ZHICHENG AquaVoyager

志成水之旅者

Navigateur Aquatique

Navegador Acuático

الأكوايوياجر

Submitted in Response to the MATE ROV Competition

Submitted by

Strandline alliance

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2025/05/09

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Executive Summary

Our team has designed an underwater robot named "AquaVoyager"—a remotely operated vehicle (ROV) and unmanned underwater submarine equipped with eight thrusters. The robot weighs approximately 20 kg (weight may fluctuate due to buoyancy tank counterweights), achieving a maximum speed of **(speed)** m/s in still water and a diving depth of **(depth)** meters. Powered continuously via a cable, its electrical system integrates underwater robotics and flight control technology, delivering unprecedented stability and operational simplicity.

The design team outfitted AquaVoyager with six thrusters: two for vertical propulsion and four for horizontal/lateral movement, each generating **(thrust)** of force. The operating system was developed using **(programming language)**, ensuring precise control and responsiveness.

A key highlight of AquaVoyager is its modular robotic arm design, engineered for easy disassembly and replacement—allowing quick swaps for task-specific tools during specialized missions. The versatile default arm features:

A lengthened gripper for retrieving floating surface objects;

An auxiliary hook for securing ropes or cables;

Rubber soft-tip pads at the gripper's end, enhancing stability to prevent slippage while protecting mission items from punctures or scratches—an improvement over traditional rigid claws.

The purpose of designing a safety system is to Protect staff members, safeguard ROV structure and electrical circuits, and preserve the natural environment and organisms.

The camera system, designed with a single degree of freedom, enables vertical tilting for adjustable observation angles. Encased in a semicircular waterproof enclosure, it ensures unobstructed vision while maintaining full water resistance.

Specification sheet

Criteria	Value
Total Weight	7 kg
Size	457*341*226 mm
Maximum & Minimum Speed	1.2 m/s
Maximum Depth	20 m

1.Team Engagement

1.1 Team Formation and Project Operation

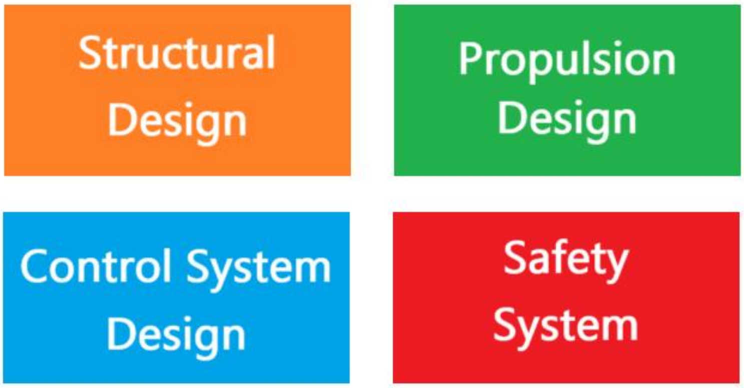


Figure 1.1 Basics of ROV Design

The "Marine Advanced Technology Education International ROV Competition" (MATE ROV Competition) was introduced to our school by Teacher Tian Ziyu from Beijing No. 35 Middle School. Initially, the team was formed by two students: Zhang Yuchen and Wang Yixing. Together, we analyzed the details of past MATE competitions and decided to recruit new members with exceptional talents and strong STEM (Science, Technology, Engineering, and Mathematics) skills.

Subsequently, Yu Haoyu (software designer), Wu Junqiao (experienced engineer), Zhao Yuhua (3D modeler), Xu Haoran (robotics engineer), and Li Zhuxuan (a highly inspired member) joined our team. The entire recruitment process took approximately two weeks.

After our experienced mentor, Teacher Tian Ziyu, introduced the specific rules and objectives of the competition, we officially began working on the MATE ROV project. Each team member chose a specific aspect of the ROV design that aligned with their expertise and interests.

1.2 State the Project Goal

The project statement encourages us to design a ROV which is capable of reconnoitre the sunken ships, maintain the underwater engineering devices, monitor the water environment in the Lake Huron. We will analyze the basic statistic requirements in the Mission Section. Here are several criteria that we have considered when designing the ROV.

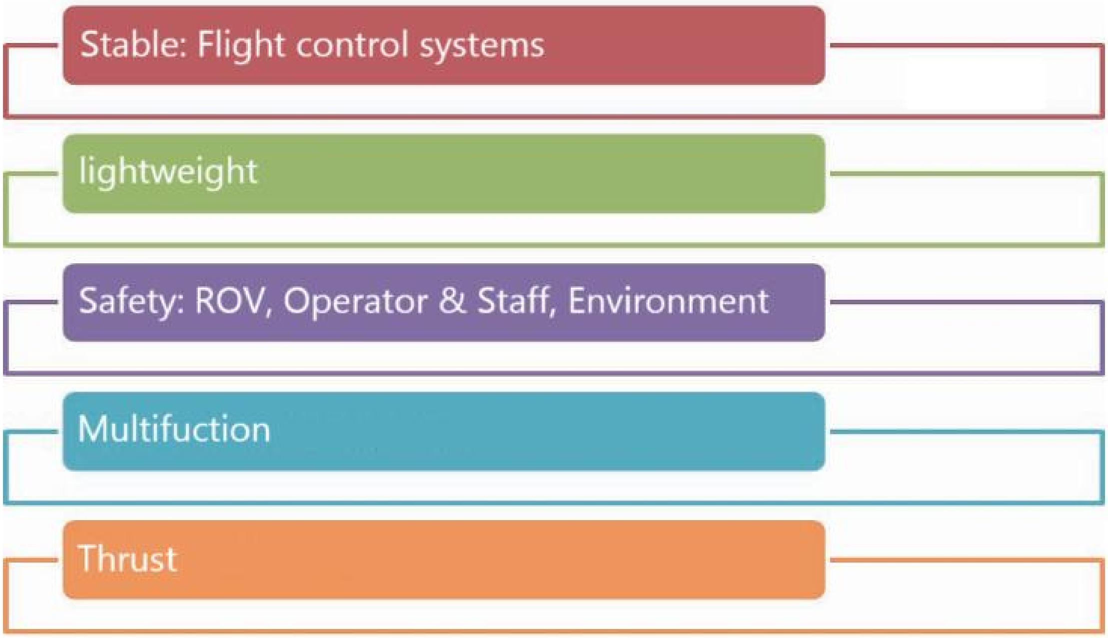


Figure 1.2 Property of ROV

Scenario:

