



# Technical

# Documentation

**Pui Ching Middle School Macau**  
**Macau SAR, China**



**Mosasaurus**

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**Competition Class: RANGER**

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**Nathan: Chief Propulsion Engineer**

**Kenny: CFO / Chief Electrical and Electronic Engineer**

**Bosco: Electrical and Electronic Engineer**

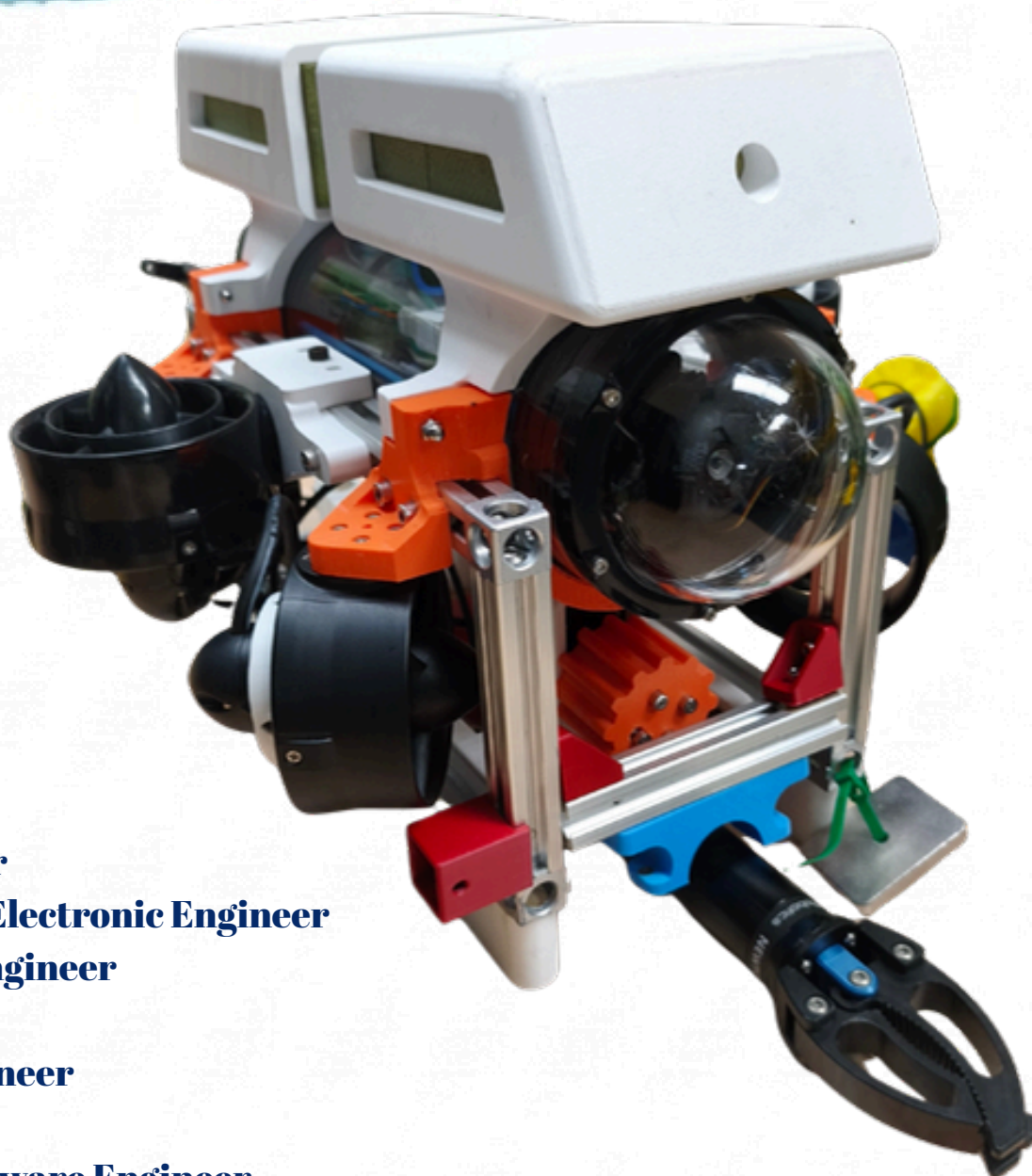
**Ryan: Pilot / Mechanical Engineer**

**Hayden Ho: Chief Mechanical Engineer**

**Patrick: Chief Software Engineer**

**Queenie: Collaboration Lead / Software Engineer**

**Rianna: Float Engineer / Safety Manager**



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## Section 1: Abstract

In this document, our team will discuss our ROV, Manta Ray's design and our development process throughout the year. Our ROV's frame is made of aluminum extrusion with dimensions 400 mm(W) × 640mm(L) × 330mm(H) mm<sup>3</sup>. Equipped with six Blue Robotics T200 thrusters in a 4+2 vectored layout for 5-DoF(Degrees of freedom) movement. The total mass is 8.2 kg. Full Load Amps is 24.65A at 75% throttle. Here are some changes that we have made compared to last year:

- Customized camera connection PCB (≈30% reduction in wiring volume);
- Modular endurance control box
- Newton Gripper with 360° rotational gear ring (eliminates ≈15s repositioning time per retrieval);
- Quick Release Payload Slot
- One-way gate structure for payloads
- YoLo v11 for detecting the invasive carb
- Iceberg hazard evaluating program

By contributing to ROV development, we strive to build a better future and to understand and protect our planet through our passion and expertise.

## Section 2: Project Management & Teamwork

Over a nine-month development period, the Mosasaurus team invested more than 300 hours, supported by standardized management practices:

- Three weekly technical meetings
- WeChat for real-time coordination
- Notion for task tracking
- A comprehensive SOP library
- A custom NFC attendance system built by a team member

This infrastructure enabled efficient session planning (pre-defined goals and post-session summaries), dual-channel communication for continuity, dynamic task allocation based on real-time attendance visibility, and a culture of transparency and accountability—allowing the team to focus on collaboration and productivity throughout the project.

### 2.1 Team Roles & Responsibilities

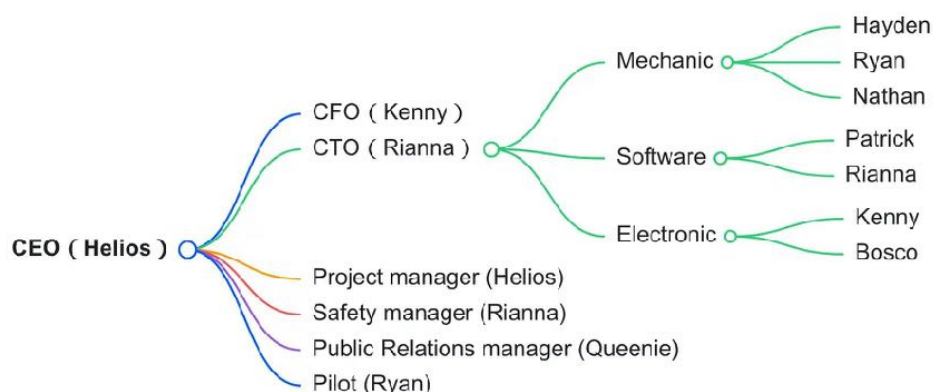


Fig2.1a Team Members and Corresponding Departments

To ensure clear division of labour and efficient project advancement, the core team members and their dedicated roles and responsibilities are defined as follows:

- Helios (CEO): Overall coordination, organizing documentations, pit communication
- Nathan (Chief Propulsion Engineer): thruster shroud development, shroud experiments, EDP(Engineering Design Process) System implementation, critical analysis
- Kenny (CFO / Chief Electrical and Electronic Engineer): Budget management, custom PCB design, endurance control box building
- Bosco (Electrical and Electronic Engineer): Tether specification design, SID drafting, endurance control box building
- Ryan (Pilot / Mechanical Engineer): flight plan design, product demonstration practice, payload design
- Hayden (Chief Mechanical Engineer): new ROV frame design, gripper rotational mechanism, payload design
- Patrick (Chief Software Engineer): Length measurement program, invasive crab detection program
- Queenie (Collaboration Lead / Software Engineer): Managing social media account, organizing corporate social responsibility (CSR) activities, marketing display design, Iceberg tracking program
- Rianna (Float Engineer / Safety Manager): Float Design, JSEA compilation, safety review

