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Development of Marine Equipment for Underwater Stereoscopic Observation

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Abstract: Establishing an underwater stereoscopic observation network to obtain scientific, real-time, and comprehensive data is an important direction for understanding and exploiting the ocean in the future. This study first analyzes the need and necessity of developing underwater stereoscopic observation equipment, then introduces the development status of the equipment in China and abroad, further analyzes the problems faced by China's field development, and presents the key breakthrough points of marine sensors that serve as the key link for underwater observations. China has made significant progress in technologies regarding marine observation platforms, but still lags behind the world in terms of advanced levels in key marine sensors and high-precision sensors. The big data obtained from ocean observation does not match the actual demand, and the ocean sensors lack support from an improved platform. To guide the long-term development of related fields, we suggest that China should support the efficient transformation of research results from key marine sensors, coordinate the management of marine equipment for underwater stereoscopic observation, and establish a national public test platform for offshore instruments and equipment.

Keywords: ocean observation; sea floor observatory network; underwater vehicle; underwater sensor

1 Introduction

Marine observation relies on the advancement of marine equipment. Early in history, humans learned about the oceans mainly on board ships or on shore. During the 20th century, the emergence of remote sensing technology made collecting dynamic marine data from space a reality. By the 21st century, underwater and seafloor marine observations have become popular research topics. Involving a time and space coupling process, marine observation requires a combination of mobile and fixed observation platforms. On such a mobile or fixed platform, a network that conducts real-time observations of the seas through wired or wireless connections is defined as an underwater stereoscopic observation network [1]. As the basis of such a network, marine observation equipment plays an important role in maintaining maritime security, preventing and controlling marine disasters, and promoting progress in marine science.

In the 1960s, the international community began utilizing various types of underwater observation equipment in numerous marine scientific surveys and marine resource gathering activities. For instance, an underwater remotely operated device can work as an unmanned and mobile observation platform in relatively deep water for a lengthy period of time, thus rapidly advancing our understanding of undersea environments [2]. In 1997, Chinese marine scientists put forward the initiative to observe the Earth from the seabed and determined that China should take actions as soon as possible in the construction of underwater observation networks, which might trigger international competition or disputes over maritime rights, interest, or security [3]. In addition, based on the

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research progress of Ocean Networks Canada (ONC), the importance of underwater observation networks was clarified [4]. Moreover, a series of research papers published by the National Ocean Technology Center provided a comprehensive introduction to the development of international underwater stereoscopic observation networks. For example, one study [5] introduced autonomous underwater vehicles (AUVs), analyzed the history and current status of the field of ocean observation, and clarified the importance and potential for China to conduct further research. Another study [6] analyzed the current status and future trends of the information networks for underwater observations both in and outside China, and put forward recommendations and suggestions.

An underwater stereoscopic observation network usually consists of three parts: a seabed observation network, mobile observation platforms and sensors, and a data processing system. Mainly focused on the first two parts, this article discusses demands for the development, existing problems, future trends, and key technologies in the field of marine observation and puts forward recommendations and suggestions.

2 Demand analysis of marine equipment for underwater stereoscopic observation

2.1 Promoting progress in marine science

Marine science is a discipline based on observation. All new discoveries and progress made in marine science depend on marine equipment for observation. The development of marine equipment for underwater stereoscopic observation is necessary for both promoting progress and providing solutions in China’s marine science research. On one hand, if we consider the ground and sea surface as the first observation platform and the space telemetering and remote sensing network as the second, the seabed observation network should then be the third. Allowing the areas from the sea surface to the seabed to be monitored and detected by humans, the underwater observation network is expected to fundamentally change the way humans understand and explore the seas, and usher in a new phase of marine science [3].

On the other hand, new discoveries in marine science can only progress through long-term observations. The development of marine equipment for underwater observation provides scientists with highly accurate, real-time, and comprehensive observation data in all directions, from the sea surface to underwater, the seabed, and finally deep inside the Earth’s crust. Moreover, underwater observations help humans better understand scientific marine issues such as ocean changes from human activities, marine organisms, seabed–seawater–atmosphere relationships, the seabed, and sediment dynamics.

