3D Bathymetry via USV

USV with Multibeam Echosounder for Shanghai Bridge Survey

By Taxiya Wang

The Donghai Bridge, located in Shanghai, China, is a key component of the Shanghai International Shipping Center's deepwater port infrastructure. Conducting underwater surveys of the bridge piers' conditions for maintenance purposes is an operational challenge. The bottom of the bridge piers is immersed in water and can be eroded by the action of sand and gravel. Hydrodynamic scour caused by rapid water flow can create scour holes and compromise the integrity of the structure. To determine whether piers need to be protected by additional riprap, the precise sediment

Donghai Bridge, Shanghai. (Inset) The CHCNAV APACHE6 USV surveying the Donghai Bridge piers.

APACHE6 with detachable trimaran design.

scour conditions need to be investigated, but this poses operational challenges for traditional 3D bathymetric surveys.

Conventional bathymetric survey solutions with a manned vessel in a marine infrastructure environment will most likely leave numerous blind spots. The use of a manned vessel does not offer enough flexibility to perform efficient and comprehensive surveys due to the density of the pile spacing and the lack of 3D data on the back areas.

The solution selected for the Donghai Bridge survey project comprises an unmanned survey vessel, the APACHE6 of CHCNAV, carrying a NORBIT iWBMS STX multibeam echosounder.

Flexible Deployment

When conducting multibeam bathymetric surveys with an unmanned surface vessel, marine survey professionals highlight three major points of concern: How secure is their investment given the cost of multibeam echosounders? Does the USV offer sufficient flexibility to handle a variety of bathymetric survey scenarios? What about the final accuracy of the high-resolution 3D bathymetric survey?

Maneuverability and ease of use in fast current situations were a key factor in the client's choice of survey platform for the Donghai Bridge project. The APACHE6 USV's hull comprises a carbon-fiber/resin composite material that minimizes weight while ensuring that the hull is strong enough to withstand potential collisions. The tight integration of the NORBIT multibeam echosounder into the USV hull provides optimal protection for the transducer array and allows for navigation and operation in shallow waters. An extended hull width of up to 1 m improves hull balance and ensures a stable rolling attitude during multibeam data acquisition, improving data accuracy. A detachable trimaran design accommodates varying wind and wave environments.

