May 21, 2025

Technical Report

25 Mate-Ranger
RongZhen KaiWu / Suzhou Street

Summary:

Rongzhen Kaiwu is an eco-conscious and minimalist-oriented startup specializing in remotely operated vehicles (ROVs). It has developed **OctaXplore**, an innovative and highly scalable underwater robot framework. Committed to continuous growth and global expansion, the company strives to strengthen its presence on the world stage and contribute to global marine conservation efforts.

Second row (l-r): Zibin Lin, Kangning Shi, Siyuan Yu, Yutong Wu, Nuo Cheng, Junming Zhang, Moyang Liu

Front row (l-r): Yuanjie Li, Jiaqi Zhang, Jinwen Li, Liyan Huang, (Mentor) Yueming Fu

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1 ABSTRACT

Rongzhen KaiWu (Rongzhen KaiWu) is an innovative team specializing in underwater robotics under the umbrella of Beijing Bayi High School in China, which is dedicated to protecting the marine ecology through the power of science and technology. The team's newly developed "OctaXplore" underwater robot (ROV) utilizes an innovative octagonal design and an environmentally friendly and economical PVC pipe for the main frame, ensuring structural stability while considering the concepts of cost-effectiveness and sustainability. Inspired by the characteristics of sea turtles, the robot is lightweight (<15kg) and perfectly suited for a wide range of underwater environments thanks to 3D modeling and printing.

Equipped with high-precision motors, grippers, and an underwater camera, the OctaXplore is capable of performing a wide range of tasks such as shipwreck mapping, buoy sensor replacement, invasive species detection, etc., and it's especially suited for operations in complex water environments, such as the Great Lakes region and offshore wind farms. It is especially suitable for operation in the Great Lakes and offshore wind farms and other complex water environments.

The research and development team adheres to the principle of environmental protection, adopting recyclable materials for the whole system, realizing zero emission through electric power drive, and minimizing the disturbance to marine ecology through non-invasive sampling technology. In terms of safety performance, the team has established a perfect safety guarantee system, with JSEA (Job Safety Environment Analysis) led by the safety officer throughout the entire research and development process, and all thrusters are equipped with all-around protective covers molded into the propellers to ensure safe and reliable operation of the equipment.

As a science and technology enterprise focusing on sustainable development, Rongzhen Kaiwu also actively fulfills its social responsibility through campus science popularization, water quality monitoring of the company's surrounding environment, etc., and is committed to promoting the innovation and development of marine environmental protection technology. OctaXplore underwater robot shows the company's strength of research and development in the field of environmental protection technology, and will continue to contribute to global water environmental protection with innovative solutions.

2 PROJECT MANAGEMENT

2.1 COMPANY STRUCTURE

FIGURE 1: GROUP PHOTO OF TEAM MEMBERS

Rongzhen Kaiwu is a high school student-run technology and innovation company dedicated to promoting sustainable ocean development. In 2024-2025, the company's core team expanded from 3 to 11 people. Each team member is highly self-driven and has a genuine passion for engineering innovation, underwater exploration, and environmental protection. The company employs a job assignment system based on individual expertise and interest to ensure that each member can maximize his or her value in the area where he or she is best suited. In day-to-day operations, the company has established an efficient and collaborative process: before each meeting, all members focus on the day's priorities and then work on their assigned tasks. The company's mentor team provides the necessary technical support to help solve technical problems in ROV development and operation, and facilitates internal communication and coordination. The company always adheres to the concept of "Safety First" and makes the creation of a safe, collaborative, and positive team environment the primary goal. Through the establishment of comprehensive safety standards, we ensure that every member can focus on innovation in a safe environment. This team culture not only enhances work efficiency but also cultivates our ability to solve complex problems collaboratively, laying a solid foundation for the company's sustainable development.

2.2 COMPANY ORGANIZATION

Rong Zhen Kai Wu Company has established a scientific and perfect division of labor system, each member is assigned the most suitable duties based on his/her professional ability and personal characteristics. Chief Executive Officer Jiaqi Zhang coordinates the company's overall strategic planning and project progress management to ensure the synergy of all departments; Technical Director Junming Zhang is responsible for all aspects of technical research and development, providing professional guidance for product innovation. Siyuan Yu, a creative thinker with independent and novel ideas for product promotion, leads Moyang Liu ASM to make our products more visible to consumers. As CFO, Jinwen Li, who has a rigorous mindset and strong computational skills, strictly controls the purchasing budget and costs. Technical backbones Kangning Shi, Zibin Lin, and Yuanjie Li focus on frame structure stabilization, control system programming, and circuit integration development, respectively, and drive core technology breakthroughs with their solid professional abilities. Nuo Cheng, safety supervisor, establishes a perfect safety management system to ensure that all $R\&D$ operations are in line with safety norms, and Junming Zhang, a 3D modeling expert, uses a variety of professional software to provide accurate structural design solutions for the products. Yutong Wu, our CPO, contributed his unique insights and professional solutions to many aspects of the product. This scientific division of labor system based on the characteristics of the members not only gives full play to the professional advantages of each person, but also forms an efficient collaboration mechanism, which provides a solid guarantee for the sustainable development of the company.

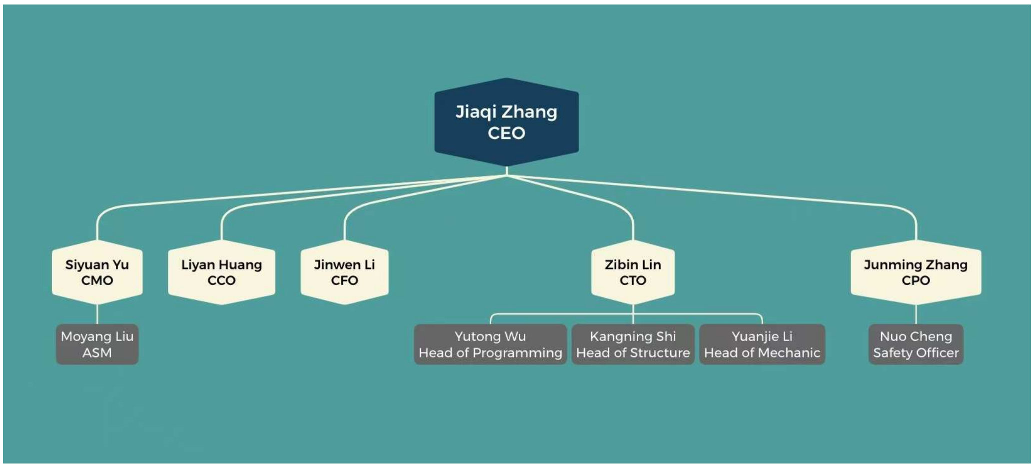


FIGURE 2: COMPANY STRUCTURE

This approach, which is precisely based on the members' specialty, not only makes everyone a full use of their own professional advantages, but also can make an efficient collaboration system. The above system delivers the guarantee for the everlasting development of the company.

2.3 PROJECT MANAGEMENT AND CHALLENGES

Rongzhen Kaiwu Company is known for its excellent project management ability, which is fully reflected in the well-designed project plan Gantt chart (as shown in Figure 3). Born out of a brainstorming session in October 2024, the team's time-planning blueprint has not only kept track of the project's overall schedule but has also helped the team to excel in regional events, while leaving valuable room for testing and optimization. The plan clearly outlines the time nodes and workflow of each step from pre-preparation, ROV manufacturing, to marketing display and engineering presentation, and its scientific nature has been verified in practice. The team strictly enforces this schedule and tracks progress in real time through a system of regular daily meetings. These meetings not only serve as a regular review of the progress of each member's responsible module but also provide a flexible mechanism for time adjustment when necessary. It is this rigorous but flexible time management system that enables the company to comfortably cope with the various challenges encountered in the course of the project (details will be discussed in the following section).

Rongzhen Kaiwu Technology Company faces two core challenges in the operation process: firstly, the team members are also facing heavy pressure from school work while undertaking research and development tasks, which requires each member to make full use of all the time after school to ensure the project progress with extraordinary work intensity; secondly, as a young team, the members have obvious deficiencies in technical accumulation and project experience, even if they have formulated detailed Secondly, as a young team, the members had obvious deficiencies in technical accumulation and project experience, so even though they had formulated a detailed work plan, the actual implementation still faced many difficulties. However, by strictly executing the time management plan, the team not only successfully overcame these challenges but also completed the development of the company's first product, "OctaXplore", within the scheduled time. This achievement fully demonstrated the professionalism and hardworking spirit of the team members and laid a solid foundation for the company's subsequent development.

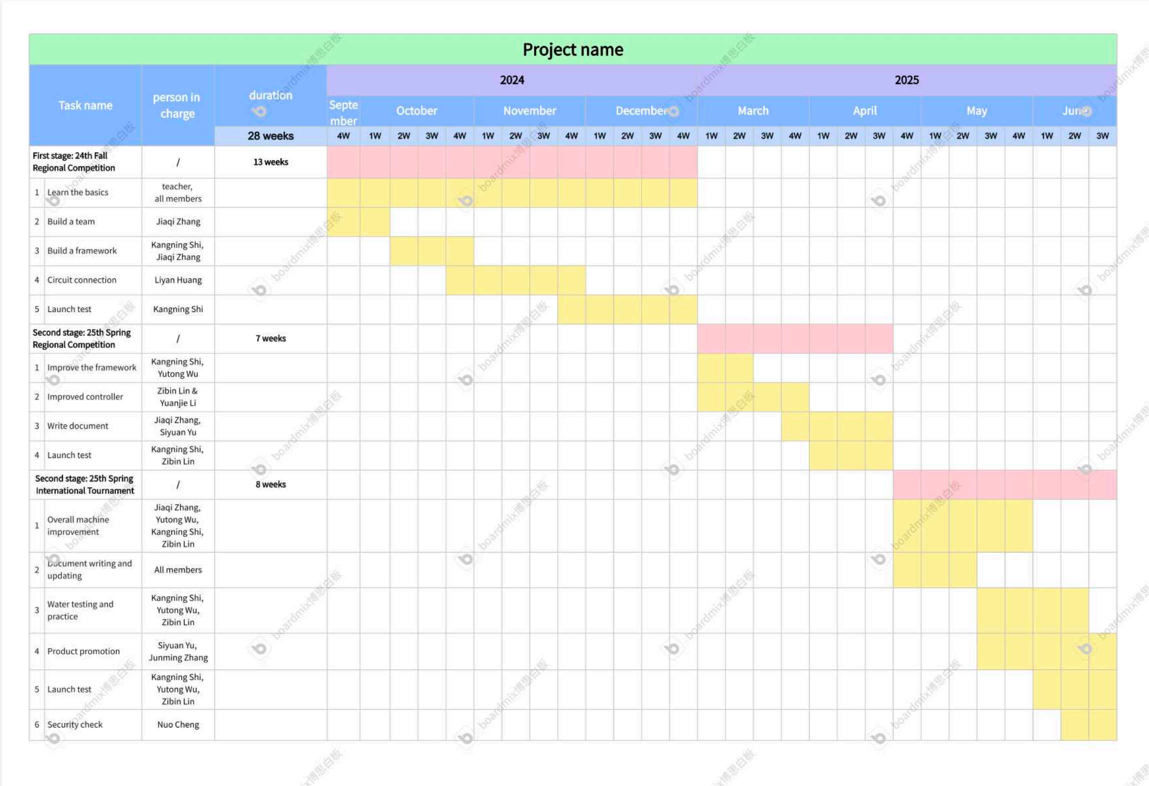


FIGURE 3: PROJECT MANAGMENT

Two key issues are confronted by the Rongzhen Kaiwu Technology Company at the stage of operational: primarily, the team members are under extremely heavy load from their school duties while conducting renovation research, so everyone should work harder and become more efficient to make proper progress; secondly, being a youthful team, each individual member distinctly lacked deep technical expertise and time devoted to similar projects as ET required, nevertheless he formulated an approximated work plan but was not confident whether an actual implementation faced any difficulties. In the same way, the group was still lacking the essential know-how and project experience, although the work plan was laid out in detail, the actual implementation was very much painful due to severe flaws. On the other hand, through the strict implementation of the time construction plan, the team surprisingly not only handled these difficulties but also finished the development of the company's first in-house product "OctaXplore" within the prescheduled dates. This success strongly denoted the professionalism and dedication of the team contributing to a wholesome and encouraging setup for further organizational development.

