Lobsta

Technical Documentation

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I. Abstract

Over-Defined is a company dedicated to developing the most advanced ROV to conquer challenges while performing complicated and perilous underwater missions. 30 dedicated and skilful engineers had been working for over 450 hours, creating the new multi-functional ROV, Lobsta, our third-generation ROV. It is designed to be state-of-the-art in ROVs and aims to put an effort into achieving the Sustainable Development Goals by the United Nations, as well as accelerating attention to marine health.

To complete various tasks in the water, Lobsta is equipped with a multifunctional gripper, a fish collector, These up-to-date designs enable our ROV to perform complicated tasks such as monitoring smart buoys, producing power, and monitoring environmental impact. An additional vertical profiling float is designed along with the ROV to assist in investigating the underwater environment.

In this document, we will talk about Lobsta design and our development process throughout the year. By contributing to ROV development, we strive for a better future and understand and protect our planet with our passions and knowledge.

Figure 1. Company Photo

II. Teamwork

A. Company Profile

Established in 2022, Over-Defined is a company located in Kwun Tong, Hong Kong. Our company specializes in designing robots that protect and restore ecosystems and biodiversity. Currently, we have a workforce comprising 30 dedicated engineers, divided into three departments: Mechanical, Electrical, and Software. Each department is led by a senior engineer who mentors and guides the junior engineers.

The CEO of Over-Defined takes on two roles within the company: managing the team's progress and designing parts of the ROV, while the CFO oversees the company's expenses and fulfills the role in the Electrical department. Furthermore, the CTO distributes work to the team leaders and also designs the documents. The CEO and CTO work closely together to conduct testing and provide feedback to the engineers, aiming to improve the design and functionality of our robots. Their collaboration allows for faster testing and ensures the delivery of reliable components. At last, the Safety Officer designs the safety checklist for members to use while designing, constructing and testing the robot.

Over-Defined experienced a 31.8% increase in the number of engineers this year. As part of their onboarding process, all new engineers underwent a one-year comprehensive learning course, which covered a wide range of knowledge and skills in Mechanical, Electrical, and Software domains. They would then choose their own path in one of the three and continue honing their skills.
This initiative was implemented to ensure that the engineers have a solid foundation in all areas, enabling them to contribute effectively to the company's long-term growth and ensuring their success in the future. Figure 2 on the right of this paragraph shows the members of the company and the detailed position of them.

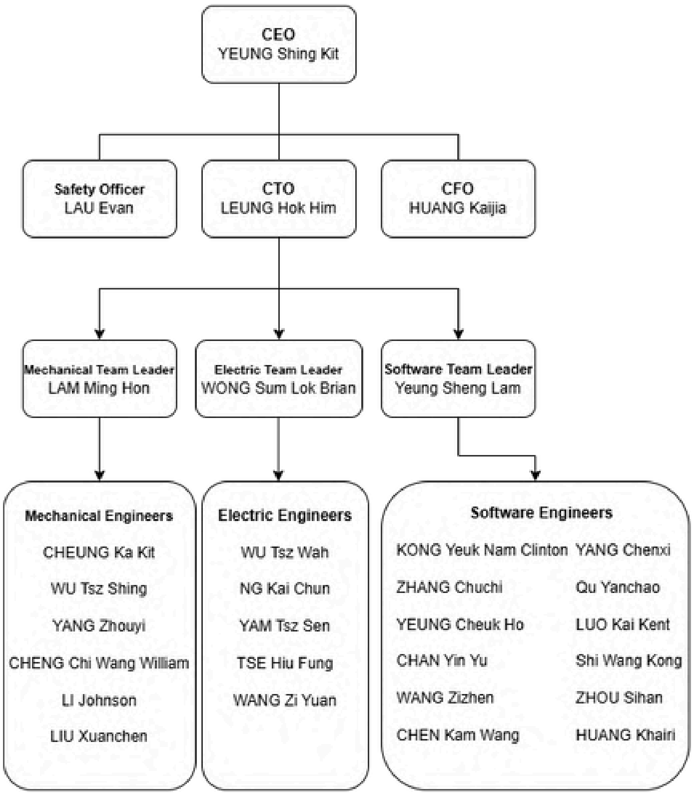


Figure 2. Over-Defined Company Distribution Diagram

B. Project Management

When it comes to program management, our company uses a table to record the progress of the task given to team members, ensuring everyone can finish the project on time. The table used lasts for a whole year, as it can keep track of how long the members have been using it to design the parts of the ROV and could remind members about it.

Our team hosts a weekly meeting on Wednesdays for members to present their ideas to others thus syncing up the teammate's progress. This action ensures that the productivity of the team would not be affected even if the main person in charge is absent due to the idea already being presented. The member in charge could ask for help from other members anytime in need, as the board would try to find others to support him to continue designing.

Figure 3. Weekly Meeting

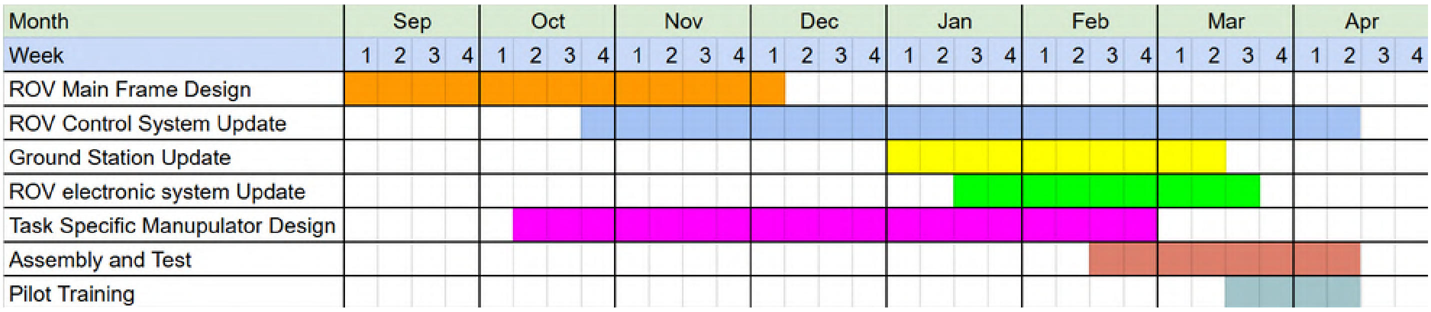


Figure 4. Project Timeline

III. Design Rationale

A. Design Evolution

1. Engineering

During the design phase of this year's ROV, we drew from our previous experience by reviewing our last year's design. After analyzing it, we decided to enhance our design in two key areas: serviceability and flexibility. To achieve these targets, we introduced several new designs such as the rotational gripper to improve flexibility in handling various situations and the quick-release latch mechanism to enhance serviceability.

In addition to improving the previous design, we also introduced new tools to complete the unique tasks of this year. We first assessed the capabilities of our old tools and identified those that couldn't be performed. Subsequently, we designed a new manipulator to address the unique challenges of this year by analyzing the specific requirements of the tasks. The new manipulator design will undergo rigorous testing to ensure its reliability and efficiency.

Our main goals were to design a 3D-printed ROV with flexible, modular parts specific to the year's tasks. To achieve the target, our ROV is equipped with a rotational gripper, pCO2 sensor, 360 degree cameras and Velcro. In addition, an octagonal-shaped frame is used as the base of the ROV. There are numerous standardized holes on the frame to facilitate the installation of off-the-shelf products such as LEGO and MakeBlock components. This can elevate freedom and reduce the predicted cost of the ROV significantly.

This year, we put emphasis on the improvement of safety, serviceability and flexibility. After several discussions, we agreed to optimize the previous components to boost the efficiency and reliability of the ROV. All the designs from last year were remade and improved. To maximize the productivity, we ditched some of the previous designs and focused on creating a specialized and mission-specific ROV. We took the centre of gravity, the water resistance and buoyancy into consideration. Based on intensive testing and pilot feedback, we made a concerted effort to strike a balance between the above factors. We agreed to lower the position of the thrusters and add more gaps to reduce water resistance.

2. Innovation

When a task requires new functions, our company creates modular parts or makes general improvements on our ROV. This year, we have made several innovations such as a new gripper design, quick-release buckle and the ping-pong system.

Our new gripper design possesses 180-degree rotational capabilities without the addition of a motor. This design allows a grip on both horizontal and vertical pipes, this enhances the versatility and effectiveness of our ROV, and allows the gripper to unleash more of its functionality.

We have also adopted a quick-release fixing system for the watertight compartment fixer of our ROV, utilizing a buckle mechanism and additionally comes with a change in thruster positions, reducing the time cost of installation and repairing.

Our strength in clever innovating can also be reflected from our fish collector. Using a thruster to suck in the fish, since it does not require much accurate alignment, it increases flexibility of the fish-collecting system.

Such components are great examples of innovations and modifications of our company that result in high functionality at reduced costs, and those presented in Lobsta's structural design and tools.

3. Problem-Solving

First, we analyze the tasks thoroughly. By identifying the task and its related requirements, we gain a clear understanding of the problem we intend to solve. Next, we observe and analyze tools and features utilized in daily life for inspiration. This allows us to draw upon similar concepts from existing products to effectively address the task at hand.

Following this, we develop a preliminary concept. By envisioning the tools required for the task, we can begin to visualize the possible solutions. After this ideation process, we create initial sketches that represent our ideas more concisely.

During this process, we use diagrams and interpretations to clearly represent our idea. Subsequently, we gather all team members to discuss various potential solutions for the task. We draw sketches to express our ideas with greater precision. After engaging in discussions, we decide on the changes in solutions in the weekly meetings, collecting feedback to inform improvements.

Once we finalize the design based on collective input, we assign different components of the design to the most suitable team members, to bring virtual concepts into tangible reality.

B. Vehicle Structure and Systems

1. Vehicle Structure

This year, we identified three types of 3D printing materials such as: PETG, PLA, and ABS, alongside three other materials: PVC pipe, stainless steel, and aluminum alloy, for structural selections.

