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National Maritime Intelligence-Integration Office

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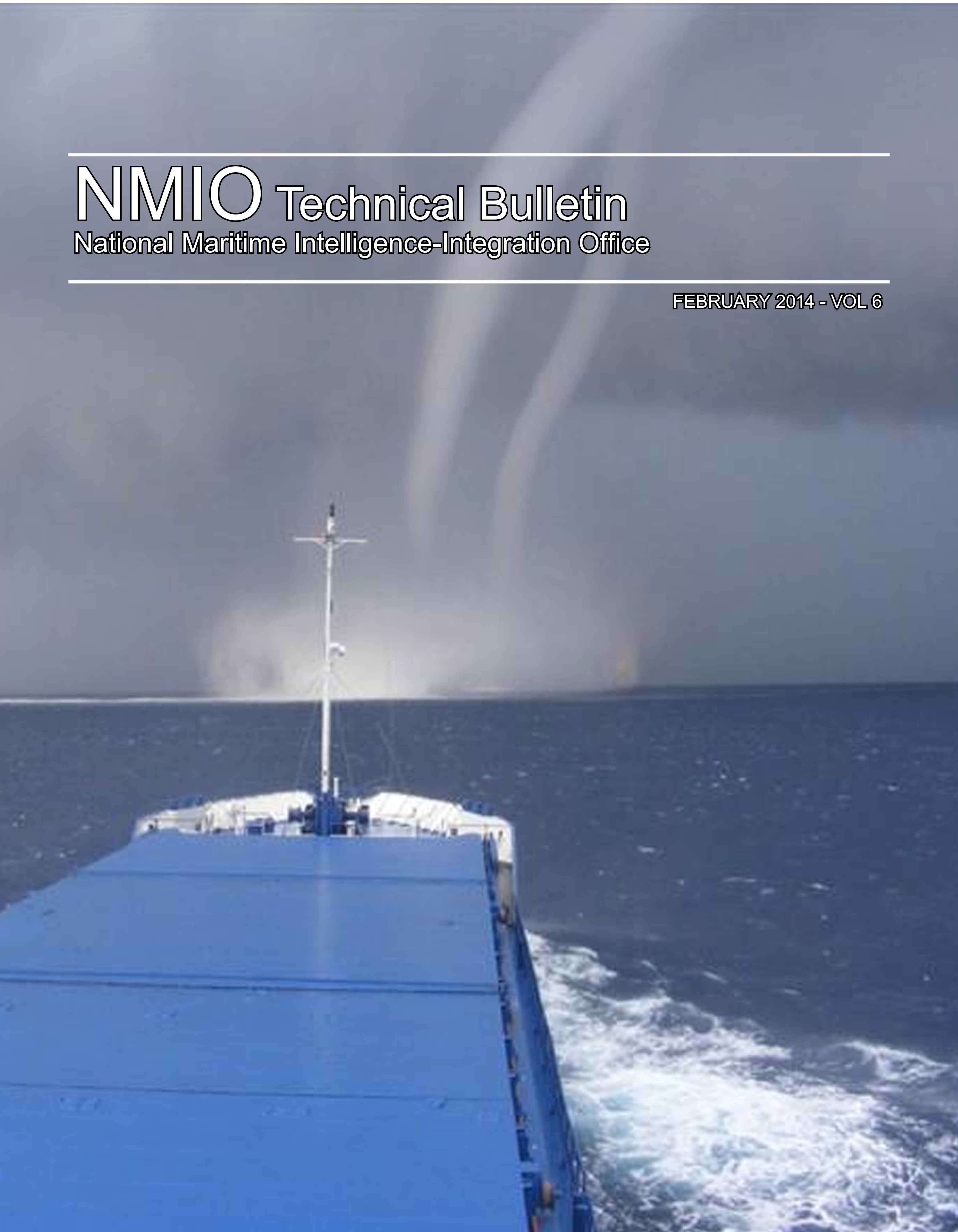

Director NMIO View:

Rear Admiral Elizabeth L. Train, USN

As the newly appointed Director of the National Maritime Intelligence-Integration Office (NMIO), I am pleased to present Volume 6 of NMIO's Technical Bulletin. I became the Director of NMIO and assumed command of the Office of Naval Intelligence (ONI) on 30 September 2013. As reflected in Presidential Policy Directive 18, "Maritime Security," NMIO is designated by the Director of National Intelligence as a U.S. Intelligence Community Service of Common Concern, providing a capability to facilitate maritime intelligence integration and maritime domain awareness information sharing for operational use by various Federal maritime stakeholder departments and agencies. NMIO continues to be the unifying maritime voice of the U.S. Intelligence Community.

As the second Navy flag officer to be dual-hatted as NMIO's Director and Commander, ONI, I have had the distinct pleasure to follow RADM Sam Cox, USN, who retired after 33 years of outstanding and dedicated service. During RADM Cox's two tours as Director of NMIO, he set the standard for success as he markedly advanced each of NMIO's strategic goals; 1) Developing the Global Maritime Community of Interest (GMCOI); 2) Improving information sharing and intelligence integration among the GMCOI stakeholders; 3) Advocating community collection and analytic priorities; and 4) Integrating Science and Technology to improve the GMCOI's awareness of emerging technologies and their implications. I share RADM Cox's commitment to NMIO's unique, unifying mission of national level maritime intelligence integration, and I am continuing to engage in this complex, global mission to promote and effectively share maritime information among our global maritime partners.

I would like to personally thank the authors who have invested their valuable time to contribute to this edition of the Technical Bulletin to share their insightful knowledge and perceptions of the world-wide maritime security community and its associated technological challenges. As we work together to promote global maritime security, I encourage others to become more involved in this community publication by submitting articles to help us broaden the topics and regions covered in this product.

I am equally grateful to our readers. Their insights, commitment, and feedback, continue to positively affect the safety of the international maritime domain. It is my hope that through increased awareness and collaboration our mutual efforts will strengthen the security of the global maritime commons. NMIO is focused on identifying concerns and issues that resonate among government, academic, industry, and foreign partners, and is dedicated to collaborating with global stakeholders to identify the most efficient and cost effective solutions to our mutual maritime challenges.

Our Technical Bulletin is just one venue that NMIO offers to promote enhanced maritime domain awareness and information sharing. We appreciate and invite your continued input, interaction, and contributions to this and other efforts that promote this common mission. I look forward to working with you in the future to advance maritime security and build shared domain awareness.

NMIO Technical Bulletin **Volume 6, November 2013**

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Contributions welcome: We welcome all contributions from Global Maritime Community of Interest's stakeholders, both domestic and international. In submitting your articles please highlight who you are, what you are doing, why you are doing it, and the potential impacts. Please limit your article to approximately one to two pages including graphics. Articles may be edited for space or clarity.
Cover image: Twin waterspouts ahead of the cargo ship Rheinfels.

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Ocean Facilities for Energy Extraction

Jennifer Hayward, PhD, CSIRO-Energy, Newcastle, Australia

Abstract: There are strong economic and environmental drivers for establishing large, energy-harvesting installations and structures in near-coastal ocean waters. While the associated technologies are advancing rapidly, the scale, value, risks, and security of these future maritime facilities remains to be characterized.

Ocean-renewable energy has the potential to make significant contributions to the world's electricity generation. There are several types of renewable energies available in our oceans:

- Wave energy – The energy embodied in the height and wavelength of waves can be extracted in various ways.
- Tidal and ocean current energy – Energy is extracted from the flow of water, either tidal flows or ocean current flows such as the East Australian Current.
- Ocean thermal energy – In some tropical regions, large thermal gradients exist between the water near the surface and deep water. Energy can be extracted from this gradient.
- Ocean salinity gradients – Similar to ocean thermal energy, salinity gradients can exist and energy can be extracted by taking advantage of this difference.

