NATO OTAN

NURC-RTH-2008

NURC

PARTNERING FOR MARITIME INNOVATION

2008 Research and Technology Highlights

June 2009

About NURC

Our vision

- To conduct maritime research and develop products in support of NATO's maritime operational and transformational requirements.
- To be the first port of call for NATO's maritime research needs through our own expertise, particularly in the undersea domain, and that of our many partners in research and technology.

One of three research and technology organisations in NATO, NURC conducts maritime research in support of NATO's operational and transformation requirements. Reporting to the Supreme Allied Commander, Transformation and under the guidance of the NATO Conference of National Armaments Directors and the NATO Military Committee, our focus is on the undersea domain and on solutions to maritime security problems.

The Scientific Committee of National Representatives, membership of which is open to all NATO nations, provides scientific guidance to NURC and the Supreme Allied Commander Transformation.

NURC is funded through NATO common funds and respond explicitly to NATO's common requirements. Our plans and operations are extensively and regularly reviewed by outside bodies including peer review of the science and technology, independent national expert oversight, review of proposed deliverables by military user authorities, and independent business process certification.

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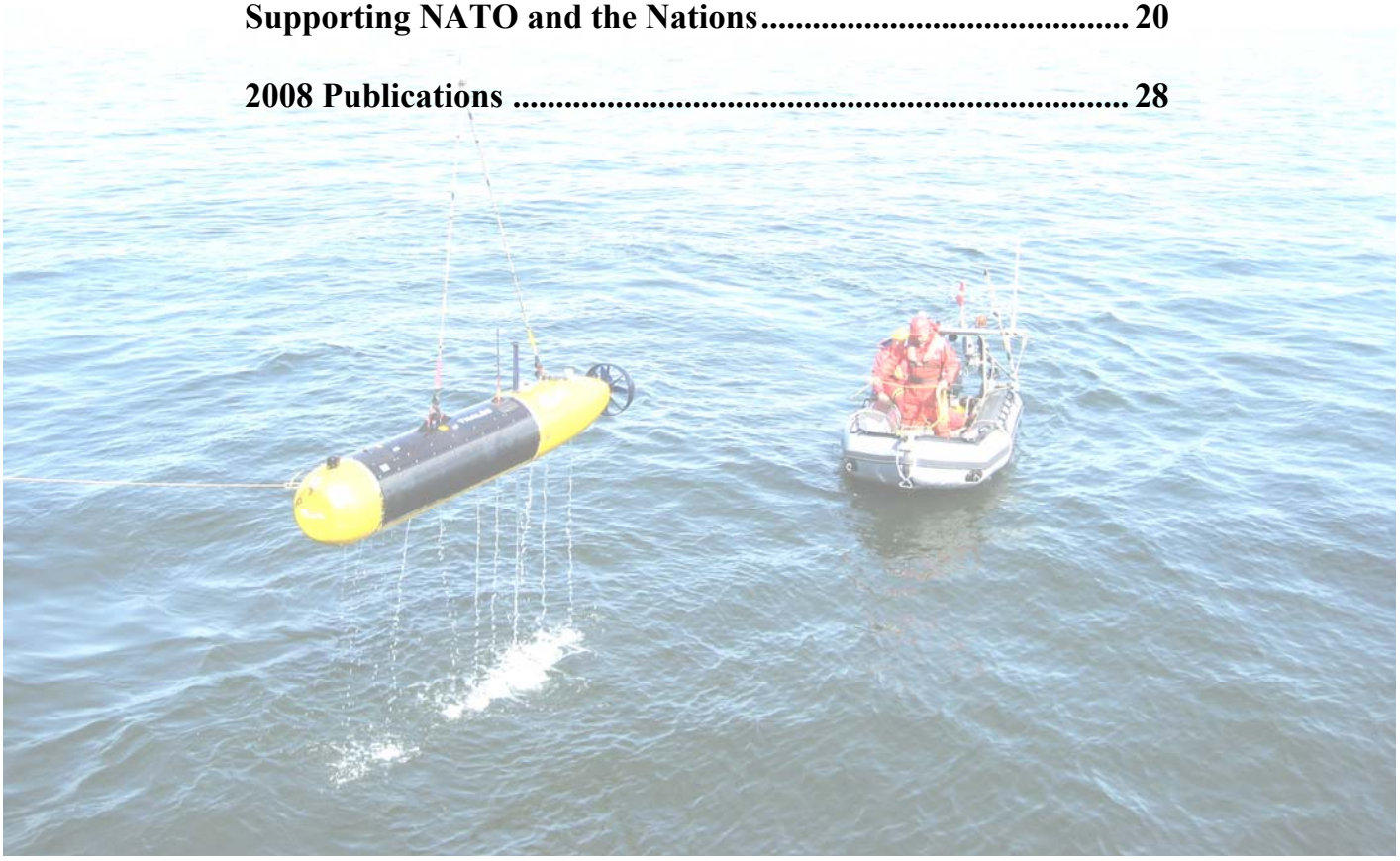


Message From the Director

François-Régis MARTIN-LAUZER
PhD, RADM (FRA, Eng. Corps, Res.)

2008 has been a year of transition for the Programme of Work of the NURC, from the organization by multiple small projects within military Thrust Areas, to more integrated projects dedicated to technical solutions within a feasibility studies' framework (advanced technological developments and joint demonstrations). While the NATO Common-Funded Programme of Work, called the SPOW (Scientific Programme of Work) was conducted according to the project management procedures of the past , it was nonetheless with a view to the new organization of activities by "deliverables", putting some emphasis on innovation and on critical technologies and operational needs.

Most of the information recorded in the next pages has to some extent been published in *The Centre Dozen*, the monthly newsletter of the Centre, or in various international newspapers such as Janes' Underwater Security Systems & Technology, Janes International Defence Review, Defense Management Journal. However this 2008 NURC Research and Technology Highlights summarized significant research projects and results of the Centre. Technical details may be found in the 40 published NURC reports that were distributed to NATO member nations in 2008.

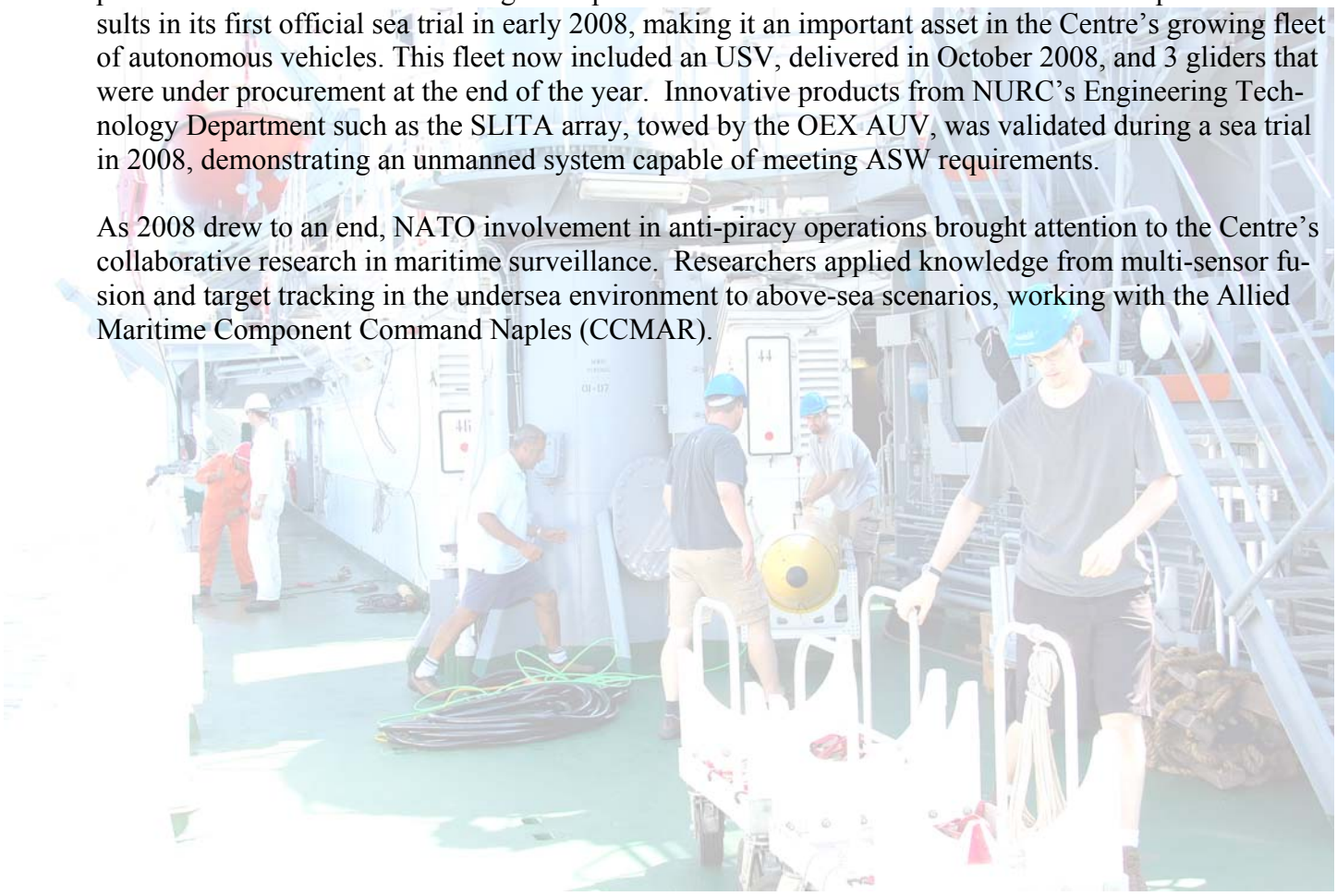
2008 in Review

New concepts of operations are emerging within the maritime and undersea environment. Limited groups of large and resource-consuming platforms are preceded or supplemented in the near future, by coalitions of autonomous and unmanned undersea networks for surveillance or reconnaissance as well as mine-hunting. Payoffs can be huge as such coalitions can be deployed in advance of an expeditionary operation and are intrinsically more able to adapt to time or spatial/environmental conditions. Researchers at NURC started moving toward this direction nearly 10 years ago. The building blocks--sensor design that facilitated object detection and classification, improved algorithms that enhanced sonar resolution, oceanographic and environmental models that improved the prediction of sonar performance and target recognition--coupled with advances in technology such as more robust unmanned vehicles, improved sonar arrays and instrumentation are bringing these new concepts closer to reality.

2008 saw significant progress in areas such as autonomy in mine-countermeasures with autonomous unmanned vehicles (AUVs), multi-sensor intruder detection for harbour detection, undersea networking, multistatic sonar, tactical prediction systems and battlespace characterization. The Marine Mammal Risk Mitigation project continued its work during the SIRENA 08 sea trial while NURC researchers provided operational analysis and support in several exercises.

A common focus that cut across projects and research areas in 2008 was the emphasis on networked autonomous unmanned systems. AUVs were employed in many of the Centre's sea trials for a variety of missions including seabed classification, target identification and tracking. NURC's OEX AUV was outfitted with new electronics and software, making it compliant with a new communications protocol, while other AUVs and autonomous surface vehicles (USVs) brought in by the Centre's partners participated in sea trials to test neworking concepts. NURC's new MUSCLE AUV delivered impressive results in its first official sea trial in early 2008, making it an important asset in the Centre's growing fleet of autonomous vehicles. This fleet now included an USV, delivered in October 2008, and 3 gliders that were under procurement at the end of the year. Innovative products from NURC's Engineering Technology Department such as the SLITA array, towed by the OEX AUV, was validated during a sea trial in 2008, demonstrating an unmanned system capable of meeting ASW requirements.

