A View of the Autonomous Underwater Vehicle Market

For a number of years now the Autonomous Underwater Vehicle (AUV) has been the undisputed tool of choice for certain niche underwater applications, but with growing acceptance the AUV has now become an established solution for the subsea survey community. The following review explores these uses and aims to summarise the latest industry trends.

For those unfamiliar with AUVs, it is a robotic platform that operates underwater and is typically powered by batteries and it has no physical link to the surface. The missions undertaken by AUVs are typically pre-programmed and the AUV is capable of carrying multiple sensors which gather data of the environment. For hydrographic applications, the AUV has demonstrated that is capable of acquiring superior, higher resolution data than is typical of ship-borne or towed systems. They are able to swim very close to the seabed and their shape provides the sensors with a very stable platform from which to gather data. By equipping latest generation multi-beam imaging sonar systems and side-scan sonar systems, AUV users can produce very accurate three dimensional and imaging maps of the seabed. They are also able to gather optical camera pictures and video from the seafloor, allowing scientists to carry out studies from a very cost-effective platform.

In the last decade, the AUV has become the tool of choice for the expeditionary Mine Counter-Measures (MCM) community and for very deepwater commercial surveys. The scientific community has also taken AUVs on board for both work in shallow waters and deep exploration. However, in this time new applications have surfaced with many AUVs proving their worth in helping to optimise search & rescue and salvage operations while also increasing the number of systems being used for archaeology work.

Navy Work

AUVs have been widely accepted by many of the world's navies to provide MCM in challenging environments such as in Very Shallow Waters (VSW). Leading navies have integrated AUVs with their existing MCM doctrine and these systems have now been used successfully in many actual MCM operations and in other missions, including Rapid Environmental Assessment (REA) work through to Persistent Monitoring. Navies operate small form factor AUVs in the VSW and larger diameter AUVs when either requiring larger coverage (as the larger systems are equipped with more batteries) or when needing to operate deeper. A typical navy operation will see the AUV operator pre-program a mission, consisting of a number of waypoints, then deploy the AUV, and process the data once the mission is completed.

Such has been the success of AUVs that many navies are now viewing the AUV as the central component towards deploying a modular off-board capability. There has not yet been a consensus as to how this capability will be deployed, but leading navies are developing novel concepts of operations, as evidenced by the US' Littoral Combat Ship, the UK's Mine warfare, Hydrographic and Patrol Capability (MHPC) and Australia's Offshore Combat Vessel. The overriding consensus for MCM is to shorten the sensor-to-shooter timeline, i.e., improve the way that AUVs are operated in order to ensure that the time taken to gather the data followed by the appropriate action is minimised. This needs to be done while maintaining or improving the overall performance. As a result, AUV manufacturers and their suppliers have been working on developing better sensing technologies and automated solutions for analysing the data so that it can be readily processed.

Though primarily driven by an MCM requirement and operated by the expeditionary force and Explosive Ordnance Disposal (EOD) divers, navies are now also looking to exploit the AUV and broaden their applications. Many navies have used AUVs for search and rescue and in many instances salvage applications. A famous case in which an AUV was used was the discovery and survey of the sunken ferry, *Princess Ashika*, by the Royal New Zealand Navy's Operational Diving Team and a specialist Remote Search Team off the coast of Tonga, helping families of the tragedy that cost 87 lives find solace.

