Colin Smith and **Phil Andrew** explain how advances in multimode multibeam sonar technology can be harnessed to neutralise underwater explosive threats more quickly and safely

WHAT LIES BENEATH

"What keeps me up at night? The threat of water-borne IEDs."
– Admiral Thad Allen, United States Coast Guard Commandant, US Coast Guard

Underwater improvised explosive devices (UIEDs) pose an array of challenges for military and homeland security forces tasked with search and deactivation. Just as IEDs up the ante from conventional land mines, so the challenges associated with UIEDs are different and much more perilous than with traditional sea mines. For that reason, an innovative approach is essential. Unlike conventional underwater mines, different types of which serve different purposes, potential targets for UIEDs may be military, industrial or civilian. They may be intended to sink warships or merely create fear and confusion and, just as on land, their size varies with the intent.

In dealing with UIEDs, the classic "detection, classification, localisation, identification, reacquisition and neutralisation" (DCLIRN) concept of operations, used in conventional underwater mine countermeasures is derailed at the second stage (classification). This is because, by virtue of UIEDs being "improvised" and thus non-conforming in terms of size and shape, the powerful and sophisticated image analysis capability used to classify mines in mine countermeasures (MCM) operations is overwhelmed by a bewildering array of unfamiliar shapes. This confounds the classification process.

According to Rear Admiral John Christenson, Vice Commander of the US Naval Mine and Anti-Submarine Warfare Command, "Underwater improvised explosive devices are a credible threat". Commander Thomas Reynolds, US Navy, Retired, makes the following point: "Dealing with roadside bombs in Afghanistan and Iraq prompted the army and marine corps to make major changes in their equipment, tactics and force structure. The navy can adapt many of them for its mine-countermeasures effort."

Harbour environments generally feature limited visibility, large amounts of sediment, shallow water and constrained space for manoeuvring, not to mention debris and obstacles on the bottom. Surfaces to be inspected may be vertical (pier faces), horizontal or sloping (seabed), or complex (pilings). Concrete seawalls or pier faces produce strong sonar returns, and certain bottom types produce high levels of reverberation that can mask sonar returns. In most harbours, a berth for a single ship and its associated pier could be as much as 1,000 feet in length, perhaps 100 feet in width (beam), and 50 feet in depth.

Manual searches using divers are labour-intensive, expensive, and dangerous. Personnel conducting these searches are generally police or military divers trained in explosive ordnance disposal (EOD), combat diving, clearance diving, pier inspection or other trades. Increasingly, however, those tasked with clearing these areas do not have a great deal of technical training. When using sonar, operators look for clear, identifiable images presented via a simple user interface, with minimal training required.

The practice of diving is inherently risky, and dives conducted in currents, near intakes, in conditions of limited visibility or in contaminated water heighten that risk. Needless to say, simply having to search for and deal with devices designed to explode puts divers

Underwater explosive attacks could have a far worse impact than the suicide attack on the USS Cole in 2000

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at considerable risk. Few would argue that reliable, efficient, and robust equipment and technology are critical, so as not to introduce any unnecessary and avoidable additional risk to personnel and equipment.

Moreover, working conditions involve transfer of personnel and equipment from shore to dive boats, necessitating loading, unloading, and setup of equipment. Equipment may be transferred from storage to the vessel, or cross-loaded from vessel to vessel as the situation requires. For expediency, it is critical that equipment be simple to deploy, rugged, and dependable.

Current detection methods include both manual (diver) and automated searches. In the former, pier inspection divers examine surfaces manually and visually, and may also be equipped with diver-held sonar or metal detectors. Automated searches, conversely, employ underwater cameras, along with a variety of sonar tools (sidescan, sector scan, multibeam, or synthetic aperture scan). By substituting equipment for human labour, automation increases the speed, accuracy, and effectiveness of the search, and reduces the safety risk to personnel. Maximising the benefits of automation, however, requires an investment in new advances in technology, software and training. But this is an investment that can pay off in many ways.

The advanced multimode sonar technology available today makes it possible to effectively conduct rapid, precise searches in real time that minimise the safety risks to personnel associated with other search techniques. Multimode sonar provides high-resolution and easy-to-interpret images by combining the rapid refresh rate of conventional multibeam sonar with image quality comparable to that from a single-beam sonar system.

