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Conception and Key Technologies of Deep-Sea Information System

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Abstract: Deep-sea information systems can facilitate the collaboration of deep-sea equipment and perform a systematic function when applied to deep-sea resource exploitation and research. This study analyzes the demand for building a deep-sea information system to support the collaborative environment of equipment, and explores the elements, focus, major challenges, and key technologies of the deep-sea information system. To promote the development of the deep-sea information system, we propose to strengthen top-level planning, focus on key technologies, and conduct timely demonstration applications.

Keywords: deep-sea utilization; information system; system construction; intelligence

1 Introduction

Because of its rich resources, wide space, and significance within the fields of politics, economics, military, scientific research, and ecology, deep sea has become a place of strategic importance for major powers in the 21st century. The demands for ocean development continue to grow and the generation of new information technologies, such as Internet of Things, cloud computing, big data, and mobile internet, expands rapidly. These technologies have been used to improve the human potential of "knowing, planning, and controlling the ocean" and have already become a major impetus in advancing developments in the marine industry. China will handle the relation among the marine military, economy, and science and technology appropriately, by choosing a collaborative and open method. With science and technology taking priority, China strives to become eminent to win leadership at sea [1].

In the civil field, the traditional maritime great powers have always focused on the "Movement of Blue Enclosures" in marine development. The U.S. has maintained a leading position in deep-sea activities and is currently in possession of the largest deep-sea resources and highest research level of development technologies. Considering the demands on strategic resources, Japan has been the world leader in investing in survey/development/scientific research of deep-sea metal minerals, gas hydrate, and deep-sea biology genes in recent years. Newly industrialized countries, like South Korea and India, also actively participate in competing for regional sea-bed resources. For example, in 1998, South Korea succeeded in developing a 6000 m undersea robot. Moreover, they have already conducted a mineral selection survey on hydrotherm sulfide and cobalt-rich crust minerals in a related area of the Pacific Ocean. India has also invested considerable resources in deep-sea development [2].

In the military field, poor permeability, significant changes in pressure, and complex hydrological characteristics in deep-sea space makes sensing difficult, but the performance of hidden and sudden tasks easy. Thus, it becomes the sixth dimension of important strategic domains after land, sea, air, space, and

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electromagnetics [3,4]. Systematic deep-sea military strength is built centered on deep-sea depots, based on deep-sea communication systems, supported by deep-sea logistic systems, and taking the strike as methods, which can implement maximum effectiveness in deep-sea battles and may disrupt the traditional approach of maritime war [5]. From the perspective of submarine platforms, underwater unmanned systems, sea-bed surveillance systems, and anti-submarine equipment, the U.S. has, to date, been the world leader [6–10] with ongoing development to build a deep-sea force, perfect deep-sea doctrines, and research deep-sea weapon systems. Russia has always regarded submarine platforms and underwater combat capability as important methods to maintain maritime asymmetric military balance, and therefore, has unceasingly developed equipment and technologies, such as new-type submarines, underwater propulsion, and comprehensive detection, making considerable effort to enhance its deep-sea military strength.

Since the 1950s and 1960s, with the technical consolidation and innovation with respect to deep-sea detection, communication, navigation, and information exploitation, maritime great powers have gradually constructed a deep-sea multi-dimensional information system and given priority to the development of a comprehensive information support capability among deep sea, shallow water, surface, air, space, and electromagnetics. Centered on the construction of ocean information systems, international organizations and ocean great states, or parts of the world, such as U.S., Europe, and Japan, have made significant investments on a series of remarkable projects in rapid succession. These projects include global ocean real-time observation network project (ARGO), integrated ocean observation system (IOOS), Neptune sea-bed observation network project (NEPTUNE), European sea-bed observation network (ESONET), and intensive earthquake sea wave sea-bed monitoring network (DONET), etc.