In figure 5, demonstrates that PVC pipe and stainless steel offer low customizability. Because of our company's advanced mechanical capabilities, we opted for more flexible materials to meet our design needs. While carbon fiber was considered, its higher cost led us to choose 3D printing materials, which provide a versatile and cost-effective solution for our ROV.

Our ROV's structure was originally made from PLA, but they broke and needed replacement material. After searching alternative materials, we found PETG and ABS as potential options because of their similar properties and their durability is higher. However, scientific studies show that ABS emits more toxic gases during printing. Therefore, we decided to use PETG instead.

	PETG	PLA	ABS	PVC pipe	Stainless steel	Carbon fiber
Cost	low	low	low	low	high	high
Customizability	higher			low	low	highest
Weight	lighter	lighter	lighter	lighter	heavier	lightest
Corrosion or Oxidation	NO	NO	NO	NO	NO	NO
Stiffness	low	high	medium	low	medium	high
Durabilility	medium	low	medium	low	high	high

Figure 5.
Comparison of different materials

We chose to use 3D printing for making the frame because it is relatively cheap and it allows more flexibility within the design. The overall size of the frame has been enlarged to enable the installation of more items. The size is 420mm * 420mm, which is the maximum size that our 3D printer can print. To minimize the time for the ROV to move from one target to another and reduce the movement during precise positioning. We have changed the angle of the thruster so that it focuses more on the increase in the forward and backward movement speed. The hole spacing 16mm allows for the installation of Lego and Makeblock for increased flexibility. The waterproof compartment mount feature uses a quick-release mechanism using latches (Figure 6) .

In figure 7, The installation position of the thrusters is improved to enable easy maintenance. The weight increases as the waterproof compartment gets larger. The inclination angles on both sides of the weight mount are set to prevent the tether from getting stuck.

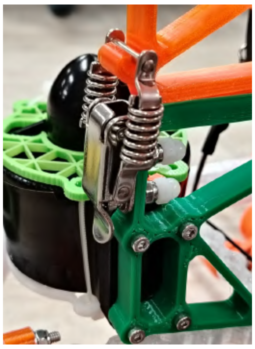


Figure 6.
Latches on the ROV

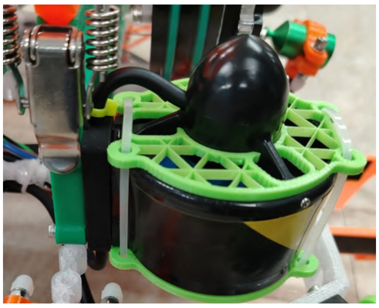


Figure 7.
Vertical thrusters placement

2. Propulsion

Our ROV features 4 horizontal thrusters and 4 vertical thrusters on an octagonal frame. The horizontal thrusters are placed diagonally to let the vehicle move in all directions. We found that we use front and backward movement much more than side to side. We place the horizontal thrusters pointing more towards the front so that the ROV can move between tasks faster and allow precise sideways movement .

The vertical thrusters are placed in the corners to increases stability. They can also be controlled to spin in different directions to control pitch and roll, in additional to standard rise and submerge.We placed the vertical thrusters with the screws exposed for easier replacement, improving form our old design, This can also free up more space for the manipulators.

The thrusters can be controlled to allocate more of the power provided to horizontal or vertical movement in additional to standard balanced mode. Prioritizing horizontal movement enables quick travel between tasks and allocating more power for vertical movement can reduce the time to travel between shore-side and bottom of the pool, The balanced mode is primarily used for precise movement control of the ROV when doing tasks.

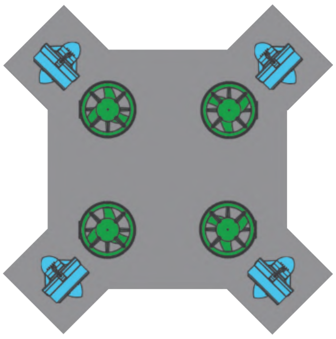


Figure 8.
Thruster placement of ROV

3. Buoyancy and Ballast

In order to place the center of gravity at the lower position of the vehicle, the weight mount is placed beneath the machine, due to the increase in the size of the waterproof chamber, our buoyancy is increased hence the weight (stainless steel plates) has also need to be increased. The stainless steel plates come in three different sizes and can be installed on both sides to precisely adjust the buoyancy and balance, resulting in neutral buoyancy and ensure the center of gravity is very low at the center, making the ROV more stable.

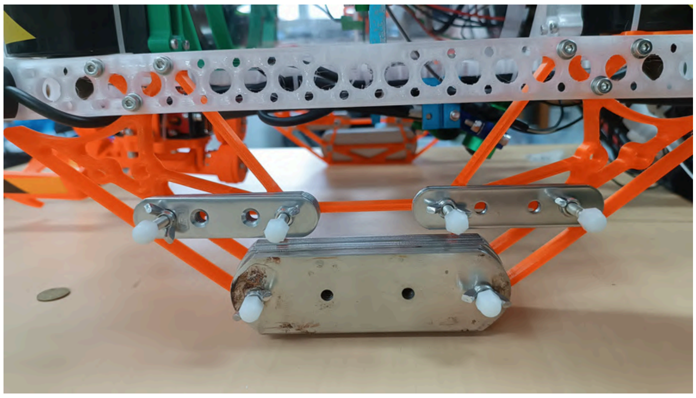


Figure 9.
Left side view of ROV installed with stainless steel plates

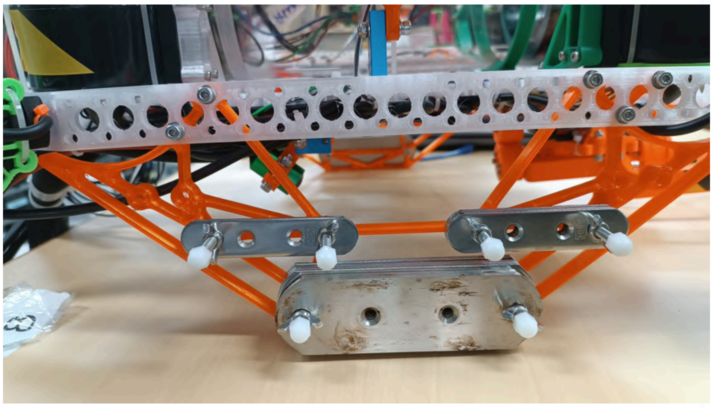


Figure 10.
Right side view of ROV installed with stainless steel plates

C. Electrical and Control Systems

1. ROV Electronics

Our ROV consist of 3 main parts in electronics, the shore side controller box, the ROV waterproof chamber side and a tether connecting between them.

2. Waterproof Chamber Side

To achieve maximum serviceability, We designed a centralized circuit board(PCB) housed within a waterproof chamber for power and signal distribution.

The new design significantly reduces the likelihood of human error and enhances wiring clarity by providing a unified platform for all electronic components. The high degree of customization allows us to create tailored shapes that make optimal use of space. It also features a unique mechanism for easier PCB installation using magnets.

The new design features multiple signal and power ports for signal and power distribution to thruster and servo, a capacitor for filtering, a dedicated voltage meter that offers real-time monitoring of current-voltage levels, and a 12V to 6V converter to accommodate varying voltage requirements.

We have added 4 spare signal ports in this design to increase expandability. Clearly printed texts on the PCB allow quick location of all connections, ensuring that every wire is correctly routed.

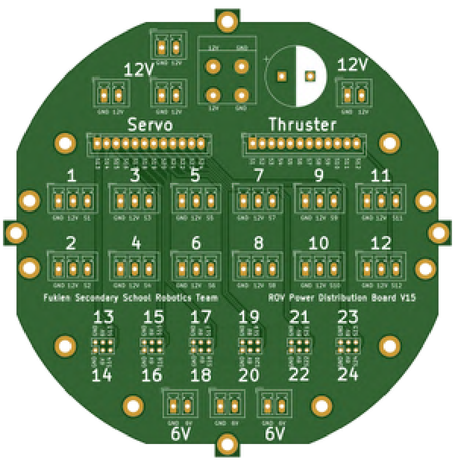


Figure 11.
Waterproof chamber side PCB

3. Tether

Over-Defined's tether is 18.3 meters in length and consists of two ten-core signal wires, two power cables, eight camera cables, and a fishing line. All tether features are in cable protection sleeves with a reliable strain relief on both ends. Three flexible foam filter strips to create neutral buoyancy and prevent entanglement in the water, ensuring a safe mission environment. The fishing line is used to make it easier and faster to replace or add cables when needed.

The voltage drops about 3V from 12V on shore to 9V underwater.

Cable diameter of ten-core signal wires is 10*0.2 mm^2, with maximum resistance of 92.3 ohms per km.

Following successful deployment, the tether manager maintains control of the tether, providing sufficient slack to enable ROV mobility while dynamically adjusting length as needed. During operations, constant tether contact must be preserved, with careful avoidance of abrupt directional changes or excessive maneuvers to maintain operational safety.

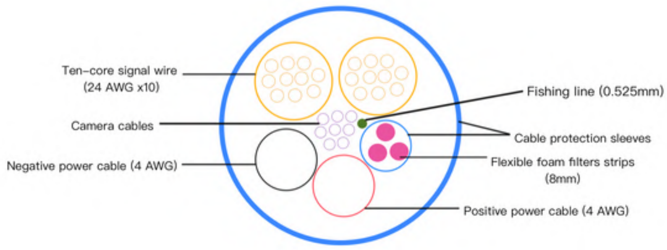


Figure 12.
The structure of the tether

4. Shore-Side (Electrical)

The controller circuit board has been designed with a focus on simplification and adaptability to meet diverse functional requirements. The controller circuit board incorporates a streamlined layout that reduces wiring complexity, enhancing efficiency during assembly. Notably, most of the components, such as switches and buttons, are symmetrically arranged on both sides to serve as backups, ensuring reliability in various operational scenarios.

