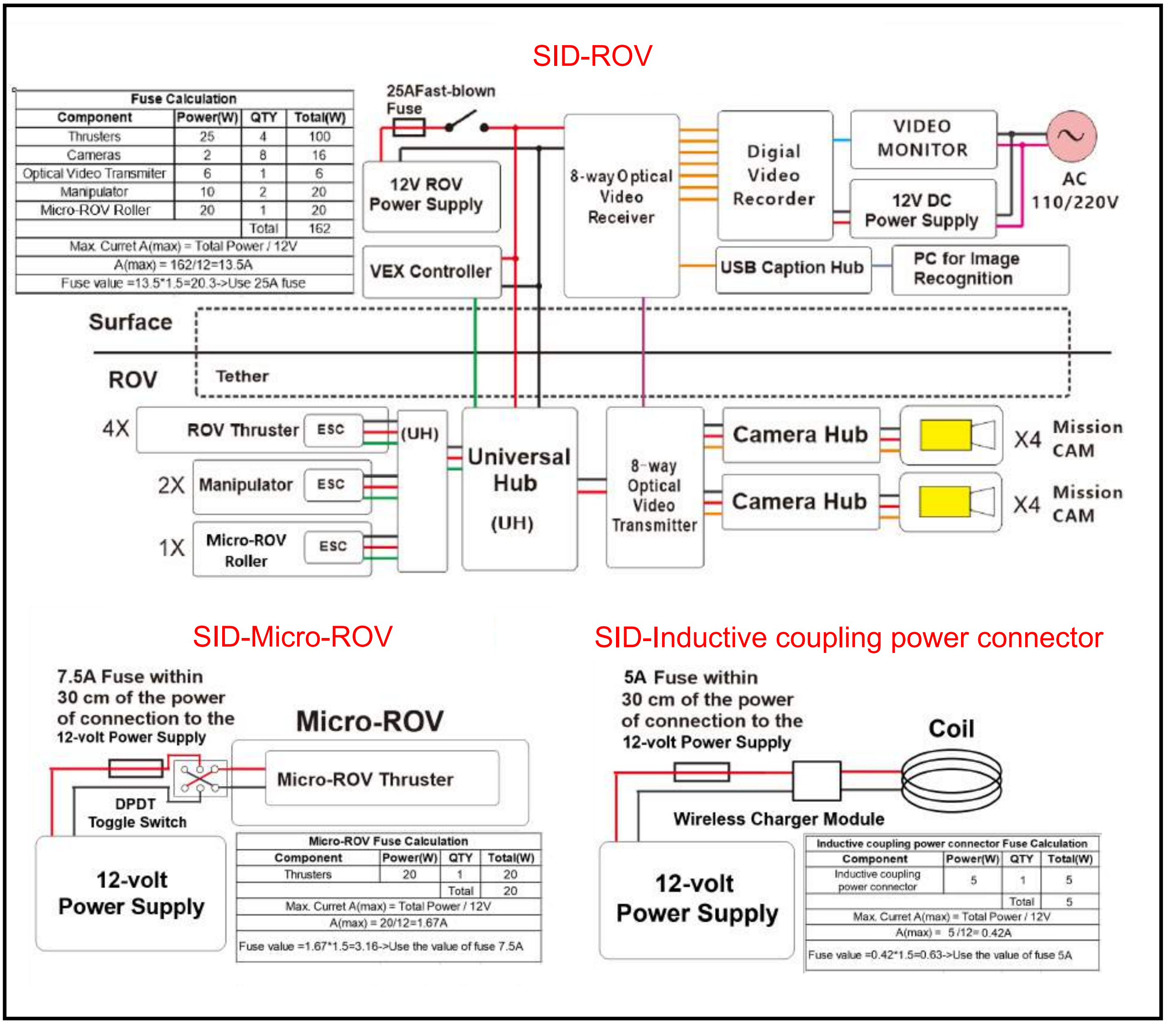


	Components	Task
1	Buoyancy made from polystyrene fiberglassed with epoxy	All
2	Main Manipulator	
3	Secondary Manipulator	
4	Thrusters for upward and downward movement	
5	Frame made from High-Density Polyethylene (HDPE)	
6	HD Cameras	ALL (especially for 2.1, 2.2, 3.2, 3.4)
7	Plastic debris collector	1.2

Figure 6: Final design of ***Iota***
(Image by Candy LEE)

Design Rationale_06

E. System Interconnection Diagram (SID)



Micro-ROV and Inductive coupling power connector powered from the second 12-volt power supply from the surface (according to ELEC-NRD-001 at the Worlds Championship)

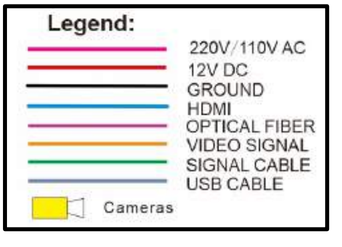


*Figure 7: SID of **Iota** with CorelDraw*
(Diagram by Terry AU)

Using optical fibers to transmit camera signals reduces interference. They also keep ***Iota*** light and ensure the tether stays thin. The control signals are transmitted from the VEX controller to the Electronic Speed Controllers (ESCs) via 8 AWG power cables for the greatest flexibility and stability.

An emergency stop button and a 40A SSR (Solid State Relay) are used to disconnect the power provided to the ROV quickly in case of emergency.

IOTA

F. Tether

Iota is powered through a 15-meter long tether. Inside there is one 8 AWG power cable, one 8 core-signal cable, DPDT Toggle switch, four optical fiber cables, two airline tubings, and one wire. We always take extra care of our tether, so we stow it in a reel to minimize its chances of cracking or folding, which would otherwise damage the wire.

The power cable is used for the power supply, the 8 core-signal cable is used for ROV's communication, while the DPDT Toggle switch is used for micro-ROV's control. For the eight AHD cameras, optical fibers are used to transmit camera signals to our monitor display. Airline tubings are inherited from previous designs, we keep it as a backup for future projects. A flexible wire is added to prevent the tether from cracking.

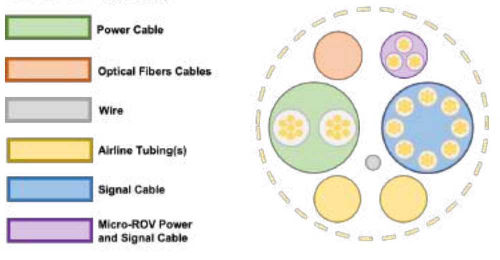


*Figure 8: Cross section of **Iota**'s tether*
(Image by Candy LEE)

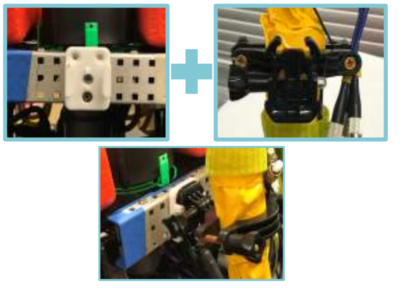


Figure 9: Photo of tether locker
(Image by Candy LEE)

G. Frame

The open frame of ***Iota*** provides minimal obstruction and houses the electronic speed controllers, optical fiber receivers, and 4 thrusters. All fixed electrical components are placed in the mainframe to condense critical parts.

To reduce the weight and size of the ROV without sacrificing strength and durability, Iota's frame is built from High-Density Polyethylene (HDPE), a material preferred over aluminum due to its low density, low cost, and high manufacturability. Compared to the density of aluminum (2.70g/cm3), the density of HDPE (0.93 to 0.97 g/cm3) is much lower, even lower than that of water (1 g/cm3). This aids the buoyancy system of Iota, reducing its dependence on a large float. HDPE can be easily cut by using a Computer Numerical Control CNC Milling Machines (CNC Milling Machines), and it is rigid enough to protect the ROV's core while keeping interior structures intact. HDPE is also cheaper than most other materials.

Apart from the material used, another distinctive feature of ***Iota***'s frame is that it is easily detachable, which can be separated into two sections swiftly by removing six screws. In case of a malfunction, this feature allows us to examine every single component easily and make corresponding repairs. The ease of installation also prevents damage while shipping.

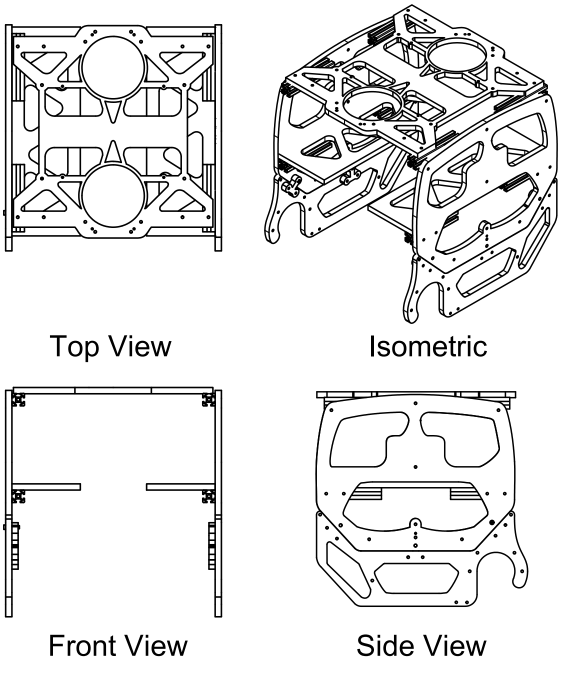


*Figure 10: Overview of **Iota**'s frame with Autodesk Fusion 360*
(CAD Drawing by Jacky MA)

Design Rationale_08

On the other hand, the corners of ***Iota*** are rounded to prevent sharp edges. The holes for the thrusters are also universal, fitting both SeaBotix and BlueRobotics thrusters, making the frame compatible with different parts.

