



SEAHORSE engineers work on a module inside one AUV of the SEAHORSE 2 bays.



SEAHORSE 2 is being prepared for launch from the IC-508 AUV Support Vessel.

# SEAHORSES and SUBMARINES

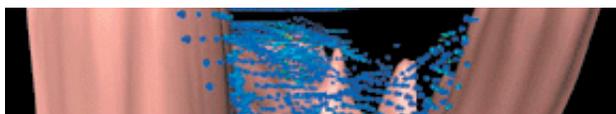
## Testing transformational capabilities with modern UUVs at NAVOCEANO

by Craig A. Peterson and Martha E. M. Head

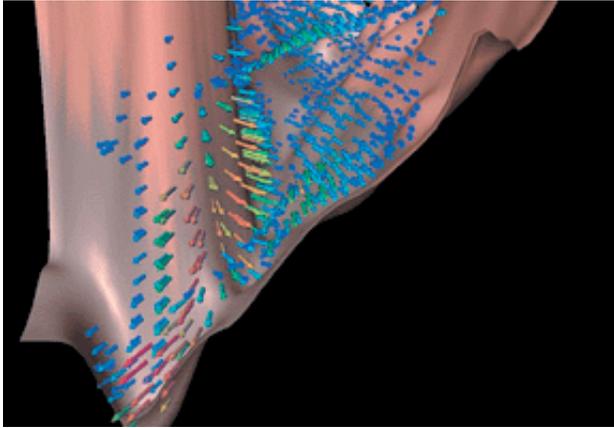
For the past 40 years, the Naval Oceanographic Office (NAVOCEANO) has been the Navy's primary source of environmental data and analysis products to support navigation and performance prediction for weapons and sensors. And similarly, NAVOCEANO will be the primary source of environmental information for supporting the operation of unmanned undersea vehicles (UUVs) in the future.

Located at the John C. Stennis Space Center near the Gulf of Mexico in southern Mississippi, NAVOCEANO has a 172-year history of military ocean survey. Ocean data is collected worldwide by dedicated fleet of eight survey ships, supplemented by ships of the University National Oceanographic Laboratory System (UNOLS) fleet and airborne and subsurface craft. Complementing this array of platforms are drifting and moored buoys, as well as satellites, NAVOCEANO uses this information to generate environmental products tailored to the warfighters' needs, and we support virtually every current fleet operation. Examples of the environmental information NAVOCEANO supplies can be viewed on the Internet at <http://www.navo.navy.mil>.

In a key naval transformation effort, NAVOCEANO has volunteered a fully-autonomous SEAHORSE-class UUV to the Undersea Technology Directorate of the Naval Sea Systems Command (NAVSEA) for use in the first of a series of Transformational Payloads and Sensors Demonstrations for the SSGN submarine conversion program. In the planned demonstration, the SEAHORSE UUV will be launched from an SSBN missile tube and will conduct a long-range, multi-mission mine countermeasures (MCM) operation. The demonstration will also feature an oceanographic survey.



As an example of why it is important to understand the details of the underwater environment in UUV areas of operation, this three-dimensional visualization of the current field at the Strait of Hormuz shows enormous variability in both speed and direction from surface to bottom. The viewer is looking from the



Gulf of Oman into the Arabian Gulf, and although the maximum depth of the strait is only 105 meters, the vertical scale is exaggerated here by a factor of over 1,000. NAVOCEANO's Shallow-Water Analysis and Forecast System (SWAFS) generated this prediction.

SEAHORSE was introduced recently by NAVOCEANO as an economical, long-endurance, autonomous UUV for collecting oceanographic data. It followed a technology program at the Defense Advanced Research Projects Agency (DARPA) that was transitioned to the Navy several years ago. Low cost and rapid development were possible largely because, for oceanographic missions, some military standards for robustness could be relaxed. SEAHORSE was developed at the Pennsylvania State University Applied Research Laboratory (Penn State ARL), which was able to leverage substantial previous work in UUVs and UUV propulsor technology.

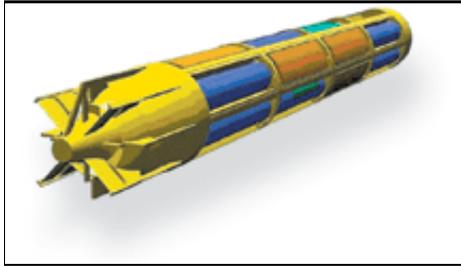
These fully-autonomous UUVs are force multipliers for oceanographic survey ships collecting high quality data in the littoral regions of the world. Intended to operate primarily from the Navy's USNS Pathfinder (T-AGS-60)-class military survey ships, SEAHORSE has a sturdy, yet adaptable, design and the long endurance needed for both demanding ocean conditions and deployment from either platforms of opportunity or even shore stations.

