Scholar Publishing Group
Frontiers in Ocean Engineering
https://doi.org/10.38007/FOE.2021.020101
ISSN 2790-2706 Vol. 2, Issue 1: 1-9

# *ROV Deep Sea Positioning in Ocean Engineering Based on Long Baseline System*

**Memon Shahbaz***

*Radboud Univ Nijmegen, Nijmegen, Netherlands*

**corresponding author*

***Keyword:*** Long baseline System, Deep Sea Positioning, Underwater Working Robot, Underwater Acoustic Positioning

***Abstract:*** In view of the demand for high-precision exploration in the complex environment of the deep-sea area, the project team has proposed an underwater working robot (ROV), which can use the precision instruments carried to realize independent scientific exploration and exploration of the deep-sea area. Combined with the structural characteristics of ROV, the corresponding long baseline underwater acoustic positioning algorithm is proposed, so as to provide real-time and accurate spatial coordinates for ROV in seabed operation. In order to verify the principle of the variable baseline underwater acoustic positioning system in the follow-up test, this paper designs a set of long baseline underwater acoustic positioning system, and studies the software and hardware design of its data processing platform, the data post-processing display and control platform and the test verification of the silencing pool. Through the design and research analysis, the ROV deep-sea positioning system based on the long baseline system designed in this paper can be well applied in the actual work, Help ROV solve positioning problems.

## 1. Introduction

The reserves of oil and natural gas in China's adjacent sea areas are about 4-5 billion tons. In order to better explore and develop marine resources, it is necessary to strengthen the research and development of marine engineering exploration devices and production equipment [1]. Offshore oil and natural gas development from exploration, drilling, production to crude oil transportation requires a large number of underwater equipment installation, maintenance and overhaul. Underwater operation is complicated and requires high technology and accuracy. Remote operated vehicle (ROV) with cable is one of the important equipment indispensable for deep-sea oil and gas exploration. ROV can undertake some heavy tasks, such as installation, inspection and maintenance of submarine oil pipelines, installation of auxiliary oil extraction equipment, etc. [2].

The operation of ROV and its dependence on positioning system, underwater acoustic positioning technology can be divided into three types according to the length of receiving array elements: ultra short baseline, short baseline and long baseline [3]. The distance between each array element of the long baseline positioning system is between several hundred meters and several kilometers. The position coordinates of the measured carrier are solved by using the distance between the underwater target sound source and multiple observation nodes; The distance between each array element of the short baseline positioning system is several meters to several tens of meters. The distance between each transducer and the transponder is calculated by calculating the underwater acoustic propagation delay value of each receiving transducer and the transponder, and the position information of the measured carrier is calculated by using the spherical intersection model; The length of ultra short baseline positioning array is only a few centimeters to tens of centimeters [4]. The acoustic array and the transponder measure the underwater acoustic propagation delay value through interrogation and response, and calculate the distance between them. The azimuth of the measured carrier is calculated through the phase difference of the received signal. At present, Kongsberg company of Norway has been studying long-range baseline navigation and positioning technology for a long time. Its hipap700 long-range acoustic positioning system launched a few days ago has a theoretical maximum operating range of 8000m, a maximum working depth of 6000m and a positioning accuracy of 12m [5]. At present, underwater vehicles are mainly divided into two categories according to whether they are manned or not. The first type is manned underwater vehicle; The second category is unmanned underwater vehicles. Unmanned underwater vehicles are smaller in size, more diverse in variety and lower in development cost. The manned underwater vehicle requires the driver to control the underwater movement of the robot in the control room inside the robot. The submergence depth of the submersible is relatively large, and it is usually used for the exploration of seabed resources and the acquisition of deep-sea terrain information. Jiaolong is a typical representative of manned underwater robot, and also a landmark achievement in the development of China's deep sea exploration equipment [6].

