Technical Documentation

Team Mosasaurus
Macau Pui Ching Middle School
Submitted: May 21, 2025
Document Version: v2.1

Competition Class: RANGER

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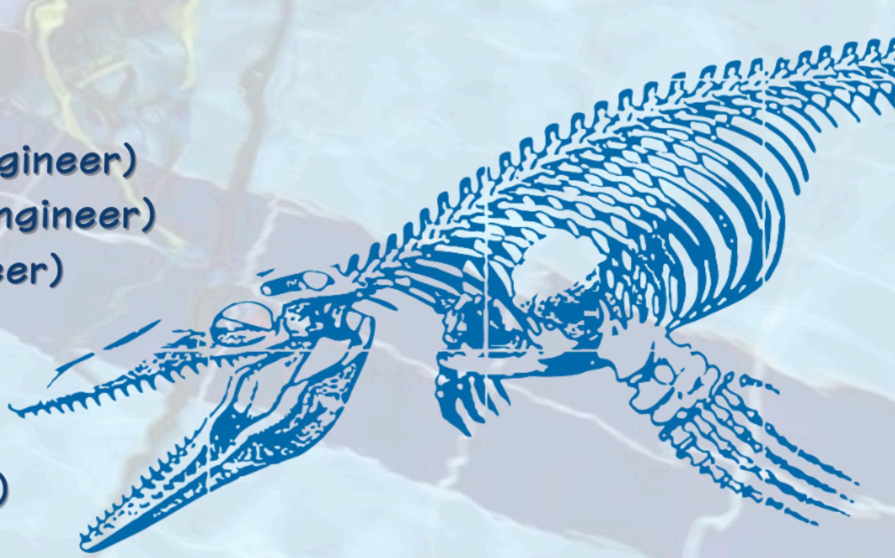

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1. Abstract

Team Mosasaurus from Pui Ching Middle School proudly presents Manta Ray, our second-generation Remotely Operated Vehicle (ROV) developed for the 2025 MATE Ranger competition. This year's design incorporates engineering innovation, modularity, and mission-specific features. Using the BlueRobotics reference frame, we applied the Engineering Design Process (EDP) to customize the base model into an ROV capable of performing complex underwater tasks.

Key innovations include a one-way gate pin remover, a multifunctional anode hook, and a custom-built buoyancy engine controlled by an ESP32 microcontroller. The ROV has six thrusters arranged in a vectored configuration, alongside a dual-computer control system utilizing Raspberry Pi and Pixhawk. It also features a watertight electronics enclosure. Our software architecture uses QGroundControl and Python-based automation for data collection, positioning, and mission logic.

Our team enhanced the ROV's stability, tool accuracy, and autonomous capabilities through iterative testing and troubleshooting. We also conducted advanced computer vision experiments, incorporating photogrammetry and pixel-based measurement tools. This documentation outlines our design rationale, teamwork, testing processes, and engineering decisions, reflecting our dedication to underwater robotics excellence.

2. Teamwork and Project Management

The Mosasaurus Team, consisting of eight 8th-grade students and one 12th-grade student from Macau Pui Ching Middle School, is participating in the MATE competition for the second time. Our goal is to understand underwater robotics better. The team has constructed a remotely operated vehicle (ROV), Manta Ray, for this competition.

A. Schedule and Team Organization

A well-planned schedule is key to tracking our vehicle's progress. Team members are encouraged to regularly update the schedule, record the working process, and set new goals. Setting short-term goals helps members understand their tasks, motivating them to achieve the final targets. To keep our team organized, we implement the following methods :

1. Our CEO is responsible for delegating tasks to each team member, ensuring everyone works on something relevant to our mission.
2. We maintain an engineering notebook to document our progress.
3. We utilize our lab's large whiteboard to analyze tasks and develop plans.

B. Team Organization and Assignments

Team organization is integral to group work, especially in building the ROV. As such, a division of work is undoubtedly beneficial, enabling members to focus on specific tasks and maximize their strengths and potential.

C. Weekly Meeting Agenda and Workflow

Team Mosasaurus holds weekly meetings every Saturday to review progress, assign tasks, and solve problems. Each meeting includes:

1. Progress Updates — Each sub-team shares its current status and challenges.
2. Schedule Review — The project timeline is updated based on actual progress.
3. Design Discussion — New ideas or issues are discussed using sketches and the lab whiteboard.
4. Task Assignment — The CEO assigns tasks for the coming week.
5. Safety Check — The team reviews safety practices, especially before testing.
6. Documentation — The File Manager records updates for the technical report.

This structure helps keep the team organized, efficient, and focused on the competition goals.

Example Agenda from Week 14:

- *Mechanical*: Present progress on the second version of the anode hook
- *Programming*: Demonstrate pixel-based measurement calibration
- *Electrical*: Report ESC wiring issues with Pixhawk
- *Testing*: Review pool test results and video footage
- *Planning*: Adjust milestone for ROV assembly completion to Week 16

Figure 2.1 Example Agenda

3. ROV Design Rationale

Our team started brainstorming and building our vehicle in September 2024, working hard on our ROV design. To supervise the team's progress, we

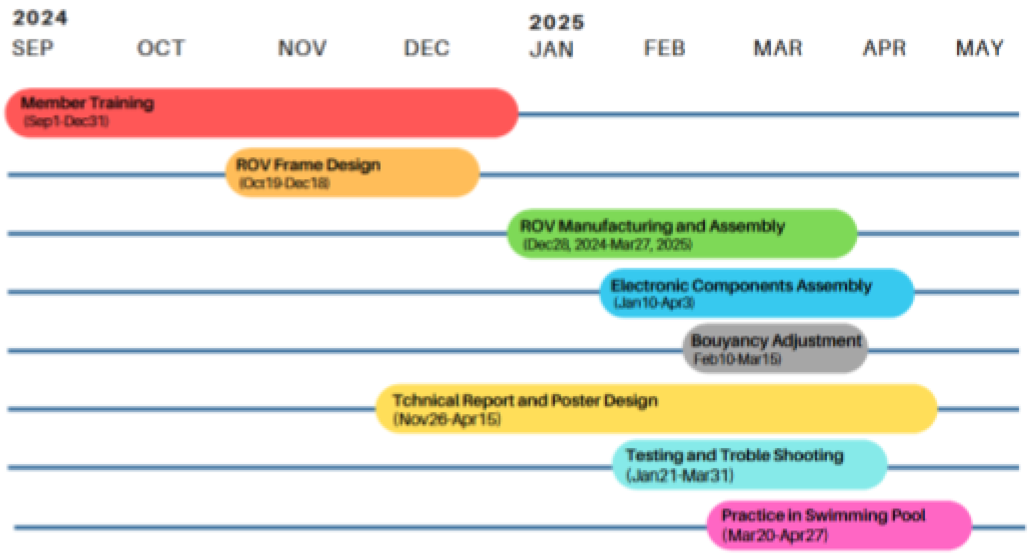


Figure.3.1.1 Gannt chart of Mosasaurus's development

hold meetings. During these meetings, each department leader reports their work process to the CEO and adjusts and updates the schedule to ensure we can finish our work on time.

