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Unmanned Vehicle Initiatives to Expand the USW Battlespace

ABSTRACT

This paper discusses the current development challenges and unmanned vehicle technology demonstrations for two on-going unmanned vehicle initiatives for expanding the battlespace for USW: MANTA unmanned undersea vehicles (UUV) and SPARTAN unmanned surface vehicles (USV). Modular payload designs common to both UUV and USV efforts enable rapid reconfiguration for numerous missions including ASW, ISR, SSTD, counter-SOF, MIW, and cruise missile defense among others. While the SPARTAN USV is envisioned as a high-speed, long endurance platform performing operations after hostilities break out, the MANTA UUV capitalizes on endurance in clandestine operations performed during the pre-hostilities phase. Operation synergy is gained with acoustic communications (ACOMMS) which would permit subsurface forces to remain clandestine for the duration of the mission. The modular MANTA technology test bed offers reduced operating cost, supports large size payloads, and provides extended operation using low cost energy sources. Both MANTA and SPARTAN will be primary asymmetric force levelers enabling the battle force commander to match inexpensive threat capability with an appropriate response. Inherent netcentricity increases USW effectiveness by providing expanded sensor coverage in areas where other assets are difficult to deploy or where risk to manned platforms is unacceptable.

INTRODUCTION

The 21st Century will bring changes to the conduct of undersea warfare. Surface combatants and submarines will be required to operate in the shallow waters of the world, close to land, and against a variety of very quiet threat submarines and a capable mix of relatively low cost undersea mines and small craft. All of these threats may exist in a relatively dense traffic environment of commercial and neutral sea going craft. In such environments, the combatant or submarine must possess an effective mix of endurance, sensors, connectivity, and weapons to engage the enemy with minimal to no collateral damage.

The concept of an autonomous unmanned vehicle (UV) shows promise in areas where traditional anti-submarine warfare (ASW) and mine warfare (MIW) employment of submarine and surface combatants are currently lacking the undersea dominance needed to attain undersea superiority in the littoral. The need for inexpensive reusable sensors that can rapidly detect and possibly react to a threat without unnecessary risk to the warfighter or ship is very real in the environments found in the littoral. Joint Vision 2010 (JV2010) establishes *full spectrum dominance* as the key characteristic for our armed forces in the 21st century. This concept is put forth to define the coverage in the littoral battlespace that needs undersea prosecution in areas where surface and air superiority are challenged or the environment is adverse. Full spectrum dominance and its four supporting operational concepts (*dominant maneuver*, *precision engagement*, *full-dimensional protection*, and *focused logistics*) could dramatically improve with the use of UVs when and where operations suggest that full-dimensional protection may be difficult or improbable to establish with conventional surface or submarine combatants.

With the Navy's operational move into the littorals comes a move towards network centric operations and the threat of asymmetric warfare. Network centric operations allow all members of the battlegroup to share a common tactical picture with identical, up-to-date information and knowledge of the environment and battlefield. The application of *unmanned surface vehicles* (USVs) and *unmanned undersea vehicles* (UUVs) directly enhances network centric USW by providing external sensing capabilities and additional nodes on the network, thereby providing an improved tactical and environmental picture. The asymmetric threat, posed by low cost assets (e.g. mines, armed small craft), may provide an adversary with the ability to limit, delay, or prohibit access or operations by U.S. forces. This threat, whether perceived or real, could undermine the U.S. response and effectiveness in the area. USVs and UUVs counter the asymmetric threat by distributing the combat system throughout the battlespace and providing low cost assets to counter low cost threats.