When compared to off-the-shelf solutions, this design offers greater flexibility and customization. Users can tailor functionalities according to specific needs, which is a significant advantage over standardized products. In contrast to previous versions, the updated circuit board introduces substantial improvements. Four three-position switches and additional components have been integrated into the base design, while single-axis joysticks have been added on both sides. The power management system is also upgraded with a dedicated 12-volt distribution feature, optimizing performance.

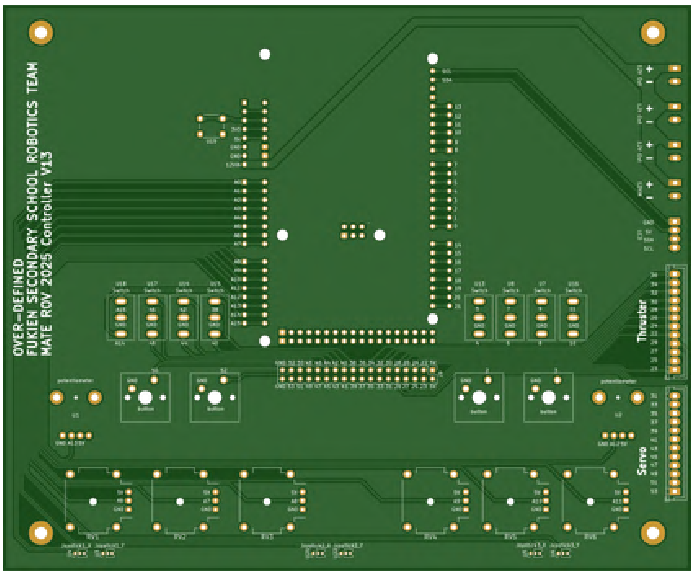


Figure 13.
Shore-side PCB

5. Shore-Side (Mechanical)

The monitor is securely mounted on the upper cover of the controller box, removing the need for manual handling. Its high-brightness display ensures clear visibility in all weather conditions. The controller is divided into two key components: the main board and the lifting system.

The main board integrates the control panel, camera PCB, LCD display, and various electrical connections. Dedicated input/output ports for the ROV ensure clean and organized cable routing. The control panel, mounted on the main board, features three joysticks connected to the controller PCB, with switches positioned at the upper part of panel, and single-axis joysticks placed just above the joysticks for better operation.

The lifting system allows the main board to be raised during operation for ergonomic control, then lowered when not in use to prevent component damage and maximize space efficiency inside the controller box.

The lower compartment houses a HIK-vision video converter and a power distribution bar. The HIK-vision device converts composite video signals to HDMI for display on the monitor, while the power bar consolidates power connections for both the monitor and the converter, eliminating the need for separate cables and simplifying setup.

Figure 14.
Rendered Controller with solidworks

6. Control System

The goal of our software is to enable pilots to control the ROV (Remotely Operated Vehicle) with unrestricted underwater movement. To achieve this, we utilize the Arduino platform and the C++ programming language.

By applying mathematical calculations, we accurately determine joystick angles and map them to corresponding thrusters. A single-axis joystick is also used to simultaneously control the gripper and servos.

We have two main switches to enhance functionality:
Power Optimization Switch: Maximizes power efficiency (capped at 25A) by dynamically adjusting thruster output.

Roll/Pitch Switch: Enables the ROV to tilt 45 degrees left/right or up/down, simplifying tasks such as navigating complex structures (e.g., polyp-stage jellyfish environments).

These features minimize task completion time, significantly improving the ROV's operational efficiency.

Additionally, an LCD (Liquid Crystal Display) displays real-time control parameters, drastically reducing debugging time and allowing swift, effective troubleshooting during malfunctions.

Before deployment, we create a flowchart to outline the robot's control logic. This ensures clarity in design, minimizes errors, and streamlines implementation.

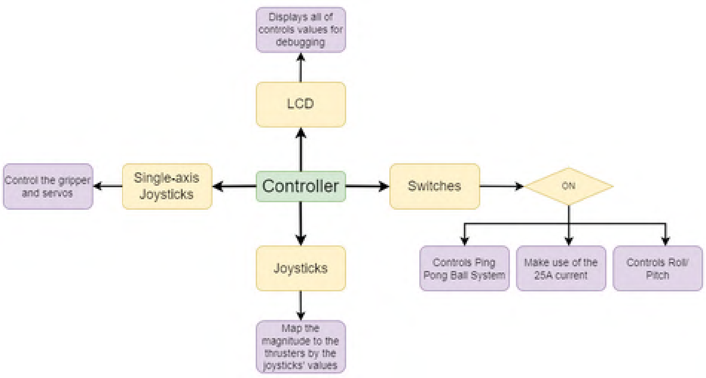
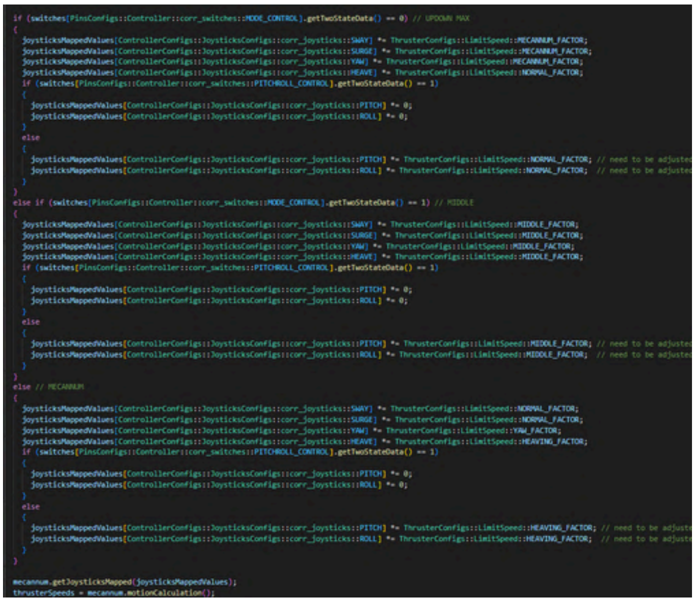


Figure 15.
Control Scheme of our ROV

The power optimization control part controls the pitch/roll and optimizes the 25A to achieve maximum power efficiency.



```
if (switches[PinsConfigs::Controller::corr_switches::MODE_CONTROL].getTwoStateData() == 0) // UPDOWN MAX
{
  joysticksMappedValues[ControllerConfigs::JoysticksConfigs::corr_joysticks::SWAY] *= ThrusterConfigs::LimitSpeed::MECANNUM_FACTOR;
  joysticksMappedValues[ControllerConfigs::JoysticksConfigs::corr_joysticks::SURGE] *= ThrusterConfigs::LimitSpeed::MECANNUM_FACTOR;
  joysticksMappedValues[ControllerConfigs::JoysticksConfigs::corr_joysticks::YAW] *= ThrusterConfigs::LimitSpeed::MECANNUM_FACTOR;
  joysticksMappedValues[ControllerConfigs::JoysticksConfigs::corr_joysticks::HEAVE] *= ThrusterConfigs::LimitSpeed::NORMAL_FACTOR;
  if (switches[PinsConfigs::Controller::corr_switches::PITCHROLL_CONTROL].getTwoStateData() == 1)
  {
    joysticksMappedValues[ControllerConfigs::JoysticksConfigs::corr_joysticks::PITCH] *= 0;
    joysticksMappedValues[ControllerConfigs::JoysticksConfigs::corr_joysticks::ROLL] *= 0;
  }
  else
  {
    joysticksMappedValues[ControllerConfigs::JoysticksConfigs::corr_joysticks::PITCH] *= ThrusterConfigs::LimitSpeed::NORMAL_FACTOR; // need to be adjusted
    joysticksMappedValues[ControllerConfigs::JoysticksConfigs::corr_joysticks::ROLL] *= ThrusterConfigs::LimitSpeed::NORMAL_FACTOR;  // need to be adjusted
  }
}
else if (switches[PinsConfigs::Controller::corr_switches::MODE_CONTROL].getTwoStateData() == 1) // MIDDLE
{
  joysticksMappedValues[ControllerConfigs::JoysticksConfigs::corr_joysticks::SWAY] *= ThrusterConfigs::LimitSpeed::MIDDLE_FACTOR;
  joysticksMappedValues[ControllerConfigs::JoysticksConfigs::corr_joysticks::SURGE] *= ThrusterConfigs::LimitSpeed::MIDDLE_FACTOR;
  joysticksMappedValues[ControllerConfigs::JoysticksConfigs::corr_joysticks::YAW] *= ThrusterConfigs::LimitSpeed::MIDDLE_FACTOR;
  joysticksMappedValues[ControllerConfigs::JoysticksConfigs::corr_joysticks::HEAVE] *= ThrusterConfigs::LimitSpeed::MIDDLE_FACTOR;
  if (switches[PinsConfigs::Controller::corr_switches::PITCHROLL_CONTROL].getTwoStateData() == 1)
  {
    joysticksMappedValues[ControllerConfigs::JoysticksConfigs::corr_joysticks::PITCH] *= 0;
    joysticksMappedValues[ControllerConfigs::JoysticksConfigs::corr_joysticks::ROLL] *= 0;
  }
  else
  {
    joysticksMappedValues[ControllerConfigs::JoysticksConfigs::corr_joysticks::PITCH] *= ThrusterConfigs::LimitSpeed::MIDDLE_FACTOR; // need to be adjusted
    joysticksMappedValues[ControllerConfigs::JoysticksConfigs::corr_joysticks::ROLL] *= ThrusterConfigs::LimitSpeed::MIDDLE_FACTOR;  // need to be adjusted
  }
}
else // MECANNUM
{
  joysticksMappedValues[ControllerConfigs::JoysticksConfigs::corr_joysticks::SWAY] *= ThrusterConfigs::LimitSpeed::NORMAL_FACTOR;
  joysticksMappedValues[ControllerConfigs::JoysticksConfigs::corr_joysticks::SURGE] *= ThrusterConfigs::LimitSpeed::NORMAL_FACTOR;
  joysticksMappedValues[ControllerConfigs::JoysticksConfigs::corr_joysticks::YAW] *= ThrusterConfigs::LimitSpeed::YAW_FACTOR;
  joysticksMappedValues[ControllerConfigs::JoysticksConfigs::corr_joysticks::HEAVE] *= ThrusterConfigs::LimitSpeed::HEAVING_FACTOR;
  if (switches[PinsConfigs::Controller::corr_switches::PITCHROLL_CONTROL].getTwoStateData() == 1)
  {
    joysticksMappedValues[ControllerConfigs::JoysticksConfigs::corr_joysticks::PITCH] *= 0;
    joysticksMappedValues[ControllerConfigs::JoysticksConfigs::corr_joysticks::ROLL] *= 0;
  }
  else
  {
    joysticksMappedValues[ControllerConfigs::JoysticksConfigs::corr_joysticks::PITCH] *= ThrusterConfigs::LimitSpeed::HEAVING_FACTOR; // need to be adjuste
    joysticksMappedValues[ControllerConfigs::JoysticksConfigs::corr_joysticks::ROLL] *= ThrusterConfigs::LimitSpeed::HEAVING_FACTOR;  // need to be adjuste
  }
}

mecannum.getJoysticksMapped(joysticksMappedValues);
thrusterSpeeds = mecannum.motionCalculation();
```