Climate Change & Invasive Species in Great Lakes

Teams identify shipwrecks, monitor water quality (pH, CO_2), and detect Asian carp DNA. These tasks address threats like rising temperatures and acidification, aiming to protect the Great Lakes' ecology and cultural heritage as vital freshwater systems.

Marine Renewable Energy & Ecological Balance

Tasks include connecting solar arrays, maintaining wind farms (anode replacement, epoxy application), and monitoring marine life (jellyfish, fish, hydrophones). The goal is sustainable energy solutions that protect ocean ecosystems during renewable resource use.

Global Ocean Observation with Floats

Teams design vertical profiling floats to collect depth, temperature, and biogeochemical data for GO-BGC. By transmitting real-time data, these floats aid ocean dynamics research and climate change modeling to inform global marine protection policies.

ROV Starting Area:

A 99cm by 99cm square on the edge of the pool serves as the starting area (see Figure 1.3).

ROV Interaction Props (see Figure 1.3):

The ROV must be capable of: gripping spherical objects, gripping rod-shaped objects, gripping ropes, hooking hooks, rotating in place, inserting into tubes, grabbing surface objects, and using syringes.

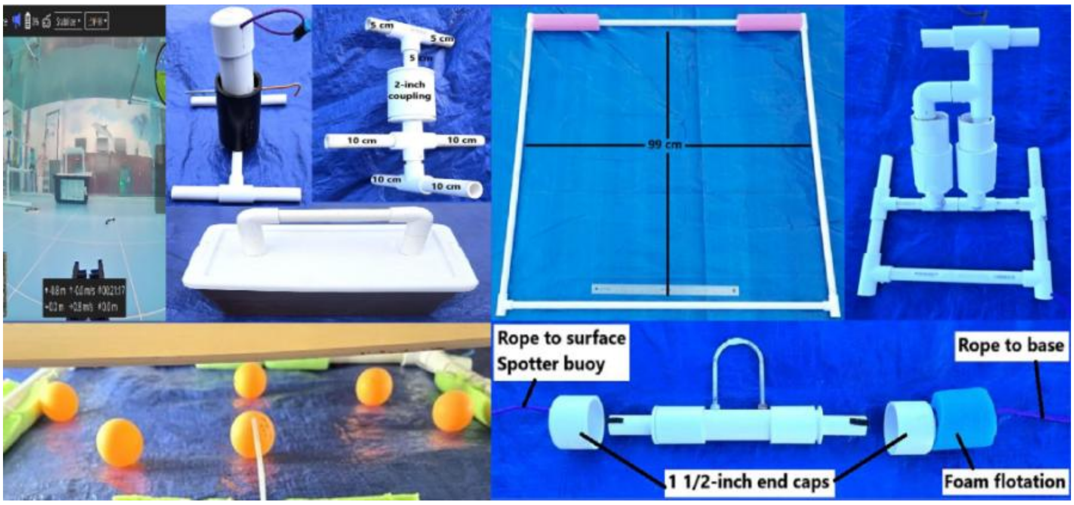


Figure 1.3 Underwater Interaction Props

ROV Non-Interaction Tasks:

The ROV must be able to: measure length, capture 360° photo spheres of props, identify objects and colors, and measure pH levels.

Desired Performance Effects for ROV:

1. Stability:
   Equipped with a self-stabilization system to maintain balance in flowing water and stability in spatial orientation.
2. Strong Mobility:
   Capable of lifting objects and achieving faster movement speeds.
3. Multiple Rotational Axes and Freedom of Movement:
   Able to pitch up/down, translate, rotate, and perform basic ascending/descending like an aircraft, enabling versatile directional movement.

Safety

Ensuring safety is critical for the ROV to operate stably and properly. The following measures are essential:

1. Ethernet Communication Failure Response
   Use Qgroundcontrol's one-key return function when communication is poor.
   If communication is completely lost, automatically exit stabilize mode and lock the motors.
2. Personnel Protection
   The ROV must be able to lock its motors while powered to safeguard operators during deployment/retrieval and when removing objects from the mechanical claw.

3.Fish Deterrence Function (Theoretical Requirement)

Equip an ultrasonic module to repel fish schools, preventing collisions (to avoid damage to the ROV and harm to aquatic life). Ultrasonic noise is short-lived and minimally impact, prioritizing mutual protection over minor noise concerns.