The requirements for UVs come from a flow down of higher level requirements found throughout various levels of the Navy. The two primary U.S. Navy requirements with respect to USW for the 21st century are "battlespace dominance against subsurface threats" in littoral areas of the world and "significantly reduced manning operations." UVs respond to these requirements in addition to the following fleet requirements and issues:

- CNO White Paper, ASW Focus, 1998 – "Develop long endurance sensors and unmanned ASW vehicles"
- N86, Surface Warfare Prioritized Capabilities, Jan 1999 – Significantly reduce manning requirements for existing and future ships
- N863, DD 21 Operational Requirements Document, Nov 1997 – "Establishment and maintenance of battlespace dominance against subsurface threats…"
- N87, Submarine Warfare Future Naval Capabilities, Jan 1999 – Cooperative littoral ASW (Net-Centric ASW); Real time data/information conversion of battlespace knowledge to a common tactical picture
- Fleet Command Capability Issues (CCIs), April 1998 – Common, consistent tactical picture; Mine warfare (offensive and defensive); Shallow water ASW; Unmanned tactical reconnaissance
- N84 Far Term S&T/R&D Roadmap (Tactical Engagement), August 1999 – Autonomous unmanned platforms with reconfigurable payloads and telemetry systems

ASN(RDA) has directed the development of the Navy Unmanned Undersea Vehicle Master Plan (in review) to establish the course of UUV development in order to meet these requirements. An integrated unmanned vehicle master plan for all unmanned vehicles does not currently exist.

SYSTEM CONCEPTS

Future unmanned vehicles share a common vision (Figure 1); they will be modular, multi-mission, and generally affordable. The technological thrusts toward miniaturization will enable UVs to be more capable and operate at longer ranges for greater endurance. Initially, sensors will be the primary payloads, but as control systems become more robust and reliable, the addition of multi-spectrum weapons will become the norm.

The USV is envisioned as a low observable, high-speed, long endurance platform performing operations primarily after hostilities break out. The USV is capable of putting large payloads on station for long periods of time. The UUV capitalizes on endurance in clandestine operations performed during the pre-hostilities phase of a conflict. As new communications systems mature, operation synergy in unmanned vehicle cooperation is gained. For instance, acoustic communications (ACOMMS) would enable the USV to be the clandestine communications conduit between surface and subsurface forces, thereby enabling submarines and UUVs to remain covertly below the surface for the duration of the mission. It would also enable submarine control of USVs, either directly or via a UUV.

FIGURE 2. SPARTAN USV vehicle conceptualization.

The SPARTAN Concept

The SPARTAN concept, shown in Figure 2, is a remote or autonomous control, reconfigurable, high speed USV capable of performing a variety of missions, including littoral ASW, intelligence, surveillance, and reconnaissance (ISR), and MIW. Due to its modularity, SPARTAN can be rapidly reconfigured (in approximately one hour) with a new mission package; the basic hull and command decision system remain common to all SPARTANs. This plug-and-play capability is an attractive naval force multiplier and would allow a single high value combatant to control one or more USVs, in either remote controlled (interactive), or autonomous mode. With this flexibility to rapidly reconfigure the USVs for single or multi-mission operation and place them at key positions as an extended warfare element of the combatant or battlegroup, the ship or battleforce's effectiveness can be significantly enhanced without adding additional combatant ships or manpower.

The USV will be deployed from various combatant and non-combatant ships. Other deployment options include being dropped by transport aircraft or being forward deployed (pre-stationed) in potential areas of operation. There exists a wide array of potential missions for SPARTAN that will cross a number of warfare areas. Potential USV missions are shown in Figure 3.

The MANTA concept

MANTA vehicles, conceptually shown in Figure 4, would be autonomous, reusable UUVs

