Safe and sound: UUV-based sonar gets closer to mines

As navies have seen the potential of unmanned autonomous vehicles to enhance mine-countermeasures missions, sonar manufacturers have risen to the challenge by developing systems capable of integration and operation aboard UUVs, writes *Cliff Funnell*

Driven by the long-held desire to remove human operators from the danger zone, technological advances are leading to rapid enhancements in the over-the-horizon military capability of unmanned, autonomous platforms.

These vehicles offer potential solutions to a wide range of maritime defence needs, such as intelligence, surveillance and reconnaissance (ISR), mine countermeasures (MCM) and even weapons delivery. The emergence of this technology not only provides military capability but also offers significant cost savings over traditional methods of fulfilling mundane, dirty or dangerous tasks.

Published in November 2004, the US Navy's (USN's) Unmanned Undersea Vehicle [UUV] Master Plan analysed the application of these platforms – also known as autonomous underwater vehicles (AUVs) – in relation to MCM missions. The authors of the master plan said this was prompted by the need of the US fleet to rapidly establish large, safe operating areas, transit routes (Q-routes) and lanes, typified by long sea lines of communication, offshore operating areas (including both carrier and amphibious operating areas) and littoral penetration areas (such as assault breach and port breakin). These areas can range in size from 100-1,000 n miles^2, or even greater, and cover the water column from ocean depths to the surf zone in support of amphibious operations.

The range of MCM mission types was identified as including: reconnaissance (detection, classification, identification and localisation); clearance (neutralisation and breaching); sweeping (mechanical and influence); and protection (spoofing and jamming). The master plan also stated that the MCM functions that lend themselves to near-term UUV solutions are reconnaissance and neutralisation, which can be broken down into detect, classify, identify and neutralise.

The first UUV to be engaged operationally was Hydroid's REMUS 100 Sculpin in March 2003, when used by a joint UK-US mine-clearing force to help clear a channel through the Khawr Abd Allah waterway to the port of Umm Qasr in Iraq. There are now a number of vehicles of varying size and capability being evaluated by navies globally. These include the larger REMUS 600 as well as those developed by Kongsberg Maritime (the parent company of Hydroid), Bluefin Robotics, Hafmynd, Société ECA and BAE Systems.

Royal Navy: 1294474

UK Royal Navy personnel launch a REMUS 100 in the Khawr Abd Allah waterway on a mine reconnaissance task.


Jane's/Patrick Allen: 1330462

The REMUS 600 system was selected by the RN to meet its Recce UUV requirement.

Conventionally, minehunting has involved an MCM vessel (MCMV) with a hull-mounted sonar approaching a suspected mined zone to detect, identify and classify submerged objects with the intention of destroying or avoiding any mines found. These sonars were designed to scan ahead of the vessel at what was then considered a safe distance from the ship. However, they were really only effective in depths down to about 100 m thanks to several factors: their position in relation to the seabed (the angle of incidence of ensonification); the problems of acoustic propagation near the surface, where thermal layers can create barriers; the effects of reverberation in shallow water; and a high ambient noise factor.

The use of hull-mounted minehunting sonars required a trade-off between the high frequency required for high definition and the lower frequency needed to ensure that the MCMV could stand off at a safe distance. To overcome this problem most MCM sonars incorporate a dual-frequency capability, using a lower frequency to survey a specific area before moving in closer to use a higher frequency to classify and identify the target.

Additionally, to ensure ship survivability against modern mines most MCMVs also carry an offboard vehicle system holding either a camera or a small, high-definition sonar (or both); alternatively they use a diver to positively identify and neutralise the detected target.

However, these existing underwater vehicles – including ECA's PAP, Atlas Elektronik's Pinguin and the Gaymarine Pluto – are limited in both endurance and range because, although connected by a fibre-optic cable for real-time control and telemetry, they have no power cable.

To overcome some of these problems, particularly for operation in deeper waters where mines began to be laid, the variable-depth sonar (VDS) was developed. The technology enabled the sonar – deployed vertically from a ship – to penetrate the inhibiting thermal layers and be placed much closer to the level of the potential target.

