

Meeting the Threat of Maritime Improvised Explosive Devices

The PROSAS Surveyor: An Operational Case Study for Harbor Protection

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Maritime improvised explosive devices (MIEDs) present one of the most potent asymmetric threats to port security posed in the post-September 11 era. Every month, around seven million tons of freight pass through the Port of New York/New Jersey. Fifty to 100 times per year, tankers—each containing around one million barrels of crude oil—arrive in San Pedro, California. Several times per day, cruise ships carrying thousands of passengers leave through the narrow straits of Fort Lauderdale, Florida. These are simple examples, and they represent the tip of the iceberg when considering how much infrastructure, business and way of life in the U.S. depends on travel through busy seaports.

An MIED, though it costs only a few thousand dollars, threatens to disrupt lives, cause ecological and environmental disaster on a scale not seen since the grounding of the *Exxon Valdez* and also cause economic fallout running into hundreds of millions, if not billions, of dollars when placed in any busy port. Even a credible threat of such a placement will cause a similar level of turmoil. An idea of the financial and ecological impact that an MIED threat/attack might cause can be estimated by looking back at historical data, like when the 2002 dockworker strike shut down all 29 West Coast ports in the United States for 11 days, resulting in direct and indirect costs of \$1.9 billion per day. In 1989, the *Exxon*

Valdez ran aground in Alaska's Prince William Sound, spilling more than 270,000 barrels of crude oil and causing devastation to the Alaskan coastal flora and fauna. The clear up cost Exxon (Irving, Texas) more than \$2.5 billion.

The protection of U.S. ports cannot be put on hold until the development of some magic bullet sensor system, deployable in times of heightened risk and able to infallibly seek out and destroy threatening objects in our sea-lanes. It must instead rely on the rigorous and continual management of harbors and harbor approach sea-lanes and provide a detailed knowledge of the underwater environment and an ability to assess its vulnerability to any prevailing threat.

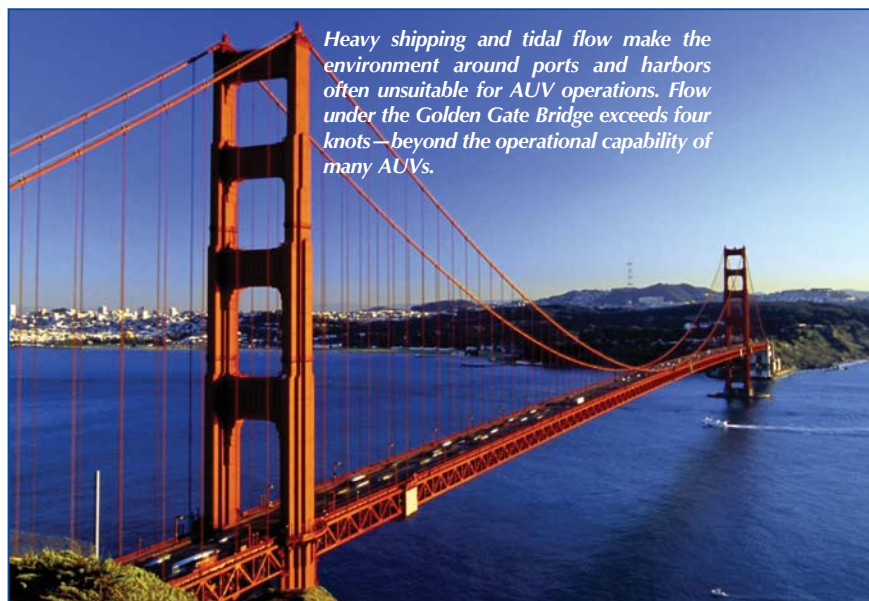
To a war fighter, the prosecution of a target can be summarized in five distinct phases: detection, classification,

localization, threat evaluation and tactical advice. The needs of a harbor underwater security program may be expressed in completely analogous terms.

First is surveying and target marking, or the ability to detect, resolve and classify to a reasonable level of confidence potential threatening objects on the seabed.

Second is location, or the ability to locate identified objects on the seabed with a precision high enough to provide comparative reports from successive surveys and to allow extraction/disposal of threatening objects.

