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Annual Progress Report 2005

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NATO Undersea Research Centre (NURC)

NURC conducts world class maritime research in support of NATO's operational and transformational requirements. Reporting to the Supreme Allied Commander Transformation, the Centre maintains extensive partnering to expand its research output, promote maritime innovation and foster more rapid implementation of research products.

The Scientific Programme of Work (SPOW) is the core of the Centre's activities and is organized into four Research Thrust Areas:

- Expeditionary Mine Countermeasures (MCM) and Port Protection (EMP)
- Reconnaissance, Surveillance and Undersea Networks (RSN)
- Expeditionary Operations Support (EOS)
- Command and Operational Support (COS)

NURC also provides services to other sponsors through the Supplementary Work Program (SWP). These activities are undertaken to accelerate implementation of new military capabilities for NATO and the Nations, to provide assistance to the Nations, and to ensure that the Centre's maritime capabilities are sustained in a fully productive and economic manner. Examples of supplementary work include ship chartering, military experimentation, collaborative work with or services to Nations and industry.

NURC's plans and operations are extensively and regularly reviewed by outside bodies including peer review of the research, independent national expert oversight, review of proposed deliverables by military user authorities, and independent business process certification. The Scientific Committee of National Representatives, membership of which is open to all NATO nations, provides scientific guidance to the Centre and the Supreme Allied Commander Transformation.

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Foreword by the Director

This Progress Report describes the Centre's unclassified technical accomplishments and outputs realised under the Scientific Programme of Work (SPOW) for 2005. The Centre conducts maritime research in support and anticipation of NATO's operational and transformational requirements via the SPOW and via a number of military experiments under sponsorship of Allied Command Transformation (ACT).

We maintain extensive partnering to expand output, to promote maritime innovation and to foster more rapid implementation of the research products. Partners include similar organisations, capability providers in the nations, and users of these capabilities throughout the alliance. Several indicators of recent partnering activities follow the section on Progress in Quality Management along with a few other overall activity indicators. Details and results of partnering can be found in the body of this Report and are often termed Joint Research Projects (JRPs).

This Progress Report reflects a continuing evolution of the research in support of maritime operations for joint, expeditionary forces across a wide range of mission types as described in the Bi-SC document, Strategic Vision: The Military Challenge.

The research is organised into four Thrust Areas. The Areas are listed below with an indication of transformational themes in each together with our current focus.

Expeditionary MCM, Port Protection

- ***Unmanned Systems:*** Transformation from Platform Based (MCMVs) to Capability Based (Deployable from afloat or ashore, Scalable Capabilities)
- Current Focus: Unmanned Underwater Vehicles with increasing Autonomy

Undersea Reconnaissance, Surveillance and Networks

- ***Distributed, Autonomous Sensing:*** Transformation from Platform Based (Ships) to Capability Based (Persistent Surveillance, Scalable Capabilities)
- Current Focus: Multi-Static Sensing with increasing emphasis on Distributed, Autonomous Sensing

Expeditionary Operations Support

- ***Information Superiority in Unknown or Denied Areas:*** Essential Environmental Information for Decision Support
- Current Focus: Tactical Prediction/Geospatial Services for Recognized Environmental Picture (REP)

Command and Operational Support

- ***New CONOPS for New Technologies***
- Current focus: Multi-static, distributed, autonomous system concepts of use and measures of effectiveness.

A few sample highlights to illustrate the 2005 programme results are:

- Continued development and numerous demonstrations of Autonomous Underwater Vehicles (AUVs) in the contexts of Port Harbour Protection and expeditionary mine countermeasures
- Further understanding of synthetic aperture sonar (SAS) techniques including novel approaches to algorithms, automatic target recognition and overall system performance.
- Advances in multistatic undersea sensor fusion algorithms.
- Further understanding and web-based tools for marine mammal risk mitigation.

- Increased use of geospatial methods in exploitation of remote sensing and environmental products.
- Further knowledge and tools for small scale ocean and coastal prediction systems.
- Increased insights and techniques for high frequency acoustic models including novel inversion methods for seafloor characteristics that affect system performance.

These are but a few achievements drawn from over 30 significant accomplishments in 2005 and described herein.

The Centre's progress in 2005 was hampered significantly by the loss of most ship services by the NRV Alliance due to a grounding incident (see description under Ship Operations). Repairs are complete and the ship has returned to full service for 2006 as planned. Two major sea trials postponed from 2005 have been re-scheduled for the coming year.

Summary: In these pages you will read of continued success for, and output from, the Centre. I consider that the research remains focused and fully relevant to modern military requirements and emerging operational needs. This Annual Progress Report, together with the annual revision of the SPOW document and the 5 year Business, give a complete picture of the Centre's outputs, activities and plans.

Expeditionary MCM and Port Protection (EMP) Research Thrust Area

Overview

Projects 3C1 (Mine Jamming) and 5E1 (DARE) were completed in 2005. 3C1 reported on the operational use of Mine Jamming and delivered a concept of employment. 5E1 delivered Version 3 of the DARE software.

The MCM AUV Programme as well as the mine-ship interaction work (Projects 3C1 on Mine Jamming and 3C3 on Generic NATO models for threat mines) successfully addressed the capability for remote MCM and partly addressed the defence of maritime forces and installations against terrorism (DAT). It is noted that the capability to conduct MCM operations in ports and harbours is critical for maritime DAT.

The second contribution to maritime DAT is the detection and tracking of intruders such as divers or mini-submarines and is addressed in a new Project 3J1 (Multi-Sensor Harbour Protection Systems). This project will coordinate the NURC contribution to the Harbour Protection Trials and represents the Centre at the NG/3 Specialist Team on Harbour Protection.

The EMP projects 5E1 (Decision Aid for Risk Evaluation, DARE) and 5E2 (Planning and Evaluation of MCM operations using AUVs) are the lead projects in the development of a common operating picture and integrated tactical decision aids in the MCM area. Project 3G4 (Evaluation of minehunting concepts based on AUVs) and Project 3C1 and 3C3 are support projects for this area.

EXPEDITIONARY MCM AND PORT PROTECTION		
Mine-Ship Interaction	Mine Jamming (Proj. 3C1)	Amleto Gabellone
	Generic NATO Models for Threat Mines (Proj. 3C3)	Amleto Gabellone
Minehunting with AUVs	Planning and Evaluation of MCM Operations using AUVs (Proj. 5E2)	Gary Davies
	DARE (Prof. 5E1)	Karna Bryan
	Evaluation of Minehunting Concepts based on AUVs (Proj. 3G4)	Edoardo Bovio
	Sensors and Automation for Minehunting with AUVs (Proj. 3G1)	Benjamin Evans
	Estimation of Acoustic Properties affecting the Performance of Minehunting AUVs (Proj. 3G5)	Finn Jensen
	Target Scattering Models (Proj. 3E2)	Mario Zampolli
Port Protection	Multi-sensor Harbour Protection Systems (Prof. 3J1)	Ronald Kessel

The highlights of the 2005 programme (see Table above) were:

- Completion of the two projects “Mine Jamming” and DARE (Decision Aid for Risk Evaluation). These two projects will be reported at the next meeting of the Scientific Committee of National Representatives (SCNR) in May 2005.
- The beginning of a new project on mine-ship interaction called “Generic NATO models for threat mines”. This project aims to deliver a modelling capability to evaluate the operational effectiveness of signature reduction, and mine sweeping and jamming systems.

The beginning of a new project on “Multi-sensor harbour protection systems” which aims to provide a capability against intruders in ports. This project is the focal point for the Centre’s contribution to Maritime DAT.

Vision

Medium Term The main thrust of the MCM work is on AUV-based MCM with direct application to both the Expeditionary Warfare and Port Protection areas. The MCM-AUV Programme consists of 5 projects whose contents, objectives and timescales are co-ordinated to form a coherent whole (Fig EMP.1). The scientific content of these projects covers a wide spectrum, from basic acoustic scattering theory to signal and sonar systems and operational research.