In view of the importance of the deep-sea positioning system in ROV and the important position in the utilization of marine resources, the long baseline underwater acoustic positioning system is designed to meet the needs of ROV for high-precision detection in the complex environment of the deep-sea area, so as to verify the principle of the positioning system in the subsequent experiments. Through a series of data analysis and verification, we draw relevant conclusions.

## 2. Overview of Related Concepts

### 2.1. Overall Structure of ROV

The underwater working robot is mainly composed of four parts: surface console, power cabinet, umbilical and ROV body [7]. The power cabinet provides power for the surface console and ROV body. The umbilical cable is the medium connecting the surface control system and the underwater control system. It is used for both power transmission and data communication. The ROV surface control system is composed of three parts: the power cabinet, the surface console and the umbilical cable [8]. The water surface monitoring system is composed of four display screens, control panel, hard disk video recorder, STM32 single chip microcomputer, industrial computer and photoelectric converter. There are color display lights for alarm and prompt on the control panel, control switches, buttons and handles for controlling the underwater robot [9].

### 2.2. Time Difference Positioning Method

In the TDOA positioning method, the solution method of time difference of arrival of conventional active radar and external emitter radar is different. The conventional active radar is integrated with the transceiver, and the arrival time difference refers to the time difference between the signal and two different receiving stations [10]. In the external radiation source radar, the time difference refers to the difference between the total time of the signal passing through the target from the transmitting station to the receiving station and the time from the transmitting station to the receiving station [11]. In the single transmitter and single receiver external emitter radar system composed of the same group of receiving stations and transmitting stations, the curves corresponding to the toa based and TDOA based information positioning equations are ellipsoids with the same focus, and both use distance and information for positioning, which are essentially the same. By solving the arrival time difference instead of obtaining the arrival time, it is not necessary to know the arrival time of the signal accurately, which can reduce the requirements of the system for time accuracy [12]. Since the multiplication of time difference and velocity can be converted into the sum of distance from the target to the transmitting station and the receiving station, the following text refers to the time difference positioning method with distance and positioning.

### 2.3. Differential Doppler Positioning Method

When the target and the receiving station move relatively, the reflected signal of the target has Doppler effect, and the frequency of change caused by Doppler change is called Doppler frequency [13]. Multiple groups of transceivers are used to observe the Doppler frequency of the target signal. There is a frequency difference between the Doppler frequencies of each group, that is, differential Doppler. Since the satellite is used as the illumination source, there is relative motion between the transmitting station and the target, and there is Doppler frequency shift, so the target can be located by using the Doppler frequency difference between multiple stations. The differential Doppler positioning equation obtained by the two transmitting stations is a complex quadratic function. Only two transmitting stations cannot be used for accurate positioning, and the positioning solution is fuzzy. Therefore, for the two-dimensional plane, no less than three stations are required to locate the target, and for the three-dimensional plane, no less than four stations are required to achieve positioning [14].

### 2.4. Basic Principle of Long Baseline Underwater Acoustic Positioning

First of all, before the deployment of the submarine buoy and ROV, it is necessary to use the GPS high-precision clock to complete the clock synchronization on the shore [15]. Secondly, as the positioning origin, the submarine buoy needs to determine its own earth coordinates (WGS84) before ROV work. The mother ship's four point positioning method is adopted to solve the coordinates of the current deployment position of the submarine buoy through the spherical intersection model [16]. Then, after the fixed time point arrives, the submarine buoy transmits a linear frequency modulation signal with a frequency of 7-11khz every 3S. The ROV synchronously receives the acoustic signal through the hydrophone array mounted on the front and rear cabins, and completes high-precision time delay estimation by using the built-in data processing platform. It multiplies the effective sound velocity corrected by the sound velocity to calculate the oblique distance between the ROV and the submarine buoy. The real-time position coordinates of ROV can be solved by using the real-time attitude and depth data provided by the attitude sensor on ROV and the temperature and salt depth meter. Finally, the acoustic communication machine carried by the ROV maintains data communication with the upper computer on the mother ship to display the three-dimensional coordinate position of the ROV in real time [17].