Throughout the process, we work in strict accordance with the EDP engineering process to ensure that the ROV is engineered properly.

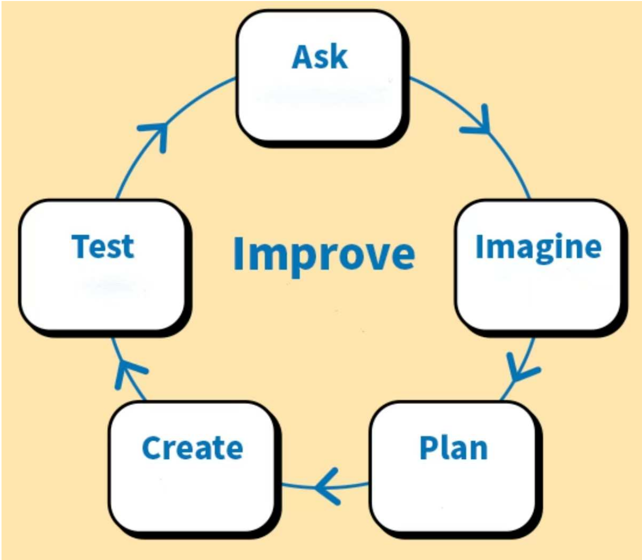


FIGURE 4: EDP ENGINEERING PROCESS

The process begins with ”Ask,” where questions are posed to identify needs or problems. Next, ”Test” involves experimenting with potential solutions to gather data and insights. The ”Improve” stage focuses on refining ideas based on test results to enhance effectiveness. ”Imagine” encourages creative thinking to explore new possibilities and innovative approaches. ”Create” is the phase where tangible solutions or prototypes are developed. Finally, ”Plan” involves strategizing the implementation and next steps to bring the idea to fruition. This cyclical process emphasizes continuous iteration and development.

3 STRUCTURAL DESIGN

FIGURE 5: OCTAXPLORE DEVELOPMENT HISTORY

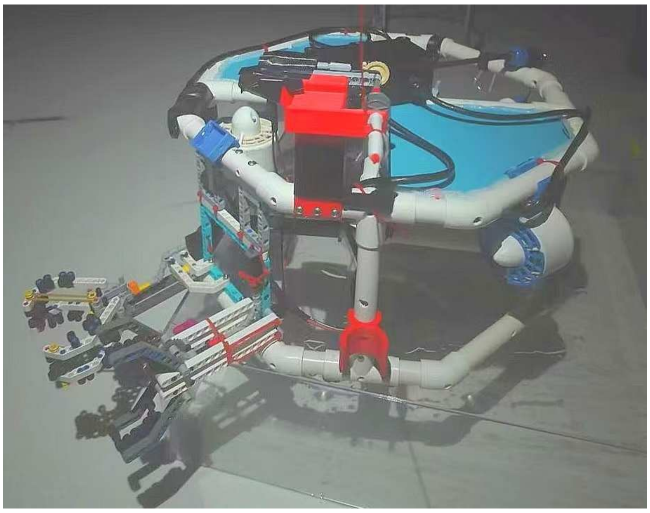


FIGURE 6: OCTAXPLORE SECOND GENERATION

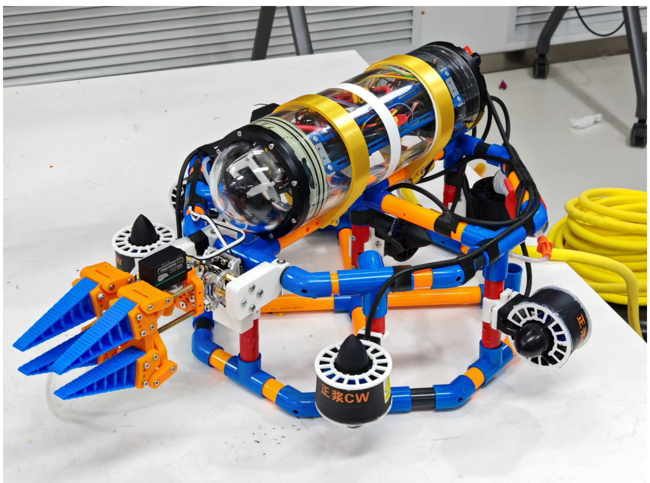


FIGURE 7: OCTAXPLORE FINAL VERSION

OctaXplore is a state-of-the-art subsea robot, created by settling for basic raw materials and combining maneuverability, modularity, stability, and durability into a product that is defined by simplicity and efficiency. Its high-efficiency multi-functional integrated system not only ensures the implementation of missions with high-quality performance, but also follows the proposal's technical requirements, as well as carrying the values of environmental protection and sustainable development.

During the research and development process, the group fully exploited tools available, such as 3D printing, PVC pipe wrench, soldering gun, and so on. On this basis, they also adopted professional design software, such as Tinkercad, Onshape, Canva, and Arduino IDE platforms, for structural modeling, functional development, and system optimization.

The hardware and software convergence provides product accuracy and increases development efficiency. The engineering and design components forming the foundation of OctaXplore are done in-house, and the following paragraphs will discuss its core technologies.

3.1 DESIGN EVOLUTION

The following diagram illustrates the transformation of underwater robots from primitive prototypes to state-of-the-art platforms, viable for various operational tasks. This reflects both the evolution of underwater robotics and the ascending degrees of complexity, capability and autonomy of the robotic platforms.

The leftmost design represents the early prototype phase, where the overall body plan is a closed oval shape, resembling a sea turtle, with a simple structure and only basic sensing equipment installed. The primary goal in conceiving this design is to achieve the most basic performance of subaquatic mobility and status observation and, at the same time, to have a perfect sealability so as to be able to stand up to the unfavorable high-pressure environment underwater. However, this design does have some flaws, like not having enough flexibility and growth potential.

We used suggestions from the environment and simplicity as the design optimization goals. This is evident by the progressive evolution in the shape and structure of the underwater robot from a closed shell all the way to an open polygonal frame structure with the use of color differentiation for the supporting rods and the introduction of cross rods for added stability. The holistic design not only boosts the structural strength but also makes more room for extra modules, rendering the robotics platform more adaptive and expandable. At this juncture, the robot is also ready to be equipped with any kind of sensors and actuators - this also means that we are gearing up for later integration of all functions.

As a result, the underwater robot successfully finished its first sim2real transition, the adaptation of the WS-1 underwater robot should now be complete, and it has transformed into a truly versatile working platform. Here, the arm, sensors, cameras, and motors are neatly integrated with the crawler body, reflecting the robot's ability to operate with multiple tools in complex underwater environments. This does not only augment their mobility but also enhance their level of autonomy and mission adaptability.

The final underwater robot form was chosen after multiple in-water trials and evaluations of task accomplishment efficacy.

Ultimately, the convergence of these trends points to the future of underwater robotics, where commodiousness gives way to performance-intended purpose.

3.2 INNOVATION POINT

The structure, function, and intelligence level of the final design version of our underwater robot are all impressive. It can not only perform a multitude of intricate underwater assignments, but also be adaptable and flexible in many situations. The overall design is a reflection of the ideas to achieve modularity and high integration, which will consequently lead to the multifunctional system that commands the operators' and industry players' attention and respect.

- The reduced structure, including modularity, allows for maintenance and expansion. It has an open structure, and the components can be plugged and moved in rapid time for maintenance and function upgrade.
- Robust task efficiency aims to feature multifunctional simultaneous operations. The carrying condition of several robotic arms permits the completion of such tasks as gripping, checking, operating, etc., at higher efficiency levels.
- The lightweight structure and permeable frame design are used to decrease resistance to water flow and enhance movement ability at the same time.
- Adaptability quickly adjusts or equips the machinery for any tasks needed, scientifically for research, maintenance, and rescue, and works in any underwater environment.
- Stable system, being characterized by its mechanical structure and the capability of controlling system, increases the reliability of the equipment in dynamic water environment.

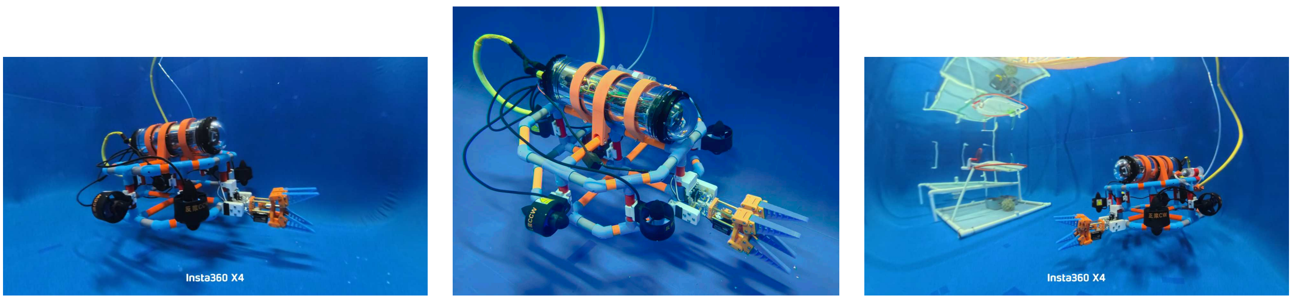


FIGURE 8: SHOW TIME

4 ROV SYSTEM COMPONENTS

4.1 STRUCTURAL SYSTEM

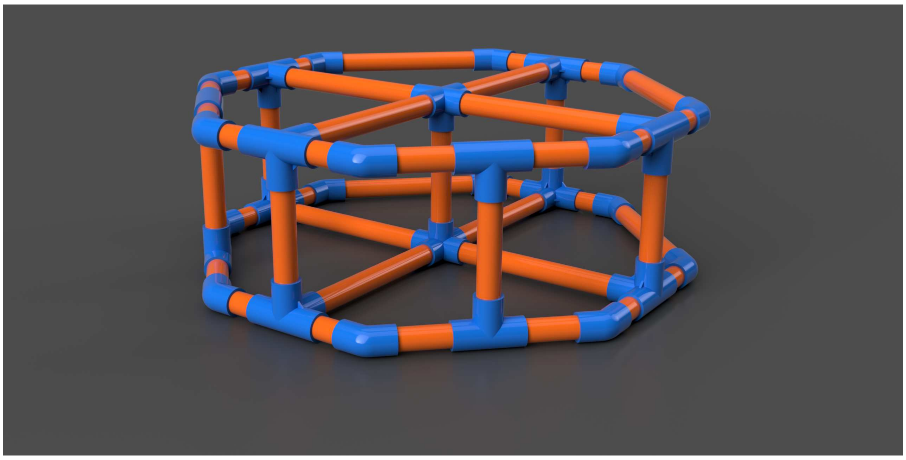


FIGURE 9: FRAME WORK

The frame of the robot is made of 2mm thick rigid PVC water pipes, with a regular octagonal shape, ensuring stable structure and light weight. The main frame of the OctaXplore underwater robot is composed of PVC pipes with a diameter of 20 millimeters, forming an octahedral shape. This is a new geometric design that maintains structural strength while significantly reducing water resistance, thereby improving stability in underwater environments. The octagonal geometric shape keeps fluid dynamics within laminar flow range, avoiding turbulence and maintaining good maneuverability even in complex underwater flows. The main connectors are fixed with universal PVC connectors. In addition, special waterproof sealing treatment has been carried out on key joints to avoid water ingress during long-term use. In order to achieve accurate installation of basic components, we used PVC connectors to tightly bond the pipes and adapters together.