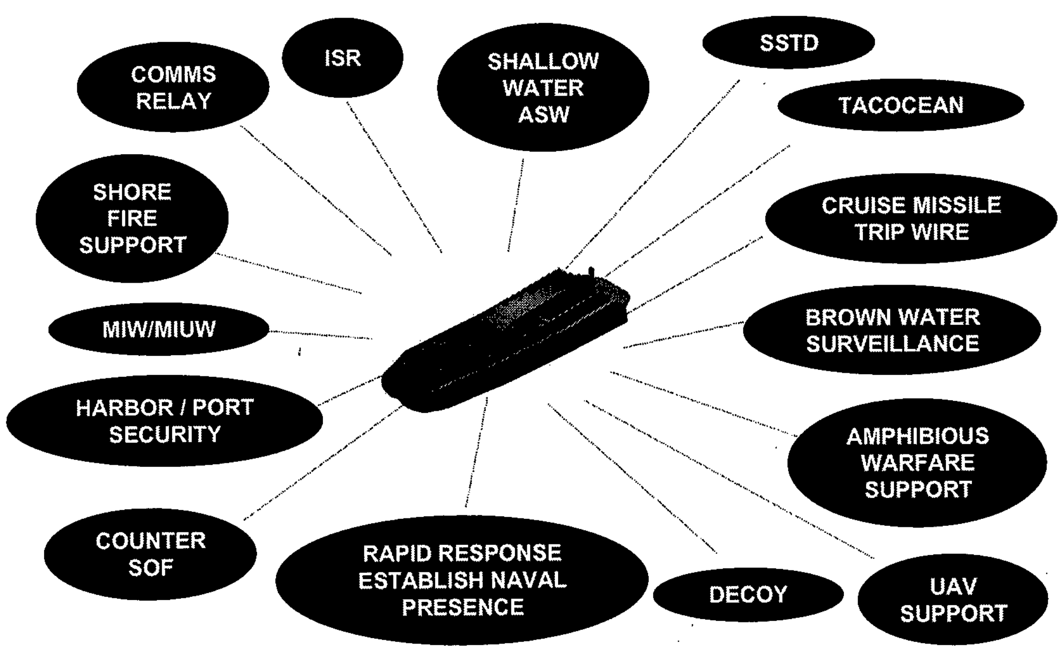


FIGURE 3. Potential USV Missions

that would be reconfigurable and have multi-mission capability. Several of these vehicles would be carried conformally within hull depressions on a submarine of the future as shown in Figure 5. They would be launched and

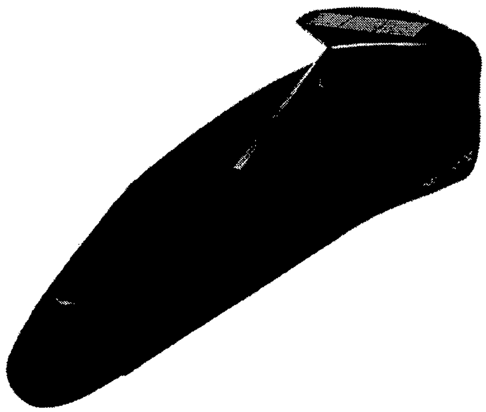


FIGURE 4. MANTA Conceptualization

recovered external to the submarine pressure hull and could be deployed from great standoff distances to transit clandestinely in shallow water areas. Carrying their own sensors, weapons, and countermeasures, MANTAs could operate independently, or if needed, be directed by other manned platforms via the local undersea network or surface communications. Communications via acoustic, electromagnetic, or optical channels would enable the UUV to exchange data with the mother ship or with other network nodes. With weapons and countermeasures, they would have the capability to provide further protection to the battlegroup.

This concept is very futuristic. Today, however, UUVs are becoming an integral part of the U.S. Navy fleet. As an example, the Navy is currently pursuing the Long-term Mine Reconnaissance System (LMRS) which will be delivered for service in FY04 and will be operated from a submarine. Additionally, the Navy has generated a UUV Master plan that calls for future UUVs to perform: maritime reconnaissance, undersea search and survey, communication/navigation aiding, and submarine track and trail.

TECHNICAL CHALLENGES

There are a number of technical challenges facing unmanned vehicles. Fortunately, many of these challenges can be leveraged with other efforts. Autonomous control, sonars, above surface sensors, navigation and obstacle avoidance, communications, and launch and retrieval are considered the major technical challenges facing unmanned vehicles.