Penn State ARL delivered SEAHORSE 1, the vehicle planned for the SSGN Demonstration, to NAVOCEANO in October 2000. It executed its first operational survey from USNS Bruce C. Heezen (T-AGS-64) a year later. The vehicle is presently equipped with a 150-kHz sidescan sonar, a 300-kHz acoustic Doppler current profiler, a mast-mounted global positioning system antenna, and an inertial navigation system. SEAHORSE 2 was delivered in October 2001 and is currently in underway testing. Penn State is also fabricating a third operational vehicle, SEAHORSE 3.

SEAHORSE construction is modular to facilitate field maintenance, rapid mission turnaround, and payload flexibility. With an integrated afterbody for propulsion and hydrodynamic control, plus variable ballast systems fore and aft, the UUV can execute a variety of high-level commands, such as maintaining a constant depth, course, and speed; navigating between waypoints; and conducting search and survey patterns. Typical mission operating depths range from 15 to 1,000 feet, with endurance up to 72 hours. SEAHORSE vehicles are 28 feet long, slightly more than three feet in diameter, and weigh 10,500 pounds. Standard alkaline batteries (D-cells) power the vehicle, allowing a 300-mile range. NAVOCEANO plans to transition to rechargeable lithium-ion battery technology in the near future.

### **SSGN Mission Demonstration**

NAVSEA will deploy SEAHORSE in January 2003 from a USS *Ohio* (SSBN- 726)-class submarine. In addition to demonstrating the feasibility of launching a SEAHORSE-size vehicle from an SSBN's missile tubes, Experiment "Giant Shadow" will illustrate how the combination of Special Operations Forces, unmanned vehicles (both airborne and underwater), and an SSGN can provide the joint commander with new capabilities . The "Forward Pass Consortium" was selected by NAVSEA to conduct the demonstration. Consortium members are Raytheon Corporation, General Dynamics Electric Boat, Boeing, and Rite-Solutions. Besides NAVOCEANO, other participants in this demonstration include Penn State ARL and the Naval Undersea Warfare Center facilities at Newport, Rhode Island and Keyport, Washington.



This computer-aided rendering of SEAHORSE shows its modular battery and payload bays. The vehicle is nearly 28 feet long by 38 inches in diameter and weighs nearly five tons. Mission range is 300 nautical miles, and endurance is 72 hours.

SEAHORSE will deploy vertically from a TRIDENT missile tube on the SSBN, rotate to its normal horizontal configuration, and then swim up to 200 miles before launching a simulated mission payload at a predetermined point. Oceanographic data and sidescan sonar images will be collected during the mission. Then SEAHORSE will be recovered onto a T-AGS-60-class military survey ship, much as it would be in a conventional oceanographic mission.

### NAVOCEANO's UUV Forerunners

NAVOCEANO has strong ties to government, commercial, and academic organizations with UUV interests. These ties facilitate an active, affordable program for oceanographic and bathymetric measurements.

For many years, NAVOCEANO has used tethered or towed unmanned vehicles for undersea exploration. Side-scan sonar, like the SeaMap system transitioned from a program at the University of Hawaii, is used for low- to medium-resolution surveys. Another example is the Towed Oceanographic Survey System (TOSS) developed at Woods Hole Oceanographic Institution (WHOI). TOSS is towed very near the sea floor (often just 5 meters above) for very high-resolution bottom mapping. It has side-scan sonar for acoustic images and both still and video optical cameras. For both of these systems, the towing cable provides mechanical control and maintains fiber-optic communications with the survey party.

In the late 1980s through mid-1990s, the semi-submersible ORCA vehicle, a diesel-powered, remotely-operated survey platform, provided NAVOCEANO some useful experience with vehicles that did not require a mechanical tether. The Naval Research Laboratory (NRL) and Chance and Chance, Incorporated (through an associated Cooperative Research and Development Agreement) led the adaptation of ORCA for oceanographic applications. The vehicle, though unmanned, was far from autonomous. It had to maintain "line-of-sight" radio communications with the mother ship, and since it operated at the surface, it had to be kept under constant visual observation to ensure the safety of local shipping. Later, the ORCA concept was adapted for the surface-ship Remote Minehunting System (RMS).