Autodesk Flow Design (Autodesk) is used to help simulate the performance of the ROV underwater. Using the data analysis provided by Autodesk, we can conduct numerous tests to refine ***Iota***'s design and performance by reducing water resistance.

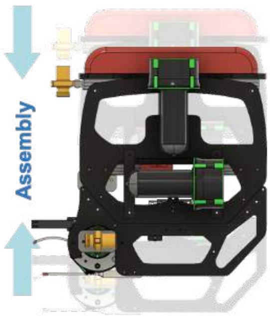


*Figure 11: **Iota**'s quickly detachable subframe with Autodesk Fusion 360 (CAD Drawing by Jacky MA)*

*Figure 12: Front shot of **Iota** in water (Image by Candy LEE)*

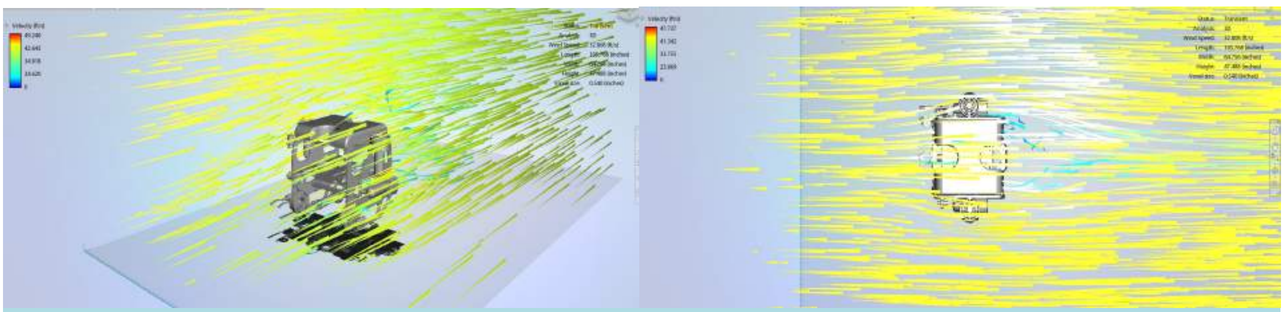


*Figure 13: Flow test simulation of **Iota** with Autodesk Flow Design (Fluid test simulated by Samuel HUI)*

H. Electrical Distribution Control Panel (EDCP)

The EDCP Control Panel holds everything together. There's the on-shore Tether Control System (TCS), the tether, communications, and electronics onboard the ROV. They're all in one flight case for better integration, safety, and convenient troubleshooting.

After receiving camera signals from an optical fiber transmitter, the optical fiber receivers on the EDCP convert these signals into video images, which are then sent to the Digital Video Recorder for regrouping. The 8 camera images can be demonstrated on the 24-inch monitor, providing a full picture of the mission tasks.

A power toggle button is used to control the power supply of major networking components inside the TCS. As a safety feature, a 25A fuse is added at the power input to minimize occurrences of accidents under operation. Voltage and current meters are also installed to allow pilots to keep track of power issues, such as equipment failure and short circuits. Another DPDT Toggle switch is used to control the movement of micro-ROV.

We have considered using a lighter or smaller briefcase in place of the control panel, but we gave up this idea soon because the delicate electronic parts in EDCP are prone to damage when we are traveling to different countries for competitions. The all-in-one flight case makes it easier for setup and maintenance, but the tradeoff is being heavier and more expensive in delivery.

Figure 14: Features of the EDCP (Image by Candy LEE)

I. VEX Controller Kit

The VEX Controller Kit controls the motion of ***Iota*** through its 4 thrusters, the main manipulator, the secondary manipulator, and the Micro-ROV's thruster and retraction.

It consists of a 2.4 GHz data radio, a receiver remote control, a joystick, a radio transmitter unit, and a compatible receiver unit. These units allow easier accommodation for future expansions of the ROV subsystems. Compared to other controllers, which mainly rely on batteries and are subject to a power outage, VEX controllers, which obtain their power from EDCP via a USB cable, have a more stable power supply.

While most components are made in-house, VEX controllers are bought because our drivers are familiar with them and have mature manoeuvring skills, leading to the smooth execution of tasks. Also, it is too difficult for us to construct a controller from scratch.

J. Electronic Speed Controllers (ESCs)

To control the speed and direction of the 4 SeaBotix thrusters, as well as the manipulator and the turntable bearing kit, eight 60A 1060 Brushed Electronic Speed Controllers (ESCs) are used in ***Iota***.

We used to seal each ESCs in respective acrylic glass boxes, fill them with epoxy and then install them on ROVs, increasing their resistance against the water penetration. Since ***Iota*** was designed to meet strict size and weight restrictions, 3D-printed casings were used in place of acrylic glass boxes, reducing ESC's size, weight, and manufacturing time by approximately 50%. Then, the same approach can be used- fill the 3D-printed casings with epoxy to reduce the rate of water absorption of PLA, the material commonly found in 3D-printing. As a standardized waterproof method for ESCs, it is easily replicable that we could always have spare one available in case of a malfunction. Due to its simplicity, ESC making workshops are arranged for our new members as a part of training. Their finished products can be used for testing, giving them a sense of accomplishment as they can participate in the process of ROV production.

To complete Task 2.1(flying a transect line over a coral reef and mapping points of interest), we rewrote the whole program. Then, we found that the motor was not working when we gave it full speed. We thought that the signals might distort when they are sent to ESC through tether. Therefore, we decreased the speed by 20% to prevent the signal from getting out of the ESC's receive range, so the motors will work.

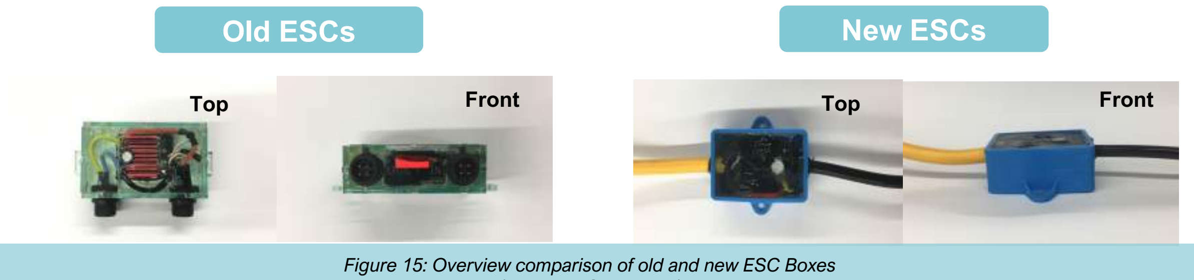


Figure 15: Overview comparison of old and new ESC Boxes
(Image by Candy LEE)

K. Thrusters

Iota is equipped with four SeaBotix thrusters. Two are mounted horizontally to allow front and backward movement at 1.2kg of thrust when 12V is applied. Two thrusters are mounted vertically for quick levitation and descending of Iota in the water. To rotate, the horizontal thrusters work in opposing directions.

To determine the best means for propulsion, we evaluate and compare the performances of Seabotix BTD-150 and Blue Robotics T200 thrusters. Seabotix BTD-150 operates using brushed DC motors, weighing 350 g in water at a cost of approximately $500, while Blue Robotics T200 operates using brushless DC motors, weighing 156 g in water at a cost of approximately $200. So in terms of weight in water and overall size, the Blue Robotics T200 is better than Seabotix BTD-150. And we also planned to reuse the Blue Robotics T200 thrusters from last year's ROV to save money. However, we conducted experiments and found that the current requirement for SeaBotix thrusters is generally smaller, so it performs better than other thrusters at a low voltage level. After careful considerations, we decided to use SeaBotix BTD-150 thrusters instead of T200 thrusters.

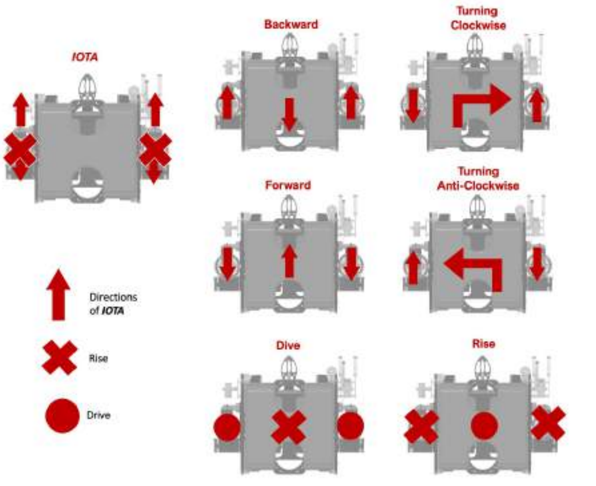


*Figure 16: Explanation of **Iota**'s propulsion system with Autodesk Fusion 360*
(CAD Drawing by Candy LEE)

L. Buoyancy

The flotation system of ***Iota*** is designed to counteract the negative buoyancy effects of heavier than water materials on it. Our buoyancy board is tailor-made for this year's missions. To prevent it from deformation under high water pressure and thus extending its life cycle, the buoyancy board is coated with fiberglass covering, bandages, and epoxy after being shaped by hand tools. After sanding, another epoxy layer is added to smoothen the surface and further increase its hardness. We also customized the board to be H-shaped, which enables ***Iota*** to move with minimum resistance.

