THE BOTTOM LINE

MULTI-BEAM TECHNOLOGY IS BEING USED TO ENSURE THE 77KM-LONG PANAMA CANAL CONTINUES TO REMAIN OPEN AT ALL TIMES. JOSÉ ALEXIS PRIMELLES CARDENAS AND JORGE F RODRIGUEZ REPORT

The Panama Canal is probably the most famous ship canal in the world. Designed to cut across the Isthmus of Panama, the 77km canal has connected the Atlantic Ocean (via the Caribbean Sea) to the Pacific Ocean uninterrupted since its official opening in August 15 1914. It has become one of the most important navigational channels for international maritime trade and such is its scale, even today it amazes those who visit it and those who use it to transport goods around the world.

To ensure safety and availability for the thousands of ships that use it every year, hydrographic surveying has been vital throughout the history of the Panama Canal.

Single-beam technology was extensively used for this until recent years, but with heavy shipping traffic and large-scale expansion projects, a more reliable and efficient method to conduct hydrographic surveys throughout the most critical areas of the Canal was required.

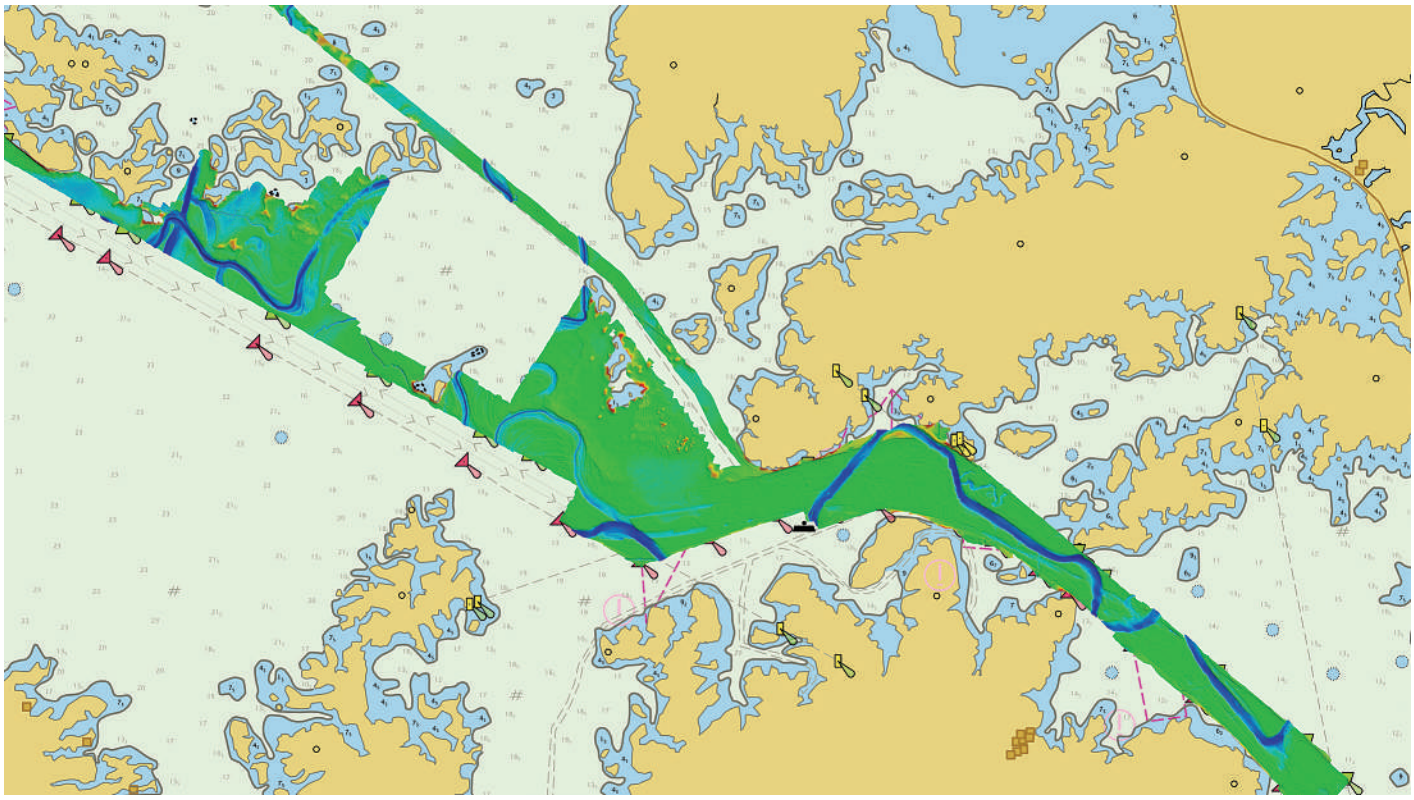
Enter multi-beam technology. Since 2011, the ACP has acquired five Kongsberg Maritime EM 3002 and EM 2040C multi-beam echo sounders. This sophisticated technology has simply put, revolutionised the way that hydrographic surveys are conducted on the canal.