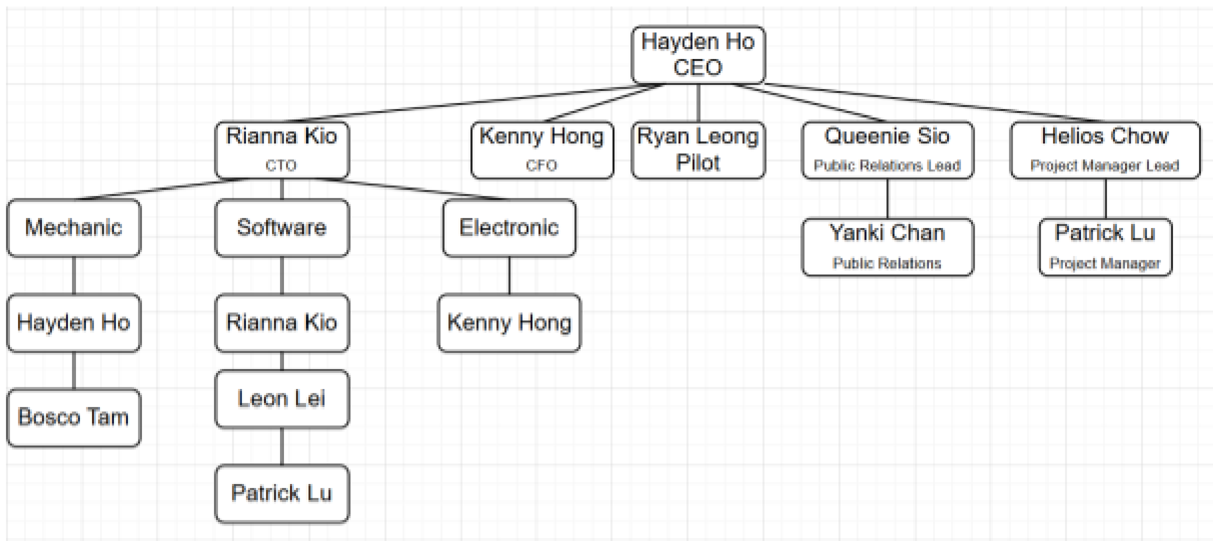


Figure.3.1.2 *Division of work table*

With the competition approaching, tests are done to ensure the performance of our ROV. In addition, all team members worked together to

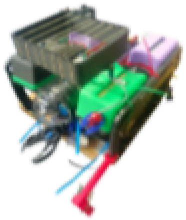
Stage	Description	Photo
Original Design (V1)	Basic concept for ROV structure, focusing on essential components and functionality.	
Enhanced Structure (V2)	Improved design for stability and durability based on initial testing feedback.	
Modular Design (V3)	Shift towards a modular approach for flexibility and ease of future modifications.	

Figure.3.1.3 Manta Ray's iteration

make all the technical documents, such as the technical report and safety documents. Below, we will go through the main parts of the ROV:

In our project, we utilize the Engineering Design Process (EDP) to learn from mistakes and apply our findings, such as testing buoyancy and adjusting the positions of thrusters and the camera. This iterative process allows us to refine our designs effectively.

3.2 Design Evolution

Furthermore, we use the Engineering Design Process (EDP) to learn from mistakes and apply what we have learnt, for example, testing the buoyancy and adjusting the position of thrusters and the camera. Here is an example of using the EDP while the team was brainstorming the structure:

- Ask: Which ROV structures have practical use?
- Research: Search for and conclude ROV structures on the internet.

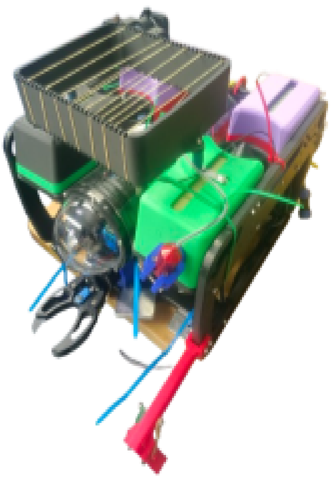


Figure.3.2.1 Photo of Manta Ray

- Imagine: Conclude the best parts in each structure and picture our structure.
- Plan: Discuss with teammates and draw the sketch.
- Create: Build the structure.
- Test: Compare different structures and filter the impractical structures.
- Improve: Use the best version to build the new structure.

By following this structured approach, we ensure continuous improvement and innovation in our designs, ultimately leading to a more effective and functional ROV.

3.3 Vehicle Structure and Systems

A. Structure

The design process for Manta Ray involved careful consideration of various factors. We made a list with some standards—a range of functions & features that it should satisfy. First, its primary use is for underwater surveys and exploration, so it must carry out simple sampling and filming operations. It should also be designed to conform to "high-speed" requirements with multi-degree-of-freedom movement to improve efficiency. Adaptability to various underwater environments is exceptionally vital, too, which means it can handle impacts, high pressure, and different kinds of water flow. The last idea is "highly modular," which might be tightly connected with the innovative technologies of the future. We selected each module's materials, shapes, and costs for further design. For the main body frame, we chose HDPE so that both the rigid & flexible requirements can be satisfied. The Dimensions of the Manta Ray are as follows: Height: 237 mm * Width: 237 mm * Length: 40.9 mm.

B. Propulsion

We have chosen to use T200 thrusters from Blue Robotics as they offer the most thrust for the size. Via the increased power consumption of using six thrusters, the

The thrusters' strong propulsion allows our pilot to perform complex movements like rotation. By utilizing these thrusters, we can finish the tasks quickly and efficiently. The Manta Ray utilizes six thrusters in a vector configuration to make the ROV stable and

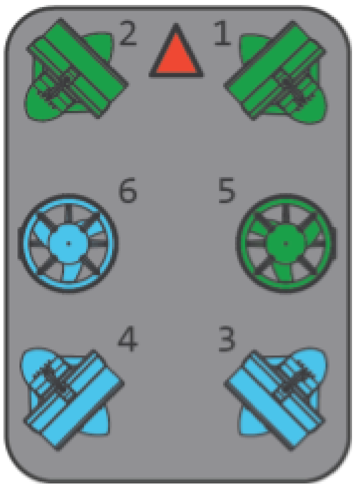


Figure.3.3.2 *Diagram of Propusion Force*

maneuverable; thrusters one to four are dedicated to horizontal movements, while thrusters five and six are responsible for vertical movements. The horizontal thrusters are strategically positioned at a 45-degree angle to maximize thrust efficiency. This configuration enables Manta Ray to smoothly pan and maneuver in any desired direction, except pitch. As a result, this design significantly enhances the convenience and efficiency of our task processes.

C. Buoyancy and Ballast

Our systems suspend the body using solid marine buoyancy materials (usually synthetic foams or polymer composites embedded with hollow microspheres). Unlike gas-based systems, this lightweight, corrosion-resistant material resists water absorption and maintains structural integrity under extreme hydrostatic pressure. Its closed-cell design requires no pumps or electronics to maintain buoyancy, ensuring passive, maintenance-free operation.