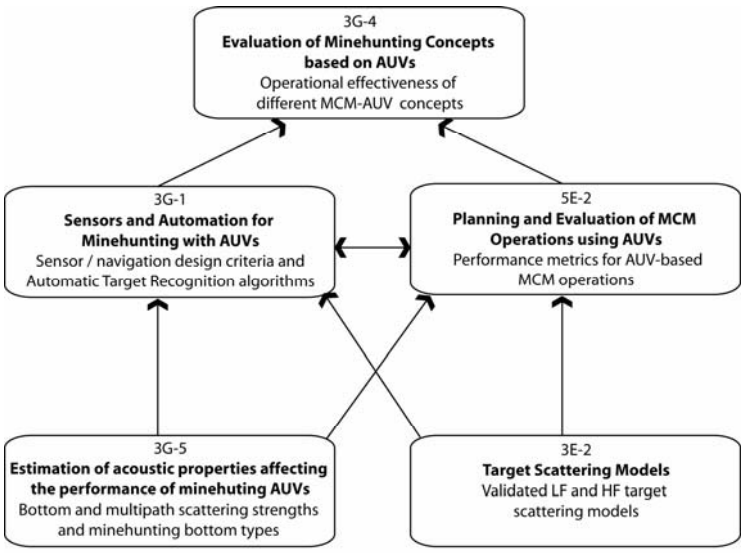

Figure EMP.1 *Structure of MCM-AUV Programme*

In addition to the AUV Programme, the work on mine-ship interaction (Project 3C3) will deliver a mine model that can be used to evaluate the operational effectiveness of signature reduction, and mine sweeping and jamming systems. This project also provides the Thrust Area with expertise in mine technology and non-acoustic sensing that is of interest in detection systems. For instance, in 2005 the state of the art in the field of non-acoustic mine detection was reviewed for appli-cation within Project 3G1.

Long Term The long-term vision for the AUV programme is an evolution towards increased automated processing on-board the AUVs, allowing more and more “intelligent” behaviours to be implemented. This will confer increased importance to AUV networks and make non-trivial “cooperative” behaviours possible. The smart AUV network will be able to plan adaptively, conduct and evaluate its MCM mission in real time. This requires an increased capability to (a) sense the key environmental parameters, (b) simulate realistic target signatures, while conducting the MCM mission in order to drive the adaptation. In addition, it is likely that the number and quality of the sensors on the AUVs will increase, to include for example fusion of sonar data with that of non-acoustic sensors (NAD) and possibly bistatic or multistatic sonar

operations. There is a clear link between this work on NAD and the mine-ship interaction work which will be exploited.

The long-term vision for multi-sensor harbour protection systems is the introduction of additional layers. The *layered concept* refers to the integration of multiple levels of protection, awareness, and deterrence, including 1) physical barriers such as instrumented nets, 2) multiple sensors, each exploited for its particular strengths, and compensating for the limitations of other sensors, and 3) graded levels of response, including unambiguous warning and non-lethal weapons. *Integration* here means bringing together all available data into a common operating picture for situation awareness, while also facilitating command and control (C2) for resource management and response. The picture must be accessible to both military and civilian authorities and be highly automated with low false alarm rates to reduce manning requirements.

Technical Accomplishments

1: Planning and Evaluation of MCM Operations using AUVs

A new project was started in 2005 to provide a software tool to support planning and evaluation of MCM operations using AUVs. The following were accomplished;

- Conventional methodologies were adapted for planning and evaluation to make them better suited for use with high-resolution sonars.
- A shadow classification algorithm, based on information theory, was developed and incorporated into the software tool, ESPRESSO, to allow the prediction of high-resolution sonar performance.
- A detailed analysis of the algorithms in the standard NATO tool, MCM EXPERT, was carried out to assess how it could best be used with AUVs using side-scan sonars.
- A workshop was held in May 2005 to launch the Joint Research Project.

During October 2005 the CITADEL sea trial took place in which the Dorado, a Canadian semi-submersible vehicle towing a Klein sonar, working with Remus vehicles gathered side-scan sonar data containing images of mines taken at a multitude of aspects and ranges. A prototype software tool was demonstrated during the sea trial to show sonar coverage of planned missions.

2: Harbour Protection exercise of diver detection sonar against underwater intruders

A state of the art, commercially available diver detection sonar (QinetiQ's *Cerberus* sonar) was installed in La Spezia harbour in May 2005 and tested against divers, AUVs, and reference targets. The objectives of the exercise were to 1) verify the performance levels of a representative state-of-the-art detector, and 2) characterize the acoustic properties (especially target strength) of the under water threat, for threat characterization and capability planning. The detection and consistent tracking of divers were observed at ranges of 400 to 600 m under difficult conditions (strongly downward refracting sound-speed profile). This performance is believed to be representative of diver detection sonars of this class of sonar (high-frequency, cluster arrays, designed using classical monostatic active sonar concepts). Preliminary results were reported at the Turkish International Conference on Acoustics in July 2005. The analysis of target strengths of divers and other objects is underway.

3: Harbour Protection: Formulate and apply new method for measuring the target strength of divers and harbour life (seals, dolphins, turtles, etc.)

A joint research project (Oct 2005) with the Royal Netherlands Navy (RNLN), exercising the RNLN's newly upgraded minehunter (Alkmaar class), in a series of trials known as ICAM (Investigation and Capability Assessment of Upgraded MCMVs), provided the opportunity for a one-day harbour protection trial in which a new method for measuring the target strength of divers could be applied. Among the advantages of this new method are that it can be applied 1) using commercially available sonar rather than specialized instrumentation, 2) it can be applied in situ, in a harbour for instance, and 3) it can measure the target strength of animate objects like divers and other harbour-transiting life (seals, dolphins, turtles, large fish, etc.) without interference beyond insonification by the sonar. This method permits the identification of underwater threats, as well as potentially troublesome false alarms, to support underwater surveillance planning, design, operation, and understanding. In the one day trial the minehunter's hull mounted sonar was used to measure the target strengths of two divers. A report is forthcoming.

4: Development of enhanced Automatic Target Recognition (ATR) toolbox

Work on ATR concentrated on the development of techniques and algorithms that can provide higher levels of performance by making full use of the higher resolution provided by synthetic aperture sonar, with the aim of maximising the benefits accruing from the investment that has been made into SAS techniques.

5: Design of real-time SAS algorithms

This year NURC have designed a motion-compensated SAS imaging algorithm which is suitable for real-time implementation on the FPGA-based system embedded in the MUSCLE AUV. The algorithm was chosen to meet the conflicting requirements for increased efficiency and real-time constraints, while maintaining sufficient flexibility to allow easy modification of key system parameters during the validation sea trials planned for 2006. Work is ongoing to implement and test the design solutions on the MUSCLE system hardware. Preliminary results indicate that full swath two-sided real-time imaging will be achievable. The generation of SAS images onboard an AUV, ie during the mission, supports enhanced ATR performance and considerably increases the tempo of an MCM mission conducted by an AUV.

6: Low-frequency target echo modelling and model- based explosive detection

The optimization of the 3-D modelling tool FESTA has made it possible to model the echo from targets at frequencies of interest for buried mine detection and classification (up to 10-20 kHz). These new modelling approaches make it possible to solve the large number of problems associated with building databases of target echo characteristics. These databases are necessary for the development of automatic low-frequency detection and classification techniques. A major milestone was the development of a first processing technique of this kind, which is capable of determining whether a spherical object is filled with explosive. The automatic explosive detection technique was developed using a database of simulated target echoes for spherical objects, which was computed by a simplified analytical model implemented on the multi-processor Itanium CPU cluster available at NURC. This detection technique will be applied to data acquired at sea as part of the planned EVA 2006 sea trial, carried out jointly by NURC, MIT, NRL-SSC, MPL:UCSD and ARL:UT.

7: Software release of Version 2.1 of DARE (Decision Aid for Risk Evaluation)

DARE addresses the military requirement for planning and evaluating methods for MCM operations that accurately assess the risk to follow-on traffic based on the MCM effort employed. DARE 2.1 builds on the DARE 2.0 version released by the NURC in 2004 and includes new algorithms and measures of effectiveness for multiple transistors, as well as added functionality for area operations. A beta version of DARE 2.1 was used in Exercise Bell Bottoms 05 and in December 180 copies of DARE version 2.1 were distributed to NATO navies. DARE has been developed under the operational guidance of the Naval Mine Warfare Planning Evaluation and Risk Assessment Panel (NMW PERAP).

8: Understand SAS performance.

Data gathered as part of the ICAM trial from the updated Dutch Tripartite class minehunter and on the SWIFT trial using the HUGIN system, fitted with an EDGETECH SAS, has provided a data set which will allow the benefits and limitations of a very simple SAS to be examined and assessed and compared with the performance of a hull mounted wideband sonar. A specially designed resolution target was used to enable the resolution versus range performance of the SAS to be examined.

