NMIO Technical Bulletin

National Maritime Intelligence-Integration Office

JANUARY 2012 VOLUME 1

Director NMIO View:

Rear Admiral (Sel) Robert V. Hoppa, USN

I am very pleased to share with you the inaugural publication of our National Maritime Intelligence-Integration Office's (NMIO) technical bulletin. Our intent is to foster the sharing of information on scientific and technical issues and activities among the maritime stakeholders, both domestically and internationally. In doing this we hope to be in a position to "connect the dots in advance" and anticipate threats in or emanating from the maritime domain before they materialize.

As some of you have noticed, our organization now has a new name: NMIO better reflects our primary function: to facilitate the integration of maritime information and intelligence collection and analysis in support of national policy and decision makers, Maritime Security Awareness objectives, and interagency operations, at all levels, both within the U.S. Government (USG) and our national and international partners.

Oceans are the largest ungoverned space on the planet. Terrorists, pirates, criminals, and smugglers can exploit this vast environment to conduct attacks and/or surreptitiously move illicit materials such as weapons of mass destruction, illegal firearms, and narcotics, in addition to conducting human trafficking. Additionally, our quality of life and economic well-being are dependent on secure maritime commerce based on unfettered use of the seas.

NMIO will continue working with the intelligence community, the interagency, and federal, state, local, tribal, and territorial partners, as well as the private sector, academia, and our foreign partners, to develop information that empowers decision-makers and operational personnel throughout the USG and abroad in the furtherance of global maritime security.

NMIO MISSION STATEMENT

To protect the United States from hostile and illegal threats in or emanating from the Maritime Domain by ensuring that intelligence is fully integrated in support of national policy and operational decisions.

Our technical bulletin is one of our many initiatives to enhance global maritime security. I hope you enjoy reading it and I encourage you to submit your ideas and activities that you could share with your colleagues in future issues.

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NMIO Technical Bulletin

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Contributions welcome: All contributions from the Global Maritime Community of Interest's stakeholders, both domestic and international, are welcome. In submitting your articles please highlight who you are, what you are doing, why you are doing it, and the impacts. Try to limit your article to approximately one to two pages including picture(s). Articles may be edited for space or clarity.

THE CHANGI Information Fusion Centre

The maritime domain continues to be easily exploited due to its porosity. It is apparent that no single country or agency is able to tackle the full range of maritime security issues on its own.

The Information Fusion Centre (IFC) was launched on 27 April 2009 and is located in Singapore's Changi Command and Control Centre (CC2C). As a regional maritime info-sharing node, it aims to enhance the Asian-Pacific region's maritime situation awareness by building a common and coherent maritime situation picture. With linkages to more than 45 agencies in 28 countries, it has been able to provide actionable information to its regional partners for further collaboration and to cue timely operational responses. The info-sharing collaboration has resulted in useful outcomes, for example during the MV Sun Sea incident from May-Aug 10.

One of the unique features at the IFC is the presence of the International Liaison Officers (ILOs). The ILOs serve as a Point of Contact to facilitate real-time info-sharing and coordination between the IFC and their parent (sending nation) agencies (customs, defence, immigration and etc). Collectively, this enables the pooling of resources and expertise to identify security trends and disseminate information in a timely manner to IFC's partners, including the international shipping community. 24 ILOs from 12 countries have been deployed at the IFC to better facilitate the sharing of information.

The IFC uses various info-sharing platforms to enable collaborative interactions with its partners. These include the Malacca Strait Patrols Information System (MSP IS) for the four littoral countries in the Malacca Strait and the Regional Maritime Info-sharing Exchange (ReMIX) for the 24 countries in the Western Pacific Naval Symposium.

Ensuring Maritime Security requires the efforts, and more importantly the cooperation, of all the maritime stakeholders. The IFC has been actively engaging the shipping companies and shipping associations through activities such as the bi-monthly Shipping Shared Awareness Meeting (SAM). This meeting allows the IFC to reach out, explain, and collate feedback on key security issues and trends which the shipping community faces. The IFC also conducts company visits and administers a voluntary shipping reporting initiative to enable a two-way interaction with the commercial maritime community.

POC: LTC Lim Chye Khiang Nicholas, Head Information Fusion Centre, Nicholas_Lim@mindef.gov.sg

Australian Border Protection Command

Border Protection Command (BPC), a government directed multi-agency operational authority, combines the resources and expertise of the Australian Customs and Border Protection Service and the Department of Defence, as well as contributions from subject matter experts from the Australian Fisheries Management Authority, the Biosecurity Services Group, and other Commonwealth, State and Territory agencies. Customs and Border Protection together with Defence lead this multi-agency construct to deliver a coordinated, national approach to Australia's offshore civil maritime security.

BPC's mission, in concert with other government agencies and stakeholders, is to protect Australia's national interest by generating awareness of illegal activity in the civil maritime domain across government, and by responding to mitigate, or eliminate, the risk posed by security threats. In conducting its maritime security operations BPC adopts an intelligence-led risk-based approach.

While responding to unauthorised maritime arrivals is perhaps the most publicly visible BPC operation, it is not the only maritime security threat for which BPC has responsibility. BPC is responsible for coordinating and controlling operations to protect Australia's national interests against the following eight maritime security threats:

1. Illegal activity in protected areas
2. Marine pollution
3. Prohibited imports and exports
4. Illegal exploitation of natural resources
5. Unauthorised maritime arrivals
6. Compromises to bio-security
7. Piracy, robbery and violence at sea
8. Maritime terrorism

AREAS OF RESPONSIBILITY AND INTEREST

BPC, established by the Australian government in March 2005, is the primary government law enforcement organisation in the Australian Maritime Domain (AMD), an area which covers approximately 11 million square nautical miles and equates to around 11% of the Earth's oceans. The AMD includes the territorial sea, contiguous zone, offshore areas predominantly within Australia's Exclusive Economic Zone (EEZ), and extends to the area bounded by Australia's Security Force Authority Area.

In support of arrangements coordinated by the International Maritime Organisation (IMO), BPC is Australia's Security Forces Authority (SFA) for the purposes of responding to acts of violence against ships within the Australian Security Forces Authority Area which equates to the Australian Search and Rescue Region. (See image on next page)

Given the nature and origin of some maritime security threats, BPC's areas of interest are dependent upon each threat and range in scope from global to regional and domestic focal areas. The size of the AMD presents a challenge for BPC as it requires assigned assets to operate effectively within an extreme range of environmental conditions; from tropical and monsoonal conditions in the north, to harsh freezing conditions in the south. This challenge, however, is effectively met by a vigilant intelligence-led and risk-based response.

2010-11 PERFORMANCE

The 2010-11 financial year was one of high operational tempo for BPC. During this increased activity, BPC maintained an effective response program of air, sea and land based patrols and coordinated a dynamic team across agencies to prevent risks from reaching Australia. BPC continued to be a vigilant, pro-active and powerful deterrent in the offshore maritime environment and detected and responded to maritime threats while concurrently strengthening relations with international and regional authorities – all of which continues to contribute to Australia's national security.