We process materials into modular blocks to achieve adjustable buoyancy through density optimization and seamless structural integration to reduce drag. Laboratory tests confirmed its compressive strength (60 MPa) and long-term stability in salt water, while field trials verified its performance in marine conditions. Although costly, we minimize waste through efficient processing and environmentally friendly materials.

3.4 Electrical and Control Systems

A. Manipulator

We first created a vertical deceleration motor for the robotic arm. However, because the height of the robotic arm exceeded the old frame, we designed a transverse motor robotic arm. We used a bevel gear to drive the robotic arm to find one that fit the old frame. But later, the frame was improved, and the length of the frame was shorter. To save more space, we used the Newton Subsea Gripper as the manipulator for our ROV. The gripper has jaws that open to grab objects up to 6.2 cm in diameter. The plastic jaws are mounted with custom aluminium screws to create a corrosion-resistant mechanism that doesn't need any

Figure.3.4.1 bevel gear robotic arm

Figure.3.4.2 manipulator

lubrication. The jaws are driven by a linear actuator that uses a geared brushed motor and lead screw. The main body is air-filled and sealed with O-rings.

B. Thruster

The T200 Thruster consists of a fully flooded brushless motor with encapsulated motor windings and stator, coated magnets, and a rotor. The thruster body and propeller are made from rigid polycarbonate plastic, and the only exposed metal components are marine-grade 316 stainless steel.

Figure.3.4.3 *Photo of Thruster*

C. Tether

The Manta ray is connected by four tethers: two 20-meter-long power cords and one 20-meter-long Ethernet cable. The power cords, which have a gauge of 10 AWG, ensure that the remotely operated vehicle (ROV) receives a steady current of 25A. The Ethernet cables serve different functions in facilitating communication between the underwater control system and the onshore computer.

One of the Ethernet cables enables the transmission of data and video signals, allowing for the exchange of information between the control system's Raspberry Pi and the onshore computer. We replaced the original Ethernet wire with a BlueRobotics Fathom tether to improve camera connection reliability during operations. This upgraded tether provides better quality and faster transmission speed, ensuring a reliable connection. Its durability withstands stress, twisting, and bending, reducing the need for frequent replacements or repairs. The cable's elasticity allows easy movement in various directions, enhancing the ROV's agility.

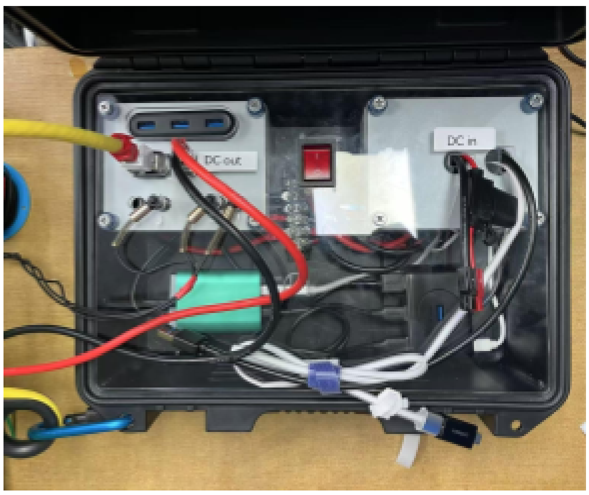


Figure.3.4.4 *Photo of the Control Box*

D. Controller Box

The ground control station consists of a computer, a joystick, an extra monitor, and strain relief. Its design involved repurposing an old toolbox for a new purpose. The box acts as a carrier for the necessary components. Company members cut 3mm acrylic sheets to the dimensions of the box, which also acts as a storage function.

E. Top Side and Bottom Side Software

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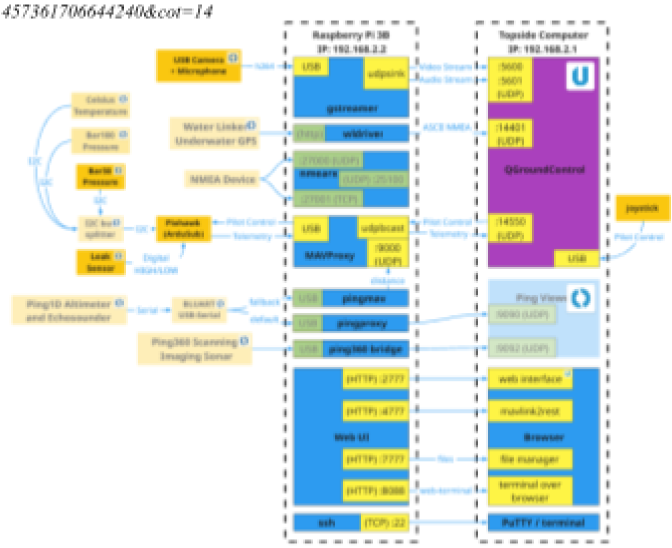

***Figure.3.4.5** Software Architecture Overview plaintext*

The software system is designed to integrate various components, including command and control, ROV telemetry, digital imaging, and joystick inputs. The software is divided into two parts: topside and companion. The topside software component provides a user interface and controls for the pilot. It consists of a control box containing an Intel NUC, which communicates with the companion computer. The control box has peripherals such as a keyboard, mouse, and monitor. Our primary software for missions is QGroundControl, which enables basic maneuvering of the ROV. Specific software missions will be assigned to other programs like PyCharm, particularly for autonomous activities.

On the other hand, the companion software component runs on a Raspberry Pi 3B. It receives command and control instructions from the topside control unit. The companion computer manages the hardware required for ROV functions, such as thruster control and sensor and telemetry data transmission. Thruster control is achieved by connecting the Raspberry Pi to a Pixhawk, which generates PWM signals to control six electronic speed controllers. The Pixhawk was selected for its reliability and compact size, which allows for adequate space for other components, including wiring for mission-specific features. By splitting the software system into topside and companion components, ROV achieves effective command and control capabilities, seamless communication between the control unit and the ROV, and efficient management of hardware functions, resulting in enhanced operational performance.

F. Watertight Enclosure

The system consists of numerous parts, both underwater and on the surface, within the waterproofed enclosure. Their locations, functions, and selection reasons are detailed below.

Raspberry Pi

The Raspberry Pi's high processing speed made it ideal for control and data collection tasks in the underwater ROV. The Raspberry Pi serves as the ROV's main control board during operation. Its primary functions are communicating with the surface computer, collecting camera footage, and receiving and transmitting data from the Pixhawk.

Figure.3.4.6 Photo of RaspberryPi 3b

Pixhawk

The Pixhawk is a flight control board widely used in uncrewed and remotely operated vehicles (ROVs). Its precise gyroscope and accelerometer make it ideal for ROV operation and ensure smooth operation. The Pixhawk's duties include controlling underwater movements, determining direction, adjusting speed, and managing depth.

Figure.3.4.7 Photo of Pixhawk

Electronic Speed Controller(ESC)

The ESC is designed to electronically control the speed of a motor in underwater ROVs. Since the motors, Raspberry Pi, Pixhawk, and servos operate at 12V, the power cable to the ROV carries 12V. Therefore, a 12V voltage regulator is used.