Expeditionary MCM and Port Protection publications and presentations 2005

Reports

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Robichaud, R., Rothenbach, M., Bovio, E., Yip, H., Klocke, F. MX1: Minehunting AUV experiment in Olpenitz, SR-430, (NATO RESTRICTED).

CD-ROM/DVD

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Conference presentations

Bovio, E. AUVs for port protection. New Concepts for Harbour Protection, Littoral Security and Shallow-Water Acoustic Communication. International conference, Istanbul, Turkey 4-8 July 2005.

Bovio, E., Baralli, F., Grasso, R., Cecchi, D., Vettori, G. Autonomous underwater vehicles for environmental monitoring and area protection. IWUR2005 International Workshop on Underwater Robotics for Sustainable Management of Marine Ecosystems and Environmental Monitoring, Genova, 9-11 November 2005.

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Truffert C., Lalanne X., Gabellone A., Martini D. High-resolution magnetic detection of buried mines. International Symposium on Buried Sea Mines - Threat to the security of the Baltic Sea Region, Riga, Latvia, 27-28 October 2005.

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Johnson, S.F., Lyons, A.P., Abraham, D.A., Pouliquen, E., Pautet, L. Bandwidth dependene of high-frequency seafloor backscatter statistics. c*In*: Pace, N.G., Blondel, P. (editors). Boundary influences in high frequency, shallow water acoustics. Proceedings of a conference held at the Department of Physics, University of Bath, UK, 5-9 September 2005. University of Bath, 2005:pp.169-176 [ISBN 0-86197-133-7].

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Zampolli, M., Tesei, A., Jensen, F.B. Finite element models for the solution of underwater acoustics problems. Presented at FEMLAB User Conference, Stockholm, 3-5 October 2005.

Zampolli, M., Tesei, A., Jensen, F.B. Finite element models for the solution of underwater acoustic problems. FEMLAB Conference webpage, Stockholm, Sweden.

Zampolli, M., Tesei, A., Jensen, F.B. Finite element models for the solution of underwater acoustics problems. Presented at FEMLAB User Conference, in Stockholm, 3-5 October 2005.

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Zampolli, M., Tesei, A., Philips, S., Canepa, G., Myers, V., Jensen, F.B., Blottman, J.B., Schmidt, H., Fawcett, J.A. Model based low frequency classification and detection clues. International Symposium on Buried Sea Mines - Threat to the security of the Baltic Sea Region, Riga, Latvia, 27-28 October 2005.

Zampolli M., Tesei A., Jensen F.B., Schmidt, H., Blottman, J.B. Model based low frequency detection and classification clues. International Symposium on Buried Sea Mines - Threat to the security of the Baltic Sea Region, Riga, Latvia, 27-28 October 2005.

Undersea Reconnaissance, Surveillance and Networks RSN Research Thrust Area

Overview

NATO maritime commanders recognize the difficulties, as well as the importance, of detecting submarines and small submersibles in shallow waters and choke points. The Strategic Commanders' specific guidance notes that priority is to be given to the all-weather detection and localization of submerged threats and secure identification and recognition of own submarines in littoral/shallow waters. This thrust area is addressing these objectives through research in the areas of distributed sensor fields, data fusion and network-enabled capabilities, active broadband detection enhancement methods, and operational and exercise-planning tools. Advances in detection using acoustic and non-acoustic sensors are coupled with research towards optimum platform placement, covert undersea communications, wireless networking and automated information fusion using LAN-based architectures. This work is aiming at maintaining an increased tactical advantage against submerged, mobile targets and thus adding value to expeditionary operations in unfriendly littoral environments.

Medium Term Vision

The new Thrust Area's structure consists of the following four main research themes:

1. **"Multi-sensor systems and methods"** focuses research into the UW sensor layer with particular emphasis on 1) distributed sensor system concepts, 2) data and information fusion methods and 3) cross-sensor node communication requirements.

2. **"Network-enabled capabilities"** is focused on network-centric methodologies supported by communication techniques with an aim of optimizing DCL performance, platform endurance and covertness of undersea sensor networks.

3. **"Environmental adaptation"** is focused on research into ASW operations-friendly environmental sensing techniques supporting the required prediction capabilities to optimally operate broadband LFAS systems in littoral waters.

4. **"Operational and exercise planning tools"** studies and develops information products (OPA/TPA software) in support of operational requirements expressed by the military ASW community.

Long Term vision

The shift from Sensor Centric towards Networked Centric Capabilities is accompanied by a gradual change of orientation in the scientific research. The fields of distributed sensor technology and data/information fusion become the main components of tomorrow's UW applied research, underpinned by advances in UW communications, [ad hoc] networking concepts and environmental modelling and assessment. Information superiority will be the driving force for improvements in Detection power (using optimally distributed heterogeneous sensors), Classification & Identification effectiveness (using information processing techniques, e.g. model-based data fusion), Localization & Tracking (using geographically referenced sensor and environmentally compensated sensor contacts & track fusion methodologies). Advances in space-time resolving methods and technologies will be exploited in UW applications. Each advance will be supported by related operational research, to design new CONOPS allowing

performance optimization in real situations and support effect-based strategies in respect of environmental constraints and regulations.

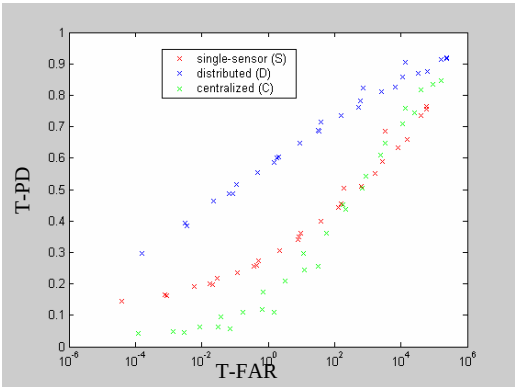
Framework table

UNDERSEA RECONNAISSANCE, SURVEILLANCE AND NETWORKS		
MultiSensor Systems and Methods	Multistatic Active Sonar (4A3)	Doug Grimmett
	Non-Acoustic Sensors Surveillance Network (4A4)	Stephane Jespers
Environmental Adaptation	Broadband Environmentally Adaptive Sonar (4C3)	Georgios Haralabus
	Through-the-sensor Environmental Assessment (4C2)	Peter Nielsen
	Performance Model for Multistatic Reverberation-Limited Sonar (4C4	Mark Prior
Decision Aids	Sound Oceanography and Living Marine Resources (4F1)	Mike Carron
	Area Search Tactical Planning Aid (ASTPA) (4F2)	Craig Carthel
	Multistatic Tactical Planning Aid (MSTPA) (4F3)	Ringo Wathelet
Network Enabled Capabilities	Time Reversal Techniques for Underwater Communications (4G3)	Mark Stevenson

Technical accomplishments

Advances in multistatic fusion and tracking algorithms

The main accomplishment was the continuing advances made in the area of multistatics data fusion and tracking algorithms. The Centre is pursuing contact-based multiple hypothesis tracking (MHT) approaches for the multistatics application with both centralized (single stage) and distributed (two-stage track fusion) architectures.



Recent modelling has shown the potential for the complementary use of Doppler sensitive and insensitive waveforms within a fixed deployed multistatics field. Extensions to the multistatics tracker have been made which will allow for the exploitation of Doppler information in addition to range and bearing.

Figure RSN.1 *ROC curves for three tracker architectures, for a range of track initiation settings (M=2-8, N=2-11) for the modelling of a four-node multistatic network. The target is fading in and out of view on each single sensor, and the best tracking performance is achieved with the distributed architecture.*

Target echo classification algorithms can provide an important benefit to the tracker performance, and tracker extensions have been designed to exploit this information. This upgrade includes the ability to enhance the likelihood calculations to reflect the different but known statistical distributions for targets and false alarms, or, by augmenting the tracker filter

state such that time correlations in classification features may be tracked. These new capabilities will be evaluated more extensively with sea trial data.

In 2005 the Centre participated in the first year of the Multistatic Tracking Working Group (MSTWG), which includes representatives from eight organizations from US (APL/UW and ARL/UT), NL(FEL/TNO), GE(FWG, FGAN) and NATO. This group's purpose is to evaluate multistatics tracking algorithms on common simulated data sets. A modelling capability and multistatics contact simulation capability has been developed to produce the data sets needed for this group's work.

