GETTING INTO FOCUS

A new sub-bottom mapping system based on an EdgeTech synthetic aperture sonar (SAS), driven by software developed at the University of Washington and carried by a stable tow platform from MacArtney, have all come together to produce a unified way of determining buried objects from cables and pipes to mortar shells and other UXO. This could significantly cut the costs of carrying out wind farm surveys.

For many years, the presence of unexploded ordnance (UXO) has been a recognisable hazard. Every time an oil or gas pipeline was planned, the route had to be cleared of munitions. In recent years, the need to lay numerous export and inter array cables has caused a resurgence in this demand although importantly, at a much lower cost base.

Underwater object detection has become a subject of interest to the engineers at the University of Washington Applied Physics Laboratory (APL-UW), particularly with regard to pipe tracking and explosive detection. They recognised that unburied targets could be acoustically detected by a dual-band EdgeTech 2205 sonar but for sub surface detection, they began to look at quite a mature technology- the EdgeTech Buried Object Scanning Sonar (EBOSS) sediment-penetrating 3D synthetic aperture sonar (SAS).

“A characteristic of the EBOSS is the intensive computational burden associated with beamforming,” said Kevin Williams, Executive Director and Senior Principal Physicist at APL’s acoustic department. Our aim was to develop code to reduce this computational load.

“Technology has progressed since the first EBOSS was developed, in particular the ability of data processing software and a graphics processing units originally developed for the high-end gaming sector, to deal with 3D volumetric data in real time.

"We now have tools such as mosaics, high-resolution volume renderings of specific targets, and extraction of acoustic features such as target impulse response information that can be used for UXO classification.

"It isn’t, however, all about software. In order to physically capture this information, we needed a highly stable Multi-sensor Towbody (MuST) vehicle able to carry multiple sensors."

The APL selected a MacArtney FOCUS 3 platform.

FOCUS 3

Accurate acoustic imaging technology benefits from a very stable platform because it does not nearly require the same amount of motion compensation to place the sonar at the desired location- within one tenth of a wavelength," said Williams.

“It is probably safe to say, that the system just wouldn’t work without the stability provided by the Focus 3."

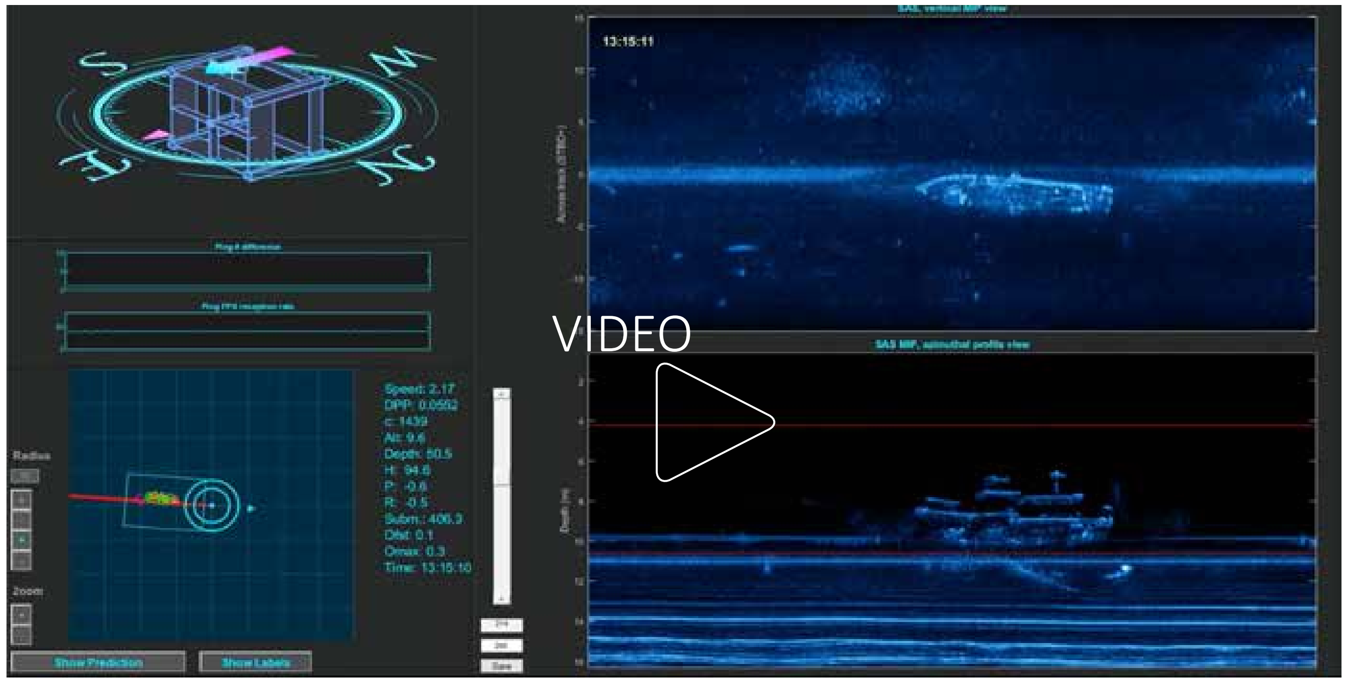
This towbody can be powered and controlled from the surface and gather data relayed in real time via its NEXUS multiplexer. Included on the vehicle is a Doppler velocity log (DVL), inertial navigation system (INS) and a sound-speed sensor to help the synthetic aperture beamforming.