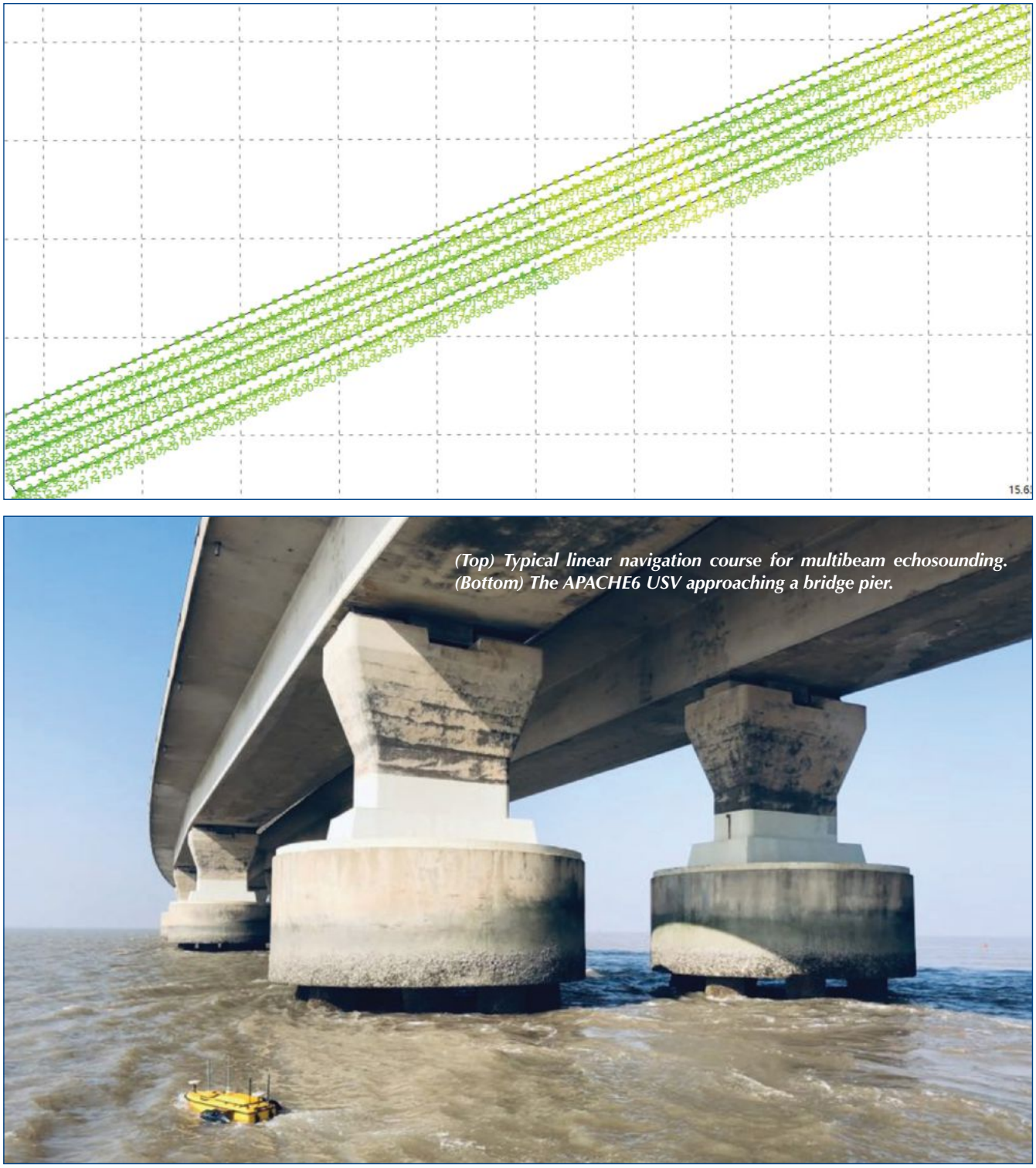
The compact size of the USV allows for on-site transportation in a car or van and deployment by only two persons. The total weight of the complete APACHE6 USV platform is less than 40 kg, allowing for extreme portability, even in remote locations.

The APACHE6 uses a pair of dedicated outboard thrusters with a maximum power of 1,300 W. Its excellent thrust allows the hull to reach a theoretical maximum speed of 5 m/s (about 10 kt.) and a cruising speed of 2.5 m/s (about 5 kt.) in normal operation.

The USV's autonomy has been considerably improved with the use of 18650 cells (lithium-ion rechargeable batteries) with very high safety factor, enabling a working span of up to 6 hr. and a much larger survey area of several kilometers, compared to previous versions of the vehicle.

The implementation of new technologies, with capabilities such as absolute straight-line course, water flow adaptive propulsion, stationary hovering, shoal reversing and inertial navigation, are unique to the APACHE series, expanding the application scenarios.

These marine drones can switch between manual and automatic modes depending on survey conditions. In automatic mode, hull positioning and attitude are combined with a specific algorithm to maintain high accuracy. When the vessel encounters the current, the propellers are controlled to automatically adjust the steering based on the strength and direction of the current on the hull to ensure that the course proceeds as planned.



(Top) Typical linear navigation course for multibeam echosounding. (Bottom) The APACHE6 USV approaching a bridge pier.

During a turn, the hull automatically decelerates so that the unmanned vessel's sounding line is at the same height as the intended line to ensure underwater data integrity throughout an operation.

Multibeam Coverage

Marine drones have to incorporate efficient automatic navigation control technology to follow the planned route in a complex working environment, with different speeds and changes in flow direction. The objective is to have a trajectory deviation of less than 20 cm.

When measuring with multibeam echosounders, the strip coverage should be greater than 20 percent. The precision of perfect linear course of crewed vessels can be largely influenced by the wind and wave environment, as well as by the pilot's experience. The absolute straight-line technology integrated in the APACHE6 ensures that a predefined planned line is maintained to guarantee data integrity.