However, the VDS in turn was limited by its habit of trailing in the water, which increased with both the vessel's speed and the depth of immersion of the body. The sonar could therefore finish up quite some distance behind the parent vessel, placing the latter in a vulnerable position if approaching the danger zone of a mine. It could also create a problem with localisation of the target, since the position of the towed body in relation to the ship was uncertain.

Propelled VDS

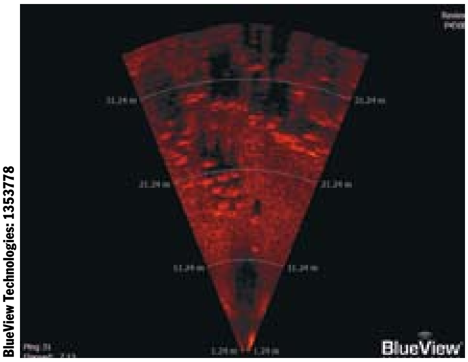
One solution has been a propelled VDS (PVDS) system, now in service with French Navy Tripartite-class MCMVs and due to be fitted in Belgian and Dutch Tripartites. Developed by Thales Underwater Systems and Saab Underwater Systems, the PVDS incorporates a Double Eagle remotely operated vehicle (ROV) and a TSM 2022 Mk III sonar, linked to the MCMV by an umbilical cable. The latter serves as both a source of power to the vehicle and a fibre-optic cable, which is used to pass the full range of sonar data to the MCMV for further processing. The Double Eagle has a maximum operating depth of 300 m and a speed up to 5 kt. The maximum distance from the mothership is 500 m and the ROV has the ability to operate both ahead of the surface vessel in what is known as 'dog on lead' mode as well as in a global mode (master/slave).

Autonomous and tetherless UUVs offer even more potential than the PVDS with their ability to function independently of a surface ship while retaining speed of operation and positional accuracy. UUVs are therefore capable of changing the way navies operate by acting as a force multiplier. For example, by being deployed ahead of an expeditionary force, UUVs can accelerate the military timeline and provide significant battlespace coverage, enabling manoeuvre space within the littoral.

There are a number of limitations, such as energy storage, but new power sources such as lithium ion or fuel cells are capable of extending endurance to several days for larger vehicles with the necessary compartment space.

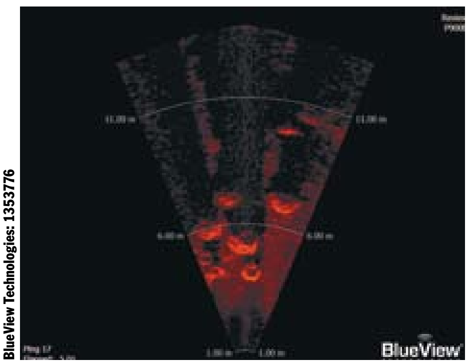
Another constraint is communications. Acoustic telemetry is capable of transmitting approximately 2 kbit/s of data over distances of 2-3 km, while the sonar system itself might be producing 1 Gbit/s. Alternatives include coming to the surface and sending the information via radio or microwave, through a satellite link or to a more distant vehicle acting as a communications relay.

Alternatively, an unmanned aerial vehicle overhead can act as a communications relay, though this will effectively change the concept of operations with more emphasis on post-mission analysis (post-processing). However, the more data that can be analysed or compressed on board the UUV, the less time and energy need be spent communicating the desired information.



BlueView Technologies: 1353778

Mine-sized targets (reef balls) imaged with a BlueView P450E-15 sonar.

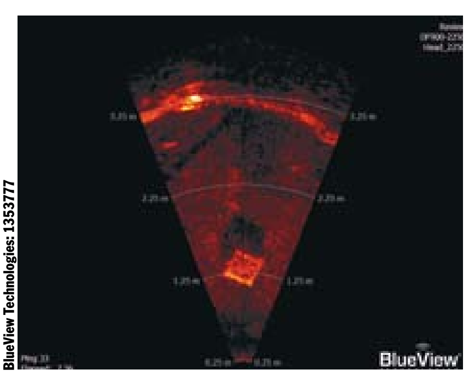


BlueView Technologies: 1353776

Mine-sized targets (reef balls) imaged with the higher-resolution P900E-20 sonar.

BlueView Technologies: 1353775

Comparison of photograph of garden cinder blocks, left, with a 3-D data set collected using a BlueView MB2250 sonar, right.