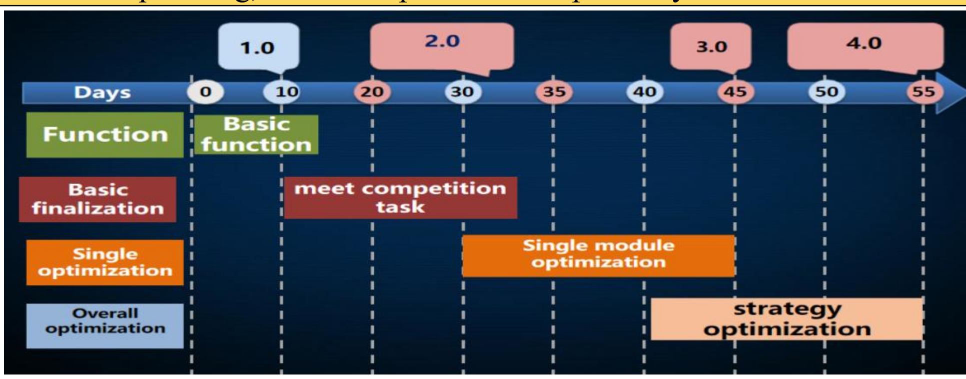
4.Special Protection for Motors

The ROV must prevent water plants, threads, plastic bags, and other waterborne objects from entangling the motors, which could cause malfunctions or loss of control.

1.3 Tool Setup/Learning/Validation/Time Table

While completing the required tasks, we use different methods to attain the tools, both hardware and software, to fulfill our needs.

Difficulty #1: PDF editing
Solution #1: Adobe Acrobat Reader DC
details: Since PDFs are widely used when writing essays, our team needs software that can edit the PDF documents for research and presentation purposes. Haoran Xu subscribed to the Adobe Premium for Adobe Acrobat DC, then offering help to other teammates who need PDF service.
Difficulty #2: Solid work using
Solution #2: Learn it on bilibili (Chinese YouTube)
details: Since 3D modeling and engineering analysis are essential for product development, our team requires software that can handle complex design, simulation, and collaboration. Yuhua Zhao subscribed to Solid Works Premium, leveraging its integrated tools for 3D modeling, stress analysis, and real-time teamwork, then assisting teammates with design validation and manufacturing preparation.
Difficulty #3: QGroundControl
Solution #3: Learn it on bilibili (Chinese YouTube)
details: Since autonomous drone navigation and mission management are critical for aerial operations, our team requires software that enables real-time flight control, precise mission planning, and multi-platform compatibility.



2 Design

2.1 Engineering Design Process

2.1.1 Structural design

ROV Main Body

Base Plates (for mounting other components): Front Thruster Plate (*S01*), Tail Thruster Plate (*S02*), Buoyancy Plate Module (*S03*)

Structural Plates (for frame stability and load-bearing): Side Plate (*S04*), Multi-Compartment Connecting Plate (*S05*)

Waterproof Compartments (for electronic components): Hemispherical Cover Compartment (*S06*), Main Waterproof Compartment (*S07*)

Material

PP plastic, with low density ~0.9 - 0.91 g/cm³ and good structural strength.

ROV Underwater Tools

Mechanical Claw (for underwater operations): Custom Multi-Functional Claw Teeth (*S08*)

Detailed Descriptions

S01: A frame connecting plate at the front of the robot, providing mounting holes for the front thruster and an installation position for the mechanical claw's wrist joint.

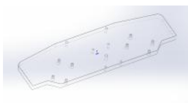


Figure 2.1

S02: A frame connecting plate at the back of the robot, providing mounting holes for the tail thruster and a quick-release position for the stainless steel cable mesh sleeve.

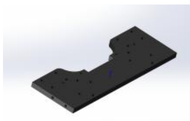


Figure 2.2

S03: Adds buoyancy to the robot's tail. The buoyancy compartment uses an easy-open waterproof box design, allowing infinite buoyancy adjustment by filling the box with water as counterweight.

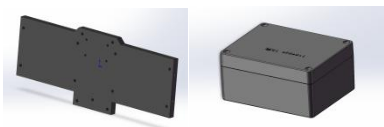


Figure 2.3

S04: The main connecting plate for the robot's overall frame, ensuring reliable structural connection using hammer head nuts for a compact design. It creates water channels for horizontal thrusters to maintain mobility and includes fixing holes for vertical thrusters.

Figure 2.4

S05: The primary connecting plate for the main waterproof compartment, cylindrical extension compartment, and hemispherical cover compartment, offering stable frame connection. Besides the main compartment, it provides additional external mounting planes on the robot's top for easy access to manual peripherals like switches and exhaust valves.

Figure 2.5

S06: Forms the main waterproof structure with the main compartment, ensuring reliable operation. It provides a clear view for the camera and a spherical movement space for the pan-tilt, enabling a wider adjustable field of view.

Figure 2.6

S07: Forms the main waterproof structure with the hemispherical cover compartment, ensuring reliable operation. Compared to cylindrical compartments, it offers more planar space for peripherals. The metal casing design aids in water-cooled heat dissipation and withstands higher external pressure.

Figure 2.7

S08: Provides a secure connection between the robot's knuckle servo and the claw, maintaining specific phase rotation for both claw sides. Material: 6061 aluminum alloy with black anodization. The mechanical claw is equipped with multi-functional structures such as hooks, grippers, soft grippers, and double-layered toothed jaws (forming a cage structure).

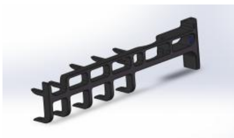


Figure 2.8

2.1.2 Dynamic system design

Mobile Power Source

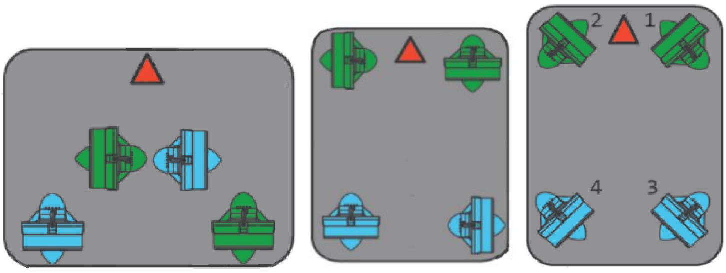
8 Motor Thrusters: Provide omnidirectional movement and attitude control for the robot.
For each thruster:
Rated voltage: 24V; Propeller diameter: 60mm; Rated thrust: ~35N; Maximum pressure resistance depth: 20m; External drivers

Layout

Layer 1: 4 thrusters for horizontal movement & rotation

Green thrusters = forward propellers; blue thrusters = reverse propellers. Each direction thrusters has one forward, one reverse. Single-direction propellers would cause tilting during movement.