In the geodetic coordinate system, assuming that the position coordinates of the sound source are

R0 (x0, Y0, Z0), it is necessary to obtain the coordinates R1 (x1, Y1, z1) of the head hydrophone and the coordinates R2 (X2, Y2, Z2) of the tail hydrophone through the positioning model. The baseline length L is the linear distance between the head and tail hydrophones on the ROV. The baseline pitch angle is obtained by solving the three-axis gyroscope carried by the ROV and the two-way joint angle data α Roll angle γ and baseline length L; The depth Z1 of the head hydrophone is measured by the temperature salt depth meter; The effective sound velocity determined by the sound velocity profile can obtain the oblique distances R1 and R2 between the underwater target sound source and the two hydrophones. The specific formula is as follows:[18]

$$x_{1i} = x_0 + A\cos^2\gamma \, \mu \sin\gamma\sqrt{c^2t^2{}_1 - H_1^2 - A^2\cos^2\gamma} \tag{1}$$

$$y_{1i} = y_0 + A\sin\gamma\cos\gamma \, \mu \cos\gamma\sqrt{c^2t^2{}_1 - H_1^2 - A^2\cos^2\gamma} \tag{2}$$

$$x_{2i} = x_0 + A\cos^2\gamma \, \mu \sin\gamma\sqrt{c^2t^2{}_1 - H_1^2 - A^2\cos^2\gamma} - L\cos\alpha\cos\gamma \tag{3}$$

$$y_{2i} = y_0 + A\sin\gamma\cos\gamma \pm \cos\gamma\sqrt{c^2t^2{}_1 - H_1^2 - A^2\cos^2\gamma} - L\cos\alpha\sin\gamma \tag{4}$$

## 3. Design of ROV Deep Sea Positioning Platform Based on Long Baseline System

### 3.1. Design Environment Requirements

The data processing platform needs to collect the 6-channel signals of the head hydrophone array and the tail hydrophone array, process and store them, and then acquire ROV attitude, depth and other data through the master computer for joint positioning calculation. The whole positioning computing platform must have the characteristics of strong computing capacity, small size, low power consumption and strong reliability. The detailed design requirements are as follows:

(1) Communication bus: 3.3 V RS422 bus is adopted, and the communication protocol is compatible with the master computer;

(2) Signal conditioning circuit: used for sensor signal conditioning and amplification;

(3) DSP processor: word length: 16 bits; Working frequency: not less than 400 MHz; Computing capacity: not less than 2000 MFLOPS; Cache: no less than 320 KB; Power consumption: lithium battery can be used for power supply;

(4) ROM: ≥ 1 Gbit, which can be used to store programs and original collected data;

(5) Ram: ≥ 1 Gbit, used to store intermediate data processing results;

(6) A / D conversion: support 6 channels of input; Conversion bits: 16 bits; 6-channel simultaneous sampling conversion can be realized, and the maximum acquisition speed is greater than 600 ksps;

(7) Status indication: indicate the current working status and fault type through the flashing frequency of LED;

(8) Software maintenance interface: JTAG debugging interface is reserved at the board level and flash ROM program can be written through JTAG;

(9) Power supply indication: indicate the current power supply status of the acquisition board through the LED;

(10) Extension interface: provide GPIO, UART, RTC and other interfaces for secondary development;

(11) Circuit board area: not more than 200 mm × 60 mm;

(12) Ambient temperature: working temperature: - 10 ℃ ~ + 55 ℃; Storage temperature: -

40 °C ~ + 70 °C; The relative humidity is not less than 95%;

(13) Power consumption: rated power consumption is not more than 15 W;

(14) Watertight: the watertight box installed in the circuit has a hydrostatic pressure of 1000 m.