Figure 16.
The program of the power optimization control part

D. Payload Tools

1. Camera System

The model of camera we chose to use on the ROV is an Analog High-Definition camera (AHD) with a 195° field of view. The camera provides us with great visibility in the water and assists the pilot when manoeuvring the vehicle. Additionally, We installed 8 cameras on the vehicle and they are located on top of each manipulator to assist the pilot in doing tasks easier.

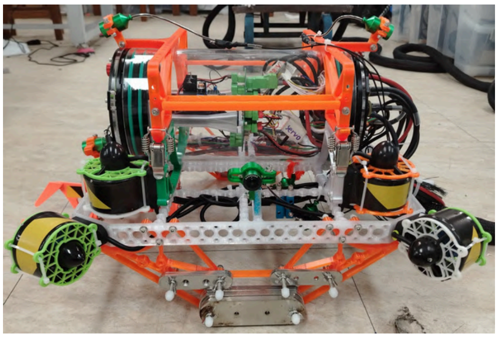


Figure 17.
Left side ROV cameras placements

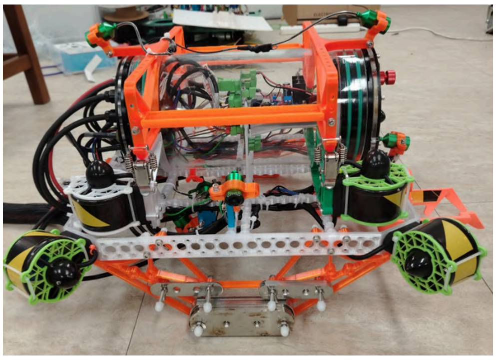


Figure 18.
Right side ROV cameras placements

2. Gripper

This year, our gripper (Figure 19) design includes the ability to rotate 180 degrees, an important improvement over last year's fixed design. The upgrade was necessary to adopt a new task in this year's competition, which required inserting a slanted pCO_2 sensor—a challenge that was difficult to address with the previous design. The updated gripper can now grab objects at various angles, making it much easier to handle competition props. It is versatile enough to work with a range of objects, such as vertical pipes and horizontal pins.

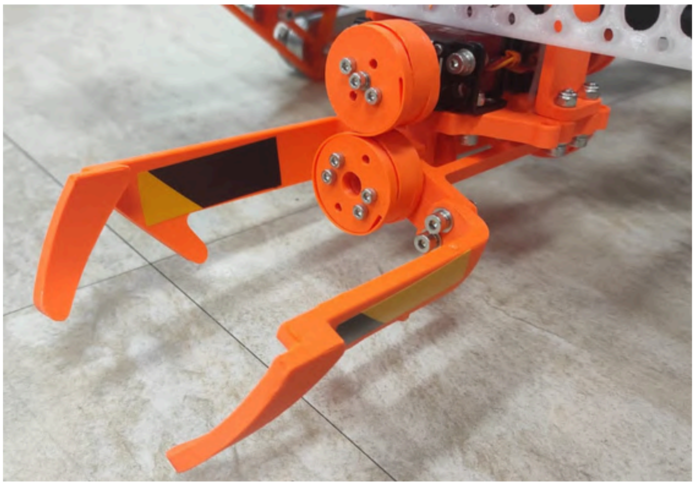


Figure 19.
The Gripper of our ROV

3.Fish Collector

We decided to use the thruster to pump water because it could create a current which sucks in the fish. Then we stop the thrusters so the fish can go up by their buoyancy. Finally we capture them by a combination of different methods like using fishnet and funnel mechanisms. One of the benefits of this mechanism is it does not require accurate alignment when doing so. Furthermore, this system is removable using magnets for quick removal and reduce drag.

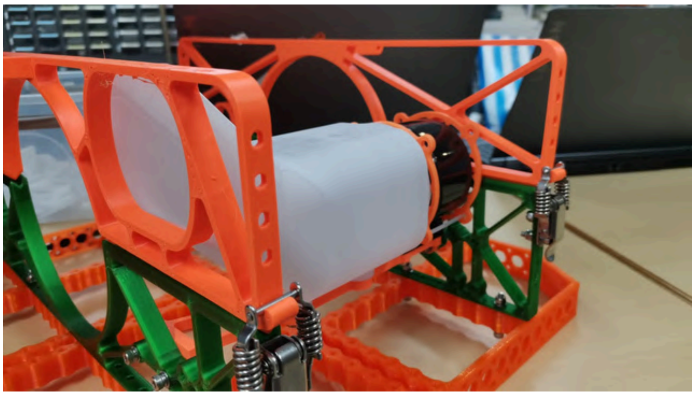


Figure 20.
The Fish Collector of our ROV

4. Photosphere

To capture a 360-degree photosphere of all seven targets, the Insta 360 X4 was used. We have to remove the battery from the camera which results in the loss of waterproofness. For solving this problem, we used a transparent waterproof container and wiring penetrator for watertightness.

Because of the USB distance limitation and for stable data transmission, we chose to use fiber-optic cable, connecting the on shore computer and the camera for real time video transmission. Secondly, the camera requires a 5V external power. In order to keep voltage steady, through setting up an underwater regulator, the 12V on shore power supply will be regulated to 5V. In order to keep the waterproofness, we used 3D printed containers and epoxy for encapsulation.

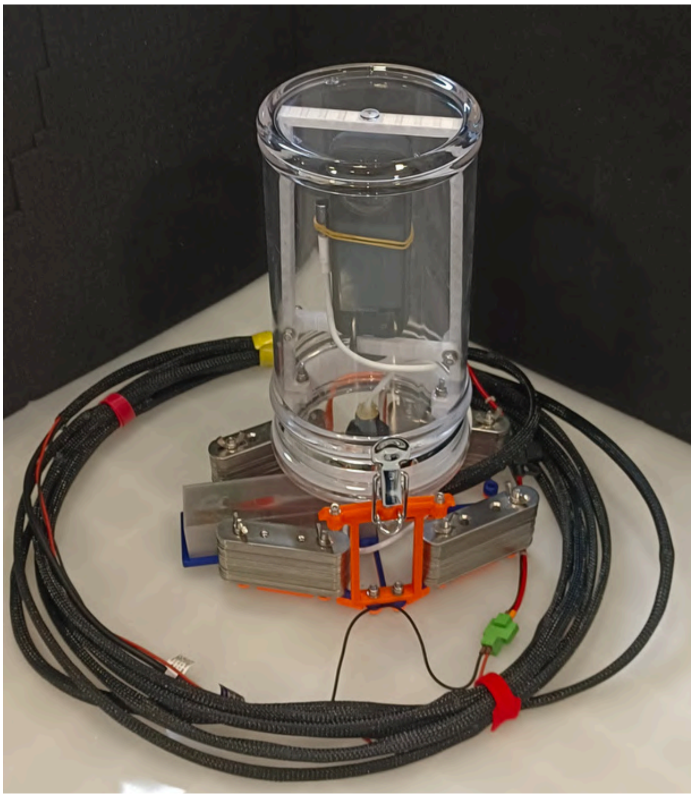


Figure 21.
Photosphere

5. Underwater Epoxy Patch

During the ideation process, our first idea was to use painting tools. However, after roughly imagining the tools in our minds, we realized that this was not the best approach to tackle the task. Through a new brainstorming session, we developed a different idea: using Velcro to partially cover the curved area of the pipe. We designed a claw-like structure to hold the Velcro in a straight line and allow it to move so that the Velcro can change its shape.

The entire tool is designed at a 45-degree angle and is used to hold the epoxy patch tightly, pulling it into a straight line.There are two Velcro hook applicator pulled by rubber bands to maintain tension. The applicators will wrap around the pipe and stick the epoxy patch onto its designated spot.

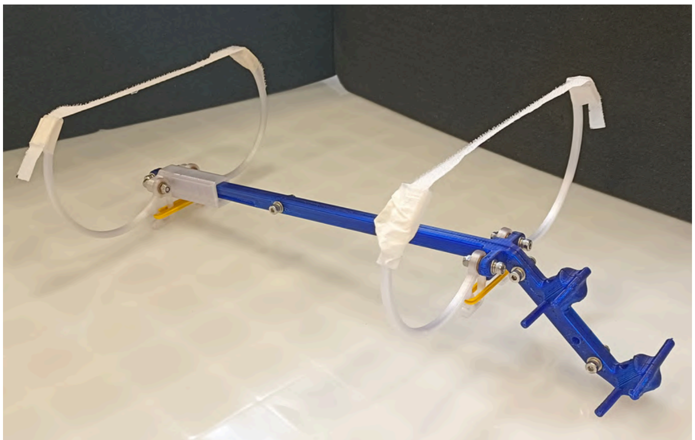


Figure 22.
Underwater Epoxy Patch

6. Polyp Stage Jellyfish Collector

We have designed a 3D printed component with many small hooks that function as a Velcro hook to collect the polyp jellies. These hooks can be used to trap the jellyfishes and prevent the jellyfishes from sliding out . They are also placed in different angles to collect the polyp jellyfishes in different orientations.