Wave energy is the ocean energy with the greatest energy harvesting potential. The majority of research and testing into Wave Energy Convertors (WECs) is occurring in the regions with the greatest potential: Europe, North America, and Australia. There are more than 200 different WECs in various stages of development globally, with only a handful having been connected to the grid and generating electricity.

Even with this plethora of devices, they can be classified as one of three types based on the collector surface orientation:

- Point absorbers are devices that incorporate a float that is small compared to the swell wavelength (Figure 1). The float is free to follow the movement of the wave and accept wave energy from any direction. It can be tethered so that it is submerged and moved by the pressure of the wave passing overhead, or it can float on the surface and track or 'heave' with the movement of the sea surface.

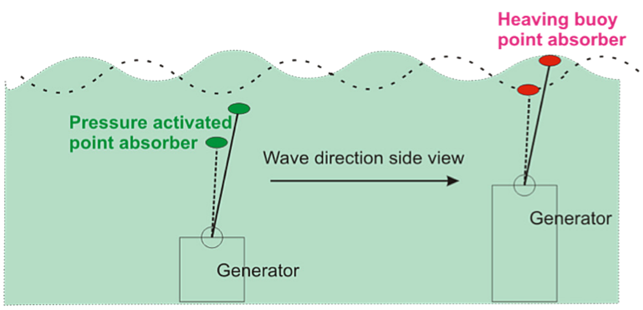

Figure 1. Schematic of two types of point absorbers, buoyantly harvesting energy from the wave's amplitude.

- Linear attenuators incorporate a float or a number of floats that are shaped or distributed in alignment with the direction of wave travel (Figure 2). Their overall length may be large compared to the swell wavelength; however, they are also wavelength dependent. Energy is harvested from the flexing of the joints. Unlike a point absorber, they need to be slack moored so that they can turn to maintain their principal axis normal to the oncoming waves.

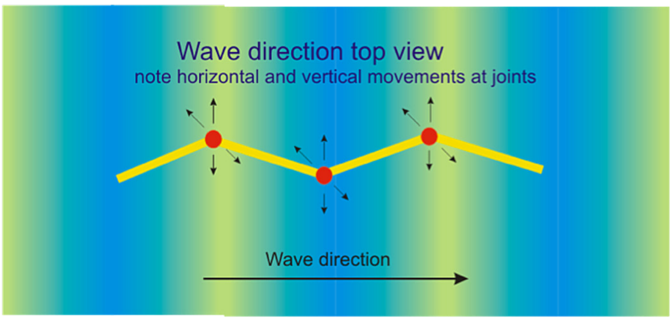

Figure 2. Schematic of a linear attenuator. Energy is obtained from the 3D flexing at the joints as waves pass.

- Terminators are designed to collect energy from waves by directly facing into the wave front (Figure 3). A terminator may include passive devices such as a tapered channel to focus energy from a wider section of wave front, as is used in overtopping devices. These devices consist of a tapered channel which allows waves to flow into a floating reservoir. Water is released from the reservoir through hydroelectric turbines that generate electricity. Terminators also include blow-hole types of devices, where the flow of waves into and out of a capture chamber pushes and pulls air through a turbine that generates electricity.

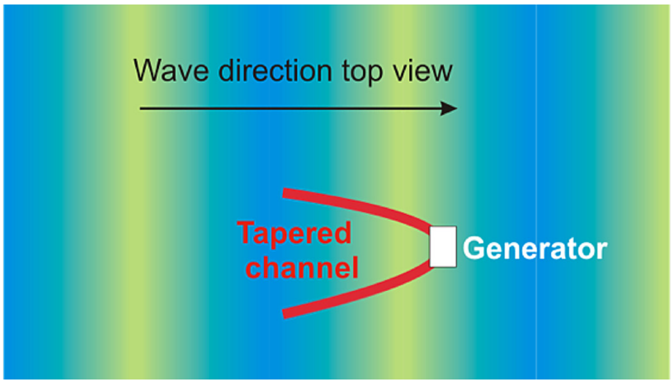

Figure 3. Schematic of a terminator featuring a tapered channel to focus wave energies on the generator.

WECs will typically be situated in 'wave farms', where devices are arranged to maximize generation and minimize impact on the environment and costs. An example of a layout of a terminator type of wave farm is shown in Figure 4. This would be situated on the 25m isobath, as this is the optimal point of generation for this type of device. These WECs are also quite large, which means they need to be widely spaced in order to avoid bumping and shadowing. However, because they are slack moored and could twist to face the waves at any time, the wave farm site would be out of bounds for any other vessels. For example, a 231MW-capacity terminator wave-energy emplacement as shown in Figure 4 would likely require isolating at least a 25-km2 region of the ocean from routine navigation. This area will also depend on the distance of the farm from the coastline.

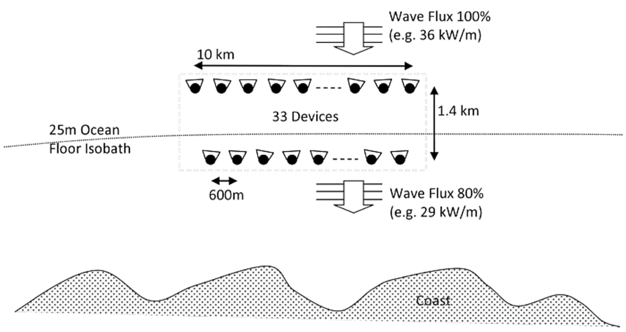

Figure 4. Illustrated emplacement dimensions of a 231MW wave energy conversion facility.

Based on a capital cost of $2,800/kW, the above wave farm would cost $650 million. Depending on the wave resource, the cost of electricity (excluding profit and taxes) could range from $80 to $300/MWh. Devices have been designed to withstand a “25-year wave”. Therefore, it could be assumed that any wave farm would have a 25-year lifetime. Operations and maintenance costs are not well understood for wave farms as they have not been constructed to any great extent. They have been estimated to be approximately 40 percent of the cost of electricity (CSIRO, 2012).

A recent study by Behrens et al (2012) examined the potential for harvesting wave energy along the East and Southern Coasts of Australia using historical wave height, period data, and a terminator WEC. This study excluded regions where it was assumed that installation of wave farms would not be permitted, such as existing protected marine areas (Great Barrier Reef Marine Park, South-East Commonwealth Marine Reserves, and State/Territory marine protected areas) as well as proposed Sanctuary and Marine National Park Zones. In addition, bays and coastlines between small islands and the mainland, such as around Kangaroo Island, have been excluded due the lower value of the resource in those areas and to exclude some major shipping areas around mainland capital cities. All of the areas excluded from this particular study are shown in Figure 5.

Other localized constraints and potential conflicts, such as sea-going shipping lanes, population sensitivity, native title, etc., will have less obvious impacts on large-scale deployment of wave farms, so these have not been plotted as specific constraints. In order to consider such impacts, the authors reduced the length of the available 25m isobath by 5 percent.

A general environmental constraint was also included, where it is assumed that no more than 20 percent of wave energy can be extracted along any part of the coastline over a given period. This restriction across the whole of a wave farm is to prevent problems with fisheries, rock lobsters, and recreational activities closer to the shore.