China have gradually developed and further conducted exploitation and maintenance of maritime rights and interests, such as sea dynamic systems, resource exploration and development, and strategic resource protection, which introduced completely new requirements on “knowing, planning, and controlling the ocean.” Corresponding to this, marine informatization, construction, and application have become fields that require urgent development. Additionally, deep-sea informatization and intelligentization have become an important development trend of the “digital ocean” [11]. With the successful research and successive deployment and application of large marine equipment, such as deep manned platforms, unmanned vehicles, and deep-sea preinstalled devices, the synchronization of planning and developing deep-sea information systems and deep-sea informatization construction become our top priorities.

2 Problems

The deep-sea information system comprises many types of information facilities that are functionally interrelated and interact with each other, and mutually complementary in their performance. The system elements, including various sensing devices, platforms, operation command and dispatch management functional systems, etc., can interconnect and intercommunicate via many types of communication methods and with other shore-based, air, and surface platforms, forming a system capable of obtaining, processing, and sharing information over a wide area. Thus, the requirement to obtain and exploit information of deep-sea operating personnel/platforms will be guaranteed.

The deep-sea information system should consider the requirements for both military and civil applications, integrate various information resources, and improve the deep-sea information perception and sharing capabilities. However, we face a series of difficult challenges in the construction of the deep-sea information system (Table 1) due to limitations of the deep-sea physical field characteristics and deep-sea equipment capabilities.

3 Tentative idea

Focusing on the requirements for observation, exploitation, management, and support of deep-sea information, a tentative idea with regard to deep-sea information system construction is presented. The deep-sea information system includes five aspects: deep-sea information perception, deep-sea information transmission, deep-sea operation management, deep-sea integrated support, and deep-sea security protection. The elements involved are: detection, communication, navigation, control, support assurance facilities that depend on deep-sea platforms/units, deep-sea dependence and sea-bed detection, navigation and communication facilities, as well as external resources such as information, laws and regulations, and doctrines.

(1) A sea information awareness system mainly comprises various sensors that are fixed to the sea-bed and a deep-sea buoy that is configured in a deep-sea platform, which can be manned or unmanned. It possesses collection and perception capabilities for various acoustic, optical, and electromagnetic field information, which

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are used for the collection of information about peace-time underwater environmental and listening for and detecting underwater targets, to meet the requirements of information perception in all-weather and entire frequency domains. Additionally, it can interconnect with the surface and air, and even space-based sensing systems to perform the function of perception at a larger system level.

Table 1. Main challenge in construction of deep-sea information system.

Main challenge	Constraints	Influence on system construction
Limited system resources	Payload of most deep-sea units is small, with limited size of platform, which is insufficient for support assurance	Small system size, with limited control range of sea area
Limited perception capability	Limited in underwater detection, identification, surveillance range, and threat identification capability	Difficult to precisely grasp deep-sea environment and situation
Limited navigation positioning methods	Small number of navigation positioning methods of low precision	Difficult for precise positioning over a large range, which will affect operation planning, route planning, and route safety
Limited communication capability	Close range, low velocity, and a small number of methods	Difficult to perform manned/unmanned autonomous coordination, which will limit the size of unmanned clusters
Constrained in platform information management capability	Constrained by platform computing capability and increased power consumption, with limited degree of intelligent information processing, decisions, and control intelligentization	Insufficient capability of operational dynamic planning and control, with a degree of system intelligentization and system intelligentization being difficult to improve
Limited integrated support	Constrained by insufficient electrical support and equipment support	System size and endurance will be affected
Lack of security protection	Long periods of time with unattended operation, lacking the capability of perceiving attacks and protecting against them	Limited platform and system safety, and vulnerable to damage and attack
Insufficient basic data	Limited in seizure of information on laws and standards, sea-floor relief, ocean current, bioecology, and geological structure	Operation planning and autonomous navigating will be limited

(2) A deep-sea information transmission system mainly comprises equipment including sea-bed fixed optical fiber communication, underwater very low frequency communication, underwater wireless radio frequency communication, acoustic spread spectrum communication, underwater laser communication, underwater communication by neutrino, as well as buoy datalink and satellite communication antenna. They are used for transmission of deep-sea perception and control information, and interconnection and intercommunication with surface, air, shore-based, and space-based information systems.