We designed Solution No. 1, then Solution No. 2, and finally optimized Solution No. 3 for the 4 "layer-1" thrusters.



Solution No. 1 ***Solution No. 2*** ***Solution No. 3***

Figure 2.9 Dynamical system

Pros and Cons Analysis

Solution No. 1:

Fast in all 4 horizontal directions (thrust isn't decomposed in the movement direction), but very slow rotation—only via forward/reverse of two longitudinal motors, unable to spin in place around the ROV's geometric center.

Solution No. 2:

Fast horizontal rotation, but blocked water flow from lateral thrusters causes thrust imbalance in 4 movement directions—slight turning during forward motion and reduced speed.

Solution No. 3 (optimal):

Faster movement and rotation than the first two solutions.

Assume single thruster force = x; thrusters tilted at 45°, so thrust decomposes to $\frac{\sqrt{2}}{2}X$ in the movement direction.

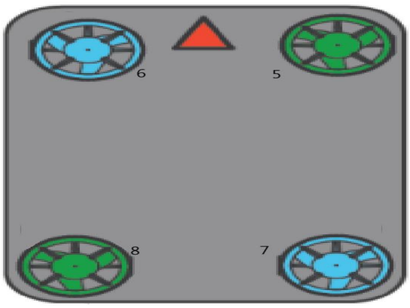
Though initial appearance shows lower force than Solutions 1&2 (2x per direction in solution1&2 VS "√2X" in solution 3), all 4 motors work simultaneously in one direction, totaling $(2\sqrt{2})$X force—best performance for the ROV, so we chose Solution No. 3 in the end.

In picture 2.9, we define four horizontal thrusters in to 1 2 3 4, which we will use: D01, D02, D03, D04, to describe them later.

Layer 2: Vertical Movement, Pitch, and Roll

Four thrusters are allocated to Layer 2: Green thrusters = forward propellers; blue thrusters = reverse propellers (two forward, two reverse, similar to rotary-wing drones). Single-direction propellers would cause tilting during movement.

This is our solution.



Picture 2.10 Dynamical system

In picture 2.10, we define four horizontal thrusters in to 5 6 7 8, which we will use: D05, D06, D07, D08, to describe them later.

ROV Movement Principles

Horizontal Movement

- Forward: **D01&D02&D03&D04** rotate **clockwise**. *(Although there are differences between forward and reverse propellers, the two reverse propellers D03 and D04 are installed upside down, so they need to rotate clockwise to provide reverse thrust.)*
- Backward: **D01&D02&D03&D04** rotate **counterclockwise**. *(Although there are differences between forward and reverse propellers, the two forward propellers D01 and D02 are installed right side up, so they need to rotate counterclockwise to provide reverse thrust.)*
- Left: **D01&D04** rotate **clockwise**, **D02&D03** rotate **counterclockwise**.
- Right: **D01&D04** rotate **counterclockwise**, **D02&D03** rotate **clockwise**.
- Rotate Left: **D01&D03** rotate **clockwise**, **D02&D04** rotate **counterclockwise.**
- Rotate Right: **D01&D03** rotate **counterclockwise**, **D02&D04** rotate **clockwise**.

Vertical Movement

- Ascend: **D05&D08** rotate **clockwise**, **D06&D07** rotate **counterclockwise**.
- Descend: **D05&D08** rotate **counterclockwise**, **D06&D07** rotate **clockwise**.

Special Maneuvers

- Pitch Down: **D05&D07** rotate **clockwise**, **D06&D08** rotate **counterclockwise**.
- Pitch Up: **D05&D07** rotate **counterclockwise**, **D06&D08** rotate **clockwise**.
- Roll Left: **D05&D06** rotate **clockwise**, **D07&D08** rotate **counterclockwise**.
- Roll Right: **D05&D06** rotate **counterclockwise**, **D07&D08** rotate **clockwise**.

Mechanical Claw Actuation:

Finger Joint Servo

Designed to provide the robot with grasping capabilities, the finger joint servo works in tandem with the wrist joint servo to form a two-degree-of-freedom robotic arm. This setup enables precise object manipulation underwater. Key specifications include: a rated voltage of 7.4V, a rated operating torque of 2 Newton-meters, a no-load rotation speed of 260 degrees per second at 7.4V, an opening/closing angle range of 100 degrees, and a water resistance depth of 20 meters.

Wrist Joint Servo

The wrist joint servo is engineered to offer variable grabbing angles for the robot, enhancing the flexibility of underwater grasping motions. When paired with the finger joint servo, it creates a dual-axis mechanical arm capable of adapting to diverse grasping scenarios. Its technical parameters are as follows: rated voltage of 7.4V, rated torque of 2 Newton-meters, no-load speed of 260 degrees per second at 7.4V, a rotation angle range of 180 degrees, and a maximum operational depth of 20 meters under water pressure.

2.1.3 Control system

Electrical part:

The ROV's electronics are designed to meet MATE competition specs, prioritizing stability and safety. At its core is an industrial-grade power supply module that efficiently converts 220V AC to 48V DC as the main power bus.

Figure 2.11

Circuit boards are functionally modular, connected via standard interfaces like Ethernet, XT-60 connectors, and PCB links. This design fits everything into a compact space, ensuring both waterproofing and reliability. The sealed electronics housing also provides buoyancy (thanks to air inside), making the system not only competition-ready and durable but also a smart part of the ROV's structural buoyancy design. All modules feature quick-release designs with self-locking connectors, allowing users to assemble, disassemble, and maintain them with ease and efficiency.