2.2 Prevention and control of marine disasters

Marine observations provide effective information for the prediction and early warning of marine disasters. Eighty percent of volcanic eruptions and earthquakes occur on the seabed, mainly along the Earth’s crust [3]. Marine equipment for underwater stereoscopic observations can monitor, grade, and locate earthquakes under the sea, accurately forecasting natural disasters such as typhoons and tsunamis through data processing, modeling, and analysis, and monitor emergencies such as storms, algal blooming, volcanic eruptions, and submarine landslides [5] to reduce the economic losses caused by disasters and provide disaster prevention for the economic and social development of coastal areas.

2.3 Maintaining maritime security

The development of marine equipment for underwater stereoscopic observation is necessary for maritime defense. China’s mainland coastline is approximately 18 000 km with eight maritime neighbors, some of which are involved in territorial maritime disputes with China. Some countries have even set up submarine acoustic monitoring networks on the first island chain, posing a threat to the safe access of China’s navy armament. To avoid situations in which China’s maritime borders are exposed and the underwater areas become one-way transparent, it is necessary for China to construct an underwater monitoring network and develop underwater monitoring equipment independently.

Marine equipment for underwater stereoscopic observations can provide long-term, real-time, uninterrupted, and wide-range monitoring to ensure the continuous and reliable functions of underwater monitoring networks and provide strong support for protecting China’s maritime rights and interests.

3 Current status and future trends of marine equipment for underwater stereoscopic equipment in China and abroad

An underwater stereoscopic observation network usually consists of three parts: marine observation platforms, sensors, and a data processing system. There is currently a large gap in data processing between China and other countries, and professional and other further discussions may be needed. Therefore, this article mainly focuses on marine equipment for underwater observations, including fixed marine platforms (the seabed observation network), mobile marine platforms, and marine sensors for underwater observation.

3.1 Seabed observation network

The plan to build a seabed observation network was first proposed by the United States, but owing to lack of funds, it was developed slowly. In June 1999, Canada took the lead in building the NEPTUNE Ocean Observatory, which forms a ring-shaped network with composite cables to monitor real-time volcanic processes, earthquakes, and tsunamis, and to provide support for further research on ocean–atmosphere interactions, climate change, and other elements. More than 138 observation instruments are currently in use by the NEPTUNE Ocean Observatory. In the 21st century, various countries have been actively building their seabed observation networks, such as Japan’s ARENA built in 2013, Europe’s ESONET in 2004, Australia’s IMOS in 2006, and India’s OMNI in 2013. These networks apply more sensors to effectively expand observation objects and areas, bringing multiple functions together, including disaster prevention, disaster relief, and scientific research.

China’s seabed observation networks were planned during the 11th Five-Year Plan period, built during the 12th Five-Year Plan period, and expanded during the 13th Five-Year Plan period. The units involved in the construction and research include Tongji University, Zhejiang University, the Ocean University of China, the Institute of Acoustics (IOA) of the Chinese Academy of Sciences (CAS), CSSC 715th Research Institute, and Hentong Group Co., Ltd. [7]. In 2009, led by Tongji University, the Xiaoqushan Observing Station was built as the first comprehensive demonstration network of marine observation and experimentation [8]. In 2013, the Sanya Demonstration Network for Marine Observation, jointly constructed by the South China Sea Institute of Oceanology, Shenyang Institute of Automation (SIA), and the IOA of CAS, was put into operation [9]. In 2014, Zhejiang University finished building Zhairuoshan Island Experimental and Research Demonstration Network for Marine Observation, with joint efforts from advanced units in China. During the period of the 12th Five-Year Plan, the IOA of CAS led other relevant units to undertake one of the major projects in the National High-tech R&D Program of China (863 Program), the Experimental Project of the Seabed Observation Network. Focusing on the overall technology of the network, this project resolved key technical problems, including the remote supply of high-voltage power underwater, the location, layout, and recycling of cables at high water depths and with high accuracy, underwater junction boxes and instruments at high water depths, high-voltage photoelectric composite cables at high water depths, remotely operated vehicles (ROVs) in deep water, and underwater wet electrical connectors, ensuring the construction and stable operation of the seabed observation network [10]. In 2017, the seabed observation network was approved to be built as a national major science and technology infrastructure, which will be led by Tongji University and jointly finished by the IOA of CAS in five years. In 2018, the Feasible Report on Submarine Observation Network as National Major Science and Technology Infrastructure was approved. As a major approach to achieving large-scale, all-weather, comprehensive, long-term, continuous, real-time, and high-resolution observations of the deep Earth crust, sea floor, sea water, and sea surface, the seabed observation network will provide support for research on topics including national maritime security, exploitation of deep-sea energies and resources, environment monitoring, and early warning and forecasting of marine disasters. On the whole, the construction of China’s seabed observation network started relatively late and has not been formally completed thus far; in addition, new technologies remain to be verified prior to further application and promotion.

