30 September 2010

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Office of Naval Research
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Subject: Final Report

Reference: Contract N00014-07-C-0722
(SRI Project P18063)

Dear Dr. Swean:

SRI International is pleased to submit our Final Report entitled "Testing and Evaluation of the Mobile Inspection Package." This report has been prepared in accordance with the requirements of CDRL A002 of the referenced contract.

Technical questions concerning this report should be addressed to John Kloske at (727) 498-6735; all other matters should be addressed to me at (650) 859-4424.

Sincerely,

Margaret Baxter-Pearson
Division Manager of Contracts

Enclosure

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14. ABSTRACT
The goal of this contract (N00014-07-C-0722) was to develop a portable system for underwater port security focusing on ship hull scanning. These, and the previous efforts, have been to develop a system guided by US Coast Guard (USCG) requirements, with input from the Navy Explosive Ordnance Disposal Team (EOD) and local law enforcement. The result is a system called the Mobile Inspection Package (MIP), which is capable of surveying ship hulls, seawall, pilings, and seafloors. The MIP can be mounted on numerous platforms such as a USCG vessel, a remotely operated vehicle (ROV), or an autonomous underwater vehicle (AUV).

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SRI International

Final Report September 2010

TESTING AND EVALUATION OF THE MOBILE INSPECTION PACKAGE

Annual/Final Report

ESD-18063-FR-10-367
SRI Project No. P18063
Contract No. N00014-07-C-0722

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1 INTRODUCTION

The goal of this contract (N00014-07-C-0722) was to develop a portable system for underwater port security focusing on ship hull scanning. These, and the previous efforts, have been to develop a system guided by US Coast Guard (USCG) requirements, with input from the Navy Explosive Ordnance Disposal Team (EOD) and local law enforcement. The result is a system called the Mobile Inspection Package (MIP), which is capable of surveying ship hulls, seawall, pilings, and seafloors. The MIP can be mounted on numerous platforms such as a USCG vessel, a remotely operated vehicle (ROV), or an autonomous underwater vehicle (AUV) (**Figure 1**).

Previous versions of the MIP have been extensively validated in real-world conditions and operational constraints in collaboration with the USCG (e.g., monitoring conducted during Super Bowl XXXIX by the Coast Guard and the Jacksonville Sheriff's Office). The remaining issue, and the focus of this contract, is the ability to scan a vessel's hull before it enters port. The ability to scan a "target" vessel before it has entered port has several benefits; primarily, enabling detection of a threat while it is far away from creating a hazardous situation and providing law enforcement with maximum reaction time. The AUV is an ideal platform to support the MIP during this kind of operation. SRI's plan is to enhance the MIP AUV payload to include a wide field-of-view (FOV) 3DSLS "line sonar," followed by testing and evaluation of the MIP-equipped Bluefin-12 AUV for ship hull scanning.

Figure 1. MIP platforms.

2 APPROACH

The current MIP uses a 3D sonar for target detection and verification of coverage area, and a high-resolution 2D imaging sonar for target identification. Because the time required to scan a ship's hull offshore will affect the ship's schedule, the AUV scanning method must minimize time required for the scanning and provide verification that the hull was completely scanned. To scan the geometrically complex hulls while minimizing scan time, the largest 3D sensor swath width must be sought that can maintain appropriate data resolution for detection of a minimally sized target. The current 3D sonar used in the MIP is the BlueView Technologies 3DSLS, which has a 45 degree horizontal FOV (**Figure 2**).

We sought to work with BlueView Technologies to increase the 3DSLS horizontal FOV to 90 degrees and to improve the signal-to-noise ratio (SNR) of the acoustic returns. These upgrades would double the scan swath width and reduce the overall ship scanning time to a more acceptable duration. SRI installed the 45 degree FOV 3DSLS as part of the MIP AUV payload, and tested the MIP using the Bluefin-12 tail section for both seafloor scans (as a baseline) and scans of the bottom of ship hulls in Tampa Bay, Florida, and offshore.