## 2.2 Annual Project Timeline

The project was implemented in phased milestones from September 2025 to June 2026, with key time nodes and deliverables as follows:

| Period                                                                                              | Key Milestones & Deliverables                                                                                                                                                          |
|-----------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  <b>Sep 2025</b> | Defined design goals; adopted modular rapid-detach concept; appointed Patrick as Problem-Solving Lead; two new members (Nathan, Bosco) joined the team                                 |
|  <b>Oct 2025</b> | Developed PCB prototype, Payload V1 and tether design; launched NFC attendance system for member management.                                                                           |
|  <b>Nov 2025</b> | Drafted SOPs on Notion; prototyped camera connection PCB(Printed Circuit Board); documented all subsystems                                                                             |
|  <b>Dec 2025</b> | Fabricated PCB; integrated BlueOS; finalised SOPs(Standard Operation Procedure) (Dec 16); developed float prototype                                                                    |
|  <b>Jan 2026</b> | Completed mission design (Jan 7); finalised float SOP (Jan 22); conducted MATE fly-through (Jan 29); held exchange activity with FuKien Secondary School (Jan 24)                      |
|  <b>Feb 2026</b> | Completed thruster 3D layout for new ROV(Feb 10); trained Yolo v11 model; finished eDNA percent frequency calculation program (Feb 25); detected and resolved terminal connector fault |

|                                                                                                   |                                                                                                                                                                                                                                      |
|---------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  <b>Mar 2026</b> | Conducted payload testing and tasks practice; finalised SID; improved invasive carb detection program; made of marketing display                                                                                                     |
|  <b>Apr 2026</b> | Submitted Technical Documents for HK Regional; performed full product demonstration practice; record actual tasks time using, adjust the flight plan; conducted presentation practice; participated in MATE HK Regionals (Apr 25–27) |
| <b>Future Plan</b>                                                                                |                                                                                                                                                                                                                                      |
|  <b>May 2026</b> | Prepared for travel documents; product demonstration practice; refined and submitted the technical Documents                                                                                                                         |
|  <b>Jun 2026</b> | Finalised competition checklist; product demonstration practice; participated in MATE Worlds (Jun 15–29)                                                                                                                             |

T2.2a List of Project Time Line Divided into Monthly Milestones

## 2.3 Risk Register

Potential project risks are identified and classified, with corresponding mitigation measures and responsible persons assigned to ensure risk controllability:

| ID | Risk                                               | Impact | Mitigation                                                                                                                     | Person In Charge |
|----|----------------------------------------------------|--------|--------------------------------------------------------------------------------------------------------------------------------|------------------|
| R1 | Critical hardware failure (T200/Pixhawk/Pi/Newton) | High   | Spare units; pre-flight Checklist; bench test after transport                                                                  | Nathan/Kenny     |
| R2 | ROV detained/damaged in transit                    | High   | Endurance case; critical electronics in cabin; equipment list                                                                  | Helios           |
| R3 | Key member illness                                 | Med    | Cross-train 2 per role; SOPs on Notion; backup pilots trained                                                                  | Helios           |
| R4 | Insufficient practice time                         | Med    | Reserve swimming pool for training early; full 15-min tasks run prioritized; record time for every run to improve flight plan. | Queenie          |
| R5 | Budget overrun                                     | High   | Monthly tracking project cost / material usage                                                                                 | Kenny            |
| R6 | ROV malfunction cause by Human error               | High   | Pre-flight checklist to prevent human error. When the ROV malfunctions, problems can be identified immediately.                | Ryan             |

T2.3a Table of Different Risks, Mitigation, and Person in Charge

## 2.4 Communication & SOP Systems

Our team has implemented several management practices, including:

- Communication Tools: WeChat for real-time daily updates; Notion for task tracking, design rationale recording and SOP library management.

- Daily Workflow: Define 1–3 session goals before work, and publish a summary upon completion. And Dual-channel communication is guaranteed for member absence.
- SOP(Standard Operating Procedure) Coverage: competition schedule and job checklist, modular ROV maintenance procedure, for ROV Task practice: control box setup, pre-flight checklist, etc.

## 2.5 NFC Attendance System for Team Management

Our programmer, Patrick, has built a NFC attendance system to help visualize and improve attendance. The instant check-in saves time. Real-time visibility lets our CEO see who is present or absent, enabling dynamic task allocation. This transparency promotes fairness and accountability, reducing administrative friction so teams can focus on collaboration and productivity. Ultimately, the system transforms attendance tracking from a chore into a seamless tool for better team coordination.

## Section 3: Engineering Design Rationale

### 3.1 Design Requirements

The Manta Ray ROV is designed with six core requirements to ensure its performance and adaptability in competition and actual underwater tasks:

1. **Mission Completeness:** Cover Tasks 1, 2 and 3 simultaneously without ROV reconfiguration.
2. **Modularity & Rapid Detach:** Equipped with quick-release waterproof compartments and magnetically mounted PCB, enabling all subsystems to be replaced in <3 minutes in the field.
3. **Reliability:** Implement a reuse policy with a  $\leq 20\%$  performance degradation threshold; conduct bench tests on T200 thrusters before the season.
4. **Efficiency:** Minimize setup time; the custom PCB reduces camera wiring volume by 30%; the endurance case eliminates transport damage.
5. **Fault Tolerance:** Configure redundant ESCs, software throttle ramp limit and real-time Arduino fault detection.
6. **Safety:** All electronics are fused, insulated and tested; JSA is completed; fail-safe is set for all actuated systems.



Fig3.1a Picture of Different Design Requirements for Our ROV

### 3.2 Innovative Design

Team Mosasaurus leverages innovation to differentiate itself, covering mechanical structures, control boxes, hardware design, software functions, team management and personnel communication. We compared our design with traditional teams, and verified the advantages and additional insights of our solutions through experimental data on efficiency improvements by exploring the nature, importance and implementation methods of each design. Several examples are as follows:

- Customized camera connection PCB(≈30% reduction in wiring volume);
- Modular endurance control box
- Newton Gripper with 360° rotational gear ring (eliminates ≈15s repositioning time per retrieval);
- Quick Release Payload Slot

- One-way gate structure for payloads
- YoLo v11 for detecting the invasive carb
- Iceberg hazard evaluating program

Details will be explained in the following sections.

### 3.3 Problem-Solving Skills

In an underwater robotics team, every task demands problem-solving capability. The ability to 'bounce back' after failures, resilience, is the hallmark of a championship team. We follow a two-step principle or called STAR method. First, clarify why the problem occurs: Situation + Task = why. Then, determine how to solve it: Action + Result = how. We do not merely fix issues; we pursue the optimal solution through layered logical reasoning. Therefore, the STAR method is introduced. Integrated into the EDP(Engineering Design Process), creating a documented fault-to-solution pipeline that transfers knowledge across seasons. Real cases are introduced in [chapter 5](#).

### 3.4 Systematic Design Thinking

We have adopted a modular and rapidly detachable architecture to significantly reduce the Mean Time To Repair (MTTR) and payload change time within product demonstration runs, and gain a competitive advantage in competition pit operations. The core design comparisons with traditional ROVs are as follows:

| Principle           | Traditional                           | Manta Ray Advantage               | Field Benefit                              |
|---------------------|---------------------------------------|-----------------------------------|--------------------------------------------|
| quick detach / swap | disassembly bolts using screw drivers | Quick Release Payload Slot        | <30s swap tool time                        |
| Tether              | Not removable                         | Aviation connector (waterproof)   | <1 minute can be removable                 |
| Control box         | Loose components in box               | 4-zone PLA panel + endurance case | Setup -40% est.; avoiding transport damage |
| Fault isolation     | Full system power-down                | Modular zone isolation            | Identify fault without mission abort       |

T3.4a Comparison between Different Core Designs with ROVs

### 3.5 Frame Structure

The frame uses aluminum T-slot structural aluminum extrusion and PETG 3D printing parts in dimensions 400 mm(W) × 640mm(L) × 330mm(H)m, and the total mass is 8.2 kg.