## 3.2. Platform Design Scheme

According to the above design requirement analysis and considering all aspects, the platform adopts advanced digital signal processing hardware calculation circuit, which is composed of signal conditioning circuit, a / D conversion chip, DSP processor chip, memory chip, communication chip and power supply circuit. The DSP positioning calculation circuit is located in the watertight compartment of the positioning circuit, and the head and tail hydrophone arrays enter the positioning circuit through two 8-pin watertight connectors, After being amplified, shaped and filtered by the signal conditioning circuit in the positioning circuit, the analog signal is converted into digital signal by the A / D conversion chip. Then, the DSP processor is used to process and calculate the collected latent target signal and the attitude data sent by the master computer. Finally, the calculated ROV three-dimensional position information is transmitted back to the master computer through RS422 serial port.

# 4. Numerical Analysis Results

## 4.1. Data Analysis of ROV Depth Determination Experiment

Firstly, the experiment of dynamic positioning of underwater working robot is carried out. The fixed depth value is 2m. It can be seen from the figure that the error is gradually decreasing.

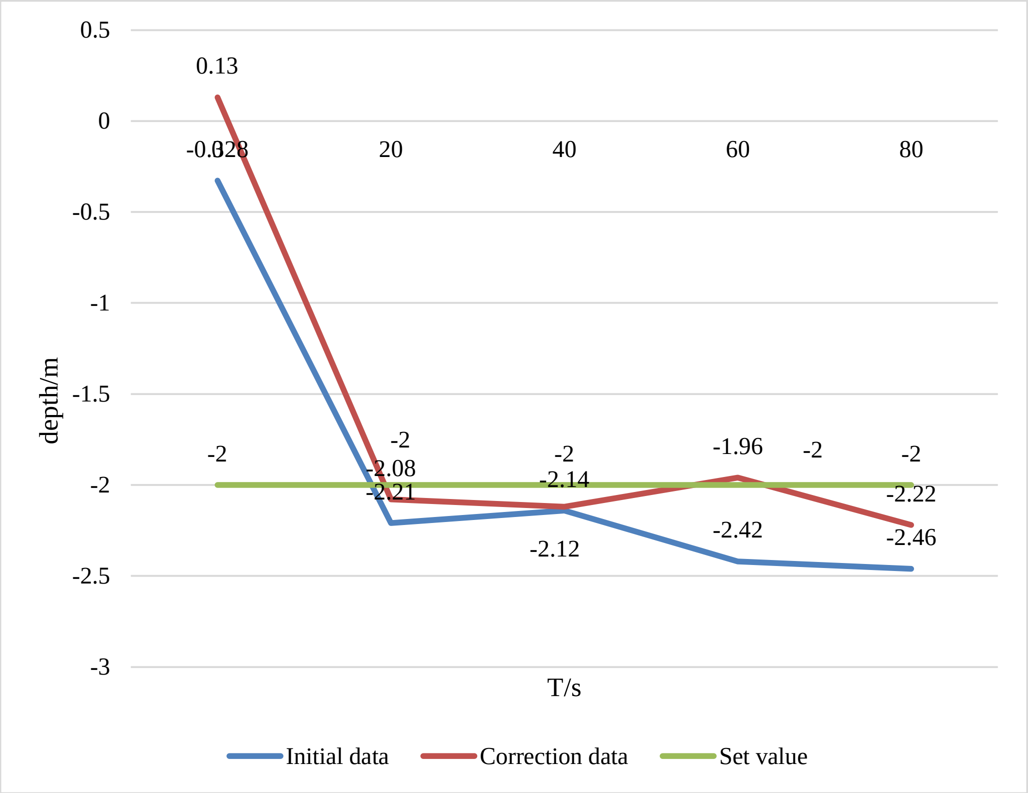


*Figure 1. Data of fixed depth experiment*

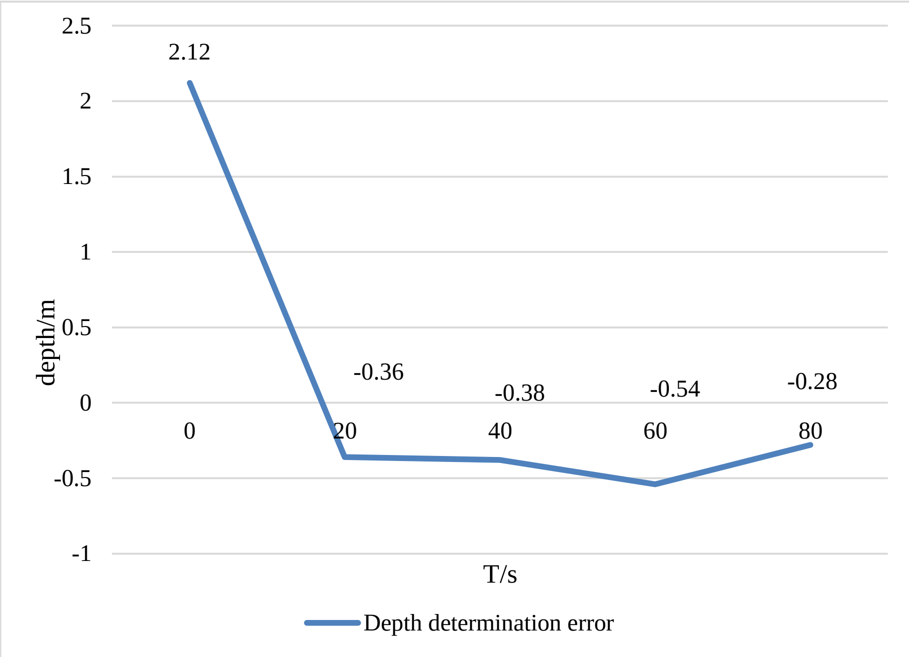


*Figure 2. Depth determination error data*

## 4.2. ROV Fixed Navigation Experiment

According to the experimental data measured at 280 degrees, the fixed navigation curve is drawn as shown in Fig. 3 and Fig. 4. The ROV is subject to two small disturbances in the course of fixed navigation. At this time, the error is large, and then the propeller adjusts the thrust, and the error gradually decreases.