BlueView Technologies: 1353777

Cinder block imaged in a test tank using the 2,250 kHz head of a BlueView DF900-2250 sonar.

The longer-term option is obviously full autonomy, with many decisions being made on board the UUV and only limited human intervention required. Software systems to support computer-aided detection/computer-aided classification (CAD/CAC) include QinetiQ's Classiphi, Kongsberg Maritime's Post Mission Analysis (PMA) and SeeByte's SeeTrack Military.

The SeeTrack software is being used operationally by the USN and provides the graphical interface for its Common Operator Interface Navy - Explosive Ordnance Disposal (COIN - EOD) system. SeeByte is also presently participating in a US Office of Naval Research (ONR)-funded project, the Very Shallow Water Mine Neutralisation programme. In the first phase SeeByte demonstrated automatic target recognition (ATR) and sonar servoing. The ATR was used to detect, track and classify bottom and floating targets observed using a BlueView Technologies imaging sonar. Sonar servoing was employed to autonomously manoeuvre an underwater vehicle and, using through-the-sensor technologies, home the vehicle to a buoyant target in the water column. An extension to the current work will focus on producing an 'operator in the loop' solution to the mine-neutralisation problem.

The Kongsberg Maritime PMA includes ATR algorithms designed to utilise the increased resolution and additional data products offered by interferometric synthetic aperture sonar (SAS). The system has been sold to the navies of Finland and Norway.

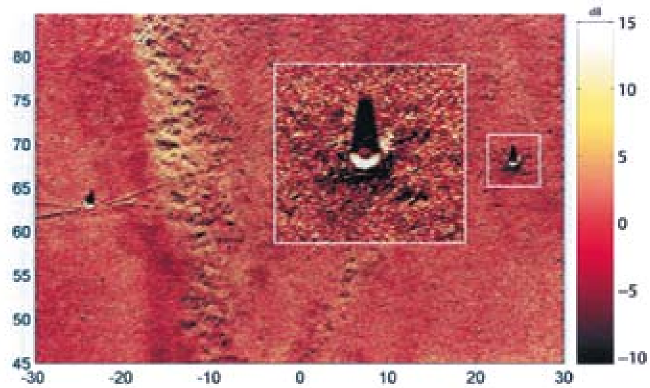
Research activity

In many ways UUVs are potentially acting as a 'destructive technology', reducing the need for purpose-built MCMVs and conventional methods while providing opportunities to a number of small companies and research laboratory spinoffs that have entered this sector, with new sensors providing competition to the traditional military sonar manufacturers.

A number of existing and developmental sonars have now been fitted to UUVs for potential MCM applications. Most of the research under way is into the use of high-resolution imaging sonars for mine identification or EOD detection in port areas, and the development of SAS. Another area of development relates to the miniaturisation of conventional side-scan and swath or multibeam sonars for installation on man-portable UUVs such as the REMUS 100, Bluefin-9 (SeaLion) and Hafmynd-manufactured Gavia.

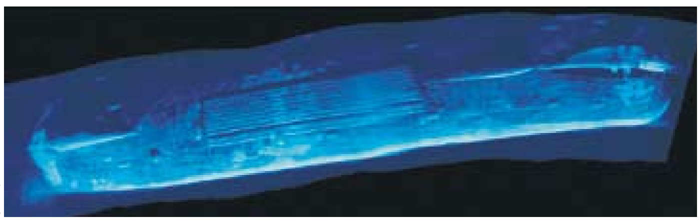
The primary minehunting sonars of the REMUS 100 and Bluefin-9 vehicles, presently in operation with the USN and UK Royal Navy (RN), are the Marine Sonics Sea Scan PC 900/1,800 kHz and EdgeTech 2200-S 850 kHz side-scan sonars. However, a number of other sonar manufacturers are working with Hydroid to ensure their imaging, swath and side-scan sonars are capable of being integrated with the REMUS 100, including sister company GeoAcoustics (both were recently acquired by Kongsberg), SEA (Group) and BlueView Technologies.