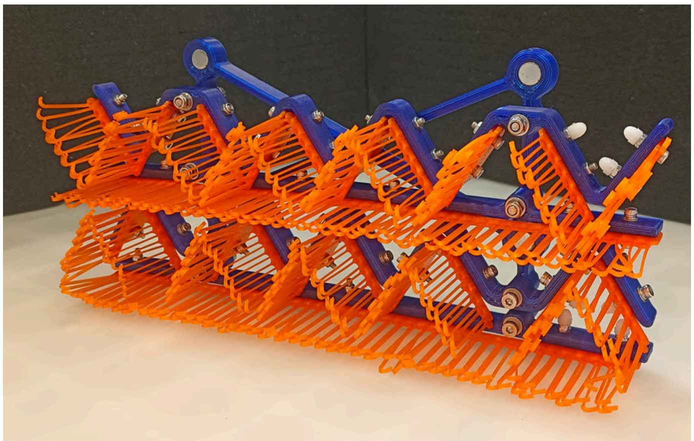


Figure 23.
Polyp Stage Jellyfish Collector

7. Medusa Stage Jellyfish Collector

In order to capture the medusa jellyfish floating from mid-water, we have designed a 3D printed container with a set of vented guides and a transparent box at the bottom. The vented guide can guide the medusa jellyfishes to slide into the transparent box easily, while the transparent box is solid and enables us to collect the medusa jellyfish with some of its surrounding water.

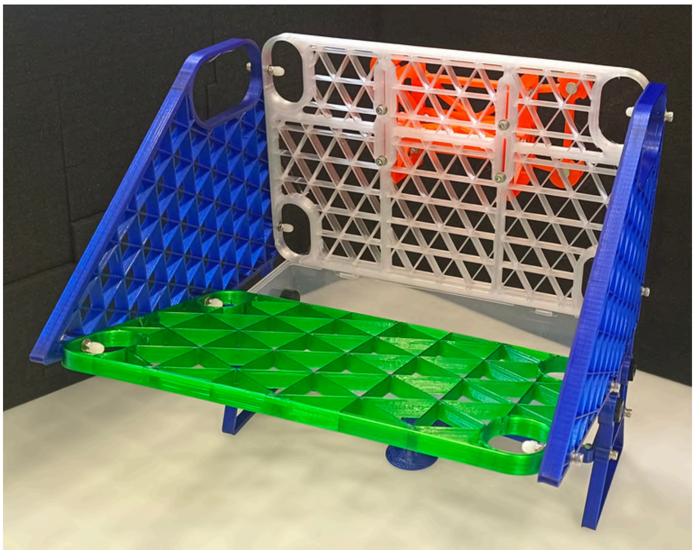


Figure 24.
Medusa Stage Jellyfish Collector

8. Bottom Claw

Designed to place the pCO2 sensor into the designated area and to change the sacrificial anode. This bottom claw is designed to complete seabed missions, facilitating the ROV's operation.

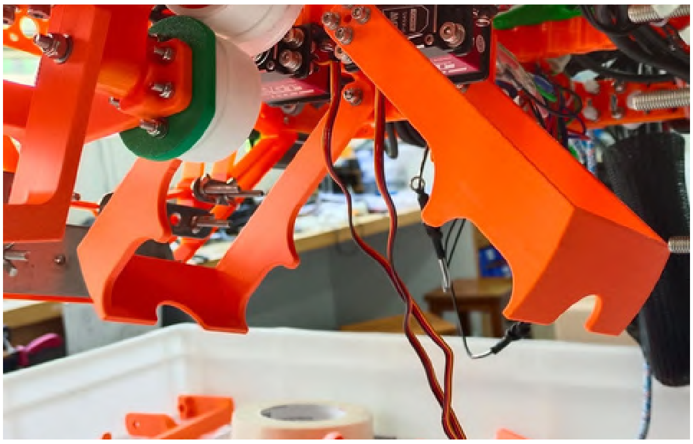


Figure 25.
Bottom Claw

IV. Buoyancy Engine

A. Structure

The VPF consists of two parts. The upper part contains a waterproof compartment housing all electronic components, while the lower part includes a stand and customized waterproof components.
Customized waterproof components consist of five parts, two acrylic boards, two o-ring spacers, and a syringe holder, each having its unique function.

The inner acrylic board holds the syringe position, preventing it from sliding into the waterproof compartment. The outer acrylic board allows sensors and switches to be installed on the VPF and squeezes the o-ring between the syringe wall and the syringe holder. Together, the inner and outer O-ring spacers prevent the O-ring between the inner and outer acrylic board from moving and provide an adequate squeeze to the O-ring to make it watertight.

Meanwhile, the syringe holder stabilises the syringe and prevents it from wobbling, pressing the O-ring on the wall of the syringe, while connecting the stand to VPF.

The stand, which is like a tripod, elevates the waterproof cabin and protects the syringe from damage. The cabin is connected by a latch to the VPF, making assembly and disassembly swifter and more convenient. The cabin's weight can also be controlled by adding or removing metal pieces, with a butterfly screw included for easier adjustments.

Figure 26. Our VPF

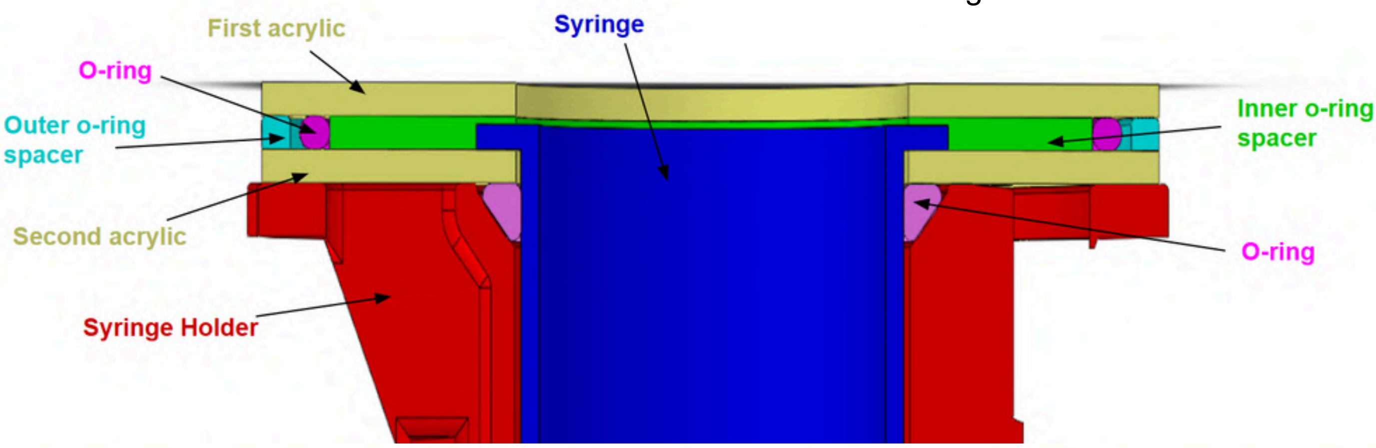


Figure 27. Structure of the VPF

B. Electrical System

The latest iteration of the VPF circuit board introduces several significant improvements over its predecessor, particularly in terms of design efficiency and functional integration. Compared to the older version, the new board features a reduced physical footprint, enabling more compact installations. A notable hardware modification involves replacing the legacy clock module with a dedicated regulator. Because the legacy clock module has no effect. This change addresses thermal limitations inherent in the previous design, as the Arduino Nano's internal voltage regulation capabilities were insufficient for prolonged operation under load, leading to overheating risks. By offloading power management to the regulator, the Arduino Nano operates within safer thermal parameters, enhancing overall system reliability.

The redesigned VPF board (Figure 26) streamlines complex tasks such as wiring and voltage management while maintaining versatile control capabilities through the Arduino Nano microcontroller. Use high-gain wireless communication modules to ensure communication is not affected by distance.

A dedicated interface supports real-time data visualization on an LCD screen, complemented by a high-intensity LED that shows clear status signals even from a distance for debugging. For sensor integration, the board interfaces seamlessly with a depth sensor, enabling precise data acquisition and transmission to the Arduino Nano. Additionally, motor driver connectivity allows precise control of linear actuators, ensuring responsive and accurate mechanical adjustments.

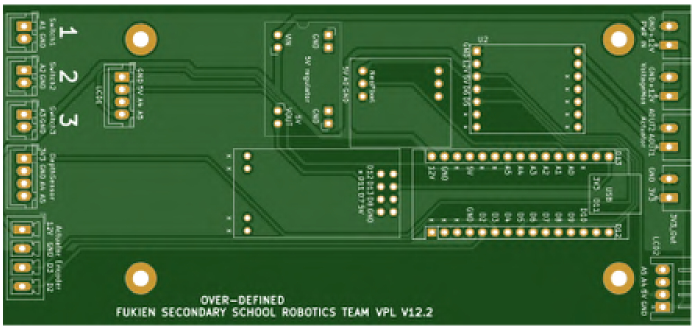


Figure 28. VPF PCB

C. Program

When it is placed into the pool, the plunger will pull to a specified position to increase the density of the VPF and reduce the buoyancy such that it sinks steadily at a relatively slow speed. It will continue to sink until it reaches the target region.

Throughout this process, it detects whether its motion is sinking or floating. If it is below the target region, the plunger automatically changes to floating mode and halts immediately so that it can travel steadily for further adjustments. With the same logic, if it is above the target region, it sinks and stops immediately, such that it could sink at a controllable speed. In this way, it could remain in the target region.