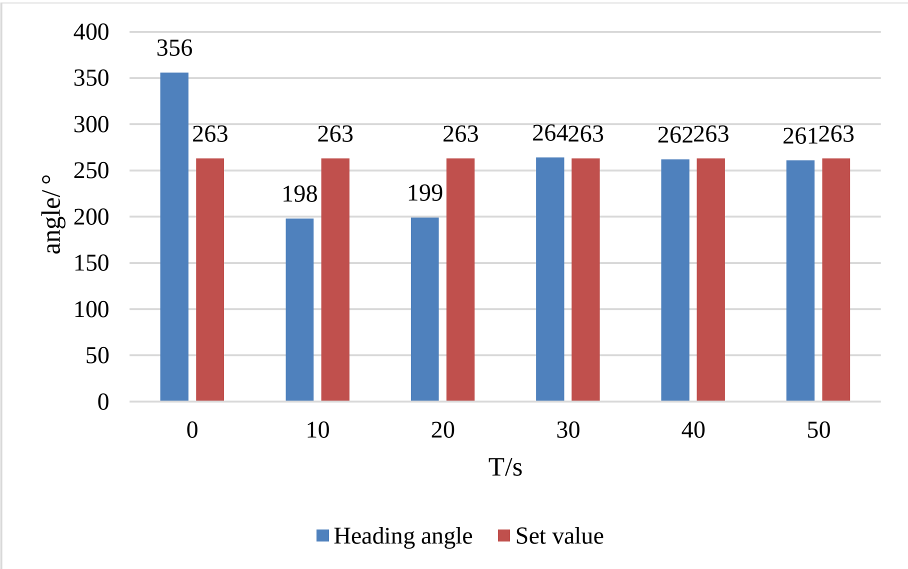


*Figure 3. Fixed navigation data*

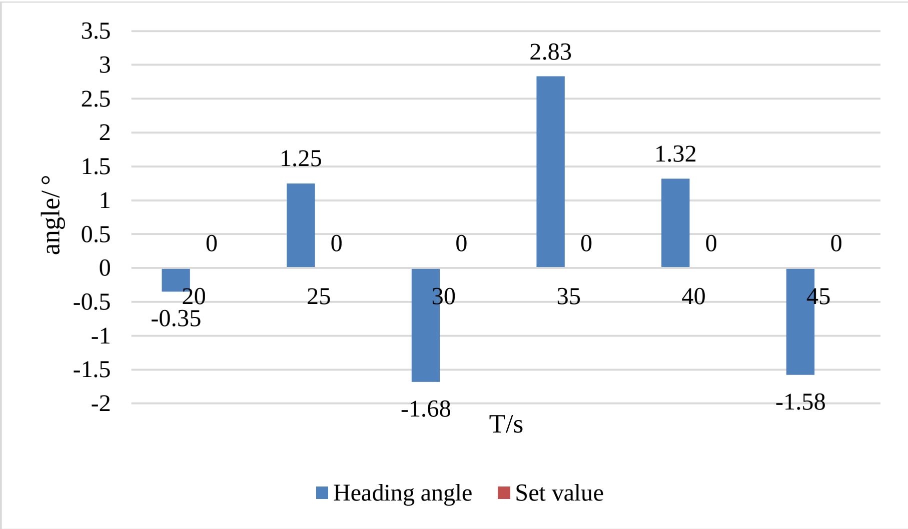


*Figure 4. Fixed navigation error*

### 4.3. Comparison of Positioning Control Effect

*Table 1. comparison of dynamic positioning control effects*

| Control algorithm | Error after heading positioning is stable | Error after stable depth positioning |
|---|---|---|
| PID | 0.3 | 0.0579 |
| Positioning system based on long baseline system | 0.000133 | 6.84*10-6 |

In order to verify the practicability of the algorithm, the dynamic model of the vertical degree of freedom and the dynamic model of the heading degree of freedom of the underwater working robot are used to carry out the theoretical simulation of MATLAB program. Firstly, the dynamic positioning control of the heading is carried out. The PID control and the positioning platform based on the long baseline system are adopted. The selected value of the heading is 5 °. As shown in Table 1, the comparison of simulation curves and error data after stabilization shows that the control accuracy of the long baseline system based on the approach rate is high, but the response time is longer than that of PID.

## 5. Conclusion

In this paper, the long baseline underwater acoustic positioning system is designed to meet the needs of ROV's high-precision detection in the complex environment in the deep sea. The design includes the software and hardware design of the signal processing platform, the data post-processing of the positioning system using Kalman filter, the design and Simulation of the positioning display and control software, the design and verification of its main structure, And the hardware and long baseline underwater acoustic positioning system are verified by the anechoic pool test. Through the analysis of the experimental results, it is concluded that the ROV deep-sea positioning system based on the long baseline platform can greatly reduce the positioning error.

## Funding

This article is not supported by any foundation.

## Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

## Conflict of Interest

The author states that this article has no conflict of interest.

## References

*[1] Abdelkarim B , Petrov R G , Thami E H , et al. Potential and sky coverage for off-axis fringe tracking in optical long baseline interferometry. Monthly Notices of the Royal Astronomical Society, 2021(1):1. https://doi.org/10.1088/1538-3873/abeca4*

*[2] Gruber J , Nothnagel A , Bhm J . VieRDS: A Software to Simulate Raw Telescope Data for very Long Baseline Interferometry. Publications of the Astronomical Society of the Pacific, 2021, 133(1022):044503 (20pp).*

*[3] Martellosio A , Pasian M , Rayet R , et al. Wideband Cryogenic Receiver for Very Long Baseline Interferometry Applications. IEEE Antennas & Wireless Propagation Letters, 2018, PP(99):1-1. https://doi.org/10.1109/LAWP.2017.2785958*