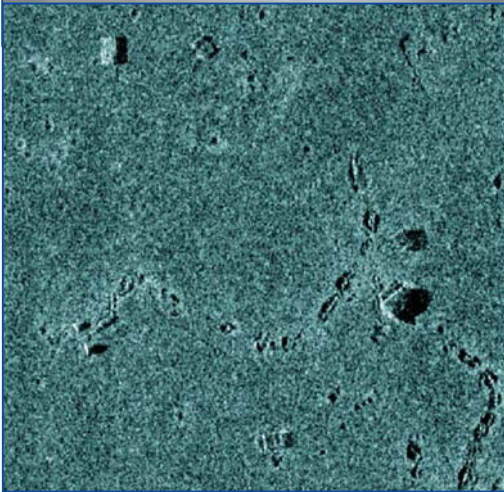
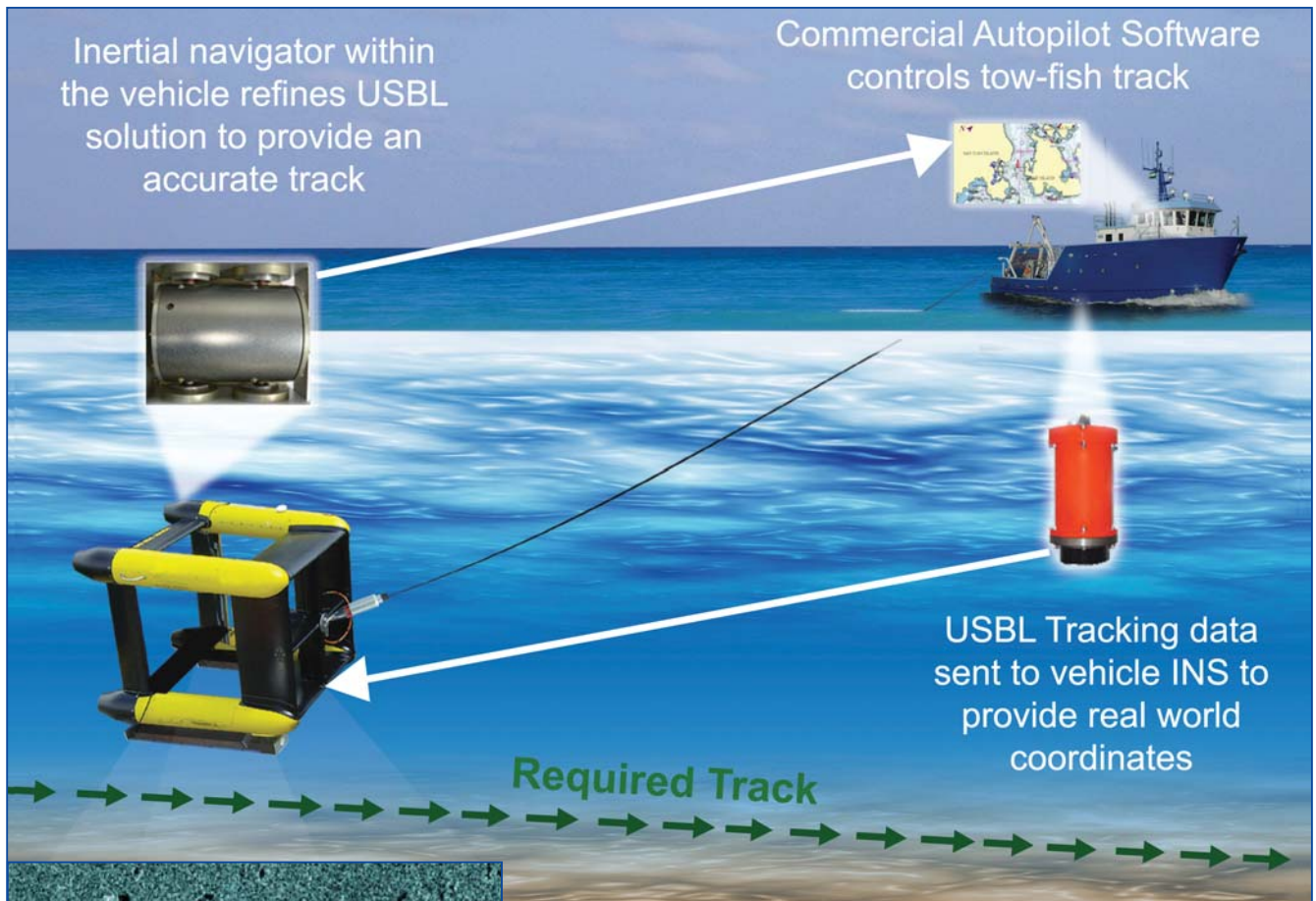
Last is change management, or the ability to assess, understand and catalog the seabed; understand areas where the seabed is stable and those where it changes rapidly; database objects within the scene; compare new data against historical records; and highlight