Control part:

The control system's hardware uses a high-performance ARM Cortex-M7 microcontroller chip, the STM32H743. The software runs on the QGroundControl platform, letting it handle mission planning, real-time monitoring of telemetry data, and manual control.

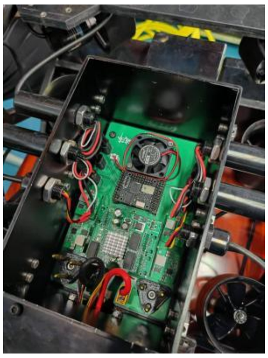


Figure 2.12

The control setup is split into two parts: higher-level control (where the ground station processes operator commands) and lower-level control (where the flight control board runs PID algorithms). The system works in both manual mode (where operators take direct control) and autonomous mode (for executing pre-programmed tasks).

For safety, it includes automatic fail-safes that kick in if communication is lost, plus a battery monitoring system to keep things running smoothly.

2.1.4 Communication System

The ROV communicates with the ground station using the MAV Link protocol for efficient and reliable data transfer. The tether, a zero-buoyancy cable, connects the ROV to the workstation. It's watertight and neutrally buoyant to avoid sinking or floating, which could disrupt the ROV's underwater balance. The cable houses two power lines and two signal lines.

Figure 2.13

The control board features 8 PWM outputs for thruster control, 2 PWM ports for servo motors, UART interfaces for camera and ground station communication, and an I2C port for hydrophone connectivity.

We've added a tilt axis to the onboard camera, allowing it to aim in any vertical direction—up, down, or at an angle—without having to move the entire robot. This extra flexibility boosts target tracking and mapping accuracy, especially for tasks like collecting jellyfish samples, inserting tubular objects downward or at an angle, or grabbing surface-level items. The adjustable tilt provides a wider field of view when we need it most for these specific operations.

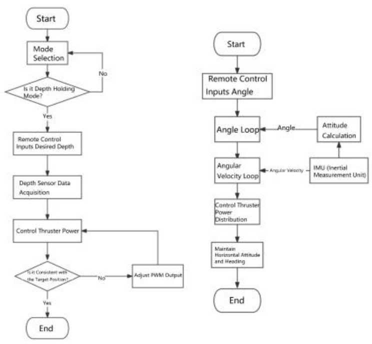
We stream video to the QGroundControl open-source software via TCP. This setup delivers relatively clear video with minimal lag, improving the operator's control experience and ensuring precise maneuvering.

Figure 2.14 & 2.15

2.1.5 Software and Programming

Ardusub Software Architecture

Ardusub, an open-source framework, powers underwater robots with modular motion control and sensor processing. Attitude control stabilizes orientation via IMU data, while depth control uses sensor feedback for precision positioning.



MAVLink Communication Protocol

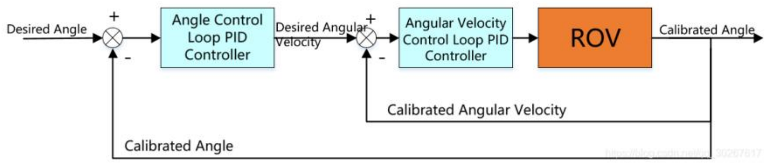
The MAVLink lightweight protocol enables robust vehicle-ground station communication over WiFi/serial. Its structured messages with checksums ensure reliability. A heartbeat mechanism triggers safety shutdowns if connectivity is lost, and V2.0 adds message signing for security.

Code Compilation & Optimization

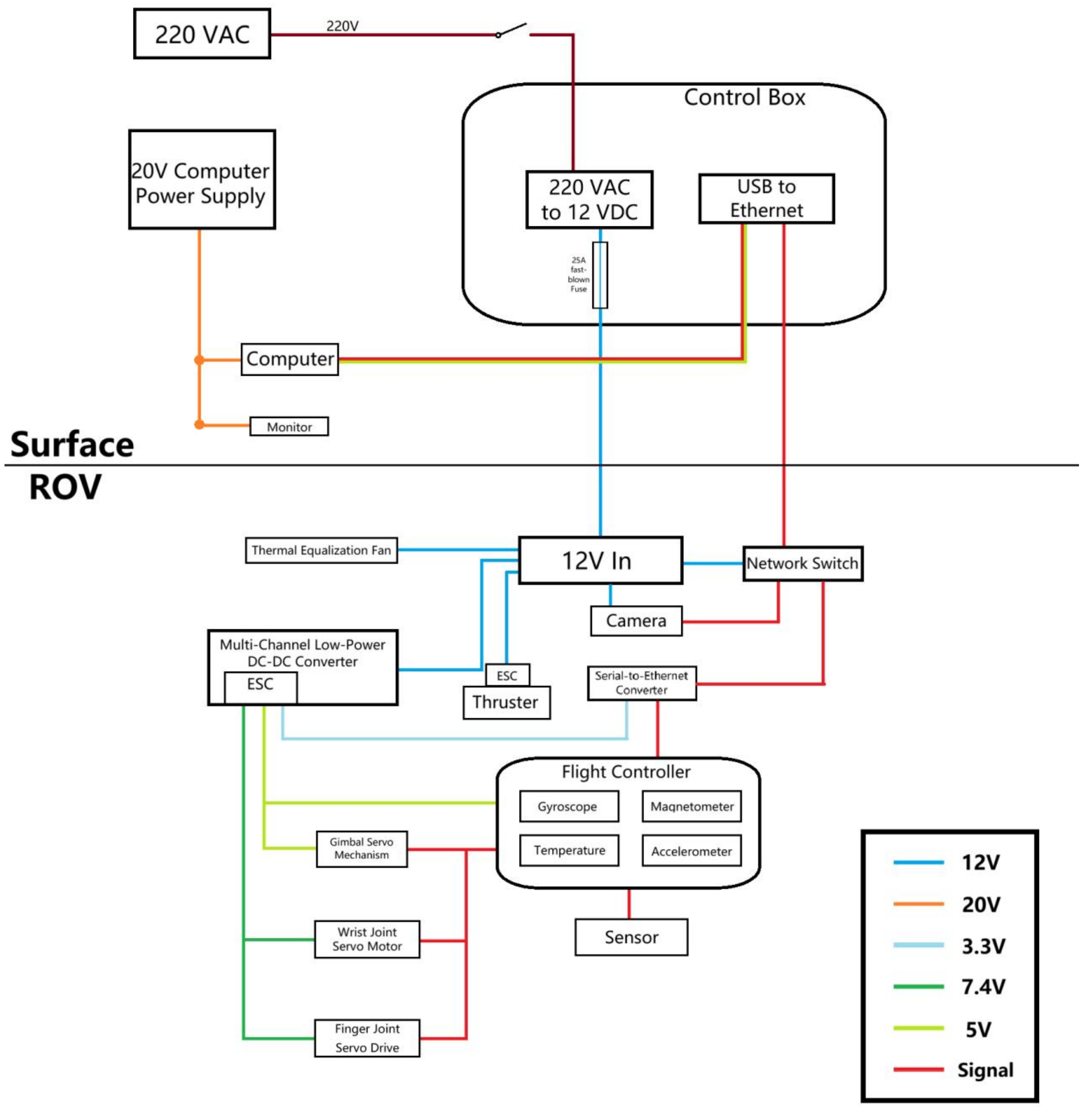
Custom hardware (STM32H7, MS5837 sensor) necessitated modifying low-level code. Calibration resolved depth inaccuracies: developers cloned the repo, adjusted scaling factors in Ubuntu, recompiled firmware, and flashed it to the STM32H7.