Geo-magnetic/electric noise compensation applied to distributed bottomed sensors

With no additional NGAS JRP sea trial this year, further non-acoustic data analysis of previous 2004 trials was pushed deeper throughout the year within the various partner laboratories: FFI in Norway, DRDC-Atlantic in Canada and SPAWAR in US. The geo-magnetic compensation of the three-axial magnetometers data from Muws3P (Dowty/Ultra Electronics) and Mag-03 (Bartington) proved to be somewhat more difficult than expected due to the presence of slow calibration drifts, some being correlated with external conditions such as the temperature. Nevertheless, noise reduction levels in excess of 10 dB were generally achieved below 20 mHz. In the higher frequency spectrum above 100 mHz, it was found by FFI that swell-induced magnetic noise was coherent with pressure sensor measurements and that therefore a substantial noise reduction was achievable. Geomagnetic noise compensation of Overhauser scalar magnetometers brought by SPAWAR showed impressive noise reduction levels in excess of 20 dB. This was mainly due to very good resistance of those sensors to calibration drifts. All the reported results above mentioned are for a distributed field of sensors several hundreds of meters apart. In a particular set-up, noise compensation was also achieved successfully using a Bartington reference sensor on land. Remarkably, FFI reported similar success in geo-magnetic noise compensation using data delivered via Internet by the Tromso Geophysical Observatory who has a number of magnetometer stations in different places of Norway (the nearest one is some 60 Km away from the noise range where the trials were performed). FFI reported also strong noise suppression in excess of 20 dB on single-axis Electric field sensors brought by DRDC-Atlantic (base-lines of 5 and 100 m). These encouraging results will now be applied in the design of the Centre's demonstrator platform which is intended to be based on the SEPTR oceanographic buoy platform.

Potential of MIMO concepts applied to underwater acoustic communications

Since 2003, NURC has conducted a series of time reversal experiments at a frequency of 15 kHz, which is a commonly used frequency for underwater digital communications. Analysis suggests applications to undersea communications whereby time reversal provides an opportunity to implement space-time multiplexing in complex environments. Our experiments indicate that vertical aperture provides a capability for implementing multiple-input-multiple-output (MIMO) communications which may increase data throughput without increasing power or bandwidth. During 2005, we extended findings resulting from earlier pilot studies at 3500 Hz that demonstrated the ability to focus acoustic signals at individual hydrophone elements of a vertical line array. This technique could possibly be extended to communications signals.

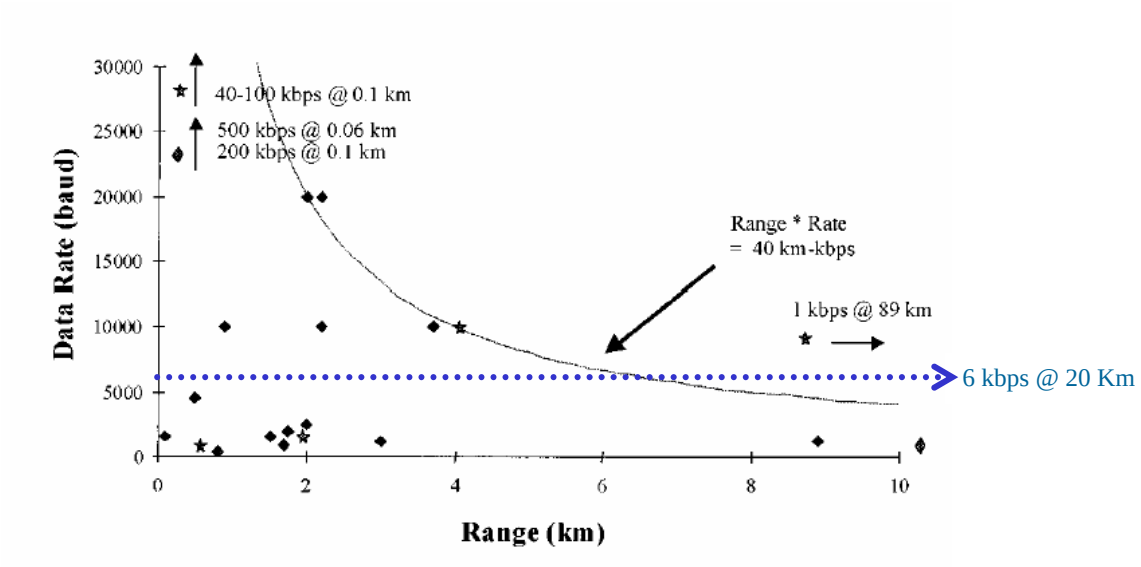


Figure RSN.2 *The figure above provides a basis for comparison of the trialled MIMO three-channel 16-QAM transmissions conducted during FAF-05 (which provided 6000 bps in shallow (~100 m) water at 20 km) with other known industrial and research references.*

This project's major undertaking during the reporting period was the FAF-05 sea trial, conducted 11-23 July 2005. The sea trial was a collaborative effort between NURC, the Marine Physical Laboratory of Scripps Institution of Oceanography, Massachusetts Institute of Technology, Woods Hole Oceanographic Institution, and the University of Pisa. The sea trial involved about 40 scientists.

Broadband LFAS calibration and performance prediction

Significant progress was made in active detection performance analysis, sonar performance model verification and environmental parameter sensitivity studies. As there were no related sea trials this year, detection analysis was based on data from the BASE ’02 and BASE ’04 experiments (both are submarine trials). The sensitivity of active detection performance to geometric parameters contributes to the overall detection problem, as common tactics to elude detection are associated with depth and aspect variations. Our results may be utilized for the validation of simulation scenarios that model realistic targets. Our efforts in this direction continued with the calibration of the cardioid beamformer. Analytical expressions are provided for the calibration of CW and LFM signals and real data comparison with LFM data acquired during the BASE ’04 sea trial. Using the SUPREMO model a sensitivity analysis was initiated to prioritize environmental parameters based on their effect on signal-to-background ratio.

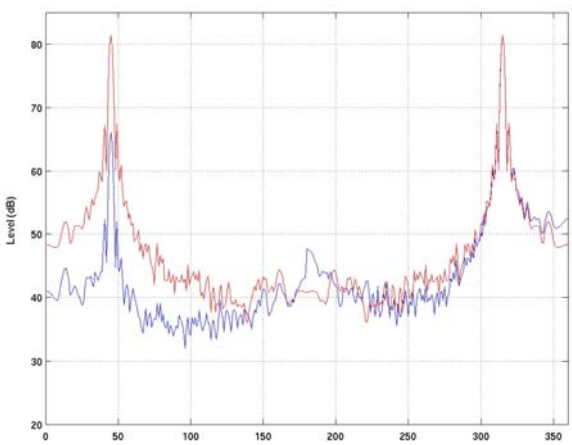


Figure RSN.3 *Beam patterns for line array processing (red) and calibrated Centre cardioid processing (blue) for a simulated point target at 315 degrees.*

At this stage in the project, our efforts are aiming to accommodate the convergence of the three components of the environmental adaptation concept in order to achieve optimization of sensors performance through on-site environmental assessment, modelling and adaptation of sonar characteristics.

Validation of low frequency forward geo-acoustic inversion

A validation of the geo-acoustic properties obtained by matched-field inversion of horizontal array data from the MAPEX 2000 experiments has been performed. The acoustic data used for the inversion covered a frequency band from 250 to 750 Hz and received 250 m towed horizontal array. The acoustic data used for validating the bottom characterization from this inversion were received simultaneously on a bottom-moored 64-element vertical array along a 10-km weakly range-dependent track. The acoustic data for the horizontal array inversions were acquired during spring with almost iso-velocity water-column properties. In addition, vertical array data for validating the extracted bottom properties were also acquired during a sea-trial in the autumn with typical down-ward refracting shallow-water sound-speed profiles. The acoustic track has both range-dependent bathymetry and bottom properties, and in order to predict the data on the vertical array for the two seasons the fully range-dependent propagation model RAM was applied. The model-data comparison of depth-averaged transmission loss as a function of propagation range and frequency is shown in Fig. RSN.4: left panels represent the spring trial and the right panels the autumn trial.