(3) A deep-sea job system mainly comprises a deep-sea space station, unmanned underwater vehicle (UUV) and autonomous underwater vehicle (AUV), deep-sea preinstalled device, and deep-sea job management tool and control system. The payload of a deep-sea space station is large (hundreds or even thousands of tons), which can carry operation submersibles and tools with extensive functions to perform deep-sea engineering operations in water areas with a depth of 1000–3000 m. The light-weight, medium-weight and heavy-weight types of UUVs and AUVs are capable of performing tasks such as oceanographic survey, ocean detection, underwater transportation, mine laying and hunting, and intelligence reconnaissance. Deep-sea preinstalled devices can supply energy and provide navigation positioning and time checking facilities to deep-sea mobile platforms. Deep-sea operation tools are important for expanding the operation capability of deep-sea vehicles and improving the deep-sea scientific investigation capability. Based on specific exploration tasks and scientific research goals, differentiated configuration can be realized. The operation management and control systems are crucial for the construction of deep-sea information systems, which are deployed on deep-sea operation platforms to perform tasks of comprehensive system resource management and control, multi-source information processing, comprehensive information management, single-platform/cluster operation command and dispatch, control, and security protection management and control.

(4) A deep-sea integrated support system mainly includes the ocean geographic environment, ocean hydrographic meteorology, basic data construction and support as well as ocean engineering construction, search and rescue, and navigation positioning information services. In deep and distant sea areas that are closely related to our interests, we should expedite the construction of hydrographic information big data systems to provide information support for the maintenance of our rights and interests.

(5) A deep-sea security protection system mainly includes deep-sea surveillance and monitoring facilities, such as deep-sea fixed monitoring network and large acreage mobile monitoring network as well as deep-sea safeguarding facilities to perform tasks of warning, jamming, interception, and expelling. Therefore, the requirements for underwater security protection of important sea areas, protection of important deep-sea facilities, and anti-submarine early warning systems will be met.

4 Analysis on key technologies

4.1 Deep-sea detection technology

By developing new-type detection, deep-sea multi-platform detection, and networked coordinated detection technology, the detection range will be significantly improved. The development of new-type endurable mobile + fixed deep-sea detection technology, the monitoring and control capability for deep-sea main routes will be enhanced. Large-range endurable mobile multi-dimension network monitoring and reconnaissance capability will be improved by developing underwater/deep-sea unmanned platform networked detection technology. Strengthening the coordinated detection technology of manned + unmanned system platforms will enable multi-dimensional spatial network unattended capability [11] to be built.

4.2 Deep-sea communication technology

A sea-bed diversified network system should be constructed and new-type technical applications through media should be expanded. By developing new methods and equipment for deep-sea acoustic communication transmission with a high transmission rate, long transmission range, and high reliability, comprehensive using sea optical fiber cable, buoy, and acoustic communication to build a network, and using the underwater unmanned platforms as mobile relay nodes, underwater information transmission in a wide range of sea areas will be accomplished. By integrating various communication resources such as platforms, systems, and shore-based base stations in a wide range of sea areas, and constructing a multi-platform, multi-method, diversified, networked, and systematic deep-sea information transmission system, more communication support can be provided for the construction of an integrated system from deep sea to space.

4.3 Deep-sea navigation technology

By developing underwater geomagnetic matching navigation technology, accurate navigation information can be obtained according to the geomagnetic field amount or tricomponent information of the carrier position as well as geomagnetic map information. By developing global ocean underwater positioning technology and combining acoustic communication with satellite navigation systems, precise positioning capability, similar to that of the global positioning system (GPS)/China Beidou satellite navigation system (BDS), will be provided to deep-sea platforms. Furthermore, navigation precision will be improved by developing quantum navigation technology. Therefore, detection/communication/navigation integrated intelligent information processing technology should be developed.