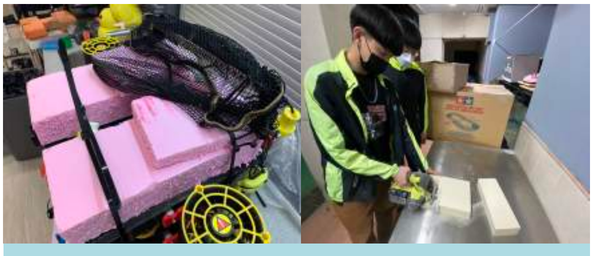


Figure 17: Samuel making rigid foam and Subsea Buoyancy Foam separately for testing buoyancy board effects.
(Image by Candy LEE)

We have considered using Subsea Buoyancy Foam: R-3318, as it performs better than the buoyancy board in terms of hardness and resistance to hydrostatic pressure and impacts. But after pool trials, we noticed that if R-3318 foam is used for buoyancy, Iota will sink in water. A solution is to increase the volume of the R-3318 foam to lower its density, but the ROV may eventually exceed the size and weight limits. Therefore, we decided that in-house buoyancy foam is more suitable for the execution of tasks.

M. Software Flow

RobotC is free coding software that we use to control ***Iota***. By writing the RobotC code, we could control ***Iota***'s manipulator and thrusters, helping the ROV to navigate.

After inputting the values for thruster control, RobotC double-checks if they lie within the safety range to prevent thrusters from overloading. The values are then outputted as PWM (Pulse Width Modulation) signals, which is a modulation technique used to encode a message into a pulsing signal with controlled Pulse Width. This mitigates the risk of malfunctioning ROV's thrusters during missions.

Design Rationale_11

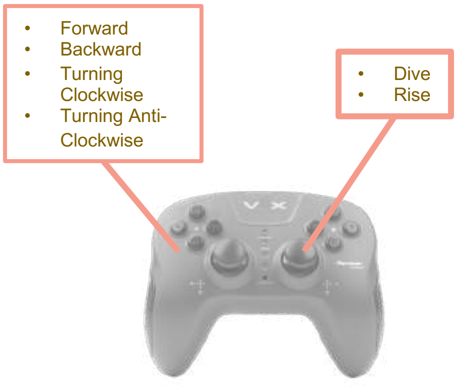


Figure 18: Program flow of **Iota**'s control with CorelDraw
(Design and image by Terry AU)

Figure 19: Program flow of **Iota**'s control with CorelDraw
(Diagram by Terry AU)

N. Mission-Specific

Camera ***(Post-production and camera position designed by Samuel HUI)***

Based on 12 years of experience, we believe that having a total of 8 camera images (1 large image and seven other smaller images) works best in achieving interchangeability in displaying the video feeds and at the same time, prevent confusion as too many screens might be confusing to the pilot.

To reduce potential blind spots and create split views in different directions to increase coverage, we have changed 3 of the cameras to Analog High Definition cameras, which yield a 170-degree Field of View that is greater than previously used cameras (150 degree). It allows for accuracy in props placement and execution of observational tasks, such as determining the health of the coral colony and creating a photomosaic of a submerged subway car.

Camera #1 (1st 170° camera) monitors the plastic debris collector.

Camera #2 (2nd 170° camera) serves as a viewing camera for navigation.

Cameras #3 (3rd 170° camera), 4, 5 monitor the main manipulator. For tasks that require accuracy, like moving the power connector of the Seabin and pulling the pin, it gives the pilot a high-quality vision, making placement more precise.

Camera #6 mounts on the secondary manipulator. Take Task 2.1 as an example, when the secondary manipulator moves downward, the camera can display how ***Iota*** flew a transect over the coral reef. When the manipulator moves to a horizontal level, it can take images of the coral colony and four sides of the subway car.

Camera #7 monitors the rear of the ROV. It helps the pilot watch out for obstacles.

Camera #8 monitors the Micro-ROV.

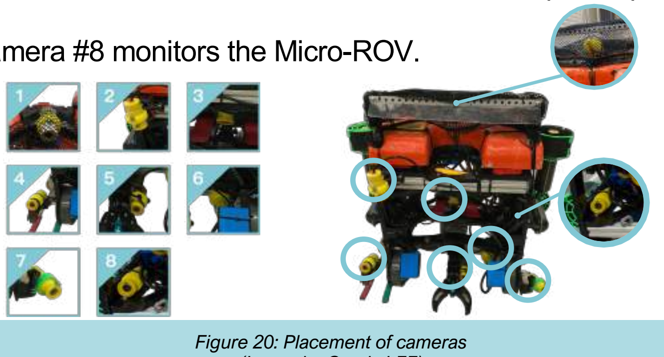


Figure 20: Placement of cameras
(Image by Candy LEE)

Figure 21: 8 cameras have a better vision for pilot
(Image by Candy LEE)

Design Rationale_12

Since cameras are scratch-prone and may expose to mechanical damage, we 3D printed covers for the cameras and waterproofed them with a 0.2-0.7 mm layer of epoxy. It not only lowers the water-absorbing ability of PLA(printing filament), but also sets the cameras in a fixed position, so that collision of ***Iota*** will not result in focusing issues.

Manipulator *(Secondary Manipulator designed and produced by Jacky MA)*

Iota is equipped with two manipulators. The main manipulator comes from Blue Robotics. It opens horizontally as a short sturdy pincer with grooved arms. It is capable of focusing and gripping small parts with precision, such as the power connector of Seabin in Task 1 and injecting the Crown of Thorns sea star in Task 3.

*Figure 22: CAD model with Autodesk Fusion 360 and demonstration of **Iota**'s secondary manipulators (Image by Candy LEE)*

The secondary manipulator is built by ourselves, consisting of two upper arms and one lower arm made from bent aluminium bars. They open vertically and are mainly used for scooping horizontal items. For example, in Task 1, two manipulators can grip both the power connector and mesh catch bag at the same time and bring them back to the side of the pool. This saves lots of time and gets tasks done effectively.

Figure 23: CAD model with Autodesk Fusion 360 and demonstration of the main manipulator(Image by Candy LEE)

When ROV tries to do task 1.2, pulling a pin and removing the ghost net, the pin falls from the main manipulator easily. Therefore, magnets are added to both sides of the main manipulator. This is important in real-world situations because once the pin falls to sea bed, it is a lost pin.

The structure of both manipulators is relatively simple, consisting of only a few components, making it readily field repairable and less vulnerable to malfunction. But when it comes to real-world situations, more manipulators can be added to help transfer more debris in one trip.

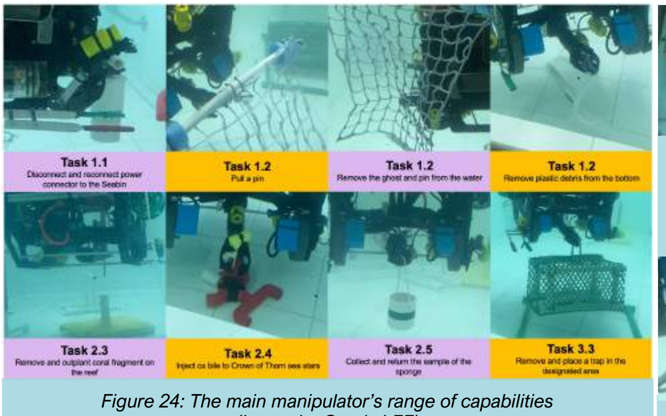


Figure 24: The main manipulator's range of capabilities (Image by Candy LEE)

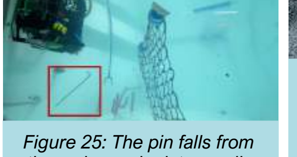


Figure 25: The pin falls from the main manipulator easily after removing from ghost net (Image by Candy LEE)

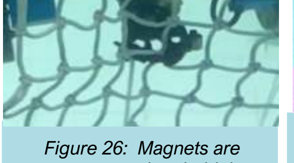


Figure 26: Magnets are strong enough to hold the pin without sinking. (Image by Candy LEE)

Figure 27: The pin falls from the main manipulator easily after removing from ghost net (Image by Candy LEE)

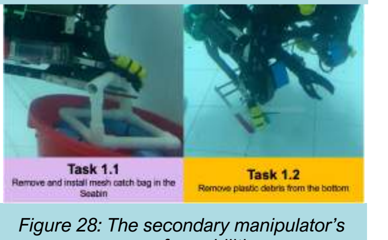


Figure 28: The secondary manipulator's range of capabilities (Image by Candy LEE)

Autonomous Control Program *(Written by Terry AU)*

Our program is coded for Task 2.1 (Flying the transect autonomously). It is using C language and PROS API. The program has two modes, driver and autonomous mode. We wrote some autonomous functions for the actions of the ROV. While in autonomous mode, the upper thruster will keep running at around 27.5% power to avoid the ROV from sinking because of gravity, and the horizontal thruster will run the time and power that the user is given. If the time is reached, all thruster will stop.

```
//Autonomous functions
void Move(int Distance, int Voltage){
  SetUpperThruster(35);
  SetHorizontalThruster(Voltage, Voltage);
  for (int Sec = 0; Sec < Distance; Sec = Sec + 1){
    delay(1000);
  }
  SetUpperThruster(0);
  SetHorizontalThruster(0, 0);
}
```

Figure 29: 'Move' function, an autonomous functions. (Captured by Terry AU)

Design Rationale_13

Inductive Coupling Power Connector *(Design and Build byJacky MA)*

The power connector is powered from the second 12-volt power supply from the surface (according to ELEC-NRD-001 at the Worlds Championship) and must have a 5 amp fuse within 30cm of the point of connection (ELEC-NRD-003).