For the 2010-11 financial year BPC:

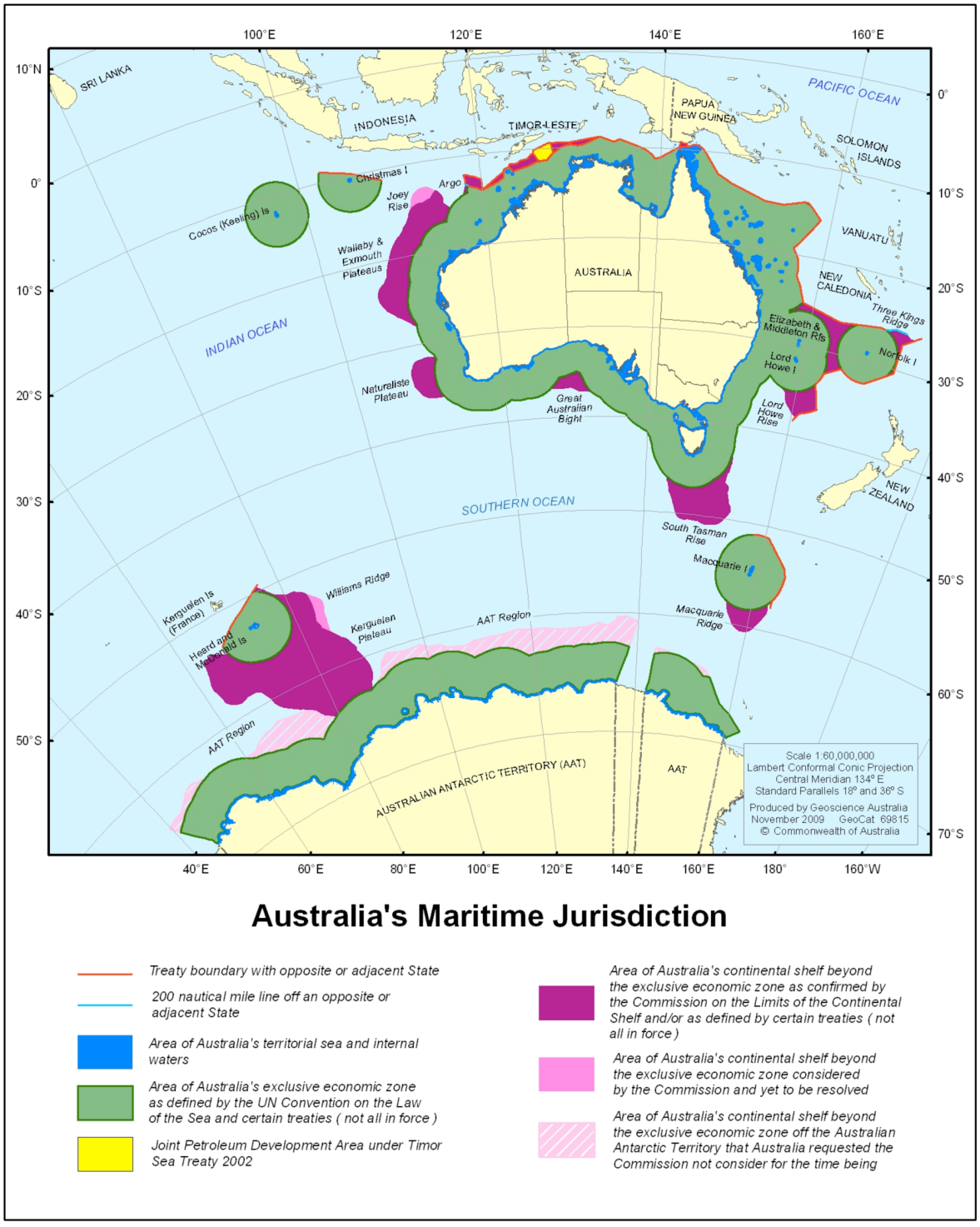
- boarded 340 foreign fishing vessels and apprehended 14 illegal foreign fishing vessels;
- intercepted 89 suspect irregular entry vessels (SIEVs), achieving a 96.6 per cent SIEV detection rate;
- through aerial surveillance of the Great Barrier Reef Marine Park area detected 41 possible offences; and
- undertook patrols of Australia's critical offshore oil and gas infrastructure.

On international issues, BPC has continued to forge strong working relationships with its counterparts in the region including Indonesia and Malaysia to increase regional offshore maritime capability, exchange information and work together to combat shared maritime threats. Highlights include:

- Commander BPC together with his Malaysian counterpart signed a Memorandum of Understanding on Cooperation and Assistance Relating to Civil Maritime Law Enforcement Operations.

- BPC engaged in reciprocal maritime capacity building activities including sharing information; training and development of staff; research and development; participating in multi-country maritime exercise; and port visits with regional partners.
- BPC coordinated joint patrols with Indonesia's Marine Affairs and Fisheries to prevent illegal foreign fishing activities in neighbouring waters.
- Forty-eight international delegations consisting of 474 people visited BPC Headquarters to understand how the Australian Government offshore maritime security model operates.

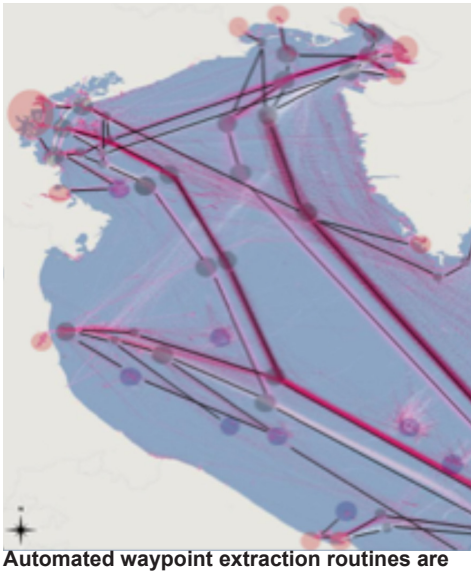
POC: Hugh Barkley, Director, Border Protection Science and Technology Support, BPC, hugh.barkley@customs.gov.au



Emerging Technologies and Techniques for Maritime Security

The NATO Undersea Research Centre (NURC) conducts world class research in the maritime domain in support of operational and transformational requirements, as well as civilian-oriented technology transfer and research. NURC has acquired, developed, and currently maintains a comprehensive range of equipment, including a fleet of autonomous vehicles, remote operating vehicles (ROVs), seafloor instrumentation platforms, towed measurement/detection systems, and specialised calibration facilities. This article highlights the NURC's programme in Maritime Security, with a focus on advanced data processing techniques for the Maritime Domain and response capability against small boats and underwater intruders.