Figure.3.4.8 Photo of Electronic Speed Controller(ESC)

Cameras

Two USB cameras capture footage during operation. One is mounted facing the front, and the other faces the pool surface. The USB camera is used when the robot tilts forward and performs autonomous tasks.

Figure.3.4.9 Photo of Camera

3.5 Payload

A. Pin Remover

In the task 2 hydrophone task, to pull the pin to release the hydrophone from its base, we created two "pin removers". In the design of the first "pin remover", we referred to the "stainless steel S-shaped hook" and printed the S-shaped "pin remover" Through 3D printing. The S-shaped "pin remover" has a groove that allows us to clamp the pin. However, due to the non-user-friendly design, it is difficult for the Controller to align under the pin, and the pin can quickly change direction. Therefore, we designed a second "pin remover". The second "pin remover" directly clamps the pin through a "one-way gate structure", and the pin will be firmly fixed in the slot of the "pin remover". The "one-way door structure" is realized using rubber bands and 3D printed parts. So Rov only needs to carry the second "pin remover" and drive to the hydrophone to remove the pins easily and quickly.

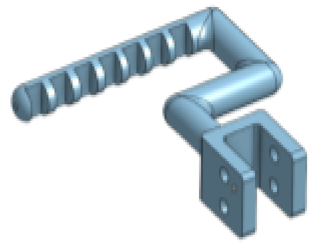

Figure.3.5.1 Photo of The First "pin remover"

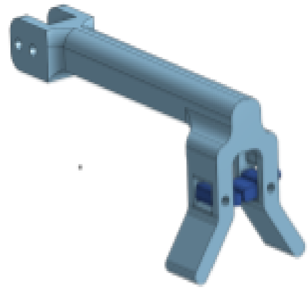

Figure.3.5.2 Photo of The First "pin remo

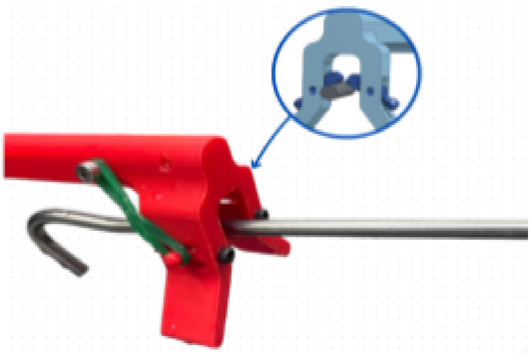

Figure.3.5.3 Photo of The Second "pin remover"

B. Anode Hook:

In task 2.1, the sacrificial anode, we originally planned to use a Manipulator to grab the anode. However, because the Manipulator is located in the front, Rov needs to go around the area to the sacrificial anode, so it is not convenient to use the sacrificial anode. So we designed two versions of "anode hooks". The first "anode hook" was crudely designed, using two "J"-shaped 3D printed parts as a sacrificial anode. However, due to design flaws, assembling was inconvenient, and the Controller could not be aligned with the sacrificial anode. Therefore, we designed a second "anode hook" with a quick-release hanger, allowing us to remove it when not in use. We also added grooves so that the anode could be fixed in the grooves. We also

Figure.3.5.4 Photo of The first "anode hook"

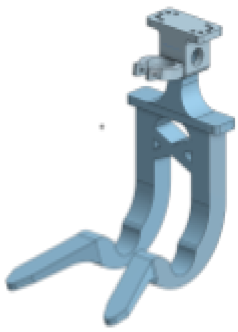

Figure.3.5.5 Photo of The second "anode hook"

increased its length and width and extended its front section following the "Y" shape to guide the anode into the groove of the "anode hook". The second "anode hook" is not only a sacrificial anode, but can also remove the cover of the cargo container and install the pC02 connector. Therefore, the second "anode hook" can complete the "sacrificial anode" task and different tasks quickly and easily.

C. Water sample collection device

In

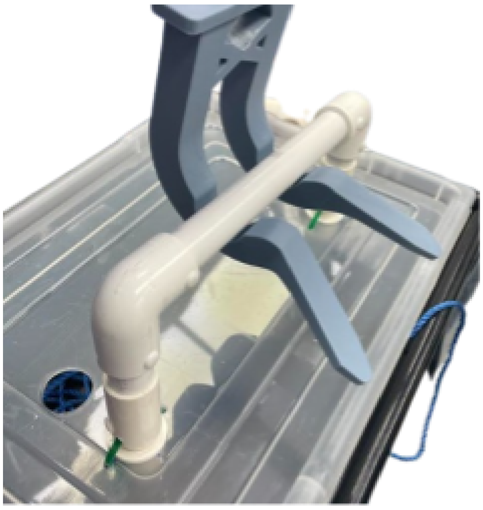

Figure.3.5.7 Photo of The second "anode hook" completing the "cargo container" mission

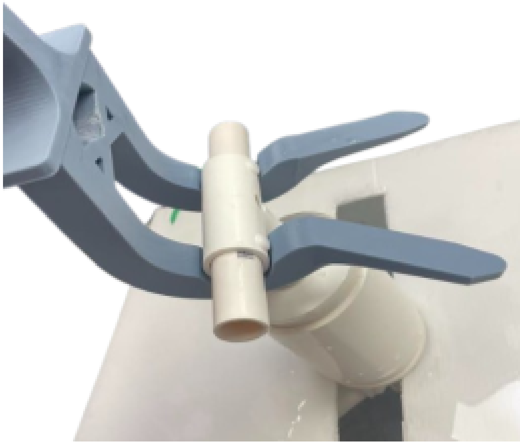

Figure.3.5.6 Photo of The second "anode hook"

completing the "sacrificial anode" mission

Task 1.3, Collect a water sample, we designed a “water sample collection device.” We would clamp it using the manipulator on the ROV. The original version used the elasticity of a rubber root to fix the gray cover, but there were problems with leakage and a limited field of view. Therefore, we improved the design by removing the gray cover, increasing visibility, improving operating efficiency, and improving sealing technology to ensure reliability throughout the pumping process. These improvements make our device more efficient and lay a good foundation for subsequent experiments.

Figure.3.5.8 Photo of the second" Water sample collection device"

D. Fish Species Collector

In Task 2.2, Collect fish species aggregated underneath the solar panel array, we designed a “Fish Species collector” and installed it on the top of the ROV to complete the task of grabbing Fish Species. We use 3d printing technology to make this frame. This frame is inspired by "the fish species picker", and rubber bands are installed regularly to use the upward momentum of the ROV to push the "fish species" into the frame. Unfortunately, our team's Fish species collector still needs technical improvements. In the end, we used the simplest fish species collector. Although it takes more time, it can guarantee the success rate of collecting fish species.