Using aluminum extrusion for the main structure is much more affordable and adoptable. We compared the aluminum extrusion, PLA structural frame and the HDPE sheets. The result is on the table below.

| Option              | Rigidity | Cost | Modularity | Decision                                          |
|---------------------|----------|------|------------|---------------------------------------------------|
| Aluminium Extrusion | High     | Low  | Excellent  | SELECTED — rigid, modular, corrosion-resistant    |
| PLA 3D-print Frame  | Low      | Low  | Good       | Rejected — inadequate stiffness under tether load |
| HDPE Sheet          | High     | High | Moderate   | Rejected — difficult to re-machine on-site        |

T3.5a Comparison Between Different Materials for Our ROV

The aluminum extrusion frame offers high rigidity, low cost (approximately \$10, and excellent modularity. Its T-slot structure allows attachments to be easily designed and repositioned by simply tightening a bolt, providing a strong balance of size, weight, and endurance. In contrast, the PLA 3D-printed frame was rejected due to low rigidity—it is too fragile to hold the frame together, despite its low cost and good modularity. The HDPE sheet was also rejected; although it has high rigidity, its cost is significantly higher (about \$290),

and its modularity is only moderate, as attachments must be pre-designed and are difficult to re-machine on-site.

## 3.6 Propulsion System

Equipped with six T200 thrusters in a 4+2 vectored layout for 5-DoF(Degrees of freedom) movement: four horizontal thrusters (H1–H4) arranged at  $\pm 45^\circ$  for surge, sway and yaw. The placement improves low-speed maneuverability. Two vertical thrusters (V1–V2) for heave and roll. All ESCs are set with a 75% throttle limit, with a Full Load Amps of 24.65 A.

The vectored layout distributes thrust across four motors. Although it draws more power in surge movement, it makes the sway and yaw movement possible. Performance is excellent for position-keeping tasks. However, control system complexity increases slightly. By just using 2 vertical thrusters, we can keep the current draws under 25 Amps when all thrusters work under 75% throttle. The pitch movement limitation is effectively mitigated by ballast adjustments.

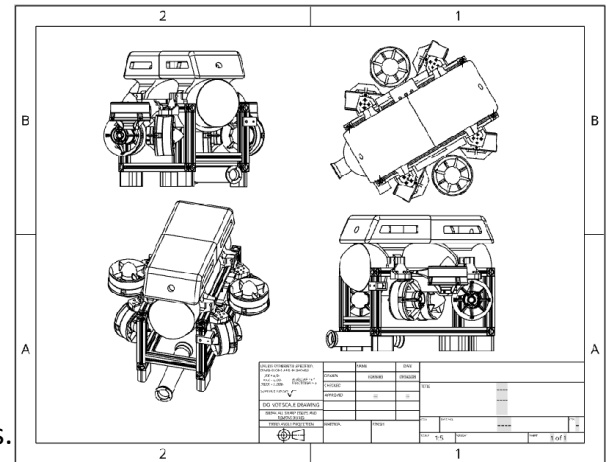


Fig3.6a Sketch of Our ROV

### 3.6.1 Thruster Shroud Experiment

#### Purpose & Fundamental:

Quantify the thrust performance of three thruster shroud configurations (No Shroud, Ring Style, Spider Web Style) across operational PWM set points to select an optimal design that maximizes Manta Ray's thrust output and maneuverability while maintaining controllability —aligning with the core engineering requirement of efficiency.

#### Result:

| Speed Level | Shroud Type      | Trial 1 (N) | Trial 2 (N) | Trial 3 (N) | Mean (N) | Std Dev | Improvement vs. No Shroud |
|-------------|------------------|-------------|-------------|-------------|----------|---------|---------------------------|
| 5           | No Shroud        | 2.98        | 3.02        | 3           | 3        | 0.02    | —                         |
|             | Ring Style       | 1.55        | 2.55        | 2.07        | 2.06     | 0.5     | -31.33%                   |
|             | Spider Web Style | 1.47        | 1.8         | 1.59        | 1.62     | 0.17    | -46.00%                   |
| 6           | No Shroud        | 10.2        | 10.5        | 10.5        | 10.4     | 0.17    | —                         |
|             | Ring Style       | 9.78        | 10.62       | 10.13       | 10.18    | 0.42    | -2.12%                    |
|             | Spider Web Style | 7.53        | 7.81        | 8.02        | 7.79     | 0.25    | -25.10%                   |
| 6.5         | No Shroud        | 12.4        | 11.3        | 11.1        | 11.6     | 0.68    | —                         |
|             | Ring Style       | 11.24       | 11.15       | 11.75       | 11.38    | 0.31    | -1.90%                    |
|             | Spider Web Style | 10.64       | 10.08       | 11.01       | 10.58    | 0.47    | -8.79%                    |

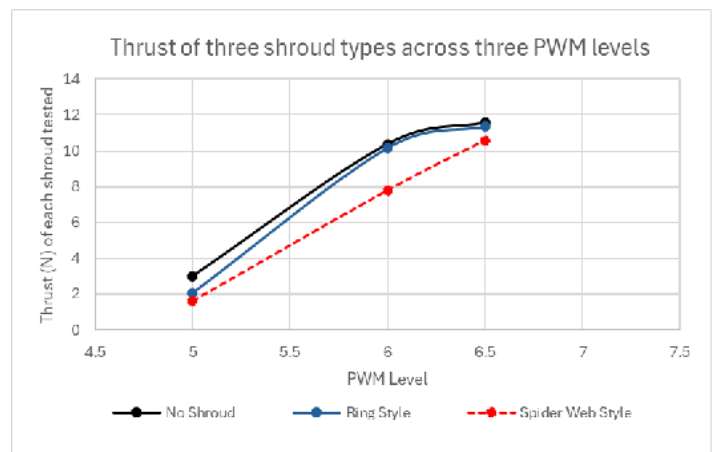
T3.6.1a Comparison Between Different Thruster Shrouds

Given safety constraints, the No Shroud configuration was retained as the baseline reference for performance quantification only; it is not implemented on the final vehicle.

Under baseline conditions, the Ring Style shroud delivered the most favorable performance profile. At PWM 6 (nominal cruise speed), it exhibited only a minimal thrust reduction of -2.12% compared to the baseline, maintaining essential

maneuverability. At higher PWM 6.5 (full power), the reduction was further constrained to -1.90%, confirming its stability under high-load conditions.

Conversely, the Spider Web Style shroud demonstrated consistent and significant thrust degradation across all operational PWM sets. At low speed (PWM 5), the performance penalty reached -46.00%, and even at higher speeds, it remained above -25%. This substantial loss in propulsion efficiency directly compromises the vehicle's ability to complete mission-critical tasks, making it unsuitable for competition implementation.



P3.6.1a Thrust of Three Shroud Types Across Three PWM

Based on the trade-off between safety, efficiency, and maneuverability, the Ring Style shroud is selected for the Manta Ray ROV. It provides a safe, low-risk configuration with performance closest to the unmodified baseline, ensuring the vehicle retains optimal responsiveness across its operational envelope.

### 3.6.2 Propulsion Trade-off Analysis

We evaluated three alternative thruster arrangements before finalizing 4+2 vectored layout:

| Configuration                       | Surge efficiency | Yaw authority | Sway capability | Total cost (est.) | Mission alignment                                      |
|-------------------------------------|------------------|---------------|-----------------|-------------------|--------------------------------------------------------|
| 4 horizontal + 0 vertical           | High             | Mod.          | Mod.            | ~\$1200           | Poor – cannot heave independently                      |
| 4 vectored + 2 vertical (chosen)    | Mod.             | High          | High            | ~\$1800           | Excellent – full 5-DoF for inspection and manipulation |
| 6 all horizontal (different angles) | High             | Very High     | Very High       | ~\$2400           | Over-budget, marginal gain                             |

T3.6.2a Evaluation between Three Thruster Arrangements

The selected 4+2 configuration offers the best balance between capability and cost. The additional two vertical thrusters increase cost by ~\$600 over a 4-thruster design but enable independent heave control, vital for depth-holding during coral measurement (Task 1.2) and lobster pot recovery (Task 2.3). Power consumption (max 24.65 A at 75% throttle) stays within the 25 A fuse limit, avoiding a need to upgrade tether wiring. By accepting a small surge efficiency loss due to the  $\pm 45^\circ$  vectored angles, we gain precise yaw control for station-keeping, directly improving task performance.