OctaXplore adopts an advanced modular structural design concept, and our framework uses PVC pipes of the same size for installing various sensors, thrusters, robotic arms, and other functional modules for quick assembly and disassembly. This design not only facilitates rapid maintenance of such devices, but also opens up channels for unlimited future applications. In terms of waterproof and compressive performance, the prototype has passed three levels of testing: static sealing test at five meters deep water, 24-hour test, and five meter water pressure test, as well as impact test under extreme conditions, which can be called waterproof. The adjustable counterweight system integrated at the bottom of the framework can achieve neutral buoyancy adjustment with a precision of ± 10 grams, and the intuitive digital display can accurately show the balance point of the camera, thereby minimizing guessing work when balancing the gimbal. On the other hand, the intelligent pitch attitude stabilization function integrated into the system maximizes the camera's set angle, thereby increasing the possibility of achieving ideal shooting results.

In the test, OctaXplore withstood a flow rate of 5 knots and remained stable at a moving speed of 2 meters per second. OctaXplore's modular design allows functional modules and products to be implemented in different projects. Its modular design is a prominent feature, which can complete the replacement of functional modules within 5 minutes or even shorter, which helps to improve operational efficiency. This innovative form of structure not only meets the requirements of the competition, but also provides a technological foundation for the construction of future products.

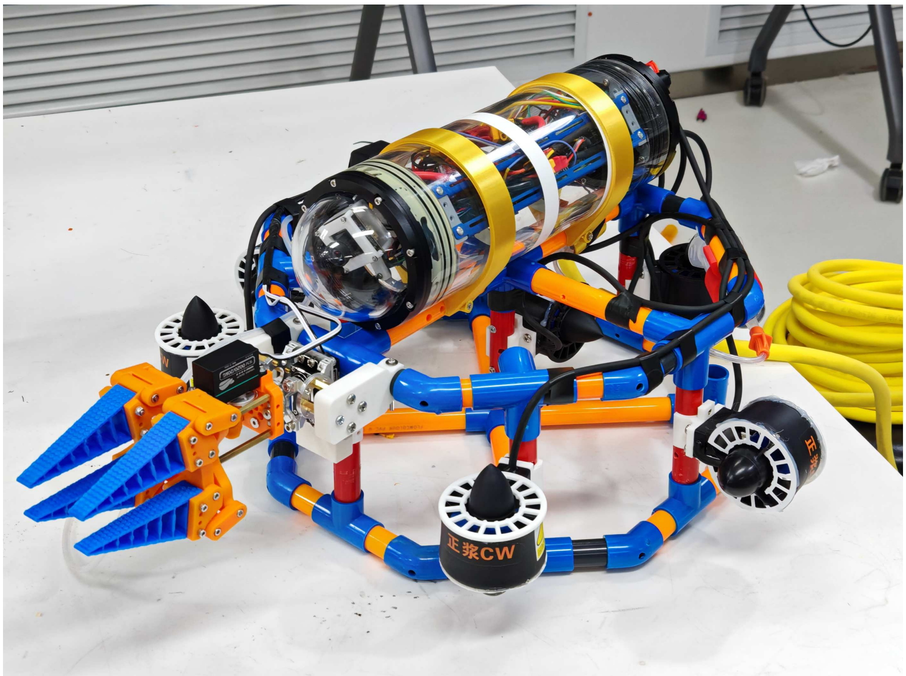


FIGURE 10: STRUCTURE IN REAL WORLD

In terms of waterproofing and pressure resistance properties, the prototype has gone through the three levels of tests: a static seal test under three meters deep water, a 24-hour test with three meters pressure, and an impact test under extreme conditions and can say it's waterproof. The adjustable counterweight system integrated in the bottom of the frame can achieve ±10g precision neutral buoyancy adjustment, and the intuitive digital display shows the precise balance point of the camera, which in turn minimizes the guess work during balancing the gimbal. On the other hand, the intelligent pitch attitude stabilization function, which is integrated in the system, maximizes the camera setup angles, hence increases the potential for a desired shot. The OctaXplore withstood water flow of 5 knots in testing and turned out to be stable at a moving speed of 2 m/s. The modular design of the OctaXplore permits functional modules and products to be implemented in different projects. Its modular design is an outstanding feature that allows the exchange of functional module in less than 5 minutes, if not less. This helps in increasing the efficiency rate of operation. The innovative form of this structure, besides being in line with the competition's demands, also provides a technical base for the future construction of the product.

4.2 PROPULSION SYSTEM

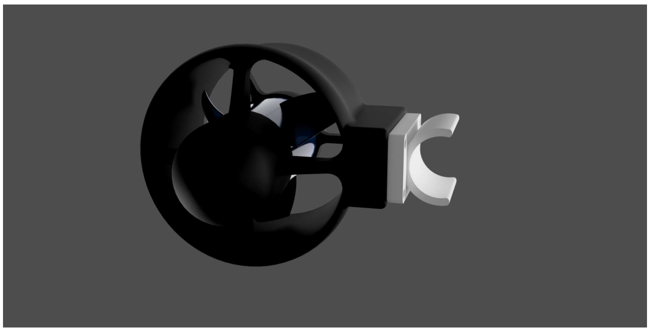


FIGURE 11: MOTOR STRUCTURE

FIGURE 12: MOTOR IN REAL WORLD

Figures 11 and 12 show the design of the thruster components as part of the propulsion system. The diagram illustrates that the external part of the thruster has a protective mesh cover, which can effectively block debris that may enter the motor, thereby improving the safety and durability of the motor. The motor body is designed as a closed structure, and the brushed motor has waterproof function, which is considered suitable for underwater environments. The propeller casing adopts a streamlined design to reduce the resistance generated by water flow during operation and improve propulsion efficiency. The entire component is compact, sturdy, runs stably, and has low maintenance costs. Figures 13 and 14 depict the overall configuration of the entire propulsion system. The robot is equipped with a total of 6 brushless waterproof motors, which are located in separate culverts. Its similar structure and configuration enable the propulsion system to achieve perfect balance and be easy to operate during operation. In addition to the three vertical thrusters used to move up and down in the water, which ensure the robot can move flexibly in different water depths, the other three horizontal thrusters are used for forward, backward, steering, and translation operations, allowing the robot to navigate freely in the water. The structure of the propulsion system provides the possibility of multi-directional thrust output, meeting the needs of underwater navigation, rotation around a point, and positioning