Essentially, the technology of multimode multibeam sonar combines three modes of sonar detection – downward profiling, forward imaging and side imaging sonar – into a single compact unit. Conducted at a speed of 1.5–2.0 knots, searches scan 1,000 l inear feet of vertical pier for a single pass in fewer than ten minutes. A two-person team, comprised of a helmsman and an operator, can accomplish the initial search. The sonar operator localises suspicious targets by electronically "marking" them. These geo-referenced targets are then reacquired for classification and neutralisation by divers or ROVs. The initial search can be completed prior to dive-team mobilisation, with targets and potential hazards located well before the first diver enters the water.

The ability to resolve targets varies depending on the area to be searched, the sonar mode chosen, and the orientation of the sonar head. Objects the size of a 200-liter (50-gallon) drum were readily detectable in trials using all three modes of sonar operation. Remarkably, during an exercise, an actual child's backpack, containing a metal cylinder that was used as a target, was detectable using imaging mode. The traditional DCLIRN sequence of operations becomes detection, localisation, reacquisition, classification, and neutralisation – very similar to the find/fix/finish approach used to target IEDs in Afghanistan and Iraq.

Once the target has been acquired, ROVs or EOD divers can be directed to the target for pursuit using the sonar's horizontal imaging mode, referencing target markers assigned during the search phase. ROVs can also serve as deployment platforms for multimode sonar, and can examine vessels from different angles and other aspects of the vessel not visible using a pole mount. ROV deployment of multimode imaging sonar is useful in examining ships' hulls for parasitic contraband containers and other attached devices such as limpet mines. ROV deployment of multimode multibeam sonar is preferable for examining the underside of ships' hulls.

During usage in the field, the multimode multibeam sonar system met all of the requirements for speed, accuracy, and safety. The end result is a UIED detection system that reduces risk to personnel, provides usable data enabling a variety of sonar techniques, produces electronic search records, and is less labour intensive than alternative search mechanisms. These benefits are achieved through a number of technological advances in

"Today, multimode sonar enables searches that are faster, less labor-intensive and safer than traditional manual diver searches."

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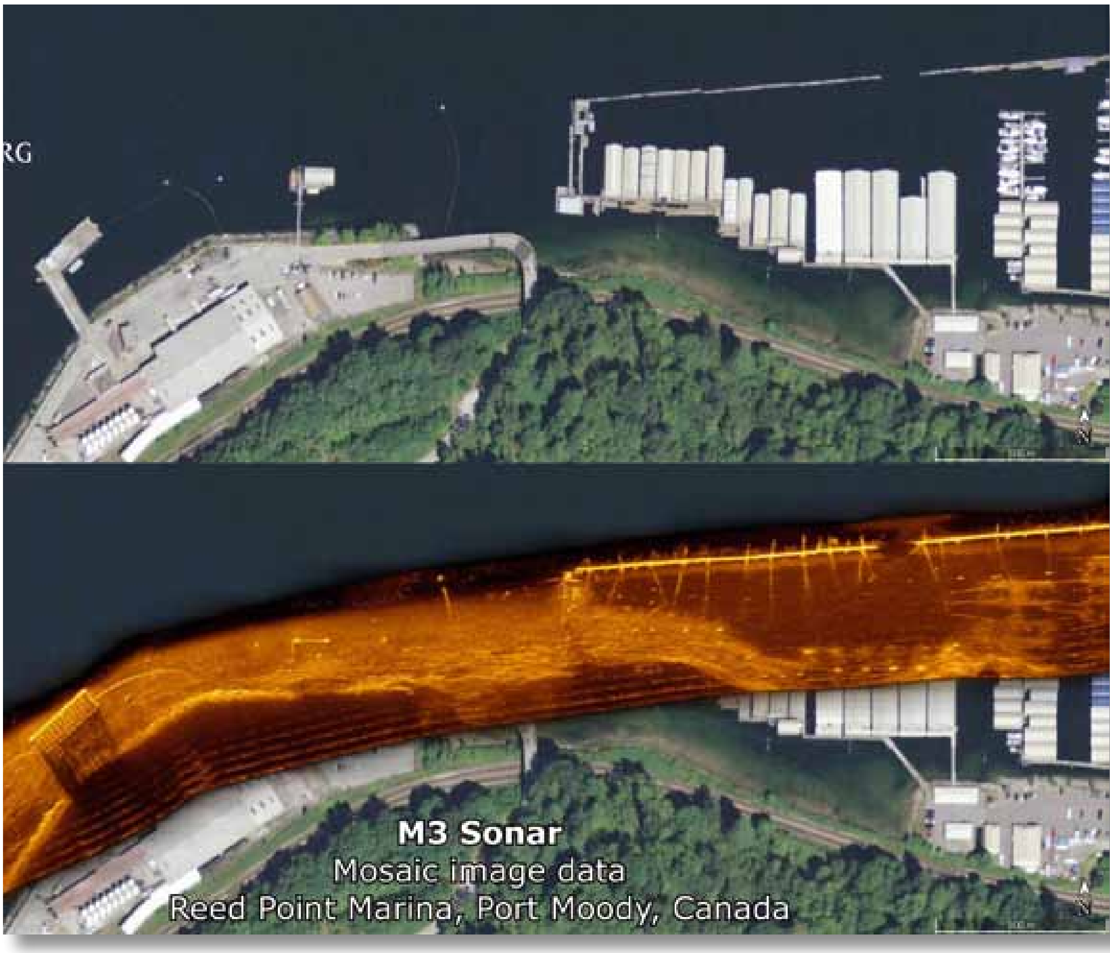