The MCM Recce UUVs based on the REMUS 600 and developed for the RN for



Large-scale and detailed imagery from the Thales synthetic aperture sonar fitted to the NATO Undersea Research Centre's Bluefin-21 MUSCLE vehicle. Visible is a slightly buried dummy target, shaped like a truncated cone, of 1 m diameter and 45 cm height. Resolution is 1.6 m x 5 cm; water depth is 20 m; and sonar altitude is 10 m.

NURC: 1193205



DIDSON data collected by Bluefin Robotics and processed by Acoustic View shows the hull of a ship.

Sound Metrics: 1345266

operation from Hunt-class MCMVs will be configured with an EdgeTech 2200-S 850 kHz side-scan sonar, an Imagenex Delta-T 1.7 MHz imaging sonar and an Edgetech 2200-S 4-24 kHz sub-bottom profiler. The REMUS 600 has also been fitted with SAS systems provided by Pennsylvania State University/Applied Research Laboratory (PSU/ARL) and Applied Signal Technology, as well as with the Kongsberg EM3000 multibeam sonar.

HUGIN for Norway

Kongsberg's HUGIN mine reconnaissance system (MRS), based on the HUGIN 1000 AUV, has been evaluated with a number of minehunting sonars; these include the EdgeTech MP-X side-scan sonar and EdgeTech 4400, SENSOTEK and HISAS 1030 SAS systems. The current generation of the HUGIN 1000 multirole vehicle includes Kongsberg's HISAS 1030 interferometric SAS, the EM3002 multibeam echo-sounder, the Imagenex forward-looking sonar and (optionally) a camera and a sub-bottom profiler. The evaluation has been done in close co-operation with the Royal Norwegian Navy (RNoN), which has had an operable AUV MCM capability for more than five years.

The Bluefin-21-based Battlespace Preparation Autonomous Underwater Vehicle (BPAUV), which will feature as part of the mine-warfare mission package equipping the USN's Littoral Combat Ship (LCS), is designed to travel on a pre-set mission plan, following waypoints, while recording bottom maps and other oceanographic data. After the vehicle is recovered, its data will be transferred via the LCS command-and-control system to the PMA software.

Contact information and environmental data will then be uploaded to the Mine Warfare and Environmental Decision Aids Library. The BPAUV is able to map 150 m swaths at depths down to 200 m, with its Klein 5500 455 kHz side-scan sonar providing 7.5-10 cm resolution imagery. Eleven BPAUVs have been built and delivered to date. The Bluefin-21 has also been fitted with a number of SAS systems developed by QinetiQ and Thales Underwater Systems.

The Bluefin-12 vehicle that forms part of the USN's Surface MCM Unmanned Underwater Vehicle Program: Increment 2 (SMCM/UUV-2) is fitted with a QinetiQ SAS, while an ONR-owned vehicle is fitted with a PSU/ARL SAS designated SAS-12, which it demonstrated last May at AUV Fest 2008 at the Naval Undersea Warfare Center in Newport, Rhode Island.

Vehicles that are required to identify mines and/or assist in their detonation are likely to carry forward-looking high-resolution imaging sonars. They can also be employed for the gap-filling role when using sideways-looking side-scan sonars or SAS systems. Other applications include close-in inspection of ships' hulls and structures within ports and harbours for improvised explosive devices, as well as obstacle avoidance, target-homing and navigation.

One of the smaller manufacturers is BlueView Technologies, which produces both high-resolution two-dimensional (2-D) imaging and three-dimensional (3-D) micro

QinetiQ: 1039918

Operations with the Bluefin-21 Gambit UUV for the UK RN have helped shape the development of the QinetiQ SAS payload.

bathymetry sonars. Commercial off-the-shelf (COTS) types are the BlueView 2-D 450 kHz and 900 kHz imaging sonars (P450E-15, P900E-20 and DF900-2250) and the MB1350 and MB2250 microbathymetry systems, operating at 1,350 kHz (~1-inch [2.5 mm] range resolution) and 2,250 kHz (~0.6-inch range resolution) respectively. BlueView has a mature Software Development Kit that is a library of C/C++ routines that enable low-level access to the sonar control routines and data output, allowing AUV control programmes to also control the sonar, read data and interpret it, and cause the vehicle to respond to the sensed imagery.