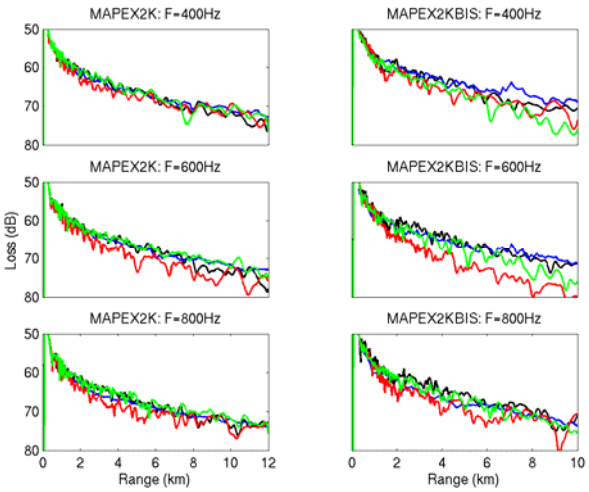


Figure RSN.4 *Model-data comparison of depth averaged transmission loss. The left panels represent the spring trial and the right panels the autumn trial. The blue curves are data, black is prediction using inverted bottom properties, green is database information, and red is assuming range-dependent bathymetry but range-independent soft bottom properties.*

In general the prediction capabilities are improved by using extracted bottom properties from inversion of horizontal array data. Errors up to 10 dB in the predictions are obtained in this case at particular frequencies and at maximum propagation range by relying on database information or a simplified description of the bottom with wrong properties. The same analysis is planed on acoustic data at frequencies up to 3 kHz acquired during the BOUNDARY JRP trials.

In June and September 2005 NATO Undersea Research Centre hosted 2 Joint Research Project meetings concerning *Geoacoustic Inversion of Low-Frequency Reverberation* and *Environmental Adaptation for Multistatic Sonars*, respectively. The latter was a combined status meeting of the ongoing Joint Research Project and a kick-off meeting of the new approved Joint Research Project *Characterization and Reducing Clutter in Broadband Active Sonar.*

This project is linked to international research *via* a JRP with CA (DRDC-Atlantic), US (ONR/NRL and Penn State University) and NL (TNO). The research and collaboration is directed toward supporting the broadband environmental adaptive sonar target capability (Projects 4C3 and 4C4) in the Thrust Area.

SUPREMO validation via comparison with measured data

Predictions of acoustic reverberation and target echo intensity, made by the SUPREMO sonar performance model, were compared with measured data gathered in the Malta Plateau region of the Mediterranean Sea. The model's ability to predict these quantities was demonstrated.

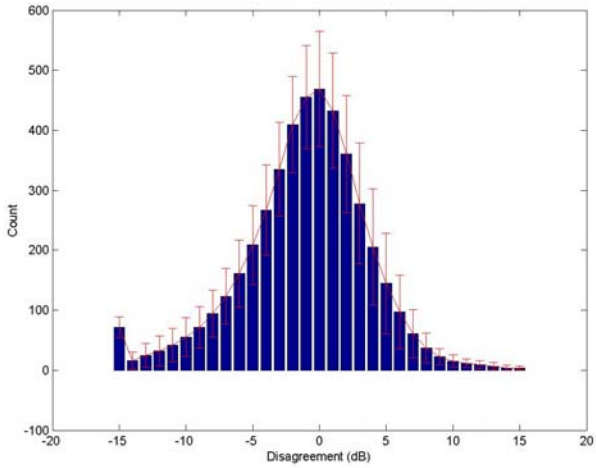
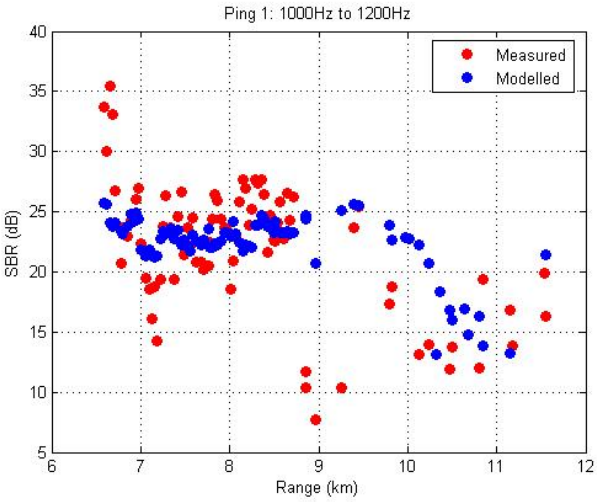


Figure RSN.5 shows that the model is capable of predicting reverberation intensity with most frequently encountered errors of magnitude around -1dB with a spread of ±4dB around this value.

Figure RSN.5 *Histogram of model-measured disagreement.*



Furthermore, as shown in Fig. RSN.6, the model was shown to be able to predict trends in signal-to-background ratio as pulse centre frequency was varied between values of 1000Hz, and 1800Hz with bandwidths of 200Hz and 800Hz. Figure RSN 6 shows results from one pulse with BW=200 Hz (1-1.2 kHz).

Figure RSN.6 *Echo-repeater signal-to-background ratio compared to SUPREMO predictions.*

Marine Mammal Risk Mitigation website update

In May the project hosted an Intergovernmental Conference on the Effects of Sound on Marine Mammals. This four day meeting, held in Lerici, Italy, was attended by approximately 100 scientists and decision makers from NATO maritime nations and Australia.

The project lead a multi-ship engineering test and experiment during the fall of 2005, *Mar Ligure* Joint Experiment 2005, in the Gulf of Genova (Ligurian Sea) to test new acoustic equipment developed by the Centre and also by the Centro Interdisciplinario di Bioacoustica e Ricerche Ambientali, Università degli Studi di Pavia (Interdisciplinary Centre for Bioacoustics, University of Pavia, Italy) designed to record the vocalizations of the illusive *Ziphius cavirostris*. The primary vessel used by the Centre was the CRV *LEONARDO*. Additional acoustic, visual, and oceanographic measurements were made from the Italian Hydrographic Office Ship *ARETUSA*,

the BluWest Whale Watching Vessel *STENELLA*, the R/V *KRILL* from the Centro in Toscana per l'osservazione e studio dei cetacei (Tuscan Centre for the Observation and Study of Cetaceans), and the R/B *MENKAB* from the Università degli Studi di Genova (University of Genoa, Italy). Scientists from University of Florence participated with visual observations onboard Krill and University of Genova (DIPTERIS) made oceanographic and chemical measurements onboard *LEONARDO* and *ARETUSA*.

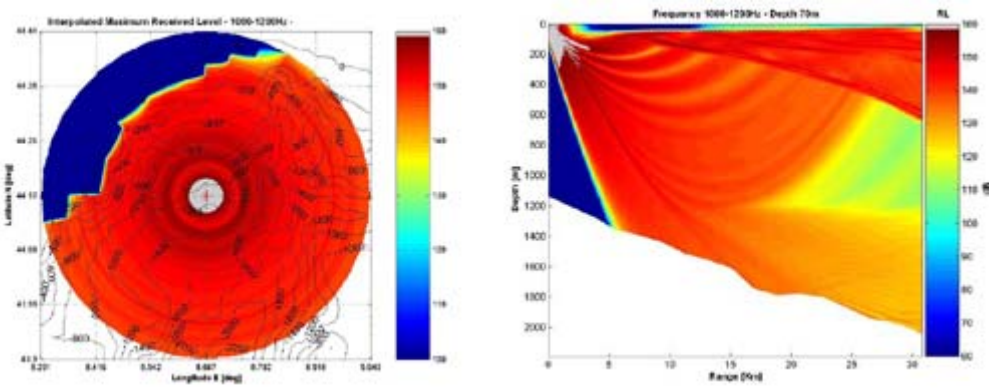


Figure RSN.7 *Solmar Tool kit welcome page*

The Project also updated its webpage (http://solmar.nurc.nato.int) with the addition of a training section on the Marine Mammals of the Mediterranean containing visual and acoustic information and a prototype Environmental Scoping Toolkit for the Mediterranean (figure above is an illustration of the toolkit welcome page).

Release of ASTPA version 1.0

The Area Search Tactical Planning Aid (ASTPA) is a personal computer based tool which is intended to assist in the development of area search tactics for mono-static acoustic systems. In ASTPA, search tactics development is driven by user-defined expected target behaviour. ASTPA development is overseen by the Area Search and Screening Panel (AS2P) which met during February to discuss the beta version of ASTPA and to recommend future upgrades. The following are improvements made to ASTPA during the year. ASTPA was upgraded to support geodetic coordinate systems and to display maps. A scenario generation wizard was developed to aid in the initial construction of complex scenarios.