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A multimode sonar image (below) shows the seabed by a marina while an aerial photo (above) shows the same shore from above

the areas of multibeam sonar, sonar processing software and multi-threaded computer processing.

Multibeam imaging sonar delivers a number of significant advances over other sonar technologies. For example, while single-beam or sector scan sonar builds up an image through sequential one or two-degree scans around an axis point, multibeam imaging sonar provides an instantaneous high-resolution, easy-to-interpret image across a wide field of view (typically 120 degrees). Multibeam images, although typically slightly lower resolution than single beam, have the advantage of a much higher refresh rate.

In addition, four pre-defined operating modes (imaging, enhanced image quality, ROV navigation and profiling) allow the multimode sonar to provide advanced application capabilities not found in any other system. Profiling sonar produces sonar returns that can create 3D point cloud images of the seabed, which are readily interpretable by non-technical operators. Imaging sonar data, while not always as intuitive as 3D point clouds, provide a higher level of detail and are much more useful in directing divers and searching vertical surfaces.

The ability to link sub-meter GPS positioning and heading data with sonar images enables sonar operators to geo-reference targets in real time. A team onboard a patrol vessel can quickly switch to directing a diver or ROV to suspicious targets after completing a pier search. Additional motion sensors provide input on the vessel's movement on three axes: roll, pitch, and heave. These MRU inputs provide the information necessary for the software to compute minute changes in the vessel's orientation, minimising possible data errors in 3D profiling data projections.

Complimenting its already exceptional functionality, advances in sonar processing software have provided impressive improvements in the processing capabilities of the multimode sonar. Developed to support a variety of applications, new multimode software features enable higher-resolution sonar imagery, 3D cloud point profiling, dual-head synchronisation, and expanded data processing and data export capabilities. Trackplotter software enables the helmsman to lay out survey lines and maintain a course for the search. Preset sonar configurations simplify operations and make it easier to switch between sonar modes.

Multimode multibeam sonar combines the capability of multiple sonar heads into a single compact housing and provides a sturdy, reliable means of deploying this advanced technology for all phases of UIED clearance operations. Proven effective under many conditions, it can also be deployed on a variety of platforms, including ROVs, further increasing its utility and value.

Operation of the system is made simpler through the use of preset operating modes, and can be undertaken at a range of speeds from zero to two knots, covering 1,000 feet of dock in less than ten minutes. Once the boat and crew are available, equipment deployment can be accomplished in less than an hour, making UIED operations faster and safer than manual searches; as a result, this reduces risk and saves time, budget, and labour. Overall, multimode multibeam sonar is a significant new defence in the ongoing war against those determined to strike at the vulnerable underside of ports worldwide.

Colin Smith and **Phil Andrew** work with Kongsberg Mesotech and have many years' experience in the application of advanced multimode sonar technologies for mine countermeasures, diver detection, ROV obstacle avoidance, fisheries and environmental research.