Motion Control Implementation

PID algorithms govern movement, with P, I, D parameters tuned iteratively. P adjusts thrusters for current errors, I eliminates drift, and D prevents overshoot. Cross-loop dependencies require systematic testing to optimize stability for diving.



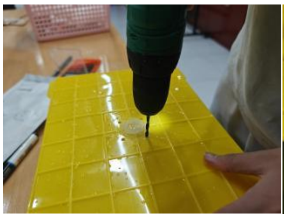
2.2 System Integration Diagram SID



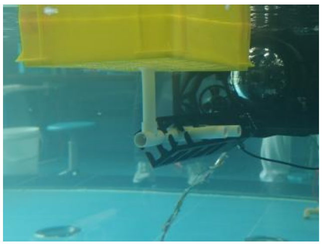
2.3 Subsystems

2.3.1 Collection box

Based on the existing device design, the underwater robot collection scheme is as follows: A water-filled floating box serves as the collection container, with a handle beneath it for the mechanical claw of a non-surfacing underwater robot to grasp.




During operation, the robot approaches the box from the waterbed, locks the handle with its claw, and dives slightly to adjust its posture.



It then activates the buoyancy system to ascend slowly, lifting the box's opening to the water's surface as it rises. At this point, the robot is maneuvered to translate horizontally, using the box's front edge to "scoop" floating jellyfish specimens into the container.

After collection, the robot pushes the box along a predefined path toward the shore at low propulsion power, monitoring the specimen's condition via an onboard camera throughout to avoid damage from abrupt movements. This four-step approach—grasping, ascending, scooping, and transporting—enables non-invasive collection of surface-floating jellyfish. The design features simple mechanics and strong compatibility with the robot's claw, making it suitable for shallow water fixed-point sample collection.

2.3.2 PH detector

The Sima PH818 Lithium Battery Version (Long Battery Life Option) features a compact 182×25×45mm pen-style body with an anti-slip groove at the tail, specifically designed for easy gripping by robotic claws. Its lithium battery power supply eliminates the need for frequent battery changes, making it ideal for prolonged underwater operations where accessibility is limited.

With an IP67 waterproof rating, this model withstands temperatures from 0 to 60°C and can directly contact seawater—though regular freshwater rinsing of the electrode is recommended to prevent corrosion from salt buildup. The large LCD screen provides real-time display of both pH value and temperature, which can be easily viewed via the robot's pan-tilt camera during deployment. It also supports manual storage of up to 50 data sets, which can be exported to a computer via USB after the device is recovered, ensuring convenient data management post-operation.

2.3.3 Strain Relief Device

We secure it to the strongest Tail Thruster Plate (*S02*) at the robot's tail end using snap clips and wire mesh. This ensures that even if the cable is subjected to strong external pulling forces, the connection points at the robot's interface will not come apart.
Additionally, the interface is equipped with a waterproof cap that can be screwed on, providing an extra layer of protection for the connection points.