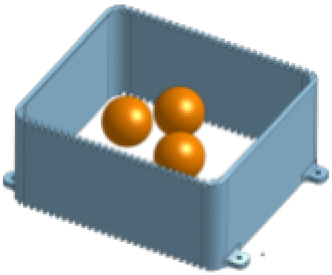

Figure.3.5.9 Photo of "Ping Pong ball collector "

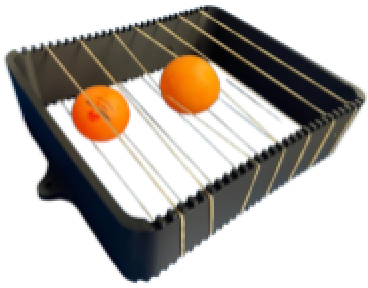

Figure.3.5.10 Photo of "Ping Pong ball collector " completing the mission

Figure.3.5.11 "the Ping Pong ball picker"

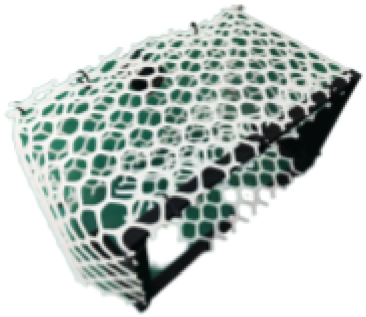

Figure3.5.12 simplest Fish Species collector

4.Buoyancy Engine

The ESP32 microcontroller serves as the control center of our vertical profiling float. It connects with a computer and executes precise commands to control the piston's movement. By pushing or pulling the syringe, the piston enables us to draw water into the float or drain it out. This mechanism can provide a 0.6 Newton difference to the vertical profiling float to influence its buoyancy, allowing it to ascend or descend in the pool as needed. Additionally, we have installed steel bars on both sides of

Figure.4.1 "the float

the float, on which we can place different small steel weights to regulate the balance of the float.

Buoyancy Engine Control Algorithm:

The vertical movement of our float is controlled using an ESP32 microcontroller and a servo-driven syringe piston. The ESP32 receives high-level commands and adjusts the position of the piston, which either draws in or expels water, altering the float's buoyancy. We implemented a MicroPython script that maps piston angle to duty cycle, enabling precise vertical control. The system's simplicity allows for modular integration and field replaceability while maintaining consistent performance.

```
from machine import Pin, PWM
import time

# Control servo connected to GPIO 5
servo = PWM(Pin(5), freq=50)

def move_piston(angle):
    # Convert angle to duty cycle
    duty = int((angle / 180.0) * 102 + 26)
    servo.duty(duty)

# Intake water (sink)
move_piston(150)
time.sleep(2)

# Discharge water (rise)
move_piston(30)
```

Figure 4.2 The float programme

5.Build vs. Buy, New vs. Used

Our team evaluated our ROV to determine whether to buy, build, or reuse it. We compiled our findings into a chart to organize our evaluation efforts. The chart helped us optimize each component's affordability, sustainability, safety, maintainability, and reliability.

Component name	Build		Reuse		Buy		End Decision
	Pros	Cons	Pros	Cons	Pros	Cons	
Thrusters	Able to develop appropriate motors on our ROV	High technology and waterproof requirements	Bugdet-friendly and decrease carbon emmisions	Need to worry about the working conditions of the thrusters	Safe and reliable	High cost	Reuse
Manipulator	Better suit the model of our ROV	Requires long time developing and high waterproof requriements	Bugdet-friendly and decrease carbon emmisions	Need to worry about malfunctioning	Can be got quickly	High cost	Reuse
Camera	Can be easiliy installed and used in our ROV	Requires deep knowledge of curcit wiring	Bugdet-friendly and decrease carbon emmisions	Worry of leaking water	Can be quickly recieved	High cost	Buy
Watertight Enclosure	Is more suitable to our standards	Worry of leaking water	Bugdet-friendly and decrease carbon emmisions	Worry of leaking water	Can be got quickly and put into work	High cost	Reuse
Control Box	Is more suitable to our standards	Requires deep knowledge of curcit wiring	Bugdet-friendly and decrease carbon emmisions	Unable to suit our standards	Is waterproof and stable	High cost	Build

Figure.5.1 Build vs. Buy , New vs. Reused

Our team has tested two types of cameras in total. For the first type of camera, we need to make it waterproof and compare the pictures ourselves. For the second type of camera, the image is not clear. The second type of camera is clearer and does not require a waterproof connection. The USB connection is more stable. Although it is 50% more expensive, the second type of camera is more durable and does not need to be replaced frequently. So,

Component name	Option A	Option B	Final Choice	Reason
Thrusters	reused Thrusters	new Thrusters	✅ reused	Bugdet-friendlyand decrease carbon emmisions
Manipulator	Single-action piston	Dual-action piston	✅ Dual	Avoids spring corrosion
Camera	Waterproof DIY	USB Camera	✅ USB	Clearer image, more durable
Watertight Enclosure	reused Watertight Enclosure	new Watertight Enclosure	✅ reused	Bugdet-friendly and decrease carbon emmisions
Control Box	Control Box DIY	NEW Control Box	✅ DIY	Is waterproof and stable

Figure.5.2 Component Selection Decision Matrix

after comparison, our team finally used the second camera.

We selected Pixhawk because of its reliable sensor integration and compatibility with ArduSub, which reduces development time. T200 thrusters were chosen for their proven underwater performance and high thrust efficiency. These commercial parts allowed us to focus on custom tools like the buoyancy engine and task-specific manipulators.

Feature	 First Type Camera	 Second Type Camera
Waterproof	Yes	Yes
Image Clarity	Less clear	Clear
USB Connection	Less stable	More stable
Cost	Less expensive	50% more expensive
Durability	Less durable	More durable
Final Decision	Not used	Used

Figure.5.3 Compare table of two cameras

6.Programming

Task 1.1 Part 1 Implementation:

Our approach for task 1.1 part 1 is as follows: We capture photos of the vessel using QGroundcontrol and then run a program. The program opens the images based on their file paths, allowing the operator to select two points on the opened image, input a length, and calculate the length of each pixel using the image's pixel ratio. By clicking on the bow and stern of the vessel, the program can automatically calculate the distance between the two points based on the pixel length. The following is a detailed calculation process:

1. Establishing reference markers within the processed imagery through dual-point calibration (R1 & R2)

Figure.6.1 *Determining the length of ship*

2. Applying projective geometry algorithms to compute unknown segment lengths (L_1-L_3) with 95% confidence intervals

Task 1.1 Part 2 Technical Approach:

The 360° environmental reconstruction utilized advanced computer vision techniques, including:

- AI-driven feature detection (SIFT/SURF algorithms) for multi-view spatial alignment
- Photogrammetric stitching with bundle adjustment optimization
- Radiometric compensation for consistent illumination across 7 geodetically distributed capture stations

7.Testing and Troubleshooting

After finishing the prototype program, the team tested it at a pool. After a series of tests, we discovered that the error is more than 10cm. At first, we thought it was a program bug, but after some testing, it was found that the camera's tilt angle influences the program's accuracy. So, we tested different angles and concluded that 45 degrees is the best angle for the program, as the error is within 5cm.

Critical challenges included maintaining geometric consistency between non-collocated vantage points (maximum parallax angle = 12°) and resolving scale ambiguities through intrinsic camera parameter calibration. The solution emerged from developing a weighted least-squares optimisation model incorporating visual odometry and inertial measurement unit (IMU) data fusion. This refined approach ensures metric accuracy while addressing real-world variables in outdoor environment reconstruction tasks.