As 2008 drew to an end, NATO involvement in anti-piracy operations brought attention to the Centre's collaborative research in maritime surveillance. Researchers applied knowledge from multi-sensor fusion and target tracking in the undersea environment to above-sea scenarios, working with the Allied Maritime Component Command Naples (CCMAR).



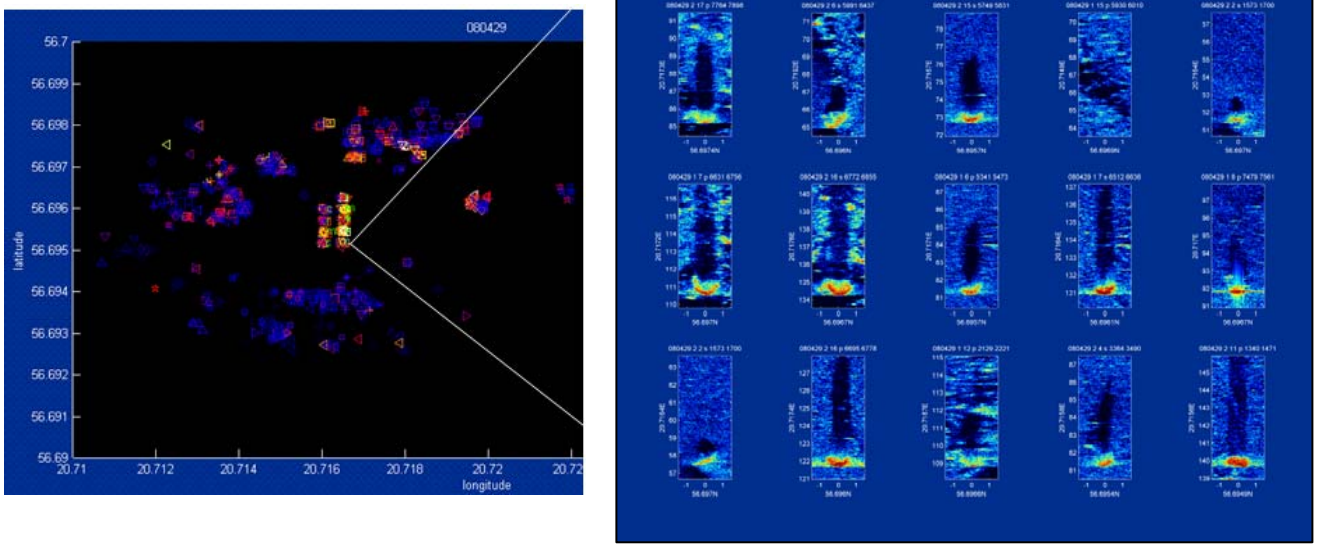
Detecting and Classifying Sea Mines

The automatic detection and classification of objects on the sea floor is an essential component to autonomous mine-hunting systems

Mine detection and classification has been an important topic for navies and national research laboratories and industry in NATO countries in the last decades. NURC plays a significant role in this area, scientifically and also as the initiator and coordinator of collaborative efforts. The collaborative scientific and experimental effort on synthetic aperture sonar (SAS) that launched this technology from basic science to operational maturity within NATO is one of the notable achievements from this programme.

The Centre's research programme broadened from sonar signal processing toward complete future MCM systems, with the three research pillars comprising of sensing, automation and autonomy. This was formalised in 2008 with the signing of an agreement between research partners from participating nations (Belgium, Canada, France, Germany, The Netherlands, Norway, United Kingdom and United States of America) and NURC. Besides the long-established practice of information exchange and collaborative sea trials, the agreement now includes joint studies using a common MCM database that was initiated and will be maintained at NURC. The database containing synthetic aperture and sidescan sonar data was introduced at a meeting at the Centre in November 2008. It will be used for testing and verifying methods like sonar processing techniques, detectors, classifiers and mission optimisation, and is to be used as the reference set within NATO. High interest from the nations reflected a need for such a database which has existed in the field of radar for a long time.

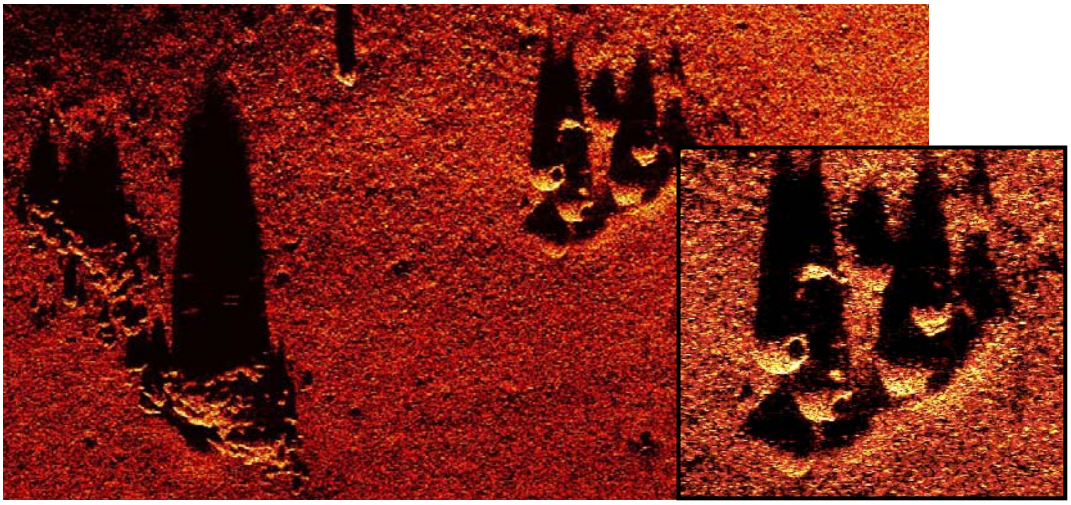
In line with the focus on technologies that will deliver capabilities for the next generation of NATO MCM systems, hardware and software were fitted into unmanned underwater vehicles (UUVs) for two experiments conducted in early 2008, MARES '08 and COLOSSUS II. MARES '08, conducted near Elba Island in Italy, saw the operational deployment of the Centre's new MUSCLE AUV for the first time. The quality of the sonar images obtained was impressive. The application of model inversion techniques to the



NURC's MCM database will provide datasets to help validate techniques in the automatic detection of mines. In this figure, automated geo-referenced detections in a cluttered sea floor provided multiple views of an object, enabling better classification as to what the object is.

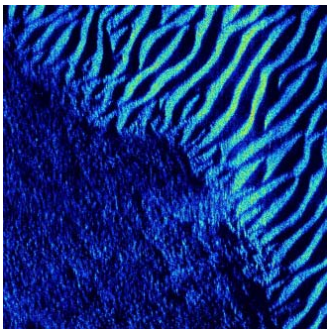
SAS images resulted in clearly defined 3-D images. Acoustic propagation and oceanographic data were also collected and co-related with the sonar data that were used to validate sonar performance models. The data will also be used to develop novel models.

During the sea trial, NURC researchers also surveyed the nearby site of an ancient shipwreck at the request of the Italian Ministry of Culture. The results of the survey, which generated a lot of public interest, will be used by the Ministry in planning the excavation of the archaeological site.

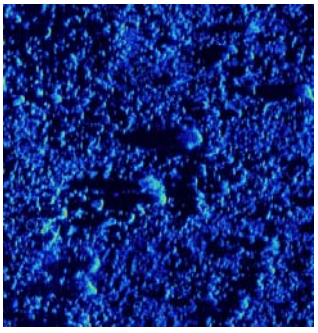


3-D image of partially exposed 2000 year-old amphora-like containers (Dolia), extracted from a SAS survey by NURC's MUSCLE AUV of an ancient shipwreck near Elba Island

COLOSSUS II, the first ever collaborative sea trial with Latvia, produced excellent data sets of different seabed types in Latvian waters. Seabeds that are rocky or contain clutter (both natural and man-made) make mine-hunting a challenging task. Even so, researchers and partners from the Latvian Navy were able to locate a number of mine-like objects. The COLOSSUS II datasets will be used for subsequent analysis, interpretation and validation of the Centre's automatic target recognition (ATR) and classification algorithms, and for the optimisation of SAS performance.



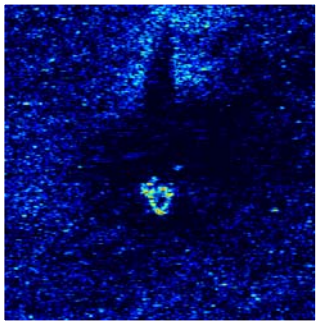
(a)



(b)

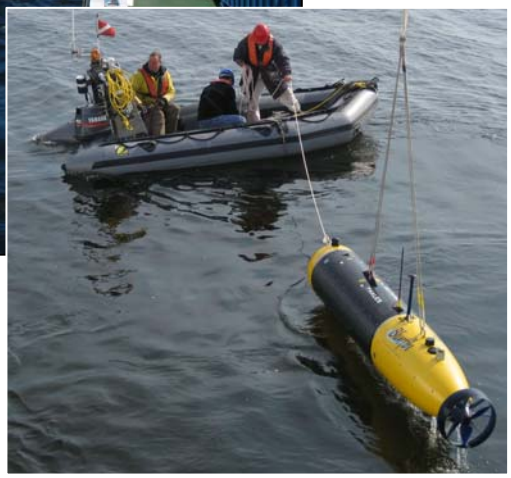
Data processing in the science lab onboard the NRV Alliance (left).

Different seabed types represented by sonar images: (a) sandy and rippled, (b) rocky and (c) small man-made object identified on the sea floor after data processing



(c)

Detecting and Classifying Sea Mines

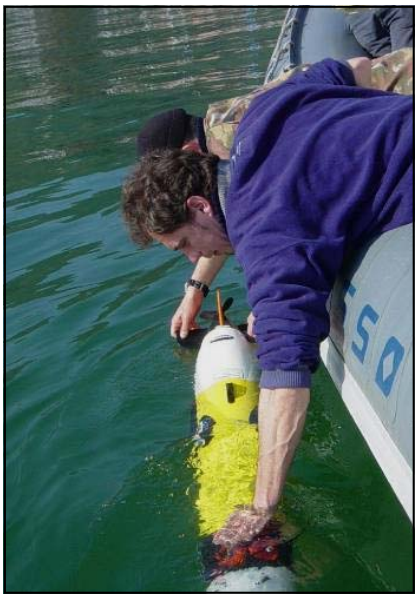


Latvian Navy boat providing support during COLOSSUS II; right, deployment of the MUSCLE AUV for a survey in Riga Bay

NURC researchers continue to refine algorithms and models used to automate the mine identification and classification process, a traditionally labour and time intensive operation. Automation reduces information flow to the operator, avoids time-consuming training for new operators, increases reliable and predictable results over time (i.e. errors caused by human factors). ATR is also an important component in autonomous missions, providing input for a UUV to adapt its mission as objects of interest are identified.