Meanwhile, the VPF uses a pressure sensor to read the pressure and generate a data packet per five seconds. Once the VPF collects ten data packets with their pressure within the target range, the VPF rises back to the surface and uses the RF24 module for wireless communication to the station on the land.

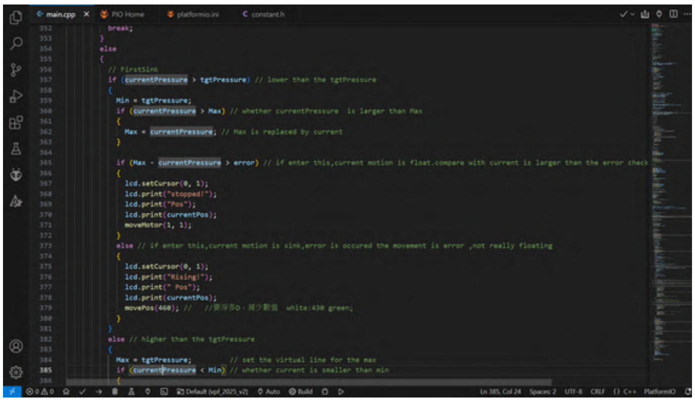


Figure 29. The Program of our VPF

V. Build VS Buy, New VS Used

A. Build VS Buy

In the designing process of the manipulators of the ROV, we sometimes buy outsourced products to research the products, giving a better understanding of the technology to our members. After researching, we would try to analyze the flaws in the design of the bought products and design our manipulators based on the data we have collected in the research, making sure that the manipulators designed have the best performance in the ROV.
Take the claw of our ROV as an example. When we first learned that a claw was needed for the tasks, we tried to find a claw online and buy it. After receiving the claw, we started testing its performance underwater. But we soon found that the claw didn't perform according to our expectations. After realizing that, we designed the claw on our own.

But, there is equipment that we do not have the skills to make on our own, like thrusters, monitors and cameras. We try to compare the options available in the market and find the ones that best suit our needs. For example, We bought a monitor that is much brighter than others so we can see the images clearly on a sunny day.

For our PCBs and the cover of our waterproofing cylinder, we designed it on our own for the customizability of them. But, as we lack the laser cutter needed for the cover to be made, we outsourced the design blueprints to shops to help us cut it.

B. New VS Used

As for the reused products, we did not use any of the products from last year. As the tasks of the competition are changing every year, the manipulators we designed last year do not suit the tasks of this year. This caused us to redesign the claw, improving it according to the tasks and ensuring the pilot could have the most comfortable experience when controlling our ROV. We also did not reuse any bought products as the ROV we used last year is used as tutoring material for primary school students and the public. The ROV Spida from last year was also being used for placing artificial reef in the ocean.

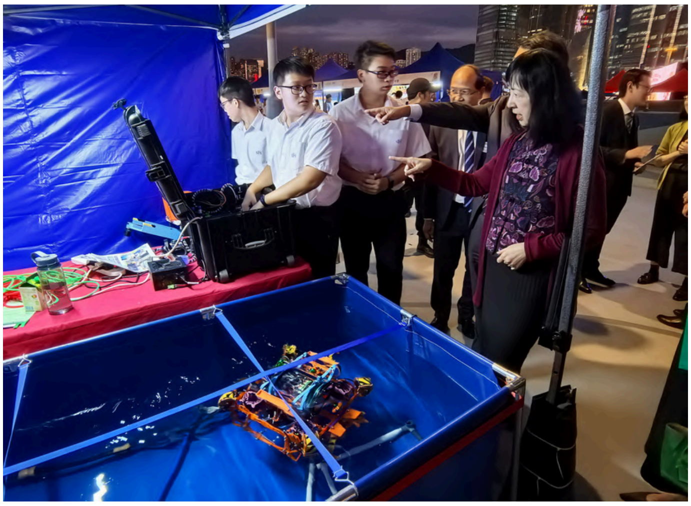


Figure 30.
The ROV Spida Showcased to the Public

Figure 31.
The ROV Spida finished placing artificial reef in the ocean

VI. Safety

A. Philosophy

Safety is of utmost importance when designing and using an ROV. This is why our company added many safety features to the ROV, ensuring safety in every process of making and using the ROV. This is why our company has a policy that ensures our members have basic safety training when joining us. This training includes equipment safety, electrical safety, etc. These safety training will make sure that new members know how to protect themselves when using tools and equipment, in order to make the inventing process smooth.

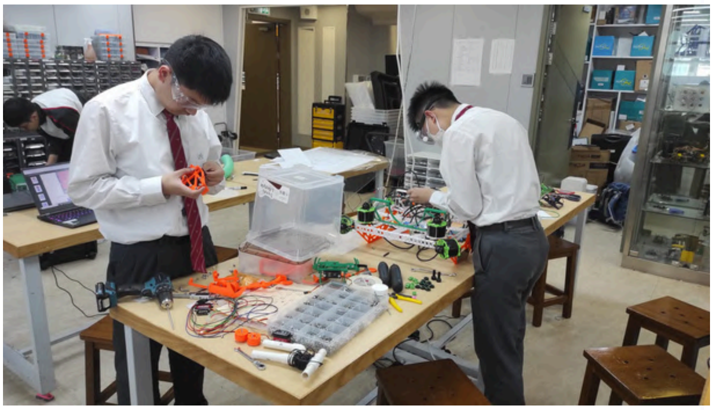


Figure 32. Members building the ROV

B. Equipment Safety

Our company sets up rules and regulations when our members use dangerous tools. When our members are assembling the ROV, they need to wear protective equipment such as safety goggles. Also, when a junior member wants to test his newly designed components, a senior member must be by his side, ensuring the safety of the testing process.

The board of our company designed the safety checklist for members to use when constructing and operating the ROV, as this maximizes safety for members. The checklist requires members to ensure workplace safety when using equipment. For example, when a member uses the soldering station, the checklist states that the member needs to wear safety goggles and keep flammable materials away from the equipment. These instructions in the safety checklist prevent our members from getting hurt by testing procedures.

Figure 33. Engineer Soldering

C. Mechanical Safety

The primary objective of implementing mechanical safety measures is to safeguard both people and ROV from potential damage. So, we implemented different safety measures into the ROV.

First of all, all of our 3D printed parts have no sharp edges to prevent users from getting cut. Then, we designed special thruster protection that meets the requirements of IP20 as this ensures that users' fingers can't get into the thrusters, potentially damaging the thruster and also hurting themselves. Next, we added stickers on the movable parts on our ROV, making sure that users can be aware of them and prevent them from being hurt by the force of the moving parts. Also, we kept our ROV as small as possible so that it could reduce the damage caused by the ROV to the environment. This act could preserve the environment and also prevent fishes being hurt by the ROV. Moreover, we have designed a strain relief on both the ROV and the controller to prevent the controller from getting dislodged and the cables from pulling the ROV.

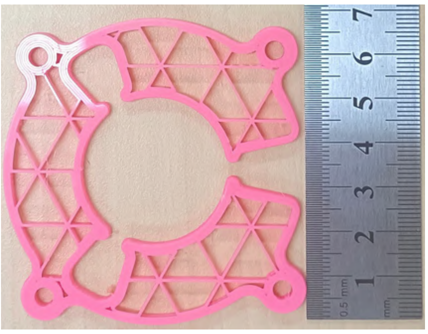


Figure 34.
Thruster guard that meet requirement

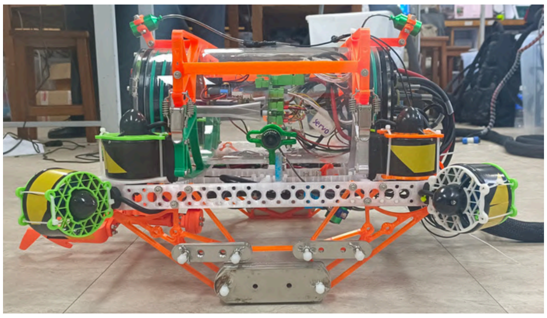


Figure 35.
Screws that are installed with screw cap and moving parts taped with yellow-black strips tape

D. Electrical Safety

The primary objective of implementing electrical safety measures is also to safeguard both people and ROV from potential damage. So, in order to ensure that the ROV's power supply is immediately cut off in case of issues, we have connected a 25-amp fuse and an emergency button to a normally open relay in our control box. When a problem arises with the ROV, we will press the emergency button to prevent the ROV from receiving power

The camera monitor operates utilizing a 220/110V AC connection to an SDI camera multiplexer, which is equipped with a 220/110V AC to 12V DC power converter. The AC and DC power supplies are distinctly separated and labelled to prioritize the safety of our ROV's power supply and to mitigate any potential wiring errors. These precautions are in place to facilitate secure and efficient operations.

Our ROV has a waterproof chamber that prevents water from leaking into the electrical parts, which will damage them and cause electricity leaking out, causing damage to the sea habitat.

Figure 36.
220V AC Power

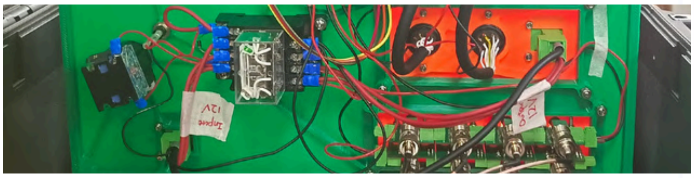


Figure 37.
12V DC Power

VII. Testing and troubleshooting

At our company, we rigorously tested each component and the ROV as a whole throughout the development process to ensure safety, functionality, and efficiency. We implemented a comprehensive array of testing and troubleshooting methods, which we refer to as the SC methodology.

The "S" stands for safety; we insist that every component meets stringent safety requirements before deploying Lobsta into the water. This commitment not only ensures the safety of our employees but also allows us to continually enhance our safety protocols. The "C" stands for calibration; after conducting safety inspections, we carefully calibrated essential components such as thrusters and servos. This step is vital to ensure optimal functioning and proper adjustment before deployment. Verifying thruster calibration enables our team to make necessary adjustments based on initial feedback, thus minimizing errors during subsequent testing.