Advanced Data Processing Techniques for the Maritime Security Awareness (MSA) relies on the ability to accurately "connect the dots" between various pieces of data arising from a broad set of actors, initiatives, and applications. The Collaborative Multi-Sensor/Source Fusion and Tracking (CoMSSoFT) Tool is NURC's contribution to the advancement of fusion and tracking capability in the maritime domain, using the CoMSSoFT Open Framework as its foundation. The Open Framework is a baseline architecture intended to be widely sharable between nations, organizations, agencies, and academia as a means of demonstrating how data and information can be processed in an implementation-independent, service-oriented manner. Information sharing and interoperability are extensively discussed as fundamental to situational awareness, and an open architecture allows entities to effectively exchange and utilize information in an affordable manner. In addition to enabling cooperation via information sharing, the goals of the open framework are to bring a common language to bridge the gap between command and control systems and advancements offered by the academic community, as well as to provide a mechanism to quickly demonstrate the utility of advanced algorithms via actual systems and data.

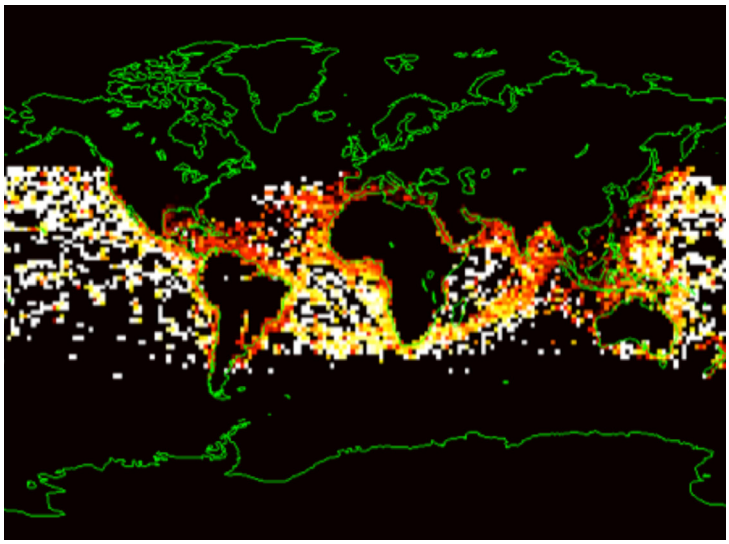


Automated waypoint extraction routines are being developed as a means of understanding maritime patterns of life with the goal of automated behavioural anomaly detection routines.

Another active area of research at NURC is the use of historical multi-sensor data to derive patterns of life from observed vessel activity. Based on this, context can be learned which can provide more accurate vessel tracking and identify abnormal activity. Current work includes the generalization of the Open Framework to include higher level information and to allow this information to interact with lower level kinematic information in automated reasoning routines. As part of this effort, data-driven extraction methods are being developed to learn traffic patterns and to detect behaviour based anomalies based on historical vessel activity.

Experimentation and support to operational activities are an additional component of the NURC research activity in MSA. One aspect of this is the use of Bayesian models to quantify performance from any given sensor mix. Currently, the methodology is being expanded to provide an empirical, pass-based characterization of satellite AIS data by combining multiple satellite streams with a coastal based network. The objective is to build an integrated real-time component which evaluates the effectiveness of the available sensor mix and to estimate sea truth (i.e. both "what you see" and "what you don't see") from the current surveillance picture. Decision makers can then be given an estimation of both known and unknown vessel traffic levels which can be used to cue and direct mobile assets for short term response, or for long term planning to make better acquisition decisions.

Response Capability against Small Boats and Underwater Intruders Maritime security missions include the protection of



military forces in ports (ships, submarines, transports), high-profile events (visiting dignitaries, international sports), human life (passenger carriers, ferries), and critical infrastructure (energy, industry). These missions often require the enforcement of an exclusion zone above the water against small boats, and under the water against intruders.

Response measures in security are usually bounded by a duty to warn, to prove hostile intent, and to use proportional force. Non-lethal response measures have a low risk of causing permanent injury or human fatality, and are therefore advisable for the early stages of response, when the intent of a person, whether hostile or perhaps simply misguided, is at first unknown, and care against harm is required.

One topic of research has been the proof of hostile intent in persons who enter a security zone without authorization. This includes the development of capabilities for long-range stand-off warning, preliminary non-lethal opposition, observation of non-compliance, and the escalation of force. First hand experience with many different technologies in experimental operation and with security providers, military and civilian, has made researchers expert in maritime security needs and in the concepts of use for emerging non-lethal technologies. Emerging non-lethal response technologies include:

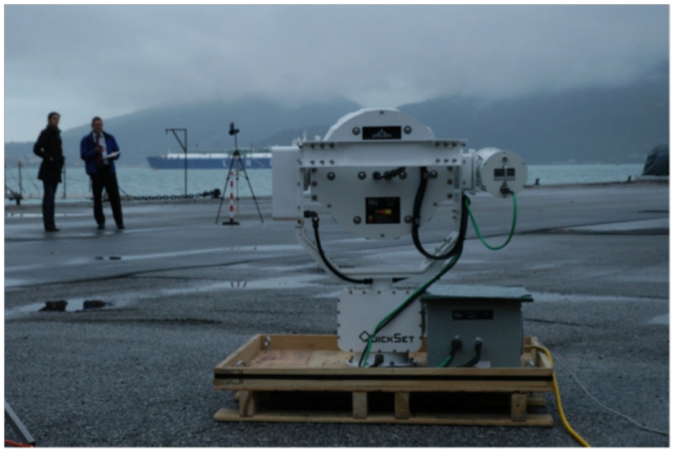
- Long-range acoustic hailing devices
- Optical disruptors
- Small boat entanglement devices
- Floating barriers
- Underwater loud hailers
- Underwater air guns
- Unmanned surface vessels (USVs)

Non-lethal technologies also find application in maritime interdiction, policing in counter piracy, and civilian merchant ship self protection. Some technology transfer between land capabilities at check points to maritime is also possible, but one often finds that the technical requirements for maritime security differ significantly from the land. Maritime distances of operation are much longer, for instance, and the energy levels, and time for response must all change accordingly.

Computer models of many surveillance and response technologies have also been developed at NURC for operations research and tactical gaming in a virtual port using NURC's OpenSea simulation platform. OpenSea is a tool for the preliminary exercise of new technology concepts by immersion into virtual operation for early de-risking of new technologies for maritime military applications.

POC: Karna Bryan, Project Leader, Maritime Situation Awareness, NURC, bryan@nurc.nato.int

A non-lethal small-boat entanglement device, the Running Gear Entanglement System from ResQmax (USA), is exercised at NURC.



NURC scientists exercise a long-range acoustic device from Ultra Electronics (USA) for use in maritime security operations.