AUV technology for mine-hunting

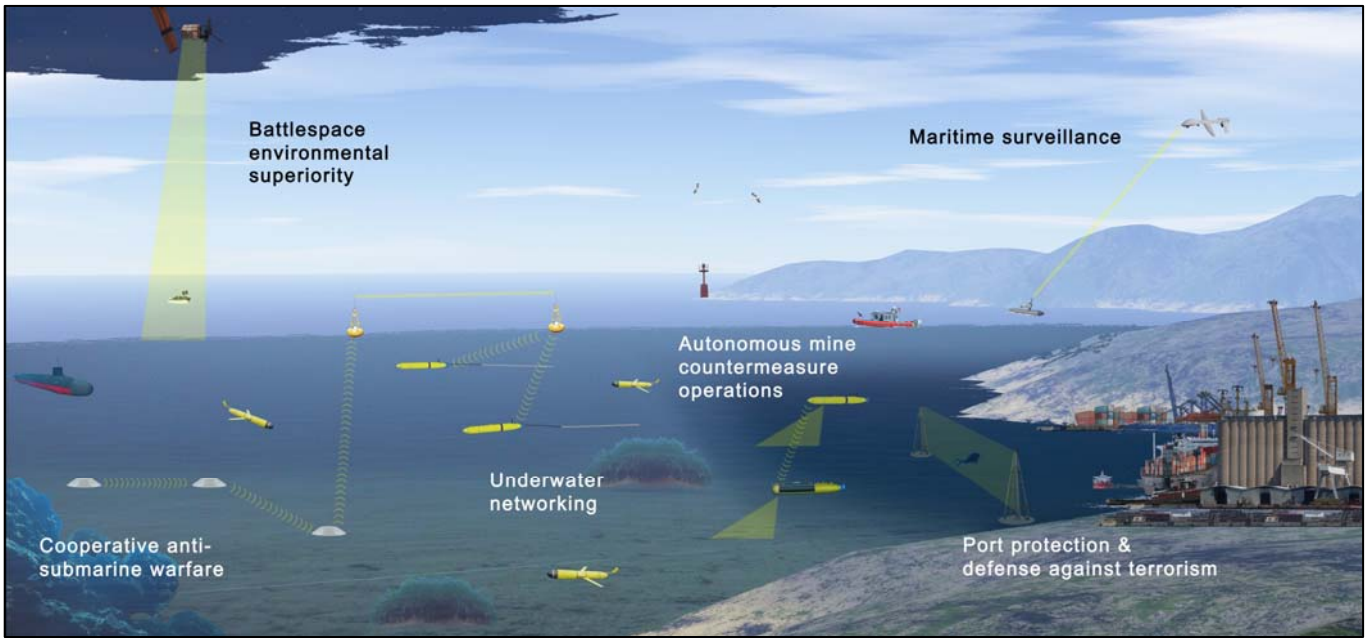
NURC's AUV team was in Split, Croatia, 29 Sep-3 Oct 2008 to demonstrate the capabilities of commercial off-the-shelf AUV technology for comprehensive surveys of shallow water port areas. Sponsored by the US Office of Naval Research Global, the team's primary focus was to enable Croatian forces and academia to evaluate the potential of the technology and identify where it may fit in their future capability requirements. The project also served to further develop knowledge of the tactical employment of unmanned vehicles in confined waters, and marked the first collaborative project between NURC and Croatia. The NURC team deployed a Remus 100 vehicle, operating in an area in front of the Split naval base. A dummy mine put in the water earlier by the Croatian Navy was located, classified, and then retrieved by a diver using the geographical coordinates given by the AUV. The entire team and the equipment was transported with a van, with deployment from a small rubber boat (pictured at right), demonstrating the portability of the technology. A major benefit of this work is the contribution to a wider humanitarian effort to identify and clear old ordnance left over from years of conflicts. Specific areas suspected to contain old ordnance can be quickly surveyed for suspect objects. Object location and classification information can then be passed on to national authorities for removal and disposal, contributing to the safety of fishermen and others who frequent these areas on a day to day basis. The added value of using small AUVs is their ability to work in shallow waters with challenging seabed types, and the cost effectiveness of the technology.



Understanding the Maritime Environment

Knowledge and prediction of the environment where maritime forces may operate provide tactical advantage in naval operations, facilitating NATO expeditionary forces as well as autonomous networked systems

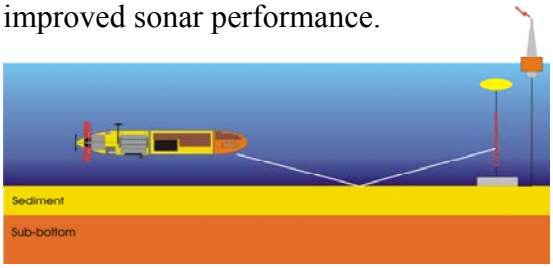
Understanding how the maritime (including the undersea) environment works is critical in ensuring the success of a communication network and the missions of unmanned vehicles. Under the sea, communications and sonar imaging are vulnerable to signal distortion and noise due to factors such as wave action, ocean currents, temperature, sediments and reflection from clutter on the sea floor. In particular, coastal and shallow regions are subject to chaotic environmental processes leading to greater difficulty in predicting UUV behaviour in such environments, and how to compensate for noise when attempting to identify an object on the sea floor. Above the ocean, satellite signals tracking shipping traffic may similarly be distorted or lost due to atmospheric or environmental interferences. Scientists at NURC work on a number of inter-related research projects in this area, which is referred to as environmental characterisation



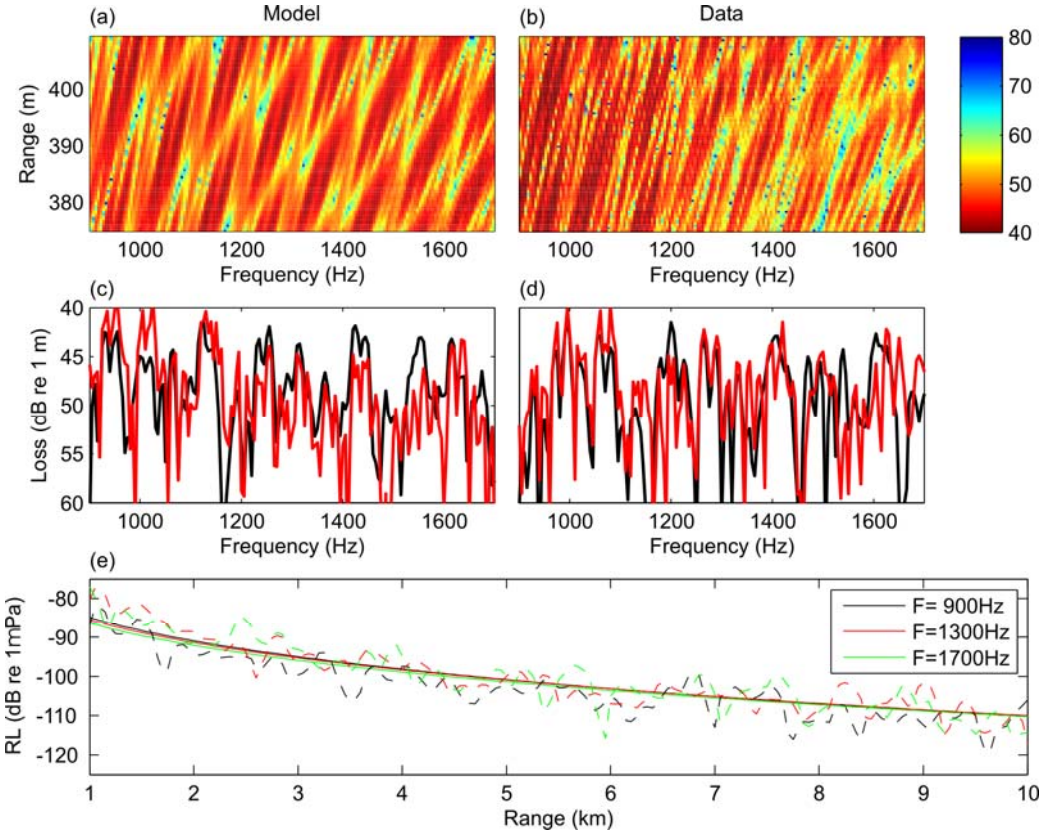
A successful autonomous network requires an understanding of the environmental factors that may affect communication, movement of assets and target recognition

Improving sonar performance

NURC scientists developed a technique to deduce bottom geoacoustic and scattering properties by inverting received acoustic signals from a towed sound source and towed horizontal array. A fast algorithm was used to perform environmental characterisation in near real time, while a more rigorous but slower algorithm was used to estimate uncertainties in the extracted bottom properties. The fast algorithm was successfully used during a sea trial in 2008 where environmental characterisation results were used to modify sonar settings in near real time, leading to improved sonar performance.

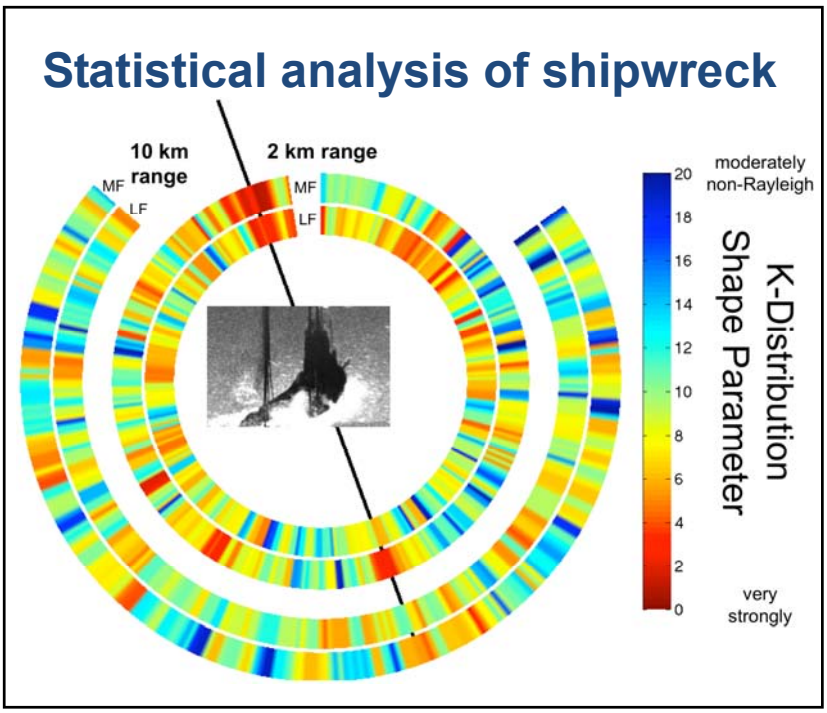


Understanding the Maritime Environment



Modelled results (a, c) and real data (b, d) of transmission loss due to sea bottom characteristics show that the algorithms developed by NURC came very close to estimating the actual environment. Model-data comparison of reverberation at 3 frequencies (e) shows a similar pattern

Reverberation and clutter are important topics in sonar operation because they influence the accuracy of object detection, tracking and classification. In 2008, NURC researchers analysed data from the CLUTTER'07 sea trial to determine the signatures of different types of clutter, both natural and man-made. As an example, scientists were able to characterize shipwreck echoes which are very likely to cause false alarms in the detection of targets such as submarines. As more of such "clutter signatures" are known, sonar operators will be able to get a clearer picture of the underwater environment. In September 2008, the Centre hosted the International Symposium on Underwater Reverberation and Clutter, bringing together scientists to exchange information on new findings in environmental acoustics, signal processing, detection, tracking and classification directed towards diffuse reverberation and target-like clutter.