To improve operational efficiency, we also created prototypes of the payload tools before developing the final versions. This approach allowed us to visualize ideas and concepts, facilitating the identification of the best solutions for our mission objectives. Additionally, it helped us assess whether the design meets the mission requirements, laying the groundwork for further enhancements. We implemented a two-step testing protocol for all tools. Once a tool is developed, it undergoes thorough testing on land, which helps us evaluate its effectiveness in meeting mission requirements. The second phase involves deploying the tool underwater to verify its performance in real-world conditions. This stage also allows the pilot to provide valuable feedback on tool functionality and placement on the ROV, contributing to improved task performance. Prior to testing, we developed and debugged movement codes, enabling Lobsta to execute crucial maneuvers, such as tilting. This capability enhances the ROV's range of motion and overall user-friendliness.

Figure 38.
ROV Testing Beside the Pool

VIII. Accounting

To maintain a clear and comprehensive budget planning, Over-Defined not only has implemented a budget sheet to allocate and estimate the expenses on hardware, electronics and experiments but also a wishlist for engineers to request for buying specific components. The wishlist requires engineers to explain why it should be bought, and a meeting will be held by each department every week to discuss whether the component has a reasonable usage.

To minimize the budget spending, we have established a SMART goal of "reduce ROV's production cost by 30% in 2025 by reusing components and tools acquired before, without delaying project milestones" before our project begins. However, as some components are not obtained from the past, engineers will also have to choose components that have a high quality but a lower price than other competitors from online stores to reduce the relevant cost.

Overall, a high portion of our budget will be utilized on hardware such as the ROV frame, waterproof cabin, and ROV controller, as there are no reusable products from previous years. In contrast, electronics will be a smaller proportion compared with last year as components, for instance, thrusters, cameras, and servos, can be reused, therefore, the estimated budget will be used for newly used sensors and other electronics. The remaining proportion will be utilized in general expenses and as well as for experiments and prototypes.

After accomplishing a project costing sheet, it is measured that our SMART goal has been successfully achieved. Compared to the previous spending in 2024 (1606.27 USD), Over-Defined has reduced the budget spending by approximately 39.09% in 2025 and has a remaining budget of 22959.89 USD. For further information on the budget sheet and project costing sheet, please refer to Appendix E and Appendix F.

IX. Acknowledgements:

Over-Defined is incredibly grateful for the support of the following organizations and individuals who have contributed to the development of Lobsta :

- Fukien Secondary School — for the continuous support, sponsorship, and resources
- HUNG Kam Fai — our supervisor, for his consistent guidance in all aspects
- HUI Shek Hin, CHAN Kam Pui and LI En Yee Ian — our mentors, for their guidance and technical help throughout the development of Lobsta
- MATE Center — for organizing the 2025 MATE World Championship, providing a platform for the community to learn about marine technology, and promoting STEM education around the world by solving real-life problems
- The Institution of Engineering and Technology, Hong Kong (IET HK) — for organizing the 20th IET/MATE Hong Kong Regional of the MATE ROV Competition and educating the Hong Kong public on marine technology
- Beltron International Limited — for their kind sponsorship of a bottle of O-ring grease

Beltron International Limited

X. Appendix

A. Safety Checklist

While constructing ROV	
☐	Wearing safety goggles
☐	Area is clear and safe
☐	Wearing safety gloves
☐	Keep the ROV away from electricity

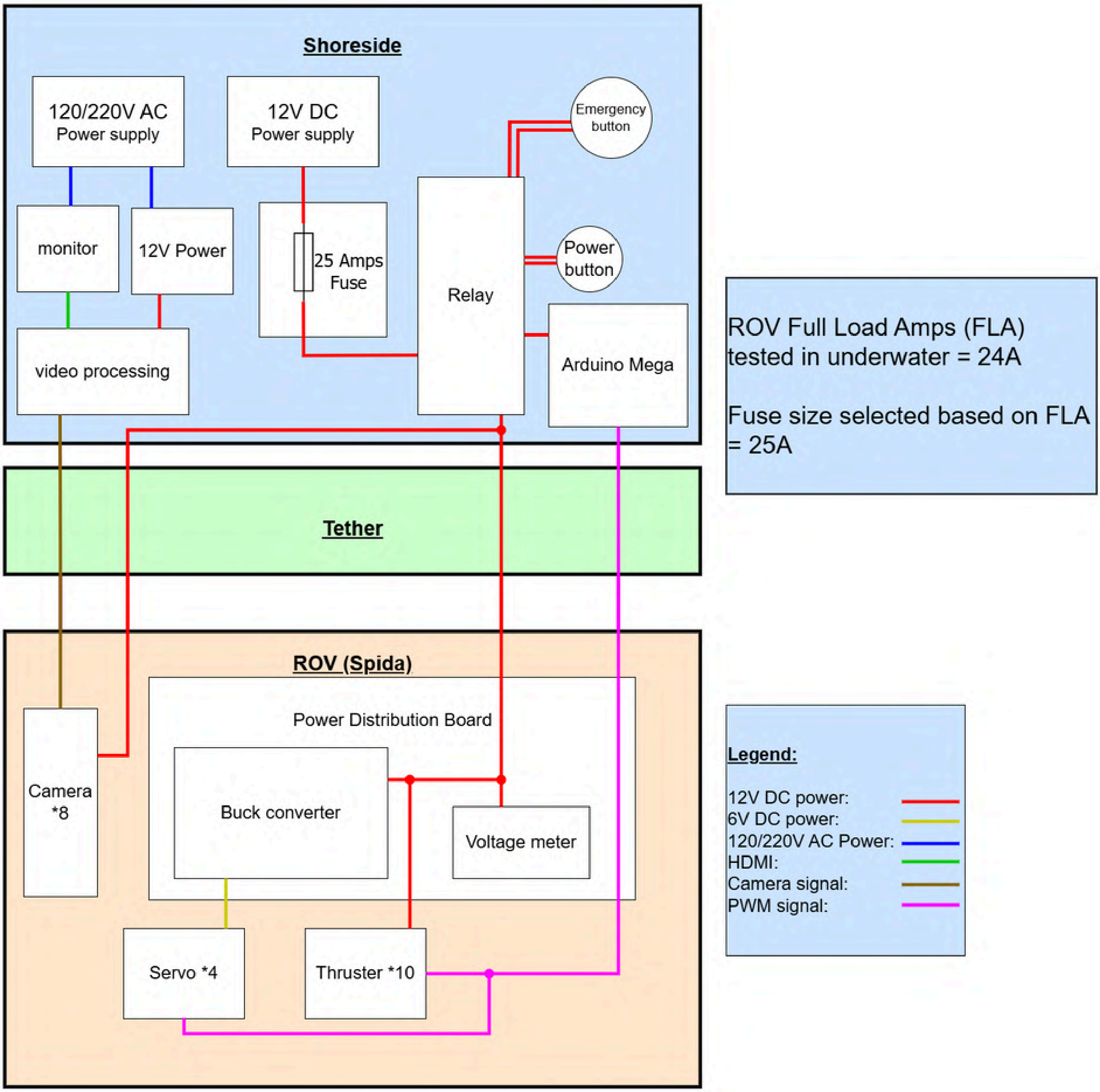
After constructing ROV	
☐	All equipment are put back to its original places
☐	Ensure the area is clear and safe

While testing the ROV in swimming pool	
☐	Area is clear and safe
☐	All members are wearing safety goggles
☐	Tether is connected to the strain relief and the ROV
☐	The waterproofing cylinder is screwed tightly
☐	Thrusters are tested on the ground
☐	All manipulators are fully functional
☐	The ROV is put slowly into the water, and inspect the cylinder carefully for bubbles If **YES**, **Proceed to Water Leakage of the Checklist** (tick the box if yes) If No, then continue putting the ROV into water
☐	Pull the ROV back on the ground after testing for 15 minutes, and check if water is leaked into the cylinder: If **YES**, **Proceed to Water Leakage of the Checklist** (tick the box if yes) If No, then put the ROV back into water
☐	Mission begins
☐	Communication is ensured during the test
☐	**Proceed to Page 4 of the Checklist**

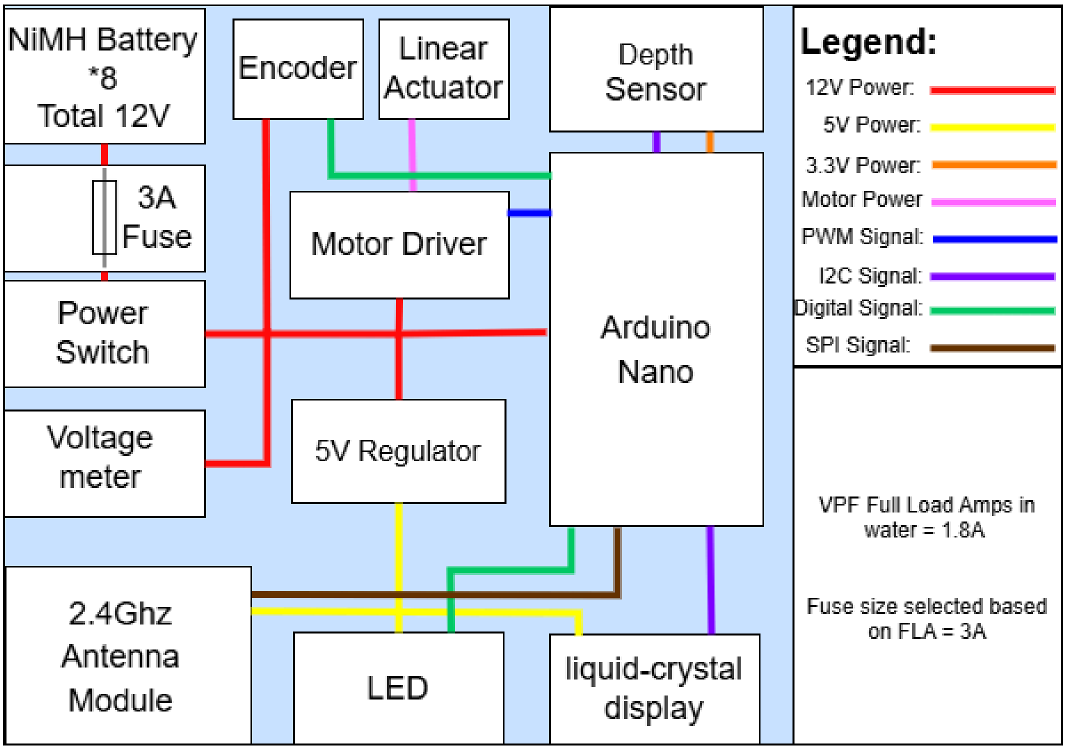
Water Leakage	
☐	Press the emergency button
☐	Open the waterproofing cylinder
☐	Use cotton to absorb all traces of water in the cylinder
☐	Ensure that the area is clean and safe
☐	Take the PCB out of the cylinder carefully
☐	Make sure that the PCB is not wet
☐	If wet, change the PCB If not, put it back into the dried cylinder
☐	Close the waterproffing cylinder and screw the screwdrivers tightly
☐	**Proceed to Page 2 of the Checklist**