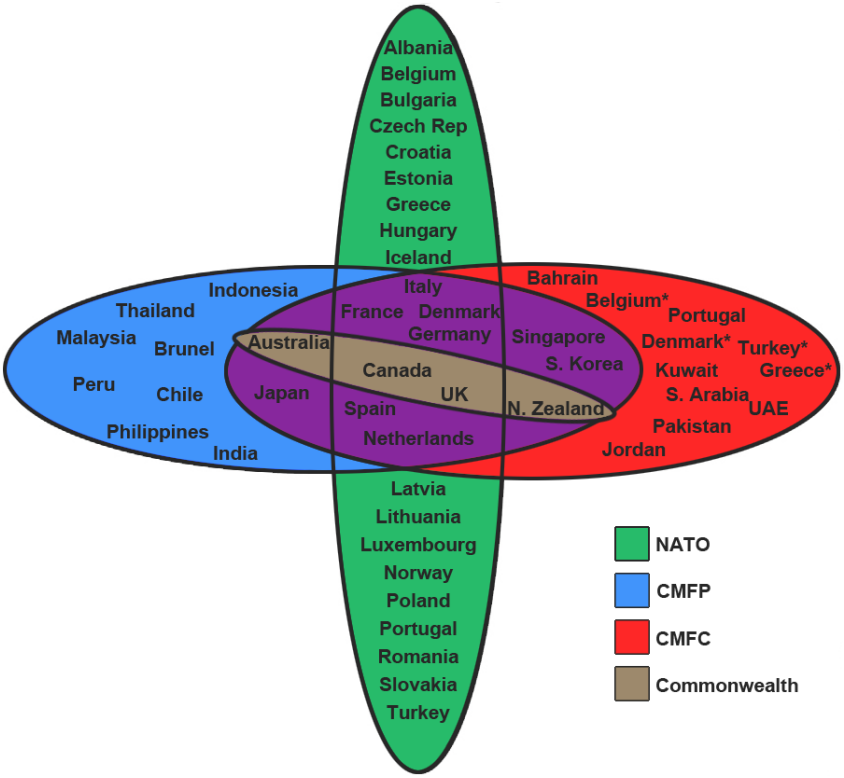
Enhancing Maritime Domain Awareness with the Single Integrated Lookout List (SILO)

As a supporting plan of the President's 2005 National Strategy for Maritime Security (NSMS), the Global Maritime Intelligence Integration (GMII) Plan called for the creation of "a single-integrated lookout (SILO) list of all vessels of domestic and global intelligence interest."

The National Maritime Intelligence-Integration Office (NMIO) funded the development of the SILO. SILO allows the sharing of Vessel of Interest (VOI) information between Government Departments, our Allies and Coalition Partners. SILO is instrumental in enhancing Maritime Domain Awareness.

SILO provides a multi-national, multi-security domain aggregated list of vessels of interest to Intelligence and/or Operations Centers world-wide.

SILO, as part of the Office of Naval Intelligence (ONI)'s SeaPort multi-domain collection database, allows VOI information to be shared across six secure computer networks (JWICS, SIPR, Stone Ghost, BICES (NATO), CENTRIX-CMFC (Combined Maritime Forces, Central Command), and CENTRIX-CMFP (Combined Maritime Forces, Pacific). This cross-network sharing gives 48 Nations access (see figure) to this data while allowing data owners to control what data is shared and with which network.



SILO/SeaPort allows analysts to:

1. Search Ship Characteristics, photography, blueprints, movement history, and other documents on over 240,000 vessels.
2. Search ONI databases for vessel events such as boarding history, Maritime Interdiction Operations (MIO) after action reports (AARs), as well as hails, and inquiries.
3. Create alerts on vessels, view other organizations' VOI lists, nominate vessels to other lists, and add additional comments to existing alerts. Additionally, SILO provides automated alerts when VOIs enter certain Geographic Areas.

This web-based shared approach to VOI information removes the need to wait until a new VOI message is transmitted. As soon as a vessel is put on a list, and depending on the classification level, the VOI is made available to the community.

SILO/SeaPort is available to everyone with access to one of the host classified networks and is designed to enable research without the need for a login. A login is required to add data to the database or to create/nominate a vessel as a VOI.

SILO addresses one of the key points of the President's National Strategy for Homeland Security: "Underlying our efforts to achieve domain awareness... is a fully developed and integrated Information Sharing Environment that supports the vertical and horizontal distribution of terrorism-related information among Federal, State, local, Tribal, and foreign governments..."

POC: Joseph Cunningham, CIP/SILO Manager, NMIO, jmcunningham@nmic.navy.mil

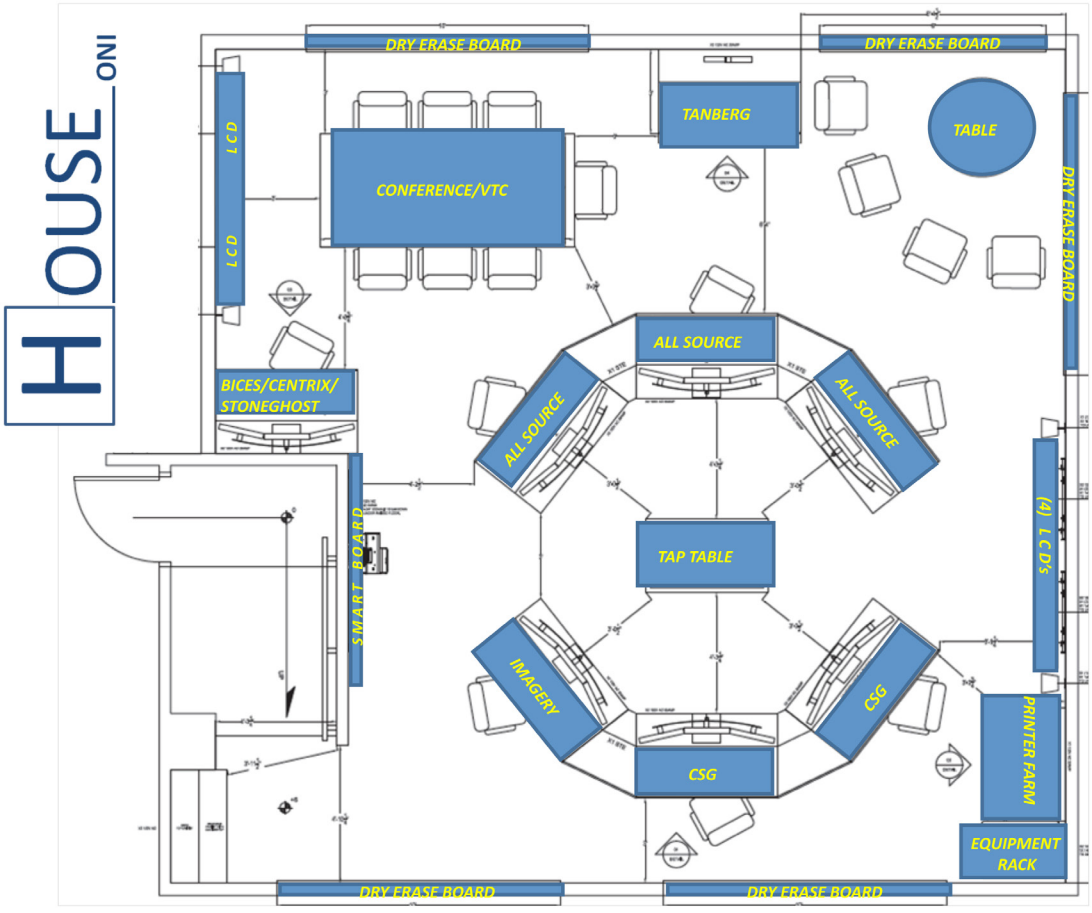
Information Dominance of the Maritime Domain