When we put the ROV into the pool for testing, we found that the "PingPong Ball Collector" we developed could not collect PingPong balls, so we targeted three factors to solve this problem.

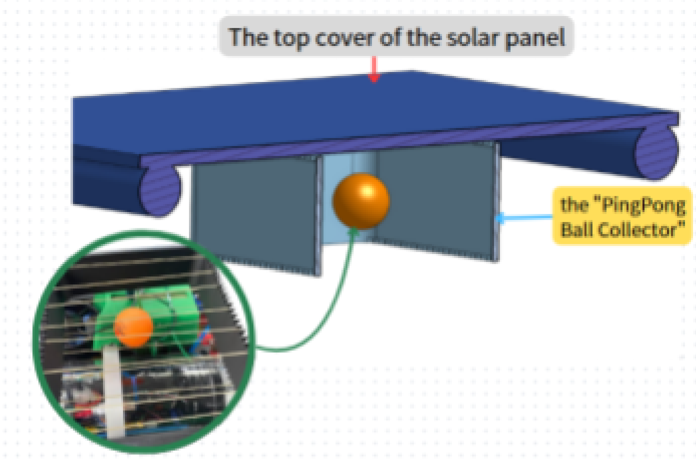

Figure.7.1 The "PingPong Ball Collector" hit the top cover of the solar panel to collect the PingPong Balls

First, we initially thought that the "PingPong Ball Collector" rubber bands were placed too sparsely, causing the PingPong Ball to be pushed out of the collection box due to the buoyancy caused by the ROV's sinking. However, after testing, we found this was not the main problem.

Second, we thought that when the ROV floated up to collect the Ping-Pong Ball, the Ball would touch the "Fish Species Collector" and slide aside, making it impossible to collect.

However, after testing, we found that this was not the case.

Initially, we focused on the principle behind the "Fish Species Collector" designed to hit the top cover of the solar panel. This impact exerts downward pressure on the Fish species, enabling it to break through the rubber bands and be collected in the box.

During testing, we observed that the collector was not high enough to contact the top cover effectively. To address this, we decided to increase the "Fish Species Collector" height by 4 cm. We reprinted the collector with the increased height, allowing it to contact the solar panel cover during operation.

Testing Results

Modification	Height Increase	Success Rate Before	Success Rate After
Initial Design	N/A	20%	N/A
After Height Increase	+4 cm	N/A	70%

Figure 7.2 Testing Results

8.Safety

Since accidents may happen at any time and are frequently unanticipated, we enforce stringent safety procedures and rules to ensure that every team member knows the risks and how important safety is. During the testing process, Mosasaurus takes appropriate safety precautions and ensures the safety of each team member.

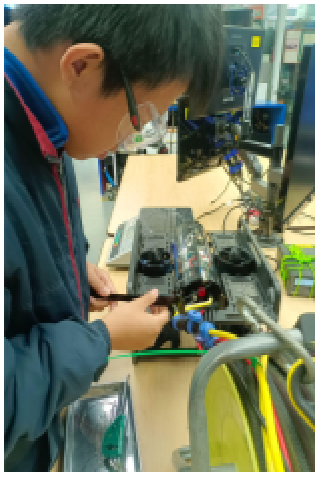

Figure.8.1 *Member wearing glasses eyepiece*

Mosasaurus emphasizes consistent safety policy and continuously educates new and returning employees in safe operation through a rigorous training process. Mosasaurus' safety training covers critical topics, including lifting safety, electrical safety, tool safety, hazardous materials handling, and housekeeping.

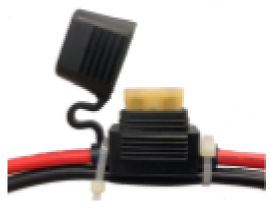

Figure.8.2 *Fuse*

Considering the importance of safety, the Mosasaurus team has established a safety protocol separated into two directions: safety measures taken by team members and safety concerns while testing our ROV. Since safety is our number one priority, we have updated all our past safety documents and compiled them into a new safety protocol, providing our members with a detailed and well-organized guideline.

All members are asked to read through the protocol, including a Job Safety Analysis (JSA) and all the safety steps they must follow while carrying out

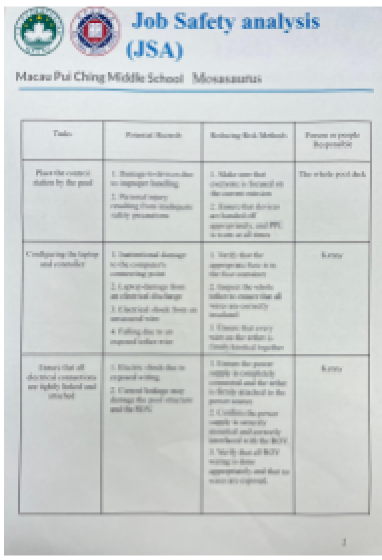
Job Safety analysis (JSA)
Macau Pui Ching Middle School Mosasaurus

Figure.8.3 *JSA*

their tasks. For example, everyone must wear goggles when dealing with dangerous mechanical tools. Furthermore, to keep team members out of potential dangers, Manta Ray is designed to meet all the safety measures. Besides being free-sharpened, all thrusters are well-shrouded. A 25A fuse guarantees that power will immediately be cut off whenever there is a short circuit. We have studied well and complied with all the safety rules set by the organizer.

Each team member completed 4 hours of safety training, covering electrical, mechanical, and lab safety. Mr. Marco Lou (Mentor) and Rianna Lei (Student Safety Officer) led the training. Only trained members are allowed to handle tools or participate in pool tests. Safety reminders are reviewed weekly.

9.Budget and Cost Accounting

A. Budget

Based on the build costs from the prior year and considering the requirements of the 2024 MATE competition, Mosasaurus creates a budget for the development of ROVs. The Macau Pui Ching Middle School provides funding to meet operating and material costs. Donations and team dues are also recognized as revenue sources. Every department drafts and submits a project proposal at the beginning of the year that details the expected costs for developing new tools and improving ROV designs. The CFO oversees orders and inventory management; mentor permission is required for all purchases. Throughout the manufacturing phase, the budget is consulted to ensure the project stays within its allocated budget. Employees of Mosasaurus are in charge of covering their own travel and meal expenses, which are allocated differently in the competition budget. Refer to Appendix B.

B. Project Costing

Last year, most expenses were allocated to acquiring electronics and cameras. A Google Sheet was used and regularly updated to ensure accurate tracking of project costs. For a detailed breakdown of costs, please refer to Appendix C. Mosasaurus effectively manages its budget by employing efficient cost management techniques, such as securing donations and carefully evaluating the necessity of purchasing, manufacturing, or reusing materials by comparing the advantages and disadvantages of each option. Mosasaurus successfully adhered to its budget by implementing these strategies, constructing custom components, and procuring reliable materials.

10.Conclusion

As a team of eighth-grade students, we are proud to have designed, built, and tested the Manta Ray ROV in six months. This experience deepened our understanding of engineering design and underwater robotics, highlighting the importance of collaboration. Despite our limited experience, we faced challenges in mechanical design and software development by using the Engineering Design Process and maintaining a growth mindset.