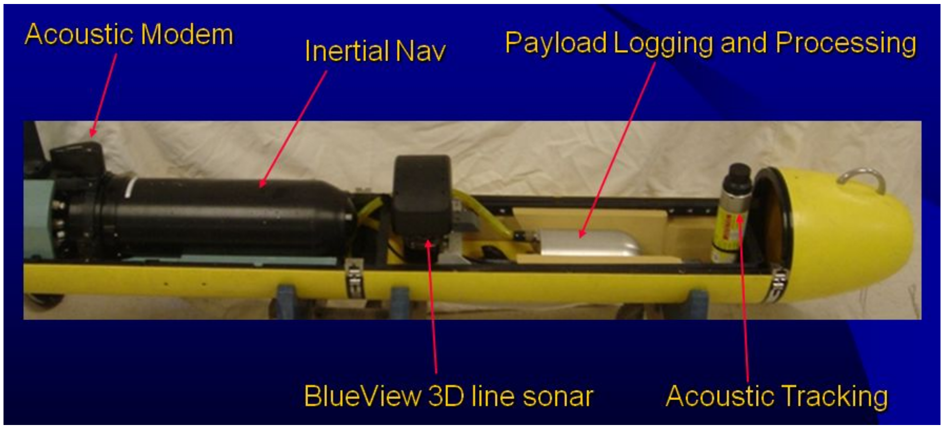

Figure 2. MIP BlueView 3DSLS MB1350 sonar payload. Main components include the acoustic modem and AUV inertial navigation system as part of the AUV tail section; the MB1350, payload data logging and processing module, and acoustic tracking transponder are located in the payload section.

The ultimate goal of this contract was to develop offshore ship hull scanning techniques with an AUV-based MIP. Initially, testing was performed with the AUV in coastal waters, to establish the AUV characteristics with this new suite of sensors. Once the AUV had been thoroughly tested and debugged, controlled under-hull scans were performed in coastal waters. This helped establish and refine operational techniques to maximize efficiency, data collection, and safety. This effort also allowed for future investigation toward development of a high-resolution, wide-FOV 3DSLS operating at 2.25 MHz, which has the potential to approach the data resolution of the MIP 3D Laser Line Scanner (LLS) (**Figure 3**).

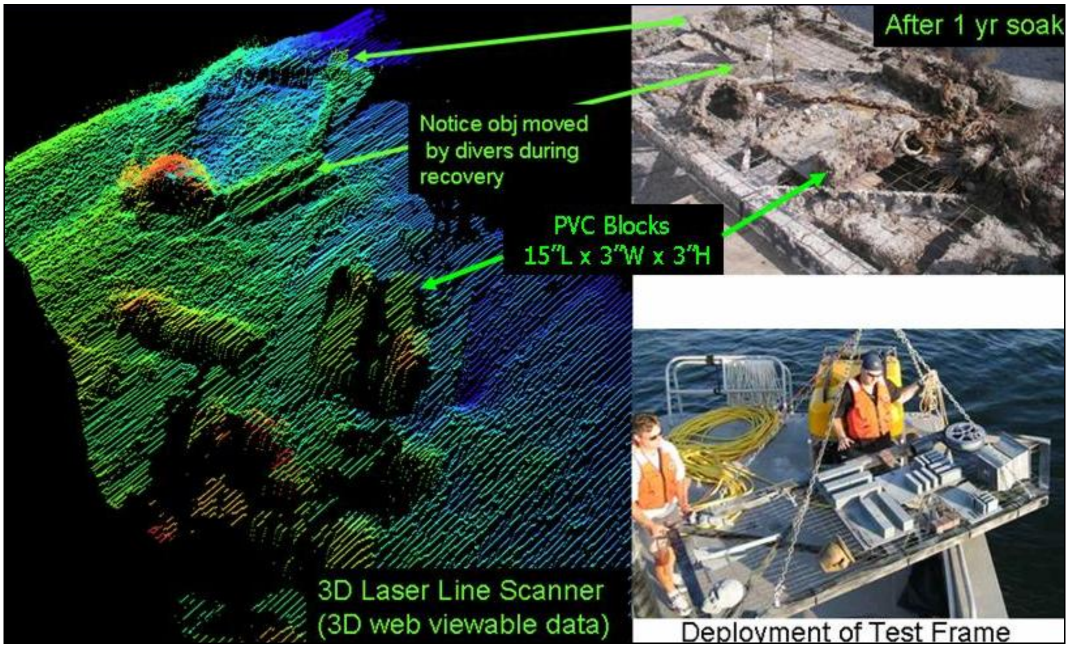

Figure 3. MIP 3D Laser Line Scanner data product of a calibration test frame deployed in Tampa Bay.