## 3.7 Buoyancy & Ballast

The buoyancy and ballast are configured to achieve a slight positive net buoyancy, with the core parameter data as follows (ballast mass to be supplemented by pool testing):

| Component      | Dimensions                  | Volume                                                       | Mass / Gravity                | Buoyancy | Note                             |
|----------------|-----------------------------|--------------------------------------------------------------|-------------------------------|----------|----------------------------------|
| Foam block     | 50×70×120 mm <sup>3</sup>   | 4.20×10 <sup>5</sup> mm <sup>3</sup>                         | 0.12g<br>1.14N                | 4.12N    | Need 4 Foam blocks               |
| ROV total mass | 400×640×330 mm <sup>3</sup> | 6.8×10 <sup>6</sup> mm <sup>3</sup><br>(Calculate by 3D CAD) | 8.2kg<br>80.36N<br>(measured) | 66.64N   | —                                |
| Ballast (lead) | 55×44×10 mm <sup>3</sup>    | 2.42×10 <sup>4</sup> mm <sup>3</sup>                         | 0.2kg<br>1.96N                | 0.24N    | Achieve slight positive buoyancy |

T3.7a Table of Different Components

- Measured total ROV mass is 8.20kg(80.36N of gravity), providing 66.64N buoyancy,
- 4 foam blocks (50×70×120mm<sup>3</sup> each) is needed. Each block provides 4.12N buoyancy. And providing 16.48N buoyancy in total.
- Lead ballast : the difference between the buoyancy of ROV attached 4 Foam and the gravity is 2.76N (0.28kgf). One cube of lead ballast is needed to achieve a slight positive buoyancy, to make the ROV perfect to operate.

## 3.8 Electrical System & Control System



### 3.8.1 Control System Requirements, Documentation, and Verification

P3.8a Photo of Our ROV

We derived all control system requirements from the mission tasks and subsystem interfaces. The following table summarizes key requirements and how each was verified:

| ment ID | Description                                        | Source (Task/ Subsystem)                   | Verification Method                                 | Result                     |
|---------|----------------------------------------------------|--------------------------------------------|-----------------------------------------------------|----------------------------|
| CS-01   | Closed-loop depth hold within ±5 cm                | Task 1.2 (coral measurement)               | Pool test with external ruler                       | ±3 cm achieved             |
| CS-02   | Joystick control of all 5-DoF with <100 ms latency | Operator interface                         | Oscilloscope measurement of command-to-thrust delay | 85 ms avg.                 |
| CS-03   | Automatic failsafe on leak detection               | All mission safety                         | Simulated leak (wet sensor test)                    | Thrusters cut within 0.5 s |
| CS-04   | Video streaming of all 5 cameras at ≥15 fps        | Task 2.1 (crab detection), pilot awareness | Frame-counting during test dive                     | 18 fps stable              |



- Failsafe Monitor: independent process that reads leak and depth sensors, and can cut thruster power via a relay if limits are exceeded.
- ArduSub Firmware (on Pixhawk): low-level stabilization, attitude control, and autopilot modes.

#### Tools:

- QGroundControl (open-source ground station)
- MAVLink protocol for efficient, low-bandwidth communication
- Python for Raspberry Pi scripts
- Git & GitHub for version control

#### Advantages:

- Modular design separates pilot interface, failsafe, and vehicle control – a fault in the camera stream does not affect navigation.
- Use of proven open-source autopilot (ArduPilot) reduces development time and benefits from community testing.
- Ethernet tether enables high-speed video and command over a single cable pair.

#### Limitations:

- The system depends on a continuous MAVLink heartbeat; a tether break would trigger a 2-second failsafe delay before autonomous surface.
- QGC does not natively support all custom sensors; data from auxiliary sensors must be piped through Python scripts.

#### Software Development Process

We followed an iterative, version-controlled development workflow. All software source code (Raspberry Pi scripts, ArduSub parameter files, and QGroundControl configuration) was hosted on a private GitHub repository. Branches were used for each feature (e.g., add-leak-failsafe, video-overlay), and pull requests required peer review before merging into main.

Module integration was tested incrementally:

1. Bench testing: ArduSub SITL (Software In The Loop) connected to QGC without hardware.
2. Hardware-in-the-loop (HITL) with Pixhawk and ESCs on a testing rig.
3. Dry integration: all onshore and offshore components powered and communicating through the tether on the bench.
4. In-water acceptance: full system deployed in a pool; each mission task simulated.

Testing methodology included:

- Automated regression tests for video frame rate and failsafe triggers.
- Pilot debriefing sessions after each pool session to identify UI or response lag issues.
- A checklist-based integration test to verify that all cameras, thrusters, and sensors responded correctly before each dive.

#### Features for System and Operator Performance

The software incorporates several features specifically designed to reduce pilot workload and improve mission reliability:

- Auto-Depth Hold: A PID controller maintains the target depth using the barometric pressure sensor, allowing the pilot to focus on manipulation.
- One-Click Station Keeping: When the pilot releases the joystick, the ROV automatically holds position and heading within a 20-cm radius, essential for tasks like coral measurement.
- Leak & Over-Depth Failsafe: If a leak detector triggers or depth exceeds the 10 m safety limit, the system cuts thruster power and triggers a positive-buoyancy ascent.
- Custom OSD (On-Screen Display): Telemetry data (heading, depth, current draw) is overlaid on the pilot's main monitor, removing the need to glance away.
- Controller Shortcuts: A button on the gamepad instantly switches between a wide-angle rear camera view and the front manipulator camera, improving situational awareness during complex tasks.

### 3.8.2.1 Control Box (Hardware)

We have made a big change to our control system. We have simplified the wiring and shortened the time to set up, as well as changed the box for the control system to a crush-proof case to decrease the chances of damaged equipment during transportation. We also integrate a computer and video recorder for camera monitoring.

To further simplify the wiring. We used PCB for the first time for our camera system. By using the PCB, we convert the audio jack used by the fishing cameras to BNC connectors. Significantly reducing the nasty cable occupied by 30% and making it easier to repair.

Additionally, we designed the top area of the control box, consisting of 4 parts, each with their specific uses. The upper right corner has a room that can store the power AC power cable for the computer. The lower right corner is designed to place the game controller. The lower left corner is for competition-needed stuff such as USB memories. And the upper left corner is for ROV connectors. The whole top area used 3D printing PLA material, ensuring it was lightweight and secure.

To ensure the pilot's view, we added pegboards at the top side. Inspired by IKEA's pegboard storage system. We printed adapters to secure the monitors. Taking advantage of the pegboard system, we can also adapt to different sizes of monitors.

Hardware Integration and Interconnection Diagram

(Enhanced – provides deeper understanding.)



Fig3.8.2.1a Control box

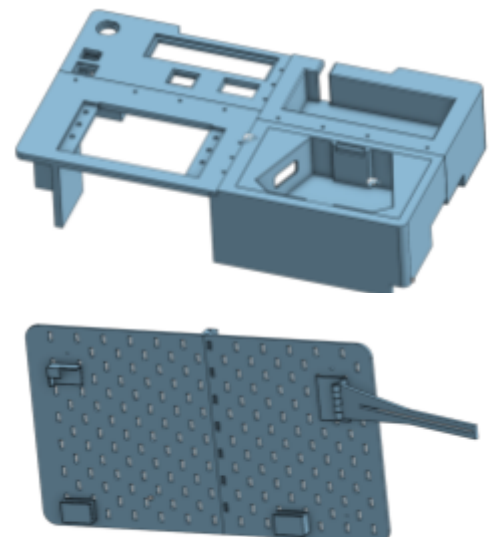


Fig3.8.2.1c 3D-design of pegboards

The control box integrates all onshore electronics and serves as the central interface between the pilot and the ROV. A detailed system interconnection diagram (see Appendix B) shows the following connections:

- Intel NUC ↔ tether (Ethernet, 12V power)
- NUC ↔ video recorder (BNC to USB video capture)
- Camera breakout PCB → BNC patch panel → video recorder
- NUC USB ↔ game controller, USB hub for memory sticks
- 12V power supply → tether, NUC, and video monitors via fused distribution board

All connections use colour-coded, locking connectors to prevent mis-connection in the field. The tether interface employs a Neutrik EtherCON for the Ethernet pair and Anderson Powerpole connectors for the 12V power – both robust, field-replaceable standards.

