# Reducing the threat of unexploded ordnance

BEAM-FORMING TECHNIQUES UK-based marine technology company Kraken Robotics has developed the 3D Acoustic Sub-Bottom Imager™ that uses advanced beam-forming techniques to trace the origin of non-specular, diffused energy back to its source, aiming to reduce the threat of unexploded ordnance. Here, Chris Almond, group director for Kraken Robotics' global business development and marketing teams, reveals details of the process.

Unexploded Ordnance (UXO) is a munition that is still 'live' i.e., has failed to detonate or has not yet been triggered. It is a global issue, however, depending on the region. The origins of UXO vary from ongoing, recent or historical conflicts, dumped following expiry when surplus to requirements, or modern-day firing ranges.

The threat posed by triggering a UXO during the construction and installation of marine assets requires any potential UXO (pUXO) to be located and disposed of. Their threat remains for decades and needs to be assessed and reduced to as low as reasonably practicable (ALARP) before installing infrastructure on or under the seabed. This is achieved in part by marine UXO surveys.

## Magnetometer surveys

Marine UXO surveys rely on collecting magnetic data sets, which provide the rough location of ferrous targets on and within the seabed. These surveys are generally acquired by a survey vessel towing one or more remotely operated towed vehicles (ROTV). These are equipped with either soft-towed magnetometers or with a fixed-frame gradiometer array. Other geophysical data can be acquired concurrently, such as sub-bottom profilers, used to delineate sub-seabed lithology.

The result of a UXO survey is the master target listing (MTL), a list of all ferrous targets which are, until verified, deemed as pUXO. Whilst widely accepted, there are limitations to the magnetic data collected. Further survey data sets can be used to complement the magnetic data, providing a more comprehensive understanding of these targets to allow for appropriate follow-on actions.

The main limitation is that the vast majority of targets on the MTL are not UXO; typically more than 95% of targets are found to be debris or 'no finds', although at this stage of the process, this cannot be confirmed until visually inspected. The magnetic anomalies are analysed, if the magnetic response and ferrous mass are similar to those of known UXO, then the target is rightly deemed pUXO. This is where additional survey data sets can be used to complement the ALARP process.

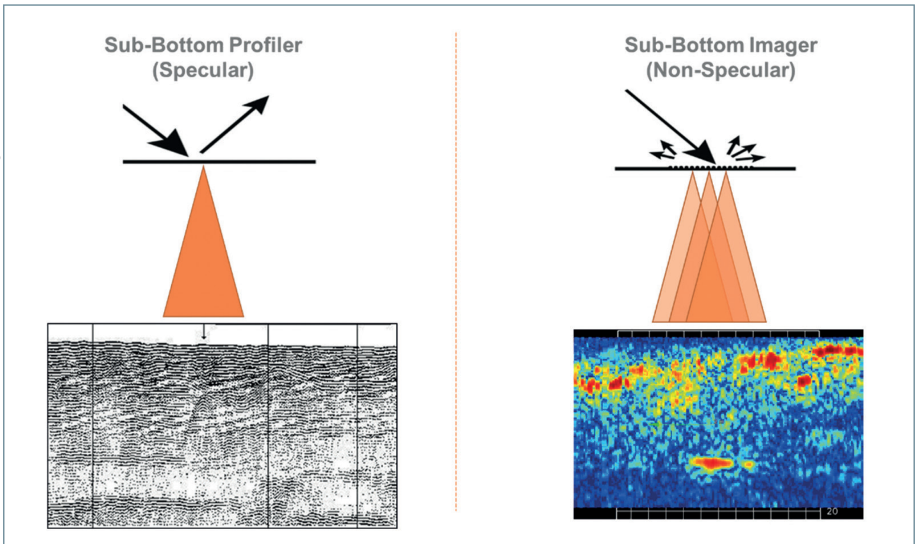


Figure 1: Aspecular acoustic return typical of a sub-bottom profile (left), and the SBI's non-specular acoustic return imaging the targets exterior (right)

Source for all images: Kraken Robotics

## The Sub-Bottom Imager™ and the science behind it

The Sub-Bottom Imager™ (SBI) is a 3D chirp-based sub-seabed imaging tool which is used throughout the lifespan of a marine asset, from site investigation through the operations and maintenance periods to the decommissioning phase. It uses advanced beam-forming techniques to trace the origins of the non-specular, diffused energy back to its source.