3 WORK COMPLETED

Characterization and integration of the BlueView 3DSLS "line sonar" as well as acceptance of the Bluefin 12.75" diameter AUV was performed based on the following statement of work:

- Continue investigation of leading edge technology that may be suitable for the MIP.
  - We pursued development of a 2.25 MHz 3DSLS with BlueView Technologies. This upgraded sonar has the potential to replace the current LLS with regard to resolution, would not be limited by clarity of the water, and would yield extremely high-resolution 3D data products in the black or zero visibility waters often found in coastal and port environments.
  - We investigated use of the BlueView 3DSLS (1.35 MHz) sonar for supporting automated target detection.

- Take delivery of Bluefin-12 AUV tail section (**Figures 4 and 5**).
  - We completed both the factory acceptance test (FAT) in Boston and the final sea acceptance trials (SAT) in January 2009 in Tampa Bay. The final portion of the SAT was held in Tampa Bay to verify the updates to the Bluefin integrated inertial navigation system.

- Attend AUV Fest 2007.
  - We attended AUV Fest and presented data collected by the MIP 3DSLS sonar and LLS, as well as providing a static display of the MIP AUV payload.

- Upgrade the ONR 3DSLS with a 90 degree FOV array set.
    - An order for the 90 degree FOV arrays was placed with BlueView. This upgrade was received September 17, 2010 (**Figure 6**).

- Test and evaluate the AUV-based MIP by performing baseline seafloor scans and scanning the bottom of ship hulls within Tampa Bay and offshore.
    - The current 3DSLS (45 degree FOV) was tested during our first attempt to complete the AUV SAT in Boston and during both follow-on trials in Tampa Bay. Data was successfully collected in all cases. We have also scanned the underside of ship hulls and mine-like targets using our ROV with the AUV-based MIP payload (**Figures 7, 8, and 9**).

- Refine the MIP AUV launch and recovery system for the Bluefin-12 AUV.
    - A safe and reliable launch and recovery method and supporting hardware was developed for operations off of the USGS Research Vessel *Gilbert*.

Figure 4. Photos of the Bluefin-12 AUV taken during our November/December 2008 acceptance trials in Boston. The MIP payload consisted of the BlueView line sonar 3DSLS (model MB1350), the payload interface module (silver "bullet"), and a USBL (ultra-short baseline) tracking beacon.

Figure 5. Recovery of the AUV during November/ December acceptance trials off Boston (left) and launch of the AUV during January 2009 acceptance trials in Tampa Bay (right).

Figure 6. BlueView 90 degree field-of-view 3DSLS integrated in Bluefin-12 MIP payload.