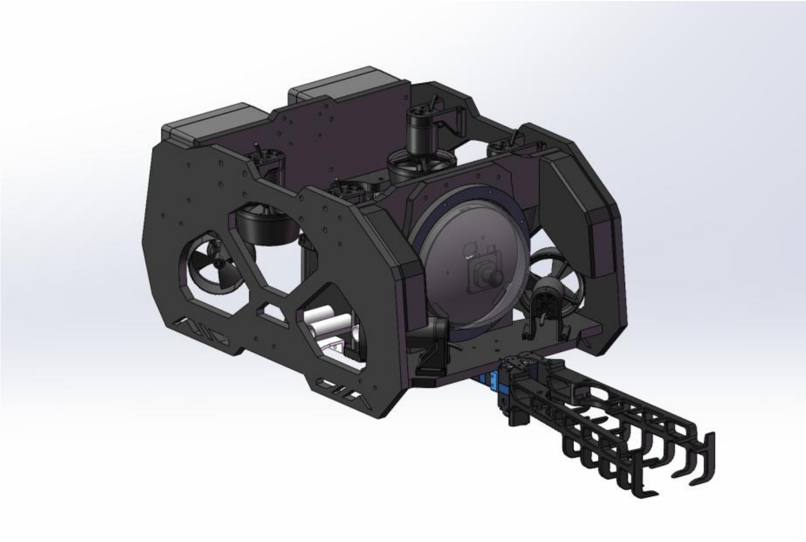
2.3.4 Ground/Support Equipment

1. Robot Placement Platform：
   While the robot powers on and automatically completes initialization, the mechanical claw twists to the middle position. If placed ROV directly on the ground during this process, the mechanical claw could become jammed, risking burnout of the servo motor.

2. "Crane"：

   we use hooks to retrieve ROVs or other equipment requiring salvage tasks from the water's edge to the shore, to prevent injury or accidents to staff.
3. Pulleys:
   Pulleys are used to retract or pay out the cable, preventing the robot from becoming tangled with the cable in water. The cable is enclosed in a zero-buoyancy waterproof sheath.

2.4 Final Design Drawing of AquaVoyager



Highlights:
The Strandline Alliance's "AquaVoyager" ROV impresses with modular design, featuring a versatile robotic arm and 45°-tilted thrusters (Solution 3) for optimal mobility. We refined PID control via ArduSub, cutting depth error to ±1.5%, and integrated an IP67 PH detector for precision monitoring. Our safety system meets MATE standards, with thruster guards and ultrasonic fish deterrence. This project showcases our STEM innovation and ecological focus, blending technical excellence with problem-solving prowess.

Build vs. Buy, New vs. Used:
Our team independently oversees the entire process of designing and crafting auxiliary props(subsystem, except of PH detector), with all items meticulously handcrafted by our members. The robot's structural panels are first modeled in SolidWorks by our team before being outsourced to a professional manufacturer for precision machining. This year, every prop and material has been innovatively developed from scratch, ensuring no reuse of designs or materials from previous years.

3. Safety

3.1 Safety Philosophy

As the ancient Roman philosopher Cicero once said: "Salus populi suprema lex esto." (The safety of the people is the highest law). The Strandline Alliance team takes this to heart, recognizing that safety extends far beyond just machinery. It encompasses the well-being of operators, the integrity of our surrounding natural environment, and every element in between. Our lab isn't just a clean, well-equipped workspace—it's a hub where safety training is ingrained in our team culture, sharpening everyone's awareness of potential hazards. This proactive approach minimizes risks of injury, safeguards our company assets, and ensures that every robot we design prioritizes both its own durability and the ecological balance of the environments it operates in.

3.2 Safety Standards

Our ROV (Remotely Operated Vehicle) adheres strictly to safety protocols set by the MATE Competition, integrating robust safeguards into both its mechanical and electrical systems:

Electrical Connections: *Anderson connectors are used to ensure secure, reliable electrical links.*

Pressure Management: *Pressure relief valves are installed to prevent over-pressurization, keeping internal systems within safe limits.*

Circuit Protection: *Fuses shield the electrical network from overloads.*

Mechanical Defenses: *A tension-resistant mechanism protects cables from excessive strain.*

These features don't just protect our team—they ensure the ROV can withstand the rigors of challenging aquatic environments with lasting reliability.

3.3 Safety Features

In line with MATE requirements:

Electrical Safeguards: *A properly sized fuse is placed 30cm from the Anderson Power-pole connectors, while an 80cm section of the tether near the interface is strain-relieved to prevent connector stress and maintain uninterrupted power flow.*

Thruster Protection: *Shrouds cover thruster intakes and exhausts to prevent obstructions without impeding water flow. Emergency kill switches are installed on the TCU's main power unit, and fuses on power terminals and boards offer quick overcurrent protection and easy replacement during debugging.*

Waterproof Design: *Electronic housings, thrusters, and cameras are fully waterproofed to eliminate short circuits. Warning labels adorn thrusters and electronics cases, while the camera compartment is physically sealed from the main electronics via O-rings. A clear acrylic cover allows visual checks for water droplets, ensuring early leak detection.*

Workplace Safety Measures:

Hazard Signage: *All risky equipment (like soldering irons) and components are marked with high-visibility warning labels.*

Smooth Construction: *No sharp edges are left exposed in the main frame or hardware components during manufacturing.*

Emergency Kits: *A kill box containing fuses and a stop switch sits ready to shut down the system in emergencies, with fire extinguishers always within reach.*

Regulatory Compliance: *Thruster guards with gaps smaller than 8mm (as required by MATE) ensure no fingers can be pulled in from any angle.*

Personal Gear: *Team members are equipped with protective glasses and gloves for all operations.*

Environmental Safety Around ROV Operations:

Fish Deterrence: *Ultrasonic modules are used to gently steer small fish away from the robot, preventing collisions or entry into open sections—all while minimizing ecological impact through their limited range.*

Illumination: *Strategically placed lights eliminate shadows, reducing the risk of collisions with underwater obstacles in low-visibility areas.*

3.4 Safety Procedures

Pre-Operation Checklist:

1.Verify the robot's casing is free of cracks or leaks.
2.Test the power system, including main switches and fuses.
3.Check propellers for smooth operation and ensure the ROV's buoyancy and stability.
4.Require closed-toe, non-slip shoes for all deck personnel.
5.Inspect canvas barriers for damage and seal leaks with waterproof tape if needed.
6.Regularly audit emergency kits (fire extinguishers, first-aid supplies) to ensure they're fully stocked and functional.
7.Clean sensors and cameras to maintain clear vision and accurate readings.

