Into the deep end

By Andrew MacNaughton, Randy H White and Michael Bendzlowicz, US Naval Oceanographic Office.

The 6000-metre depth rated SAMS AUV provides the US Navy military survey access to nearly 97 per cent of the world's ocean floor – and allows for faster oceanographic surveying than traditional towed deepwater systems.

> "SAMS is rapidly becoming the standard for deepwater oceanographic surveying."

Deep-ocean surveying is an expensive and time-consuming process. Tethered vehicles, although slow to tow and cumbersome to manoeuvre, enjoy virtually unlimited power, can carry numerous sensors, and can telemeter back data at extremely high rates. Recent developments in autonomous underwater vehicle (AUV) technology have cut into these advantages, as advances in sensors, batteries and software controls have enhanced the traditional AUV advantages of speed and manoeuvrability.

The Subsurface Autonomous Mapping System (SAMS) is the US Navy's deepwater oceanographic survey AUV. Full-ocean-depth capable, SAMS is designed to conduct two types of survey: independent physical oceanographic data collection and sidescan sonar bottom mapping. Maintained and deployed by the US Naval Oceanographic Office (NAVOCEANO), SAMS is the emerging workhorse for NAVOCEANO's deepwater surveys.

SAMS was developed and built by the USA's Woods Hole Oceanographic Institution (WHOI) Ocean Systems Laboratory (OSL) for NAVOCEANO. SAMS is built around the Remote Environmental Monitoring Unit System (REMUS) AUV software (another OSL product) and has many of the same sensors as that shallow-water system.

Vehicle characteristics

SAMS is a free-swimming, programmable and redirectable AUV. The SAMS vehicle is full-ocean-depth rated (6000 metres, 20,000 feet) and has been tank-tested to that depth. Field testing to 5000 metres (16,500 feet) was completed in March 2003, and testing of a second vehicle was recently completed in August 2004.

SAMS is typically navigated using long baseline (LBL) techniques for high positioning accuracy; acoustic transponders are deployed and surveyed by the SAMS host vessel, and the SAMS vehicle computes its position based upon signal time-of-travel from the transponders. SAMS' LBL navigation is essentially identical to that of the REMUS vehicle. SAMS is also capable of independent navigation, using GPS positions at the surface and a high-accuracy internal gyroscope and Doppler velocity logger (DVL)-determined bottom-track speed to estimate subsurface velocity and position.

The vehicle is both programmable and redirectable. A set mission is typically downloaded to the vehicle during topside workups, and if programmed correctly the vehicle will operate accordingly. However, the SAMS operator can also redirect the vehicle during a deployment, allowing for mid-mission changes in vehicle tasking. This allows for active investigations of unusual oceanographic features or fronts or of unusual bathymetric or geologic features identified during data playback and analysis.

SAMS is powered by two rechargeable lithium-ion battery assemblies. The batteries supply eight kilowatt-hours at 25 volts and can sustain vehicle operations for at least 12 hours. After vehicle recovery, the batteries can be completely recharged within six hours. NAVOCEANO deploys the vehicle with two pairs of battery assemblies, reducing turnaround time and therefore maximising survey time.

A summary of vehicle characteristics is provided in Table 1. The vehicle is usually deployed with a descent weight and recovered after dropping the ascent weight. These are the most efficient means of moving the vehicle vertically, although SAMS is capable of driving itself up or down as required.

Thus, the SAMS vehicle, at a 5000-metre site, if most efficiently deployed (using a descent weight and releasing the ascent weight), could spend more than 10 hours on the bottom conducting a mapping survey and would cover nearly 7.5

Capability	Specifications
Maximum depth	6000m (20,000ft)
Endurance	
Oceanographic survey	16hrs
Bottom-mapping survey	12hrs
Descent rates	
Self-driven	25m min^{-1}
Descent weight	50m min^{-1}
Cruising speed	4 knots
Ascent rate	
Self-driven	45m min^{-1}
Ascent weight released	140m min^{-1}

Table 1. Vehicle characteristics.

square kilometers (assuming 100 per cent coverage of a 100-metre-per-side swath width).