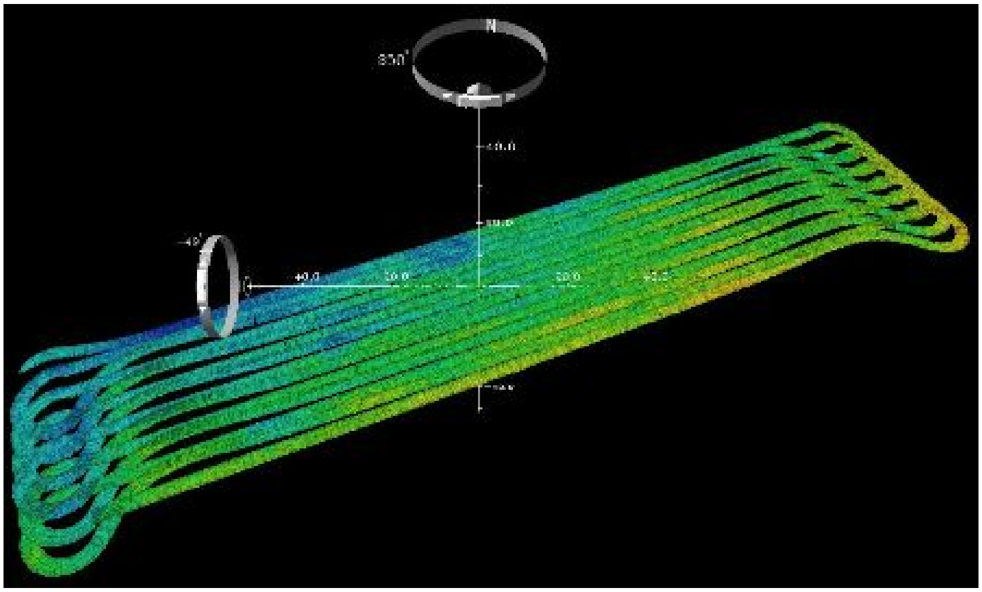

Figure 7. A targeted AUV survey using the BlueView 45 degree 3DSLS. The survey width is 50 m, while the survey region of interest is 100 m. The 3D geo-referenced data products clearly show the stabilization portions of the individual tracks (30 m on each end) and the high precision of the AUV navigation system.

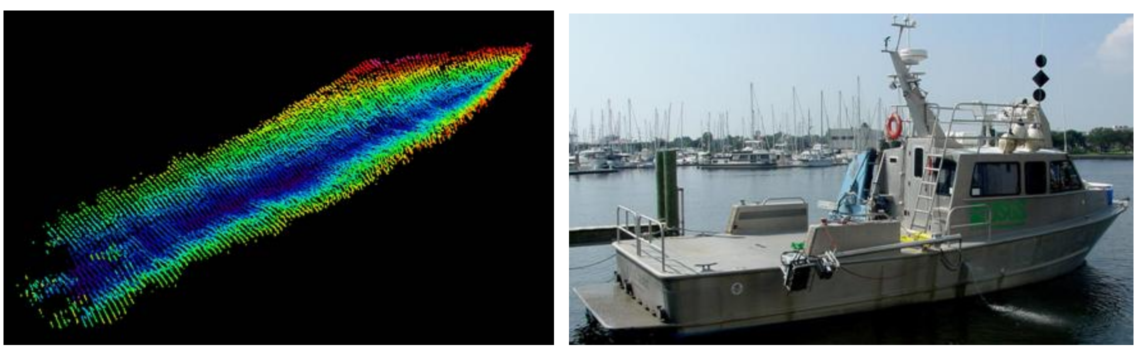

Figure 8. Left: Ship hull scan of the 50-foot long R/V *Gilbert* from data collected using the AUV BlueView payload (Figure 2) in Tampa Bay. Right: Photo of the R/V *Gilbert*.