Heavy shipping and tidal flow make the environment around ports and harbors often unsuitable for AUV operations. Flow under the Golden Gate Bridge exceeds four knots—beyond the operational capability of many AUVs.

Reprinted from Sea Technology magazine.

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(Above) A control system uses navigation data from the USBL to aid the vehicle inertial navigator. The resulting position feeds an autopilot which steers the vehicle.

(Left) Seabed clutter is characterized using high-resolution sonar and catalogued for future reference. Here, an anchor and chain lay next to a lobster pot.

change.

These three requirements are set against the background of a difficult working environment and a time and budget-limited resource pool.

Harbors and their approaching seaways represent one of the most challenging operational environments for any hydrographic survey system. The requirement to operate in shallow water limits the performance of sonar systems, with surface reverberation and multipath interference limiting the operational range of the sensor. Strong tidal flows and currents in the vicinity of inlets and river estuaries, where many harbors are located, provide a difficult

working environment. The presence of large amounts of shipping traffic and pleasure craft limit maneuverability. The mixing of fresh and salt water can provide other challenges.

Applied Signal Technology has been working over the past several years to put together a system able to provide the capabilities necessary for the routine underwater management of a port environment. While the PROSAS Surveyor system is only one of a number of systems capable of addressing such a task, the ideas behind the development of the system and the concepts for its operation in this environment provide a good framework to the decision makers within a port authority, who are charged with providing tools

and processes for the protection of their environment.

Tethered/Autonomous Operation

One of the key decisions that needs to be made in developing a survey capability for a port is what transportation vehicle to use. Autonomous underwater vehicles (AUVs) are becoming more accepted in a mine-hunting environment but are possibly not ideal for harbor security.

The advantages of AUVs are that the lack of a tether makes them highly maneuverable and less susceptible to motion artifacts associated with vehicle tow behavior. Unfortunately, AUVs are slow moving and have very limited navigation and obstacle avoidance capabilities, and the legal issues associated with the collision of an autonomous vehicle and a commercially operated pleasure craft have not been resolved. In addition, the current generation of survey-capable AUVs are operated in deep water and, usually, under the close supervision of a support boat. This is not a reasonable concept of operation in a harbor or approach environment.

For these reasons, the PROSAS

Surveyor system was developed using a towed vehicle. The advantages of this approach are that data gathered are immediately available for viewing and the vehicle is capable of operation in high current flows, unlike AUVs. The presence of a tow platform, together with suitable limited maneuverability markings, provides a good platform for work in busy shipping channels.

Geo-Location and Navigation

The issues associated with geo-location and navigation fall into two main areas. First, it is important to know where objects seen in a sonar record really are on the seabed. This knowledge is needed to allow the comparison of one data set with another and to allow the reacquisition of previously identified targets for further investigation and/or removal.

A second, equally important consideration is the dependence of a target image and the shadow structure behind that image on the aspect at which it is viewed. In a system where the most important question to be asked is "What has changed since the last survey?" retention of the same aspect to the seabed from one survey to the next dramatically simplifies the task of change detection and improves the reliability of the resulting list of objects identified.

With the variations in tide, current and wind direction and the general difficulties in navigating a vessel, it is extremely difficult to guarantee that a tow fish travels the same path through the water on successive surveys. The PROSAS Surveyor system utilizes a MacArtney (Esbjerg, Denmark) Focus-2 dynamically controlled tow fish to significantly improve the track-to-track repeatability.