Autonomous Control

Autonomous control poses a large technical risk. The approach to reducing this risk is to develop the vehicle's autonomy in stages. This can be accomplished by beginning with a remotely controlled vehicle, gradually providing more autonomy, and eventually arriving at a fully autonomous vehicle capable of executing mission order commands from the battlespace commander.

Autonomous control is a common problem being worked on by the U.S. Army and U.S. Air Force for unmanned ground vehicles (UGV) and unmanned aerial vehicles (UAV), respectively. The Navy has developed a remote controlled jet ski capable of carrying a small ISR package known as Owl (NSAP Program). According to the FY99 UGV Master Plan, the Army has developed tele-operated and semi-autonomous UGVs (Demo I, II) and is currently continuing the effort with the development of autonomous mobility technology for tactically maneuvering a small UGV over rugged terrain (Demo III). Current programs such as the Long-term Mine Reconnaissance System (LMRS) will also provide valuable technology for UV development, especially UUVs. Utilizing knowledge gained from these efforts can further reduce the risk for USV and UUV autonomous control development.

Sonars

In the past, sonar systems have been developed and optimized for blue water operation. With the move of operations into shallow-water environments, the sonar systems will need to be developed and optimized again. The sonar system needs to enable the UUV to formulate a tactical and environmental "scene" within its patrol area.

Above Surface Sensors

In order for the UUV to maintain clandestine operation and perform its mission, above surface sensors will be integrated into stealthy, low-observable masts. Development of these stealthy, low-observable masts poses a technical challenge that can be leveraged with development efforts in low observable above-surface sensors for submarines.

Navigation and Obstacle Avoidance

Navigation and obstacle avoidance are issues for both USVs and UUVs, however, the context is different for each. USVs are concerned with avoiding semi-submerged objects as well as proper navigation through waves in high sea states. UUVs are concerned with below surface objects and underwater currents. Obviously, there are different challenges associated with each case. The challenge in UV navigation and obstacle avoidance requires a balance between object detection capabilities and vehicle dynamics. The need for access into the littorals increases the navigation and obstacle avoidance challenges facing USVs and UUVs alike.

Communications

Communications pose a technical challenge because of the bandwidth requirements for transferring sensor data and information in real time back to the battlegroup. Data transfer required for vehicle control is not seen as a major technical challenge since the bandwidth required is relatively small, especially when compared with the bandwidth required for sensor data and information transfer. With the limitations in bandwidth, the challenge becomes balancing between the amount of data passed versus data processed by the UV.

Launch and Retrieval

Launch and retrieval (L&R) is one of the greatest challenges facing unmanned vehicles. Current surface ships use davits and well decks to launch and retrieve various craft including rigid inflatable boats (RIBs) and landing craft, air cushion (LCAC). Current davit systems require a man on the deployed craft in order to disconnect/connect the L&R system.

Automation is one solution to the challenge of L&R of unmanned vehicles. Automated retrieval may be achievable for USVs through an adaptation of the arrestor hook and cable system used on aircraft carriers for landing aircraft combined with an existing davit system. This concept allows for "error" in the relative positions of the USV and host ship caused by disturbances such as high sea states.

Well decks reduce the complexity of the moving parts associated with the automated davit concept, but still pose some challenges. Since space is a valuable commodity on all naval vessels, the open hull area available to the USV or UUV is quite small and will require relatively precise maneuvering of the UV.

Another potential L&R system for USVs is the concept of an articulated rail or ramp system. The system would extend from the host platform and the USV would drive up onto the ramp (or rail). Once the USV is on the ramp, the ramp would be brought into the host ship.

The vision of UUVs mounted into depressions (Figure 5) in the hull of the submarine is one of many future possibilities; these future concepts pose some interesting challenges. One of the main challenges in the launch and retrieval of the UUV is the maintenance of the acoustic advantage of the submarine.