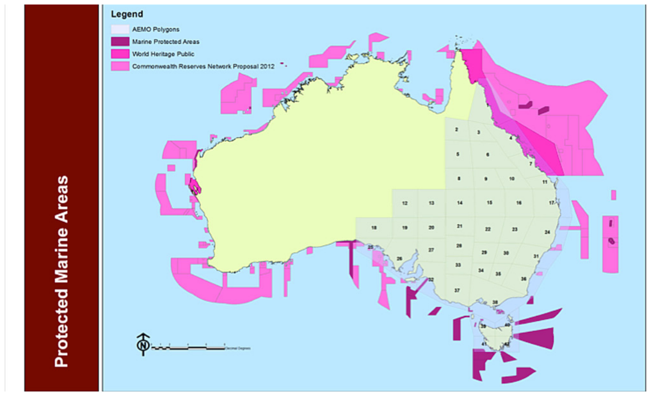

Figure 5. Exclusion zones assumed in Behrens et al. (2012) study – both environmental and political restraints considered.

It was found that the potential annual electricity generation from wave energy as calculated in Behrens et al. (2012) equates to approximately one-third of Australia’s current electricity demand. The majority of generation occurs along the southern coastline where the resource is the greatest. In order to reach a more modest target of generating enough electricity to power a city the size of Melbourne (population of approximately 4 million), a wave farm would need to use 62 devices and occupy 20 km of coastline, which is double the size of the farm shown in Figure 4.

Wave farms are currently at the demonstration/early commercialization stage of development. Two marine energy test centres are available in the United Kingdom to test the capabilities of devices in oceans over longer periods of time. A wave farm was constructed in Portugal using the Pelamis device, but due to financial reasons, it was abandoned. The Pelamis device is a linear attenuator type of WEC. A wave test facility has been operating at Lysekil, Sweden since 2001 using an array of Seabased AB point absorber WECs. This site is now being turned into a full-size wave farm using the same technology. The first generator was installed in March 2013. In Australia, a CETO point absorber was installed off the coast of the Australian Navy’s Garden Island base and sends power to the local grid.

Ocean renewable energy has the potential to be a viable and major source of electricity, both now and in the future. Wave energy is particularly abundant globally, and WECs are already being installed in the sea, albeit on a demonstration scale. In order to reduce costs for grid connection, mooring, operations, and maintenance, WECs will be located in arrays or wave farms, stretching for tens of kms along coastlines. These farms will cost millions to construct and maintain and will have long lifetimes. As they will be supplying electricity to the grid, they are important assets which will need protection.

There is still much to be understood about installing, operating, and maintaining wave farms. Economically, wave farms should be installed in areas with the best resources; however, these areas may also be used for maritime operations. Local approval processes will need to be established with all stakeholders in mind.

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Ad hoc Sensor Networks to Support Maritime Interdiction Operations

John Osmundson, PhD, and **Alex Bordetsky,** PhD, Naval Postgraduate School

Abstract: Networking sensors, decision centers, and boarding parties supports success in Maritime Interdiction Operations. Led by a team from Naval Post-graduate School (NPS), experiments were conducted in 2012 to test the use of ad-hoc, self-forming communication networks to link sensors, people, and decision centers. The experiments involved international participants and successfully shared valuable biometric and radiological sensor data between boarding parties and decision centers.

In June 2012, a group of international maritime security experts took part in Maritime Interdiction Operations (MIO) exercises in the Baltic Sea and in Souda Bay, Greece. Led by Dr. Alex Bordetsky, an associate professor in the Department of Information Sciences at the NPS in Monterey, California, the experiment aimed to link nuclear detector and biometric sensors over ad hoc, self-forming communication networks. This was the latest effort in the set of experiments conducted over the previous five years (2007-2012), which explored using networks, advanced sensors, and collaborative technology to support integrated detection and collaboration against land and maritime nuclear radiological threats.

Two key MIO issues are how to configure and link sensors, people, and organizations and how to provide information to decision makers and boarding teams to determine interdiction actions in response to detection alarms and events. Deployed units involved in MIOs must be able to collaborate in real time with partner forces and operations centers. Deployed boarding teams must be able to access subject matter experts (SMEs) through "reach back" for support and assistance in adjudicating MIO tasks.

The June 2012 experiment represented the most recent step in the collective field studies of socio-technical models to counter globally distributed maritime threats. Some key achievements were:

- Implementing an ad hoc mobile networking architecture that integrated tactical-level boarding teams equipped with hand-held portable and unmanned system-based detectors with geographically-distributed technical experts and data fusion centers.

- Implementing an information management architecture for sharing alerts from threats aboard small maritime craft or between land/ports of entry/borders and for translating active and passive detection alerts into the shared situational awareness events.

- Using surveillance techniques to enable global locating, tagging, and tracking of small maritime craft that were transporting illicit materials.

- Incorporating cooperative command and control (C2) and interoperability to search models for stand-off and high-speed drive-by detection, in combination with remotely network-controlled unmanned surface (USV), aerial (UAV), and ground (UGV) systems.

- Using knowledge and social networking architecture for network-enabled integrated detection.

Figure 1. Constructing a node in the ad hoc mobile mesh network.

The ad hoc mobile mesh network that was set up at the start of the exercise is shown in Figure 1. During the initial phase of the exercise, a simulated radiological source was transferred from land to a small vessel in the Baltic Sea. A beacon on board the small vessel allowed the small vessel to be tracked using GPS and a Norwegian nanosat as shown in Figure 2. The Norwegian satellite track was inserted into the ad hoc network using GSM (Global System for Mobile) communications and then sent to the Maritime Operations Centers.

Figure 2. Nanosatellite confirmation of target in Souda Bay

The small vessel then proceeded to the Mediterranean where it was acquired and tracked in Souda Bay, Greece using GPS information as shown in Figure 3. Small manned and unmanned boats equipped with active interrogation sensors were used for stand-off detection and tracking of the small vessel in Souda Bay with information relayed to boarding teams in the vicinity.

Figure 3. Track of small vessel in Souda Bay, filtered from general vessel activity in the area.

Figure 4. Boarding team preparing to intercept small vessel.

Figure 4 shows a team preparing to board the small vessel. When the small vessel was boarded, the boarding teams employed hand-held nuclear radiation detectors to gather spectra from the suspect device. Radiological spectra from the handheld sensors were transmitted electronically in a standardized format via the ad hoc network to a remote site as illustrated in Figure 4. SMEs in gamma spectroscopy collaboratively analyzed the spectra and other pertinent information using the Elluminate™ collaboration tool to provide results or make recommendations for additional collection.

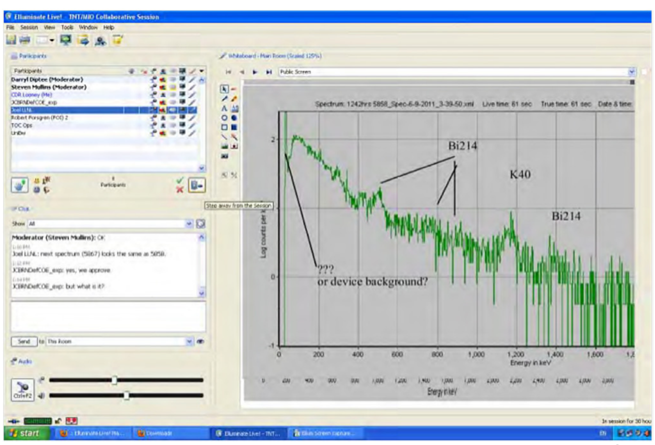

Figure 5. Radiological spectra analysis using Elluminate™ for collaboration among subject matter experts.

Boarding parties also employed hand-held biometric sensors to gather fingerprint data from the suspect device on board as shown in Figure 6. Fingerprint data was then transmitted via the ad-hoc network to analysts at a remote location; the analysts determined an identity based on a match in their database.