The entire NORBIT multibeam echosounder system weighs less than 10 kg and fits into a single carrying case, making it easy to transport. The transducer, attitude,

surface sound velocity and other data can be transmitted with a single interface cable for easy installation and use and to minimize the risk of damage.

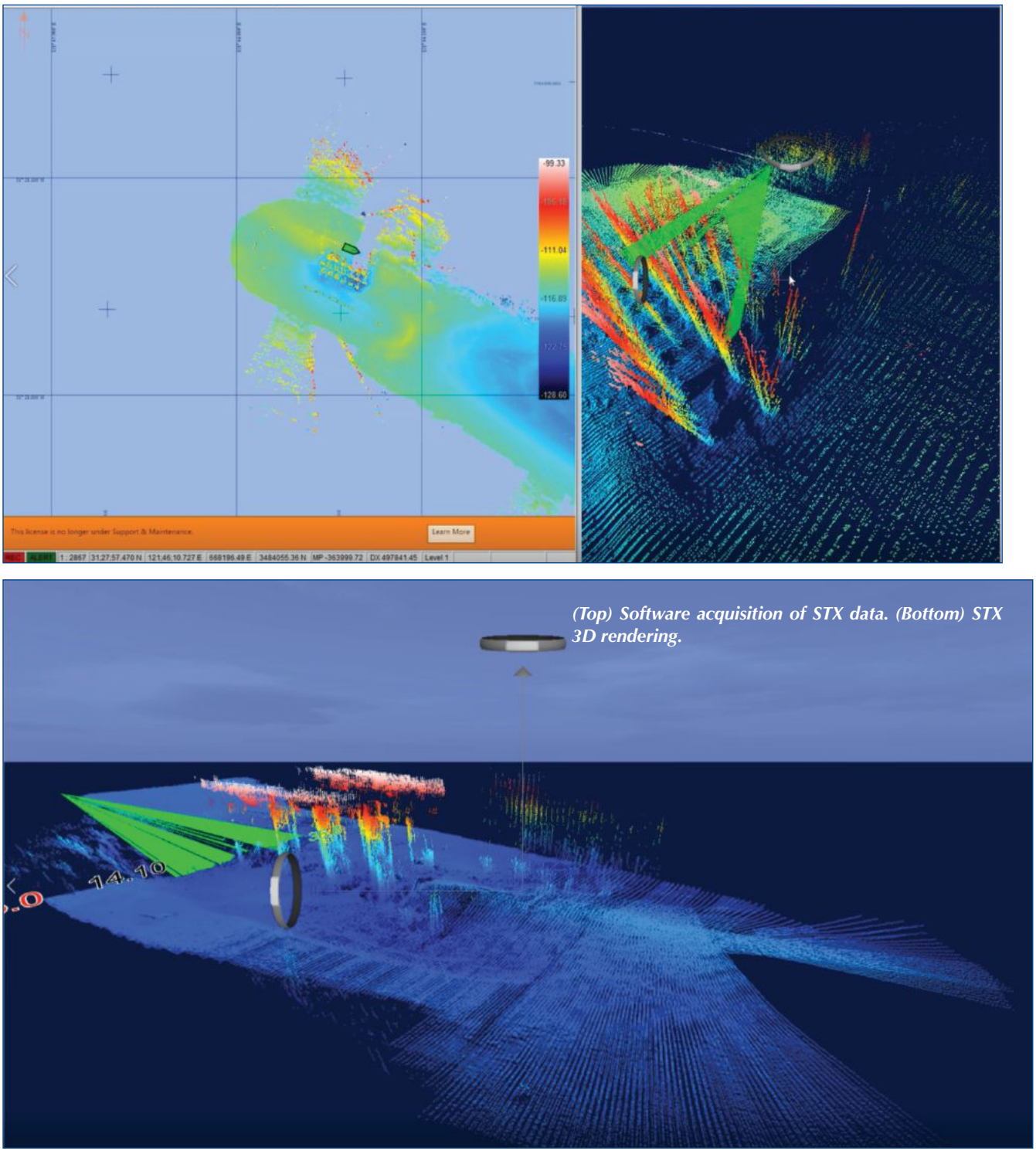
When the USV is stationary, the STX multibeam echosounder, in addition to its 210° horizontal scan coverage, also has 20° longitudinal scan coverage, so that the real-time dynamic 3D scanning effect can be achieved.