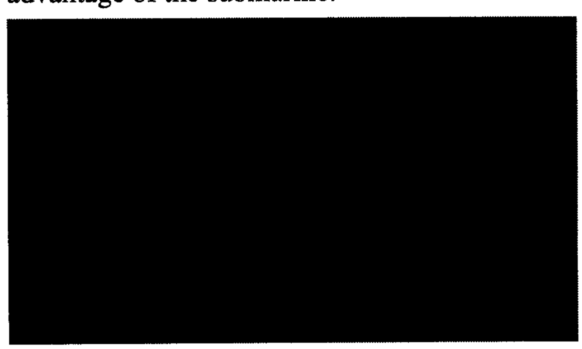


FIGURE 5. MANTA UUVs launched from depressions in the submarine hull.

PROVING THE CONCEPT: UV TEST BEDS

In order to reduce risk and address the technical challenges facing UVs, test beds are being used. The SPARTAN USV test bed and the MANTA UUV test bed are available as test platforms.

SPARTAN USV Test Bed

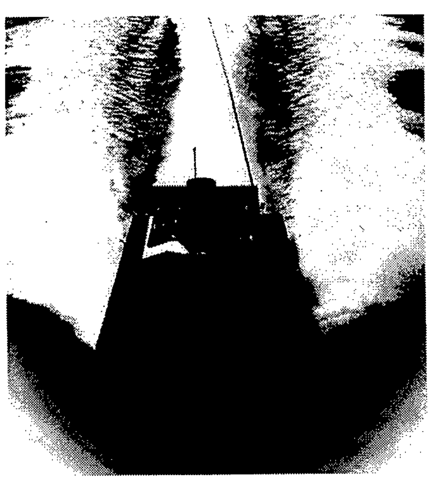
The USV platform is based upon a high-speed, multi-mission patrol craft capable of being equipped with various modules. The SPARTAN USV concept consists of a family of platforms in a variety of lengths, including 7 and 11 meter Rigid Inflatable Boats (RIB) or High Speed Patrol Crafts (HSPC). The design speed is over 50 knots in Sea State 3 (SS3), 20 knots in SS4, and capable of making way in SS5. The USV endurance at 20 knots is 24 hours, which equates to a range of 480 nautical miles, however, maximum range is approximately 1000 nmi.

A non-developmental item (NDI) test bed, TEAM ONE USA's *GB-12-296 Challenger,* has been designed for backfit to major surface combatants utilizing NDI davits, capable of manned L&R in sea state 4. The forward fit design is envisioned as a powered drive into well decks with rail launchers. The craft is also transportable/deployable by heavy lift aircraft. Basic specifications of *GB-Challenger* platform are given in Figure 6. These performance numbers are representative of today's technology base. As technology improves, so will the performance capabilities of USVs. Given the modular design, technology upgrades can be installed more rapidly and USVs will have the ability to react faster to emerging or changing threats.

The SPARTAN USV effort is a combination of a Navy laboratory and industrial team. Naval Undersea Warfare Center (NUWC) Division, Newport, Raytheon Systems Company, Northrop Grumman, and TEAM ONE USA are all contributing expertise to the USV development.

MANTA Test Vehicle

The MANTA test vehicle, shown in Figure 7, is a large-scale, fully autonomous UUV that will demonstrate future concepts with a variety of payloads and technologies. The MANTA test vehicle design (shape and size) was chosen not only to allow the vehicle to function as a multi-mission modular testbed, but also to demonstrate two desired MANTA features: weapons deployment, and submarine interface/integration. For weapons deployment, the MANTA Test Vehicle design allows for a torpedo in the forward center bay; the torpedo would have a low speed swimout capability. This design requirement drove the vehicle length. In the near term (for possible testing on a 688-class sub) the MANTA test vehicle was designed with a low profile shape, to minimize potential impacts to the submarine's



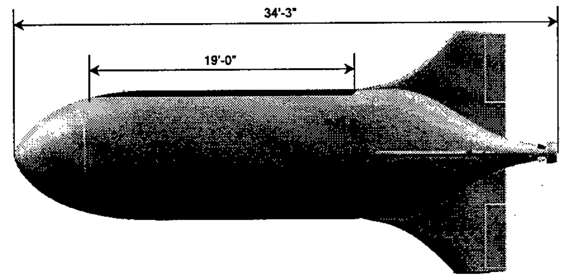
Long-range, Multi-Mission, Modular *GB-12-296 Challenger* High Speed Patrol Craft