In doing so, the data displays an image of the exterior of buried items such as energised cables, buried boulders and pUXO. By mapping acoustic impedance, the SBI can locate not only buried objects but provides a context as to their location within the seabed i.e. above or below the non-mobile reference layer of a UXO, achieved by mapping lithological boundaries.

The SBI is acquired in motion along survey lines, and when used for UXO detection, these survey lines are acquired overlapping one another, providing a minimum of 200% coverage below the seabed to check repeatability in data sets. As a geophysical survey sensor, the SBI can be mounted to various platforms depending on the survey requirement. These include remotely operated vehicles (ROVs), shallow-water deployment frames or Kraken Robotics' a remotely operated towed vehicle (ROTV), SeaKite, for example. The SeaKite can be mounted with the SBI and a magnetometer array, acquiring both UXO data sets simultaneously.

## Discriminating pUXO alongside magnetometer data

By tracing the scattered, non-specular energy back to its source, the SBI identifies the buried target (as seen in Figure 2), providing accurate dimensions but also detailing the shape of the target. This gives the explosive ordnance disposal (EOD) experts in attendance the ability to characterise the target and compare this with the desktop study results.

The SBI data is built up of 3D voxels, a cube of data which is initially acquired in a 10cm x 10cm x 10cm form. For UXO surveys, this data is rendered in 5cm voxels, enhancing the shape of the target and providing the most accurate dimensions (as seen in Figure 3).

When working with acoustics, it is important to remember that there are no definitive dimensions. So, when reporting the size of an object, Kraken Robotics has developed a method of delivering both the apparent dimensions and a processed dimension, giving a size banding. Once the data has been re-rendered to 5cm voxels, a size measurement is taken. This is the apparent dimension.

The processed dimension is generated by first measuring the dominant amplitude of a target. This is created firstly during the surrogate item trial (SIT), whereby a target of known dimensions is surveyed and interpreted in the acquired SBI data. This produces a standard deviation which is applied to the size of a target that can then be compared with the UXO MTL.

## Case studies

Kraken Robotics has recorded an average reduction in the MTL of 70% on projects where the SBI has been used in conjunction with other survey data sets and trained EOD personnel. The achieved reduction is subject to factors including, but not limited to, the quality of data acquired, the familiarity of the EOD personnel with survey data, and the correlation of acoustic and magnetic data sets.

In 2022, Kraken Robotics supported a Dutch wind farm export cable UXO Identification and Control (ID&C) campaign, where the SBI was deployed to survey 242 pUXO targets which had previously been located using a magnetic UXO survey. Following review by the EOD experts on board the survey vessel, the MTL had been reduced to 186 targets, which exhibited magnetic readings similar to those expected by UXO in the area.

The SBI was then used to survey each of the remaining targets, with an anomaly contact report produced for each target. An average of more than 20 targets were surveyed daily, enabling a cost-effective survey. Upon review by the EOD, the MTL was reduced to 82, a 66% reduction overall, saving the client an estimated 32 vessel days of their ID&C campaign.

The SBI has also supported non-ferrous UXO surveys, searching for LMA/LMB mines which are aluminium-based munitions and not easily detectable using magnetics. Here, the SBI's ability to ›

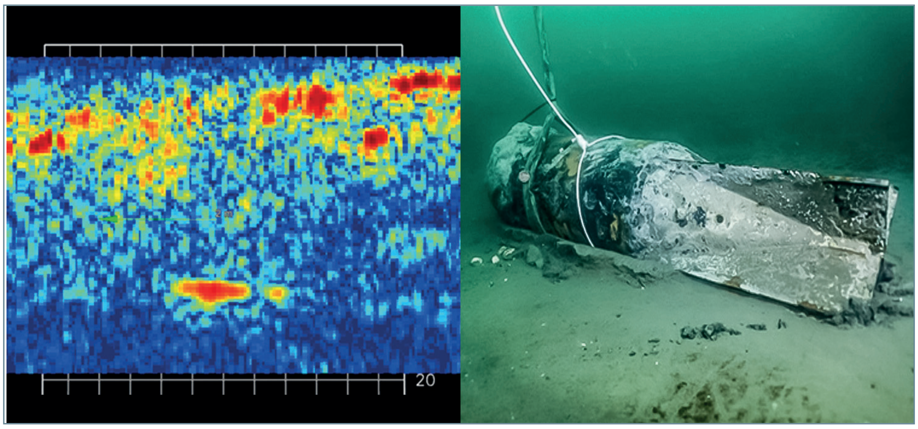


Figure 2: The SBI image of the buried target (left), identified as an elongated, elliptical target lying parallel to the seabed and the recovered UXO (right)