During multibeam sounding, the USV moves along the sounding line at a controlled constant speed of 4 to 6 kt. The display, control and data acquisition software that supports multibeam sounding runs on the data acquisition computer to acquire and display data and manage measurements and navigation.

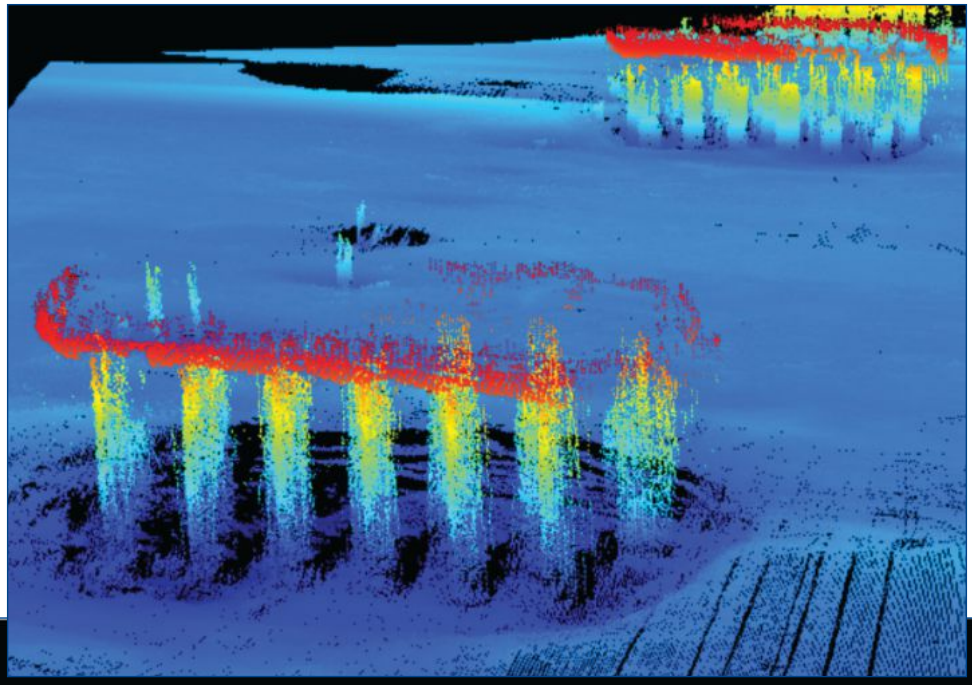
Survey Results

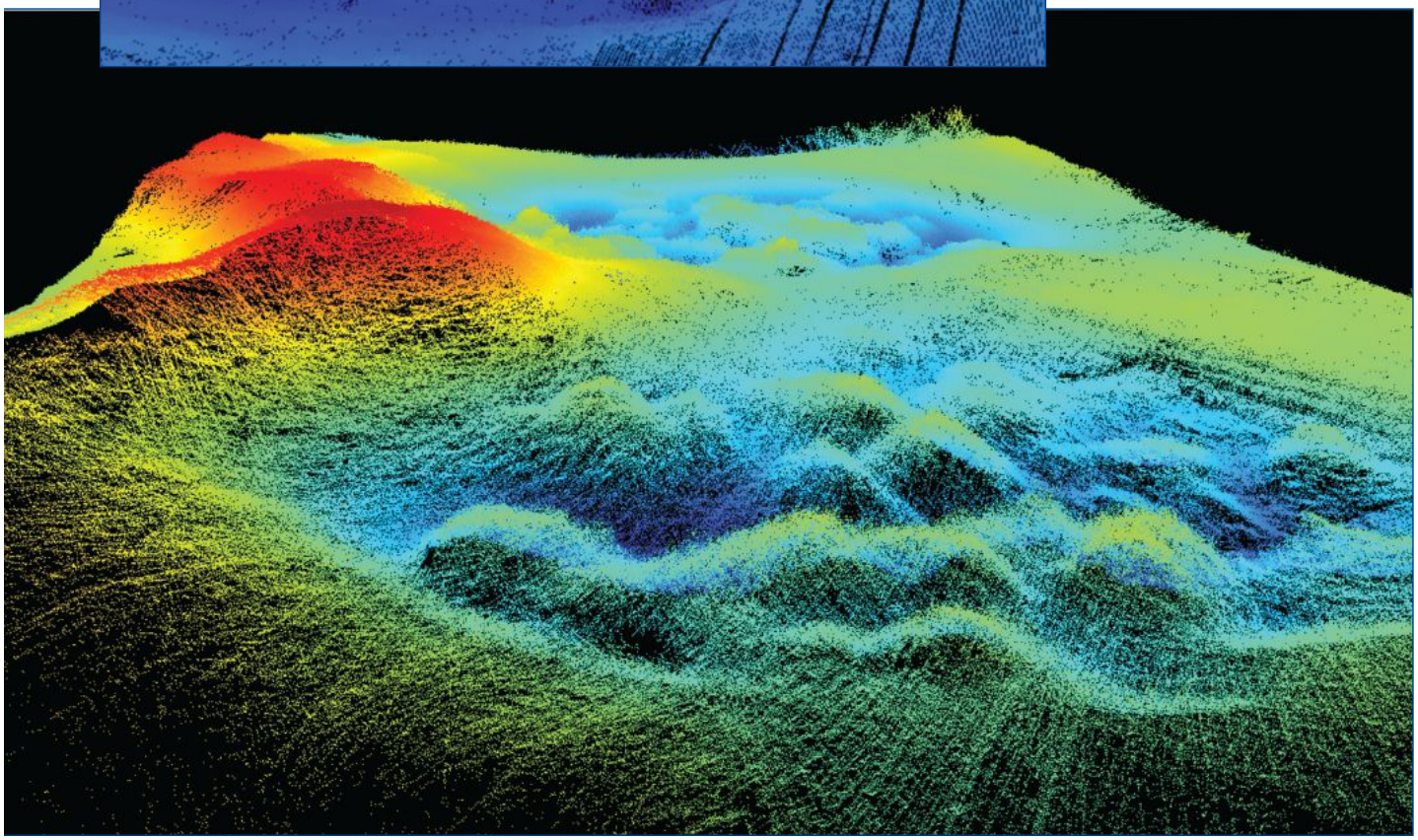
The combination of the APACHE6 USV and NORBIT multibeam echosounder enabled the Donghai Bridge survey to be completed in less than 1 hr. To obtain the best accuracy and completeness of data, the APACHE6 was operated in manual mode in the immediate vicinity of the bridge piers to collect additional data during the survey. This hybrid approach would not have been feasible with a manned vessel. The data collected were later filtered and edited by post-processing software and imported into the sound velocity profile data to obtain the outputs.

The bridge management unit compared the data ob-



(Top) Software acquisition of STX data. (Bottom) STX 3D rendering.





(Top) Bridge section piling and water bottom scouring rendering. (Bottom) Extracted row piles to view underwater scour details.

tained throughout this survey with the original bridge construction design to determine if additional riprap was required. After data post-processing and analysis, a total of 18 piles were identified for further investigation for routine maintenance.

Conclusion

During underwater terrain mapping, marine survey professionals often need to map dense underwater structures, such as bridge piers, as in the survey case in Shanghai. One of the main problems encountered is how to survey the topography behind the piers and the internal topography of the dense structures. When it is difficult to achieve this with traditional crewed boats, hydrographers now have the option of deploying USVs.

USVs reduce survey time, improve work efficiency and produce high-resolution 3D data to meet the requirements of the most demanding marine infrastructure projects. The CHCNAV APACHE6 USV is an innovative and fully integrated solution for 3D bathymetric surveys, underwater objects and offshore construction. **ST**

Taxiya Wang has been involved in the development of CHCNAV's international marine business since 2017. She works on the development and promotion of USV solutions for bathymetry and hydrological surveys and unmanned water exploration.