Specifications:
Aluminum Hull Craft with Closed Cell Foam Sponsons
Length: 36 feet (11 meters nominal)
Beam: 12 feet
Full Load Displacement: 22,000 lbs.
Payload: 5,000 lbs.
Engines: Two EA Caterpillar 660 BHP @ 2300 rpm
Waterjet Pumps: Two KaMeWa Model F-40
Design speed: 50 knots in SS3, 30 knots in SS4, Steerageway in SS5
Endurance: 12 hours @ 50+ kts ≈ 600 nmi (26 hours @ 30 kts ≈ 800 nmi)

FIGURE 6. SPARTAN USV Test Bed Specifications: *GB-12-296 Challenger®* High Speed Patrol Craft. (Photo Courtesy of TEAM ONE USA)

MANTA Test Vehicle

Specifications:
Speed: 0-10 knots
Endurance: Varies with Energy System Configuration
Depth: 800 feet
Weight in Air: ~16,000 lbs.
Free Flood Region: ~16,000 lbs.
In-Water Run Trim: Neutral +/- 200 lbs.
Dry Payload Capacity: 3476 lbs.



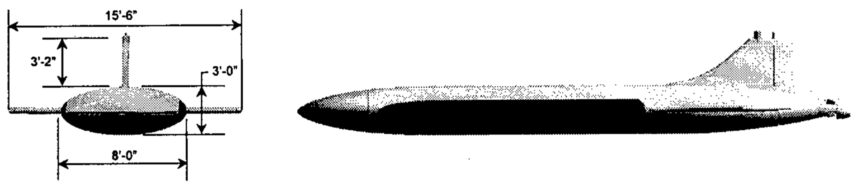


FIGURE 7. MANTA Test Vehicle Specifications

maneuvering capability. For future concepts such as the MANTA, the shape is desired to be conformal to the submarine bow as shown in Figure 5. This 'flattened' shape would allow fitment into a shallow depression in the submarine's outer hull.

Another primary requirement for the MANTA test vehicle was to allow implementation of future payloads - above-surface surveillance sensors, low frequency sonars, and communications antennas - all of which require relatively large volumes and energy allocations. To house and deliver large-size payloads, it was necessary to design a sufficiently large vehicle.

Lastly, volume is needed for navigation, guidance and control, computer processors, data storage, and power subsystems. The need for operations of long duration pushed the requirement for sufficient dry volume to house state of the art energy sources.

The resulting UUV system design, driven by the factors above, incorporates dry pressure hulls tied together by a flooded superstructure and surrounded by an outer hydrodynamic fairing.

Pursuit of the MANTA concept is a team effort. NUWC Division, Newport houses the MANTA Test Vehicle at the Newport, Rhode Island laboratory, and continues to develop technology payloads which are planned for future at-sea demonstration. Draper Laboratory is performing research on autonomous control system technology for various military and civilian applications. Boeing North American is working on high-resolution forward-looking sonars for object detection/recognition and UUV guidance in shallow water threat environments. Reson Corporation is developing new, affordable technologies for improved high-resolution sonar performance in shallow water. The University of Massachusetts, Dartmouth Center for Marine Science and Technology, is researching subsurface to surface laser communications. Electric Boat Corporation is currently researching future submarine concepts – addressing multiple missions and the ability to carry payload and offboard sensors.