3.2 Marine underwater mobile platforms

With high maneuverability, mobile underwater mobile platforms, such as ROVs, human occupied vehicles (HOVs), and AUVs, are widely applied during the process of underwater stereoscopic observations and play an important role in the installation and maintenance of a seabed observation network. In return, the seabed observation network can provide mobile underwater platforms with services such as charging, information transmission, and transfer. Therefore, the combination of both will play a greater role.

3.2.1 ROVs

During the 1960s, the international community began to utilize ROVs in many different marine scientific surveys and marine resource exploration, mainly because ROVs can operate for a long time in relatively deep water. Under manual control, ROVs can accomplish various types of instructions and orders. In addition to observations, ROVs equipped with manipulators can also conduct tasks such as underwater sampling, installation, and maintenance, and thus possess unique advantages. Countries with mature ROV technology include the United States, Japan, and France, which have the ability to research and develop ROVs at or below a depth of 6000 m. ROVs for deeper water are still under testing and have not yet been promoted or applied.

In June 2020, the Haidou-1 ROV made by SIA of CAS dove to a depth of 10 907 m and became China’s first unmanned submersible to submerge more than 10 000 m, creating a deep-sea diving and operating record for China. The Haima and the Hailong ROVs developed by Shanghai Jiaotong University can operate at depths of 4500 and 6000 m, respectively. The ROV developed by the CSSC 715th Research Institute can operate at a depth of 5000 m [11]. China has become one of the countries with 6000-m ROVs, together with the United States, Japan, and France.

3.2.2 HOVs

HOV first emerged in the 1960s but was not popularized owing to limited navigation and operation capabilities, a large size, and inconvenience in terms of transportation. In 1964, the Alvin HOV was successfully developed by the United States. In 1996, Alvin assisted in a salvage and in the 1970s, it discovered hydrothermal vents in the Mediterranean [12]. The maximum diving depth of Alvin is 4500 m, which allows researchers to reach approximately 2/3 of the seabeds on Earth. After upgrades and improvements, the diving depth is close to 6500 m, allowing it to cover 98% of the sea areas. The Deep Sea Challenger developed by the American Woods Hole Oceanographic Institute dove to 10 908 m in the Mariana Trench, and Japan’s Shinkai 6500 had a maximum diving depth of 6500 m.

In China, the diving depth of the Jiaolong HOV reaches 7020 m and the localization rate of the Shenhai Yongshi HOV reaches 95%. The stable performance and technical status of the core domestic equipment indicates that China has made significant progress in deep manned deep diving technology and equipment manufacturing.

3.2.3 AUVs

AUVs with low cost and excellent safety can continuously work for a long period of time. They can autonomously set routes and carry multiple underwater sensors to obtain excellent observation results of target areas. In foreign countries, AUVs have been developed for decades, and the product technology network is relatively mature with basically a stable functional performance. The countries occupying the major share of the international market of AUVs include the United States, the United Kingdom, and Norway, and there are over 100 types of AUV products on the market.

In China, AUVs developed by SIA of CAS and other institutes have completed autonomous navigation at a depth of 6000 m, but are still under the testing and evaluation stages. In the future, AUVs will be developed into bionic and multifunctional equipment, considering improvements in both flexibility and endurance.

3.2.4 Underwater gliders (UGs)

UGs move under the water driven by the horizontal power generated by the flanks, and float and dive by adjusting the internal counterweight. They carry multiple sensors such as conductivity temperature depth (CTD) sensors to search for and collect underwater environmental parameters over a wide range and conduct continuous and wide-range sensing. With these functions, UGs have become one of the most economical underwater observation tools in marine scientific explorations. The United States is the first country to research and develop UGs and has the most mature technologies, whereas France, the United Kingdom, and Japan also carried out early research in UGs.

The Haiyi underwater glider developed by SIA of CAS realizes an operating depth of 300 to 7000 m, an endurance life of 40 days, and a voyage distance of over 1000 km. The Haiyan underwater glider, developed by Tianjin University, realizes an operating depth of 3630 m, an endurance life of 30 days, and a voyage distance of over 1000 km. The research, development, and application of such products indicates that China has established a technology system for UGs [10].