ONI's Intersection of Intelligence, MDA Data and the IDC

The Office of Naval Intelligence (ONI) and NIMITZ Operational Intelligence Center (OIC) are leading the advancement of an Information Dominance Corps (IDC) approach to Maritime Domain Awareness (MDA). Coincident with the OPNAV reorganization in 2009, the U.S. Navy published its "Vision for Information Dominance" and established the IDC. The convergence of MDA in the new era of Information Dominance led ONI to redefine its MDA responsibilities and activities as Maritime Domain – Information Dominance (MD-ID). MD-ID is specializing in advanced, multi-discipline, all-source intelligence tradecraft development in accessing NSA and the IC cloud-based architecture to deeply penetrate our adversaries. Embracing this new MD-ID perspective has produced dramatic intelligence breakthroughs and operational results and is helping to re-shape how the Navy views MDA. MD-ID is pioneering the advanced intelligence tradecraft development for analysts assigned within ONI and deployed to the Fleet Maritime Operation Centers (MOCs).

In early 2011, ONI's MD-ID established the Navy's first IDC-based, multi-discipline collaborative analysis framework called HOUSE. HOUSE is revolutionizing the way ONI conducts intelligence analysis through the use of advanced cloud-computing and by assembling teams of expert analysts drawn from across the Navy IDC. ONI's HOUSE teams function much as Dr. House and his group of specialists do on the FOX network television show; but instead of solving medical mysteries, they tackle the Navy's most challenging maritime intelligence cases. HOUSE analysts are leading the Navy's use of cloud computing - enabling them to collaborate and sift through massive amounts of information and rapidly discover, assemble, and visualize data. ONI's HOUSE analytic collaboration with Fleet/MOCs has resulted in a number of significant intelligence discoveries, actionable intelligence, and operational end-game on key members and components of illicit trafficking networks in the EUCOM, CENTCOM, AFRICOM and SOUTHCOM AORs. A new HOUSE analytic facility is under construction at ONI and it is designed specifically to promote collaboration and provide analysts with access to the intelligence community's most advanced technologies and data. These capabilities provide the Navy with a more profound understanding of our adversary's use of the maritime domain and deliver decision superiority to our commanders.

POC: Joe Taylor, Outreach Action Officer, ONI, jotaylor@nmic.navy.mil



HOUSE Analytic Facility-Feb 2012

Global Maritime Awareness via Space

Although all nations of the world, both developed and the developing, depend on maritime trade as the main engine that drives their part of the global economy, the international community has largely ignored the very real vulnerabilities of its marine assets, including resources (such as fish), the maritime transportation system, and threat of significant pollution, as well as seaborne threats, pose to many countries' well being. What efforts underway or being considered to address this requirement that are not commensurate with the multiple threats and their possible consequences.

In "A Cooperative Strategy for 21st Century Seapower" (MS21), the United States has called for more open collaboration across the entire maritime domain. Because many of the nations and international organizations engaged in discussions regarding maritime threats do not have any capacity to handle classified data, an unclassified system is an absolute core requirement to promote the sharing called for in MS21. This is not to say there cannot be other, more classified systems fed by this system, but rather that an international unclassified system is an absolute fundamental requirement to achieve the cooperation and synergy envisioned by MS21.

A global system to adequately address threats in and to the maritime domain requires a shared database which should include coastwise trade, international shipping, fishing vessels, recreational boaters, environmental impacts, as well as safety and security information. In order to be viable for all of those entities to be addressed in a data base, and to receive timely and relevant information that is important to their security, the system must be unclassified, and primarily law enforcement-based. This is not just a problem for the United States, or even just the maritime nations of the world. In order to get and disseminate the information related to maritime security that the world requires, we must be willing to share that information with all of our trading partners.

Another requirement key to achieving greater visibility of maritime-related threats is for a world-wide maritime surveillance system, and international cooperation is key to solving this challenge as well. Several recent tests of various groupings of unclassified earth observation satellites have shown that these systems, if combined effectively, can provide a sturdy backbone for global maritime surveillance which would make international information sharing much more effective and valuable for a variety of information consumers. This same system will also provide for the early detection of smugglers, resource poachers, polluters, as well as provide enhanced safety for all mariners.

The creation of the Collaboration in Space for International Global Maritime Awareness (C-SIGMA) concept is an effort to start to scope the requirement of such a system. C-SIGMA can be summarized as using unclassified systems, including a number of highly capable space systems now on orbit or planned for in the near future, to build a truly global maritime awareness system.

Besides the obvious strategic, operational and tactical advantages of having a much better picture of what is happening off one's coasts, there are other, less obvious reasons to move toward implementing something like C-SIGMA. One of the main points made in MS21 was the need for information sharing among the world's navies and coast guards. That information sharing has been reiterated as a core goal at several International Seapower Symposiums (the CNO'S annual gathering of all of the leaders of the world's navies and coast guards.) To date most of the action toward achieving this MS21 goal has been a long list of bi-lateral meetings. C-SIGMA could change this, offering the opportunity to build the global common data exchange called for in the MS21 by giving global maritime authorities a means/subject on which to focus all data sharing efforts. Developing and sharing a much clearer picture of what is happening off one's coasts is a recognized security requirement shared by all maritime nations. Most nations see this requirement as one that is impossible to be fulfilled due to resource constraints, and it was indeed beyond the reach of many nations until the advent of space-based AIS and commercial high resolution synthetic radar satellites in the past few years. Building on that developing satellite infrastructure, C-SIGMA provides a means to dramatically satisfy that shared need by providing a common framework for discussions on info sharing. It would lead to the synergistic melding of diverse capabilities held by diverse nations, to achieve a common good. In summary, C-SIGMA, if done correctly, offers a huge opportunity for trust building across the maritime domain.