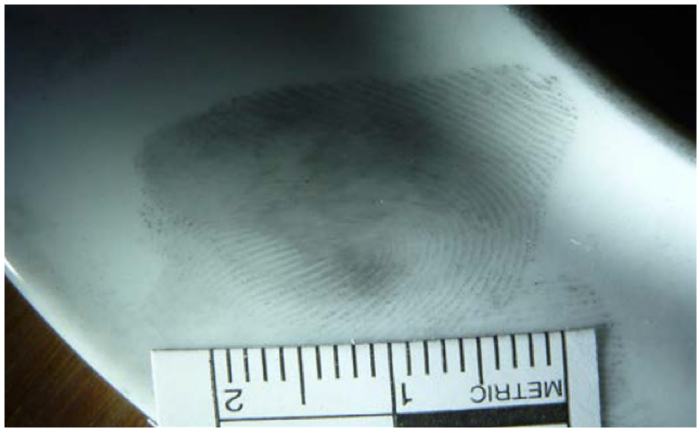

Figure 6. Fingerprint captured by biometric sensor

As another part of the overall 2012 exercise, experimental network-enabled daily detection operations were conducted in San Francisco Bay, as shown in Figure 7.

Figure 7. Boarding crew training in the San Francisco Bay.

For the first time in MIO experimentation, two marine police boats and several U.S. Coast Guard vessels used integrated network-enabled detection and technical reachback to SMEs in their daily patrol activities. Daily networking and collaborative C2 patterns occurring between and during the source detection events provided longitudinal observation data. The main goal for this unique training exercise was to put daily patrols of the San Francisco police department, the Alameda County sheriff, the Contra Costa County sheriff, and other contributing organizations and vessels in the network-controlled detection environment. The exercise allowed patrol crews to learn how to communicate with radiological health department experts and to share their situational awareness.

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Atom-based Gravimeters and Inertial Sensors – Potential Emerging Capabilities

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Summary

Over 250 years ago Sir Isaac Newton recognized that the same force that caused an apple to fall also held the Moon to the Earth. This stimulated him to develop his Law of Gravitation, and led to the principle that all objects fall with the same acceleration irrespective of their mass, as observed by Galileo Galilei. These pioneers understood gravity as well as many scientists do today. In reality, we still measure gravity by dropping a proverbial apple; a falling test mass whose trajectory we measure through space–time. Developments of optical lasers, atom interferometers, and atomic oscillators/clocks over the past 50 years have led to a vast improvement in our measurement precision.

Mankind's most precise instruments are those that measure space and time. At the heart of these measurement devices is the phenomenon of wave interference. For example, the most precise rulers to date are optical interferometers, built for the detection of gravitational waves using very long baseline interferometers such as the Laser Interferometer Gravitational Wave Observatory (LIGO). This device measures distance with a sensitivity up to 1 part in 10^{24} (The LIGO Scientific Collaboration and The Virgo Collaboration 2012). On the other hand, the most precise keeper of time is an atomic clock. With its ceaseless ringing, a caesium atom is an oscillator that defines the International System of Units (SI) second at the level of 1 part in 10^{16} (Heavner et al. 2005). Precise measurement of the absorption of radiation at 9,192,631,770 Hz by caesium again relies on interference, in this case the interference of matterwaves in an atom interferometer.

More recently, atom interferometers have been used to measure inertial forces, such as the acceleration due to gravity. Indeed, state-of-the-art absolute gravimeters now include those that use free falling atomic ensembles (Altin et al. 2013, Peters et al. 2001). The measurement of gravity and its gradients has wide spread applications in the Earth sciences and the geophysics community (Figure 1). Such measurements give valuable information about density structure and changes to the geoid due to tectonic plate movement, magma flows, volcanic activity, and tidal forces. One notable recent example of gravity measurement is the data taken from the GRACE (Gravity Recovery and Climate Experiment) satellite mission (Leblanc et al. 2009), which has allowed monitoring of groundwater variation in Australia's Murray-Darling tidal basin. Such measurements have a direct impact on Australian government policy. In geophysical exploration, gravity and its gradients are a key metric for performing broad surveys of potential resource sites. For example, gravity gradients have become commercial ventures for Fugro, using its Falcon device, and Bell Aerospace with the Lockheed-Martin Full Tensor Gravity Gradiometer (FTG). These devices operate on mature, mechanical technology dating as far back as the 1970s. The University of Western Australia, in collaboration with Rio Tinto, has also been developing a competing aircraft-based gradient system (Anstie et al. 2010). More recently, time-resolved gravity data have been used to monitor oil and gas reservoirs, including the movement of fluid fronts (Zumberge et al. 2008).

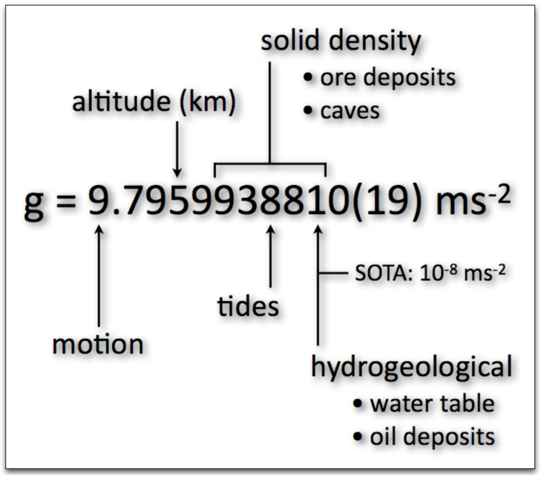

Figure 1. Examples of various factors that affect the local value of gravity on Earth's surface, and their magnitude. This gives an idea of required precision in any sensor targeting the measurements of such effects. State of the art (SOTA) is currently at a 10^{-8} ms^{-2} order of magnitude for an absolute measurement (Altin et al. 2013, Peters et al. 2001). Graphic based on a seminar by Richard Lane, Geoscience Australia (Lane 2012).

Advances in current quantum-based gravimetric systems will provide increased sensitivities and portability. These capabilities and will likely lead to useful tools for screening and surveying maritime systems and commerce. A particularly challenging goal within the maritime security domain continues to be the detection of possible special nuclear materials, shielding materials, or even nuclear devices transported within cargo containers; sensitive gravimetric detection of mass anomalies may provide these capabilities (Libby 2011).

Atomic gravimeters

Atomic sensor devices are not only becoming viable technology for the next generation gravimetric devices, they also offer potential increases in precision. With increased precision comes increased vision into the Earth's surface. In part, this is the result of developments in technology, which has seen our ability to control the motion of atoms using lasers reach exquisite levels. Combined with their universal properties (all atoms of a given element are equivalent), and their non-mechanical nature, atoms offer potentially fewer systematics, and more robust, reproducible, and configurable systems than alternative devices such as free-fall corner cube systems (Niebauer 1995). In an atomic based gravimeter, atoms are allowed to fall freely in vacuum, and their position is tracked precisely with an optical laser beam, while an atomic clock is used to time their motion. The laser, aligned vertically, effectively forms a ruler, encoding the number of wavelengths the atoms have fallen through onto the quantum state of the atoms. Interference of the atomic matter waves then allows precise counting of the number of traversed wavelengths, just as interference in an optical interferometer allows precise measurement of, for example, a mirror displacement. We extract this information by detecting and counting the number of atoms in each of two quantum states – equivalent to measuring an interference pattern in an optical interferometer. This idea is illustrated in Figure 2.