### Build Process and Hardware Testing

The control box was assembled in a structured sequence, documented with in-process photos and checklists:

1. Wiring loom fabrication: Pre-cut and labelled all internal cables; crimped and soldered connectors according to wiring diagrams.
2. PCB assembly: Hand-soldered the camera adapter PCB and tested continuity on every channel.
3. Box layout and dry fit: All components were placed in the crush-proof case without fastening; cable lengths were verified.
4. Final assembly: Components secured with 3D-printed brackets and screws; cable ties tidied into the pegboard channels.
5. Hardware-in-the-loop test: The fully assembled control box was connected to the vehicle (tether coiled) and all functions—video, control, failsafe—were exercised for 2 hours cycle test.
6. Transportation vibration test: The box was carried in a backpack over a 1 km rough path and re-tested; no loosened connections or board faults were detected.

### Hardware Layout Features for Operator Performance

The control box layout is specifically designed to reduce pilot workload and minimize setup time:

- 30% cable reduction via the PCB: saved approximately 15 minutes during setup compared to the previous season's hand-soldered adapters.
- Pegboard monitor mounting: Allows monitors to be repositioned in seconds to suit different operators' eye lines; the system accommodates 7-inch to 15-inch screens.
- Dedicated storage compartments: Keep accessories organized and immediately accessible; no more rummaging through bags for USB drives or controller, which cut the pre-dive setup from ~30 minutes to 18 minutes.
  - 30% cable reduction via the PCB: saved approximately 15 minutes during setup compared to the previous season's hand-soldered adapters.

- Pegboard monitor mounting: Allows monitors to be repositioned in seconds to suit different operators' eye lines; the system accommodates 7-inch to 15-inch screens.
- Dedicated storage compartments: Keep accessories organized and immediately accessible; no more rummaging through bags for USB drives or controller, which cut the pre-dive setup from ~30 minutes to 18 minutes.

### 3.8.3 Tether

The 18m-long tether system is divided into signal and power cables, with waterproof and wear-resistant protection components. Key parameters such as outer diameter (OD), material and AWG need to be supplemented by actual measurement:

- Signal Cable: 8-core, for Ethernet and MAVLink transmission.
- Power Cable: 2-core, for 12V DC power supply.
- Accessories: aviation connector (watertight junction), aluminum carabiner (strain relief to prevent connector tension), nylon mesh sheath (abrasion protection).

#### **Tether function of quick-release and swappable :**

Since this tether features an aviation connector at both ends, it can be connected to the aviation connector in the Manta Ray's main compartment. This allows for a successful connection in approximately 3 seconds. It can be replaced during maintenance and testing. The advantages of this device include the ability to detach it, its portability, and the option to upgrade to a longer tether as needed. It offers standard ROV interchangeability and is compatible with our own ROVs.

## 3.9 Payload and Tools

### 3.9.1 Sub Cameras' Placement

The Manta Ray has five cameras: one main camera and four sub cameras. The main camera is housed in a waterproof enclosure. It can tilt up and down and provides a front view of the vehicle. The sub cameras are positioned as follows: two facing downward, one on the right front of the vehicle and one at the rear. The downward-facing cameras are primarily used for detecting invasive crabs in Task 2.1, while the second is used for retrieving the lobster pot. The right front camera provides a better view of the manipulator and any payloads at the front. And the rear camera is used to check the tether to prevent tangling.



Fig3.8.3 Demonstration of Aviation Plugs Connected

### 3.9.2 Manipulator 360 Rotational Gear

The manipulator system has undergone four generations of iterative upgrades, and the final version V4 combines commercial mature products and independent innovation to achieve efficient underwater operation:

The first generation relied on simple hooks to perform tasks, but due to their basic structure, they could not handle complex tasks. For this reason, we developed a second-generation manipulator using 3D-printing technology. We used a gear set to drive and rotate the arm; however, because the entire assembly consisted of 3D-printed gears and a basic waterproof motor, it frequently broke and operated unstably.

As a result, for the third generation, we purchased a Blue-Robotics manipulator to accomplish more complex tasks. Yet we found that this manipulator only had one degree of freedom, making it difficult to grasp objects requiring specific orientations or complex shapes.

Therefore, we separately 3D-printed two gears, two motors, and a mount for the manipulator. By integrating the waterproof motors with the printed parts, the gear on the waterproof motor drives the gear on the manipulator mount, allowing the manipulator to rotate 360 degrees. This enables the ROV to capture more complex target objects.



Fig3.9.2a Photo of Gear Installed on Manipulator

### 3.9.3 Quick Release Payload Slot

We leverage the inherent versatility of the Aluminum Extrusion T-slot Structure to design a Quick Release Payload Slot system. By establishing a standard 20×20 mm<sup>2</sup> plug-and-slot interface, any payload can be securely mounted by using a quick-release pin. This standardization allows us to develop new sensors, lights, or tooling mounts that natively adapt to the system, enabling rapid installation and swapping without tools.

Crucially, because the T-slot frame allows any bracket to be repositioned by loosening a bolt, the slot locations on the ROV remain fully adjustable. This means we are not locked into a single configuration. For different missions, we can instantly reconfigure the attachment points. To accommodate payload of different sizes, or optimize hydrodynamics. As a result, the same ROV chassis can support diverse task loads—from inspection cameras to manipulator arms—making the vehicle truly modular and mission-ready in minutes, not hours.



Fig3.9.3a Photo of Quick Release Payload

### 3.9.4 One-way Gate Structures

We designed several one-way gate structure payloads. The same mechanical design serves as the attachment interface for different mission props, including basket stars(Task 1.1), lobster pot (Task 2.3) and buoy anchor (Task 2.4). Those payloads are

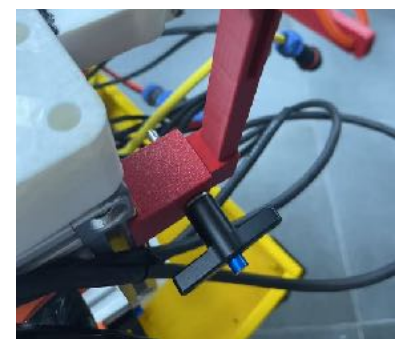


Fig3.9.3b Photo of Quick Release Pin

made by 3D printing parts and rubber bands to achieve a reliable locking function. We use the same mechanism , but in different shapes to archive the tasks.

The right one on the figure is for collecting basket stars (Task 1.1). We will install two units at the rear of the ROV, allowing us to collect two basket stars simultaneously. This keeps the manipulator free for other missions.

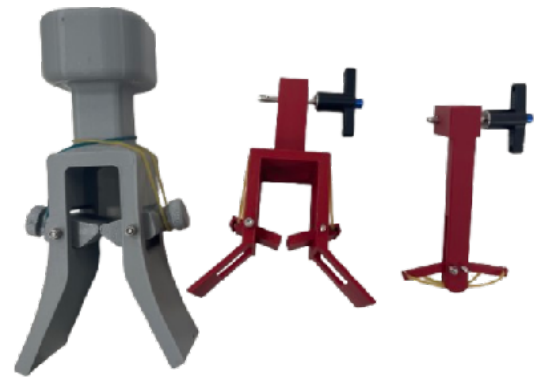


Fig3.9.4a Photo of Different One-Way Gate Structures

The middle one is for the lobster pot recovery (Task 2.3). It will be mounted at the bottom of the ROV. The gravity will stay mostly at the center of our ROV. That enables us to pull up the pot effectively by using all the up thrust power.

The left one is for the buoy anchor recovery (Task 2.4). It features a knob designed as a firm gripping handle. Allowing the manipulator to hold it firmly.

Additionally, we integrated a guidance structure into the designs. This helps the pilot align and lock the props quickly and firmly. Significantly reducing mission time and improving success rates.