Basically, we followed the instructions to build an inductive coupling power connector that provides power to the connector. Jacky is responsible for soldering all the component parts and Samuel is responsible for the waterproof part.

#1 is the receiver. #2 is the transmitter. The transmitter does not have enough area for connection between power connections to the power port. Therefore, transfer the receiver (the circle part) into the transmitter. It makes the area bigger for touching.

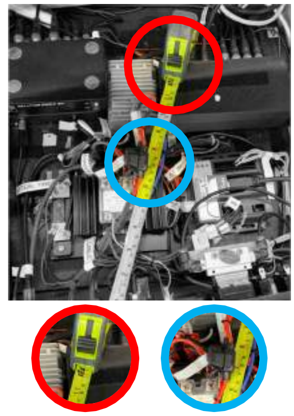


Figure 30: The power connector is fully built according to the requirements.
(Image by Candy LEE)

Figure 31: Final Testing in the tank. It works after touching and lighting on the red LED light.
(Image by Candy LEE)

Plastic Debris Collector *(Designed by Samuel HUI)*

In Task 1, we are required to remove floating plastic debris in a designated area. The debris comes in the form of ping-pong balls, and they float and move around, so we decided that a net would be the most efficient tool for collecting all the debris.

Our plastic debris collector is made of fish net, aluminium bars, zip ties, and a polypropylene sheet (PP sheet). We have placed the net at the top of our ROV, and debris is collected through a top-down clamping motion.

At first, we made a collector by using a plastic bag with holes, aluminium bars, zip ties, and polypropylene sheets. As shown in Figure 32, it actually worked quite well, but our mechanical engineer indicated that the plastic bag may give way after several tries, using the ping-pong balls to fall out of the plastic bag easily. After careful consideration and discussion, we decided to use a fish net as it is more environmentally friendly and has a longer service life. The PP sheet prevents the debris from falling out from the net when the ROV is in motion.

Figure 32: First idea of collector made by plastic bag
(Image by Candy LEE)

Figure 33: First idea of a plastic debris collector is able to collect ping-pong balls successfully
(Image by Candy LEE)

Figure 34: Plastic debris collector changes to a fish net and succeed in collecting ping-pong balls
(Image by Candy LEE)

Figure 35: Final design of plastic debris collector after the modification
(Image by Candy LEE)

Micro-ROV *(Designed by Jacky MA)*

In Task 3.1, we need to retrieve a sediment sample from a long drain pipe tube. The sediment sample has a surface made of velcro loops, so we decided to use velcro hooks - it is a counterpart for attachment.

The size of Micro-ROV is 55 x 50 x 90mm, so it is capable of entering the drain pipe (radius = 152.4 mm). It is constructed from a PVC tube, a brushed motor, velcro tape (the hooked side), and a net.

Figure 36: Micro-ROV retrieving a sediment sample by using Velcro kooks and Velcro loop successfully .
(Image by Candy LEE)

Design Rationale _14

The brushed motor has a current at 1.67 amp. It is tailor-made by adding a shroud and propeller to a Bilge Pump. The mesh around the Micro-ROV has a size smaller than 12.5mm (propeller shroud meets IP-20 safety regulation) and is labelled by hazard warning labels.

Following the Non-ROV device power specifications (ELEC-NRD-001 at the Worlds Championship), the Micro-ROV is powered from the second 12-volt power supply from the surface. It also has a 5 amp fuse within 30 cm of the point of connection (ELEC-NRD-003) with Iota.

Micro-ROV is controlled by the DPDT Toggle switch, so it can move forward, backward or stop. When in use, the Micro-ROV brushes past the sample, the velcro tape extending from the Micro-ROV, which functions like the tentacles of an octopus, can maximize the chances that the two velcro surfaces come into contact, so the sample will attach to the velcro extensions of the Micro-ROV easily. Also, there is a roller for tether collecting back in docking.

Process & Analysis

A. Challenges

Technical

Our biggest challenge was developing image recognition of coral colonies. In our team, only Terry, the electrical engineer, has acquired the fundamental knowledge and practical skills in basic coding, such as using C language for building an online game server and debugging. From last season, we knew that shape recognition works by using OpenCV, so we did the same for image recognition. Before Terry set out to handle pictures on OpenCV, he spent a lot of time finding samples and resources available on the Internet and reference books.

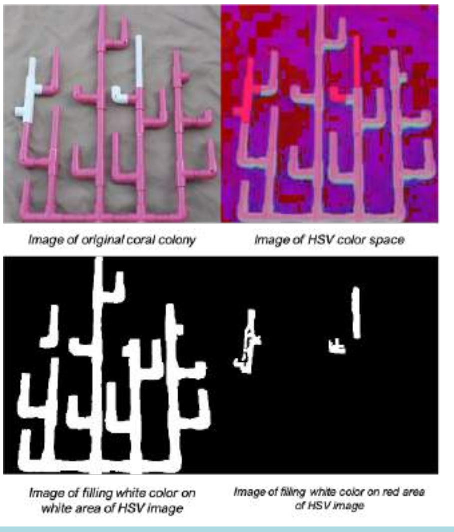


Figure 37: Terry using OpenCV for developing image recognition of coral colonies. (Captured by Terry AU)

The majority of current detection systems perform detection by repurposing classifiers. It is slow and complex as each individual component needs to be trained separately. Therefore, we decided to adopt 'YOLO' (You Only Look Once), a real-time object detection system that uses a totally different approach. It makes predictions with a single network evaluation, enabling the image to be processed at around 30 FPS, which is extremely fast. There is a database covering different kinds of human characteristics in 'YOLO', including eyes, ears, mouth, and nose. We believe the same principle can be applied to coral colonies, its image recognition can be developed based on the coral's characteristics, such as color, shape and bleaching.

To make the data of coral's characteristics, a tool in 'YOLO' called 'darknet'. It can divide the image into regions and weighted each region by the predicted probabilities. Then, 'darknet' will print out the objects it detected, its confidence, and how long it took to find them, so Terry can find out all characteristics of the coral colonies by using the program. However, Terry is still struggling with the ways to find the image difference by using OpenCV techniques. He will keep working on it.

Non-Technical

A 213cm(L) x 182 cm(W) x 100cm(H) tank was constructed in our lab in 2017. The tank is mainly used for buoyancy testing and trials for executing the missions. But some mission props are too large that could not be put into the tank. Task 1.1 as an example, the 5-gallon bucket should be suspended at least 0.6 meters above the bottom and

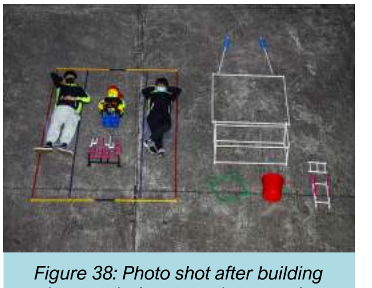


Figure 38: Photo shot after building larger mission props in car park. (Image by Candy LEE)

IOTA

completed at least 2 meters of depth. The limited space in the tank makes it impossible for us to comply with the competition requirement.

Figure 39: Micasa Studio's swimming pool
(Image by Candy LEE)

Once we gained the qualification to represent Hong Kong in the MATE International ROV Competition, our marketing executive, Candy, immediately wrote letters to companies and organizations, requesting sponsorship of a 2 meter depth pool for recording product demonstration videos. A week later, Micasa Studio accepted our request, offering available time slots on weekdays at discounted prices.

Micasa Studio recommended their services to us, which is 'Underwater Wedding Photography' and diving lessons. We are considering taking their diving lessons after this season ends.As we will continue participating in this competition in future, if at least one teammate can dive and set up the field on our own, it avoids miscommunication between the diver and engineers, thus speeding up the process of setting up. We can also save money in hiring the diver as well.

B. Troubleshooting

Troubleshooting is essential to the development of ***Iota***. Our vehicle has undergone hours of water-testing and dry-runs, while all processes are closely supervised to ensure the functionality of the machine.

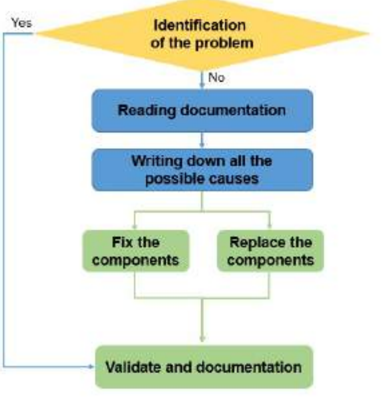


Figure 40: The troubleshooting approach of CMA Underwater Expert Ltd.
(Diagram by Terry AU)

Using our troubleshooting approaches, most problems, if not all, can be solved. It is a step-by-step process that involves identifying the problem, reading documentation, filtering, diagnosing, and recording. To begin with, after a problem is found during water-testing, we would test it again to confirm its existence, not resulting from an accident. Secondly, we would go through historical records, logbooks, and ask mentors whether they have encountered these kinds of problems before. Thirdly, the process of finding the cause starts by writing down all the possible causes of the problem, then narrowing down the source of the problem to a single component and examining each component carefully. After diagnosing the problem and replacing the malfunctioned components, the solution will be validated and documented for future use.