For tighter integration with specific UUV platforms, BlueView has been building custom engineered-to-order versions of its sonar systems, including those providing multiple forward-looking fields of view (both horizontal and vertical, or multiple frequency), wider fields of view (90 degrees rather than the conventional 45 degrees) and combination forward-looking and microbathymetry functionality in the same sonar attachment.

At AUV Fest 2008, two Nekton Research man-portable Ranger UUVs, each fitted with a BlueView N900X sonar, demonstrated automated homing on simulated mine targets. At the same demonstration two Ranger UUVs equipped with an N900X used algorithms developed by the Massachusetts Institute of Technology (MIT) to automatically detect and track sonar image features in 46 successful data-collection missions. Other UUVs that have incorporated BlueView sonars are the Bluefin Hovering AUV, REMUS 100 and the US Naval Postgraduate School's Aries vehicle.

Another high-resolution imaging sonar is the DIDSON (Dual-frequency IDentification SONar), an acoustic lens-based sonar system able to produce high-resolution images for the inspection and identification of underwater objects. The sonar was developed at the Applied Physics Laboratory, University of Washington, with funding from the USN's Space and Naval Warfare Systems Command, and is now manufactured by Sound Metrics.

The standard system operates at two frequencies (1.8 MHz and 1.1 MHz) and uses acoustic lenses, which provide sharp images from 1 m to more than 30 m in range. The longer-range system results in a lower resolution but has a range up to 90 m. DIDSON has been evaluated on both the REMUS 100 and the Bluefin Hovering AUV developed jointly by Bluefin and MIT under ONR and EOD Program Office funding, and part of US Naval Sea Systems Command's EOD Hull Unmanned Vehicle Localization System (HULS) contract.

The basic principle of the SAS is to combine successive pings coherently along a known track in order to form an image with much higher resolution than conventional sonars –typically 10 times higher. The azimuth or along-track resolution of a sonar can be computed as the ratio between the acoustic wavelength and the length of the array. A longer array will increase this ratio but fitting such a long array is not always possible or practical on most underwater vehicles. Operation at a higher frequency will increase the ratio but will at the same time limit the achievable range due to higher acoustic attenuation. The SAS principle overcomes these limitations by utilising data from several consecutive pings to synthesise a longer sonar array. Thus, SAS technology is not as limited by either range or resolution as practical-sized side-scan sonars are, and is therefore capable of providing high-resolution images from UUVs.

The USN master plan declared that SAS is "the current leading candidate to best meet the requirements of the MCM mission. SAS promises to provide both increased area coverage rate (or a reduced required number of UUVs) and increased resolution. A vehicle with SAS would likely have a three- to fivefold improvement in classification area coverage rate and a threefold improvement in resolution".

Custom-made systems

A number of minehunting SAS systems – including QinetiQ's Vision 600, Kongsberg's HISAS 1030, Ultra Electronics' ARTEMES and the PSU/ARL system – have been developed specifically for UUVs. Other companies developing such systems, or fitting them to UUVs, include Applied Signal Technology, Thales Underwater Systems and Atlas Elektronik.

QinetiQ's SAS – Vision 600 is the COTS version – has been fitted to a number of UUVs. These include: the Bluefin-21 Reliant and Gambit that were developed as part of a UK/US collaborative venture; the Sapphires UUV delivered by Saab Underwater Systems to Sweden's Defence Materiel Administration (FMV) in October 2007; and the two Bluefin-

QinetiQ: 1193208

The SMCM/UUV-2 programme combines the Bluefin-12 UUV with the QinetiQ Vision 600 synthetic aperture sonar.

12 vehicles that form part of the SMCM/UUV-2 contract awarded to Bluefin Robotics in August 2006, for deployment and operation from the USN's Avenger-class MCMVs and vessels of opportunity. The aim of SMCM/UUV-2 is to provide a vehicle capable of detecting bottom and partially proud mines to a range of 100 m, as well as offering a capability against shallow, buried targets.