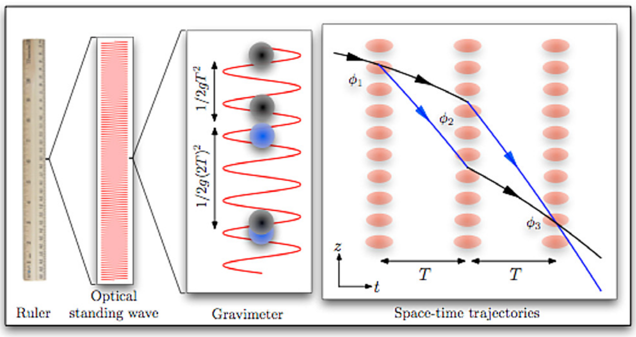

Figure 2. An atomic cloud falls freely under gravity through an optical standing wave, which forms an 'optical ruler' with a precision proportional to its wavelength. Three pulses of the standing wave are applied, separated equally in time and with appropriate durations to beam split, reflect, and recombine the atomic wave packets as shown in the space-time diagram on the right. The phase of the laser at each pulse is written onto the atomic state, encoding distance and time information onto the atomic state.

A gravimeter at the Australian National University

At the Australian National University, we have developed a state-of-the-art gravimeter, based on ultra-cold atoms and atom interferometry (Altin et al. 2013). Rubidium-87 atoms are laser cooled in a glass vacuum cell, and are dropped over a distance of ~20 cm. The cell can be seen in Figure 3. Laser cooling is important not only to localise the cloud, but to reduce its expansion during the drop due to thermal motion. This is equivalent to using collimated light in an optical interferometer. During the drop, the vertical reference laser – our ruler – is pulsed on in order to measure the position of the cloud. We use three pulses separated equally by a time T to build the atomic equivalent of a Mach-Zehnder interferometer. Typically, T is on the order of 100 ms. The resulting signal from the atom interferometer (or more precisely, the interferometric phase shift) is given by $4n\pi\lambda\, gT^2$, where g is the acceleration due to gravity, λ is the wavelength of the vertical laser beam (~780 nm in our case), and n is an integer, which we choose experimentally, and determines how strongly the laser interacts with the atoms at each pulse. The colder the atoms, the more readily n can be increased (Debs 2012, Szigeti et al. 2012). For typical parameters, the signal is on the order of 10^7 radians, whereas noise in a quiet environment is typically on the order of 10^{-2} radians. We have achieved state-of-the-art sensitivity to gravity of up to 2.7×10^{-8} ms^{-2} (equivalent to 2.7 μGal). To confirm operation and stability of the gravimeter, Figure 4 shows data monitoring the deviation of gravitational acceleration from its mean over a 36 hour period during 19–21 May 2012. Data points show a clear signature of the solid-Earth tide, with the solid line a tidal model calculated using the Tsoft software package of Van Camp and Vauterin (2005). No modification of the raw data logged from the gravimeter is performed in comparing the data to the model. It is worth noting that, although systematics shifts on our signal were not robustly investigated within our funding environment; from the project commencement, we designed, built, characterised, and reached state of the art sensitivity in just under a year.

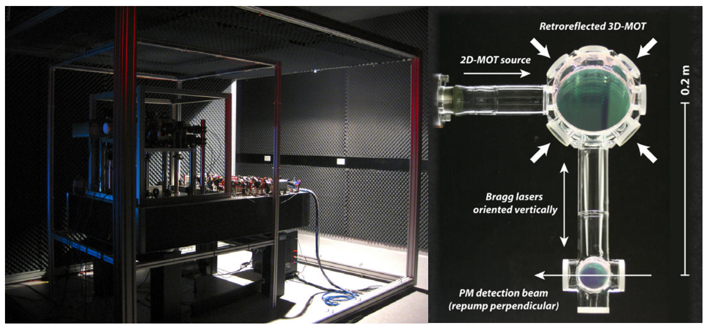

Figure 3. (Left) Photograph of the ANU high precision atomic gravimeter. (Right) Photograph of the glass vacuum cell in which atoms are dropped to measure gravity.

Measuring gravitational gradients

One of the fundamental principles of Einstein's theory of relativity is that it is not possible to distinguish between acceleration and a gravitational field. Thus, any vibrations of the reference laser used to measure the atomic trajectories, introduces parasitic noise into the gravitational signal. Every effort has therefore been taken to reduce environmental noise in out laboratory. In particular, no electronics are kept near the device, and the room has been acoustically damped. Furthermore, the device sits on a vibration isolation system. This is indeed required of any absolute gravimeter, in order to reach state-of-the-art precision. Such a device is potentially suited to a ground station, where long-term data is required, and it can be setup in a purpose-engineered environment. An alternative for noisy environments, such as a mobile device mounted in a vehicle or aircraft, is the measurements of gravity gradients. By using two spatially separated gravimeters, referenced to a common laser, vibrations become common to both sensors and can be subtracted, leaving only the gradient signal – the difference in gravity between the two gravimeters. Although devices such as Falcon and the Lockheed-Martin FTG system operate as excellent gradiometers, these devices are mechanical and specifically built for only this purpose. The ability to exquisitely control atoms using light allows us to split the atomic ensemble into two spatially separated ensembles, before releasing them into free fall. We may then perform the same measurement of their trajectories, and subtract the two signals giving the gravitational gradient. This whole process requires no hardware modification, only a minor variation to the control software of the system. Laboratory-based gravity gradiometers have already demonstrated sensitivities on the order of 10^{-9} s^{-2} (equivalent to 1 Eo) (McGuirk et al. 2002).

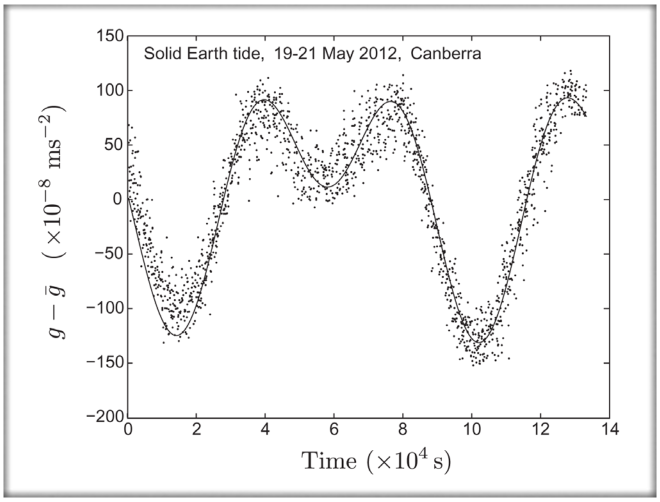

Figure. 4. Gravity data taken over a 36 hour period compared with a solid Earth tide model. Each data point represents the average of 38 individual measurements. T = 60 ms, and n = 2 for the interferometer configuration.

The future and miniaturization

One key question for our team at ANU is whether such a device could ever be field deployable? The answer is a confident 'yes', provided there is a reasonable effort and adequate investment in engineering. There is already work internationally, which has demonstrated the ability to miniaturize and cut power requirements of such atomic systems. For example, in Germany, the QUANTUS project has managed to reduce a system of similar complexity to that of Figure 3, to a volume on the order of 1 m^3 (Muntinga et al. 2013). The purpose of the project is to perform experiments under micro-gravity in a 110 m drop tower in Bremen. The entire device, including vacuum system, laser systems, electronics, and battery power, is placed inside a drop capsule. This is then loaded into the tower and dropped, experiencing 4.5 s of free-fall during which experiments are performed. The entire unit is not only compact, but robust enough to survive the 'catch' stage where it experiences 50g of deceleration, in order to be reloaded for the next experimental run. The long-term goal of such research aims to put these devices in satellite orbit, in order to make space-based measurement of, for example, gravity, as well as other tests of fundamental physics. There is also work in the USA, which has seen relatively high bandwidth (up to 330 Hz), high precision atomic inertial sensors reduced in size to approximately 0.2 m^3, operating under the same principles discussed above (McGuinness et al. 2012).