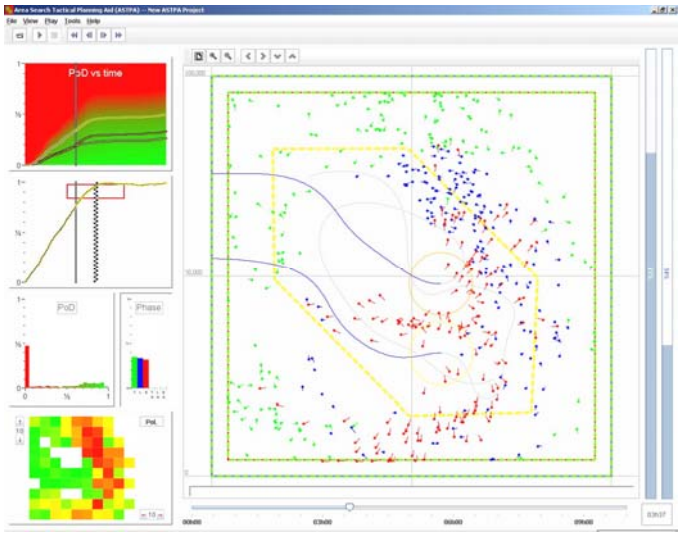


Figure RSN.8 *Screenshot of ASTPA's scenario viewer during an area clearance scenario. The main window animates a Monte-Carlo simulation of the scenario. The yellow hexagon represents the area which is to be cleared of undetected targets. A target's behaviour depends on its phase which can be patrolling (green), localizing (blue), or avoiding (red). The top graph represents the scenario's cumulative detection probability as a function of time. The second graph represents the probability that the clearance area is cleared of undetected targets as a function of time. The checker*

line in this graph indicates the time at which it is desired to have the area totally cleared. The bottom density plot represents the distribution of undetected targets at the current scenario time.

Graphical editing abilities in the scenario editor were enhanced to allow existing scenarios to be resized and transformed into new scenarios. Additional measures of effectiveness were integrated into the user interface and optimization algorithms, which allows for the development of tactics for area clearance and barrier operations.

The simulation engine was enhanced by refining the definition of target behaviour and by improving the sonar equation calculations. The optimization algorithms were enhanced to include additional constraints which give the user more control over the complexity of the resulting solutions. A ping optimization algorithm was incorporated into the optimization algorithms. User guides for ASTPA and the ASTPA wizard were developed. ASTPA version 1.0 was released in early December.

Undersea Reconnaissance, Surveillance and Networks publications and presentations 2005

Peer reviewed journal papers (published)

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Coraluppi, S. Multistatic Sonar Localization, *IEEE Journal on Oceanic Engineering*, **30**, 2005.

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Teloni, V., Zimmer, W.M.X., Tyack, P.L. Sperm whale trumpet sounds, *Bioacoustics*, **15**, 2005:163-174.

Zimmer, W.M.X., Tyack, P.L., Johnson, M.P., Madsen, P.T. Three-dimensional beam pattern of regular sperm whale clicks confirms bent-horn hypothesis. *Journal of the Acoustical Society of America*, **117**, 2005:1473-1485.

Peer reviewed journal papers (submitted)

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Coraluppi, S., Grimmett, D., Carthel, C., Gerard, O. Multistatic sonar tracking: technical advances and sea trial evaluation. Submitted to U.S. *Journal of Underwater Acoustics*.

Reports

Coraluppi, S., Grimmett, D., Gerard, O. Distributed multi-hypothesis sonar tracking and extensions, SR-421 (NATO CONFIDENTIAL).

Coraluppi, S. Performance Modelling and Validation for Distributed Multistatic Tracking, SR-397.

Grimmett, D. Multistatic sensor placement with the complementary use of Doppler sensitive and insensitive waveforms, SR-427.

Haralabus, G. Baldacci, A. Active detection performance sensitivity to target depth and aspect changes in a shallow water environment, SR-433 (NATO CONFIDENTIAL).

Nielsen, P.L., Fallat, M., Marconi, V. Seabed characterization by inversion of acoustic propagation and reverberation data received on a towed horizontal array, SR-417.

Prior, MK., Baldacci, A. Comparison between predictions made by the SUPREMO sonar performance model and measured data, SR-429.

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Baldacci, A., Haralabus, G. Adaptive normalization of active sonar data. UDT Europe 2005.

Coraluppi, S. Analysis of Tracker Performance Models for Centralized and Distributed Tracking. 8th International Conference on Information Fusion, July 2005, Philadelphia PA, USA.

Willett, P., Coraluppi, S. Application of the MLPDA to Bistatic Sonar. 2005 IEEE Aerospace Conference, March 2005, Big Sky MT, USA.

Coraluppi, S. Localization and Fusion in Multistatic Sonar. 8th International Conference on Information Fusion, July 2005, Philadelphia PA, USA.

Erdinc, O., Areta, J., Coraluppi, S. Willett, P. Multistatic Sonar Sensor Placement: A Tracking Perspective. *2005 SPIE Conference on Signal and Data Processing of Small Targets*, August 2005, San Diego, USA.

Haralabus, G., Baldacci, A., Laterveer, R. Active detection enhancement in coastal areas. Underwater Acoustic Measurements - Technologies and Results, International Conference, Crete, Greece 2005.

Nielsen, P.L., Fallat, M., Dosso, S., Siderius, M. Measurements of weakly varying geoacoustic properties and their impact on acoustic propagation. Proceedings of the International Conference on Underwater Acoustic Measurements: Technologies and Results, Heraklion, Crete, Greece, 28 June - 1 July 2005.

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Roux, P., Kuperman, W.A., Culver, R.L., Lutz, S.D., Bradley, D.L., Stevenson, M. On the relationship between sea state and the coherent-to-incoherent intensity ratio for high frequency, shallow water propagation. 149th Meeting of the Acoustical Soceity of America, Vancouver, Canada, 16-20 May 2005. *Journal of the Acoustical Society of America*, **117**, 2005:2433:2aUW8.

Tesei, A., Stevenson, J.M., Sabra, K., Roux, P., Akal, T., Kuperman, W.A. Comparison of data processing methodologies for robust detection of small intruders crossing a high-frequency, time-reversal-based acoustic barrier. New Concepts for Harbour Protection, Littoral Security and Shallow-Water Acoustic Communication. International conference, Istanbul, Turkey 4-8 July 2005.

Tesei, A., Stevenson, M. A forward-looking acoustic barrier for detecting and tracking small underwater intruders - experimental results. Underwater Acoustic Measurements - Technologies and Results, International Conference, Crete, Greece 2005.

CD-ROM/DVD

Stevenson, M., Guerrini, P., Akal, T., Kuperman, W., Hodgkiss, W., Cavanna, A. FAF05 Focused Acoustic Field Studies, CD-83.

Guide to the cetaceans of the Mediterranean Sea (English version). CD-84.

Guida ai cetacei del Mediterraneo (Italian version), CD-85.

Grimmett, D., Wathelet, R. Proceedings of the NATO Workshop on Multistatic Operations Research held at NATO Undersea Research Centre on 15-17 November 2005, CD-88, NATO RESTRICTED.

Baldacci, A., Carron, M., Portunato, N. Infrared Detection of Marine Mammals. European Cetacean Society Meeting, April 2005, La Rochelle, France, DVD-5.

Expeditionary Operations Support (EOS) Research Thrust Area

Overview

NATO military planning emphasizes the ability of expeditionary forces deploy and operate anywhere in the world. The NATO Response Force is a critical element of expeditionary operations and will be required to deploy on five days notice often under crisis conditions without adequate advance knowledge and intelligence of the operating area, which will often include the littoral zone. The METOC staffs at both Strategic commands have developed an integrated Meteorological and Oceanographic (iMETOC) support plan that provides the framework for future operational support to NATO operations including the NRF.

The principal, long-term objective of the Expeditionary Operations Support (EOS) Thrust Area is to improve NATO's capability to assess and exploit the operational environment in support of future NATO operations. Support for expeditionary operations will involve data collection, data analysis and data dissemination in the littoral. The EOS Thrust Area aims to deliver military capabilities that are designed to develop and transition new capabilities to support these activities.