*[4] Niell A , Barrett J , Burns A , et al. Demonstration of a Broadband Very Long Baseline Interferometer System: A New Instrument for High‐Precision Space Geodesy. Radio ence, 2018, 53(9-10):1269-1291. https://doi.org/10.1029/2018RS006617*

*[5] Thomson D , Dosso S E , Barclay D R . Modeling AUV Localization Error in a Long Baseline Acoustic Positioning System. IEEE Journal of Oceanic Engineering, 2017:955-968. https://doi.org/10.1109/JOE.2017.2771898*

*[6] Haaf K , Adamowski M , Bremer J , et al. Overview and status of the Long Baseline Neutrino Facility cryogenics system. IOP Conference Series Materials Science and Engineering, 2019, 502:012124. https://doi.org/10.1088/1757-899X/502/1/012124*

*[7] Gumilar I , Bramanto B , Kuntjoro W , et al. Contribution of BeiDou satellite system for long baseline GNSS measurement in Indonesia. Iop Conference, 2018, 149:012070-. https://doi.org/10.1088/1755-1315/149/1/012070*

*[8] Stolz R , Schmelz M , Anders S , et al. Long baseline LTS SQUID gradiometers with sub-μm sized Josephson junctions. Superconductor Science and Technology, 2020, 33(5):055002 (10pp). https://doi.org/10.1088/1361-6668/ab78ba*

*[9] Everett M V , Park L K .Exploring deep-water coral communities using environmental DNA. Deep-Sea Research, 2018, 150(APR.):229-241. https://doi.org/10.1016/j.dsr2.2017.09.008*

*[10] J Grinyó, Francescangeli M , A Santín, et al. Megafaunal assemblages in deep-sea ecosystems of the Gulf of Cadiz, northeast Atlantic ocean. Deep Sea Research Part I: Oceanographic Research Papers, 2021, 183:103738-.*

*[11] Lund-Hansen L C , Juul T , Eskildsen T D , et al. A low-cost remotely operated vehicle (ROV) with an optical positioning system for under-ice measurements and sampling. Cold Regions Science & Technology, 2018, 151(JUL.):148-155. https://doi.org/10.1016/j.coldregions.2018.03.017*

*[12] Lund-Hansen L C , Juul T , Eskildsen T D , et al. A low-cost remotely operated vehicle (ROV)*

*with an optical positioning system for investigating under-ice irradiance fields in landfast sea ice. Cold Regions ence & Technology, 2018, 151:148-155. https://doi.org/10.1016/j.coldregions.2018.03.017*

*[13] Teague J P , Allen M J , Scott T B . The potential of low-cost ROV for use in deep-sea mineral, ore prospecting and monitoring. Ocean Engineering, 2018, 147:333-339. https://doi.org/10.1016/j.oceaneng.2017.10.046*

*[14] Hidaka M . Gelatinous zooplankton community around a hydrothermally active deep-sea caldera: results from ROV video records. Plankton and Benthos Research, 2021, 16(1):40-58. https://doi.org/10.3800/pbr.16.40*

*[15] Enrichetti F , Bava S , Bavestrello G , et al. Artisanal fishing impact on deep coralligenous animal forests: A Mediterranean case study of marine vulnerability. Ocean & Coastal Management, 2019, 177(JUL.):112-126. https://doi.org/10.1016/j.ocecoaman.2019.04.021*

*[16] Jackson R . Birmingham Water Works Forges a Diverse Utility. Journal - American Water Works Association, 2021, 113(4):78-80. https://doi.org/10.1002/awwa.1712*

*[17] Miller D G . Manchester Water Works Epitomizes Partnership Principles. Opflow, 2021, 47(1):8-9. https://doi.org/10.1002/opfl.1483*

*[18] Telepneff M . Building information modeling optimizes Tongzhou Water Works design process. World Water & Environmental Engineering, 2018, 41(3):30-32.*