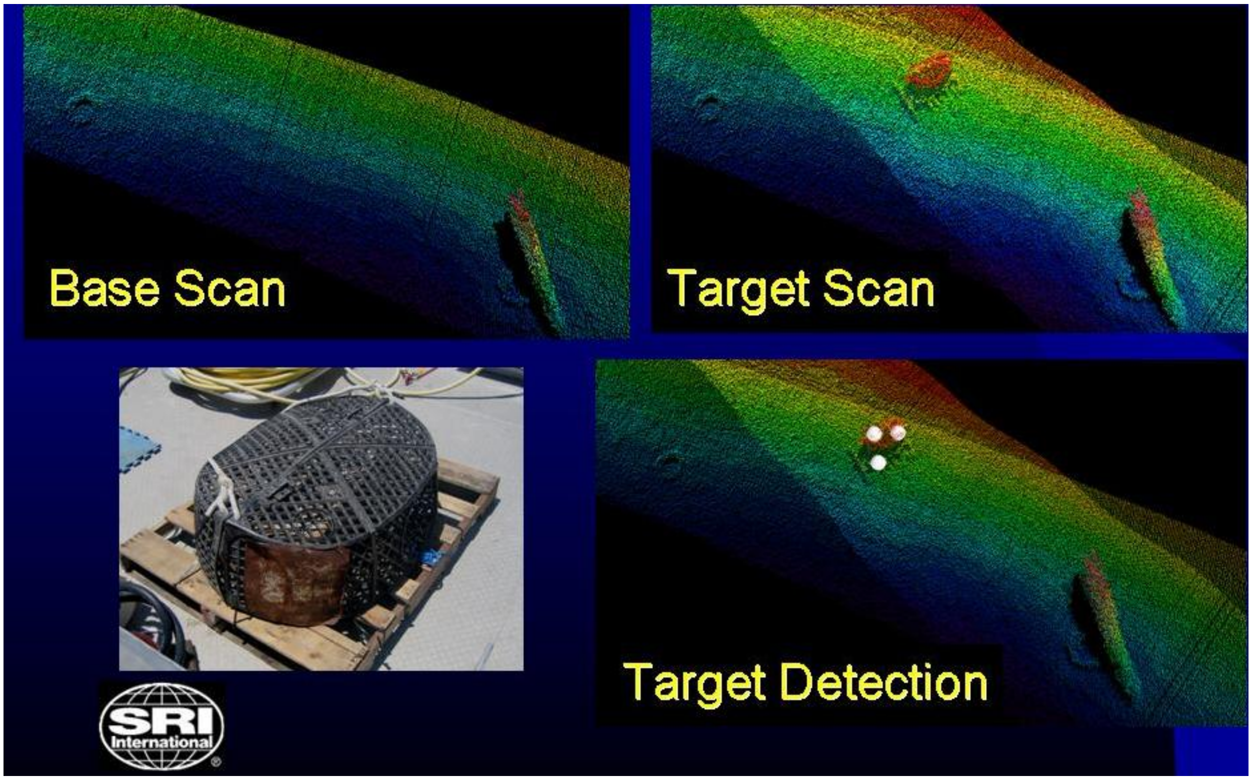

Figure 9. Sonar scans to investigate the feasibility of using the 3DSLS sonar for automated target detection. The 3DSLS was mounted to a small harbor craft with a swing pole to perform a "Base Scan" of the Port of St. Petersburg, Florida. Next, a plastic fish trap on a wooden pallet (lower left image) was deployed. Then a "Targeted Scan" of the area was performed. Finally, the base scan and targeted scan data were processed with automated target detection software, which detected the new object and placed a white color sphere at that location ("Target Detection").

RESULTS

Development and testing of the AUV-equipped MIP payload has occurred primarily within Tampa Bay. The testing included both wide-area bottom surveys for mine countermeasures (MCM) and accompanying targeted surveys for mine identification (**Figures 7 and 10**).

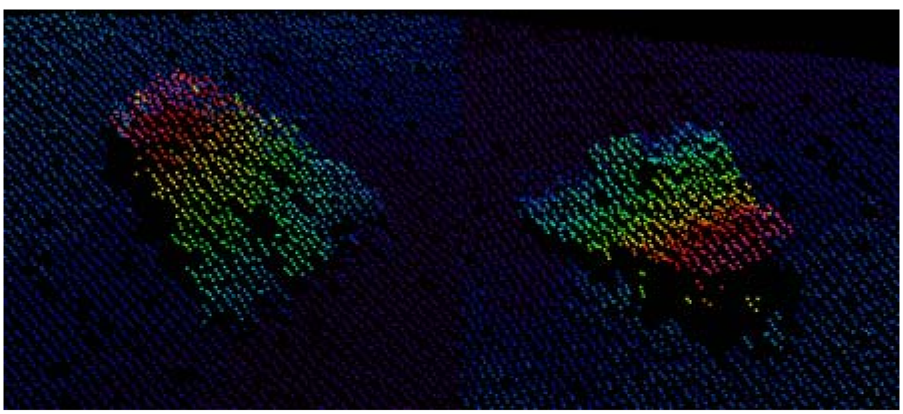

Figure 10. Example results from a targeted survey of an angular practice target.

4 IMPACT AND APPLICATIONS

Future funding to refine the AUV ship hull scanning procedures to more closely match US Navy and Coast Guard concept of operations would be the next logical step. Thereafter, the MIP-AUV capabilities should be migrated to smaller, two-person deployable AUVs such as the REMUS and Bluefin 9" diameter vehicles. This would enable Navy and USCG field personnel to quickly scan ship hulls offshore from a minimally sized support vessel that could be readily deployed worldwide. Additionally, the development of automated detection/classification tools would greatly enhance performance of the MIP.

Previous Related Projects

- **ONR Award N0014-03-1-0750** *Testing and Evaluation of the Mobile Inspection Platform*
- **ONR Award N0014-02-1-0825** *Autonomous Underwater Vehicle for Homeland Defense and Research Support*
- **ONR Award N0014-02-1-0719** *Autonomous Underwater Vehicle for Homeland Defense*

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