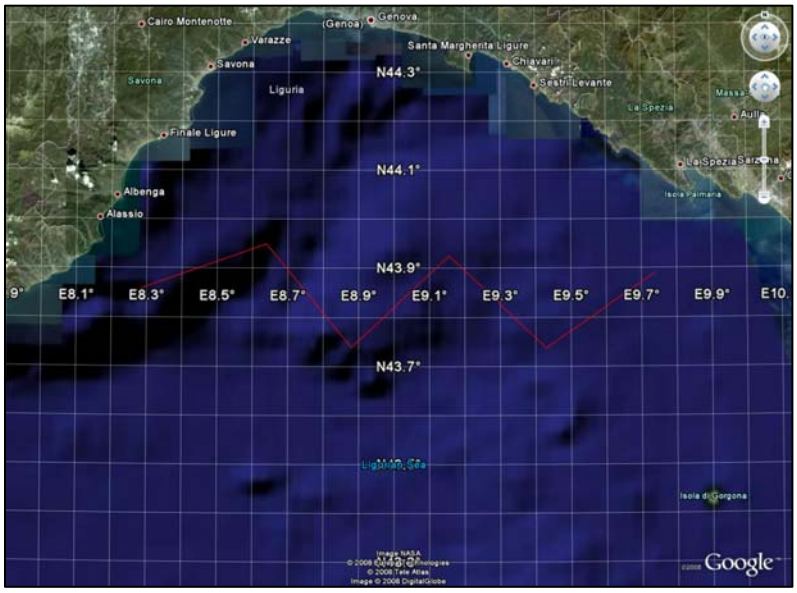
Visual display of the statistical description of echoes from a ship-wreck on the sea floor as a function of propagation range, frequency and sonar aspect. The shape parameter here is likely to cause false alarm in a sonar system aimed at submarine detection

Tactical prediction systems

Understanding the maritime environment leads to accurate environmental prediction, important for safe and effective NATO expeditionary operations. Naval operations are increasingly focused on coastal-littoral waters and adjacent land areas. Operational environmental monitoring and prediction in such areas are challenging. Current prediction models have limited reliability due to the high chaotic nature of coastal environments as well as the difficulty of collecting real time data, whether due to heavy maritime traffic and fishing activities, or the fact that the areas are denied access in times of conflict, commonly referred to as denied areas.

NURC began using underwater gliders in some of its 2008 sea trials. Gliders are a recent technology developed to observe large ocean regions. Unlike UUVs, gliders are not propelled but make use of buoyancy changes, special hydrodynamic shape and wings to induce zig-zag motions in the water column, surfacing at regular intervals to communicate with a control centre. Their autonomy and long endurance at sea make them very attractive for long term data gathering. The relevance of this technology was evident during the 2008 European Glider Observatories (EGO) Workshop and Glider School held at NURC in October which brought together over 85 international scientists and technologists.

Some participants at the EGO Workshop stayed on to attend the Glider School, where they learned the mechanics of gliders and how to deploy them



Mission plan (red line) for one of the gliders during the LSCV 2008 experiment in the Ligurian Sea

The advent of glider technology created a demand for specific tools to allocate observational resources more efficiently and to increase their performance at sea, especially in unknown or denied areas. NURC researchers have created a tool to produce optimal sampling points for gliders that incorporate information from satellites. The tool also plans glider trajectories for a mission with a network of gliders, and a sampling strategy that balances time constraints with minimal estimation errors. This tool was applied in planning glider missions during the LSCV 08 sea trial in October .

Understanding the Maritime Environment

Forecasting in challenging environments

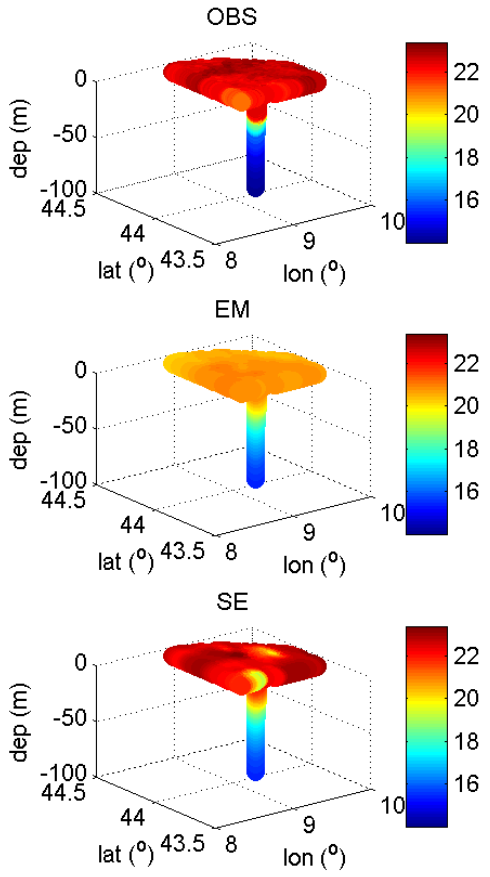
Improving forecasting and diagnostic skills in littoral areas contributes to the success of the NRF and other NATO forces conducting expeditionary operations. This requires tailored data collection and prediction of critical environmental information in areas of high variability, uncertainties, and operational risk. This in turn translates to improved prediction of areas that are denied access to NATO forces, or where knowledge of the local conditions is unknown or limited. The Centre conducted a major sea trial TSS08 in September, in a challenging geographical and oceanographical region in order to test models to improve forecasting skills. The Black Sea, the Sea of Marmara and the Dardanelles are exceptional locations with heavy ship traffic, dense coastal population and political sensitivities. In addition, the complex oceanographic conditions due to the specific nature of the flow in the region makes it difficult to provide real-time predictions of battle space conditions where short temporal and spatial scales are important. The air-sea coupled model (COAMPS-OS and HOPS) was used operationally in the Black Sea to demonstrate the concept of interdisciplinary real-time shipboard forecasts, generating a complete characterization of conditions in the littoral environment. The sea trial also demonstrated the ability of a net-centric spatial data infrastructure (SDI) to support military oceanography in an operational environment.

Above: NURC staff deploying sensors in the Black Sea from the deck of NRV Alliance during TSS'08

Right: Three port calls by the NRV ALLIANCE during the TSS08 cruise at Istanbul (Turkey), Constanta (Romania) and Varna (Bulgaria) provided opportunities for members of the national military and research communities to visit the ship and to discuss future collaboration. As a result some of these organisations became participants in the TSS'09 sea trial.

The power of super-ensembles

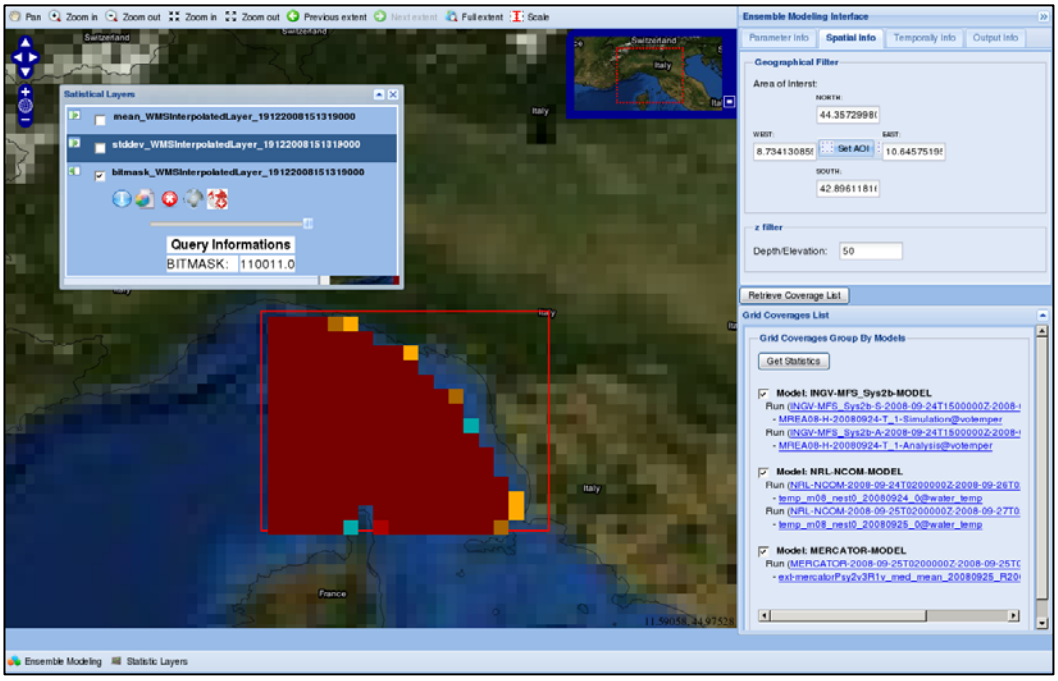
Current prediction models have limited reliability due to the highly chaotic nature of coastal environments as well as the difficulty of collecting real-time data in heavy maritime traffic and fishing zones to correct and validate these models. The use of Multi-model Super-Ensembles (SE) which optimally combine different models, has been shown to significantly improve atmospheric weather and climate predictions. In the highly dynamic coastal ocean, the presence of small-scales processes, the lack of real-time data, and the limited skill of operational models at the meso-scale have so far limited the application of SE methods. The basic idea of the SE techniques is that a certain combination of several runs could yield better results than just one single model run, even if it has a higher temporal or spatial resolution. Classically the SE methods can be sorted in five categories which are the individual models, the ensemble mean (EM), the linear or non-linear combinations and the dynamical methods such as Kalman Filters or Particle Filters. As strong correlations can exist in the considered system, one should be able to take benefit of them to improve the prediction in a larger surrounding than the only grid cell containing the observation point. Satellite images of sea surface temperature (SST) or Temperature and Salinity measurements collected by gliders can be used to regularly correct for model drifts.



Comparison between observations (OBS) and various 24 hours forecasts: numerical forecasts (M1, M2), ensemble mean of M1 and M2 (EM) and Super-ensemble prediction (SE). The method assimilates Sea Surface Temperature (SST) from satellites and Temperature and Salinity from Gliders collected during the MREA/CalVal08 experiment.

Understanding the Maritime Environment

In 2008, a new method was developed to assimilate satellite and glider data into the multi-model space so as to combine available forecasts and observations into a super-ensemble prediction. This approach is multivariate (by fusing various ocean parameters, e.g. temperature and salinity in the ocean), covariant (by exploiting spatial correlations between parameters on the horizontal and the vertical) and dynamic (model-data combinations are updated in time based on the various numerical prediction skills and observation errors using a Kalman Filter). A graphical user interface (GUI) has been developed and integrated into the NURC Data Fusion Center to automatically compute forecast ensemble mean and uncertainty product. This Web-GIS service is OGC compliant. In 2009, this tool will evolve into a Super-ensemble prediction tool to assimilate data streams from gliders and remote sensing.