We believe that thorough and transparent documentation is the key to composing quick yet meticulous troubleshooting strategies. Thus forming a habit of detailed documentation is one of the aims of our training for newcomers.

C. Pool (Tank) Trial

Iota is regularly tested in water to assess its performance and reliability. It is essential to the development of ROV as water-testing provides an efficient and accurate estimation of Iota's reliability and potential problems, simplifying the troubleshooting process.

Water-testing can be divided into two stages. The first phase is tank trials in our lab, accounting for approximately 100 hours in total. The core functionalities of the ROV (such as buoyancy, cameras, and manipulators) are evaluated and the mission props (such as Seabin connector, mesh catch bag, and injection device with velcro hooks) are tested. Since we can conduct a tank trial at any time and no money is required, it is a convenient way to accurately estimate any unforeseen shortcomings in the design. For example, the debris kept falling out from the plastic debris collector during the testing phase, so we rectified the problem by adding a PP sheet.

The second phase is pool trials, accounting for approximately 30 hours. Starting from late June 2021, we conduct pool trials every two weeks because it takes time to complete the administrative works and it is expensive to hire the divers. Every time when we arrive at the pool, we conduct a full run of all 3 tasks and ensure that our ROVs are capable of meeting all mission objectives.

Every test is well prepared, well planned, and well documented. Meetings are held to reflect on the mistake of the last trial, find rooms for improvement, and discuss the aim of the next pool trial. The logbook is updated after each pool trial, documenting the process, important findings, information, and changes made on Iota.

Figure 41: 3 meters of coral reef cannot be put into our tank (Image by Candy LEE)

Figure 42: Tank trial for collecting ping pong balls (Image by Candy LEE)

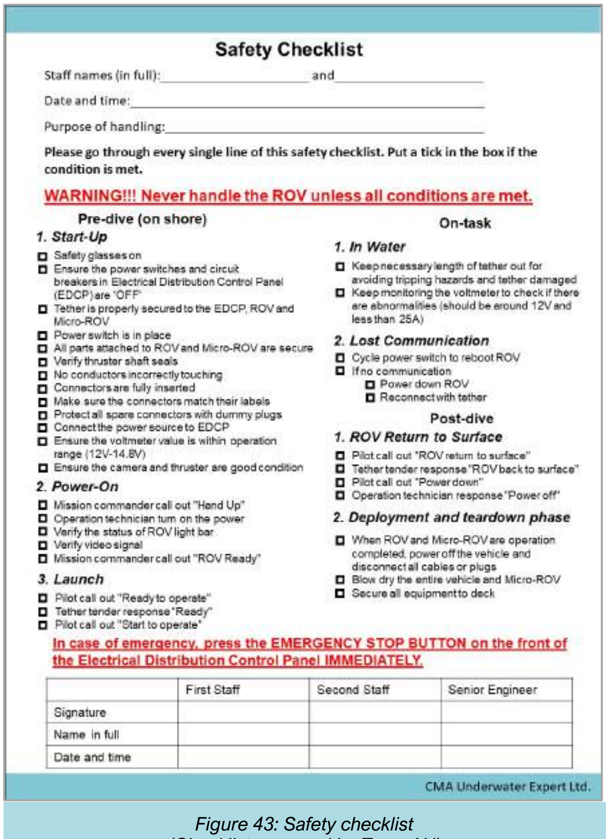
Safety Measures

A. Company Safety Philosophy

Our company believes that most accidents are preventable, if not all. As employees in CMA Underwater Expert Ltd, we embrace the social responsibility and core value of promoting safety. To achieve said beliefs, CMA Underwater Expert Ltd. has set up a lot of safety protocols, including devising a rigorous safety checklist and providing training to every member before they operate the ROV or use any equipment in the lab.

B. Safety Checklist

To ensure proper operation of our vehicles and the safety of our crew, a rigorous checklist must be completed and checked before we operate the ROV. The checklists are designed for 3 situations, including pre-dive (startup power on, launching), on-task (in water, losing communication) and post-dive (returning ROV to surface and deployment). At least two operators should be present, together with the authorization of a senior engineer, are needed every time for approving the list and handling the ROV. Especially for this year's mission, we make some adjustments on the safety checklist, such as adding some safety concerns before setting up and after the Micro-ROV dive.



Safety Checklist

Staff names (in full):____________ and ____________

Date and time:____________

Purpose of handling:____________

Please go through every single line of this safety checklist. Put a tick in the box if the condition is met.

WARNING!!! Never handle the ROV unless all conditions are met.

Pre-dive (on shore)

1. Start-Up

- ☐ Safety glasses on
- ☐ Ensure the power switches and circuit breakers in Electrical Distribution Control Panel (EDCP) are "OFF"
- ☐ Tether is properly secured to the EDCP, ROV and Micro-ROV
- ☐ Power switch is in place
- ☐ All parts attached to ROV and Micro-ROV are secure
- ☐ Verify thruster shaft seals
- ☐ No conductors incorrectly touching
- ☐ Connectors are fully inserted
- ☐ Make sure the connectors match their labels
- ☐ Protect all spare connectors with dummy plugs
- ☐ Connect the power source to EDCP
- ☐ Ensure the voltmeter value is within operation range (12V-14.8V)
- ☐ Ensure the camera and thruster are good condition

2. Power-On

- ☐ Mission commander call out "Hand Up"
- ☐ Operation technician turn on the power
- ☐ Verify the status of ROV light bar
- ☐ Verify video signal
- ☐ Mission commander call out "ROV Ready"

3. Launch

- ☐ Pilot call out "Ready to operate"
- ☐ Tether tender response "Ready"
- ☐ Pilot call out "Start to operate"

On-task

1. In Water

- ☐ Keep necessary length of tether out for avoiding tripping hazards and tether damaged
- ☐ Keep monitoring the voltmeter to check if there are abnormalities (should be around 12V and less than 25A)

2. Lost Communication

- ☐ Cycle power switch to reboot ROV
- ☐ If no communication
  - ☐ Power down ROV
  - ☐ Reconnect with tether

Post-dive

1. ROV Return to Surface

- ☐ Pilot call out "ROV return to surface"
- ☐ Tether tender response "ROV back to surface"
- ☐ Pilot call out "Power down"
- ☐ Operation technician response "Power off"

2. Deployment and teardown phase

- ☐ When ROV and Micro-ROV are operation completed, power off the vehicle and disconnect all cables or plugs
- ☐ Blow dry the entire vehicle and Micro-ROV
- ☐ Secure all equipment to deck

In case of emergency, press the EMERGENCY STOP BUTTON on the front of the Electrical Distribution Control Panel IMMEDIATELY.

	First Staff	Second Staff	Senior Engineer
Signature			
Name in full			
Date and time			

CMA Underwater Expert Ltd.

Figure 43: Safety checklist (Checklist prepared by Terry AU)

C. Safety Features of *Iota*

Mechanical Safety

Seabotix thrusters on ***Iota*** have safety covers in their designs, protecting human hands from the blades. But the mesh holes are larger than acceptable (12.5 cm). To comply with the IP-20 solid particle protection regulation, and further enhance safety, we made an additional shroud for thrusters. Jacky designed using CAD drawing, and then 3D printed in PLA (Polylactic Acid).

To avoid any sharp or scratch-prone points, ***Iota*** has a frame with rounded edges and all corners are rounded and streamlined. All moving parts, such as thrusters, are clearly labelled with hazard warning stickers in yellow and black to warn the team members about the possible dangers.

Regarding the Micro-ROV, a 7.5 amp fuse is added to the copper wiring. This breaks the circuit if there is a fault and causes too much current to flow.

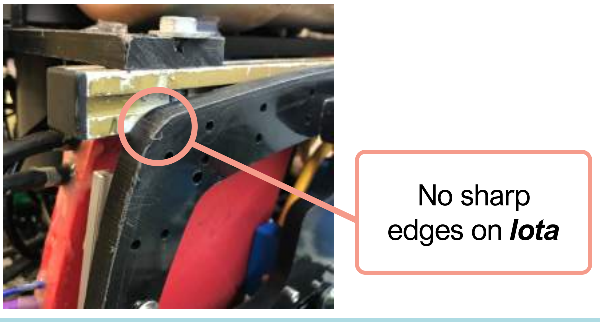


*Figure 44: No sharp edges on **Iota***
(Image by Candy LEE)

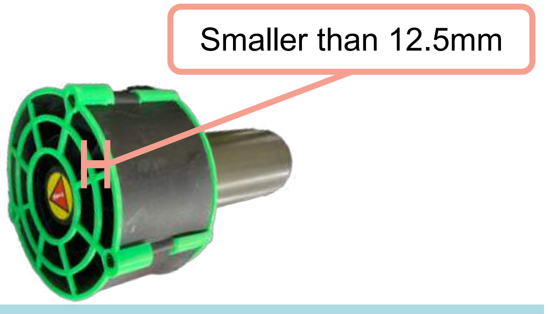


Figure 45: All propellers are shrouded with 3D-printed shrouds
(Image by Candy LEE)

Electrical Safety

A large red emergency stop button is located on our EDCP to cut the power source from the tether in case of an emergency.