After testing the ROV in swimming pool	
☐	Disable all the thrusters
☐	Remove the ROV from water
☐	Power off the monitor and controller
☐	Pack up the belongings
☐	Go back to the lab

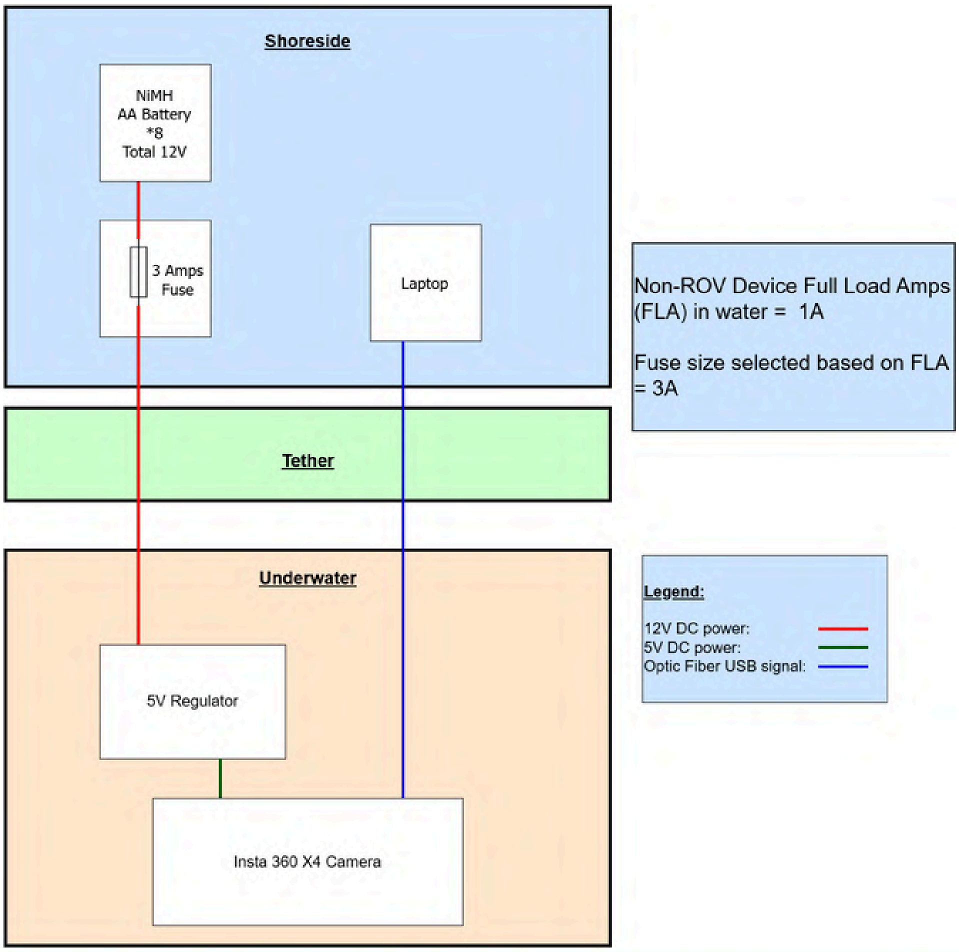
B. ROV SID


Shoreside
120/220V AC Power supply
12V DC Power supply
Emergency button
monitor
12V Power
25 Amps Fuse
Relay
Power button
video processing
Arduino Mega
Tether
ROV (Spida)
Power Distribution Board
Camera *8
Buck converter
Voltage meter
Servo *4
Thruster *10
ROV Full Load Amps (FLA) tested in underwater = 24A
Fuse size selected based on FLA = 25A
Legend:
12V DC power:
6V DC power:
120/220V AC Power:
HDMI:
Camera signal:
PWM signal:

C. VPF SID



D. Independent Sensor SID



E. Proposed Budget

			Reporting period	
School Name:	Fukien Secondary School - Over-Defined		From: 1/9/2024	
Instructor / Sponsor:	Mr. HUI Shek Hin, Mr. HUNG Kam Fai, Mr. CHAN Kam Pui, Mr. Li En Yee Ian		To: 21/5/2025	
Total Income				
Source				Amount ($)
Funding from Fukien Secondary School				12771.16
Funding from team members				45976.16
Estimated Expenses				
Category	Type	Description / Examples	Projected Cost	Budgeted value
Hardware	Purchased	ROV frame	127.71	191.57
	Purchased	ROV controller	306.51	319.28
	Purchased	Waterproof cabin	114.94	127.71
	Purchased	Non-ROV device frame	63.86	63.86
Electronics	Purchased	Thrusters	408.68	510.85
	Purchased	Cameras	191.57	204.34
	Purchased	Servos	63.86	63.86
	Donation	Grease	25.54	/
	Purchased	PCB and wires	38.31	63.86
	Purchased	Insta 360 camera	574.7	638.56
Experiment and prototype	Purchased	Including hardware, electronics and software	1256.68	1277.12
Travel	Purchased	1 round-trip airfare to Detroit	47891.83	48530.39
	Purchased	Hotel and other expenses	6130.15	6385.58
General	Purchased	Marketing materials	140.48	191.57
Total income				58747.32
Total expenses				57334.82
Total expenses - Re-used / donations				58568.55
Total fundraising needed				0

F. Cost Projection

					Reporting period	
School Name:	Fukien Secondary School - Over-Defined				From: 1 September 2024	
Instructor / Sponsor:	Mr. HUI Shek Hin, Mr. HUNG Kam Fai, Mr. CHAN Kam Pui, Mr. Li En Yee Ian				To: 21 May 2025	
Funds						
Date	**Type**	**Category**	**Expense**	**Sources / Notes**	**Amount ($)**	**Running Balance ($)**
9/13/2024	Purchased	Hardware	Detachable tether plug	Used for ROV	38.31	38.31
9/25/2024	Purchased	Hardware	24 inch monitor	Used for control system	159.64	159.64
9/28/2024	Purchased	Electronics	Thruster	Used for ROV	330.77	490.41
10/16/2024	Purchased	Hardware	Tether	Used for ROV	63.09	553.5
10/16/2024	Purchased	Hardware	Tether foam float	Used for ROV	4.34	557.84
10/18/2024	Purchased	Electronics	Arduino	Used for ROV & Non-ROV Devices	9.65	567.49
10/25/2024	Purchased	Electronics	DVR monitoring host	Used for control system	34.35	601.84
11/6/2024	Purchased	Electronics	Servo	Used for ROV	71.52	673.36
11/6/2024	Purchased	Electronics	Wires	Used for general vehicle construction	63.86	737.22
11/6/2024	Purchased	Electronics	Wire connecting plugs	Used for general vehicle construction	11.49	748.71
11/20/2024	Purchased	Hardware	Waterproof cabin	Used for ROV	114.94	863.65
11/22/2024	Purchased	Hardware	Controller protection box	Used for control system	68.96	932.61
12/18/2024	Purchased	Electronics	Wire connecting terminals	Used for general vehicle construction	15.33	947.94
1/3/2025	Purchased	Electronics	Emergency button	Used for ROV	3.68	951.62
1/8/2025	Purchased	Electronics	Piston	Used for Non-ROV devices	38.31	989.93
1/15/2025	Purchased	Electronics	Printed circuit board	Used for ROV & Non-ROV Devices	25.54	1015.47
2/7/2025	Purchased	Hardware	3D printing filament	Used for ROV & Non-ROV Devices	114.94	1130.41
2/8/2025	Purchased	Electronics	Depth sensor	Used for Non-ROV devices	55.94	1186.35
3/5/2025	Purchased	Electronics	Camera	Used for ROV	192.08	1378.43
3/5/2025	Purchased	Electronics	Joystick	Used for control system	1.91	1380.34
3/14/2025	Purchased	Electronics	Serial peripheral interface (SPI)	Used for Non-ROV devices	4.09	1384.43
3/15/2025	Parts donated	Electronics	Grease	Donation from Beltron International Ltd	25.54	1409.97
4/9/2025	Purchased	Electronics	Power button	Used for control system	15.96	1425.93
4/30/2025	Purchased	Electronics	Insta 360 Camera	Used for Non-ROV devices	487.05	1912.98
5/21/2025	Purchased	Travel	Airfare	1 round-trip airfare to Detroit	27585.68	29498.66
5/21/2025	Purchased	Travel	Operating expenses	Hotel and other expenses	6130.15	35628.81
5/21/2025	Purchased	General	Other expenses	Including tools, other components & machineries	140.48	35769.29
Total raised						0
Total expenses						35782.06
Final balance						35782.06