One key lesson was the value of teamwork and adaptability. When team members were absent due to illness, we created a shared folder system that enabled everyone to access updated files, ensuring project continuity.

For the next season, we plan to build a 360-degree manipulator for greater flexibility during underwater tasks and enhance our software with computer vision techniques to improve task accuracy. We also aim to optimize our buoyancy engine for better control and energy efficiency and expand our knowledge of autonomous navigation systems.

Participating in the MATE ROV competition has inspired us to explore STEM fields further and continuously improve our skills and teamwork. We look forward to the challenges ahead!

A. Acknowledgements

The Mosasaurus team would like to express our appreciation and gratitude for the opportunity to participate in the MATE program. Thank you to MATE and the Marine Technology Society, sponsors of the 2025 competition, for providing this incredible educational opportunity. We would like to acknowledge the following for contributing to the success of our company and Manta Ray:

澳門培正中學 PUI CHING MIDDLE SCHOOL MACAU	ICBC	DSEDJ 教育及青年發展局 Direcção dos Serviços de Educação e de Desenvolvimento da Juventude	MATE ROV COMPETITION	SOLIDWORKS

- Macau Pui Ching Middle School - for providing us with laboratories, tools, and persistent help
- Mr. Lao Kun Wa Thomas - our instructor, supervisor, and mentor
- Mr. Lou Weng Keong Marco - our instructor, supervisor, and mentor
- Escola Luso-Chinesa Técnico-Profissional- for providing and permitting us to test in a swimming pool

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- OpenCV guide and library: https://opencv.org/
- Python style guide: https://www.python.org/
- QGroundControl user guide: https://github.com/mavlink/qgroundcontrol

11. Appendices

A. Budget

			Reporting Period	
hool name:	Macau Pui Ching Middle School		from	9/1/2024
tructor:	Thomas Lao,Marco Lon		to	4/10/2025
ome:				
urce				amount
acau Pui Ching Middle School				$1,000.00
dustrial and Commercial Bank China (Macau) Limited				$1,236.60
penses:				
tegory	type	Description	porjected cost	budget value
ame Structure	Re-used	HDPE,T200 Thruster(6),buoyancy block, Newton Subsea Gripper	$1,200.00	-
ame Structure	Purchased	waterproof cameras	$20.00	$20.00
her	Re-used	cable,Waterproof connectors	$70.00	-
ctronics	Re-used	Regulator,Raspberry pi 3B,Pixhawk, Wetlinks,Network cable head,USB camera ,ESC Brushless Motor	$150.00	-
atertight Enclosure	Re-used	Acrylic dume	$50.00	-
ntrol box	Re-used	USB hubs,Ethernet to USB,Container box ,USB cvbs capture device	$30.00	-
avel	Purchased	Hotels,car rental,air tickets	$21,000.00	$20,000.00
			Total Income	$2,236.60
			Total Expenses	$22,520.00
			Total Expenses - Reused	$20,020.00
			Fundraising Needed	$17,883.40

Table 11.1 Budget

B. Project Costing

ategory	Type	Category	Expense	Sources Notes	Amount(USD)	Running Balance
OV:						
	Re-used	Frame Structure	HDPE	For Frame	$16.50	$16.50
	Purchased	Frame Structure	waterproof cameras (3)	Provide images	$15.00	$31.50
	Re-used	Frame Structure	T200 Thruster(6)	Providing power for ROV	$714.00	$745.50
	Re-used	Frame Structure	buoyancy block	Provide buoyancy	$109.00	$854.50
	Re-used	Frame Structure	Newton Subsea Gripper	Pick up items	$320.00	$1,174.50
	Re-used	Tether	8-core cable(18M)	Provide signal line	$45.00	$1,219.50
	Re-used	Tether	2-core cable(18M)	Provide power	$20.00	$1,239.50
	Re-used	Tether	Waterproof connectors	Connecting ROV and cable	$2.50	$1,242.00
	Re-used	Electronics	Regulator（12V-5V）	Changing current	$0.65	$1,242.65
	Re-used	Electronics	Raspberry pi 3B	Process signals	$17.30	$1,259.95
	Re-used	Electronics	Pixhawk	Control all motors	$75.80	$1,335.75
	Re-used	Electronics	Wetlinks	water proof	$16.60	$1,352.35
	Re-used	Electronics	Network cable head	Adapter	$1.40	$1,353.75
	Re-used	Electronics	USB camera	Provide images	$6.25	$1,360.00
	Re-used	Electronics	ESC Brushless Motor	Control Fhruster	$19.00	$1,379.00
	Re-used	Watertight Enclosure	Acrylic dume	Install electronic parts	$45.00	$1,424.00
ontrol box:						
	Re-used	Control box	USB hubs （2)	Extended USB header	$4.30	$1,428.30
	Re-used	Control box	Ethernet to USB	Ethernet to USB	$2.50	$1,430.80
	Re-used	Control box	Container box	Install electronic components	$4.50	$1,435.30
	Re-used	Control box	USB cvbs capture device （3)	Analyze camera footage	$21.00	$1,456.30
avel:						
	Purchased	Travel	Hotels (7nights)	lodging	$3,654.00	$5,110.30
	Purchased	Travel	car rental	Transportation	$578.00	$5,688.30
	Purchased	Travel	air tickets （8)	Transportation	$16,360.00	$22,048.30
					Total Raised	$0.00
					Total Spent	$22,048.30
					Final Balance	$22,048.30