### 3.9.5 Length Measurement

Our approach for Length Measurement of the coral garden(Task 1.2 ) and the keel of the Iceberg(Task 2.2) is as follows: We capture photos through our ROV. The program allows the operator to select two points on the image and input a known length, and calculate the desired length using the image's pixel ratio. The following is a detailed calculation process:

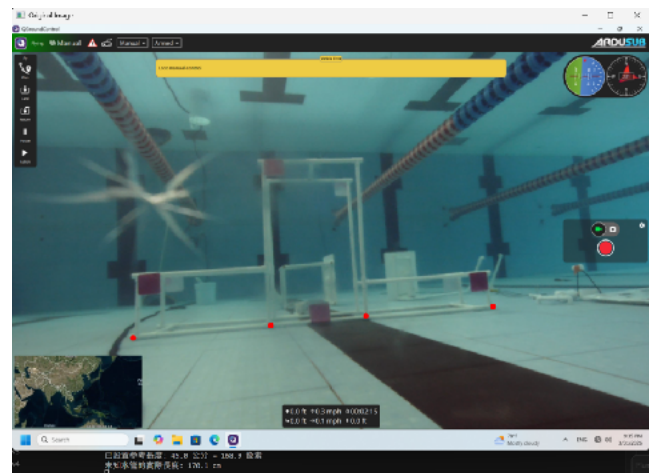


Fig3.9.5a Test of Length Measurement

### 3.9.6 Coral garden ridge modeling

#### Algorithm overview

The goal of this work is to support the Coral Garden competition task by recognizing a three-dimensional underwater frame made of multiple pipes and red square markers. Our system needs to locate the pipes and detect the red squares on them so that the overall structure can be modeled.

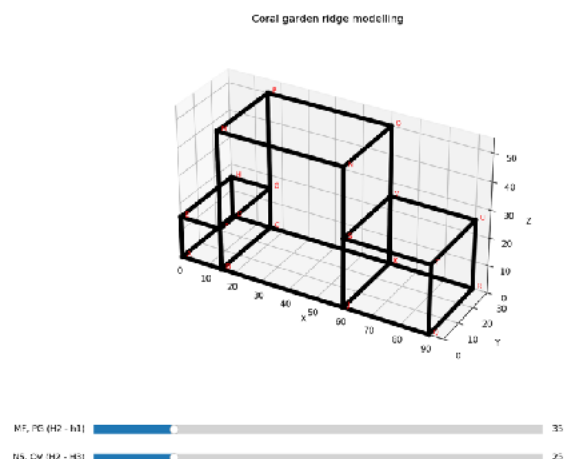


Fig3.9.6a Photo of Modeling Results

### Underwater preprocessing

Underwater images usually have strong blue-green color, low contrast, and noise. To make detection easier, we first balance the color channels to recover part of the red component and reduce the color cast. The image is then converted to LAB space and enhanced with CLAHE on the L channel to improve local contrast. A small Gaussian blur is finally applied to remove fine noise. All steps are implemented using OpenCV.

### Red square detection

The current program focuses on detecting red square markers on the pipes. After preprocessing, we convert the image to HSV color space and apply two red ranges to build a binary red mask that is more robust to light changes. We then apply adaptive thresholding on the grayscale image and extract contours. For each contour, we compute its bounding box, area, width, height, and aspect ratio.

A region is treated as a square candidate if its width and height are similar and fall within a predefined size range. Very small regions are discarded. For each candidate, we measure the ratio of red pixels inside it using the red mask, and keep only those with a red ratio above a threshold or a suitable position in the contour hierarchy. The final output includes the annotated image, the number of detected red squares, and basic statistics for parameter tuning.

### Use for pipe structure recognition

In the full system, pipes are detected mainly by line features: we select horizontal and vertical line segments, and filter them using angle, length, spacing, and overlap conditions to match the expected frame structure. The red square markers, especially at corners, act as additional geometric cues. By combining pipe segments with the coordinates of these red markers, the program can better estimate pipe lengths and frame layout, improving the stability and accuracy of underwater structure recognition in the Coral Garden task.

## 3.9.7 Mitigate invasive species

We use YOLOv11 to detect the invasive crab (Task 2.1). And here is the development process and how we do problem-solving.

During model training, we encountered a key issue: the training images we captured differed from real-world conditions. Particularly in terms of shooting angle and lighting. These inconsistencies negatively affected recognition accuracy. To solve this problem, we implemented two main solutions:

1. Developed a brightness adjustment program: calculating the average brightness of all images and standardizing them to the same brightness level, resulting in much more stable recognition performance.
2. Tested the same image from different angles: using the same image and rotating it to different angles. If recognition performance dropped significantly (e.g., from full

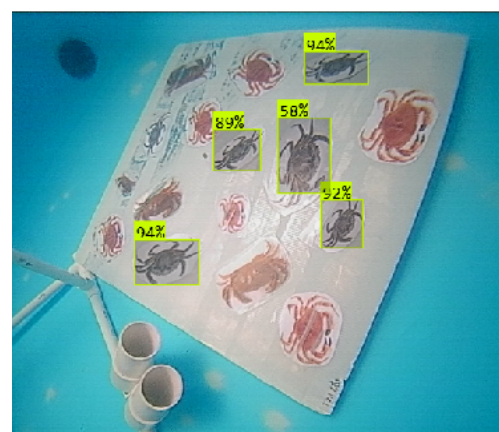


Fig3.9.7a Photo of Detecting Invasive Species

detection to only three or four objects detected at a certain angle), that shows we need to add more image samples at those angles. We collected images from those difficult angles and used them to retrain the model to improve its robustness. These steps effectively improved the model's stability and accuracy.



Fig3.9.7b Photo of Detecting Invasive Species  
Fig3.9.7c Photo of Detecting Invasive Species

### 3.9.8 Iceberg hazard evaluating program

We try to use Vibe programming to do the Iceberg tracking program. After reading the request in the competition manual. We ask the AI agent to make the separate parts of the program, such as counting the great-circle distances between the platforms and the Iceberg, and determine the ground potential of the Iceberg. Then combine all the programs and finish the final program.

Using the program to evaluate the threat posed by an iceberg to offshore oil platforms. It computes great-circle distances using the Haversine formula, and calculates the perpendicular distance from each platform to the iceberg's projected path. For each platform, using water depth, closest-approach distance to determine the threat level. The program offers a straightforward, physics-based screening tool for situational awareness rather than a full operational risk model.

### 3.9.9 Sensor Selection for Mission Requirements

Beyond the cameras, the Manta Ray carries a suite of sensors chosen to meet specific mission tasks and safety needs:

| Sensor                          | Model                                | Purpose                         | Mission Link      | Selection Rationale                                                      |
|---------------------------------|--------------------------------------|---------------------------------|-------------------|--------------------------------------------------------------------------|
| Depth/Pressure                  | Bar30<br>(MS5837-30BA)               | Depth hold, depth telemetry     | All tasks, safety | $\pm 2$ cm accuracy, I <sup>2</sup> C interface, compatible with ArduSub |
| Leak Detector                   | Custom two-pin probe                 | Water ingress detection         | Safety (all)      | Simple, low-cost; triggers fast failsafe                                 |
| IMU (Inertial Measurement Unit) | ICM-20948<br>(integrated in Pixhawk) | Attitude and heading estimation | Stabilisation     | Proven compatibility with ArduPilot; 9-DOF                               |

|                 |                           |                            |                                 |                                                            |
|-----------------|---------------------------|----------------------------|---------------------------------|------------------------------------------------------------|
| Temperature     | DS18B20                   | Water temperature reading  | Optional environmental data     | One-wire, easily added to hull penetration                 |
| Voltage/Current | ACS712 Hall-effect sensor | Real-time power monitoring | Safety, tether limit compliance | Enables pilot to observe current draw and avoid fuse trips |

### T3.9.9a List of Different Sensors in the Control System

Each sensor was selected based on a trade-off between accuracy, cost, water resistance, and software integration effort. The Bar30 and IMU are critical for autonomous functions (depth hold, station-keeping) and were verified to meet the required precision in pool tests. The leak detector and current sensor are mandatory safety features, tested repeatedly to ensure reliable triggering. This sensor suite ensures that the control system receives all data necessary to execute mission tasks safely and effectively.

## 3.10 Float / Depth Control

- Hardware: Depth sensor + linear actuator + iron-plate ballast (10g increments, 5× finer than iron blocks).
- Control Algorithm: P-control ( $\text{Output} = K_p \times (\text{target\_depth} - \text{measured\_depth})$ ), with I and D terms under development (the actual tuned  $K_p$  value needs to be supplemented).
- Prototype & Review: A variable-resistor to depth-sensor substitution prototype was developed in December 2025; the first draft of JSEA was completed. A step-response plot (0→50cm) needs to be supplemented (hand-drawn photos are acceptable).