A key application for multi-beam technology on the canal is providing accurate data for channel maintenance at actual navigational depth for vessel traffic, with the goal of ensuring safe navigational depth ranges in the Pacific and Caribbean channel areas. Other daily hydrographic applications include dredging operations and flood control; the latter is critical in the man-made 'Lake Gatún'. However, multi-beam applications are diverse and depend on the specific daily needs of the Panama Canal Authority (ACP).

A number of demanding tasks in today's operations are intended to double the capacity of the Panama Canal by creating a new lane of traffic, and accommodating more and larger ships. Working towards this, dredging control and monitoring operations are conducted almost daily, with expansion works currently focused on widening the Corte Culebra area and the northern areas of Lake Gatún.

The different multi-beam echo sounder models are used for different water depth requirements and several versions of each model are available with different resolution capabilities. A typical multi-beam system consist of four units, a transmit transducer, a receive transducer, a transceiver unit and an operator unit.

The transmit transducer is long in the along-ship direction and short in the athwart-ship direction, enabling the system to generate a swath of sound that is wide athwart-ship and narrow along-ship. The receiver is correspondingly wide athwart-ship and narrow along-ship, enabling the system to receive the wide swath produced by



Multi-beam bathymetry and ENC/S-57. Image courtesy of Panama Canal Authority

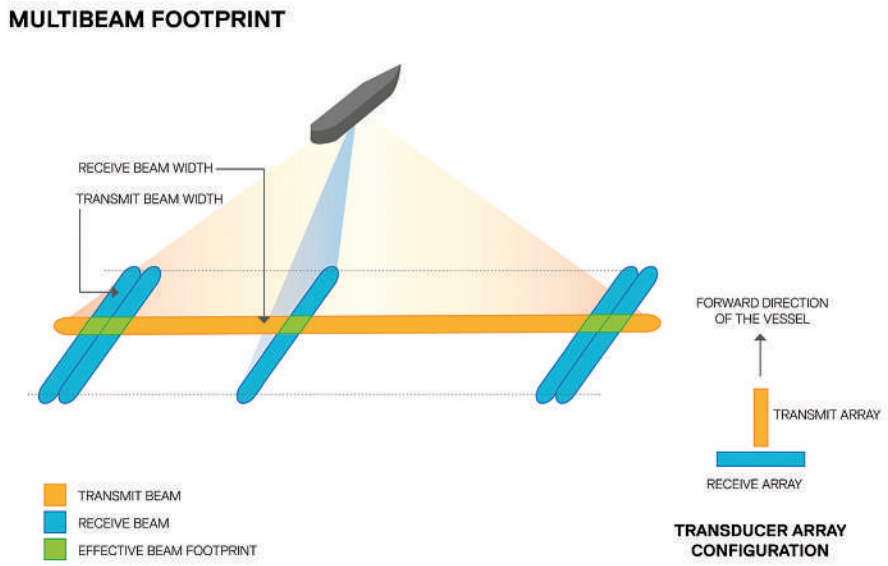
the transmitter, but still have narrow beams in the along track direction. The sound generated by the transmit array is reflected by the seafloor at different angles and is received by the receiver transducer at slightly different times. The footprint is formed by the intersection of transmit and receive beams. All the signals are then processed by the transceiver unit, converted into depth values and plotted as a bathymetric map on the operator unit.