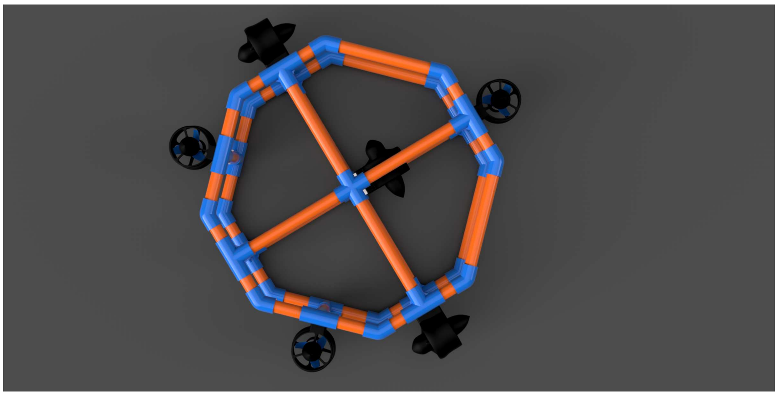


FIGURE 13: MOTOR DISTRIBUTION

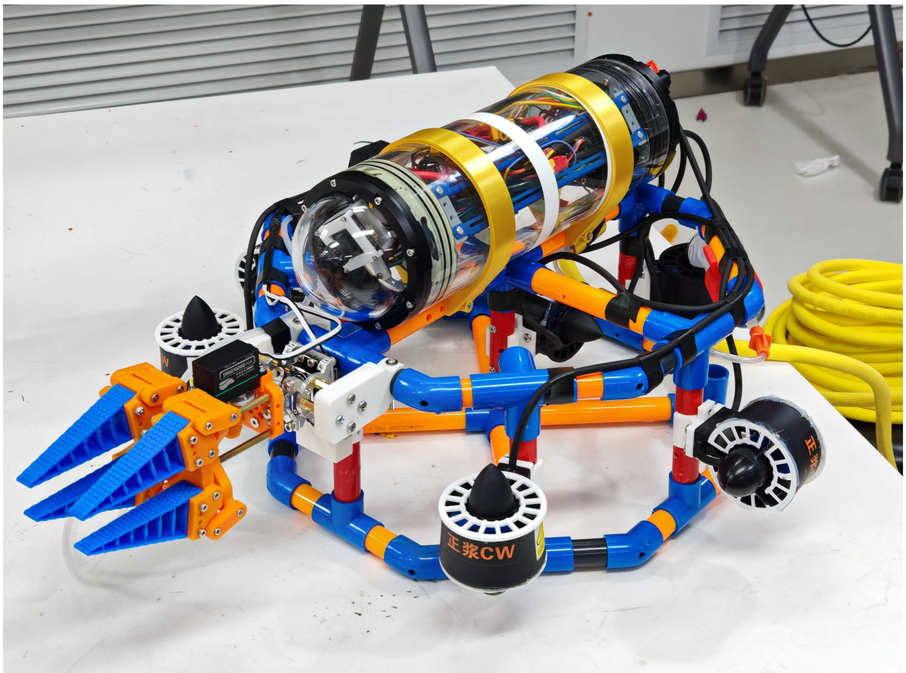


FIGURE 14: ROV IN REAL WORLD

4.3 BUOYANCY

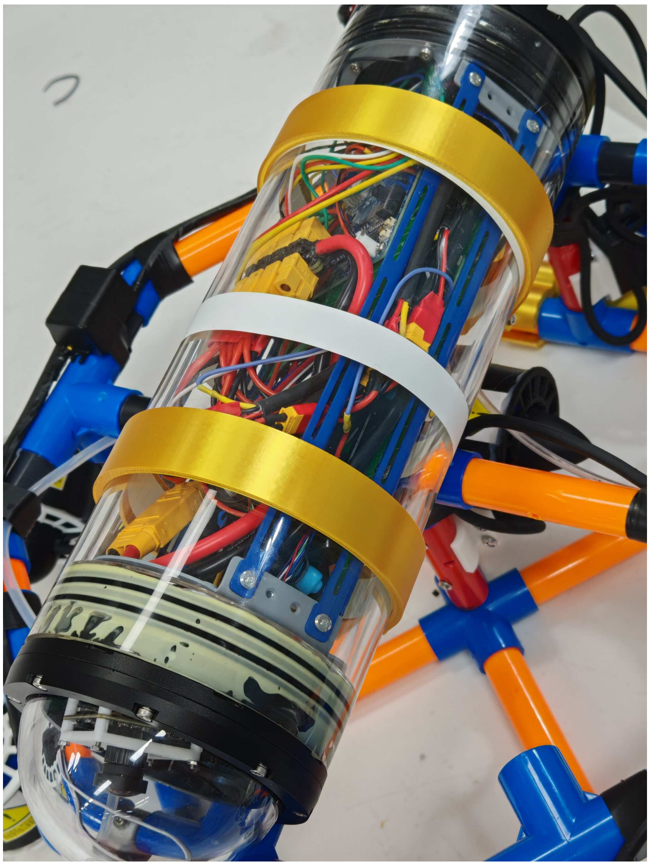


FIGURE 15: BUOYANCY

We also used an acrylic sealed cabin to seal our flight control device. Through repeated underwater tests, we ensured that the flight control device would not leak water under a water pressure of five meters. We also used modular expansion interfaces, reserved standardized electrical interfaces (such as ISO 1175 waterproof plugs), and supported the loading of side scan sonar, robotic arms, and other loads, meeting the multi task requirements of underwater inspection, scientific observation, and more. We will also evacuate the acrylic sealing tube to create a pressure difference between the external water pressure and the internal vacuum, so that the entire machine can sink better. Reduce its buoyancy.

4.4 CONTROL SYSTEM

The underwater robot control system consists of a shore control unit, an underwater actuator unit, a communication and transmission unit and auxiliary function modules. The onshore control unit is responsible for receiving the operator's commands and converting them into control signals, the underwater actuator unit drives the robot to complete the corresponding actions according to the received commands, and the communication and transmission unit ensures the stable transmission of data between onshore and underwater. In addition, the system also integrates depth monitoring, robotic arm control, video observation and other auxiliary functions, constituting a complete set of underwater operation solutions.

4.4.1 FLIGHT CONTROL SUBSYSTEM

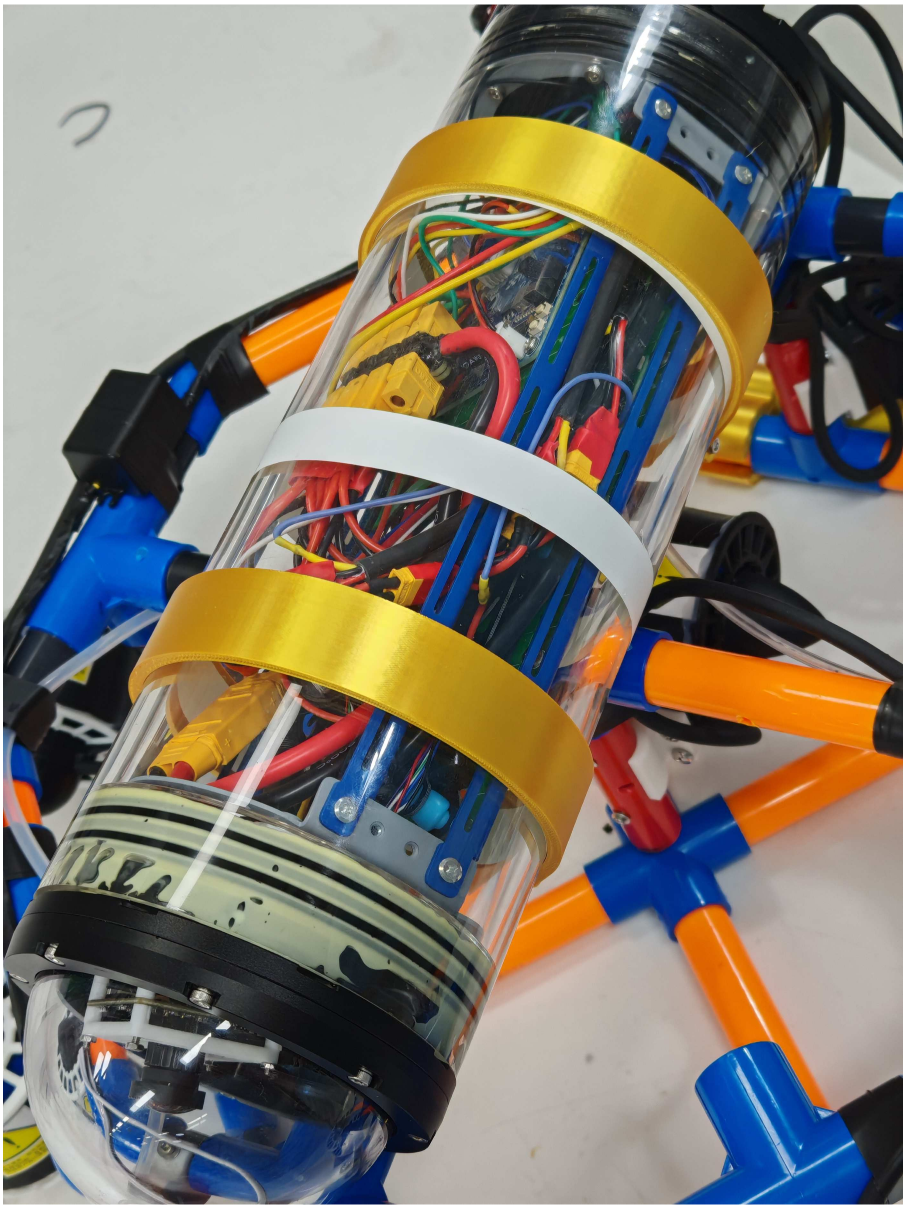


FIGURE 16: FLIGHT CONTROL

Power Supply and Protection:The electric power source supplies 12V power, with a fuse inserted into the circuit. This fuse serves as a protective measure, safeguarding the system from over - current situations and potential electrical damage. STM32F103RCT6 - Based Sub - System:The STM32F103RCT6 board acts as a key control unit. It receives 12V power from the source and manages connected components: A 12V peristaltic pump, which can be utilized for fluid transfer tasks (such as sampling or fluid - related propulsion management). 5V servos that drive the gripper. These servos enable precise control over the gripper's motion, facilitating tasks like object grasping or manipulation. PIX Flight Control Sub - System: The PIX flight control board is central to motion and sensor management: It controls multiple motors, enabling coordinated movements (such as forward/backward movement and steering). It connects to a depth sensor, providing real - time depth information, which is vital for underwater operations (like maintaining a specific depth during sampling or inspection). Human - Machine Interaction and Communication: Computer and Software: Functions as the operator's interface, running software that processes inputs from: A joystick, allowing intuitive control over the system's movements and actions. A camera, providing visual feedback for tasks requiring visual guidance (such as precisely targeting an object with the gripper). Serial Ethernet Transmission Module: Facilitates data transfer between components, ensuring smooth communication (such as sending control commands from the computer to the PIX board or receiving sensor data). Switch (Telecommunications): Supports network - based communication, enabling multi - device integration and potentially remote operation or data logging. Functional Integration: The system integrates power, control, sensing, and communication modules. Motors enable mobility, the gripper (driven by servos) allows for manipulation tasks, the depth sensor aids in underwater navigation, and the camera - joystick - computer interface ensures precise operator control. This integration makes it suitable for applications like underwater exploration, sampling, or inspection, where coordinated movement, manipulation, and real - time feedback are essential.

FIGURE 17: CONTROL BOX

4.4.2 SENSORS AND DATA ACQUISITION

The underwater robot is equipped with a high-precision depth sensor for real-time monitoring of the current water depth, and the data is sampled and stored at fixed intervals (e.g. 200ms). When the robot surfaces, the system automatically packages and uploads the stored depth data for subsequent analysis. In addition, the system can be extended to integrate temperature, water quality (such as pH, turbidity) and other sensors to meet different scientific research or industrial testing needs. All sensor data are transmitted to the main control chip via 485 bus to ensure real-time and accurate data.

FIGURE 18: DEPTH SENSOR

4.4.3 APPLICATION SCENARIOS AND EXPANDABILITY

The system is suitable for various scenarios such as underwater exploration, equipment overhaul, environmental monitoring, scientific investigation and so on. The modular design makes it has good expandability, users can add more sensors or actuators according to the demand, such as side-scan sonar, mechanical claw fixture and so on. In the future, wireless communication module (e.g. hydroacoustic communication or RF link) can be added to realize wireless control in some scenarios, further enhancing the flexibility of the system.

4.5 ENERGY SYSTEM & COMMUNICATION SYSTEM

The system adopts RS-485 bus as the main communication mode, which has the advantages of strong anti-interference ability and long transmission distance, and is suitable for underwater long-distance signal transmission. The main cable contains six wires, two of which are used for power supply and four for 485 communication. The video signal is transmitted through an independent coaxial cable to ensure that the high-definition images captured by the camera can be transmitted back to the shore display in real time. The control signals of the robotic arm are transmitted through eight-core network cables, using differential signals to reduce noise interference. All cables are waterproof, tensile resistant and equipped with reinforced connectors to ensure stable operation in complex underwater environments.

FIGURE 19: ANDERSON POWER PLUG CONNECTOR

5 LOADS AND TOOLS

5.1 VIDEO SYSTEM

Our ROV is equipped with GeoVision Industrial L10.1-inch HD display, which supports HDMI input and MP5 video playback function to ensure clear and stable picture during underwater operation. The video signal is transmitted through a special cable to ensure the reliability of real-time monitoring, while facilitating video playback and analysis. The compact structure of the whole machine, strong adaptability, with perfect after-sales protection, for underwater detection to provide stable and efficient visual support.

