海天雄鹰队

鲲鹏方舟号潜航器

“Kunpeng Ark” ROV

Team Sea&Sky Eagles

Guangzhou Bayi Experimental School(Guangzhou, Guangdong, China)

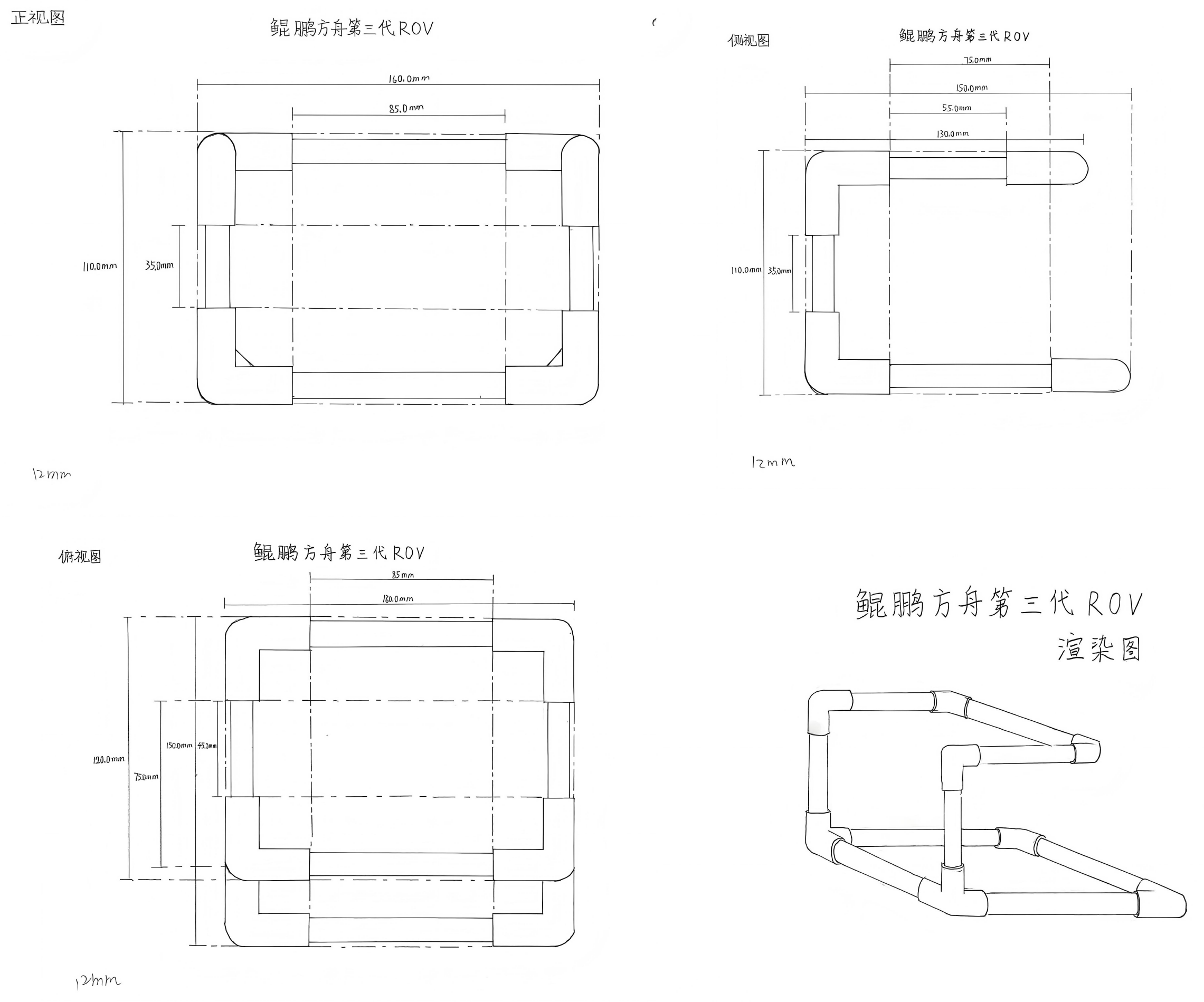
Abstract

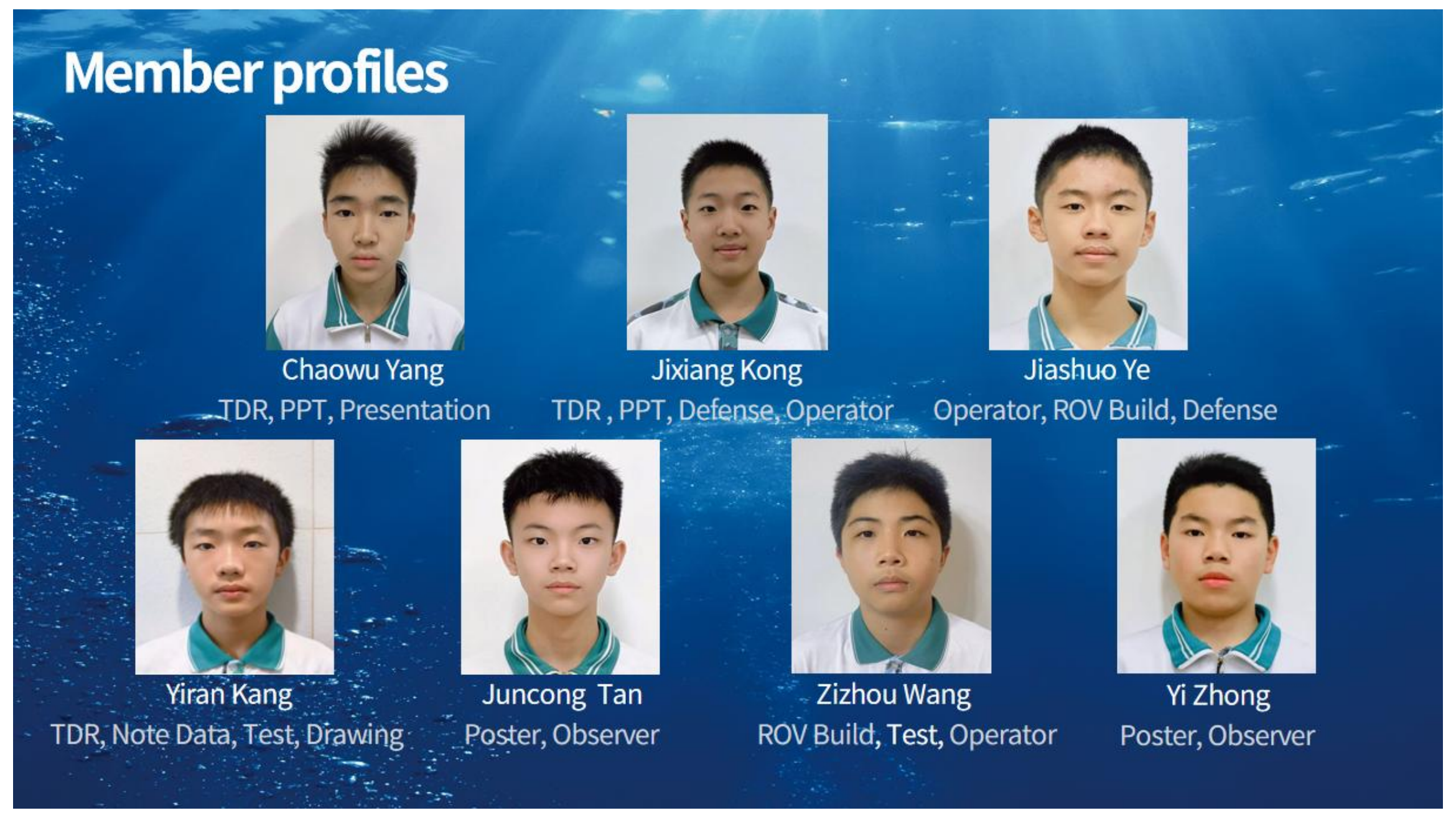
Aligned with the SeaPerch 2026 "Storm Response" theme, our project focuses on high maneuverability, speed, and stability. Through multiple iterations of the Engineering Design Process (EDP), we developed a compact ROV featuring a modular structure that optimizes the center of gravity and buoyancy layout, significantly improving vertical mobility and stability.