POC: George "Guy" Thomas, Science Advisor, US Coast Guard
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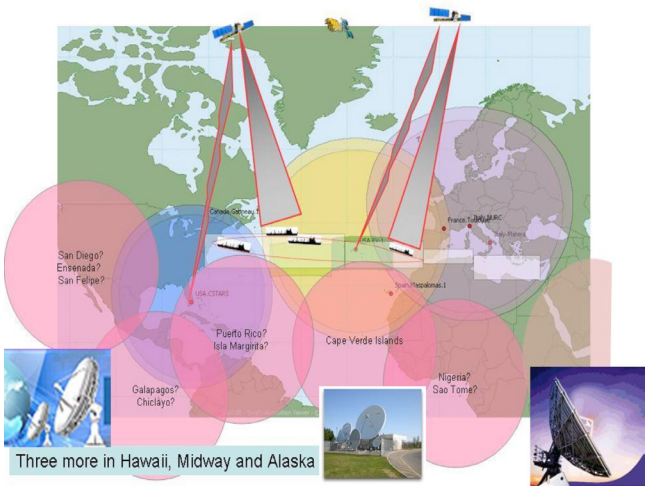
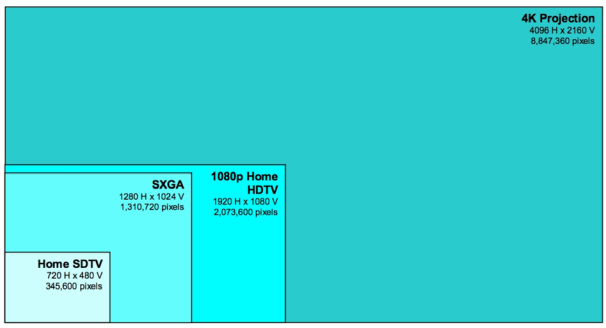
Proposed Network of Ground Stations



Digital Cinema Industry Provides Navy with Enabling Technologies

In 2008, the Office of Naval Research (ONR), National Oceanic and Atmospheric Administration (NOAA), and Naval Undersea Warfare Center (NUWC) Division - Newport developed a first-of-its-kind communications piece entitled Partnership Runs Deep. As a way to showcase the technical achievements of AUVFest, the partners produced a documentary film that captured audiences' attention with undersea robot exploration of revolutionary war shipwrecks. A short-form version was then accepted by the Smithsonian's Museum of Natural History and displayed through its Ocean Today Kiosk exhibit. Recently, NAVSEA program offices, Naval Research Lab (NRL), and CNO Strategic Studies group have each benefited through NUWC support by incorporating state-of-the-art visualization into their communications products. What soon became evident were the benefits of applying the same technologies and workflows used within the media production pipeline to warfighter solutions for increased effectiveness in data visualization, analysis, simulation, training and tactical systems.

As advances in digital media technology gained additional ground in 2009, improvements in display technologies, image sensors, signal processing & enhancement software, compression algorithms, GPU technologies and networks all contributed to increasing the viewer's experience and deeper immersion into virtual environments, interactive gaming and linear storytelling. Today, a new revolution in 4K video technology and 3D stereoscopic workflows has taken the industry by storm. 4K resolution (4 times the resolution of 1920x1080 high definition video) with improved color sampling, dynamic range and advanced compression techniques will change the way that humans experience and process moving images. This technology can improve the quality of image sensing on both manned and unmanned platforms. In addition, this enhanced visualization capability could allow imagery analysts to generate faster and better assessments, as well as improve data visualization techniques.



More pixels make for a far larger, far more immersive viewing experience and provide space for more visual information.

NUWC continues to expand its role by exploring new and innovative ways to apply these technologies. As a leader in this area, NUWC was asked to provide technical leadership for an emerging partnership in 2012, initiated by National Maritime Intelligence Center (NMIC, now NMIO), and to include Naval Postgraduate School (NPS) and USSOUTHCOM as collaborative partners. The technical foundation was based upon emerging digital cinema tools, technologies, and workflows in 4K video that can improve data visualization and help inspire better man-machine interface concepts. Several concepts are being explored to improve the way an operator might interact with a computer. This next photo illustrates how a Sailor can better interface with information systems in a way that communicates the complex tracking concepts involved in Naval navigation and targeting:

As an example of ongoing work, 4K and 3D stereo techniques are being used to combine real and virtual environments to quantify the benefits that this technology may bring to data visualization, analysis, and training tools. NMIO, the Navy's sponsor and advocate, has provided the foundational assets to be employed. Aligning with the NMIO mission, this collaborative partnership will help break down barriers to information sharing and create enabling structures and cultures to optimally share data across maritime partners. The unique approach will provide a collaborative foundation and common baseline for future connectivity between a Navy lab (NUWC), academia (NPS), and a COCOM (USSOUTHCOM), known as the 4K Tri-site. This expandable model can enable scientists; researchers and engineers to work directly with the customer and warfighter to gain better insight into real-world problems. In addition, it enables the operational commands to reach into the research (S&T) community and influence design emerging capabilities that might not otherwise be identified through traditional requirements gathering.

NUWC has taken great strides to incorporate these new digital cinema technologies and workflows over the past several years, as this would reduce the probability of falling behind the technology curve in the future, and empower the next generation warfighter by enabling collaboration between DOD, academia and industry experts.

POC: David Bellino, Digital Media Producer, NUWC, david.bellino@navy.mil

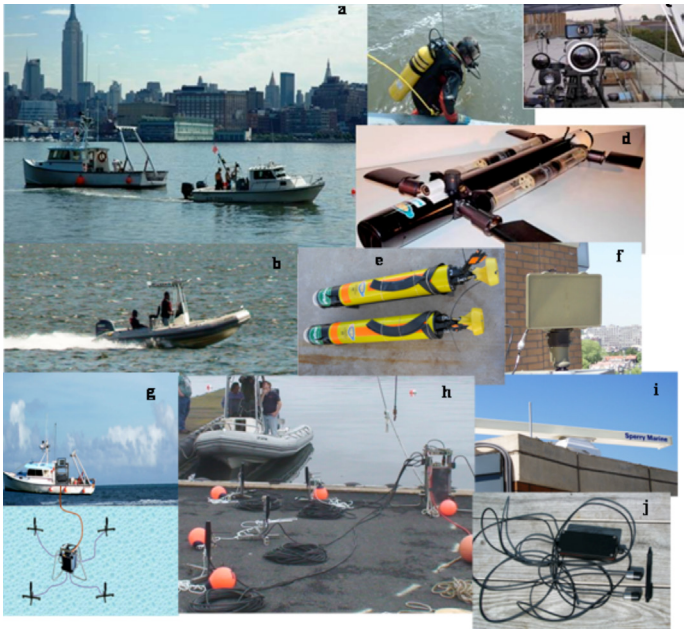
Passive Acoustic Research in Maritime Domain Awareness

The ability to safeguard domestic shipping and waterside facilities from surface and underwater threats is critical to ensuring a viable means to Maritime Domain Awareness. Small surface vessels and divers have already been employed as weapon delivery vehicles elsewhere in the world. The research being conducted in the National Center for Secure and Resilient Maritime Commerce (CSR), a DHS S&T National Center of Excellence for Port Security examines some basic science issues and emerging technologies to improve the security of ports as well as coastal and offshore operations. CSR work relies on a layered approach utilizing above water and underwater surveillance techniques. The investigated layers include satellite-based wide area surveillance; HF Radar systems providing over-the-horizon monitoring; and nearshore and harbor passive acoustic surveillance.