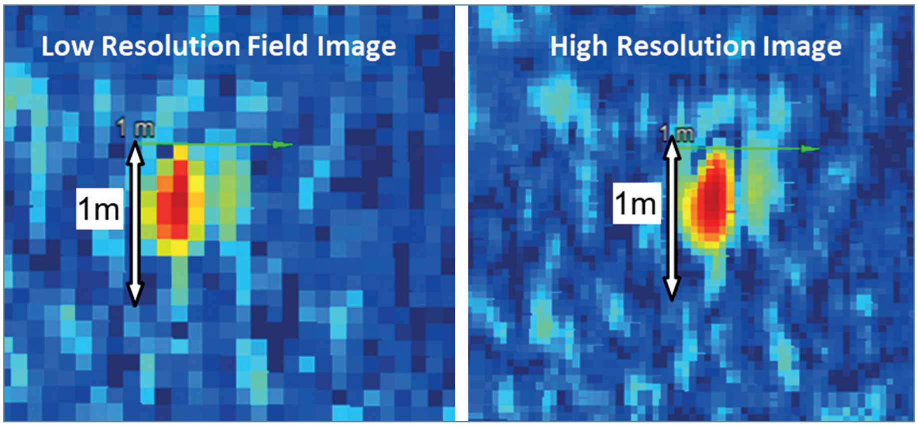


Figure 3: Standard 10cm voxel SBI data (left) and a 5cm rendered example of the same anomaly (right), enhancing the shape of anomalies in 3D acoustics

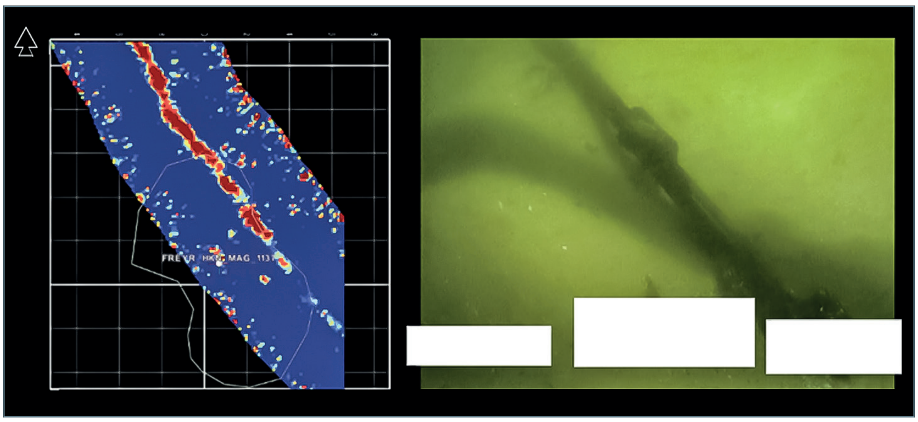

Figure 4: Elongated acoustic anomaly (left) and confirmed debris wire item (right)

map acoustic impedance is paramount and often, acoustics is the only data set available for review.

In 2020, SeaKite surveyed an offshore wind farm in the Netherlands, tasked with locating non-ferrous UXO along all IAC cable corridors and within the footprint of the WTG locations. From the 42m-long Geo Ranger, SeaKite surveyed 1,100km of 3D acoustic data at speeds averaging 3.7 knots, acquiring 130km of data per day. The result of the survey was the issuing of the ALARP certificate based on the acoustic data. As the SBI covered 100% of the wind farm footprint, the acoustic data was also used to discriminate the existing magnetic pUXO anomalies, reducing the MTL by 75%.

## Outlook

Looking into the near future, Kraken Robotics is continuing to push the boundaries of 3D acoustics within the application of UXO surveys, combining both acoustics and magnetics/electro magnetics to support a data-driven UXO reduction approach and to help projects deliver on time and budget.