The SAS system consists of a 60 cm array with 24 receive array elements per side. By utilising a configuration that is theoretically capable of achieving a 0.5-inch resolution, QinetiQ seeks to ensure the consistent production of a 1-inch resolution across a wide range of environmental conditions. The array is designed to provide close control of transmit and receive beam patterns, reducing the susceptibility to multipath, while the increased number of phase centre overlaps realised by the longer array with smaller element spacing allows for effective filtering of the motion data, further excluding the destructive multipath effects. The increased number of phase centres allows the QinetiQ motion compensation system, QDAVA – which integrates information from the displaced phase centre antenna (DPCA) algorithm, vehicle motion sensors and acoustic modelling – to produce higher-accuracy results than are obtainable from a high-grade inertial navigation system. This provides the ability to extend the path reconstruction capability and hence the range/resolution of the system. The increased overlap and QDAVA also seek to reduce reliance of the SAS on high platform stability.

QinetiQ's SAS processing algorithms have been demonstrated through the successful completion of hundreds of at-sea runs with the Gambit UUV in research trials and operations with the RN. Each vehicle is furnished with a removable data storage module (RDSM) so that raw sonar data can be physically removed from the vehicle, eliminating long data downloads and enabling rapid on-deck vehicle turnaround. The RDSM, along with removable batteries, enables the Bluefin-12 vehicles to be turned around on deck in 30 minutes or less.

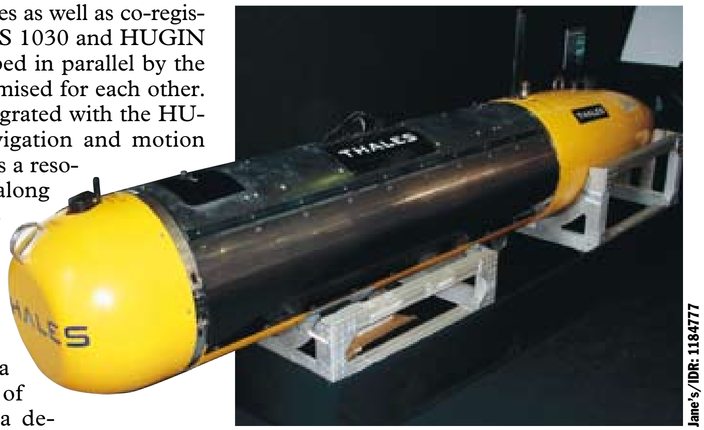
Resulting from the SENSOTEK technology demonstrator project managed by Kongsberg and the Norwegian Defence Research Establishment to develop an interferometric SAS for the HUGIN vehicle, the HISAS 1030 is a wideband SAS sonar with a frequency range of 60-120 kHz, capable of producing high-resolution acoustic images as well as co-registered bathymetry. HISAS 1030 and HUGIN 1000 have been developed in parallel by the same team and are optimised for each other. The sonar is tightly integrated with the HUGIN aided inertial navigation and motion sensing platform and has a resolution of 2-5 cm both along and across track. HISAS has a range of up to 200 m to each side at 4 kt, and 260 m at 3 kt, contributing to an effective area coverage rate higher than 2 km²/h. Data is recorded at a rate of about 60 Gbit/h onto a detachable RAID system for post-processing on board the surface vessel.

For bathymetry, HISAS 1030 has two full-length receive arrays on each side of the HUGIN to form two SAS images of the same scene with slightly different geometry, enabling very-high-resolution interferometric processing from SAS data. Typical SAS bathymetry resolution is 10x10 cm, allowing 3-D imaging of mines and mine-like objects. HISAS 1030 also has a steerable phased-array transmitter, which can be optimised to avoid multipath and hence extend the range in shallow water. Full-quality HISAS imaging is typically available out to a range of 10 times UUV altitude in shallow and very shallow water.

A full-capability HUGIN MRS, incorporating a HISAS 1030 high-resolution interferometric SAS, was delivered to the RNoN in March 2008 to undertake rapid environmental assessment, high-precision seabed route surveys and mine detection, classification and localisation. HUGINs fitted with the HISAS 1030 will also equip the Finnish Navy's three new MCMV 2010 ships.

Ultra Electronics' ARTEMES high-resolution SAS system, featuring co-located high-resolution swath bathymetry and side-scan imagery, has been developed for high-speed coverage for mine detection and is also capable of being operated from UUVs and unmanned surface vehicles. One concept considered for future mine warfare operations is the integration of ARTEMES with the SeaFox mine-disposal system in an unmanned underwater vehicle, enabling a single asset to deliver an integrated mine-detection and -disposal capability. ARTEMES is available in frequencies up to 360 kHz and is in service with a United States-based client, with six systems operational.