Advantages

These multibeam systems have many advantages. The transmitters have individual control of all the single elements in the array, so can be used to form several transmit beams, and to stabilise for roll, pitch and yaw. Stabilisation for pitching is obtained by steering the transmit beam electronically forward or aft at the time of transmission, based upon input from the motion sensor.

Each receive beam is stabilised for roll by the beam-former, using input in real-time from the motion sensor every 10ms. All beam-angles are thus constant and are related to the vertical axis. The systems have the option to be fully stabilised for yaw by using sector transmission with frequency coding and individual tilt control, enabling simultaneous transmission on all sectors. Each beam has individual heave compensation, using input in real time from the motion sensor

Sound velocity can be corrected in real-time, the basic algorithm ray-tracing through the water column for each beam using a unique 'intersection of cones' technique.



Multi-beam footprint

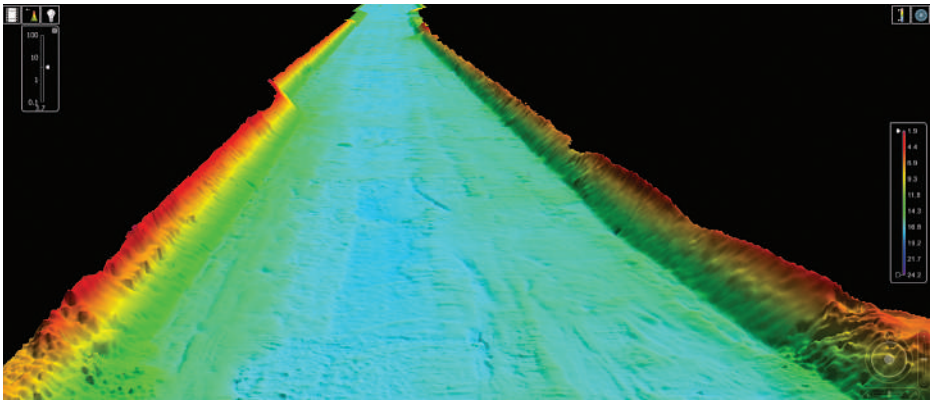
It also computes the steered beam angles based on the surface sound speed at the transducer. The result is a depth solution datagram that contains along-track, across-track, and reduced depth values for each beam.

Equiangular, equidistant and high density equidistant beam spacing techniques are available. The horizontal resolution is significantly improved due to the introduction of focused beams for both transmission and reception and the high density signal processing technique. Near-field focusing is essential for retaining angular resolution. Receiving near-field focusing is dynamic (the focal point is shifted as function of time/range) and on transmit, each sector will have independent focal points.

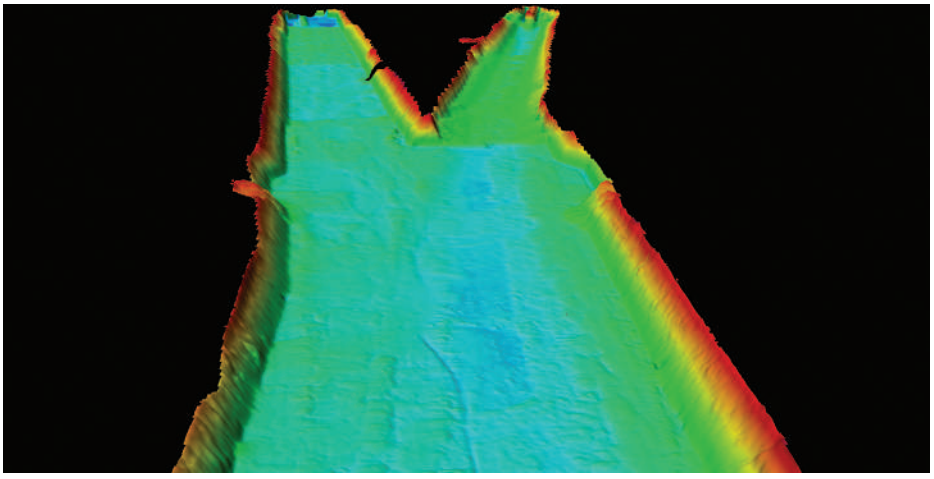
The use of new frequency independent hardware makes it possible to generate signals other than continuous wave (CW) pulses, like frequency modulated chirp (FM) waveforms for extended range performance and with pulse compression on reception. The use of FM gains approximately 15dB in signal-to-noise-ratio compared to CW pulses.