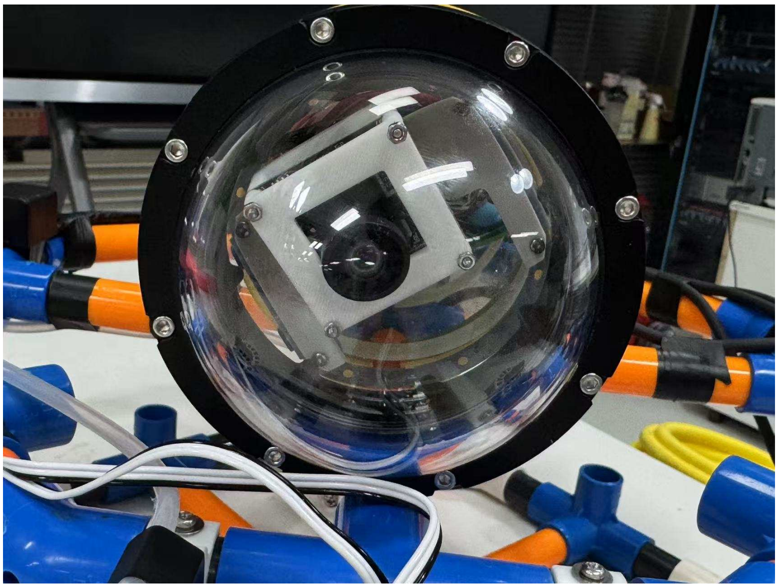


FIGURE 20: PANORAMIC CAMERA

In addition to this, we have placed a panoramic camera on the top of the ROV to facilitate the collection of all kinds of information underwater, and wirelessly transmit the underwater situation back to the surface in a clear way.

5.2 DELIVERY SYSTEM

The OctaXplore gripper employs a 3D-printed structure, characterized by its robust durability, rapid iteration capability, ease of modification, and exceptional flexibility. Through iterative optimization, the final design incorporates a servo-driven mechanism and structure, enhancing the gripper's flexibility and degrees of freedom, thereby enabling adaptability to a wide range of diverse environments and conditions.

In terms of grasping performance, a flexible silicone layer has been integrated onto the gripper's surface to augment frictional force, facilitating the secure handling of smooth and otherwise challenging-to-grasp objects. Additionally, the internal hollow design of the gripper allows for adaptive deformation under pressure, achieving a soft-grip effect that conforms more closely to the object's surface, ensuring a more stable and secure hold. The rubber material provides superior underwater friction, guaranteeing reliable grasping of objects of various shapes. These design features collectively endow our gripper system with a combination of reliability, adaptability, and high efficiency.

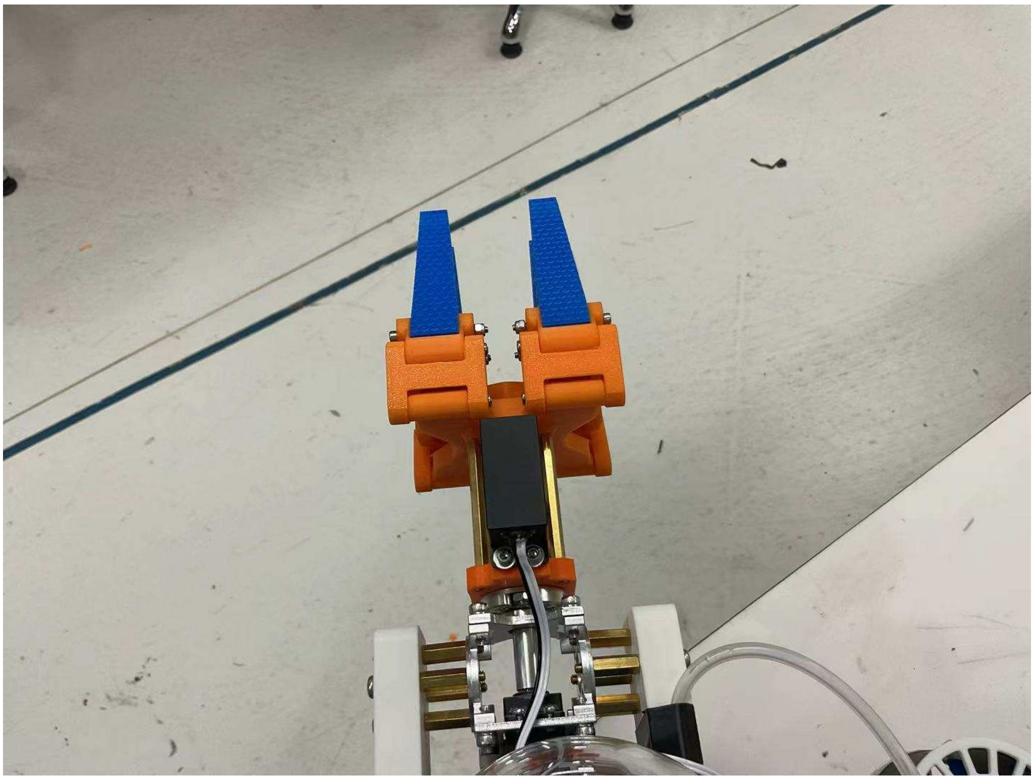


FIGURE 21: DELIVERY SYSTEM

6 OCTAXPLORE INSTRUCTIONS

6.1 INSTALLATION AND PREPARATION

6.1.1 CABLE CONNECTION AND FIXING

Before installing the underwater robot, please make sure that all electrical connections are correct and waterproofed: The cables for thrusters, power cables, signals cables, and the underwater waterproof junction box must have been installed properly before operation begins. The connections of all combinations must be waterproof, and the stuffing box should be water-resistant.

Junction Box Installation: Employ unique 3D printed clips to fix the impermeable junction box to the middle cross node of the PVC structural frame, so that the junction box is not easy to loosen during use, and the subsequent disassembly and repair is convenient.

Main cable connection: Direct lead the main cable from the waterproof junction box and link it to the control box on the shore. Verify that the voltage output of the power supply system is 12V DC (direct current) and take precautions not to use the wrong polarity.

6.1.2 PRELIMINARY CHECK OF THE SYSTEM

Initiate the control box on the shore, check if the monitor can receive the images with camera and they should be vivid and stable without delay.

Using the control handle (joystick), check one after another if all the propellers are responding well and if the flight is in the direction you have set.

If a situation like a control delay, unusual direction was detected, stop the usage right away and check the condition of the propeller cable connection and control signal line.

6.2 OPERATION GUIDE

6.2.1 STARTUP AND DEBUGGING

Before the official sinking into water, the equipment must be debugged in the following manner:

1) Activate the supply of the shore control box and monitor the process of system startup for each part.

2) See if the video signal is correct. The images should be clear and real-time.

3) A little bit of jamming must be avoided to ensure all systems operate well, and all propellers move fast in response with some jamming and abnormal noises.

6.2.2 BASIC CONTROL METHODS

The below-listed basic operation is performed on the control handle (rocker) of the shore:

1) Push the rocker forward - the underwater robot moves forward.

2) Pull the joystick backward - the underwater robot goes backward.

3) Push the joystick to the left - the robot turns left.

4) Push the joystick to the right - the robot turns right.

5) Push up the vertical control lever - the robot rises.

6) Pull down the vertical lever - the robot dives.

NOTE: Operations that are harsh and rugged should not be conducted, as this will result in hitches in machine operations and will in the long run shorten the life of the machine systems.

6.3 MAINTENANCE AND STORAGE

6.3.1 ROUTINE MAINTENANCE

For the purpose of guaranteeing a long-term uniform working function of the underwater robot, please conduct the following maintenance procedures after every usage to assure proper functioning.

1) With clean water, rinse off the exposed parts, especially the thrusters and camera area, in order to entirely remove impurities, sediment, and salt from the water.

2) Examine the frames of the whole cables, cable connections, stuffing boxes, snaps, and waterproof junction boxes to look for any deficiencies in this equipment.

3) If water ingress or corrosion is detected, discontinue usage immediately, and repair or replace parts as necessary.

6.3.2 STORAGE GUIDE

1) When finishing the operation, the power supply should be cut off, and all cables should be carefully disconnected.

2) Hence, all cables should be arranged properly by coiling them to avoid bending or over pulling, which can damage cables or wires.

3) Store the robot in a dry, ventilated, dust-free interior space to prevent deterioration of electronic parts by humidity and high temperature.

6.4 TROUBLESHOOTING

issue	possible cause	solution
Motor non-rotation	The power supply is faulty or the connection is loose	Check the power connection and ensure that the cable holes in the drilling equipment are correct and the voltage is normal.
No picture signal	Camera damage/connection issues	Check the sealing effect of the camera cable and stuffing box, and replace the device or adjust the installation position if necessary.
Unable to go up/down	Vertical propeller failure	Check the vertical propeller connection and the wiring in the waterproof junction box to ensure that the waterproof seal is in good condition.
Unable to go forward/backward/turn	Horizontal propeller anomaly	Check the connection status of the horizontal propeller, if there is damage, adjust and replace the parts according to the 3D printed buckle design.

6.5 THINGS TO NOTE

Here are some noteworthy points.

1. Prior to operation, ensure that all cables and waterproof junction boxes are adequately sealed to avoid moisture penetration, which may result from installation mistakes or errors.

2. Continuous running under high current or heavy load conditions is strictly prohibited as it may cause overheating of the motor or failure of the components, which are intended to be waterproof.

3. In cases where an anomaly (such as noise, bubbling, no response) is detected, the operation must be terminated immediately, and the drilling tools, clips, and stuffing box, etc., should be checked to see if any damages have occurred.

4. Avoid tampering with the control system or power wiring without prior approval. Should you wish to upgrade, please seek the necessary assistance from certified technicians.

7 DESIGN AND IMPLEMENTATION OF FLOAT

7.1 DESIGN SPECIFICATIONS

7.1.1 POWER SUPPLY SYSTEM

The buoyancy device is powered by AA-type dry batteries (1.5 V nominal voltage, $12\,000$ mA h typical capacity, and a maximum continuous discharge current of 2 A). The system employs a 3-parallel 4-series (3P4S) configuration of 12 batteries to achieve a 6 V supply, with an integrated fuse for circuit protection. To meet the motor system's voltage requirements, a DC-DC boost converter steps up the voltage from 6 V to 12 V, ensuring a stable output current of ≥ 2 A for reliable operation.

7.1.2 CONTROL SYSTEM

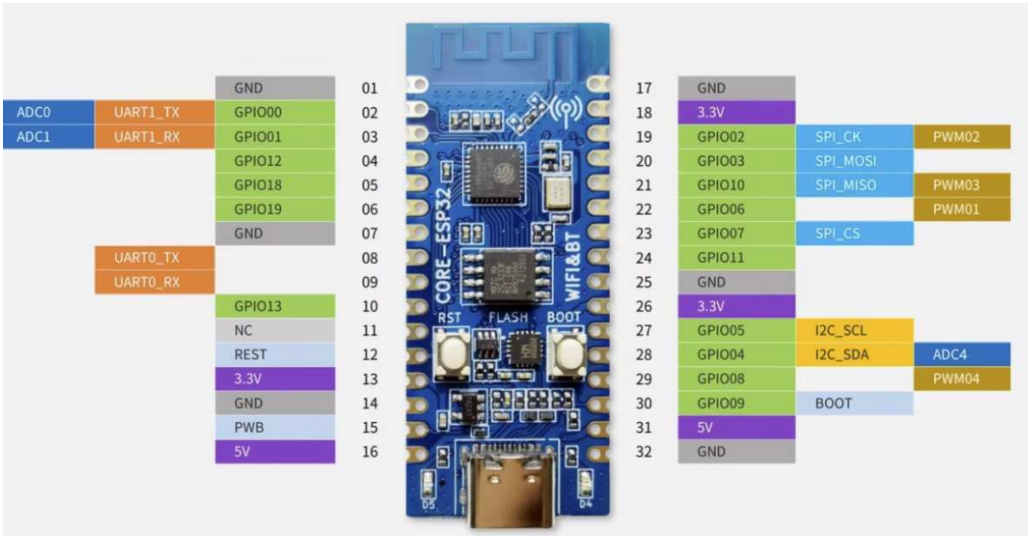


FIGURE 22: ESP32 MICROCONTROLLER

The ESP32 microcontroller serves as the core control unit, leveraging its low-power Wi-Fi/Bluetooth capabilities and versatile I/O resources for wireless communication and motor control. For motor actuation, the design currently utilizes the RZ7899 H-bridge driver IC, which supports 4.8 V to 28 V input and delivers up to 5 A continuous current. Direction, speed, and enable/disable functions are controlled via DIR, PWM, and ENABLE pins, respectively. Alternatively, the DRV8870 driver (with broader voltage/current tolerance) is under consideration for enhanced performance.