Operational Safety Protocol:

1.Ensure everyone wears appropriate PPE and compliant attire before starting.
2.If water is detected during pressure testing, cut power immediately via the main controller or kill switch.

3.Mandate rubber gloves for all team members handling equipment.
4.Secure the control box on a stable, level surface under dedicated supervision.
5.Brief all members on tether locations to avoid tangles or tripping hazards.
6.Use team lifts for heavy components to prevent overexertion.
7.Keep pressure chambers fully sealed at all times during underwater missions.
8.Use grounded, high-quality leak-proof pumps to avoid electrical risks.
9.Ensure all team members are trained in proper deck procedures.
10.Keep batteries and power sources dry and away from pool edges.
11.Always power down the ROV before any maintenance or handling.

3.5 Testing Methods

Our school has been highly supportive of our underwater robot project, providing us with a transparent pool in the robotics lab. And we also often go to the school’s swimming pool for testing.This setup allows us to observe the robot's condition from multiple angles, which is incredibly helpful. Robot testing primarily consists of two main components: timed task testing and robot motion endurance testing.

Timed Task Testing:
To better align with the competition's requirements, we conduct daily timed task completion tests for our operations team. Within a 15-minute window, we assess the team's execution capabilities and collaborative efficiency. Whenever issues arise, such as the robot's claw getting entangled in cables or the propeller getting stuck, we promptly address them.

Robot Motion Endurance Testing:
We subject the robot to a continuous 40-minute run in the pool, rigorously testing its ability to move forward, backward, side-to-side, as well as its yaw and roll capabilities. This comprehensive evaluation ensures that each motor is functioning properly. Additionally, we utilize the QGC open-source platform to automatically collect data on various aspects of the robot's performance, such as speed, angle, and depth stability, to guarantee its sustained functionality.

3.6 Troubleshooting

We initially employ tools like “5 Why technique” to conduct root cause analysis. For instance, when encountering inconsistent propeller performance, we traced the issue back to PID parameter adjustments and unstable power supply.

When diagnosing a communication delay between the motherboard chip and QGroundControl, we switched the communication method from UART to Ethernet, significantly reducing the latency.

All procedures and outcomes are meticulously documented in shared files for future reference. This practice ensures that we can swiftly resolve issues and minimize downtime, thereby enhancing our overall efficiency.

4. Finance

4.1 Budget

We have prepared a budget of $10,000. The main source of the budget is school sponsorship, and the secondary sources are personal advances and financial support from parents.

4.2 Cost

Category	Items	Amount	Unit Price (USD)	Type	Total Price(USD)
Hardware and circuitry	PCB Board Printing(include MCU)	8	$27.69	purchase	$221.52
	Switch	2	$0.70	purchase	$1.40
	9Vto12V DC-DC Module	5	$1.47	purchase	$7.35
	Wire	10	$4.12	reused	$41.20
	U Type Terminal Wires	20	$1.68	purchase	$33.60
	XH6 Terminal Wires	30	$1.54	purchase	$46.20
	Dupont Terminal Wires	30	$0.84	purchase	$25.20
	Flight Control Board	10	$56.00	purchase	$560.00
	Power Carrier Module	2	$87.51	purchase	$175.02
	Stress Relief Components	2	$4.90	reused	$9.80
	Servo	8	$22.40	purchase	$179.20
	Microwater pump	10	$2.66	reused	$26.60
	Vertical Profiling Float Battery	2	$0.17	purchase	$0.34
	Vertical Profiling Float Battery Box	2	$0.84	purchase	$1.68
	Underwater Lighting	4	$76.16	reused	$304.64
Mechanical and assembly	RCV Frame 3D Printing	10	$94.72	purchase	$947.20
	Ground Station Box	2	$18.25	reused	$36.50
	Counterweight Block	10	$4.13	purchase	$41.30
	Vertical Profiling 3D Printing	5	$21.01	purchase	$105.05
	Cehai Thruster	10	$110.00	purchase	$1,100.00
	MOI-P75-170ESC Thrusters	6	$93.66	reused	$561.96
	Power Steering Servo	5	$77.00	purchase	$385.00
	Power Tether Cable	20	$2.93	purchase	$58.60
	Signal Tether Cable	20	$12.64	purchase	$252.80
	Cable Connection(or Power)	10	$3.58	purchase	$35.80
	Cable Connection(or Signal)	10	$3.58	purchase	$35.80
	M10 Nylon Bolt	10	$0.50	purchase	$5.00
	Waterproof glue	2	$20.16	reused	$40.32
software and testing	Servo screws	2	$3.22	purchase	$6.44
	Waterpool	2	$600.00	purchase	$1,200.00
	Ladder	1	$42.00	reused	$42.00
	Props	30	$2.80	purchase	$84.00
	Software Fees	1	$4.20	purchase	$4.20
Team development and traveling	Team Building	1	$300.00	purchase	$300.00
	Accommodation	10	$56.00	purchase	$560.00
	Transportation	5	$182.00	purchase	$910.00
	Competition Fees	1	$1,540.00	purchase	$1,540.00
Total Cost					$9,885.54

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Special acknowledgment

Special thanks to Tian Ziyu for full guidance and company, Beijing No. 35 High School for fund support. Gratitude to Wang Lingna, LiuRuichang, Cindy, Xie Lingbo, Wei nan, Gao qiang, Song xiaojun and Li xiaohui for their support and encouragement. Thanks to Du chunyan, Zhang Boya and CeHai Tech for technical support, Yin Wenchang for artistic support, and Guo Yuening for website technical support! Sincerely grateful for all the help in making the project a success!