Table.11.2 Project costing

C. SID

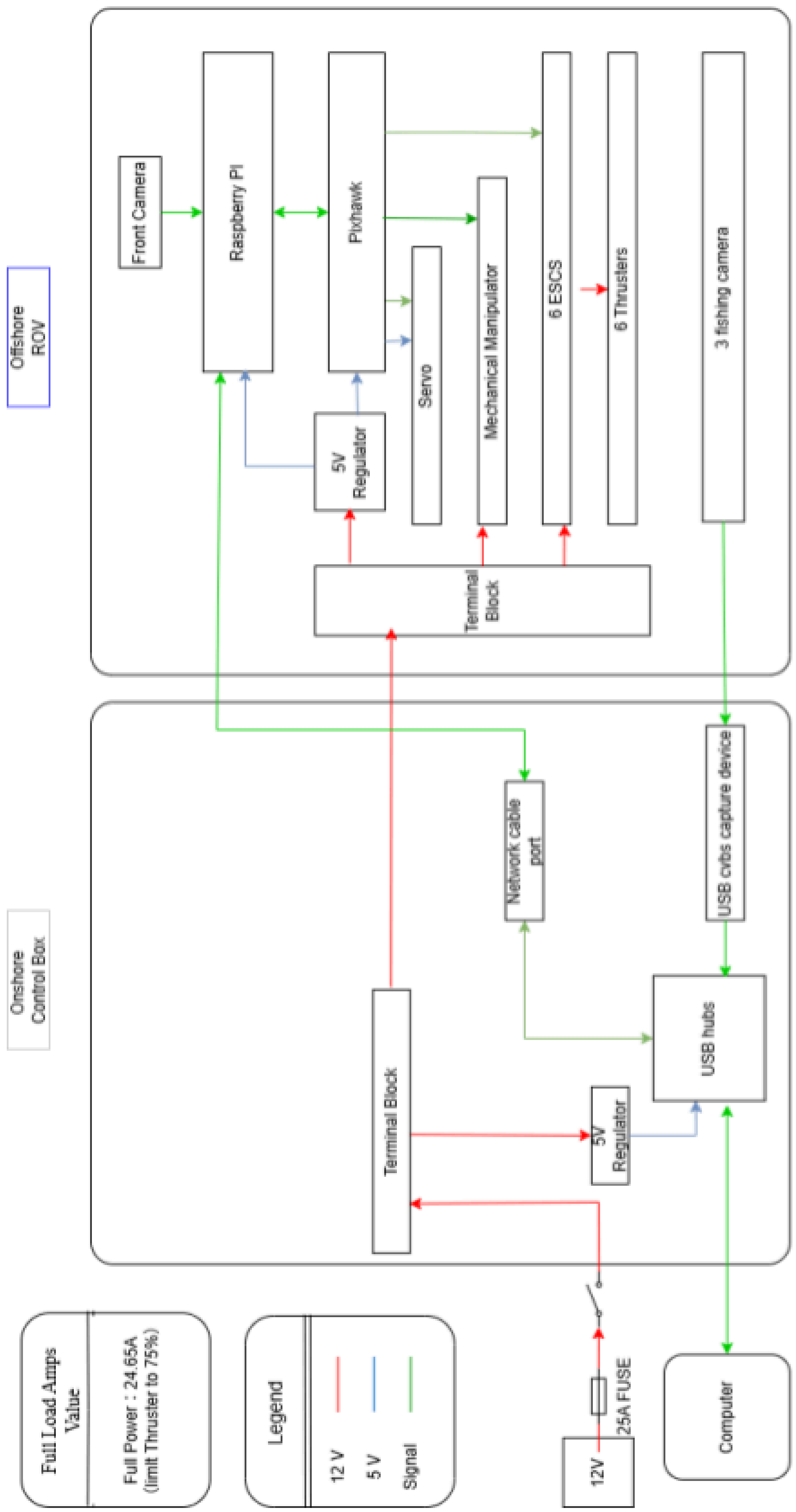

Figure.11.1 Photo of SID

D.non-rov device(independent sensor)

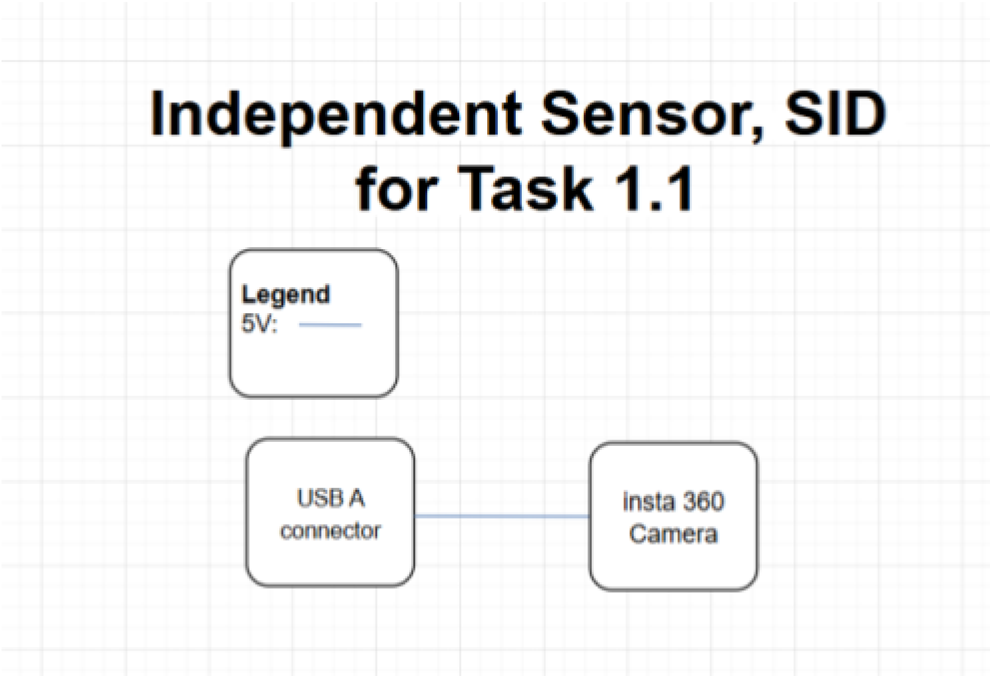

Figure.11.3: 360 camera, SID

According to ELEC-IS-004, an additional fuse is not needed for USB Power Sensors.

E.non-rov device(Float SID)

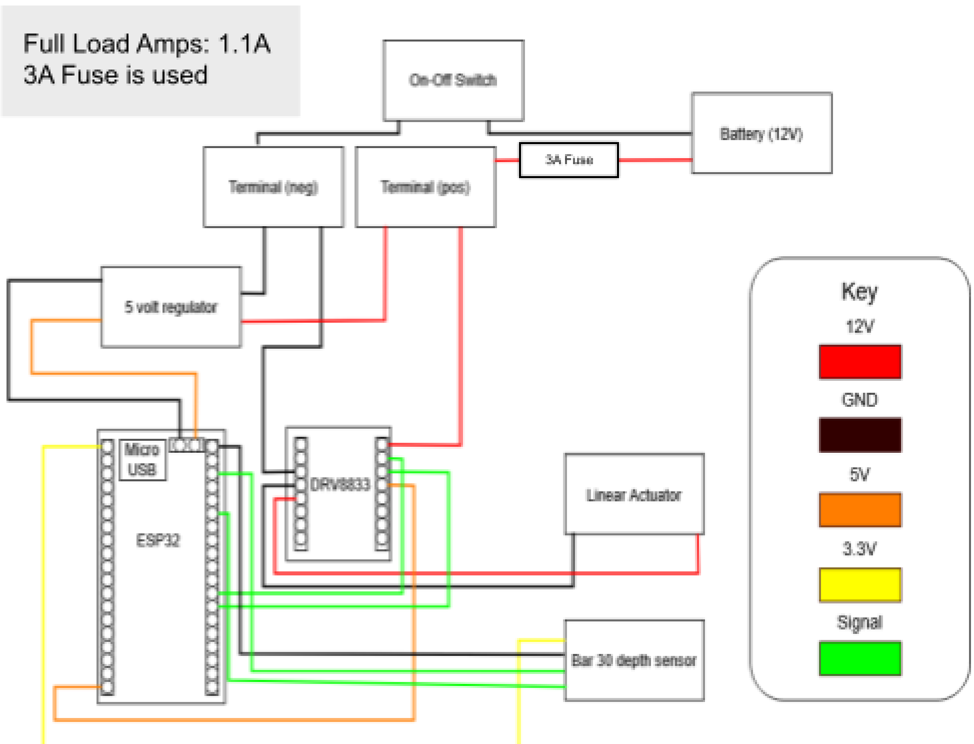

Figure.11.4: Float SID