FIGURE 23: RZ7899 H-BRIDGE

7.1.3 BUOYANCY ADJUSTMENT SYSTEM

Buoyancy is dynamically regulated by a miniature brushed DC gearmotor that drives a syringe mechanism. By injecting or expelling water, the system adjusts internal ballast volume to enable controlled ascent and descent.

7.1.4 STRUCTURAL DESIGN

FIGURE 24: BUOYANCY CONTROL DEVICE

This is the gear motor used this time. It operates at 3 V and 200 rpm. We designed a lead screw for the motor. Anaerobic adhesive is used to prevent relative sliding between the shaft and lead screw. We also designed a stepped motor bracket to fix the motor and gear box. Also, a motor and syringe barrel fixing bracket is designed. M3 screws are used for fixation from both ends. After assembly, the lead screw and syringe are eccentric. This prevents the piston from rotating. The piston rod is removed to free up space, and a corresponding internally threaded piston is rod designed for the syringe.

7.1.5 STRUCTURAL DESIGN

FIGURE 25: FLOAT STRUCTURE (INSIDE)

The housing incorporates a 25 mm pressure relief vent to prevent structural stress from internal pressure buildup. Batteries are secured at the base via 3D-printed mounts to optimize center-of-gravity stability. A depth sensor provides real-time feedback for closed-loop control, ensuring precise depth management.

Our floats have an overall 3D printed structure, with internal pressure adjustment via two syringes, and push and pull operation of the syringes controlled by a motor. It is waterproof and has a counterweight to stabilize the float in the water. A depth sensor is mounted on the bottom of the float to accomplish the task, and a pressure relief valve is installed for safety. The top of the float is raised to allow for the placement of the communication device, and by aligning the buoyancy, we ultimately achieve a float that is just above the water to reveal the signal transmission section.

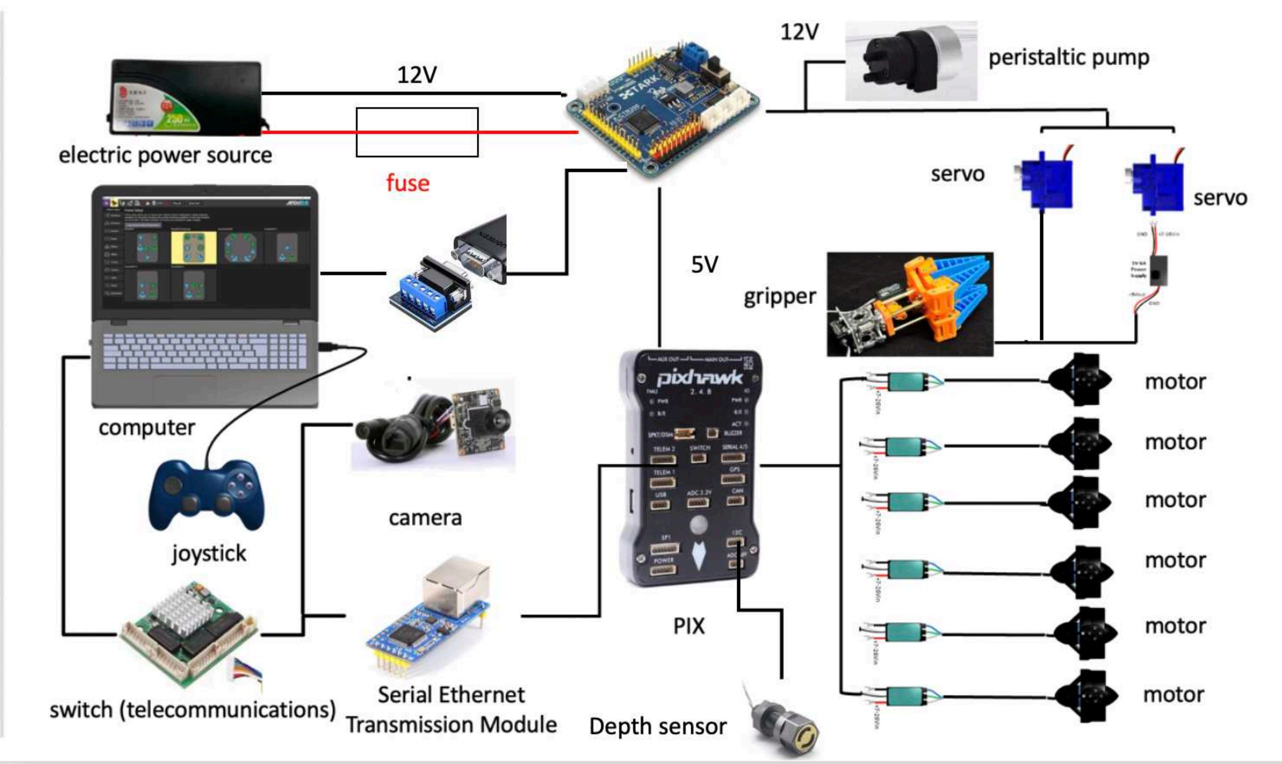
FIGURE 26: FLOAT STRUCTURE (OUTSIDE)

Our float features an overall 3D-printed structure. The raised top part of the shell is designed for installing communication devices, while the bottom is equipped with a depth sensor to ensure precise underwater positioning and data collection. The external design of the buoy is minimalist, adhering to the minimalist concept, and at the same time, it guarantees the stability and functionally of the equipment in water.

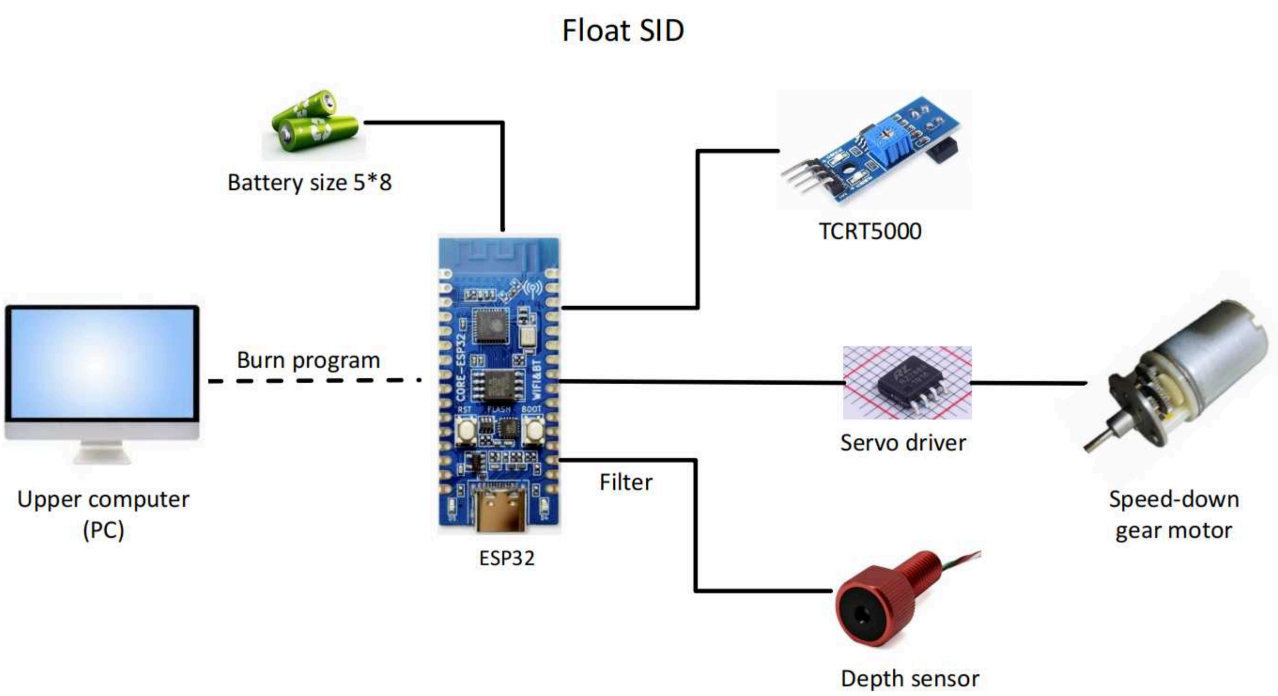
(For more detailed information about floats, please refer to the float technical documentation.)

8 SID

8.1 ROV SID



8.2 FLOAT SID



9 TESTING AND PROBLEM SOLVING

1. **Learning Competition Rules and Safety Standards**
   As first-time participants in the MATE competition, we initially lacked familiarity with event procedures and safety requirements. Through intensive study of competition manuals, consultations with veteran teams, and specialized training from mentors, we eventually established a comprehensive safety management system that met all competition standards.

2. **Software Learning Curve**
   When working on structural design and circuit programming, we encountered new software like Tinkercad and Onshape for the first time. Team members overcame this through online tutorials and peer-to-peer coaching, ultimately mastering these tools to complete high-precision 3D modeling and system debugging.

3. **Early-Stage Goal Ambiguity**
   During initial phases, unclear task divisions led to low engagement from some members. We held team meetings to redefine objectives and assigned roles based on individual strengths (e.g., programming, structural design, safety oversight), which significantly improved efficiency and collaboration.

4. **Waterproofing Test Failures**
   Early waterproof enclosures leaked during pressure tests. We solved this by redesigning 3D-printed seals, applying waterproof coatings, and adding multi-layer rubber gaskets, eventually passing 24-hour pressure tests at 3-meter depths.

5. **Insufficient Propulsion Power**
   Horizontal thrusters showed delayed response in strong currents. We upgraded to higher-torque waterproof motors and optimized propeller blade angles, enabling stable navigation at 2m/s flow speeds.

6. **Time Management Challenges**
   Balancing academic workloads with project deadlines proved difficult. We implemented strict Gantt charts, focused work during weekends/holidays, and daily online progress reports to stay on schedule.

7. **Control Signal Latency**
   Long cables caused communication delays. By shortening cable lengths, installing signal boosters, and using shielded anti-interference wiring, we achieved real-time video transmission and control response.

8. **Unexpected Structural Fractures**
   PVC frames cracked during collision tests. The team reinforced structures with stainless

steel brackets and cross-supports, complemented by 3D-printed positioning aids, dramatically improving durability.