### PID Control

We are currently testing the use of a depth sensor to control a servo motor. Since we had already successfully controlled a 12V fan (motor) using a potentiometer during the previous break, we are now simply replacing the potentiometer with a depth sensor. The Arduino IDE is used for the control software, which was largely written with the assistance of AI.

We have currently implemented the P (Proportional) component of the PID control loop. The hardware setup is essentially the same as last year's. We are currently considering whether to change the ballast configuration—swapping iron blocks for iron plates—to achieve more precise buoyancy control.

## Section 4: Safety Management

### 4.1 Job Safety and Environment Analysis (JSEA)

| Hazard              | Cause                           | Control Measure                                                        | Residual Risk |
|---------------------|---------------------------------|------------------------------------------------------------------------|---------------|
| Electrical shock    | High-voltage PSU / 12V rail     | 25A fuse; panel switch; insulated terminals; ammeter monitor           | Low           |
| Tether entanglement | Cable wrap around ROV/obstacles | Dedicated tether manager; pre-dive inspection; carabiner strain relief | Low           |
| Water ingress       | O-ring failure                  | Pre-dive O-ring check; desiccant packet; post-dive rinse               | Low           |

|                                               |                                                                                     |                                                                                                                                                                                   |     |
|-----------------------------------------------|-------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| Thruster injury                               | Rotating propellers in air                                                          | Thrusters unarmed until ROV in water; plastic guards during transport                                                                                                             | Low |
| ROV sinking                                   | Buoyancy failure                                                                    | Net positive buoyancy +50g target; tether retained at all times                                                                                                                   | Low |
| Battery over-discharge                        | Cell below safe voltage                                                             | Pixhawk voltage telemetry; audible alarm at 15V                                                                                                                                   | Low |
| Connector overheating (→ see S.T.A.R. Case 2) | Aged/non-spec screws → increased contact resistance → $I^2R$ heat → thermal runaway | Pre-dive terminal visual inspection + tug test (Patrick SOP); current meter monitoring; pilot briefing: max 75% throttle; spare terminal block in pit bag; wiring diagram updated | Low |
| Depth system failure                          | Push-rod actuator jam                                                               | Manual override; fail-safe spring returns to neutral buoyancy                                                                                                                     | Low |

T4.1a List of Several Hazards

## Section 5: Critical Analysis

### 5.1 Framework: EDP + S.T.A.R.

A two-layer problem-solving framework is adopted to ensure systematic iteration of the ROV and standardized documentation of faults:

- EDP (Engineering Design Process): For macro iteration, following the steps of Define→Research→Brainstorm→Prototype→Test→Evaluate→Redesign.
- S.T.A.R. (Situation–Task–Action–Result): For micro fault documentation, adhering to the principle of "Why before How" — Situation+Task to identify the root cause, Action+Result to deliver the optimal solution.

This framework forms a documented fault-to-solution pipeline, enabling cross-season knowledge transfer.

### 5.2 S.T.A.R. Case Studies

#### 5.2.1 Control Box Terminal Connector Overheating

**Situation:** In February 2026, the rightmost power terminal connector on the control box overheated and emitted visible smoke during ROV operation preparation. The root cause was aged/non-spec screws leading to insufficient clamping force, increased contact resistance, elevated  $I^2R$  power dissipation and thermal runaway, with risks of complete ROV power loss, fire and competition disqualification.

**Task:** We power down immediately and inspect the affected connector; quantify the fault by measuring contact resistance; source and install compliant replacement parts; brief pilots on the 75% throttle limit; verify under load and update pre-flight SOP and JSEA to prevent recurrence.

**Action:** Powered down immediately, inspected and found oxidized contact surfaces and undersized non-spec screws; measured contact resistance with a multimeter; replaced the terminal block with a compliant unit and screws with M4 stainless steel ones ; added terminal inspection steps to pre-flight SOP and updated the hazard record in JSEA.

**Result:** The contact resistance returned to the nominal specification of  $<0.05\Omega$  with no subsequent overheating incidents; a spare terminal block was prepared in the pit bag for  $<10$

min field replacement; the control box was redesigned to route all high-current connections to a dedicated upper-left zone for visual monitoring.

## Section 6: Mission Analysis

### 6.1 Task–Payload Matrix

All competition tasks are assigned with dedicated tools and responsible members to ensure clear task execution and efficient collaboration. Here is part of the Tasks Analysis:

- Task 1.1 (Collect 2 basket stars + 1 coral species): using dual-hook(One-way gate payloads on the rear) + gripper
- Task 1.2 (Measure coral garden length): take photos and using the python programs (length measurement, coral garden 3D modeling)

This mission involves conducting underwater length measurements of a coral garden constructed from PVC pipes. It is required to formulate a standardized flight plan to determine the measurement route and use a ruler reference tool for accurate distance measurement, taking into account the length tolerance range with 5cm to ensure that the measured data meets the competition requirements.

- Task 1.3 (Crab species % calculation): crab detection with YOLOv11  
This task requires accurately identifying native and invasive crab samples in the area through image recognition technology.
- Task 2.1 (Mitigate invasive species): using gripper
- Task 2.2 (Iceberg tracking): measure the keel(python program) + Iceberg Hazard Detection Program
- Task 2.5 (Recover old eDNA + deploy new): using gripper + copilot navigation
- Task 3.2 (Wind farm power connector): using gripper + precision piloting
  - Lobster pot retrieval: using gripper
  - Buoy anchor: using one-way gate payload hold by gripper + tether management with care

## Section 7: Budget & Cost Accounting

### 7.1 Budget Overview

Every formation of a team requires a budget. When the 2025 competition season ended, our CEO, CFO, and the instructor formulated the total budget of the 2026 competition system. The total budget for this year is \$ 38,300 USD. This budget covers all travel expenses (hotels, airfares) for the team of 9 for this year's competitions, the modification of the team's ROV, the cost of the ROV testing site, and expenses for various exchange activities. It's important to note that this year's ROV is an upgrade from last year's model. so most of the materials of the ROV are reused. This year, 94% of expenses are used in travel expenses, because we have to travel across half the globe (about 12000km), so airplane tickets account for 77.5%. To raise the necessary funds, our team launched numerous fundraising campaigns, including school grants and bank sponsorships to maintain team operations. Furthermore, to keep expenses within budget, our team has a complete procurement process. First, team members need to confirm the names and quantities of the required materials and submit this information to the CFO and mentor before deciding whether to purchase. The detailed list can be found in the appendix.

## 7.2 Build vs Buy Framework

Our team typically prioritizes our budget and whether the upgrade is truly beneficial to the ROV. We carefully consider whether to build it ourselves, reuse existing parts, or buy new ones. We usually reuse existing parts, so our team has its own process for testing reusable items. At the end of a competition, we disassemble all the parts from the ROV for testing to see if they can be reused. For example, with motors, we first test a brand new motor to measure its thrust and speed, then test the old motors for comparison. If the loss exceeds 20%, we consider replacing it. Another option is to build it ourselves, like our manipulator, in which we analyze different tasks and then design the forearm of our robotic arm to meet our requirements.

## Section 8: Acknowledgements & References

### 8.1 Acknowledgements

- IET HK - Holding the Hong Kong Regional Competition
- MATE Center and Marine Technology Society - Sponsoring this year's competition
- Oceaneering International - Their support of the MATE competition
- Pui Ching Middle School Macau - Their generous donation of funding
- Our Coaches (Thomas Lao and Marco Lou) - Their dedication, guidance, and time
- GitHub - Providing complimentary code repositories
- Autodesk - Supplying a quality CAD software for 3D modeling
- easyEDA - Providing a free, open-source software environment to design PCBs
- Our Families - Their continued support and encouragement