Integration of these systems is aimed at achieving surface and underwater threats detection, classification, identification, and tracking at various scales. The acoustic part of the CSR research is aimed at the investigation of applying passive acoustic methods to surface and underwater threat detection, classification and tracking in coastal zones. Acoustics is the only tool that provides detection of underwater threats and Stevens Institute of Technology (Stevens) work has concentrated on passive acoustic methods that are much simpler and cheaper than conventional sonar techniques mainly applied for underwater threat detection.

Stevens has been conducting experimental research of the physical phenomenon connected with acoustic wave generation and propagation in the realistic environment of the Hudson River Estuary. Initially, the focus of the Stevens efforts was on threats posed by surface and subsurface intruders including SCUBA divers and later was extended to small boats using passive acoustic techniques.

Hence, the estuary itself is an integral part of our laboratory. The estuary is equipped with instrumentation to collect weather and environmental data, and through modeling, to predict their characteristics. The Stevens research is supported by three research vessels, several UUVs, passive acoustic components, instrumentation, and computing. Surface water traffic is monitored by two radars, an AIS receiver, and Infrared and optical video cameras. Research vessels, UUVs and other assets are shown in Figure 1. The larger boat is the RV Savitsky (Figure 1a) is specially constructed and fitted out for maritime research purposes. Towards the stern, is an A-frame for loading large and

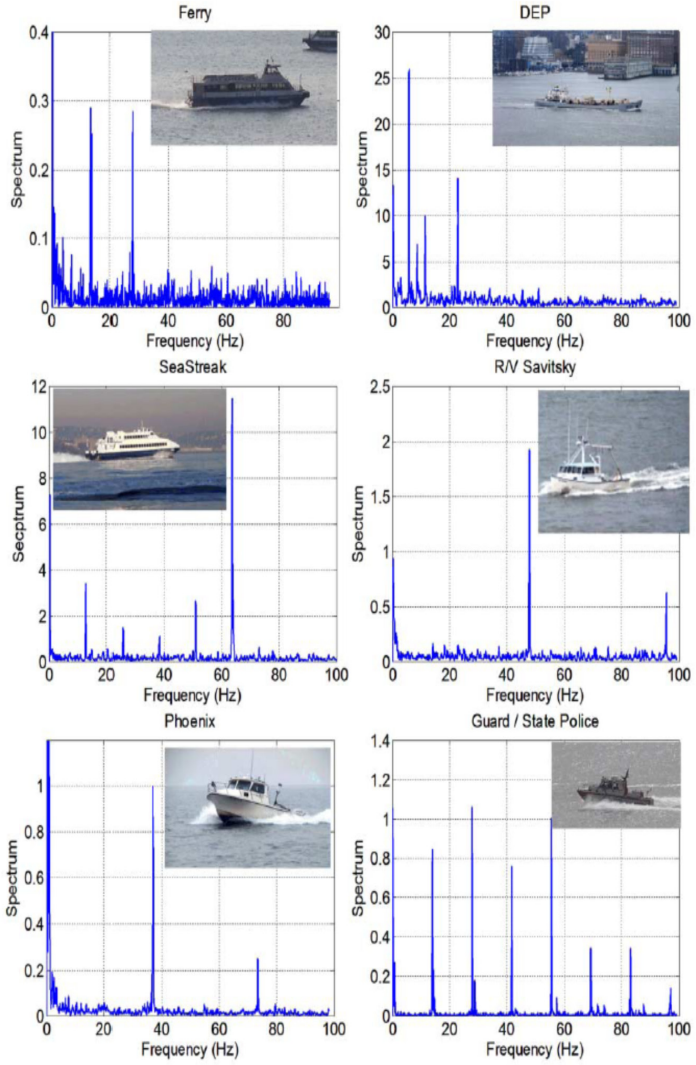


heavy items onto and off of the boat. Two smaller boats (Figures 1a and 1b) are used to deploy remote instrumentation and divers, support experiments, and provide for safety. In addition, they are used as points of radiation or reception in experiments involving acoustic propagation between several points for measurements of temporal variability of acoustic fields. The Stevens research is supported by several UUVs, e.g., the iRobot Ranger (Figure 1e) and the iRobot Transphibian (Figure 1d), a fin-powered vehicle that is both a mobile UUV and a bottom crawler. The fins enable the robot to navigate with 6 degrees of freedom.

The majority of the acoustic tests were conducted using the Stevens Passive Acoustic Detection System (SPADES) shown in Figures 1g and 1h. SPADES allows the passive acoustic detection, tracking and classification of various surface and underwater sources of sound including surface vessels, swimmers, various types of divers, and unmanned underwater vehicles.

SPADES has been widely used for surface and underwater target detection in various domestic and international locations, including New York Harbor, Newport, Rhode Island, Key West, Miami, and the Netherlands. These field experiments have allowed us to examine different signatures, noise levels, and acoustic propagation conditions under a wide variety of ambient noise and ocean conditions for the detection, tracking, and classification of divers, small vessels, and underwater vehicles. Figure 2 below shows various vessel acoustic signatures measured by SPADES.

This system has been tested with a variety of other Maritime Domain Awareness sensors that allow surveillance under various environmental conditions. For example, Figure 3 shows SPADES



working with radar and AIS. Another example is combining passive acoustics and satellite surveillance for small vessel detection, classification and tracking. The advantages of using passive acoustics include:

1) Vessel classification. Satellite imagery provides information for vessel classification. The resolution of the satellite images can often allow for the differentiation between large ships and small vessels. Acoustics can provide a reliable method for vessel classification.

2) Tracking. The satellite system can provide vessel detection across a very wide area, but cannot provide vessel tracking due to the typically long times between passes. The passive acoustic system can provide a continuous track of vessels that have been detected via satellite.

3) Detection of underwater targets. Underwater acoustics is the primary tool for the detection of underwater threats, including submarines, UUVs, SCUBA divers, etc. In many cases, it is not clear if the detected sound belongs to a surface or an underwater target. Satellite imaging can exclude surface targets, and what is invisible for a satellite may be detected as a source of sound from an underwater target using the acoustic system.