Each solution not only enhanced OctaXplore's performance but also transformed our team through technical growth, crisis management skills, and strengthened collaboration.

10 SAFETY

10.1 POWER SUPPLY SECTION

Figures 27 and 28 show fuse and the Anderson power plug connector. The distance between the Anderson power plug connector and the fuse is within 30 centimeters.

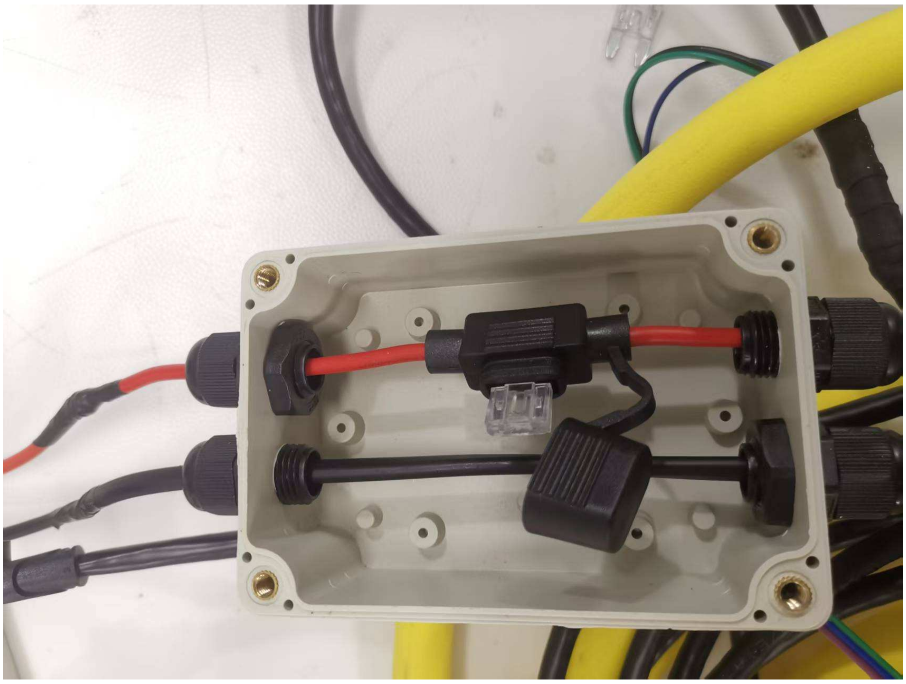


FIGURE 27: FUSE

FIGURE 28: ANDERSON POWER PLUG CONNECTOR

10.2 WATERPROOF PRESSURE-REDUCING MODULE

Convert the input voltage to the required output voltage to meet the working requirements of other components in the circuit. Monitor the output voltage through the control circuit to ensure it remains stable at the set value, preventing equipment damage or performance degradation caused by voltage fluctuations. The voltage-reducing module usually also has overload protection and short-circuit protection, which can cut off the output in time in abnormal situations

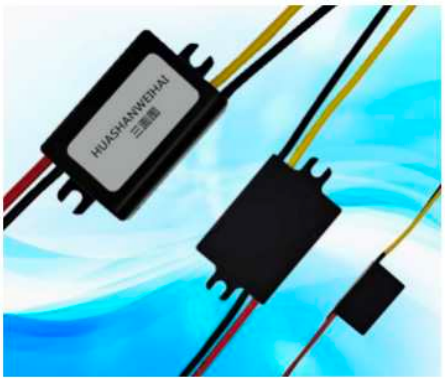


FIGURE 29: WATERPROOF PRESSURE-REDUCING MODULE

10.3 CABLE SAFETY

We have designed a zero-buoyancy cable. We use high-strength tensile material, Kevlar bulletproof wire, as the tensile structure. After testing, this structure can withstand a tensile force of 100kg. We also use tin-plated copper mesh braided shielding to ensure stable and safe signals.

FIGURE 30: CABLE

All propellers will have a 3D-printed propeller shield. A safe and hard shell (with a diameter of less than 12.5mm) ensures that no foreign objects will be sucked in and has been firmly fixed, so its safety can be guaranteed. Figure 31 shows an example of the propeller shield.

FIGURE 31: THE PROPELLER SHIELD

10.4 ANTI STRETCHING DEVICE

The robot is equipped with anti-stretching devices at both the connection points from the cable to the controller and from the cable to the robot to prevent direct pulling of the cable and reduce the risk of cable damage. Figure 32 shows the anti-stretching device of the control box, and figure 33 shows the anti-stretching device of the ROV.

FIGURE 32: ANTI STRETCHING DEVICE

FIGURE 33: ANTI STRETCHING DEVICE

10.5 MACHINE TESTING

We tested the thrust of the motor under different currents and voltages in the laboratory, which enabled us to precisely know the driving force of the machine underwater and allowed us to control it more safely.

voltage	electric current	driving force
12V	7.5A	1.74KG
14V	8.8A	2.03KG
16V	10A	2.45KG
18V	11.3A	2.65KG
20V	12.3A	3.05KG
22V	13.7A	3.23KG
24V	14.8A	3.48KG

FIGURE 34: EXPERIMENTAL DATA

10.6 FUSELAGE SAFETY

The ROV has no sharp shapes. In the following pictures we can see that the ROV has no sharp edges or parts that can cause damage.

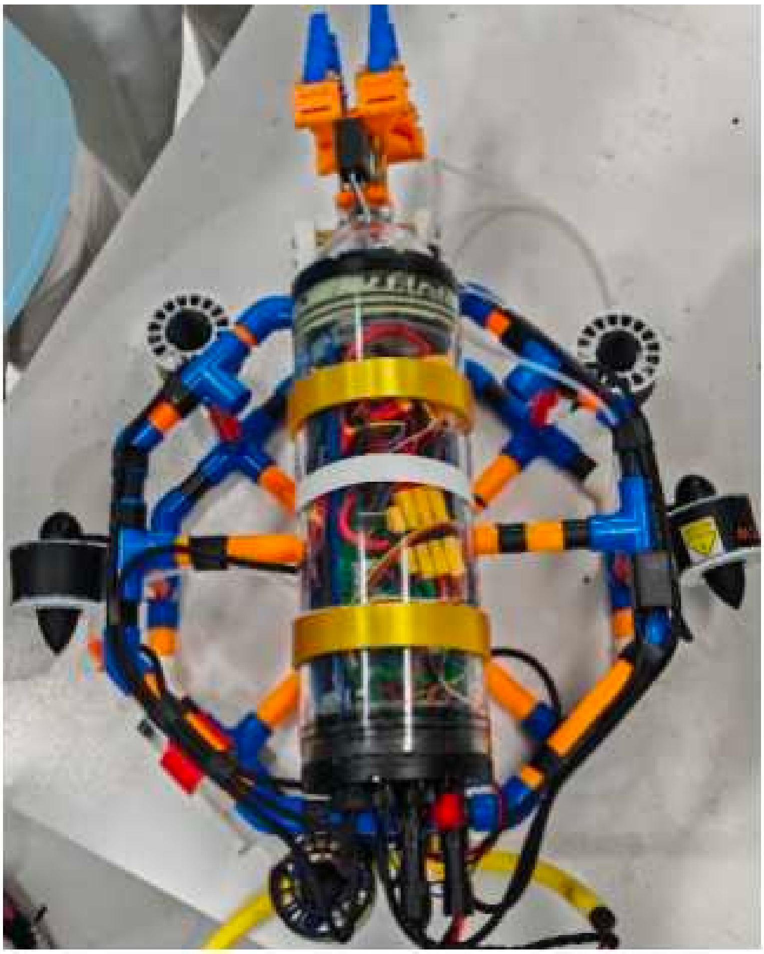


FIGURE 35: VIEW FROM ABOVE

FIGURE 36: VIEW FROM FRONT

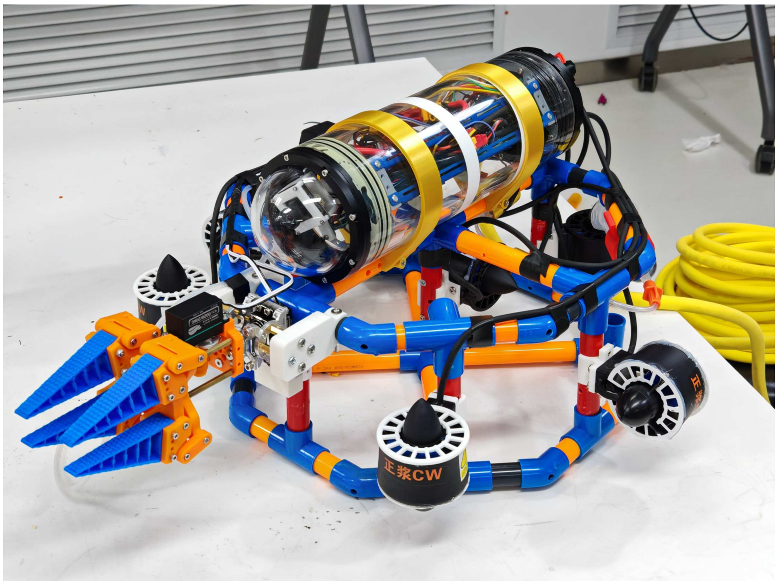


FIGURE 37: VIEW FROM SIDE

10.7 WATERPROOF OF THE SEALED CABIN

We have set up a double-layer waterproof wiring panel at the connection between the cable and the machine and applied Vaseline at the connection for double-layer waterproofing, which can effectively protect the internal circuit.

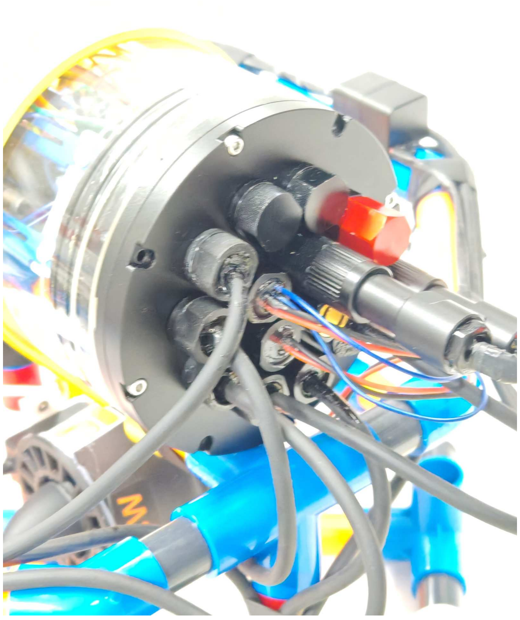


FIGURE 38: WATERPROOF OF THE SEALED CABIN

10.8 THE FASTENERS OF THE 3D-PRINTED SEALED CABIN

We used a 3D printer to make a fixing device for the sealed cabin and fixed it on the cross-shaped PVC pipe on the top of the machine, ensuring that the sealed cabin would not fall off during underwater driving and guaranteeing the safety of signal transmission.