MANTA Test Vehicle Trials

Recently, the MANTA Test Vehicle performed its inaugural at-sea trials (Figure 8) in Rhode Island's Narragansett Bay. During the summer of 1999, the final fabrication, sub-system

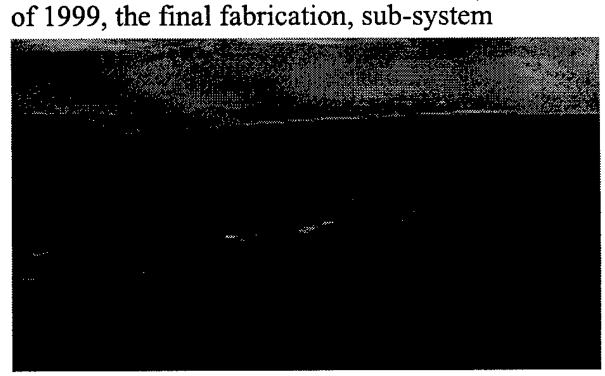


FIGURE 8. Inaugural at-sea trials of the MANTA Test Vehicle that took place in Narragansett Bay in August 1999 verified platform stability and maneuverability.

integration and testing, system level development and testing prior to the in-water runs were completed. Several tests were performed to verify platform stability and maneuverability in late August 1999. Initial results indicate good controllability characteristics. The ability to dive from the surface without a variable ballast system was also demonstrated. Further upcoming tests will allow an opportunity to refine the control system performance, at which point, at-sea payload demonstrations and evaluations will begin.

SPARTAN USV Test Bed Tow of a Side Scan Sonar

TEAM ONE USA's *GB-12-296 Challenger* high-speed patrol craft (HSPC), the USV test bed, has been outfitted with Northrop Grumman's AN/AQS-14 side-scan sonar system and supporting launch and retrieval hardware (shown in Figure 9). TEAM ONE USA and Northrop Grumman teamed up to successfully demonstrate the launch, tow, bottom mapping, and retrieval operations in January 1998 in Keyport, WA. Sonar data was acquired and analyzed in real time by an operator onboard the *GB-12-296 Challenger* HSPC. The operator utilized Northrop Grumman's built-in computer aided detection and computer aided classification (CAD/CAC) system to highlight sonar contacts and to provide a confidence factor for each contact. This platform-sensor combination is an important step in the realization and development of the USV.

FIGURE 9. *GB-12-296 Challenger* HSPC towing an AN/AQS-14 in Keyport, WA in January 1998. (Photo courtesy of TEAM ONE USA and Northrop Grumman)

FUTURE PAYLOADS

Module designs that can be carried by both USVs and UUVs provide greater flexibility to the warfighter and will reduce development costs. The logistics support for USVs and UUVs utilizing common mission modules is also simplified with this approach.

Chemical and biological threat detection packages could be utilized by USVs and UUVs, thereby providing valuable information for our forces to avoid unnecessary risk. These packages, along with others, could be carried by all UVs and serve as a secondary mission capability.

In general, the mission responsibilities of USVs and UUVs are likely to vary depending on the phase of the conflict or operational requirements. UUVs are likely to perform missions during pre-hostilities or where clandestine operation in required. USVs may take over some of the missions of UUVs once hostilities break out. The potential USV missions presented in Figure 3 could also be performed by UUVs.

MANTA Payloads

Several major mission payloads are currently being investigated for integration and at-sea demonstration. Undersea acoustic sensors are the primary sensors to be used in the shallow-water denied environment. In shallow water, the sonar enables the UUV to formulate a tactical and environmental "scene" within its patrol area. To enhance ASW capability, UUVs may also serve as either acoustic transmitters or receivers in a multistatic operational scenario. "Above surface" sensors will be implemented in stealthy low observable masts. In this way, surveillance can be performed clandestinely in near-shore areas for long periods in a low-risk posture.

Communication systems provide the means for the UUV to send its real-time data set back to the battlegroup quickly, so that the tactical scene is available to the entire battlegroup. Surface communications include UHF satellite communications, and/or two-way UHF Line of Sight (LOS). By taking advantage of acoustic multi-path, today's acoustic communications systems provide higher speed and more robust communications between submerged platforms.