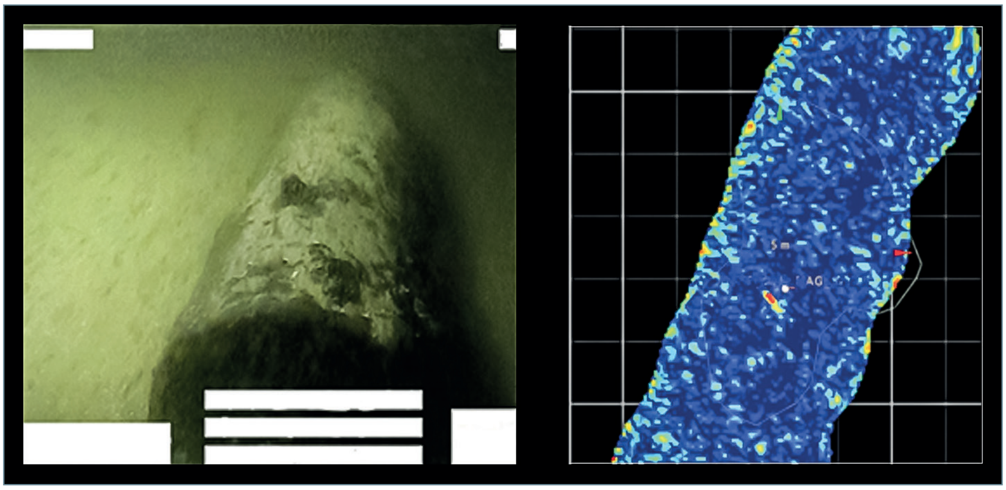

Figure 5: Recovered UXO (left) and the 3D acoustic image (right) demonstrating good correlation to the as-found anomaly

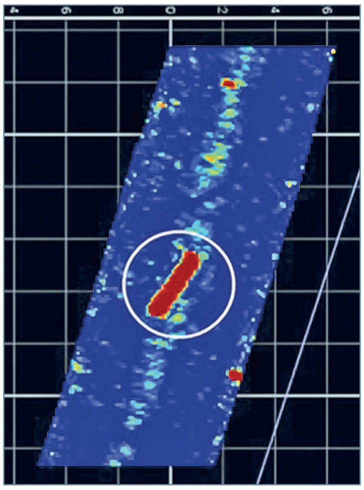

Figure 6: A very clear acoustic image of a non-ferrous UXO

# Partners collaborate on SOV performance optimisation

ARTIFICIAL INTELLIGENCE | Athens-based Metis Cyberspace Technology (MCT), a data and predictive analytics specialist, is collaborating with Danish offshore service vessel company, Esvagt, to develop real-time performance monitoring and analytics systems for service operation vessels (SOVs). The aim is to optimise fleet performance.

SOVs fulfil a range of functions including transporting personnel and components, providing accommodation, warehousing and workshop facilities, and fulfilling maintenance functions at offshore sites. With assistance from Esvagt, MCT has used its high-frequency data acquisition and advanced performance analytics to provide transparency on SOV performance.

Panos Theodossopoulos, MCT chief executive, commented: “The result is an exciting example of how advanced analytics deliver a competitive edge, in this case creating the opportunity for SOVs to offer added value services to end clients. I would like to thank Esvagt for its cooperation in taking our product and service development in a new direction.”

He explained that Metis has developed a way of visualising SOV operations which correlates the full range of vessel activities to fuel efficiency and emissions in the context of a five-day forecast of weather conditions. Features include analysis of total fuel oil consumption by activities such as transit voyages, personnel transfer, and time in port, taking into account different weather conditions.

The enhanced software functionality also introduces a heightened level of transparency into dynamic positioning operations. The new Metis DP Motion Analysis App analyses the performance of the vessel’s power system during dynamic positioning operations to deliver a visualisation of aggregated SOV performance based on fuel and energy efficiency, environmental conditions, and motion dynamics.


Metis and Esvagt are collaborating to develop new fleet performance optimisation functionality Source: Metis

Another new function is the combination of weather forecast and vessel performance data to support site managers and vessel operators in the most efficiency scheduling of maintenance. The ‘Smart Scheduler’ refines existing Metis voyage routing optimisation to take account of planning for wind farm operations, including safety requirements.

Esvagt deputy chief executive, Kristian Ole Jakobsen, said: “The new functionality supports better voyage planning and performance at sea during the key tasks which define SOV utilisation. In doing so, AI-based analytics is helping vessel operators to contribute to a more efficient and sustainable offshore wind industry.”