EXPEDITIONARY OPERATIONS SUPPORT		
High Resolution Environental Modelling and Shallow Water Acoustics	Air-Sea Interaction Effects on Expeditionary Warfare (Proj. 1A2)	Joao Texeira
	NATO Surf Modelling (Proj. 1A3)	Daniel Conley
	NATO Tactical Ocean Modelling System (Proj. 1A5)	Emanuel Coelho
	Acoustic Modelling and Prediction Capability Development (Proj. 1C1)	Thomas Folegot
	Shallow Water Acoustic Tomography (Proj. 1C2)	Thomas Folegot
Data Collection for Battlespace Preparation	Battlespace Characterization using Autonomous Vehicles (Proj. 1B1)	Francesco Spina
	Battlespace Preparation using High-Resolution Satellite Remote Sensing (Proj. 1B4)	Farid Askari
	Geoacoustic Inversion of Ambient Noise (Proj. 1C3)	Chris Harrison
Data Fusion and Exploitation	Fusion and Exploitation of Geospatial Information (Proj. 1D1)	Farid Askari
	REA/REP Communications in a Netcentric Architecture (Proj. 1D2)	Alex Trangeled

The technical focus of the EOS Thrust Area is development of "out of area" capabilities required to support Expeditionary Operations and the NATO Response Force (NRF). This effort is consistent with the Integrated METOC concept accepted by the Nations on 24 October 2005 and supports the development of the Recognized Environmental Picture (REP). This is a Bi-SC concept and is integral to supporting the NRF and expeditionary operations. The research goal of the EOS Thrust Area is to develop the capabilities needed to enable the successful

operational implementation of the REP, with the ultimate objective of assisting the CJTF and maritime commander to exploit the environment to their strategic and tactical advantage.

The EOS Thrust Area is structured into three research areas:

- Geospatial Information Services and Communications:
- Small Scale Oceanographic Prediction Systems:
- High Frequency Acoustic Propagation:

Vision

Medium Term The overarching goal of the EOS Thrust Area is to develop and demonstrate methods for timely collection, analysis and dissemination of METOC information and products for operational use. The thrust area will continue to move into new technical areas to better support NATO's plans for iMETOC and the REP. The principal efforts are (1) development of covert data collection for battlespace characterization using remote sensing and autonomous vehicles, (2) improvement of methods for METOC data analysis, prediction and effects and (3) investigation of geospatial data services to provide timely exchange of METOC data and efficient use of the information technology infrastructure. Battlespace characterization uses X-Band remote sensing ground station and advanced all weather, high-resolution satellite measurements. Seabed mapping with AUVs and a supporting network of profiling buoys will be equipped with a wide range of sensors and exercised together with international collaborators to evaluate REA performance. The AUVs will go thorough a series of sonar and programming upgrades for survey work aimed at the capacity for intelligent, covert shallow water surveys in unfamiliar waters. METOC data analysis and prediction is focused on improving our knowledge and abilities in littoral waters including coastal regimes. The primary effort is better understanding the effect of air-sea interaction on operations. Geospatial data service efforts are exploring the open standards Geographic Information Systems (GIS) for operational support as well as new methods for processing and analysing Geospatial and remote sensed data.

Long Term Vision (Beyond 2007) The long-term vision for the EOS Thrust Area is the evolution of an innovative approach to provide integrated METOC support to NATO expeditionary operations. Geospatial data fusion technologies will become increasingly important in the efforts to support NATO's evolving plans for the IETOC concept. The littoral and coastal zones including, air-sea interaction on operations, will continue to be one of the major drivers for the thrust area. Characterization of the battlespace environment, data assessment and sensitivity, and the generation, maintenance and delivery of the Recognized Environmental Picture will be the three main areas of research. Space based remote sensing, autonomous vehicles, acoustic tomography and in situ sensors will be used to measure METOC parameters in a sampling network, and then combined using robust data assimilation methods to provide advanced battlespace characterization. New applications of satellite systems will be employed with new oceanographic and acoustic models to define adaptive precursor and covert sampling strategies for cooperating autonomous aircraft, vehicles, vessels and buoys. The data from targeted measurements, model results and archives will be fused into networked GIS visualisations, performance models, and graphical decision aides provided to ship and shore via networked Command and Control Information Systems.

Technical Accomplishments

Geospatial Information Services and Communications

Fusion and Exploitation of Geospatial Information: At the end of 2005 the architectural Design of the GDFC (Geospatial Data Fusion Centre) has been completed along the OGC/ISO specifications and based on OS software. The servers for features (WCS) and maps (WMS) are also completed and operational, initially as support of a pilot application (WEB publication of marine mammals strandings and sightings in support of the Marine Mammal Risk Mitigation project). An operational demonstration of the interoperability of the OGC servers was conducted in the major NATO exercise Coalition Warfare Interoperability Demonstration (CWID) 2006. Preparation of TDAs by fusion of model products with remote sensing data using fuzzy logic was also tested and demonstrated.

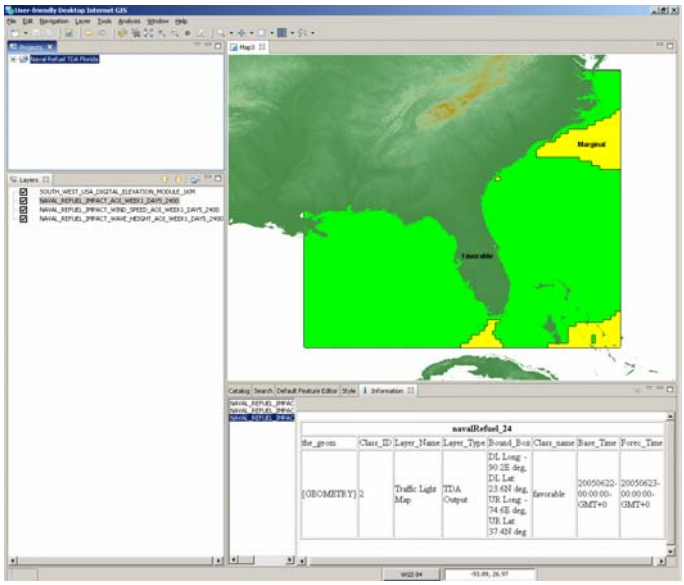

Figure EOS.1 *UDIG (an OS, ISO compliant GIS client) shows a multi-layer map from NURC WMS (Map Server). The layers are the DEM, a traffic light TDA (Naval Refuel) , and the input METOC data from which the TDA was derived with fuzzy logic rules. The low, right window shows the values of the input data on a selected position.*

Remote Sensing X-Band Antenna Ground Station: The Centre continued expansion of the remote sensing capabilities developing the capability to fully utilize the X-Band Antenna Ground Station in support of the SPOW and other activities. The X-band ground station provides a unique capability within NATO to receive satellite remote sensing imagery in real-time from the following satellites: TERRA/MODIS, AQUA/MODIS, RADARSAT1, ENVISAT-ASAR, and ENVISAT-MERIS. In 2005 RADARSAT International and the Canadian Space Agency CSA certified the NURC to receive and disseminate RADARSAT-1 imagery to various users making the NURC a member of networked ground stations around the globe. NURC also was authorized by the European Space Agency (ESA) to receive and exploit the use of ENVISAT imagery for Earth observation and validation. A successful test of our ability to deploy and operate the system at a remote location was conducted in November at the Italian Naval Arsenal in Aulla.

REA Network Simulator: An initial version of a network simulator has been developed. This tool integrates communications modelling, emulation and data ingestion, to mimic the primary elements of a virtual REP network, including maritime WLAN and EMACS/FE. Communications

between virtual computers is simulated utilizing actual applications software, providing a firm test bed for the development and real-time testing of future REA/REP network using limited resources on a single platform. The aim is to provide the means to identify the technical capabilities required to successfully deliver the REP to expeditionary operations, including the NATO Maritime Reaction Force (NRF), and allow the operator to identify alternative processing strategies and delivery mechanisms in order to successfully deliver appropriately scaled product in a timely manner utilizing available NATO infrastructure.