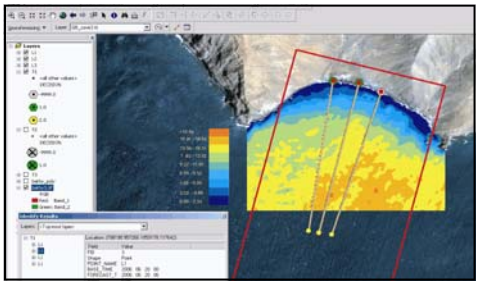


Graphical User Interface (GUI) of the Ensemble prediction tools. The Service Oriented Architecture (SOA) provides Web GIS Services and is Open Geospatial Consortium (OGC) compliant.

Geospatial Data in the Operational Decision Making Process

The impact of the environment is an important factor in determining the effectiveness and safety of operations. Knowledge, understanding and ability to assess the variability and uncertainty of geospatial information have increased in recent years. The next and more important step is to move the improved knowledge of geospatial data into the operational decision making process. The Centre organised a workshop in November 2008 to investigate technical issues that need to be addressed to provide geospatial support for operational decision making, in areas including risk assessment, human factors in data representation, knowledge management and the operational effectiveness of METOC data.

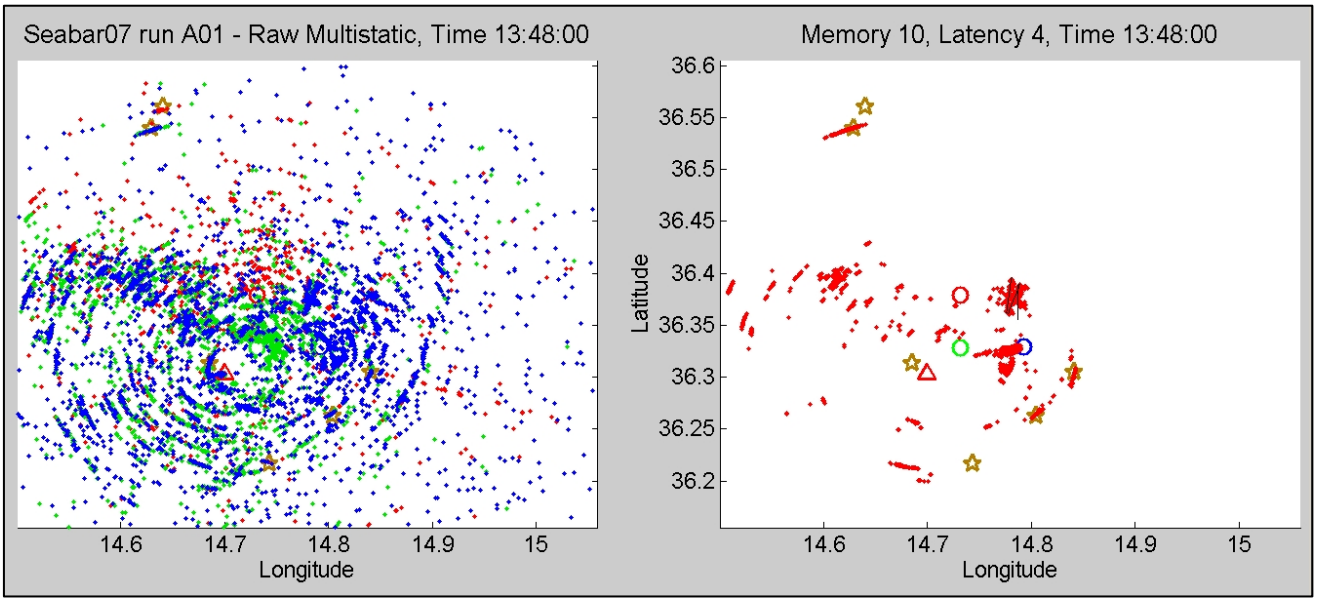
Thirty researchers representing universities, research centres, commands and sponsor organisations in Canada, Estonia, France, Italy and the USA participated. Besides presentations and discussions, the initial concept and plans for a jont research project (JRP) were developed. The aim of the JRP was to conduct at-sea testing of new operational decision support methods, in particular, during the NURC REP'10 sea trial scheduled for the spring of 2010.



Littoral Undersea Surveillance

The objective is to improve undersea reconnaissance and surveillance capability such that future NRF and other NATO forces have an increased warning and tactical advantage against mobile submerged threats in the littoral

Anti-submarine warfare (ASW) and undersea surveillance, the original research specialities of the Centre at its establishment almost 50 years ago, continued to be a core activity in 2008, although greater attention was given to littoral waters compared to blue waters of the past. The objective here is to improve undersea reconnaissance and surveillance capability such that future NRF and other NATO forces have an increased warning and tactical advantage against mobile submerged threats in the littoral. The Centre is a pioneer in the field of multistatic sonar and conducted extensive research and sea trial evaluation of multistatic sonar fusion and tracking algorithms and technology. 2008 saw the completion of the Multistatic Sonar Project (04A3), which determined the feasibility of interoperable surveillance and tactical (LFAS) multistatic systems for ASW operations. The project covered the fields of signal processing, automated data fusion and tracking, as well as concepts for multistatic sonar human computer interfaces (HCI). The 4 sea trials, with the last one being SEABAR'07, were major milestones during the project. Working with partners from the nations, researchers tested algorithms used to fuse multistatic data, and evaluated tracking techniques developed against real data collected from the sea trials. Work was also performed on HCI display concept, to illustrate improved performance with the application of distributed detection theory to multistatic data.

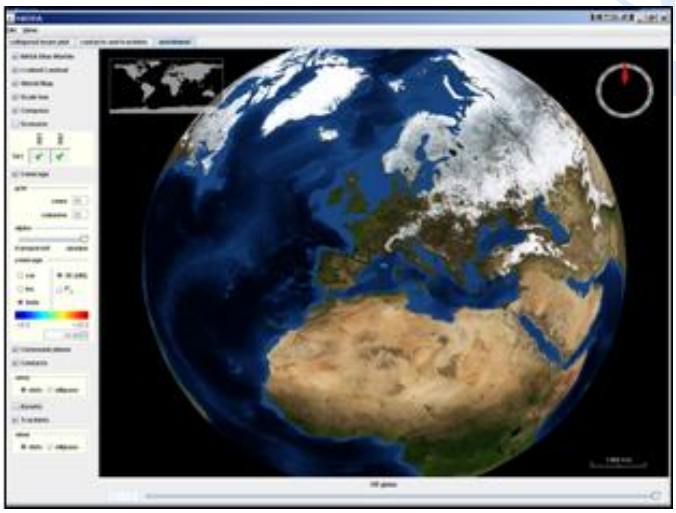


Comparison of simple contact plotting (left) with multistatic HCI (right) [Overview of surveillance area]

Research findings from the project concluded that multistatic active sonar systems have proven to be technically feasible and showed improved performance when compared with monostatic systems. Improved performance is due to short latency (because of effective Doppler processing), high precision (due to triangulation), fewer false alarms and anti-stealth. It was also found that improved performance can be exploited automatically; and that deployable systems can be used to achieve multistatic active sonar coverage.

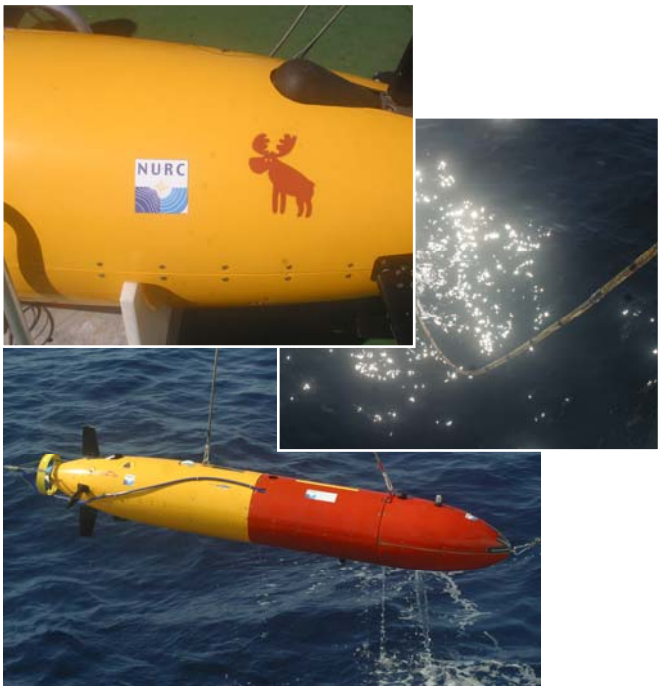
Littoral Undersea Surveillance

A new version of the Multistatic Tactical Planning Aid (MSTPA) was released in 2008 and featured an accurate multistatics core model, a full visual interactive graphical user interface (right) and optimization for static multistatic active sonar assets. It was distributed as a beta release to the Nations for evaluation and feedback. A future release will include range dependent bathymetry and optimization of dynamic multistatic active assets such as frigates with variable depth sonar and AUVs.



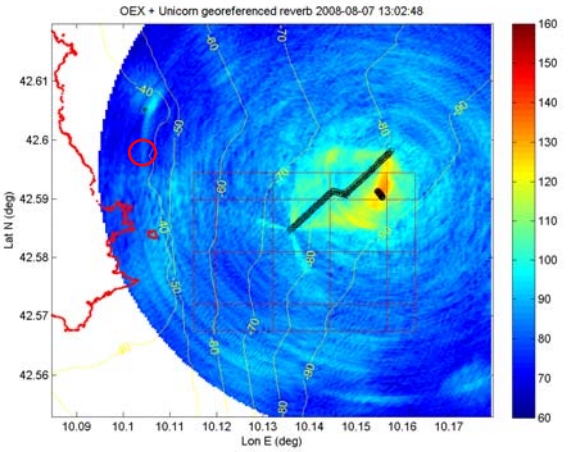
Planning and analysis for the CASW (Cooperative Anti-Submarine Warfare) programme started in 2008, with the identification and description of operational scenarios and application requirements, and an analysis of the different components of a CASW system. Scheduled to begin officially in 2009, CASW will investigate novel and innovative approaches to counter the proliferation of quiet, small, diesel-electric submarines which pose a threat to NATO and national forces, taking an integrated approach to ASW that focuses on sensor networks with distributed intelligence. The new programme will incorporate several 2008 research activities related to sensors, automation, data fusion and clutter classification.