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3.3 Sensors for marine observation

With the development of marine observation activities and driven by the demand for long-term and continuous observation in multiple environments such as underwater, the sea floor, and the deep sea, some countries such as the United States, Japan, and Germany have developed new types of sensors applicable to multiple marine environments, such as CTD sensors with improved accuracy. Using such sensors, the temperature is accurate to plus or minus 0.001 °C, the conductivity to plus or minus 0.003 $mS \cdot cm^{-1}$, and the pressure to plus or minus 0.015% FS.

Although sensors, equipment, and the measurement system for marine observation were developed late in China, rapid progress has been made in the field of national support. Currently, some technical indicators of China have reached the same level as similar foreign products, some marine equipment for underwater observation has been developed in a series of products, and some hydrological instruments have been applied in ocean trips and international investigations. Supported by scientific research projects such as the 863 Program and the Ocean Public Welfare Scientific Research Project, China has successfully developed various types of instruments for marine observation and sampling, such as automatic weather stations, high-accuracy CTDs, current profilers, and magenetometers, as well as deep-sea samplers such as a deep-sea TV grab and a multi-pipe sampler [13]. In addition, China has developed multiple types of marine observation platforms, including passive platforms such as surface and submerged buoys. The development and application of such equipment has led to the technical advancement of sensors exclusive for marine investigation, detection, and monitoring.

3.4 Future trends of marine equipment for underwater stereoscopic observation

With the continuous development of demands in underwater observation, marine observations have been upgraded to all-round and stereoscopic observations from the sea surface to underwater areas, and then to the seabed. This requires a marine network for underwater stereoscopic observation consisting of various observation platforms such as research vessels, surface and submerged bouys, underwater vehicles, and seabed-based observation stations to perform all-round and stereoscopic observations. Multi-platform stereoscopic observation networks will help expand the scope of marine observation from the sea surface to the underwater, and from the offshore to the high and deep seas. In the future, underwater observation platforms are expected to evolve into adaptive and organically integrated arrays of underwater observation platforms.

Driven by the demand for long-term and continuous observations of deep-sea environments and ecological environments, sensors for marine observation have become key products, including full ocean depth absolute current profilers, high-accuracy deep-sea current meters, multi-electrode salinometer sensors, fast-response temperature sensors, shear stress sensors for turbulent flows, and multi-parameter water quality analyzers. With the development of ocean observation platforms, environmental monitoring sensors with automatic compensation functions for sports platforms have also emerged, such as temperature, salinometer, turbulence, pH, nutrients, and dissolved oxygen sensors, which are applicable to mobile platforms including AUVs, ROVs, UGs, and deep-sea towed devices. In the future, the development will focus on the application of improved sensors with automatic compensation functions to the adaptive and organically integrated arrays of observation platforms.

In future underwater observation networks, marine sensor technology is expected to be developed in the direction of serialization, modularization, standardization, and generalization, whereas a marine observation platform is diverse and multi-functional. The industrialization of ROVs tends to be mature with the appearance of new types of ROVs and the improvement of marine observation instruments and equipment, providing solid support for the construction of marine equipment for underwater stereoscopic observation. In addition, because of the advancement in digital signal processors and large-capacity memories, marine observation equipment is expected to be smaller with more functions.

4 Challenges faced by China’s marine equipment for underwater stereoscopic observation

4.1 A large gap between home-grown and foreign sensors

After over a decade of development, China’s marine observation platforms have become mature, but the percentage of imported core sensors carried by observation platforms, including CTD sensors and optical sensors, remains high. Except for measuring instruments such as tide gauges and meteorological measurements, most home-grown marine observation equipment appear to have low reliability and a low level of industrialization. The management system of networked observation instruments is imperfect, and the development, production, application, and management of operational marine observation equipment are still in an uncoordinated and "sub-healthy" state. Moreover, the capacity of data collection is insufficient, as is the data quality, and under poor conditions, even the basic data necessary for early disaster warning are inaccessible through operational marine observations. For China, it is difficult to master the technologies of data collection and follow-up maintenance independently owing to the outage of equipment and the leakage of key information in marine observation activities during special periods. At present, the development of most home-grown sensors is at a stage of producing elementary prototypes or engineering prototypes, lacking competence in the international market. Moreover, some core technologies still need to be focused on to make progress, and the industrial transformation of sensor technology needs to be improved through field monitoring, testing, and application.