Our current work at ANU is centred on improving the sensitivity and stability of our sensor. In particular, the Heisenberg uncertainty limit in quantum mechanics places a fundamental limit on the sensitivity of such a device. This limit depends on the number of atoms detected in the sensor (106 atoms in a typical device). Currently, our and other similar atomic devices are two orders of magnitude above this fundamental limit. Our group has a history of working with atom-lasers. Compared with a thermal atomic gas, atom-lasers are the atomic analog of the optical laser, compared with light from an incandescent bulb. Given the immensely positive influence the optical laser had, and continues to have, on precision measurement, and particularly optical interferometers, it is reasonable to ask if the atom laser can offer similar advantages for atom interferometers.

Ultra cold atomic source

We believe the answer to this question is yes, for similar reasons that the optical laser has been so successful, as outlined in the thesis of Debs (2012) (See also, Debs 2011, Robins 2013). Recently, we have shown that there is a fundamental difference between an atom laser and a thermal atomic source (Hardman 2014). Namely that the extended coherence of the atom laser allows for signal extraction under situations where technical effects in non-ideal systems prevent this for a thermal source. We are currently implementing an atom laser into our high precision gravimeter in order to further investigate this question at high sensitivity. Such a device operating as a gradiometer has the potential to approach the fundamental limit sensitivity limit, opening access to a new regime of precision gravity measurements.

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References

T. M. Niebauer et al., A new generation of absolute gravimeters, Metrologia 32, 159 (1995)

J. E. Debs et al., Cold atom Gravimetry with a Bose-Einstein Condensate, Phys. Rev. A 84, 033610 (2011)

S. B. Libby et al. Feasibility Study of a Passive, Standoff Detector of High Density Masses with a Gravity Gradiometer Based on Atom Interferometry, Final Report LDRD 10-FS-003, Lawrence Livermore National Laboratory (2011)

R. Lane, Australian Society of Explorative Geophysicists conference, Brisbane, Australia (2012).

N. P. Robins et al., Atom lasers: production, properties and prospects for precision inertial measurement, Physics Reports, 529, 265 (2013)

K. S. Hardman et al., The Role of Source Coherence in Atom Interferometery, Accepted Phys. Rev. A (2014). See arXiv:1312.0675.

International Collaboration in Maritime Trade Protection: Exercise Bell Buoy 13

Michael Stephens, LTCDR, RNZNVR, **Vicki Rendall**, LTCDR, RNZN, and **Phil O'Connell**, CAPT, RNZNVR

Abstract: Exercise Bell Buoy is an annual inter-Navy exercise for the Pacific and Indian Oceans Shipping Working Group (PACIOSWG) focused on the protection of maritime trade and shipping. The Royal New Zealand Navy (RNZN) hosted this 2013 International Maritime Trade Protection exercise involving participants from 10 nations.

Bell Buoy 13 was aimed at testing the capabilities of the member nations' participants to respond to a range of significant events affecting shipping. This year's fictional exercise scenario was set in the South West Pacific, and included a natural disaster, the grounding of a container ship, acts of sea robbery/piracy, and civil unrest. The dynamic scenario required planning for emergency operations for the provision of humanitarian aid, issuing navigation warnings, and disseminating guidance to commercial and military shipping. Exercise events were largely based on recent worldwide occurrences and provided a realistic setting to the challenges and obstacles faced in maintaining secure shipping routes in the South West Pacific and beyond.

The exercise convener, Captain Phil O'Connell of the RNZNVR says an exercise of this type is relevant to New Zealand as the security of shipping is crucial to the nation's economy. Around 85 percent of New Zealand exports by value are carried by sea. "With New Zealand being responsible for a large area of the Pacific Ocean, we have an important role in protecting the sea lanes. The Navy works alongside other nations to ensure regional security. Bell Buoy 13 was an excellent opportunity to demonstrate New Zealand's commitment to practice these vital skills alongside our international colleagues who bring a diverse range of valuable experience to the exercise."

Held from 13-23 May 2013, this is the first time the exercise has been hosted by the Royal New Zealand Navy. The exercise was an international affair, bringing together a range of military and maritime trade specialists from Australia, Brazil, Canada, Chile, Korea, Singapore, UK, US, and one observer from Uruguay. The exercise was based at Devonport Naval Base in Auckland where Exercise Control and Maritime Trade Operations Headquarters cells were established. Field training exercises were also held at NZ ports including Auckland, Tauranga, and Whangarei.

Key highlights for the exercise participants included international teams conducting rapid port assessments, working with ship's masters, pilots and port companies to conduct briefings, and operating with other nations in a deployed combined joint task force environment. Other exercise activities included planning a range of operations and training. Exercise participants disseminated navigation warnings alerting ships to pirate activity, ensured that charts and publications provided consistent routing advice, exercised Working Group chain-of-command, self-protective measures, and advised units responding to boardings and attacks.

The exercise went beyond a Maritime Trade Operations focus as it required coordination and guidance of merchant shipping to be conducted directly in the context of a multinational humanitarian assistance or disaster relief operation. The participants also tested civilian and military cooperation (CIMIC) doctrine designed to establish and maintain cooperation between the military, civilians, civil authorities and non-governmental aid organizations.

Bell Buoy 13 provided a realistic setting to replicate likely interactions between the military and various government and civilian agencies. It helped orient RNZN Maritime Trade Operations team toward the New Zealand Defence Forces capabilities and objectives. The international Naval Reservists working alongside Regular Force Navy and Army personnel were quickly integrated into a cohesive team to successfully deliver the Bell Buoy 13 exercise objectives.

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GINA Network-Centric Assemble-to-Description Architecture

Gary Langford, PhD, Naval Postgraduate School, Monterey, CA

Abstract: Global Information Network Architecture (GINA) is an analytic modeling environment that represents the entire information environment as super metadata and captures the interoperation between the user and the system as data. GINA allows the definition of a user-interaction model to be easily changed over time, conforms to new usage patterns as additional facilities are brought online, and allows interoperability between any end-product systems.

GINA is the new model for managing the complex interoperability demands of large system-of-system implementations. In 2012, the U.S. Army Corps of Engineers Engineering Research and Development Center (ERDC), the Army Training and Doctrine Command, and researchers from Big Kahuna Technologies demonstrated a semantically-rigorous modeling and implementation capability that dramatically improved the means to achieve interoperability. The goal was to provide a form of GINA to the 129th Rescue Wing of the California Air National Guard to link and integrate a wide range of sensors and platforms not designed to work together. The result was the Dragon Pulse Information Management System (DPIMS) – a multi-sensor-type array for situational awareness.

DPIMS is a semantic modeling environment in which the various meanings in language or logic are transmuted into assemblies that accurately implement a model in which all systems, sensors, etc., are interoperating transparently. While DPIMS enables the aggregated information to be treated as a single application or information store, the data can also be interoperated with and understood by disparate computational structures. DPIMS makes it possible for very different (and unlikely) platforms to communicate, aggregate, format, interoperate, and visualize data that is meaningful to all platforms.

Figure 1 illustrates the types of data that can be fused and rendered interoperable across platforms. The concentric range rings and a range gate may be applied to any given entity; a proximity rule can then be implemented. In this case, the range ring is assigned the color red. Different entities may be visually discerned by assigning different colors to their attributes. Command and control now gains an instant picture of the different entities on the map. Figure 2 illustrates the ability to show sensor alarms in various detail and sensor-specific configurations.

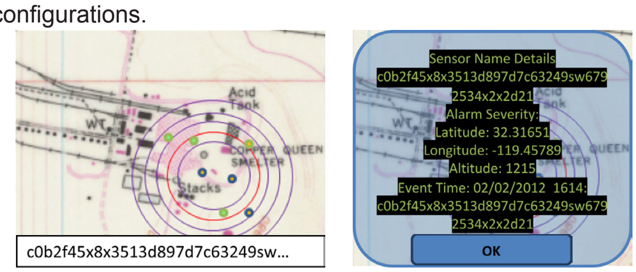

Figure 1. Sensor alarms shown using a smartphone as a sensor.