A 25A in-line fuse is installed to prevent the overpowering of the electrical system. A voltmeter and an ammeter are installed in the Control Panel to make sure the power stays within a normal range (12V – 14.8V), so ***Iota*** is in stable operation.

Figure 46 illustrates the safety features of the power delivery system of ***Iota***.

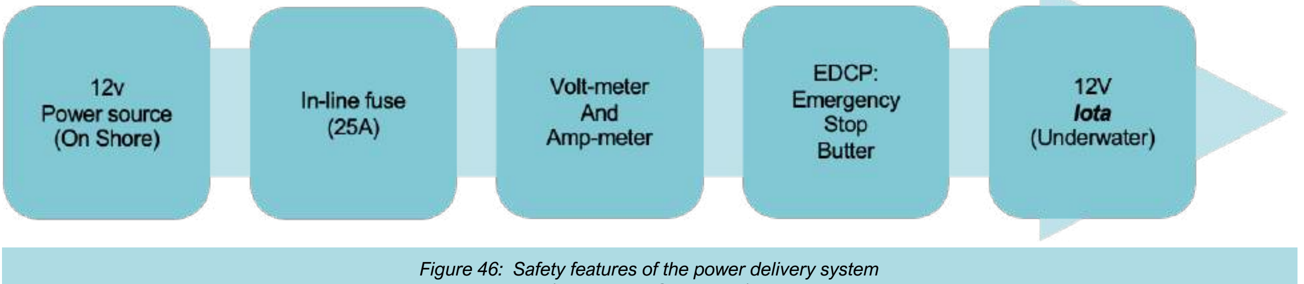


Figure 46: Safety features of the power delivery system
(Diagram by Candy LEE)

Tether Safety

To avoid the cables inside the tether from leakage and other hazards, we have set a protocol standardizing tether storage and management.

Firstly, before transporting the tether by hand, it would be coiled into the shape of an "8" and hung around the shoulders of a team member, for neat and secure transportation. Secondly, after each mission, our team members will coil the tether into a reel for storage. Not only can it reduce inductance and pressurization on the cable, but also makes it more portable and time-efficient. This extends tether life and minimizes the possibility of power leakage on and offshore. Thirdly, a safety hand guard is used to provide further protection for our palms.

The protocol is set based on past competition experience. We had encountered two major mishaps - (i) a critical misconnection that led to a power breakdown in our 2nd product demonstration in the 2017 MATE ROV International Competition, and (ii) a crack in our signal wire during our pool trials that led to a short-circuit and all direction signals are jumbled up. Since then, we have taken extra care in waterproofing our parts, and securing our connections. A tether locker is attached to the section closest to the ROV to prevent snagging the tether on the ship.

Figure 47: Members added a tether locker to the ROV. (Image by Candy LEE)

Logistic Safety

Tether is stored separately from the ROV to make it easier to tidy up and repair. Also, core components, such as the manipulator, buoyancy board, and subframe, can be easily uninstalled for regular inspection and maintenance.

We used to transport the ROV in one-piece in the past. However, the parts tend to become loose or damaged after long-time delivery and shipping. To ensure that they remain intact and functional during missions, they are separately stored and protected by bubble wraps during transport.

D. Training

To ensure that all members are familiar with the operating procedures of both ROVs and equipment in the lab, returning members would hold a 4-day course for the entire team. The course consists of 10 lessons, each lesson lasts for 45 minutes. Assessments and exercises are given to the attendees to check their understanding of each topic. At the end of the course, attendees are required to demonstrate the operation of several types of equipment and undertake a safety test. If they do not have a thorough understanding of the procedures or fail the test, they are required to attend the training again.

For newcomers, peer mentors would pay extra attention and provide more assistance when they are in need. We try to maintain a high mentor-to-mentee ratio to cater to different learning abilities.

To boost member retention and keep them up-to-date with the latest technology, it is necessary to provide members with regular training, such as conducting pool trials, practicing setup, and disconnection of equipment. With proper training and standard protocols, we can guarantee a safe working environment, only those who are qualified can operate ROV.

Project Management_19

A. Company Structure

To provide guidance and clarify the specific human resource issues, a formal organizational structure is implemented. This improves the operational efficiency as employees have a clear understanding regarding the hierarchical relationships that govern the workflow of the company. Daily production goals are assigned to each employee in morning meetings, according to their specific roles and duties, and are subsequently reviewed in the debriefing session at the end of each workday. Figure 48 shows the organizational structure of CMA Underwater Expert Ltd.

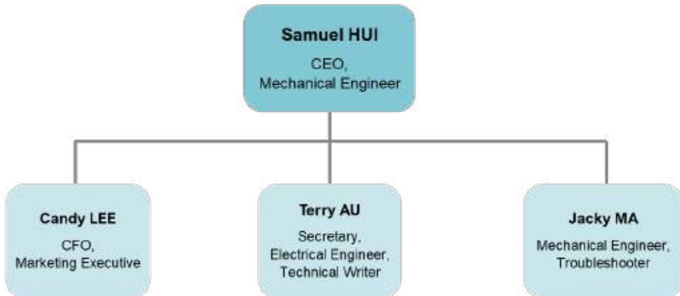


Figure 48: Hierarchy chart of CMA Underwater Expert Ltd.
(Diagram by Terry AU)

B. Scheme of Work

To make sure everyone is aware of the deadlines, a well-designed schedule is devised. Our CEO delegated different production duties to different members according to their respective roles and interests. The schedule is updated and evaluated in every weekly meeting and debriefing session, for exchanging timely updates and important competition-related news. Figure 49 shows the detailed role and response for different duties.

Unlike previous years, the number of members in our team has decreased to 4 this year. As a result, each member needs to take up more responsibility and handle multiple duties at the same time. For instance, most of the documentation duties are assigned to Terry and Candy, while the parts related to robot design and ROV operations are assigned to Samuel and Jacky. Everyone is satisfied with their duties and promise to do their best, achieving the goal of making the best possible ROV.

Schedule					
2021					
Name	APR		MAY	JUN	JUL
Samuel HUI *CEO, Mechanical Engineer* **Jacky MA** *Mechanical Engineer, Troubleshooter*	Get to know ROV design Research on the terrain, economy, and ecosystem of Norfolk, Virginia, and on the history and maintenance of Delaware River	Test EDCP, cameras Use Fusion 360 to create initial the design of ROV Attaching thrusters on the ROV Modify and attach the previous buoyancy Make mission props	Modify ROV structure Modify tether Design and build mission tools Waterproof test in our lab tank	Modify the function of components and ROV Modify and reinforce all the mission tools Practice Sales Presentation for regional competition Receive comments from regional contest and improve the performance of the Sales Presentation and the ROV including all the mission tools, control system, electrical system and Sales Presentation	Use Fusion 360 to create finalized design of ROV Purchase, attach and test new cameras, buoyancy Modify and reinforce manipulator and tether. Practice Sales Presentation for International competition in Telepresence Waterproof test in swimming pool
Terry AU *Secretary, Electrical Engineer, Technical Writer*		Job Safety Analysis Safety Checklist Company Safety Review	Design and develop the program of control system and electrical system Develop the image recognition of coral colony by OpenCV Write GUI Write technical documentation	Develop the image recognition of coral colony by OpenCV Write technical documentation Practice Sales Presentation for regional competition Receive comments from regional contest and improve the Sales Presentation, Technical Document	Coding for task 2.1: Flying the transect autonomously Develop the image recognition of coral colony by OpenCV Write technical documentation Company Safety Review Practice Sales Presentation for International competition in Telepresence
Candy LEE CFO, *Marketing Executive*	Calculate the budget of *Iota*	Take photos of team photo, ROV, mission tools Design ROV Logo and theme color Prepare financial report Design marketing display Write technical documentation		Design marketing display Write technical documentation Practice Sales Presentation for regional competition Receive comments from regional contest and improve the Sales Presentation, Technical Document and Marketing Display	Retake photos of ROV, mission tools Prepare financial report Design marketing display Write technical documentation Practice Sales Presentation for International competition in Telepresence

Figure 49: Season schedule
(Prepared by Terry AU)

C. Budget

At the beginning of the season, We have prepared a project budget (Figure 50), estimating expenses based on actual expenses from previous years to control cash flow.

School approved USD 1,200 for preparing the regional competition. Also, we submitted a proposal to CMA Secondary School Education Trust in early September 2020, asking for sponsorship to participate in the regional and MATE International ROV Competition like in previous years.