4.2 Disconnection between massive data and realistic demands

Marine observation data have multiple roles as the engine of research and development of key information equipment, a direct purpose in underwater stereoscopic observation networks, the carrier of transmission networks, the basis of a central processing platform, and the foundation of marine applications. After long-term development, China's remote-sensing, offshore, emersed, underwater, and other observation platforms have collected massive data but have not taken full advantage of them. From the perspective of academic research, the main reasons for this are that the inaccuracy of the data inversion, the non-scientific nature of the data collection, and the unintelligent knowledge service. After the collection of massive data, the effectiveness and efficiency of data use should be improved to serve the ultimate goal; otherwise, "isolated data islands" will be formed, making it difficult to produce an actual performance and return on investment.

4.3 Lack of application testing and necessary improvements for home-grown sensors

Currently, marine monitoring institutions are still applying multiple-party management, which leads to scattered research forces and an unbalanced allocation of resources, thus hindering the development of key projects. In terms of information processing and collection of underwater stereoscopic observation networks, the service targets are insufficiently clear, the scope and objects of information flow are relatively low, the standards of information collection and exchange are inconsistent, the levels of data integration and utilization are low, and the enthusiasm of social forces to participate is not high, which is not conducive to the application of underwater observation information. Consider the special project in the field of marine technology of the 863 Program as an example. Some home-grown sensors are basically in the prototype phase and have yet to be used in the field, making it different to perform necessary corrections and improvements. Some home-grown sensors are only on trial and have not entered the productization phase, or gained any updates, improvements, or corrections. Owing to insufficient resource support and a lack of conversion mechanisms in subsequent applications, improvements, and experiments, a gap has appeared between R&D and industrialization.

5 Key technical trends of marine equipment for underwater stereoscopic observation

In addition to marine observation platforms, marine sensors carried by these platforms have become key to marine underwater stereoscopic observations. After carrying underwater operating instruments, such as marine observation and detection devices and seabed samplers, different types of underwater observation platforms jointly play a role in a comprehensive technical network. The development of all types of sensors, detection devices, and general and exclusive operation tools that can be carried by submersibles is a fundamental approach to advance underwater operation technologies, as well as an important way to understand the seas and exploit deepwater resources.

It is worth noting that, although China has made significant progress in traditional technologies of marine observation and sensing, and has gradually reached the international standard, large gaps still exist in new sensors types and special-function sensors, particularly in high-accuracy CTD, expendable temperature/depth sensors, expendable conductivity/temperature/depth sensors, acoustic Doppler current profilers, and phased array acoustic Doppler current profilers. Efforts should be made to improve the comprehensive performance of marine equipment for underwater observation and detection and strive for the full localization of key sensors. While keeping up with hotspots of research on platform technology such as mobile platforms and networking observation, efforts should also be made to plan for effective responses to the potential challenges faced by future sensors of being smaller and anti-fouling and reducing power consumption.

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5.1 *In situ* biochemical sensors

It has been decades since the first physical oceanographic sensors were produced. Internationally, sensors for measuring the conductivity, temperature, and depth have achieved a high level of maturity and miniaturization, whereas the progress of biogeochemical and biological oceanographic observation sensors has lagged seriously behind. To realize the sustainable development of marine econetworks, it is necessary to understand and master the whole life chain of oceans from plankton to whales, not only focusing on edible fish. Biological oceanographic monitoring technologies are imperfect both in and out of China, creating a good opportunity for China to advance its research in biological oceanographic sensors. Internationally, biological monitoring has gradually gained attention, and new chemical measuring technologies (such as nitrate and phosphate) have been developed and are expected to be applied in the near future. Therefore, China should keep pace with the international community and attach importance to and develop related sensors, such as *in situ* nutrient sensors, 220 nmbUV-VIS spectrophotometers, *in situ* silicate electrochemical sensors, and *in situ* nitrate electrochemical sensors.

5.2 *In situ* chip technology for marine observation

None of the reagent-based chemical and biological sensors publicly sold in the international market has applied the *in situ* lab-on-a-chip (LOC) technology because the technology patent is only authorized to a few countries, such as the United Kingdom and Japan, and to a few laboratories. Although new progress has been made in microfluidic and LOC technologies, their potential for marine observation still remains to be explored and clarified. With a potential excellent performance and low cost, *in situ* chip technology for marine observations can measure various parameters underwater, significantly improving the results of marine observations. To popularize *in situ* chip technology, it is necessary to improve its usability by improving the supply and exchange, the integration of reagents, and the extension of time. In addition, the technology is expected to play a promising role in the measurement of biological parameters.