Key innovations include a custom control PCB to reduce electrical risks, oil-sealed motor housings for protection and efficiency, and zero-buoyancy cables to minimize drag.

Experimental results confirm the ROV's superior performance in complex environments, providing a practical foundation for lightweight small-scale ROV design and application.

Keywords: Underwater Robot (ROV); Structural Optimization; Circuit System Design; Stability Control





Chaowu Yang
TDR, PPT, Presentation

Jixiang Kong
TDR , PPT, Defense, Operator

Jiashuo Ye
Operator, ROV Build, Defense

Yiran Kang
TDR, Note Data, Test, Drawing

Juncong Tan
Poster, Observer

Zizhou Wang
ROV Build, Test, Operator

Yi Zhong
Poster, Observer

Methodology

ROV Frame EDP Design： During the preparation process, we applied the Engineering Design Process (EDP) to guide the design and optimization of the machine. The frame structure design primarily underwent three rounds of the EDP cycle:

	Ask	Imagine	Plan	Create	Test
1	How to achieve high stability in machines?	The original framework is too cumbersome. Consider adopting a structure that combines stability with flexibility.	Adopting a positive trapezoidal structure		Best race time: 1 minute 45 seconds Best individual time: 60 seconds
2	How to make the machine faster?	The existing framework structure is stable, but the operating resistance is relatively high. We are considering ways to reduce this resistance.	The original trapezoidal frame structure was modified to an inverted trapezoid shape, and a hull design with a ship-like cross-section was adopted to effectively reduce frictional resistance between the hull and the underwater environment during navigation,thereby increasing speed.		Best racing time: 1 minute 18 seconds Best mission completion time: 68
3	How can machines achieve the goals of reducing weight, increasing speed, and enhancing structural stability and operational flexibility?	Although the second-generation machine exhibits strong stability, its speed remains relatively slow, with significant weight and drag surface area. It is recommended to redesign the structure and adopt 12mm tubing materials.	The original structure was redesigned, and the tubular cross-sectional dimensions were correspondingly reduced to 12 mm to reduce weight.		Best racing time: 35 seconds Best mission completion time: 100

What are the innovation of our ROV?

Key innovations include:

Innovative Circuit Board Design: To address the recurring short-circuit issues found in standard boards, this study involved the independent design and iterative optimization of a dedicated circuit board. The core advantage of this custom design lies in the high degree of circuit simplification. The design features excellent adaptability, allowing for rapid adjustments based on specific mission requirements, which significantly enhances the overall reliability and flexibility of the system.

Optimization of Interface and Connection Reliability: We performed a specialized optimization of the power and signal connection sections. By selecting industrial-grade connectors with more robust structures and higher current-carrying capacities, we effectively improved the safety and long-term operational stability of the electrical connections.

Innovative cable: We focused on reducing the friction between the tether and the underwater rings. We conducted repeated comparative experiments with network cables, flexible cables, and foam lines. After evaluating factors such as friction, buoyancy, weight, elasticity, and current capacity, we ultimately selected the foam line (zero-buoyancy cable) to maximize racing performance.

Modular Design: The system is divided into a main module and operational modules, allowing the ROV to quickly swap or upgrade components based on specific task requirements. This enhances its multi-tasking capabilities and adaptability to diverse scenarios. Modularization also simplifies maintenance, as damaged sections can be rapidly replaced without requiring extensive system-wide overhauls. Furthermore, this approach drives standardization, effectively reducing costs and improving interoperability.

Innovation of Motor Waterproof Housing： During the use of the first-generation motor waterproof housing, it was found that the hot melt adhesive softened due to the heat generated by the motor during operation, causing the motor to shift forward and backward, resulting in water ingress. Therefore, we carried out optimization and upgrading:We adopted a 3D-printed rear cover and used springs to provide continuous pressure, ensuring stable waterproof performance of the shaft seal. In addition, we designed limit posts in the 3D-printed rear cover to completely prevent the springs from moving, further enhancing the waterproof effect.