Project Budget (April 2021 - July 2021)				
Income				
Source	Description			Amount (USD)
CMA Secondary School Grant	For Regional Competition from CMA Secondary School			1,200.00
CMA Secondary School Education Trust	For Regional and International Championship from CMA Secondary School			55,000.00
Expenditure				
Category	Description	Type	Project Cost (USD)	Budgeted Value (USD)
Hardware	**ROV Parts** Sealed Connector, Camera, Styrofoam, Electronic Speed Controllers	Purchased	400.00	400.00
Hardware	**ROV Parts** Frame, Thruster, Tether Cabling, Manipulator Components, Optical Video Transmitter,	Re-used	3,940.00	-
Hardware	**Mission Tools**	Purchased	150.00	150.00
Electronics	**Miscellancous Components**	Purchased	20.00	20.00
Electronics	**Electrical Distribution Control Panel (EDCP)**	Re-used	1,000.00	-
General	**Registration Fees and Fluid Power Quiz**	Purchased	250.00	250.00
General	**Comsumables**	Purchased	500.00	500.00
Travel	**Transportation**	Purchased	350.00	350.00
Travel	**International Chmapionship:** Transportation, Lodging, Meal, Logistics, Registration Fees	Purchased	50,000.00	50,000.00
			Total Income:	56,200.00
			Total Project cost:	56,610.00
			Total Project cost - Re-use=Budget of Expenditune	51,670.00

Figure 50: Project budget of ***Iota***
(Prepared by Candy LEE)

To make ***Iota*** more affordable and hit target costs, certain components from our previous ROVs were reused. We decided to re-use some parts from ROV and EDCP because it cost 80% of ***Iota***. After our professional inspections, they had no serious damage, so we decided to keep those 2 parts re-used. Therefore, the budget was mainly used for maintaining the EDCP, tether cabling, manipulator components and optical video transmitter, building mission props, making camera waterproof and mission-specific tools.

Because of the COVID-19, our school has already been suspended for almost a year and after-school activities can't be organized to keep social distance. This is the reason why we do not hold any fundraising activities this year. The income mainly came from school grants and CMA Secondary School Education Trust. We believe that this year's project costs will not go over budget.

This year, we spent USD 7,349.05 for purchasing new parts and other expenses with a surplus of USD 38,700.95. The detailed project costing is shown in Figure 51.

The reason for the larger amount of surplus was that our proposal which was sent to CMA Secondary School Education Trust also included the budget of traveling expenses for international competition. Since the COVID-19 has prompted many countries and regions to introduce restrictions on travel, we cannot participate in the MATE Competition in person.

Luckly, we won the Hong Kong regional competition. We spend some of the budget in organizing the international competition by ourselves, such as booking a swimming pool, hiring lifeguards, transportation between swimming pool and school and meals, etc.

Project Management_21

Project Costing (April 2021 - July 2021)

Income	Description	Type	Qty	Cost Per Item (USD)	Total Cost (USD)
	Income				
CMA Secondary School Grant	For Regional Competition from CMA Secondary School	Donated	N/A	N/A	1,200.00
CMA Secondary School Education Trust	For International Competition from CMA Secondary School	Donated	N/A	N/A	44,850.00
				Total of Income	46,050.00
Expenditure	**Description**	**Type**	**Qty**	**Cost Per Item (USD)**	**Total Cost (USD)**
	ROV Parts				
Frame: High-density polyethylene (HDPE)	Re-used from 2017 ROV (Zeta)	Re-used	N/A	N/A	385.00
SeaBotix BTD 150 Thruster	Re-used from 2013 ROV (Beta)	Re-used	4	769.23	3,076.92
Tether Cabling	15m, Re-used from 2017 ROV (Zeta) 1 for 8 AWG Power Cable, 1 for 8 Core Signal Cable, 1 for Wire, 1 for Airline Tubling, 4 for Optical Fiber Cables	Re-used	N/A	N/A	390.00
Sealed Connector	Used in Motors, Electronic Speed Contollers	Purchased	32	2.56	81.92
170-degree Wide Angles Camera	Front and Back ROV camera	Purchased	20	5	100.00
Subsea Buoyancy Foam R-3318	24in x 8in x 2.5in	Purchased	2	152	304.00
Manipulator Components	Re-used from 2016 ROV (Epsilon) 2 for Turntable Bearing Kit, 2 for Waterproof Motor, Metal Rods	Re-used	N/A	N/A	55.00
Manipulator	Newton Subsea Gripper	Re-used	1	329	329.00
Optical Video Transmitter	Re-used from 2017 ROV (Zeta) Video Signal to Media Convert	Re-used	2	16.03	32.06
Electronic Speed Controllers (ESCs)	8 for ROV, 12 for separate part	Purchased	20	19.23	384.60
				Sub-total of ROV Parts	5,138.50
	Mission Tools				
Plastic Debris Collector Task 1-3: Micro-ROV Seabin connector Inductive coupling	Made by: PP sheets, Fish Net, brushed motor, tether cabling, PLA, PVC tube, velcro tape, magnets	Purchased	N/A	N/A	100.00
				Sub-total of ROV Parts	100.00
	Electrical Distribution Control Panel (EDCP)				
VEX Contoroller Kit	Re-used from 2012 ROV (Alpha)	Re-used	1	205.13	205.13
Optical Video Receiver	Re-used from 2017 ROV (Zeta) Video Signal to Media Convert	Re-used	2	16.03	32.06
Flight Case	26" (L) x 24" (W) x 39" (H) For Building the Control Panel	Re-used	1	187.50	187.50
Tether Reel	Storage of Tether	Re-used	1	12.50	12.50
24" Monitor	For Building the Control Panel	Re-used	1	100.00	100.00
8-channel DVR	For Building the Control Panel Re-used from 2017 ROV (Zeta)	Re-used	1	250.00	250.00
Optical Video Transceiver	For Building the Control Panel Re-used from 2017 ROV (Zeta)	Re-used	1	25.00	25.00
220V AC to 12V DC Converter	Re-used from 2017 ROV (Zeta)	Re-used	1	12.82	12.82
Amp Meter	50A Max, Re-used from 2015 ROV (Delta)	Re-used	1	2.56	2.56
Volt Meter	100V Max, Re-used from 2015 ROV (Delta)	Re-used	1	2.56	2.56
Miscellancous Components	Switches, Wires, Connentors	Purchased	1	12.82	12.82
				Sub-total of EDCP	842.95
	Others				
Comsumables	Sand Paper, Glue, Drill Bits, Epoxy, Solder, Saw Blades, Zip Ties	Purchased	N/A	N/A	128.21
PVC Tubes	Building prop	Purchased	N/A	N/A	125.00
3D printer Filament: 1kg PLA	Used in Camera, ESCs, Optical Fiber and Styrofoam	Purchased	5	3.5	17.50
Fluid Power Quiz	Pay at Active.com	Purchased	1	25	25.00
Regional Registration Fees	Active.com: IET/MATE Hong Kong Underwater Robot Challenge 2021	Purchased	1	120	120.00
	Internation Championship (Telepresence)				
MATE Registration Fees	Active.com: MATE International ROV Championship	Purchased	1	100	100.00
Swimming Pool with Lifeguards	Renting Service	Purchased	30	120	3,600.00
Transporation	Renting Coach from School to Swimming Pool	Purchased	6	200	1,200.00
Meal	5 days for 4 employees and 3 mentors	Purchased	105	10	1,050.00
				Sub-total of Others	415.71
				Total Expense of Re-used (ROV) in USD	5,098.11
				Total Expense of Purchased (ROV) in USD	7,349.05
				Total Expenses of Iota in USD	**12,447.16**

Figure 51: Project costing of Apr 2021 – Jul 2021
(Diagram by Candy LEE)

	USD
Total Income	46,050.00
Less: Total Expenses of purchased (ROV)	7,349.05
Surplus of 2020-2021	**38,700.95**

Figure 52: Summary of incomes and expenses from Apr 2021 to Jun 2021
(Diagram by Candy LEE)

The COVID-19 pandemic has seriously affected the preparation of the MATE ROV competition since our school has been suspended for almost a year, even though sometimes our school returned to face to face classes. However, the Education Bureau has extended a temporary ban on extracurricular activities. That is the reason why we started our project in April 2021 as soon as schools announced resumption of half-day face-to-face class arrangements.

The CMA Underwater Expert team, together with its supervisors and mentors, had altogether contributed approximately 480 hours for planning, designing, building and testing in this project since April 2021.

A. Lesson Learnt

While working on the project, we have obtained and improved upon a variety of skills in mechanics, engineering, electronics and programming as well as teamwork. It provides invaluable experience that in no way could be taught in class.

Technical

In this project, we have obtained a variety of skills in mechanics, engineering, electronics, and programming. It provides an invaluable experience that in no way could be taught in class.

First, we learned that safety is of utmost importance in engineering design. Theoretically, the power supply for the ROV should be set at 12 volts as regulations stated. Yet, during one of pool trials, the voltage spiked up to around 15 volts and exceeded the maximum value of operating voltage. Fortunately, most of the electronic components in circuits have a reaction mechanism for overvoltage that cuts the current before they are burnt. Since then, we have learned to add safety factors and plan for a degree of flexibility when calculating payload capability, voltage acceptance, and other aspects of the ROV. This is necessary for protecting the equipment and operating personnel.

Secondly, we realized the importance of documentation. After the first pool trial, a camera turned mouldy. It was the time when we realized that only one team member is experienced in the fabrication process of cameras. Therefore, we made a step-by-step guide for beginners. By using a graphic method to break complicated theories into user-friendly chunks, the guide can act as the training manual to help newcomers move up the learning curve faster. It can be accessed by anyone in times of need, if there is confusion regarding what are the best practices for a task, one can look at the detailed documentation and operational ambiguity can be reduced. Also, by following guides, we can ensure that our products are consistent and compatible with previous ones.