The vehicle has three swimming modes: depth, altitude and triangle. While in depth mode, the vehicle swims at a near-constant depth. In altitude mode, the vehicle maintains a certain altitude above the bottom (as determined by acoustic Doppler current profiler [ADCP] bottom detect). Altitude mode is used for sidescan bottom-mapping missions. In triangle mode, the vehicle cycles between two depths while moving along a transect line, thus collecting profile data while following a preset pattern.

Vehicle sensors

SAMS is intended to serve as a platform for multidisciplinary survey missions. It has a full suite of oceanographic and bottom survey sensors, all of which are full-ocean-depth rated. The systems and manufacturers are listed in Table 2.

The pressure, conductivity-temperature-depth (CTD), ADCP and optical backscatter (OBS) sensor data are fed to the mission computer within the SAMS vehicle. The Marine Sonics sonar data are processed and stored on a separate, dedicated computer.

The vehicle software relies on data from the pressure sensor and the ADCP. Bottom detect data from the ADCP are used by the vehicle to determine vehicle altitude, which is integral to effective use of the sidescan sonar.

Expanding survey capabilities

One of the primary missions of NAVOCEANO is "to conduct multidisciplinary ocean surveys and to collect and analyse all-source oceanographic data." To meet this task, NAVOCEANO operates seven oceanographic survey vessels worldwide. From these ships NAVOCEANO deploys either smaller survey platforms (including Hydrographic Survey Launches, or HSLs) or sensor systems to collect high-precision, high-resolution data. Although shallow-water hydrography and littoral oceanography requirements dominate NAVOCEANO's survey agenda, the Navy also requires NAVOCEANO to maintain a deepwater capability to augment its survey fleet.

SAMS is that deepwater capability, but the vehicle also offers NAVOCEANO considerable flexibility. Nearly 97 per cent of the world's oceans is shallower than 6000 metres and is therefore accessible to SAMS. NAVOCEANO's investment in deepwater AUV technology is by no means wasted, as shallower depths merely allow for greater survey time for the vehicle. Compare that to a 3000-metre-rated vehicle, which could only access 16 per cent of the world's ocean floors.

Ultimately, the AUV improves NAVOCEANO's survey efficiency. While SAMS is deployed, the ship can operate independently, collecting other types of data to aid environmental characterisation of an area. It is also important to note that SAMS is a roll-on/roll-off (RO/RO) system that can be easily shipped worldwide. NAVOCEANO can deploy SAMS to any of its ships (or even to ships of opportunity) to meet immediate Navy needs or emergent requirements. There are no dedicated SAMS platforms; all the ships can be leveraged as host vessels for the AUV, therefore all the ships have host capabilities.

Sensor type	Manufacturer
Pressure sensor	Paroscientific (USA)
CTD	Sea-Bird Electronics (USA)
ADCP	RD Instruments (USA)
OBS	Sea-Tek (Norway)
Sidescan sonar	Marine Sonics (USA)

Table 2. System sensors.

Summary

NAVOCEANO's SAMS AUV has been engineered to serve as a multipurpose, multidisciplinary RO/RO survey tool. The combination of sensors useful for physical oceanography, bathymetry mapping or sidescan sonar mapping allows for considerable flexibility when scheduling and planning missions.

The vehicle augments the capabilities of NAVOCEANO's ships while providing an efficient means of collecting relevant data. The SAMS vehicle is capable of independent operation for eight to 12 hours of each mission, thus freeing the host vessel to conduct separate surveys nearby. This is a tremendous advantage relative to traditional towed vehicles. SAMS can collect data at triple the rate of some towed systems and allow the host ship to operate semi-independently.

It can therefore be argued that the SAMS AUV offers a compromise between data collection and survey rate. However, the AUV also frees the host ship to conduct semi-independent operations during SAMS missions. These are the hallmarks of a successful AUV programme: more data, collected faster, more efficiently, and independently. SAMS has already met these benchmarks and is rapidly becoming the standard for deepwater oceanographic surveying.

Note: The inclusion of names of any specific commercial or academic product, commodity or service in this paper is for informational purposes only and does not imply endorsement by the US Navy or by NAVOCEANO. ■