Commercial Use of AUVs

In parallel, the oil and gas industry has been driving the commercial use of AUVs in very deep waters. A number of contractors now regularly operate fleets of between one and six AUVs to carry out very precise surveys of the seafloor that may be used to facilitate deepwater construction. These fleets have been deployed all over the world. The requirement here is to develop survey quality data more efficiently than would be possible with a Remotely Operated Vehicle (ROV). The ROV is another type of underwater robot, but in its case it has a tether (cable) linking it to the surface. When operating an ROV in depths of over 1000 metres the tether management, the process of ensuring that the right amount of tether is paid out, becomes an issue and may slow down operations, as many metres of tether experience drag when moving across the water column. Without a tether to drag it down the AUV can turn and fly quicker than an ROV so that a survey can be carried out at a fraction of the cost due to time saved. Over the last 5 years, the oil and gas industry has also commissioned AUVs in shallower waters on the strength of the quality of the data and the ease of operation. Navies demonstrated the higher value of data from surveys carried out in the VSW. This enabled the demonstration of the ease of operation compared to towing sensors or deploying, and at a fraction of the cost of ROV operations it has become a simple business model that is gaining in acceptance. AUVs are now being used in all corners of the world to carry out landfall inspection work and also inspect the infrastructure of fixed platforms in shallow waters. Recently, these systems have been used commercially to inspect pipelines as part of the oil companies' commitment to ensuring that their infrastructure is kept in the best condition. Smart software algorithms are processing data on board the AUV to find the export pipelines in the sensor data and guide the AUVs through the inspection.

New initiatives are developing hover capable AUV concepts to inspect the subsea infrastructure autonomously. These concepts are looking to inspect, not just the pipelines, but other infrastructure too, such as subsea wells, manifolds and risers (pipes that guide the oil and gas product to the surface). The requirement is for a more advanced concept of operations and for increasing levels of autonomy. A good example is the Autonomous Inspection Vehicle, currently in final stages of development by Subsea 7. This system boasts up to 24 hours of endurance and has demonstrated the ability to gather data and carry out oil and gas inspections subsea.

Science Use and Academic Groups

The scientific community has also taken delivery of many AUVs. A number of systems are operated by leading scientific institutes to carry out work at massive depths and have helped carry out innovative research in the field of volcanology, marine life around hydrothermal vents and also helping understand the Arctic and Antarctic. Good examples of scientific work are the exploits of the Autosub operated in the National Oceanographic Centre in Southampton, UK. No other AUV programme has been as successful in learning about the Polar environment. But many centres are procuring smaller form factor AUVs and also glider AUVs for research purposes and their impact is being felt across the scientific world. AUVs are helping inform decisions across multiple scientific disciplines.

Where to Next?

Navy and Defence

The world's navies are driving two technical concepts:

- swarms and
- large displacement AUVs.

The **swarm** concept involves multiple AUV squadrons collaborating to achieve common goals. The systems may help each other to deal with each vehicle's individual limitations in sensing, by helping form a common picture of the environment that they share. This is leading to the development of behaviours that will see AUVs react to their environment and then share the information with the AUV team to improve and expedite the operations.

The **large displacement** concept will enable persistent surveillance over extended periods of time in coastal water, helping keep our borders safe. They will drive improvements in autonomy and battery technology. These concepts have been prevalent for a number of years now but it is only recently that initial work is being carried out at research level and select products are starting to deliver some of the capability required.

Oil & Gas Industry

Two overriding goals are driving oil companies to use AUVs, namely, the cost of maintaining infrastructure in deepwaters and the requirement for Arctic exploration. The consensus is to develop field resident AUVs capable of operating in challenging environments as well as possibly very deep waters. These requirements are driving research into new ways to power the AUV and to improve communications to the AUV. These systems also require a new level of sophisticated autonomy, never before required by the AUV. In many circumstances the AUV will need to be able to navigate and make decisions in relation to its environment while unsupervised. The industry is already answering to these challenges with some of the concepts introduced by the Subsea 7 AIV and other hover capable systems. The final outcome will most likely result in a number of different solutions deployed on-site and operated from the comfort of the office. Some of these systems will be capable of monitoring icebergs, others will be used to inspect and interface with the subsea infrastructure. In other words their primary role will be to fulfil a capability gap not addressable by current concepts of operations.

Science

The scientific needs for the future of AUVs vary according to the scientific field and these are hard to summarise. The overriding requirement is for evermore specialist and efficient tools. The industry is researching and producing new sensing technologies and the ability to deploy such technologies in the right place at the right time.

It is an exciting time for the AUV industry with commitment from governments and industry to invest in technologies that stand to improve operations, make business sense and remove humans from harm's way. The following survey details the choice and range of systems available to consumers and it paints a picture of an industry that is maturing and provides users with excellent value for money.