“The FOCUS 3 also includes a dual-antenna GPS for determining heading and position when surfaced while heading, tilt, altitude and pressure/depth sensors", said Hans-Jorgen Hansen, MacArtney’s Sales Director, Ocean Science. “We use it for control and navigational feedback in order to know the position of the body at all times, with high accuracy.

SONAR

"The EBOSS is a very powerful tool, allowing us to use frequencies of 5 to 25KHz so we can penetrate deep into the sediment," said Williams."It can image 3m below a sandy seabed although this can be increased to 12m in soft sediment.

“The tow speed itself is not critical



On the top view is the plan view and below, the elevation showing the buried cable in the 20cm–60cm of sediment although it is possible to see even deeper. On the right side is a compass to show that the Focus 3 is flying flat and stable. In addition to the objects it is also possible to look at greater environment.

but from experience, have found 4kts to be optimum. At that speed, the Focus 3 is really stable," said Williams.
"We have flown it faster but to do so, it is necessary to increase the ping rate. We have found the sweet spot at 60Hz which translates as a ping every 3-4cms and this allows us to resolve images of one inch (2.5cms). One of the reasons we limit the sonar to 60 Hz is that we need to ensure the sonar does not overheat."

"The stability of the Focus 3 towbody means that we can safely fly at 5m above the seabed in order to look deep into the sediment," continued Hansen. "This height allows a 20m swath. In many applications such as using it to track a pipeline, however, this is not critical.

"As we fly higher, say at 10m, we don't get such a good resolution but benefit from a 40m swath. Flying higher, is that it very much increases the swath at a rate of four-to-one so at 15m height, we could ping it at 30 Hz and benefit from a 60m swath.
"The Focus 3 is very manoeuvrable and the integral wings allow it to fly a steady altitude above the seabed, but also enables it to move side to side.

This effectively means that the Focus 3 can move at 50m either side of the pipe and still have the it within the field of view. Having 100m to play with circumvents any navigation issues."

All the information can be streamed up to the wheelhouse to provide navigational information on the seabed bathymetry while keeping track of the cable.

"Because of the little vehicle motion we are able to process the SAS information in real time which in turn adds to the ability to use it," said Williams. "Looking at images on the fly has great benefits, especially tracking buried cable.

POST PROCESSING

The APL has developed a data-driven, feature-based navigation refinement algorithm to augment the onboard navigation sensor suite and improve the navigation precision.

"An important feature of post-processing is the accurate fusion of data from different scans," said Williams."The number of non-overlapping acoustic images can be often a determining factor for the accuracy of an image. As a result data fusion relies on pixel-scale navigation precision.

"This *renavigation* enables the features captured by various observations from different scans to be accurately aligned. It also results in significant improvements to mosaic data products as these can undergo speckle reduction and significant signal-to-noise ratio improvements when fusing data together from different scans.

Following the sonar run, the data taken from various passes can be assembled to create a very high fidelity three dimensional image.

"The post processing systems we have developed not only allow us to cut the image and effectively visualise it in slices like medical tomography scans," said Williams.
"In one test project, we were able to see internal structures in a ship sitting on the seabed.

We could not only cut the image sideways forward to aft but also port to starboard. We could then grab a cube from the model and rotate it. In this way, we could see the decks but also two stairways of between them."

Recovering the Focus

In addition, high resolution spectral processing can be used for UXO identification and classification, and that is the area that the group are really interested in.

"We are getting about an inch resolution so for larger items, we are getting a lot of pixels on target and that helps to the final classification. We can classify structures about 8 inches long and three inches in diameter. We can look at a variety if shapes

"A medical ultrasound of the UXO target is very useful in identifying the shape of the object but the more difficult challenge, and something we see as a very useful diagnostic tool, is to discover what happens as it is hit with sound.

"These frequencies literally cause metal bodies to resonate is like ringing the bell and that oscillation allows us to match frequency responses from a database in post processing and allows us to classify the target. This library is in active development. Each target has its own signature so it is possible to tell if the body is dense or not.

"From the interference patterns, we can actually use it to identify the target better than if we had just its shape.

INVERSION

When doing a UXO survey along a desired path, by far the largest area surveyed will be clear.

"From the EBOSS, we can determine the sound speed and density of the sediments. This provides information on the lithology and gives information to the geotechnical group to provide information on if there are hard layers, how large an area do they cover and how deep.

COST SAVINGS

"A conventional UXO detection procedure is to fly a magnetometer over an area and look for responses. These are listed in priority and divers or vehicles are then sent to look at and intervene with at these targets in detail. This part of the operation is *very* expensive.

Any method of detecting and classifying targets with greater accuracy can dramatically reduce overall costs, potentially by an order of magnitude."