Underwater networking and communication

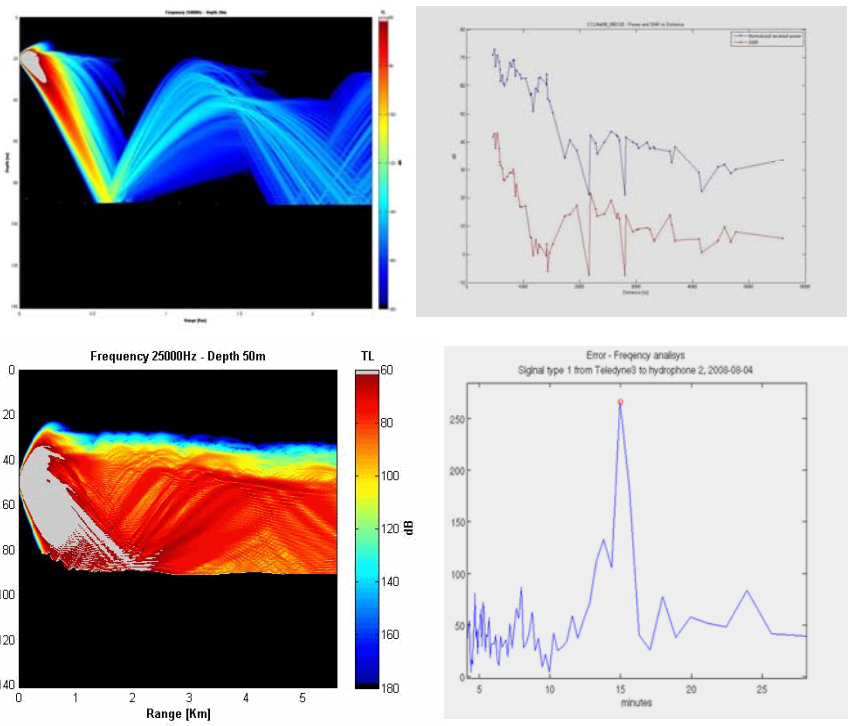


***Left**: NURC OEX, modified to run MOOS-IvP, being deployed from RV Alliance, along with its SLITA array.*
***Above right**: Fused multistatic reverberation intensity measured by AUVs. The red circle indicates an artificial target position and the two black tracks indicate the time history of the AUVs.*

The GLINT08 sea trial conducted summer 2008 demonstrated the deployment of a cohesive, heterogeneous sensor network. Assets included a record of 5 different autonomous vehicles and several fixed and towed assets, using a common portable autonomy architecture, MOOS-IvP, and a common communication infrastructure. The experiment provided the first ever demonstration of multi-static active sonar signals recorded and processed on a network of AUVs, and the first successful field demonstration of bearing-time



records processed in real-time on an autonomous vehicle and communicated via the underwater communication path to the topsides operator. Another accomplishment was the demonstration of adaptive CTD YoYo measurements from an autonomous platform for estimating the spatial and temporal variability of the thermocline, the most significant environmental acoustic feature of the shallow water ocean. Several new autonomous behaviours were demonstrated, including fully autonomous "synchronized swimming" by two AUVs with towed arrays, of significance to the coordinated, collaborative use of these assets in multistatic acoustic systems. An advanced mission control center was established on NRV ALLIANCE, with a comprehensive situational display showing the positions of all the underwater nodes based on status reports received through the undersea acoustic communication network, and incorporating real-time AIS (Automatic Identification System) contacts. The same situational display was shown on a computer screen on the bridge of NRV ALLIANCE, aiding the crew in the complex operations of the ship among the many assets and commercial ship traffic. A new wireless network bridge was used to connect the two research vessels and the shore lab, allowing the same situational display to be available on all stations in real time. Other significant accomplishments included the use one of the MIT SCOUT autonomous kayaks as a mobile communication gateway optimizing communication capacity by adaptively tracking and trailing the submerged assets using a towed, high rate Phase Shift Key (PSK) modem.



The ever-changing environment influences the propagation of communication signals. Communication using the JANUS protocol remained robust even under adverse conditions

The NURC developed JANUS communications protocol was utilized and confirmed as a robust method to communicate into a heterogeneous underwater network. JANUS is a low complexity signalling method for underwater communications. The beacon-like JANUS transmission does not solicit a reply. It uses a frequency-hopped binary frequency shift keyed ((FH-BFSK) method. Testing during GLINT'08 confirmed the utility and robustness of JANUS encoding, matched filter usage and decoding tools for ranges up to 6000 meters. JANUS is intended to be used as a simple beacon scheme, the foundation upon which additional communications and networking functionality will be built. At a NURC sponsored workshop in March 2008, participants who were involved in the development of JANUS agreed that NURC should serve as the custodian of the JANUS standard and that partners will continue the implementation and testing at their own institutions. JANUS is intended for public use, to encourage vendors to incorporate the communication standard into their systems. JANUS and the Matlab code required to create is available at http://nrcsp.zftp.com/users/janus-tmp/.

Protecting Ports and Harbours

Technology evaluations have shown that many components are ready for use in port protection, yet many challenges remain in their integration and concepts of use

Risk analysts have pointed out the vulnerabilities of maritime facilities to terrorist attack, as well as the severe consequences that are possible in terms of loss of life and considerable environmental, economic, and military impact. The scenarios to be averted include a) the *economic* scenario—a major harbour is closed for a time with significant economic impact; b) *health-safety-environmental*—dangerous chemicals are spilled or detonated; c) *political*—a high-profile event is marred and exploited by terrorists. Many nations have therefore begun concerted efforts toward increased port security. In 2004 NATO's Conference of National Armaments Directorate (CNAD) announced its 10-point Technology Development Programme of Work which features Port Protection as item no. 2, with Italy taking the lead and with NURC in a supporting role. NURC advances protection technologies on three fronts: in its Scientific Program of Work (SPOW), in the Allied Command Transformation's Experimentation Program of Work (EPOW), and with the European Commission and others in the Centre's Supplementary work program (SWP).

Technology evaluations have shown that many components are ready for use in port protection, yet many challenges remain in their integration and concepts of use. NURC has concentrated its effort thus far on generating system requirements for integrated surveillance and response against underwater intruders, and on unmanned systems for rapid response. The effort continues by expanding to include pier and seafloor inspection for improvised explosive devices (IEDs), capitalizing on the work underway at NURC in mine countermeasures in shallow waters, expanding to counter the threat posed by small surface craft, and expanding to include nonlethal weapons among the options for response. Current and future work combines technology evaluation, developing concepts of use, system integration and exercise under realistic conditions, operational analysis, and requirement generation.

SecTronic Security System for Maritime Infrastructures, Ports and Coastal zones

marss Marine & Remote Sensing Solutions

Forsvarets forskningsinstitutt

NURC

BW Offshore

ACS ADVANCED COMPUTER SYSTEMS

UNIRESEARCH

CHALMERS

Port of Rotterdam

BW Gas

Autorità Portuale della Spezia

DNV

CARNIVAL CORPORATION&PLC

In February 2008, NURC featured as one of six R&D partners (above) that was awarded funding by the European Commission through its Framework Program 7 (FP7) for civilian maritime security research. The project is called SECTRONIC: Security System for Maritime Infrastructures, Ports and Coastal Zones.

Shipping carries 90 % of the world's trade. Cruise liners carry more than 12 million people each year. European liquid natural gas (LNG) imports from Africa and the Middle East are expected to quadruple by 2030. Incidents of piracy increased an estimated 10 % in 2007. The vulnerabilities of these and other maritime activities are too diverse to itemize, and the consequence

of security gaps are too far-reaching and uncertain to quantify. What is clear is that the economy of scale (decreased unit cost for increased quantity) that characterizes maritime activities increases the risk of security incidents, especially incidents near shore.

SECTRONIC undertakes to improve the security of civilian ships (passenger and cargo carriers), energy platforms and facilities, and ports through advanced information, sensor, and response technologies. It aims to develop an integrated security system that combines surveillance, intrusion detection, and response to events and incidents. NURC takes the lead on work related to non-lethal response technologies and tactics. In particular, the Centre will be exploring new technologies that enable proactive capabilities in a security system through unambiguous warning, evasion, screening, and applying non-lethal force.

Central to the project is the advice and testing by system end users, hence six shipping and energy related industry partners are also included as members of the SECTRONIC consortium. The project began with kick-off meetings in London Feb 2008 and runs for three years. More about SECTRONIC can be found at the project's website http://www.sectronic.eu/.

Enforcing security exclusion zones, underwater and above

NURC researchers demonstrated the utility of an unmanned surface vehicle (USV) as part of a mission package designed to counter underwater intruders. PROVEx (Practices, Operations & Validation Experiment) showed that a USV can be consistently positioned such that its onboard sonar will provide imagery of sufficiently high quality to be useful for the classification of underwater contacts, e.g. divers who are unseen from the surface.

The aim of the experiment was to test key system elements for enforcing security exclusion zones, underwater and above, to further determine key surveillance and response system requirements, focusing on a USV capability for rapid response. The trial took advantage of the USV recently acquired by NURC and a recently signed Joint Research Project agreement between NURC and WTD-71 (Bundeswehr Technical Centre for Ships and Naval Weapons) in Eckernförde, Germany. WTD-71 hosted the trial, which was conducted to assess the benefit of the USV as a stand-alone asset as well as when used in conjunction with the sensors of the LEXXWAR fixed surveillance system that WTD-71 has assembled.

In the weeks leading up to the trial, the USV's capability was augmented by the installation of two classification sonars. A sidescan sonar that could be used for area search and bottom surveys in the harbour environment was installed, as well

as a forward-looking blazed array sonar used for more detailed classification imagery. Other additions included more computing and network resources aboard the USV. These resources were used in part to implement IvP Helm, an interval programming approach to vessel autonomy, an effective technology demonstrated in prior collaborative experiments between MIT and NURC. The IvP Helm process handles higher-level autonomy such as mission tasking, while the low-level control of the vessel is handled by its native spectre processor. The combination of these processes and the modular approach to control software proved successful as the high level command for the USV to pursue and position itself appropriately relative to a diver was executed to perfection on repeated occasions during the experiment. NURC scientists, technicians and visiting military personnel from three NATO nations shared time at the controls. They noted numerous positive aspects of the experimental system.

The common operating picture was enhanced with the addition of a number of sensors. The sensors, including the QinetiQ Cerberus diver detection sonar, a USV controlled and monitored via MOOS (Mission Oriented Operating Suite), the LRAD in-air acoustic loudhailer with spotlight and camera, have never been demonstrated operating together in combination. The researchers also experimented with the capability to click on contact a sidescan display as a way to task the USV to perform a drive-by with forward-looking sonar in order to provide an alternative look at a potentially interesting bottom object, usually within a minute after it was seen on the sidescan display.

In summary, the experiment demonstrated a credible capability of responding to maritime threats using an unmanned surface vehicle with sidescan and forward-looking classification sensors. The NURC USV will be the basis for further experimentation associated with concepts for operational deployment, with missions to be expanded to surface threats in 2009.

NURC USV responding to an underwater intrusion detected on sonar during PROVEx

NURC at HPT'08

Two NURC personnel joined an international team of specialists from a variety of institutes as part of the analysis team for the Harbour Protection Trials 08 (HPT 08) in August 2008. The trial was held in Eckernförde, Germany and is part of a series of trials established by the Maritime Capability Group 3 on Mines, Mine countermeasures and Harbour Protection (MCG/3) to test and verify capabilities of new technologies for the Defence Against Terrorism (DAT) in ports and harbours and to ensure the interoperability of national systems.