Results & Discussion

Experimental Results:

ROV Version 1: The regular trapezoidal frame provides static stability, but it exhibits high hydrodynamic drag and an uneven mass distribution (front-heavy), resulting in low propulsion efficiency and insufficient maneuverability, which makes it difficult to meet the competition requirements for both speed and precision.compromised control, rendering the design unsuitable for the current season's mission objectives.

ROV Version 2: This version achieves fluid optimization of the frame by reducing overall dimensions, precisely trimming PVC pipes, and adopting an inverted-trapezoidal form combined with a hull-like cross-section, which lowers hydrodynamic drag and enhances navigation stability. Additionally, a multi-purpose hooking device has been integrated to improve mission execution capabilities. While it offers strong stability, increased speed, and significantly improved operability, drawbacks remain, including a still-large vehicle volume, limited drag reduction, and speed that falls short of expectations.

ROV Version 3: Adopting a standard rectangular cross-section and 12mm pipe diameter, the design achieves weight reduction, increased speed, and enhanced structural stability and mobility, thereby significantly improving operational speed and control stability. Version advantages: High speed, low drag, light weight, rapid buoyancy response, and stable handling.

Through underwater task testing, we clearly recognized that our current ROV still faces three core pain points: attitude instability during dynamic operations leading to hook positioning deviations, lack of active adjustment mechanisms affecting hovering balance, and reactive forces from the mechanical structure impacting overall stability. In response to these challenges, we have developed a systematic optimization plan:

- **Structural Lightweighting and Fluid Optimization:** Utilizing Tinkercad for 3D modeling analysis to precisely control the vertical alignment of the center of gravity and center of buoyancy; reducing overall dimensions while adopting a streamlined frame design to lower fluid resistance by 30%, thereby enhancing spatial adaptability.
- **Intelligent Upgrade of Control Systems:** Introducing a multi-degree-of-freedom servo system to establish a roll-pitch active adjustment closed loop; optimizing vectored thruster layout to improve turning response speed by 40%, with significantly enhanced resistance to water current interference.
- **Enhancement of Reliability and Functionality:** Improving oil seal structures and waterproof cover interfaces to establish a dual-sealing assurance system; expanding buoyancy adjustability by 20% through modular buoyancy material layouts; reconstructing the hook transmission structure to reduce reactive forces to within the body's stability threshold.
- **Modular Innovative Design:** Developing a quick-release tool interface to support second-level switching of task-specific modules (gripping, cutting, etc.), endowing the ROV with rapid adaptability to multi-scenario operations.

Conclusion

Looking back on our preparation journey, our team was once mired in bottlenecks due to conceptual differences and poor communication, causing project progress to stagnate. However, it was precisely the tempering of this competition that allowed us to deeply grasp the true essence of "seeking common ground while reserving differences" in teamwork—differences are not obstacles, but opportunities for complementarity.

Guided by a shared goal, we gradually established a trust-based collaboration mechanism:

Chaowu Yang and Jixiang Kong constructed the technical report and presentation framework with rigorous logic, Jiashuo Ye endowed the machine with life through precise operational skills, Yi Zhong and Yiran Kang consolidated the hardware foundation with exquisite craftsmanship, while Zizhou Wang and Juncong Tan infused aesthetics and reliability into the project through visual design and waterproofing.

This complementary collaboration model not only enabled us to break through technical barriers but also deepened team camaraderie through mutual understanding.

Next Steps

Standing at a new starting point, we deeply understand that technological innovation knows no bounds. Our next focus will be tackling intelligent attitude control algorithms and multi-sensor fusion technologies, striving to create a new generation of underwater robots with environmental perception and adaptive regulation capabilities. This competition was not merely a technical contest but also a tempering of team spirit. We firmly believe that through continuous technical breakthroughs and collaborative innovation, we will steadily advance small ROVs toward high precision and intelligence, contributing greater practical value to the field of underwater operations

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Most importantly, we thank every team member for their dedication and hard work—through shared learning and collaboration, we have grown together on this journey.