The Semi-Autonomous Mapping System (SAMS) is a smaller, acoustically-controlled UUV capable of 12- hour mapping missions to a maximum depth of 20,000 feet. Here, it is prepared for launching from USNS *Bruce C. Heezen* (T-AGS-64).

NAVOCEANO's first fully autonomous UUV was transitioned in the late 1990s from the discontinued Defense Advanced Research Projects Agency (DARPA) program mentioned above. The actual vehicle, designed and built at Draper Laboratories - and named Lazarus at NAVOCEANO - incorporated advanced technologies and offered long range and reliable autonomy. Although the DARPA vehicle's monolithic construction was not suitable for field maintenance aboard oceanographic ships, it served well on NAVOCEANO's Gulf of Mexico range to provide the experience that helped make the SEAHORSE class affordable and effective.



An earlier unmanned platform, the Towed Oceanographic Survey System (TOSS) is typically trailed behind a survey ship and positioned as close as 15 meters above the bottom to do high-resolution mapping.



Currently, the SEAHORSE group of vehicles, including the SSGN demonstration's SEAHORSE 1, is the backbone of NAVOCEANO's untethered fleet. However, a semi-autonomous UUV, the Semi Autonomous Mapping

System (SAMS), is also being acquired from WHOI. SAMS is an outgrowth of Woods Hole's Remote Environmental Monitoring UnitS (REMUS) program and will operate primarily in conjunction with TOSS surveys. It is "full-ocean-depth" capable (i.e., to 20,000 feet) and has 12-hour endurance. SAMS could readily be converted for fully autonomous operation, but it is now designed for use within a coned-shaped volume of acoustic control transmissions under an oceanographic ship. Like TOSS, it will collect high-resolution side-scan images by working very near the bottom. SAMS has completed in-water testing with deployment from a T-AGS-60 platform. Its first operational survey with full operating capability will be in May 2003. Information on SEAHORSE and other NAVOCEANO UUV projects are also available on the Web site noted previously.

To maintain close ties with industry and academia, NAVOCEANO, along with its second-echelon command, Commander, Naval Meteorology and Oceanography Command (COMNAVMETOCOM) , and the Office of Naval Research, sponsor biannual Autonomous UUV (AUV) demonstrations on NAVOCEANO's Gulf of Mexico test range near Gulfport , Mississippi. These "AUV Fests" are planned to demonstrate the application of emerging AUV technology to military hydrography and oceanography requirements.

### **Environmental Considerations**

The forthcoming SSGN demonstration can also be expected to show in a realistic scenario the extent to which operational use of truly autonomous UUVs will require detailed knowledge of the ocean environment. Environmental information is necessary for advance planning, current operations, and post-mission data analyses. For the approaching demonstration, this background information includes sea surface environmental effects, as well as ocean currents from the surface to operating depths, tides, temperature and salinity profiles, and bathymetry. Other key information includes local-area fishing activities and hazards to navigation.

In general, safe, cost-effective operation of UUVs, whether for undersea warfare or commercial and academic applications, demands a minimal set of meteorological and oceanographic information in addition to bathymetry, coastal configuration, and hazards to navigation. This information for planning, conducting, and analyzing UUV operations should include analyses and forecasts of:

- Sea state and direction for launch and recovery
- Ocean current fields, including tidal currents and tidal cycles along the proposed track and at potential working depths
- Temperature and salinity (water density) along the proposed track
- Area overviews, including information about ocean fronts and eddies
- Weather in the area and weather approaching or otherwise affecting ocean conditions in the operating area
- Surf or river outflow for some operations
- Acoustic-propagation, if acoustic communications will be used at a distance
- Electromagnetic propagation, if radio communications will be used at long range

For nearly a half century, the Naval Oceanographic Office has provided the Navy's air, surface, and subsurface forces the environmental data and analysis they've needed to best carry out their

missions in harm's way. That tradition continues as new technologies, such as fully autonomous UUVs, transform the Navy and expand its need for operational oceanography.

**Craig Peterson is Director of the Ocean Projects Department at the Naval Oceanographic Office. He came to NAVOCEANO after a 30-year active-duty Navy career that included both flying helicopters and serving in the Navy's METOC (Meteorology and Oceanography) officer community.**

**Dr. Martha Head is an oceanographer at NAVOCEANO with broad program management experience in ocean acoustics, ocean modeling, remote sensing, and oceanographic databases.**

### **Table of Contents**