The tow fish provides control surfaces to dictate roll, side-to-side and vertical position within the water column. This allows the vehicle to fly independent of the track of the tow vehicle (within the limits of the tow cable) and allows repeatable survey tracks to be run regardless of the prevailing conditions.

The PROSAS Surveyor system has a highly sophisticated navigation system with an inertial navigator, aided by a Doppler velocity logger and an ultra-short baseline (USBL) tracking system, which allows precise navigation of the tow fish. Autopilot facilities allow tracks

to be accurately repeated from one run to the next.

Using a system such as this, it is possible to geo-locate objects on the seabed to within around two meters and to repeat track lines from survey to survey with a similar level of accuracy.

Imaging Performance

The use of synthetic aperture sonar (SAS), as opposed to conventional side scan technology, allows the imaging of the seabed at a constant resolution across the whole swath. With a high-frequency side scan, resolutions of the order of three to five centimeters are achievable at close range. At longer ranges, performance quickly drops, owing to the absorption of sound in the water channel. Lower frequency side scan systems can provide longer range operation as well as short range, because they use multielement focusing techniques that can provide high-resolution images. At longer ranges, the array apertures needed to focus a beam to the three to five-centimeter level required for classification are prohibitive, and the resolution of the system falls off linearly with range.

To effectively keep a port secure, the seabed must be imaged with an adequate resolution to allow (hopefully) positive classification and (at a minimum) a reduction in the clutter that can be falsely classified as an object of interest.

The limitation in range performance of a conventional side scan means that they are typically operated with very high levels of overlap between adjacent tracks. With an SAS system, the resolution remains constant at all ranges, so the track spacing can be set according to the available water depth. In harbor and estuarine environments, this ability saves significant time in carrying out the survey. Typical area coverage rates in excess of two square kilometers per hour can be achieved in 40 feet of water using the PROSAS.

Environmental Awareness

Once the area surrounding a harbor has been surveyed, an enormous number of contacts will be generated. These represent the clutter and debris which have accumulated on the seabed over the operational life of the port as well as naturally occurring objects such as rocks and outcrops. A high-resolution sonar system, such as is provided by the

SAS, will allow the operator to work through these contacts and hopefully reduce the number to a manageable quantity to be investigated or removed.

Key to successful monitoring of the area is understanding the hopefully benign clutter structure on the seabed at the current time and having the ability to alert the operator to new items of potential threat.

Within the PROSAS Surveyor system, a database of contacts is maintained. Every time the system travels over the same area, existing contacts within the database are automatically updated with new images of the objects. Every time a new object is identified, the database of previous surveys can be scanned to find what that particular area of seabed looked like on those past occasions.

Building up knowledge of which parts of the environment remain fairly static and which parts are subject to rapid change takes time. Tasks such as these need to be repetitively undertaken to inform decisions in times of increased threat.

Conclusions

The maritime environment is vital to the United States' way of life. In an era of intense terrorist threat, the insertion of MIEDs into this environment represents a significant risk to the security, safety, economy and ecology of a port. Key to containing this risk is the management of the port and approaching sea-lane environment. This requires knowledge that has to be built up over a period of time before a credible threat is posed. RAdm. John Christenson, vice commander of the U.S. Naval Mine and Anti-Submarine Warfare Command, recently said, "If you want to get a port opened quickly, you have to do your homework in advance. You have to know what's on the bottom before you start."

To achieve this mission, a holistic approach must be taken to system specification, including imaging performance, navigation accuracy, interaction with port traffic, track repeatability and change management.

The utilization of a system such as the PROSAS Surveyor and some of the concepts of operation discussed above provide the port authority with a cost-effective tool set to meet their security management obligations.

Acknowledgments

The author would like to acknowledge the support of MacArtney Underwater Technology A/S, EdgeTech Inc. (Boca Raton, Florida) and the Ocean Works Group (Fernandina Beach, Florida) for their support in the development and testing of the PROSAS Surveyor system. ■

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