Into the Deep End: The Naval Oceanographic Office's Subsurface Autonomous Mapping System (SAMS) AUV

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The 6000-m-rated SAMS AUV provides the U.S. Navy military survey access to nearly 97% of the world's ocean floor—and allows for faster oceanographic surveying than traditional towed deepwater systems.

Deep-ocean surveying is an expensive, time-consuming process. Tethered vehicles, although slow to tow and cumbersome to maneuver, 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 maneuverability.

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

SAMS was developed and built by the 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 m, 20,000 ft) and has been tank-tested to that depth. Field testing to 5000 m (16,500 ft) was completed in March 2003, and testing of a second vehicle was recently completed August 2004.

SAMS is typically navigated using Long Base Line (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 8 kWh at 25 V and can sustain vehicle operations for at least 12 hours. After vehicle recovery the batteries can be completely recharged within 6 hours. NAVOCEANO deploys the vehicle with two pairs of battery assemblies, reducing turnaround time and therefore maximizing survey time.

A summary of vehicle characteristics is provided in the table below. 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.

TABLE I
VEHICLE CHARACTERISTICS

Capability	Specifications
Maximum Depth	6000 m (20,000 ft)
Endurance	
Oceanographic Survey	16 hrs
Bottom-mapping survey	12 hrs

Descent Rates	
Self-Driven	25 m min^{-1}
Descent-Weight	50 m min^{-1}
Cruising speed	4 knots
Ascent Rate	
Self-Driven	45 m min^{-1}
Ascent weight released	140 m min^{-1}

Thus, the SAMS vehicle, at a 5000-m site, if most efficiently deployed (using a descent weight and releasing the ascent weight), could spend over 10 hours on the bottom conducting a mapping survey and would cover nearly 7.5 square kilometers (assuming 100% coverage of a 100-m-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 side-scan 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 II.

The pressure, conductivity-temperature-depth (CTD), ADCP, and optical back scatter (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.

TABLE II
SYSTEM SENSORS

Sensor Type	Manufacturer
Pressure Sensor	Parascientific
CTD	Sea Bird Electronics
ADCP	RD Instruments
OBS	Sea Tek
Side-scan sonar	Marine Sonics

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 side-scan sonar.

EXPANDING SURVEY CAPABILITIES

One of the primary missions of NAVOCEANO is "to conduct multidisciplinary ocean surveys and to collect and analyze all-source oceanographic data." To meet this tasking, 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% of the world's oceans is shallower than 6000 m 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-m-rated vehicle, which could only access 16% 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 characterization of an area. It is also important to note that SAMS is a roll-on/roll-off (RO/RO) system that can be shipped worldwide easily. 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.

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 side-scan 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 8 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 program: 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 Navy or by NAVOCEANO.