The specific objective of HPT 08 was to demonstrate protection of harbours, anchorages and approaches from attack by terrorists using small surface/ subsurface craft, slow low flyers, divers and IED/mines against military vessels, commercial shipping and port infrastructures. This represented an increase in complexity when compared

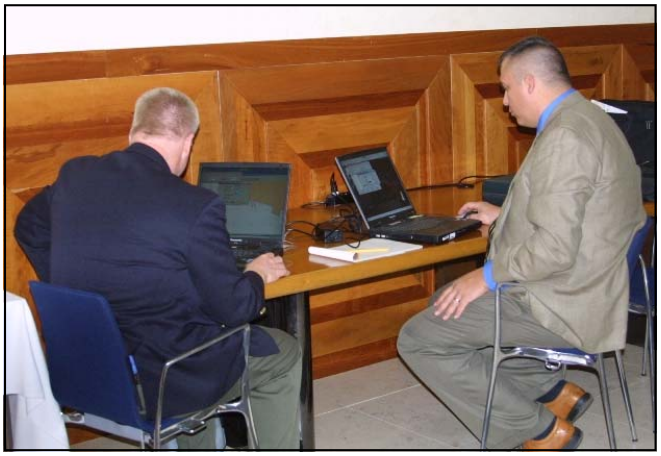
with the scenarios of HPT 06 (La Spezia) and HPT 07 in (Taranto). The organizers of HPT 08 asked for the employment of integrated systems comprising suitable sensor packages (Radar, Sonar, Electro optics, etc.), Threat Evaluation and Weapon Assignment (TEWA) functionality and associated interfaces. In response to the call to nations, the trial organizers received 27 industry offers. Seventeen of those were tested in three scenarios (protecting ship in harbour, protecting ship at anchor, and mine countermeasures in harbour approaches). The analysts observed system setup and calibration in the week preceding the actual trials. The scenarios of the second week exercised each system against a series of staged intrusion events by simulated terrorists against a background of clutter traffic. The intruders used fast boats, divers, and small aircraft to stage their attacks and diversions.

Participants at the HPT'08 in Eckernförde, Germany

Among the preliminary conclusions of the analysts were observations that (1) modularity allows for easy re-configuration related to the threat changes in perceived threat, (2) mobile sensors aboard a truck, trailer, ship or small vessel proved effective, (3) non-lethal weapons and warnings would have high operational value in determining hostile intent, and (4) a system of systems needs well integrated and reaction chains to ease manning and reduce reaction time. An analysts' report will be completed by March 2009 and is expected to provide guidance for future experimental and operational efforts in protection of ports, harbours, and associated waterfront infrastructure.

Table-top exercise on harbour defence

A Rapid Response Harbour Defence 2008 Seminar & Exercise was conducted in La Spezia. Representatives of the Italian maritime administrations and the German Navy participated in the table exercise, 30 September-2 October which focused on 4 Italian harbours as examples. Software developed by the USA was used, and NURC was assisted by the Naval Postgraduate School (USA) and the US company SAIC.



Two participants in the exercise analyzing a simulated scenario

The exercise provided a stimulating environment for specialists to explore a range of the technical, operational, and organizational aspects of the threat scenario in order to gain a broader understanding of relevant issues and the actions and activities that might help address these issues. It also expanded the understanding of the impact of preparatory activities such as crisis response planning and organizational coordination by providing added insight into potential and existing threats, the nature of the operational, political, and economic environment, and the available means to prepare now to successfully defeat these threats. Such exercises also help to develop insights and recommendations concerning the prospective operational application of NATO Experimental Tactics (EXTAC), Command Structures, and ongoing S&T activity expected to transition by 2015, and to identify possible gaps or deficiencies in current approaches.

Supporting NATO and the Nations

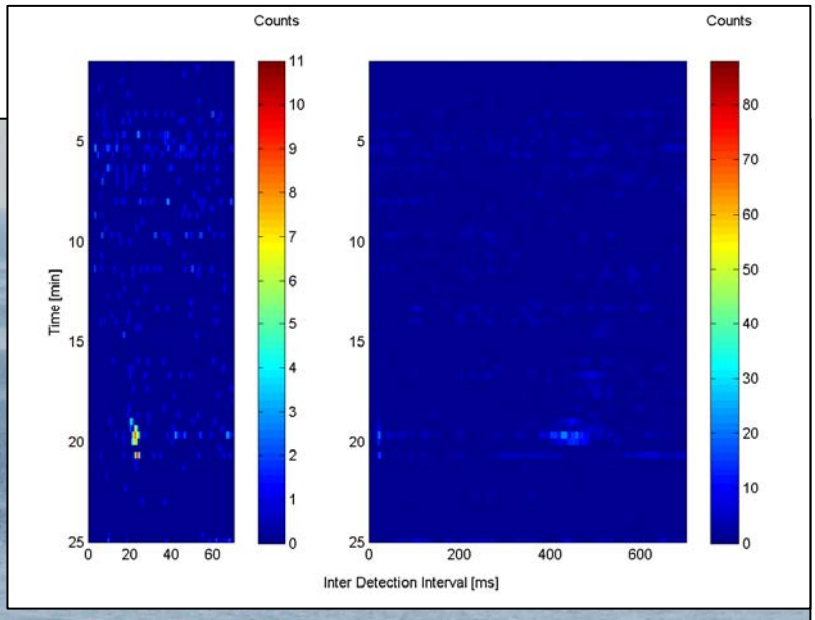
NURC directly supports NATO operations by providing expert advice and analysis for exercises and projects. The Centre also supports the Nations through projects under the Supplementary Work Programme, and by acting as a hub for the exchange of information through meetings and workshops.

Marine Mammal Risk Mitigation

NATO's Military Committee's directive, MC 0547 (Use of Active Sonar to Ensure the Protection of Marine Mammals), establishes the responsibilities of NATO in this area. It calls upon the NURC to be a collection centre for sighting and stranding data and to develop models and in-water tools to assist the military commander. The specific objective of this project is to provide marine mammal risk mitigation reachback support (i.e., risk assessments, expert advice, and protocols) to maritime exercise planners and centre scientists so that NATO maritime components may continue to use tactical active sonar during operations and experiments with minimal environmental impact. Active sonar exercises are essential to train against the threat from quiet submarines; however, the ability to execute these exercises is at risk due to legal and public pressures that derive from temporal and spatial associations between several marine mammal stranding events and the operation of NATO naval assets with tactical active sonar.

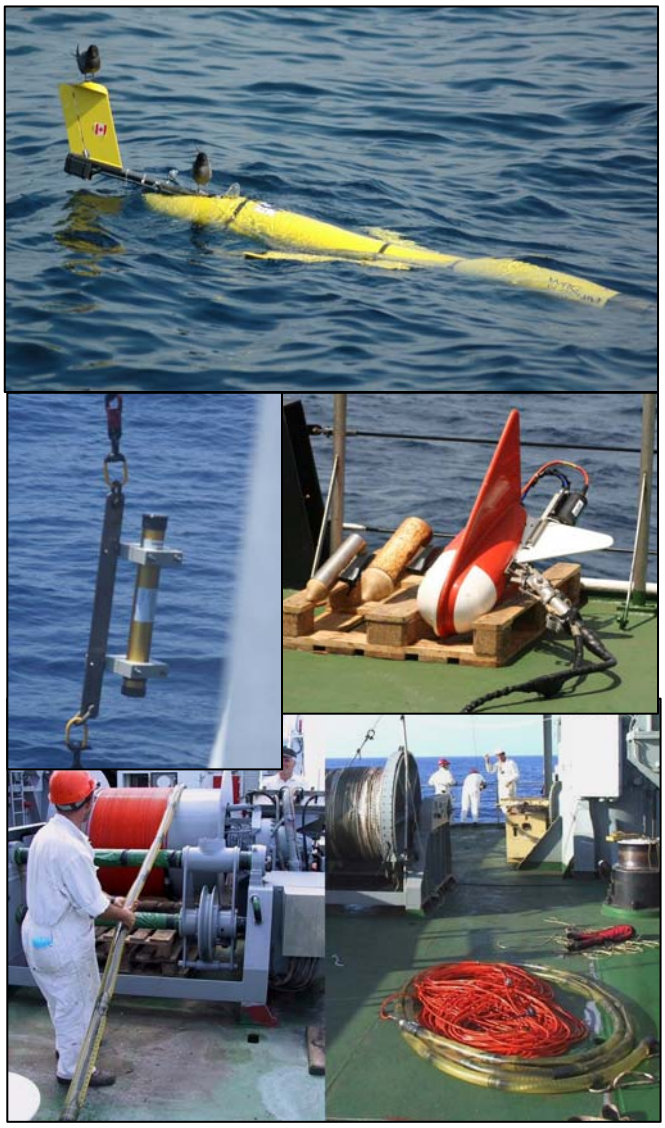
In 2008, reports were issued on methods of passive acoustic detection of beaked whales and the

Z. cavirostris click acquired using passive acoustic monitors and processed with DC algorithms during Sirena 2008 sea trial



Cuvier's beaked whale (Ziphius cavirostris) breaching during Sirena 2008 sea trial. Three whales were subsequently tagged and tracked to acquire diving and vocalization behaviors

Centre's risk mitigation policy. The SIRENA'08 sea trial with participation from eight nations (CAN, DEU, ESP, FRA, GBR, ITA, NLD, USA) tested the predictive marine mammal habitat model, recording 285 sighting events for a total of 3967 animals. Passive acoustic devices and DC(L) algorithms were integrated to enable inter-dependent function, while marine mammal risk mitigation software packages were evaluated. The ongoing analysis of data from the sea trial supports continued work on the detection, classification, and localization (DCL) algorithm and the integration of visual and acoustic data into a predictive distribution model. A post SIRENA'08 meeting was conducted in October to facilitate data exchange and Identify focal areas for collaborative work with existing and future partners, while work began to develop a geospatial database with biological and environmental information. NURC also provided reachback support for the NATO exercises Noble Midas, Loyal Mariner, and Noble Midas.



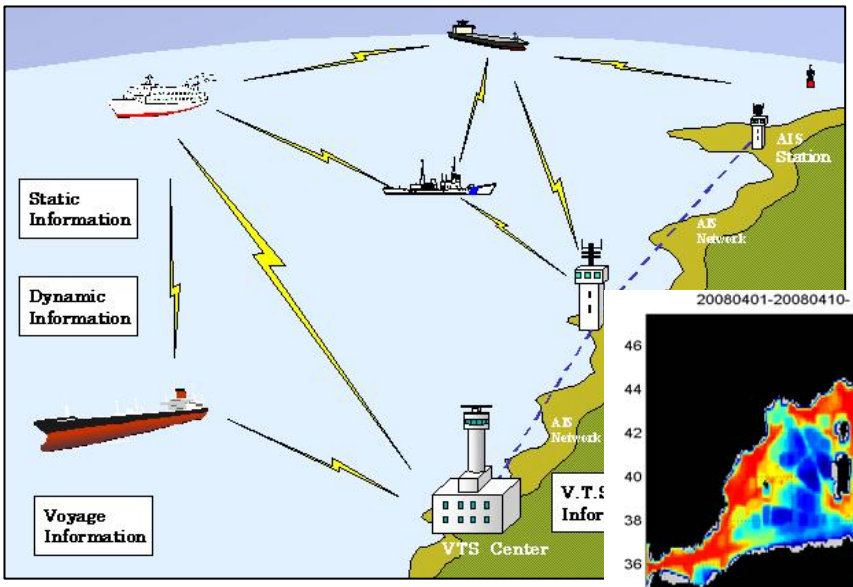
Passive acoustic monitors deployed during Sirena 2008. From top clockwise: Slocum glider (CAN), CPAM towed body (NURC), T-POD buoy (DEU), CIBRA array (ITA).