Interpersonal

We have obtained the Champion Award in the Ranger Class at the IET/MATE Hong Kong Regional - Underwater Robot Challenge 2021 in mid-June. This granted us the qualification to represent Hong Kong in the upcoming MATE International ROV Competition. Because of the pandemics, this year the host institutions organize the Competition online and we must prepare a pool of at least 2 meters of depth by ourselves. Companies that cannot meet these specifications may not complete any steps of the task. However, all swimming pools are closed during the time of this pandemic. And we don’t have any similar facility or equipment in our lab. After a formal request, Micasa Studio promised to rent their pool for our practice. We will continue cooperating with each other in the future, for the pool rental services.

B. Future Improvement

We have improved a lot on the design (such as modified camera positions and added magnets to the main manipulators for pulling a pin) and innovated new tools (Plastic debris collector, Micro-ROV) for ***Iota***. But we believe there is always room for improvement.

In task 3.4, we need to pilot the vehicle to take images of the four sides and top of the subway car and create a photomosaic of the subway car. There are two options available, including creating a software program to autonomously “stitch” the images together, or using art programs such as Photoshop and MSPaint to “cut and paste” the images to create the photomosaic. We selected the latter one, as Terry does not thoroughly understand all the techniques in OpenCV. The photomosaic can be made by using software to combine the side view image of the subway and its top view image.

Although no extra points would be given for creating the photomosaic autonomously, we think that creating a software program to autonomously “stitch” the images can save more time, which means earning more ‘reward’ marks. Also, the chances of human mistakes can be reduced as we are not required to “cut and paste” the images. While this suggestion could not be realized in ***Iota***’s design due to time limitations, we will continue to improve and develop on this limitation in future designs.

C. Reflection

Samuel HUI, CEO,
Mechanical Engineer (Grade 11)

It is my first year bearing the enormous responsibility of being the CEO of CMA Underwater Expert Ltd. Last year I was responsible for Mechanical Engineers. Since many senior team members have graduated, and only four members participated in the MATE ROV competition this year, each of us is responsible for more duties than we used to. To be honest, it is very stressful to be the CEO, but I will try my best to lead the team. Our goal is still the same as ever, to build the best ROV we possibly could.

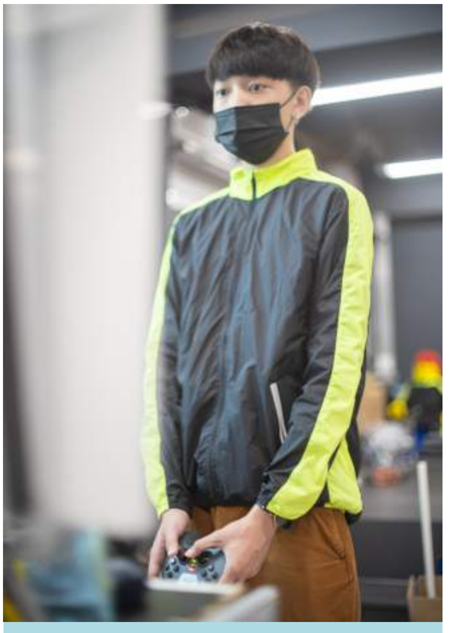


Figure 53: Samuel being pilot and CEO in the team.
(Image by Candy LEE)

ROVs have always been something special to me, something way bigger than other school projects. It has opened up countless windows for me to learn and see. Since I will focus on schoolwork next year, this will be my final year participating in the MATE Competition. With this in mind, I will be extra attentive to every detail, pushing our team to the next level.

Terry AU,
Secretary, Electrical Engineer, Technical Writer (Grade 10)

This is my third year participating in the MATE International ROV competition. I became a secretary last year and found that this position suited me well. Reflecting on last year’s experience, I focused more on team communication as it has always been my strong suit, to become the glue of the team to help everyone stay focused and become more considerate.

Figure 54: Terry operates our ROV under CEO supervision.
(Image by Candy LEE)

This year, I was appointed as the Secretary of CMA Underwater Expert Ltd again. Same as last year, being in charge of a vast majority of administrative and report-related duties is not an easy job. I have to communicate a lot with my teammates regarding the scheduling and completion of reports. There were often disputes, but I learned how to be professional and just carry on with my job.

I will use all the knowledge I learned in previous projects, while the most important thing is to enjoy the process of learning.

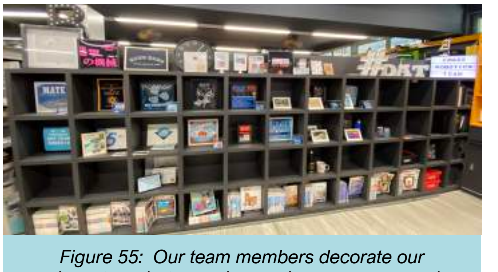


Figure 55: Our team members decorate our underwater robot room by previous years souvenirs
(Image by Candy LEE)

Last year, we renovated our robotic room. We also use the souvenirs from 2012 to present, such as clothes and pins for decoration, so we can record and remember how we and MATE grow. And to express thanks to teammates' dedication, we made a mini 3D print ROV and put it together with the the awards we obtained in the past MATE Competition. I hope the decoration can help promote our company and thus raise people's awareness of underwater robotics.

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Jacky MA,
Mechanical Engineer, Troubleshooter (Grade 11)

This is my third year participating in the MATE ROV Competition. In previous years, I was responsible for tether management and assembling ROV. Also, I was the department head, responsible for planning strategies and monitoring our department's progress to achieve our goal. However, this year we only have 4 members in our company. Everything needs to be handled by ourselves. I have to take responsibility as the leader. Without a doubt, it is challenging to connect with all the teammates, not to mention guiding them.


Figure 56: Jacky has a tank test with ROV for testing ROV performance.
(Image by Candy LEE)

Therefore, I undertake most of the duties related to building ROV. For example, since one of the cameras was damaged a year after the last season, I need to sketch and create a cover for that camera in Fusion 360. Then, I use ideaMaker as a slicing software and use a 3D printer to print the PLA cover. The next step is the most important, which is putting epoxy between the cover and camera. I need to be extremely careful and patient to make sure the epoxy fully covers the camera, for it to be fully waterproofed. It is very interesting and brings much satisfaction when my design comes out.


Figure 57: Jacky making Micro-ROV tether
(Image by Candy LEE)

I am so happy to work with my colleagues this year. However, it is likely to be my last year joining the MATE ROV competition because I will be a senior student next year. I should focus more on my studies, but I will not give up learning about robotics.

Candy LEE,
Marketing Executive, CFO (Grade 10)

I participated in the MATE International competition 3 years ago, but only for the presentation part. I had no idea about the vehicle design, building specifications, or the competition rules. But this year, I decided to get more involved, for it to be a full experience. Since I am studying Business, Accounting, and Financial Studies (BAFS) in school, one of my roles is the Marketing Executive of CMA Underwater Expert Ltd, which is mainly responsible for conducting research, analyzing statistical data, and devising ideas and strategies. I wish I could learn more marketing knowledge and apply them to real work experiences. By acquainting myself with the business field, I could also explore my career path, helping me determine if the field is right for me.


Figure 58: Candy proofreading all documentation before submission.
(Image by Terry AU)

In this competition, we have to think of ourselves as an entrepreneur and work in a company to solve some real-world environmental problems. Without a doubt, this is a whole new experience for me and I have learned a lot more about the business operations, such as division of labor, communication skills, and media outreach.


Figure 59: Candy record all the tank test for debriefing sessions.
(Image by Terry AU)

D. Reference

1. Bradski, Gary and Adrian Kaehle (2008), *Learning OpenCV. Sebastopol California: O'Reilly*
2. Morecki, and G. Bianchi, and K. Jaworek(1995), *Theory and Practice of Robots and Manipulators :Proceedings of RoManSy 10 : the Tenth CISM-IFToMM Symposium. New York : Springer Verlag*
3. Bohm H., Jensen V. (2010), *Build Your Own Underwater Robot and Other Wet Projects. Hong Kong: Printing International Co. Ltd.*
4. Information Resources Management Association (2013), *Robotics Concepts, Methodologies, Tools, and Applications. United States: Hershey, PA :Information Science Reference*
5. MATE Center, *Underwater Robotics Science. Retrieved March 31, 2017 from http://www.marinetech.org/main/*
6. Niku, Saeed B (2011), *Introduction to Robotics: Analysis, Control, Applications. United States: Hoboken, N.J. : J. Wiley & Sons*
7. Thierry Peynot, Sildomar Monteiro, Alonzo Kelly, Michel Devy (2015), *Volume 32, Issue1, Journal of Field Robotics: Special Issue on Alternative Sensing Techniques for Robot Perception. United States: Wiley Company*
8. Gianluca Antonelli (2006), *Underwater robots: motion and force control of vehicle-manipulator systems, Berlin : Springer-Verlag, 2006*
9. Bessa, Wallace M ; Dutra, Max S ; Kreuzer, Edwin(2013, Vol.10(9)), *Dynamic Positioning of Underwater Robotic Vehicles with Thruster Dynamics Compensation, International Journal of Advanced Robotic Systems*
10. Lee, Tae-Seok ; Lee, Beom , 2014, Vol.19(1), pp.75-89,*A new hybrid terrain coverage method for underwater robotic exploration, Journal of Marine Science and Technology*

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Figure 60: Logos of the acknowledged parties
(Prepare by Candy LEE)