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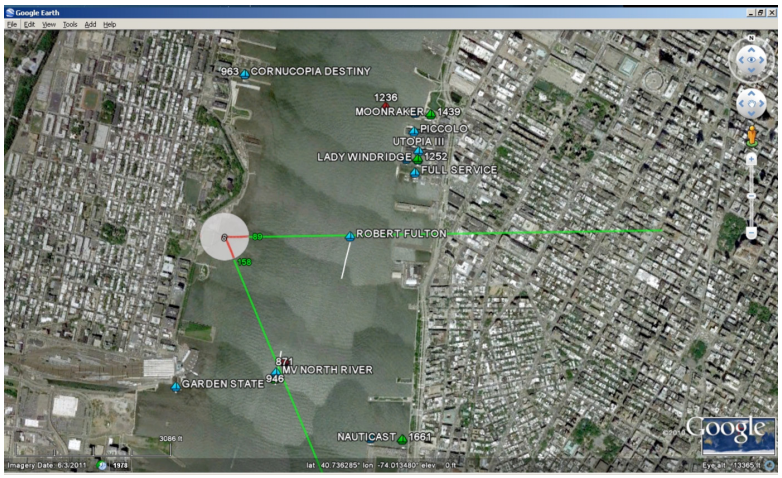


Haptic Technologies for Maritime Applications

ONI's Future Technologies Team monitors, evaluates, and reports on emerging technologies that have the potential effects on the future maritime operational environment. The team supports Navy and DoD acquisition efforts with specific focus on Office of Naval Research programs. Characterizing potential advances in materials, sensors, bio-technologies, energetics, human performance, information technologies, and other areas helps to define and project potential future threat capabilities and to inform current research and acquisition investments. A recent assessment evaluated the implications of rapidly developing haptic research and technologies, just one area of advancing technologies that ONI is monitoring for the Navy.

Haptic technologies (also "haptics" or "force feedback") describe the application of technologies to remotely recreate a sense of touch. In its simplest form, information about the force present in interaction with an object is captured by a sensor and provided to a user, generating a sensation as if they were actually touching the object. The actuator is the device used to represent the forces or deformations to the user. The users receive the force feedback from an "end effector" which can be a joystick, glove, seat, or other device. Haptic feedback can come in many forms such as vibrations created by a vibrotactors (vibrating actuators), movement of the interface, or force applied by an actuator. Force feedback is crucial to functional haptics because it enables the user to feel the interactive sensations of an object that they are not physically touching. This feedback also allows the user to apply appropriate forces to the remote or virtual object they are handling. Current applications fall into three categories: teleoperations, virtual environments and communication/guidance.

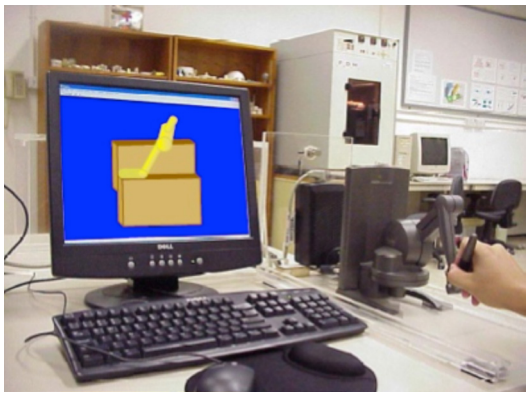
Teleoperation refers to the operation or machine from a distance. Enhancing teleoperations with haptic feedback technologies allows the user to have increasingly realistic telepresence; enabling them to perform tasks remotely and at different, scales, with more precise control. Such systems provide the user with force, tactile, and visual feedback and allow the controller to remotely perform tasks using manipulators in unfavorable environments such as underwater or hazardous environments or inaccessible locations such as the cranium, a kidney, or a ballast tank. These applications expand the use of manipulators on unmanned vehicles to better perform delicate tasks such as surgeries, inspections, repairs, and explosive/hazmat disposal. Some of these applications may not have been previously possible by robots or humans.

Haptic virtual environments have some similarities with tele-operations in the user is receiving force feedback from an effector. In virtual environments the force feedback is generated via interactions with simulated physical objects. Haptic enhanced training simulations will allow for navies to gain familiarity with various scenarios, environments, and equipment. Recent worldwide haptic system research and development has included simulating the forces of seawater flows on underwater welding tools, creating a realistic operator training simulator.

Variations of haptic feedback systems can be used for communications, non-verbal cueing, and guidance, particularly in environments that have decreased visibility or high noise levels. If stealth is desired, this form of feedback may be silent and subtle, making it difficult to detect. Such cueing applications include haptic belts that communicate directional information or instructions to a user via vibrational patterns and GPS systems that incorporate real-time haptic guidance for waypoint navigation.

Haptics have the potential to enhance many maritime missions in the near-term. Underwater systems including unmanned underwater vehicles and diver support equipment will have significantly greater capabilities as haptic augmented controls are integrated. Haptics are already supporting a number of training tasks and simulations worldwide. There are also many opportunities to integrate haptic communications in operator and command interfaces to add additional alertment beyond visual and auditory information, allowing further optimizations of system interfaces to specific individuals.

ONI continues to work with intelligence community, service/national laboratory, and allied agency scientists and analysts to provide forward-looking assessments for the maritime community.



"An underwater wet arc welder is shown on the left and the haptic training system for training these skills is on the right. The training simulation consists of a haptic welding tool and computer. Welding simulations are seen on the display as the trainee uses the haptic tool to practice. Haptic feedback is used to replicate the forces of seawater and the welding bead on the welding tool to accurately replicate the drag and resistance that the operator will feel in the underwater environment. The coordinated visual display feedback illustrates the task, the progress of the weld, and the continuity of flow and contact with the task surfaces."

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Hydrographic Unmanned Semi-Submersible

The Hydrographic Unmanned Semi-Submersible (HUSS) was developed by the Naval Research Laboratory (NRL) and its industry partner C&C Technologies, Inc. for shallow water (7-100ft) surveying in ports, harbors, and channels. This vehicle addresses a long standing technical problem of poor efficiency for shallow water surveying.

With ample space capacity and electrical power for a variety of sensors, it is well suited for bathymetry, mine or unexploded ordnance search, post-disaster or attack rapid response, pre-salvage assessments, and hull-side inspections.

Its unique design combines the advantages of:

- a surface craft: speed, endurance, real-time communications, maneuverability, high area coverage rates, 10cm navigation accuracy, in-situ re-tasking and navigation safety
- an unmanned underwater vehicle (UUV): stability, easy launch and recovery, autonomy, energy efficiency, safe stand-off distance. It offers 3X the productivity of small surface craft and 12X the productivity of UUVs.

With an endurance of 48 hrs @ 6 knots on one tank of diesel, and offering real-time telemetry, this system requires very little down time for refueling. It can operate easily both inshore and offshore. Launch and recovery can be done using a trailer at a sailboat ramp, with a crane either pier-side or shipboard, or using a stern launch system for open ocean. Remote vehicle control options include joy-stick, heading commands, autonomous (waypoint), and over-the-horizon.

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