5.3 Antifouling technologies of sensors

The accumulation of biological fouling can interfere with the operation of sensors, reduce the water flow to sensors, impede the mechanical movement of platforms, increase the mass and resistance of instruments, and affect the accuracy of observation results. Therefore, protecting sensors from biological fouling is extremely important. Traditionally, the main antifouling measures use antifouling paints, coatings, or substrates that prevent biofouling, which are not friendly to the environment under observation. They also use wipers with different frequencies to remove all kinds of newly deposited fouling and to prevent the deposition of organisms using ultraviolet irradiation, freshwater rinses, and nanocomposite coatings. In areas with highly accumulated fouling such as the East China Sea, sensors need to take multiple measures to protect themselves from fouling. In the future development of sensors, biological adhesion should also be considered. According to the fouling environment, antifouling measures with different frequencies should be taken. In particular, attention should be paid to antifouling solutions including active wipers, electrolytic chlorination schemes, ultraviolet radiation, and nanocomposite coatings.

6 Suggestions

6.1 To support effective transformation of research results

Sensors are the most important part of underwater observations, and their performance directly reflects the level of marine equipment for underwater stereoscopic observations. In China, it is difficult to transform the results of R&D projects on marine sensors into effective outcomes due to a lack of follow-up support. This leads to a disconnection between the supply of sensor technologies and the market demand, and the lack of necessary trials and improvement in the R&D of products, thus affecting the input-output ratio of R&D. These common problems faced by different types of key marine sensors should be sorted out in time and solved.

It is recommended to carry out a top-down design to demonstrate the overall planning for marine sensors at the national level and strive for necessary resources related to the development and application of key marine sensors, adopt a market-oriented approach and formulate clear rules to promote the efficient transformation of scientific and technological achievements in key marine sensors, encourage innovations in development and application to focus on the breakthrough of key technologies of sensors that are in urgent demand and difficult to be imported in China, and provide necessary policy support.

6.2 To coordinate the construction of a big data processing and sharing center for marine underwater stereoscopic observation

Marine observations take a large amount of funds, long study periods, and effort from multiple parties. It is normal for multiple units or even multiple countries to jointly implement a marine project. On one hand, a multidisciplinary cooperation can realize a combination of different disciplinary backgrounds, including different academic and different levels of research forces based on a shared marine observation platform, so as to solve major issues in marine sciences. On the other hand, a shared marine observation platform can significantly improve the cooperation efficiency and promote technological progress and update observation equipment and key sensors. With the continuous development of marine equipment for underwater stereoscopic observation, massive data have been accumulated; thus, the processing, integration, supply, and management of data have become an urgent task. It is the joint responsibility for the competent departments and scientific research personnel to realize data sharing to eradicate the phenomena in which domestic researchers can only share data with foreign countries, and some domestic data can only be obtained through foreign channels, and to reverse the situation in which the ocean-related data are self-isolated and self-managed.

It is recommended that the construction of a big data processing and sharing platform for underwater stereoscopic observation be put on the agenda to carry out an overall planning in the field and build a data sharing system, taking full advantages of existing national major technological infrastructure to support the development of key technologies of marine equipment for underwater stereoscopic observation and thereby steadily advance the localization of key equipment, sensors, and observation instruments, allowing China to be ranked among the most advanced countries in the world in marine equipment and environmental monitoring.

6.3 To establish a national public trial platform for marine equipment for underwater stereoscopic observation

Establishing a national public trial platform is conducive to equipment testing and program improvement to strengthen the performance of marine equipment and can help train researchers and technicians in the field of marine sciences. In addition, the platform can collect experience in the development, research, and improvement of marine equipment and instruments, leading to the acceleration of engineering applications.

It is recommended to establish a national public trial platform of marine equipment for underwater stereoscopic observations, which is run in an enterprise-operated, business-driven, and market-oriented manner, providing long-term, continuous, real-time, multidisciplinary, synchronized and integrated equipment testing as a piece of infrastructure; and to build offshore test fields that can share resources and be used both by the army and the people, offering unified and high-quality services for the research, development, testing, and engineering of China’s marine equipment and models.

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