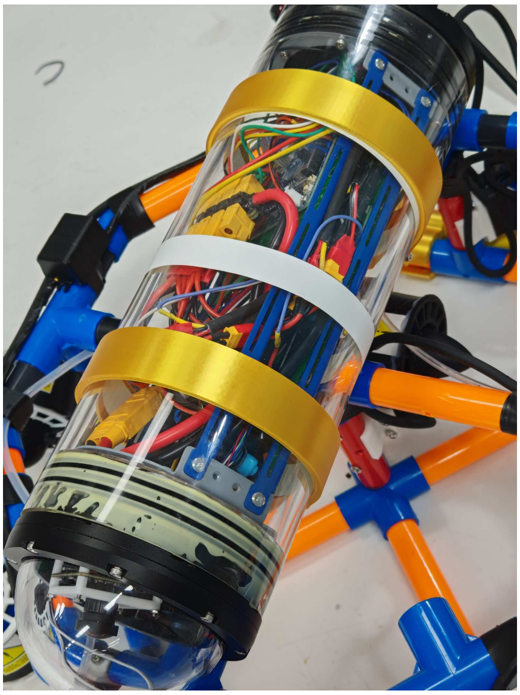


FIGURE 39: THE FASTENERS OF THE 3D-PRINTED SEALED CABIN

10.9 CONTROL SECURITY

We installed a protective shell outside the control device and placed a sponge pad of the appropriate size between the protective shell and the controller to prevent the controller from being bumped.

FIGURE 40: CONTROL BOX

10.10 WORKSHOP ENVIRONMENT

The laboratory is equipped with vertical rotating power plug boards with on/off switches at each main plug board, which ensures safety and convenience during our experiments.

FIGURE 41: POWER SAFETY

Fig. 41 and Fig. 42 show the storage and organization of tools and materials in our lab, this prevents accidental injuries from improperly placed tools.

FIGURE 42: STORAGE OF TOOLS

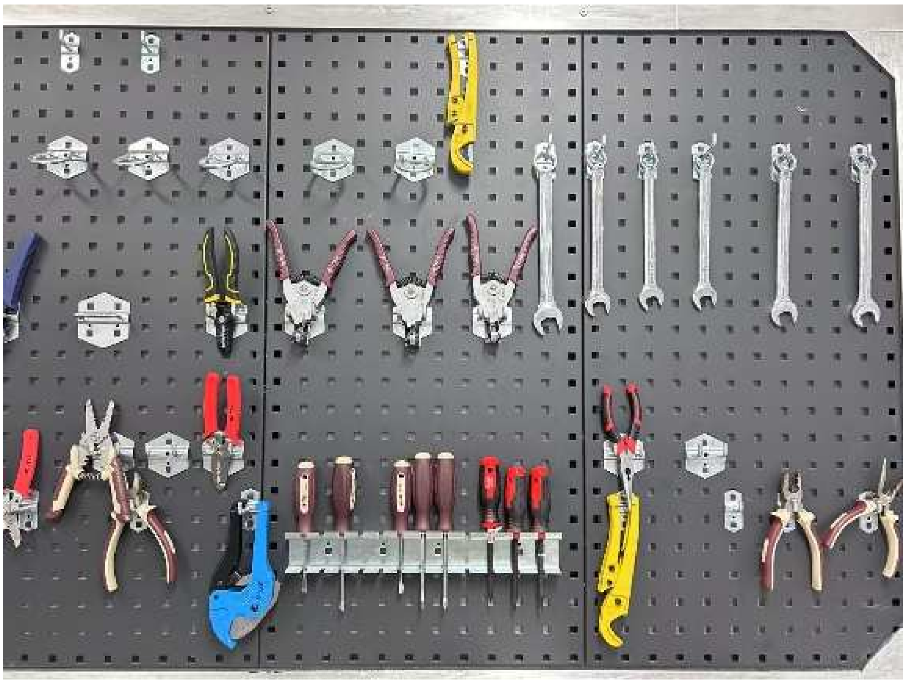


FIGURE 43: ORGANIZATION OF TOOLS

Fig. 43 shows our pre-competition training site with pool materials that are safe and secure for testing.

FIGURE 44: EXPERIMENTAL SITE

11 EXPENSES

11.1 ROV EXPENSES

Category	Item	Description	Unit Price	Quantity	Total Price
Structural Components	Orange PVC Pipe	0.5 20*2mm	16.3	16	260.8
	Red PVC Pipe	0.5 20*2mm	5.9	7	41.3
	Grey PVC Pipe	0.5 20*2mm	4.1	8	32.8
	Five-Way Connector	20mm Three-Dimensional Five-Way Connector	0.8	2	1.6
	Four-Way Connector	20mm Four-Way Connector	0.7	8	5.6
	Three-Way Connector	20mm Three-Way Connector	0.4	4	1.6
	Elbow	20mm	0.2	16	3.2
	Cable Clamp	2 pieces	0.5	2	1
	Mechanical Gripper	3D-Printed Outer Shape	129	1	129
	Servo Cage		154	1	154
	Fuse + Box	Waterproof Fuse Box + Small Fuse	15	1	15
	Flight Controller Shock-Absorbing Plate	Shock-Absorbing Plate	29	1	29
	Hatch Cover	Aluminum Alloy 14-Hole Hatch Cover	105	1	105
	Bracket	Aluminum Alloy Bracket Set-300 Length	182	1	182
	Dome	Acrylic Dome + Aluminum Alloy Pressure Plate	149	1	149
	Flange	Aluminum Alloy Flange	165	2	330
	Acrylic Tube	Acrylic Tube/300 Length	335	1	335
	Shelf	300 Length + 200 Length	70	1	70
	Cable Gland	Hollow Screw + Solid Screw	19	55	1045
Propulsion System	Underwater Thruster	12V Brushless Motor with Built-in ESC	285	6	1710
Electrical System	Step-Down Module	DC Waterproof Step-Down Module 5V/3A	23	1	23
	Flight Controller	Pixhawk2.4.8	1099	1	1099
	Power Distribution Board	Power Distribution Board	57	1	57
	Zero-Buoyancy Cable	ROV Underwater Robot Zero-Buoyancy Power Cable	40	12	480
	Driver Board	STM32 Controller with Motor Driver	47	1	47
	Depth Sensor	MS5837	219	1	219

	Waterproof Servo	20kg	280	2	560
	Water Pump	Micro Diaphragm Pump	146	1	146
	Signal Conversion Module	Serial to 485	30	1	30
Camera System	Network Camera	6 Million Pixels, 2.8mm, 110 Degrees Distortion-Free	499	1	499
	360-Degree Camera	Insta 360 X5	2679	1	2679
	360-Degree Camera Protective Case	Camera Waterproof Protective Case	199	1	199
	Switch	Small 3-Port 100Mbps Switch	79	1	79
Shore - Based Control System	Control Handle	XBOX Handle	99	1	99
	Engineering Plastic Protective Case		520	1	520
	Waterproof Connector	Ethernet + USB Plug Panel-Mounted	48	2	96
Others	Potting Compound	Epoxy Resin AB Glue	110	1	110
	Air Tightness Test Nozzle	Manual Vacuum Pump + Self-Sealing Air Nozzle	650	1	650
	Underwater Connector	6-Core Male Cable + 6-Core Female Socket	230	2	460
	Syringe	60mL	2.4	1	2.4
	3D Printing	PETG 1kg	22	1	22
	Heat-Shrink Tubing	164 pieces	4.8	1	4.8
	Plastic Tube	1.8m	5.6	1	5.6
	Electrical Tape	18mm*10m	3.2	5	16
	Waterproof Tape	2.5cm*5m	12.7	5	63.5
				Total	12703.7

11.2 FLOAT EXPENSES

Float material list				
item	**description**	**Unit price (Yuan)**	**quantity**	**Total price (Yuan)**
Dry battery number five	1.5V dry battery	3	8	24
ESP32 development board	Master controller with wireless communication	20	1	20
moter drive	Dc motor drive, H bridge	10	1	10
Dc speed reduction motor	Drive syringe push and pull piston	20	1	20
injection syringe	20ml specification	6	1	6
3D printing fixed bracket	For battery and syringe mounting	30	2	60
UPVC watertight compartment	Protect motor and electronic components	80	1	80
depth transducer	MS5837-30BA	309	1	309
Pressure relief hole assembly	diameter 25mmh	8	1	8
waterproof cable	connect individual electrical components	20	1	20
fuse	overcurrent protection	8	1	8
connector	electrical connection	2	10	20
Total				**585**

12 SUMMARY

The OctaXplore underwater robot, developed by Rongzhen Kaiwu, represents a significant advancement in eco-conscious and minimalist-oriented remotely operated vehicles (ROVs). Designed with an innovative octagonal PVC pipe frame, the robot emphasizes modularity, stability, and environmental sustainability. Key features include a lightweight and durable structure, high-precision motors, a multifunctional integrated system, and non-invasive sampling tech- nology to minimize ecological disturbance. The ROV's propulsion, control, energy, and com- munication systems are meticulously engineered for efficiency and reliability, supported by rigorous waterproofing and safety measures.

The project highlights the team's dedication to sustainable technology, utilizing recyclable materials and electric power to achieve zero emissions. Safety protocols, led by a dedicated safety officer, ensure compliance with environmental and operational standards. The company's organizational structure, with clear role divisions and efficient project management, underscores its commitment to collaboration and innovation.

OctaXplore's applications span diverse underwater environments, from shipwreck surveys to offshore wind farms, demonstrating its versatility and adaptability. The team's efforts extend beyond technical development, encompassing educational outreach and marine conservation initiatives. With a total project cost of 2000 CNY for the ROV and additional investments in float systems, Rongzhen Kaiwu has successfully delivered a cutting-edge solution that aligns with global goals for environmental protection and technological advancement.

This project not only showcases the team's technical prowess but also reflects their unwavering spirit, perseverance, and teamwork, marking a transformative chapter in their journey as young innovators.

13 ACKNOWLEDGMENT

Finally, we want to thank ourselves. Together, we persevered through countless late nights, debated over every detail, and pushed forward with determination. Regardless of the outcome, we have all gained invaluable experience. What matters most is not a ranking but the priceless lessons we learned—from starting from scratch to achieving our goals—and the unbreakable team spirit we built. This journey has been an unforgettable and transformative chapter in our lives.

We would like to express our deepest gratitude to Bayi School for its tremendous support. The school has provided our company with invaluable opportunities for establishment and com- petition, allowing us to explore the world of underwater robotics. Throughout this journey, we have experienced the wonders of technology, honed our teamwork skills, and unlocked our potential.

We are also immensely thankful to our mentors and instructors for their guidance. From the initial project introduction to overcoming technical challenges at every critical stage, our teachers have been there for us. Despite our repeated questions, they patiently shared their expertise and experience, helping us break through one obstacle after another.

Our heartfelt thanks go to our parents for their unwavering support and understanding. As our strongest backing, they ensured that we could focus entirely on the competition without any worries. We also thank the FTC team 27570 and FLL team 59968 from 8-1 High School for their great support!

Finally, we want to thank ourselves. Together, we persevered through countless late nights, debated over every detail, and pushed forward with determination. Regardless of the outcome, we have all gained invaluable experience. What matters most is not a ranking but the priceless lessons we learned—from starting from scratch to achieving our goals—and the unbreakable team spirit we built. This journey has been an unforgettable and transformative chapter in our lives.

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