Ultra has also developed a Mini-SAS tri-frequency (273 kHz, 310 kHz and 247 kHz) system specifically for use with mid-sized 12-inch UUVs. Making use of wideband pulse compression with long-transmit pulses and the Ultra Versatile Sonar Architecture, Mini-SAS aims to provide concurrent side-look with multi-aspect forward and aft 'squint' looks to augment detection and classification survey. An optional bathymetric capability, to full SAS resolution, can also be included. Mini-SAS has been demonstrated in very-shallow-water operations providing SAS and seabed bathymetry coverage at slant ranges in excess of 10:1 of the sonar altitude.



The Bluefin-21 AUV, equipped with Thales Underwater Systems' synthetic aperture sonar modular payload section.

Forward Look Sonar

Another complementary development is Ultra's VSS Forward Look Sonar (FLS), designed to be configured as a gap-filling sonar, an obstacle avoidance sonar, and as a stand-alone forward-look detection and classification sonar, operating at centre frequencies from 60 kHz to 450 kHz. Orthogonal pulses are combined in the processing to increase the effective physical aperture length in order to improve the resolution of the system.

Small independently sampled elements unambiguously sample the full sector of interest forming sector widths of up to ±75 degrees using a curved transmitter array. Bathymetry is obtained from wideband processing of the beam-formed data to generate a 3-D image over the full-range swath from each ping. The FLS is also available in a dual-frequency 75 kHz/300 kHz version. It can also form part of a combined system with the SAS system. The first delivery to a US client was due to be completed in early 2009.

The PSU/ARL SAS installed on the Bluefin-12 UUV – SAS-12 – operates at 180 kHz in the side-looking mode. A suite of arbitrary waveforms can be transmitted to optimise SAS performance in a given environment. The broadband receiver is designed for minimal channel-to-channel gain and phase errors necessary for acquisition of high-fidelity signals. Signals are filtered and decimated then passed to the recorder and processing systems. The individual element aperture determines the ultimate resolution limit. In principle, SAS-12 can be processed for 25 mm resolution at all ranges out to a maximum of 150 m.

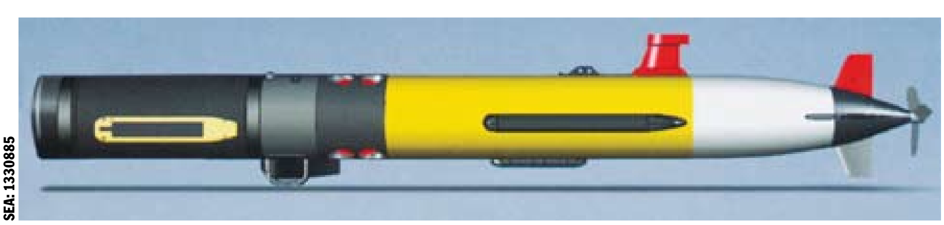
Another Bluefin-21 UUV fitted with an SAS was that acquired by Thales Underwater Systems as part of the MUSCLE technology demonstrator system built for the NATO Undersea Research Centre (NURC) at La Spezia, Italy. The MUSCLE SAS is a 300 kHz wideband interferometric SAS optimised for shallow-water minehunting; it consists of two receiver arrays with different vertical fields of view, each appropriately narrowed to reject multipath but steered in different directions so as to cover almost all the full swath. The vertical receive element comprises upper and lower arrays made up of 19 and 10 vertical sub-elements respectively. The sub-elements are connected by a shading capacitor-resistor network that allows a degree of flexibility, by hardware modification, in forming the vertical-beam pattern of both arrays. The MUSCLE SAS system has 13 beams spaced 4 cm apart. It was planned to implement onboard SAS processing resolution up to 2.5 cm at 225 m.

MUSCLE is being used to demonstrate high resolution at extended ranges, improved highlight data (to enhance classification performance) and increased search rates. Acceptance testing began at La Spezia in May 2006. A trial conducted by NURC in June 2006 demonstrated imaging with shadow contrast in excess of 5 dB at up to 170 m range in 20 m water depth, with resolutions of 1.6 cm in range and 5 cm in cross-range.