4.4 Deep-sea job control technology

By developing technologies for designing deep-sea operation control system and constructing deep-sea data resource, multi-source information processing and support on demand, deep-sea platform resource intelligence management and control, coordinated perception and task dynamic planning, cluster operation cooperation and autonomous control, and library management of deep-sea ocean and target characteristics, the intelligentized deep-sea equipment systems that can sense both stereoscopically and transparently in deep sea and that are secure and reliable as well as capable of cross-domain information sharing will be constructed. Thus, multi-layer comprehensive integration and operation control capability of single-platform, multi-platform, and clusters of deep-sea equipment will be built to support the construction and application of deep-sea information systems and deep-sea data resource systems.

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5 Development suggestions

During the three-step implementation phase of the development strategies, i.e., “deep-sea entry, deep-sea detection, and deep-sea development,” an efficient and secure deep-sea information system has always been the crucial for deep-sea development and exploitation. Based on the fundamental realities of the country, technical aspects, and future requirements, the following targeted development suggestions are presented.

5.1 Enhance top-level planning of deep-sea information system

Top-level design should be enhanced, with a focus on system-coordinated development to improve deep-sea system capability. The deep-sea detection, navigation, and communication system should be developed. By developing resource management, mission planning, task management decisions, control mission systems, the autonomous navigating, autonomous intelligent operation, and autonomous intelligent safeguarding system, deep-sea data system engineering should be enhanced and platform autonomous capability should be built. By developing manned/unmanned coordination, unmanned cluster coordination, and cross-system coordinated (coordinated situation awareness and evaluation, coordinated task assignment, coordinated route planning, coordinated navigating control, and coordinated intelligent decision) systems, the platform-coordinated autonomous capability construction should be strengthened.

5.2 Enhance deep-sea equipment spectrum planning

The information equipment spectrum should be standardized to guide serialized equipment research, adapting to deployment requirements of deep-sea equipment of different sizes and different tasks. The standard specifications from the aspect of information collection, information exchange, and information control should be built to support comprehensive integration inside the system and among other systems.

5.3 Enhance breakthrough of key technologies and equipment research

Major breakthrough directions that may constrain the system development should be planned in advance. Research on key technologies, such as quantum detection, multi-base networked detection, underwater integrated navigation positioning and timing, gravity field navigation as well as platform autonomous intelligent control, cluster joint perception and intelligent autonomous coordination, ocean big data analysis, exploitation, etc., should be strengthened, to provide support to deep-sea equipment development and system construction.

References

[1] Wang P X. The opportunities in the deep sea and China’s choice [J]. Frontiers, 2017 (18): 4–11. Chinese.

[2] Li J, Jiang X Y. Promoting the construction of marine power: Ocean information interoperation, deep integration and smart application—Summaries of the China ocean information technology forum 2018 [J]. Marine Information, 2018, 33(3): 6–10. Chinese.

[3] Han S P, Cheng Y S. Development and current situation of U.S. underwater detection system [J]. Modern Navy, 2011 (7): 24–29. Chinese.

[4] Ewing D. Jane’s underwater warfare systems 2011—2012 (23rdedition) [M]. London: Jane’s Information Group, 2011.

[5] Zhang Y, Song J W, Chen S L. The development and key point of China’s marine information equipment [J]. Marine Information,2018, 33(3):62–65. Chinese.

[6] United States Navy. Autonomous undersea vehicle requirement for2025 [R]. Washington DC: United States Department of Defense,2016.

[7] Defense Science Board. Next-generation unmanned undersea systems [R]. Washington DC: Office of the Secretary of Defense,2016.

[8] United States Department of Defense. Unmanned systems roadmap2017—2042 [R]. Washington DC: United States Department of Defense, 2018.

[9] DARPA. Positioning system for deep ocean navigation (POSYDON)[R]. Virginia: DARPA, 2015.

[10] Yang Z D, Li R, Cai W J, et al. Development and key technologies of preset undersea weapon: A review [J]. Journal of Unmanned Undersea Systems, 2018, 26 (6): 521–526. Chinese.

[11] Wang J. Investigation into underwater net-centric warfare information systems [J]. Command Information System and Technology, 2010, 1(5): 6–8. Chinese.