To obtain tactical oceanography data, the UUV will employ sensors common to the core UUV capability (bathymetry, navigation) and other add-on sensor modules (sound speed, turbidity, and bioluminescence). Such sensors allow development of a tactical oceanographic scene.

Future MANTAs will be capable of carrying torpedoes for offensive capability. Additionally, high-speed underwater projectiles are a potential payload for threat neutralization.

SPARTAN Payloads

The SPARTAN USV will have two sets of payloads: those associated with the core (or command decision system) and those associated with the modules. The USV requires certain core sensors and systems such as a surface search radar and communications. These core systems provide mission capabilities without additional module payloads. The surface search radar, required for navigation, is also capable of detecting incoming threats. The communications system allows any USV to act as a node for over-the-horizon (OTH) communications. Mission modules may include more robust communications equipment to support the high bandwidth required for data transmission and relay.

With the addition of modules, the mission capabilities of the USV are increased. Modularity also allows USVs to be rapidly reconfigured with the appropriate mission package given a warfighting need. Initially, USVs will be developed as a platform to distribute ASW, ISR, MIW, and other sensor packages throughout the battlespace.

Eventually, USVs will not only carry sensors, they will carry weapons such as lightweight torpedoes (Figure 10a), rolling airframe missiles, 5-20 mm guns, or the Avenger Missile System. The USVs could also carry mine neutralization packages such as ALISS or SWIMS.

Eventually, USVs may be able to deploy smaller UUVs, further distributing the available fleet assets. Similarly, USVs may serve as a deployment and support platform for unmanned air vehicles (UAV) and unmanned ground vehicles (UGV), shown in Figure 10b. USVs will also support logistics over the shore (LOTS) operations as a small resupply platform.

(a)

(b)

FIGURE 10. (a) USV with ASW package including ALFS and MK-54 Lightweight Hybrid Torpedoes. (b) USV deploying UGV.

CONCLUSION

Both the UUV and the USV will be primary asymmetric force levelers, enabling the battleforce commander to match inexpensive threat capability with an appropriate response. The battleforce commander is also able to expand the distribution of the available sensors and weapons throughout the battlespace by using UVs. USVs and UUVs can be utilized in ISR missions, provide a protective barrier around the high value and strategic manned assets, or be disbursed throughout the battleforce providing support where needed.

Individually, a USV or a UUV add tremendous capabilities to the battleforce commander. However, utilizing both USVs and UUVs along with other unmanned vehicles can provide an even greater capability, thereby allowing access to *all* areas of the battlespace. The combined UV force provides greater connectivity in a network centric environment, thus enabling a rapid establishment of battlespace dominance.

LIST OF ACRONYMS

ACOMMS	Acoustic Communications
ALFS	Airborne Low-Frequency Sonar
ALISS	Advanced Lightweight Influence Sweep System
ASW	Antisubmarine Warfare
CAD/CAC	Computer Aided Detection/Computer Aided Classification
CCI	Command Capabilities Issues
CNO	Chief of Naval Operations
HSPC	High Speed Patrol Craft
ISR	Intelligence, Surveillance, Reconnaissance
L&R	Launch and Retrieval
LCAC	Landing Craft, Air Cushion
LMRS	Long-term Mine Reconnaissance System
LOS	Line Of Sight
LOTS	Logistics Over The Shore
MIUW	Mobile In-Shore Undersea Warfare
MIW	Mine Warfare
NDI	Non-Developmental Item
NMRS	Near-term Mine Reconnaissance System
NSAP	Naval Science Advisory Program
OTH	Over-The-Horizon
RIB	Rigid Inflatable Boat
SOF	Special Operations Forces
SSTD	Surface Ship Torpedo Defense
SWIMS	Shallow Water Influence Mine Sweep
UHF	Ultra-High Frequency
UAV	Unmanned Aerial Vehicle
UGV	Unmanned Ground Vehicle
USV	Unmanned Surface Vehicle
UUV	Unmanned Underwater Vehicle
UV	Unmanned Vehicle

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