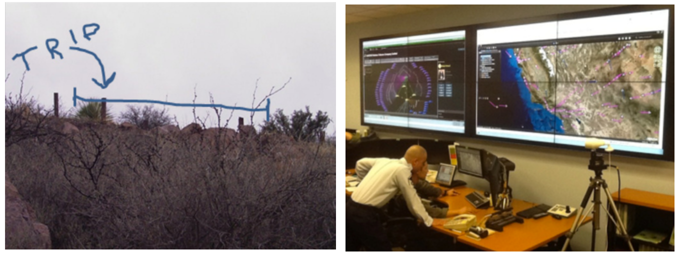

Figure 2. Edits to imagery made using third-party applications on smartphones (photos, 129th Rescue Wing).

Interoperability in the maritime domain poses problems beyond those of simple network operations involving different sensor systems, such as those that would be found on ships of different navies (Figure 3). Depending on the level of coupling and cohesion required to connect the intended network of systems (i.e., cooperation and interoperability), GINA's ontological structures support information sharing, reuse, and stability through product inheritance to provide and maintain interoperability.

Figure 3. USS Ronald Reagan and the Brazilian Navy aircraft carrier BNS Sao Paolo.

GINA interoperability is more than systems or their elements communicating and working with each other. Interoperability is the action of completeness (having all the appropriate and necessary parts and forms) and incompleteness (establishing the limitations) when two or more systems or components interact and exchange energy, matter, material wealth (e.g., money), and information (EMMI). Interoperability is achieved when two or more systems interact and exchange EMMI in a manner necessary and sufficient for the individual systems to retain their autonomous behaviors and enact meta-level system-of-systems functionalities.

GINA is the result of successfully constructing an architecture for assembling systems-of-systems using an extended modeling vocabulary for completely describing them and a component-based object model that forms the raw material for implementation. GINA defines the relationship between the user and the model, rather than the user and the computing platform, and performs a more refined information access and control structure than is possible using traditional modeling and/or programming techniques. Using standard communications protocols and serial interfaces, GINA works with interoperability protocols such as Web Services and operates with syntaxes such as forms of XML.

GINA was designed as a set of services on the network, rather than as an application on any particular computing platform. The result is that the implementation is truly "network-centric". GINA takes traditional applications to the "cloud" or creates "cloud-based" alternatives to existing systems. GINA's network-centric, assemble-to-description architecture is scalable, extensible, and expandable with minimal effort.

Figures 4 and 5 illustrate the traditional means to achieve some level of interoperability and the GINA means to achieve full interoperability. The simplicity of Service Oriented Architecture (SOA) is carried out by a "star"-type implementation. In contrast, GINA's simplicity is through its interoperability model; GINA connects all nodes to all nodes. The cost and schedule impacts for traditional means are prohibitively expensive and time-consuming. In comparison, GINA required less than 16 labor hours to completely implement a fully interoperable, integrated operational capability of multiple sensor systems at Camp Roberts near San Luis Obispo in central California in support of search and rescue missions.

GINA development began as a Cooperative Research and Development Agreement at the Naval Postgraduate School in FY 2004. GINA was DITSCAP-Certified Class 3 (Network-Aware Business Data Management System) in 2005, and various U.S. government customers began using GINA in 2006. GINA is the next technological step beyond the N-Tier approach; GINA supersedes N-Tier as the most advanced approach for integration and interoperability.

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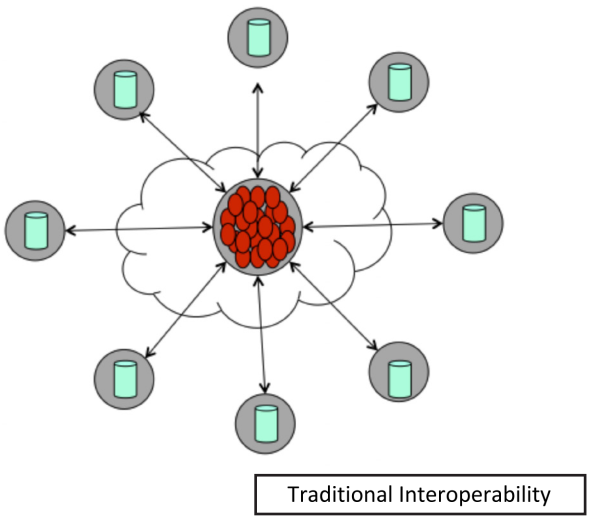

Figure 4. "Simple" interoperability of Service Oriented Architecture shown as geometric in nature.

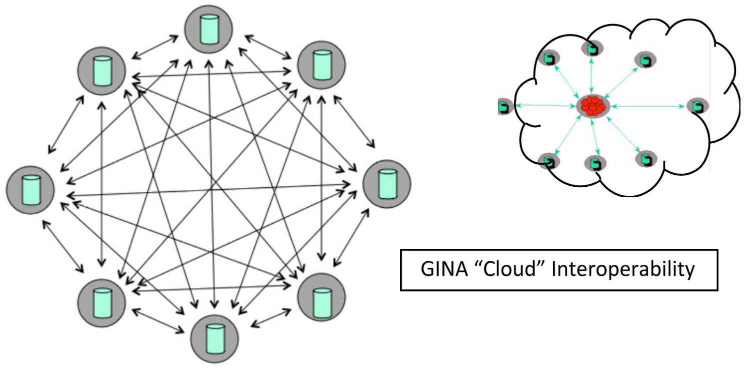

Figure 5. GINA interoperability allows for complex integrations with "simple" interoperability.

Mine Warfare Area Folders

Marvin Roe and **Brian Bourgeois**, PhD, Naval Research Laboratory; **Ronald E. Betsch**, Naval Oceanographic Office

Situational awareness (SA) among agencies and actors involved in waterfront security is a requirement for coordination and optimal event responses. Given that a picture is worth a thousand words - geospatial presentation of spatially ordered information has long been presented in the form of static paper maps and charts; however, these charts are time consuming to make, and each product is designed for narrow and specific purposes. In contrast, a dynamic picture can be worth a billion words. In the way Excel provides limitless spreadsheet functionality, modern Geographic Information Systems (GIS) provide dynamic manipulation, analysis, and display of geospatial data to address myriad purposes. Figure 1 contrasts the difference between geospatial and file-based SA data.

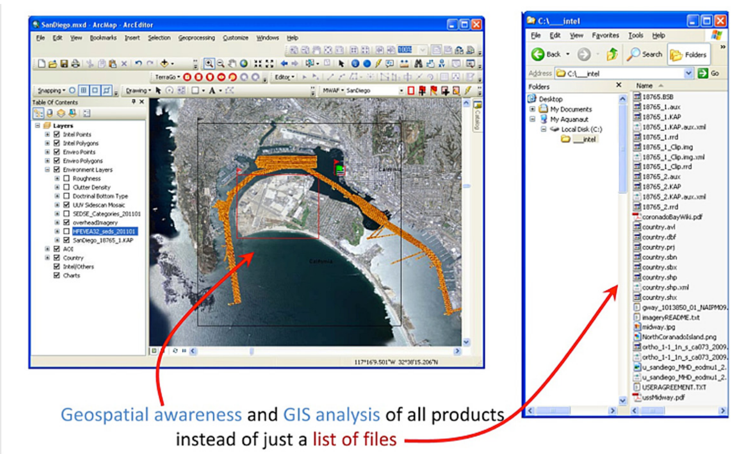

Figure 1. Comparison of Situational Awareness presentation methods: Geospatially-enabled (left) and file-based (right).