### 8.2 References

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# Appendices

## Budget Sheet

|                               |                               |                                                      | Reporting Period      |                     |
|-------------------------------|-------------------------------|------------------------------------------------------|-----------------------|---------------------|
| school name:                  | Macao Pui Ching Middle School |                                                      | from                  | 5/1/2025            |
| ins/ructor:                   | Thomas Lao,Marc Lcn           |                                                      | to                    | 4/10/2026           |
| income:                       |                               |                                                      |                       |                     |
| Source                        |                               |                                                      |                       | amount              |
| Macao Pui Ching Middle School |                               |                                                      |                       | \$6,500.00          |
| Expenses:                     |                               |                                                      |                       |                     |
| category                      | type                          | description                                          | projected(usd)        | budgeted value(USD) |
| hardware                      | purchased                     | aluminum, PLA, PETG,fasteners                        | \$139.83              | \$50.00             |
|                               | Re-used                       | Acrylic dome, attachments                            | \$72.00               | -                   |
| electronics                   | purchased                     | control box                                          | \$174.58              | \$420.00            |
|                               | purchased                     | float electronics                                    |                       | \$110.00            |
|                               | Re-used                       | camera hub,screen                                    | \$139.71              | -                   |
|                               | Re-used                       | waterproof camera                                    | \$15.00               | -                   |
|                               | Re-used                       | control system                                       | \$419.32              | -                   |
|                               | Re-used                       | robotram                                             | \$431.76              | -                   |
|                               | Re-used                       | motors                                               | \$714.00              | -                   |
|                               | purchased                     | Travel to robotcup for 9 people for 5days            | \$3,126.97            | \$4,500.00          |
| travel                        | purchased                     | Travel to guangzhou practice for 9 people for 3 days | \$653.83              | \$900.00            |
|                               | purchased                     | Travel to Regionals for 9 people for 3 days          | \$779.36              | \$1,500.00          |
|                               | purchased                     | Travel to Worlds for 9 people for 8 days             | -                     | \$29,000.00         |
| general                       | rov testing                   | swimming pool, Lifeguard                             | \$405.00              | \$1,370.00          |
|                               | purchased                     | props                                                | \$43.58               | \$50.00             |
|                               |                               |                                                      | Total Income          | \$5,500.00          |
|                               |                               |                                                      | Total Expenses        | \$7,113.94          |
|                               |                               |                                                      | Total Expenses - Reus | \$5,023.15          |
|                               |                               |                                                      | Fundraising Needed    | \$2.00              |

## Project Costing

| Category     | Type      | Category             | Expense                                | Source Notes                     | number        | Amount(USD)   | Running Balance |
|--------------|-----------|----------------------|----------------------------------------|----------------------------------|---------------|---------------|-----------------|
| ROV:         |           |                      |                                        |                                  |               |               |                 |
|              | Purchased | Frame Structure      | Aluminium Bars                         | For Frame                        | 4*40cm*4*20cm | \$5.06        | \$5.06          |
|              | Re-used   | Frame Structure      | Waterproof Cameras (4)                 | Provide images                   | 4             | \$15.00       | \$20.06         |
|              | Re-used   | Frame Structure      | 1200 Thruster(6)                       | Providing power for ROV          | 6             | \$714.00      | \$734.06        |
|              | Re-used   | Frame Structure      | Buoyancy Block                         | Provide buoyancy                 | 4             | \$109.00      | \$843.06        |
|              | Re-used   | Frame Structure      | Newton Subsea Gripper                  | Pick up items                    | 1             | \$320.00      | \$1,163.06      |
|              | Purchased | Frame Structure      | 3D Printed Material                    | Payload                          | 1kg           | \$9.98        | \$1,173.04      |
|              | Purchased | Frame Structure      | Servo Motor                            | Manipulator                      | 1             | \$111.67      | \$1,284.71      |
|              | Re-used   | Tether               | 8-core Cable(18M)                      | Provide signal line              | 18m*2         | \$45.00       | \$1,329.71      |
|              | Re-used   | Tether               | 2-core Cable(18M)                      | Provide power                    | 18m           | \$20.00       | \$1,349.71      |
|              | Re-used   | Tether               | Aviation Connector                     | Connecting ROV and cable         | 2             | \$2.50        | \$1,352.21      |
|              | Purchased | Tether               | Carabiner                              | Strain Relief for Tether and ROV | 1             | \$2.00        | \$1,354.21      |
|              | Re-used   | Tether               | Nylon braid cable sleeves              | Protect Tether                   | 18m           | \$2.50        | \$1,356.71      |
|              | Re-used   | Electronics          | Regulator (12V-5V)                     | Changing current                 | 1             | \$0.65        | \$1,357.36      |
|              | Re-used   | Electronics          | Raspberry pi 3B                        | Process signals                  | 1             | \$17.30       | \$1,374.66      |
|              | Re-used   | Electronics          | Pixhawk                                | Control all motors               | 1             | \$75.80       | \$1,450.46      |
|              | Re-used   | Electronics          | Wetlinks                               | water proof                      | 10            | \$16.60       | \$1,467.06      |
|              | Re-used   | Electronics          | Network cable head                     | Adapter                          | 2             | \$1.40        | \$1,468.46      |
|              | Re-used   | Electronics          | USB camera                             | Provide images                   | 1             | \$6.25        | \$1,474.71      |
|              | Re-used   | Electronics          | ESC Brushless Motor                    | Control Thruster                 | 6             | \$19.00       | \$1,493.71      |
|              | Re-used   | Electronics          | Different sizes of screws and nuts     | Secure parts                     | -             | \$6.79        | \$1,499.50      |
|              | Re-used   | Watertight Enclosure | Acrylic dome                           | Install electronic parts         | 1             | \$45.00       | \$1,544.50      |
| Control box: |           |                      |                                        |                                  |               |               |                 |
|              | Purchased | Control box          | Monitor                                | Show camera footage              | 2             | \$81.18       | \$1,625.68      |
|              | Re-used   | Control box          | NUC                                    | computer                         | 1             | \$181.54      | \$1,807.22      |
|              | Purchased | Control box          | Container box                          | Install electronic components    | 1             | \$174.25      | \$1,981.50      |
|              | Purchased | Control box          | camera hub                             | Analyze camera footage           | 1             | \$52.28       | \$2,033.78      |
|              | Purchased | Control box          | switch                                 | Control main power and camera    | 2             | \$0.29        | \$2,034.07      |
|              | Purchased | Control box          | PCB                                    | audio source to BNC converter    | 1             | \$0.00        | \$2,034.07      |
|              | Purchased | Control box          | Ethernet Port                          | Connect Tether Ethernet port     | 1             | \$1.16        | \$2,035.23      |
|              | Re-used   | Control box          | Ethernet Cable                         | NUC to Ethernet port             | 1m            | \$3.04        | \$2,038.27      |
|              | Purchased | Control box          | Aviation Connector                     | Connect Cable power              | 1             | \$1.20        | \$2,039.47      |
|              | Purchased | Control box          | BNC to BNC                             | Extension cord                   | 4*15cm        | \$3.77        | \$2,043.24      |
|              | Re-used   | Control box          | inox controller                        | Maneuver ROV                     | 1             | \$48.21       | \$2,091.45      |
|              | Purchased | Control box          | 10AWG Cable                            | power connect control            | 1m*2          | \$2.61        | \$2,094.06      |
|              | Purchased | Control box          | fuse                                   | Protect circuit                  | 1             | \$1.16        | \$2,095.22      |
|              | Purchased | Control box          | 3Dprint                                | Frame                            | 2kg           | \$10.00       | \$2,105.22      |
| venue fee    |           |                      |                                        |                                  |               |               |                 |
|              | Purchased | venue fee            | props                                  | do mission                       | -             | \$43.58       | \$2,148.80      |
|              | Purchased | venue fee            | swimming pool                          | do mission                       | 6h            | \$406.00      | \$2,554.80      |
| travel:      |           |                      |                                        |                                  |               |               |                 |
|              | Purchased | Travel               | Hotels robotcup (5nights)              | lodging                          | -             | \$1,242.19    | \$3,796.99      |
|              | Purchased | Travel               | air tickets (9) zhuhai to shijiazhuang | Transportation                   | -             | \$1,884.78    | \$5,681.77      |
|              | Purchased | Travel               | Hotels shenzhen (2nights)              | lodging                          | -             | \$348.70      | \$6,030.47      |
|              | Purchased | Travel               | car rental                             | Transportation                   | -             | \$305.11      | \$6,335.58      |
|              | Purchased | Travel               | Hotels Hong Kong (2nights)             | lodging                          | -             | \$535.92      | \$6,871.50      |
|              | Purchased | Travel               | car rental                             | Transportation                   | -             | \$242.44      | \$7,113.94      |
|              |           |                      |                                        |                                  |               | Total Raised  | \$6,500.00      |
|              |           |                      |                                        |                                  |               | Total Spent   | \$7,113.94      |
|              |           |                      |                                        |                                  |               | Final Balance | \$134.42        |

System Integration Diagram (SID)