In some applications or due to weather condition, the user might want to reduce the swath width. If so, the systems will not cut-off the outer beams, but will maintain all beams in the new coverage sector set by the operator. Hence, both the resolution and the

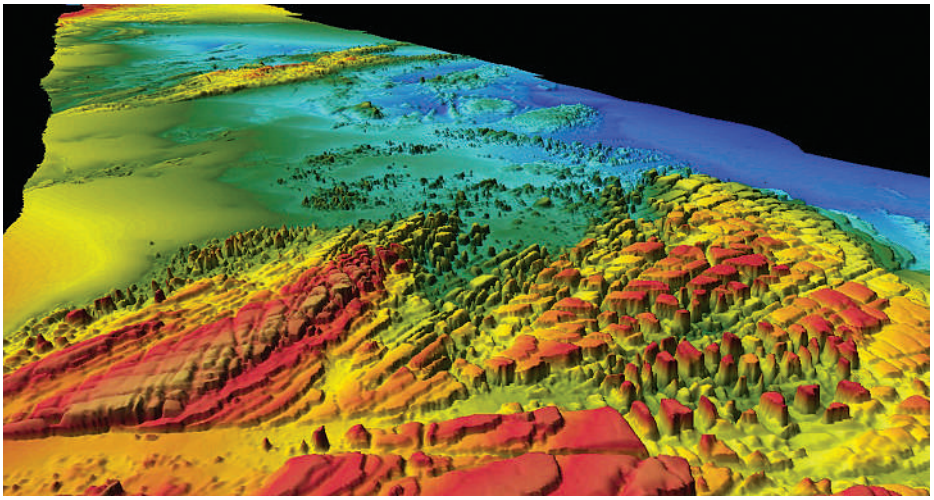
EM 3002 multi-beam bathymetry of Corte Culebra area. Image courtesy of Panama Canal Authority



Multi-beam bathymetry of a dredged channel area. Image courtesy of Panama Canal Authority



Scan of the Panama Canal. Image courtesy of Panama Canal Authority



North entrance to the Port of Lisbon using KONGSBERG EM 2040C. Image by the Hydrographic Brigade, Portuguese Hydrographic Institute

ping rate will increase. This is a unique feature and very useful when surveying a wreck or feature on the seabed. The operator may also select a maximum coverage to ease the line planning in sloping terrain. The system will then run in an automatic mode and maintain all beams within the selected coverage.

Coverage

The average depths in the current working areas of the Panama Canal range from 16.76m to 18m. The wide swath coverage of the multi-beam systems allows coverage of channel areas up to 200m wide, so very few survey lines are needed, even including mapping the foot of the slope on both sides of the navigational channel – a very important task for inspection purposes, as it can be used to detect bottom scour, slope failures or massive slumping of the seafloor.

The implementation of Kongsberg's multi-beam echo sounders has also positively affected data processing times, as well as improved delivery of cartographic products. For example, in the area of Corte Culebra what used to take a significant period of time using previous multi-beam systems, from data acquisition to data processing and final products, now takes only a couple of days. The time at sea conducting hydrographic surveys has been reduced and productivity has increased immensely. This of course also has a direct impact on the survey operators bottom-line.

The technological advances that come with Kongsberg multi-beams in the field are very important to Panamanians. These tools are changing the way the marine industry in Panama and Central America operates.

A third, wider lane of locks is currently under construction and is due to open this year. With the new expansion works of the Panama Canal, the ACP's new generation of multi-beam systems will continue to prove that this technology delivers the most reliable and convenient seafloor mapping tools for shallow water hydrographic surveys.

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