SAS is regarded by NURC as a powerful enabler towards achieving reliable ATR. Research at NURC is addressing ATR algorithms to complement SAS/high-resolution data (these include model-based techniques, adaptive approaches to cope with environmental changes and online learning algorithms) and the use of shape theory to support ATR performance prediction.

Although a number of multibeam swath sonars have been developed for surface craft, towed fish or larger UUVs, the challenge has been to integrate this capability with the smaller, man-portable vehicles. One such development has been the GeoSwath Plus, a PC-based shallow-water (down to 200 m) swath bathymetry system from GeoAcoustics. The system provides swath coverage of up to 12 times water depth to a maximum of 600 m. It is believed that the 500 kHz version has been fitted to the REMUS 100, Gavia and Talisman vehicles. This has a maximum swath width of 150 m, a range of up to 12 times depth and a resolution slant range of 1.5 mm.

Another system is the Sea (Group) SWATHplus-RS100 high-resolution bathymetry and side-scan sonar, purpose-designed for the REMUS 100. This is a 468 kHz sonar featuring 1-3 composite transducer technology and is supplied as a short (38 cm-long) section of the UUV. According to SEA, the SWATHplus-RS100 has a swath width of up to 15 times the vehicle altitude (maximum 75 m) to



The SWATHplus-RS100 sonar fitted to the front end of the REMUS 100 UUV.

a maximum of 200 m (less than 160 degrees swath width equivalent). Coverage density is more than 150 samples per metre at a maximum update rate of up to 30 Hz. Resolution across track (best case) is quoted as 3 cm. The first in-water trials of a SWATHplus-RS100 integrated with a REMUS 100 were performed in the UK in March 2008.

Collaborating with nearly all minehunting sonar and man-portable UUV manufacturers is BAE Systems Integrated Systems Technologies. In the words of Andy Tonge, project manager for the Talisman vehicle, "the future potential [of autonomous systems] is vast, particularly if the paradigm shift towards designing systems to integrate a total system from mission payload to combat management system [CMS] is made".

Talisman is a family of maritime UUVs using common technology from air and land systems. Its design concept is that of an underwater 'truck' capable of carrying a range of payloads weighing up to 500 kg. The second generation of the Talisman concept is the Talisman M, which is designed for remote MCM and configured to carry minehunting sonars and four Archerfish mine-disposal neutralisers. As a consequence, it has the capability within a single mission to locate mine-like objects then either telemeter data to an MCM operator or perform CAD/CAC on board and, on operator command, deploy an Archerfish to dispose of the mine. Talisman has already been integrated into the NAUTIS CMS that equips the RN's Hunt- and Sandown-class MCMVs, avoiding the need for separate control equipment to be installed in the ships and allowing existing trained MCM operators to utilise Talisman as an extension to their existing capability.

Jane's/Patrick Allen: 1367620

The Talisman UUV with SeaBat 7123 integrated into the nose.

A number of demonstrations have been staged for the RN and USN, both in very shallow inshore waters and at sea in a dummy minefield. A typical mission consisted of Talisman conducting a sonar survey to identify mine-like objects, then surfacing to establish high-bandwidth communication, data transfer to the MCM operator and simulated disposal of the mine with Archerfish. While an onboard CAD/CAC system was available, in order to demonstrate the utility of the system a full data set from a GeoSwath sonar was telemetered to the operator over the radio-frequency link. Following the identification of a mine target, and with Talisman holding position in a geostationary hover, the operator initiated an automated Archerfish launch and vectored the round to the target, demonstrating the practicality of combining mine location and mine disposal into a single mission sortie.

Talisman is also capable of carrying Atlas Elektronik's SeaFox mine-disposal system and the REMUS 100. The vehicle can also be deployed from a vessel of opportunity, avoiding the requirement for an MCMV to enter a minefield.

Talisman has recently had a forward-looking Reson SeaBat 7123 advanced MCM sonar installed, operating at 110 kHz, 240 kHz and 455 kHz. This sonar was designed for installation on surface ships and has demonstrated that the Talisman is capable of operating with the same minehunting sonar as a traditional MCMV. ■

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