Applying Technology for Maritime Situational Awareness

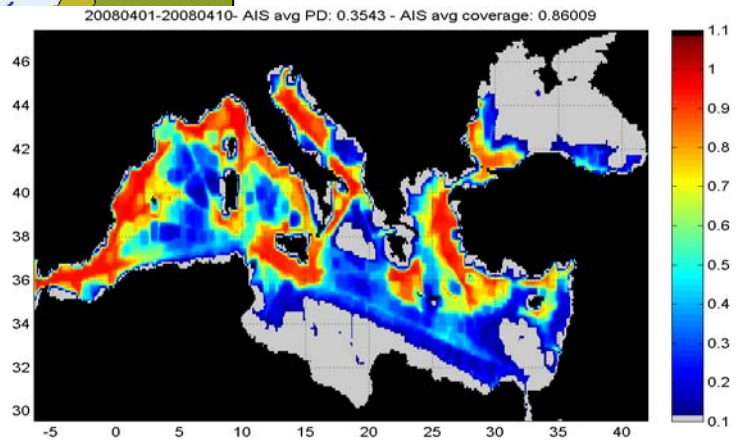
In early 2008, NURC worked with the Allied Maritime Component Command (CC MAR) Naples, to develop an AIS range prediction tool that can support decisions on the most effective deployment of assets when tracking ships movements. CCMAR Naples runs Operation Active Endeavour (OAE), a ship tracking and monitoring operation in support of NATO interests in the Mediterranean Sea. OAE uses the Automated Identification System (AIS) as the primary source of information for location and tracking. Shipborne AIS transponders automatically broadcast information, such as their position, speed, and navigational status, at regular intervals via a VHF transmitter built into the transponder. AIS messages are collected by AIS receiving stations (land-based, airborne or on satellites), which share their information in an integrated Vessel Traffic Service.

Since VHF propagation is affected by atmospheric conditions, AIS coverage can undergo significant variability. The prediction of reception range of AIS transmission is required in order to efficiently schedule asset allocation for OAE. NURC developed a tool to estimate the actual AIS coverage from the real AIS contact distribution. An example of actual data-based AIS coverage, averaged over the first ten days of April 2008 and as obtained from the analysis of AIS data, is shown in figure on the next page. Such information is then used in operational planning for the next 48 hours to understand where there will be gaps in AIS coverage, and to provide more accurate tracking of shipping in the Mediterranean Sea.

Supporting NATO and the Nations



Pictorial representation of an integrated Vessel Traffic Service. Source: Tidepedia



Average AIS coverage (1-10 April 2008)

In October 2008, NURC personnel onboard the NRV ALLIANCE participated in Trial Imperial Hammer '08 (TIH08) in Sardinia to demonstrate sensor fusion and ship tracking capability in an operational scenario, providing the maritime component to the Trial. TIH08 demonstrated how NATO's ability to share time critical intelligence can better protect NATO forces and populations from terrorist attacks through better identification and tracking of enemy combatants. With just 6 working days of preparation time, NURC scientists on the NRV ALLIANCE were able to apply new research in maritime surveillance, fusing data from AIS (automatic identification systems) and ship-borne radar information to track ships in the operational area. They demonstrated the ability to apply core technical capabilities in the areas of multi-senor fusion and target

Google Earth image shows a time sequence of AIS and ship-borne RADAR information inside a 10-mile radius, with the anomalous behaviour (red circle) of a vessel moving toward the coast at high speed, going ashore and then back to open waters.

tracking to multiple operational environments. The Centre's tracking and anomaly detection algorithms were set during the exercise to identify high speed small boats and other vessels of interest. The resulting ship tracks, updated every 15 seconds, were presented on a Google Earth background with related applications.

The information and images were sent in real time from NURC's data fusion centre to the maritime component command cell at the SIGINT and Electronic Warfare Operations Centre. NURC's participation in this Trial underscores the joint aspects of NATO operations and the benefits of quick-reaction science, technology and development that the Centre brings to the Alliance.

Leveraging NURC Research for National Use

In an example of how NURC research can already be leveraged by NATO nations, the Centre's REMUS AUV (autonomous underwater vehicle) operating team was in Puglia, southeast Italy, in November 2008 to conduct a survey of the harbour of Molfetta and its approaches. This is the first phase of a 2-year project commissioned by the local authorities to clear the region of unexploded ordnance, in particular chemical artillery shells leftover from World War II, using modern mine-hunting technology that is part of NURC's research programme. As with NURC's survey of Capo Teulada for the Italian Navy in 2007, AUV technology was again confirmed to be affordable, portable and highly effective in shallow waters, especially enclosed inside a port, with a high density of marine growth. The NURC team were able to locate targets in difficult environmental conditions, and discovered that the density of contacts of interest in the area surveyed was extremely high. Targets located and identified as ordnance were marked for disposal by the Italian authorities at later stages of the project. During the latter part of the operation the team was joined by the NURC public affairs assistant and a film crew from the Public Diplomacy Division at NATO HQ who filmed the operation and interviewed the team and a number of local nationals for a documentary being produced by NATO to demonstrate the impact of NATO on the lives of ordinary citizens. The video report "Molfetta: Danger on the Seabed" was part of a video series "Six Colours" that was released in March 2009.

Earlier, in October 2008, the same AUV team was in Split, Croatia to demonstrate the capabilities of commercial off-the-shelf AUV technology for comprehensive surveys of shallow water port areas. Sponsored by the US Office of Naval Research Global, the team's primary focus was to enable Croatian forces and academia to evaluate the potential of the technology and identify where it may fit in their future capability requirements. The project also served to further develop knowledge of the tactical employment of unmanned vehicles in confined waters, and marked the first collaborative project between NURC and Croatia.

NURC's REMUS AUVs being loaded for deployment at Molfetta, demonstrating the portability and usefulness of the technology in shallow waters.

Providing Expertise

... Slovenia Port Protection Trials

The Centre provided technical advice to the Slovenian (SVN) Navy during a series of demonstrations to evaluate equipment for port protection with a view toward a procurement by SVN. A NURC port protection specialist assisted with trial plans and was onsite in Koper over a 2 week period in June 2008. Among the technologies demonstrated were AUVs (autonomous underwater vehicles) from Hydroid Europe GBR (*Remus 100)*; ROVs (remotely operated vehicles) from Ageotec ITA (*Perseo)* and Gaymarine ITA (*Pluto-Gigas*); and sonars from Coda Octopus GBR (*Echoscope),* RESON DNK (*Seabat 7128)*, and Sonardyne GBR (*Sentinel*).

NURC scientist joined representatives from the Slovenian military, police, universities, and industry at the technical demonstrations; right, sonar mounted on side of research vessel used for pier and seafloor inspection

... Mine Clearance Trials

NATO's northern mine hunting force (SNMCMG1) visited La Spezia from 22nd-31st August. During this time NURC coordinated and subsequently assessed percentage clearance trials. These trials consisted of a number of exercise mines laid within a channel which must be cleared by the MCM units. The trial was an important opportunity for the mine hunters to practice mine clearance operations in a challenging environment such as the initial detection of mine-like contacts using onboard sonars and subsequent identification using ROVs and/or divers. Following the trial NURC provided rapid feedback to the commanding officers of all units detailing their performance during the trials.

MD/ICI nations get together to discuss maritime issues

NURC hosted a three day Mediterranean Dialogue and Istanbul Cooperation Initiative Open House in December 2008 to bring together senior military representatives from member nations to share ideas on Maritime Environmental Safety and Maritime Safety and Security. The Open House, sponsored by Deputy Supreme Allied Commander Transformation (DSACT), Admiral Luciano Zappata, was held within the framework of the NATO Training Cooperation Initiative (NTCI) which started after the Riga Summit and is in line with the goal of modernizing NATO defence structures.

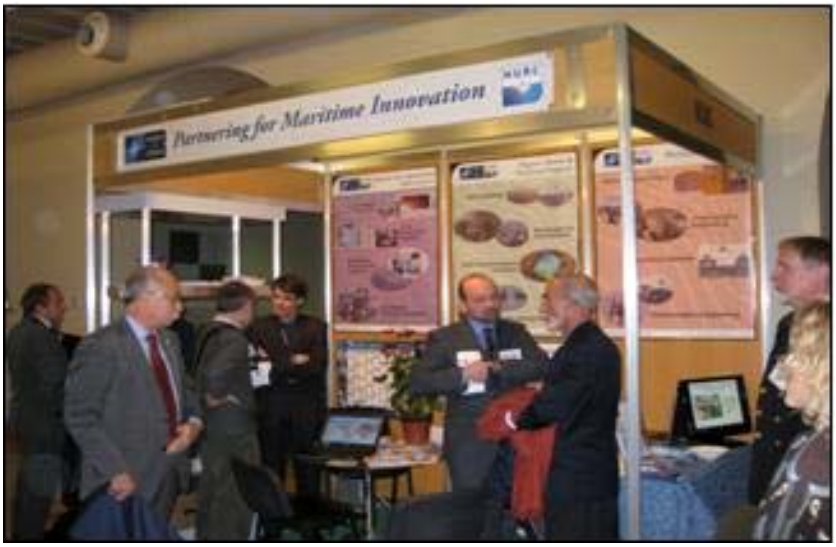
NURC and NATO/ACT representatives led discussions on topics related to maritime security, while representatives from EMSA (European Maritime Safety Agency), Cedre (Centre de Documentation, de Recherche et d'Expérimentations sur les Pollutions Accidentelles des Eaux) and ISPRA (Istituto superiore per la Protezione e la Ricerca Ambientale) covered topics of envi-

ronmental concerns, marine pollution and accident response and oil spill contingency management The objectives of this meeting were met in that a strong foundation for the sharing of information between NATO and member nations of the Mediterranean Dialogue and Istanbul Cooperation Initiative was laid. Specifically, insight into the programs of work of the member nations on maritime security provided an excellent opportunity to validate the scope and direction of the work being done at the center on the topic. Among the possibilities for future work are establishing this workshop as an annual event, expanding the effort to include collaboration within the respective programs of work and the development of a course at NURC in order to facilitate and to standardize the sharing of information.

NURC takes a stand at conferences and trade shows

In 2008, the Centre participated in several NATO and research events, showcasing its research activities and achievements, especially to audiences who may be new to NURC. These events included the following.

- 100th Meeting of the NATO Naval Armaments Group (NNAG) in NATO HQ in November 2008 where the Centre presented projects with NNAG involvement/participation, in particular through its Maritime Capability Groups.
- NATO R&T Day Symposium and Exhibition, October 2008 at NATO HQ. NURC staff presented projects, activities, live demonstrations and equipment that support NATO maritime operations and future needs.
- Oceanology'08 (March) in London, where the Centre presented the capabilities of its research vessels as well as NURC's research activitiesto the oceanology community.
- Acoustics'08 in Paris, June/July 2008 signified the start of the celebration of NURC's 50th anniversary scheduled for April 2009, with a special session "50 years of progress in sonar acoustics research: the role of NURC/SACLANTCEN". The invited speakers comprised prominent Centre alumni including two former directors, one long-serving SCNR member, and several distinguished scientists from both Europe and North America.
- 3rd Maritime Systems and Technology Conference and Tradeshow (MAST), November 2008 in Cardiz was an opportunity to introduce the Centre to military and scientific communities in Spain.



NURC researchers talking to visitors at the Centre's exhibit stand at MAST 2008 in Cardiz, Spain

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