A current approach used by maritime security forces to improve presentation of data in separate source files is the laborious process of cutting and pasting the file contents into a PowerPoint presentation for easy viewing. For nearly two decades, the Naval Research Laboratory (NRL) at Stennis Space Center has been adapting and extending GIS technology to improve that process and enable geospatial decision-making aid for military strategic and tactical planning through the rapid ingest, analysis, and display of geospatial data. The Mine Warfare Area Folder (MWAF) is the latest development from NRL Stennis that is accelerating information display for today's maritime security forces.

The MWAF provides operational military staffs the ability to 1) rapidly assimilate relevant SA and environmental products into a single integrated system, 2) visualize the geospatial battle space to provide superior SA and understanding of spatial and temporal relationships, 3) enable expert analysts to perform numeric and logical geospatial analyses and create custom, value-added SA products for the maritime security, and 4) rapidly disseminate subsets of geospatially enabled SA products to boots-on-the-ground field activities. Geospatial enablement of source SA and environmental data is the key value added for maritime security personnel and can result in an 80% reduction in operational time lines compared to existing cut and paste SA preparation methods.

A key usability characteristic of MWAF lays in the way it "right sizes" resource requirements and capabilities commensurate with the way military commands operate. Forward deployed headquarters typically gather SA data to create SA products for tactical decision making. Here you will usually find ample network bandwidth for gathering data from multiple sources, computing resources for creating SA products from the gathered data, and the expert analysts who create those products. The MWAF system provides the capabilities to create geospatially-enabled SA products at the headquarters level, leveraging the availability of bandwidth, computing resources, and expert analysts. The SA products created for maritime security forces using MWAF suite are geospatially-enabled yet, because of the system design, are small, portable, and can be used without a network connection on a laptop or a tablet.

The MWAF product creation suite was constructed using a commercial off-the-shelf (COTS) GIS, the TerraGo Publisher, and NRL tools that enable the rapid ingest of a variety of data sources and tailor the GIS functionality to reduce the prohibitively high level of training and expertise required to usefully employ a GIS. The TerraGo Publisher is used to export the SA product created within the GIS to a GeoPDF file, which are highly portable, intelligent, and interactive maps and imagery. The United States Geophysical Survey (USGS) is another user of this approach for dissemination of geospatial information, and it distributes its nationwide 7.5- and 15-minute topographic maps on the web using GeoPDF files. The NRL also created the capability to enable MWAF products to be exported as Keyhole Markup Language (KML) files. GeoPDF SA products are viewable using Adobe Reader with the TerraGo toolbar, and the KML format is viewable using Google Earth. An advantage of the GeoPDF is that Adobe Reader provides the ability for waterfront security personnel to embed their own annotations and notes into the SA product while in the field and, when network connectivity becomes available, send the annotated version to headquarters for further analysis and dissemination as needed.

A significant advantage of the MWAF development approach is that the end-user computer only requires free, widely available COTS software with large customer bases, leveraging the business model adopted by Adobe, TerraGo, and Google Earth to provide free reader software and to charge only for the publishing software. This reduces the overall acquisition and maintenance cost of the MWAF system in that licensed software need only be purchased for headquarter locations, but the products can be deployed to an unlimited number of users with no additional software cost.

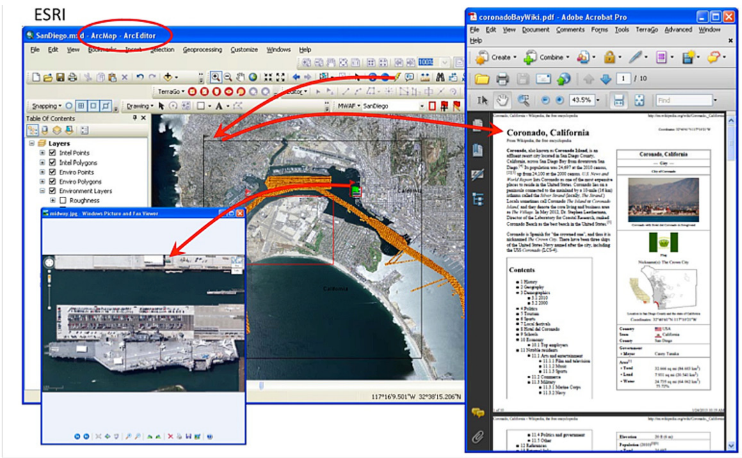

Figure 2. Example showing how non-geospatial SA information can be provided with a geospatial context by integration with geospatial data.

In Figure 2 we see in the main window satellite imagery of the San Diego, CA area and overlaid sidescan imagery of seafloor (orange swaths). Symbols, markers, and boxes can indicate to the user when additional information about a location or an area is available such as the picture of an aircraft carrier or a web page providing information on the local area, shown in the pop-up windows. The system has the ability to launch native applications (such as an image viewer, web browser, Adobe, etc.) from within the geospatial environment eliminating the extra steps needed to externally launch the application and load the files for viewing.

MWAF provides new capabilities that enhance the understanding of SA data and dramatically speeds up the process of creating SA products. Capabilities and methods include:

- Enhance understanding:
  - o Geo-registration of geospatial data sets – eliminates confusion with pictures from disparate data sources showing different areas at different scales.
  - o Ability to rapidly control spatial and temporal extent of displayed data for discussion of both strategic and tactical level scenarios.
  - o GIS numeric/logical analysis on multiple layers shows conclusions, not just data.
  - o Controllable, layered display of geo-spatial data:
- Show/hide/arrange data displayed based on relevance to current discussion.
- Alleviates 'clutter' problem that occurs with static maps.
- Display of temporal changes – time lapse, before/after, difference views.
  - o Display of non-geospatial SA within a geospatial framework that:
- Enhances understanding through geospatial context (Figure 2).
- Dramatically improves ability to find relevant information ('click-to-show' text file or images for a point or area target on a map).
- Automatically launches data source native applications (*.doc, *.ppt, *.xls, etc.) from within the GIS environment for review, evaluation and analysis.
- Speeds up SA preparation workflows:
  - o Automated data ingest – tools built to contend with both modern and disparate legacy data sources that enables 'single button' ingest of data into a common geospatial analysis and display system. This step is typically the greatest consumer of human labor to 'geospatially enable' source data.
  - o Preservation of community specific cultural symbology and display standards.
  - o Project oriented Intelligent Table of Contents (ITOC) construction enables quick access to relevant information to even the novice user.
  - o Intelligent Area of Interest (AOI)-based data management to enhance performance speed and minimize data product sizes for ease of transport – automated spatial/temporal trimming of source data to just the area required for the product being created.
  - o 'One-button' export of geospatial data products based on context and/or classification, eliminating the time-consuming cut-and-paste process used to make a static PowerPoint presentation.

MWAF is tailored to the Mine Warfare area in that tools have been built to enable rapid ingest of data sources specific to this community of interest. The approach taken and capabilities constructed for the preparation of geospatially-enabled SA products is of course generic beyond the details of this community's specific data sources and presentation cultural issues. Because of its optimal employment of both COTS and government components, NRL created an initial capability in a little over one year. Prototype systems have been deployed operationally to the Naval Oceanographic Office, the Naval Mine and Anti-Submarine Warfare Command, CTF-52 in Bahrain, and MCMRON7 in Sasebo, Japan. Future work on MWAF will expand the data ingest tools and address data synchronization between collaborating military components. Near real-time synchronization of SA data between disparate law enforcement, first responders, government, and other groups involved in waterfront security will be essential for coordinated responses to events.

The authors acknowledge the Naval Mine and Anti-Submarine Warfare Command for funding this effort and providing the opportunities to expedite fielding MWAF operationally. We also acknowledge the Naval Oceanographic Office's Maritime Homeland Defense group for providing the initial concepts for this capability.

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