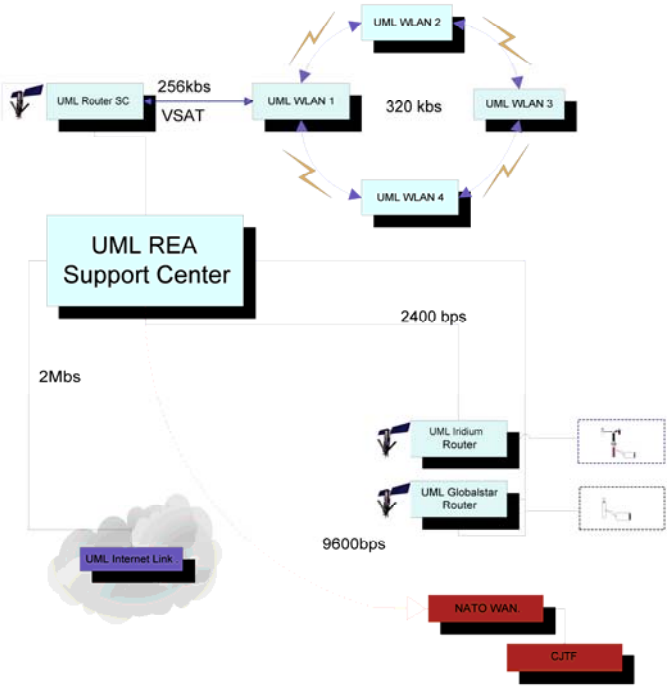

Figure EOS.2 *Example of simulation scenario with deployed wireless LAN and Forward Eyes system.*

Small Scale Oceanographic Prediction Systems:

Tools for Rapid Environmental Assessment: The recent technical accomplishments of this project are twofold. First, standard multi-model super-ensemble (SE) techniques have been successfully applied to acoustic and surface drift problems. Secondly, the standard multi-model technique has been drastically improved by combination with a multi-scale/multi-process approach, the so-called Multi-Scale Super-Ensemble (MSSE), which allows to recover high frequency phenomena usually averaged out in the original method (Fig. EOS.3). A demonstration of these achievements was to occur during the DART05 sea trial, a 26 institutions collaborative effort, now postponed to 2006 because of the *ALLIANCE* grounding. It is expected that the MSSE concept will serve as a paradigm for data fusion in a networked enabled environment, directly contributing to the Recognized Environmental Picture (REP) and providing the NRF with definitive Information Superiority through efficient and reliable environmental forecasts.

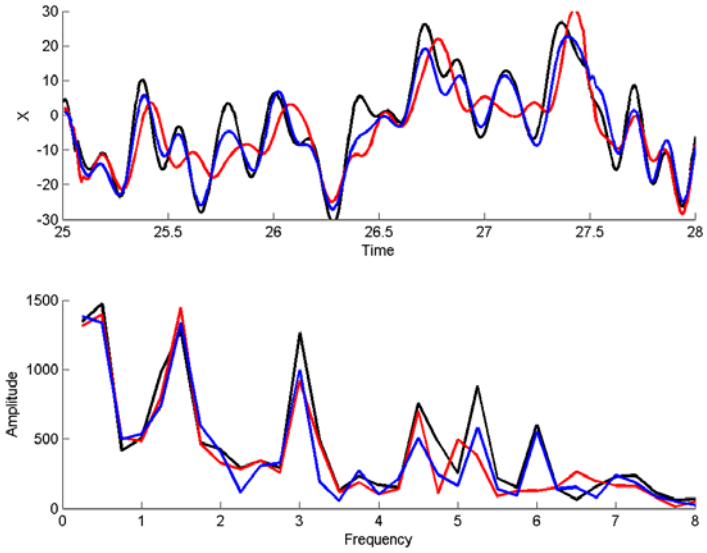

Figure EOS.3 *Time series (top) and spectra (bottom) of reference run (black), optimal Super-Ensemble (SE, red) and Multi-Scale Super-Ensemble (MSSE, blue) over time.*

High Resolution Coastal Prediction: During this period the NURC High Performance Computing Cluster was upgraded to increase performance and to allow it to run a high resolution coastal mesoscale model. Memory was increased from 1GB to 4 GB per node and disk space was increased to 500 GB shared. This was an essential part of the preparation for the utilization of the mesoscale prediction system COAMPS-OS (Coupled Ocean Atmosphere Model Prediction System- On Scene) at NURC. The first successful model run was conducted on 2 December. NURC is now coordinating a World Meteorological Organization (WMO) working group dedicated to the evaluation of atmospheric models over the ocean, in particular for air-sea interaction parameters, with the participation of seven nations. A workshop was organized at NURC on 'High-resolution Coupled Coastal Prediction' with more than 35 external participants from 11 nations. This workshop reported on the significant scientific and technical challenges for providing high resolution environmental support in a coastal region.

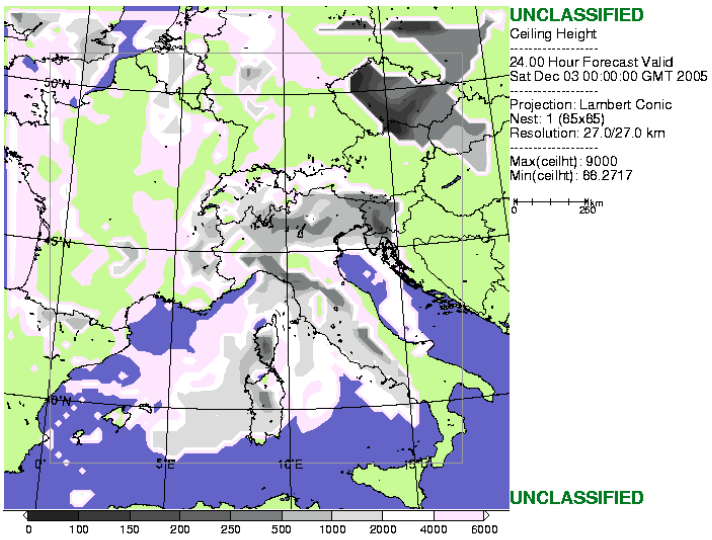

Figure EOS.4 *24 hour prediction of cloud ceiling height from the first high-resolution COAMPS-OS simulations performed at NURC.*

Seabed mapping payload (SMP) on the Ocean Explorer AUV: Work commenced on upgrade of the SMP which will include sea bed mapping sensors (normal incidence programmable wide band echo sounder, Forward Looking sonar, and possibly a high resolution bathymetric sensor). It also includes a payload computer for sensors control, data acquisition and real time data processing, and ready to host software for adaptive missions. By the end of 2006 OEX will be able to operate autonomously on unknown sea floors for battlespace preparation Cat 3 missions

Shallow Water Prediction: A field exercise which was conducted at Porto Ferro, Sardinia in February 2005, with the collaboration of multiple research partners from Italy and the USA. It resulted in an excellent data set for illustrating the limitations of surf zone modelling techniques as well as for validating more sophisticated 3-D surf models. Initial 3-D modelling efforts at this site were begun both at NURC as well as at NRL, Stennis Space Center. A simple analytical swash boundary condition for 3-D surf models has been tested using the Porto Ferro data and the directions for improvements to this algorithm have been identified. Progress is continuing in the area of sediment transport modelling including effects on Mine Burial and a major development for the improvement of nearshore predictions was presented at the Coastal Dynamics conference.

As part of the concluding efforts of the 1-D surf modelling project, a relatively simple Matlab based graphical user interface for performing surf modelling has been developed and tested against multiple data sets. The software and a user manual will be distributed to the member nations.

Figure EOS.5 *Photo of the SURF04 field site on a low energy day. Four instrument clusters and swash bathymetry monitoring stakes can be seen in the lower left foreground and Leonardo performing multibeam survey is seen in the background.*

The Forward Eyes final proto-type system was developed and demonstrated during Loyal Midas 2005. The system was completely installed and data collection of relevant site information was 100% performed by a Spanish UDT team and the associated REP data was distributed via an autonomous web page creation package. Testing of the system has shown that the expected lifetime of the sensors in the Forward Eyes system exceed the design lifetime of 10 days.

High Frequency Acoustic Propagation

Sub Bottom Profiling using Ambient Noise: Work at NURC has shown that various seabed properties can be obtained from the directionality or coherence of ambient noise. These can also be mapped by a moving array. To date measurements have been made with a drifting vertical array, and these properties include: reflection loss, geoacoustic parameters of a number of upper sediment layers, profiles of layers relative to the seabed. Recently another processing technique, where upward and downward beams from the same VLA are cross-correlated, has been developed to obtain an absolute depth from the sea surface. This also shows potential for mapping returns from directions other than the specular, and perhaps separating out scatter returns from a rough surface or even point-like objects.

Work continued on a demonstrator for an autonomous system (64 element nested vertical line array, design frequencies: 2, 4, 8 kHz).is being built by NURC, and experiments are expected in the 2006. An air deployable prototype may be developed in the future.

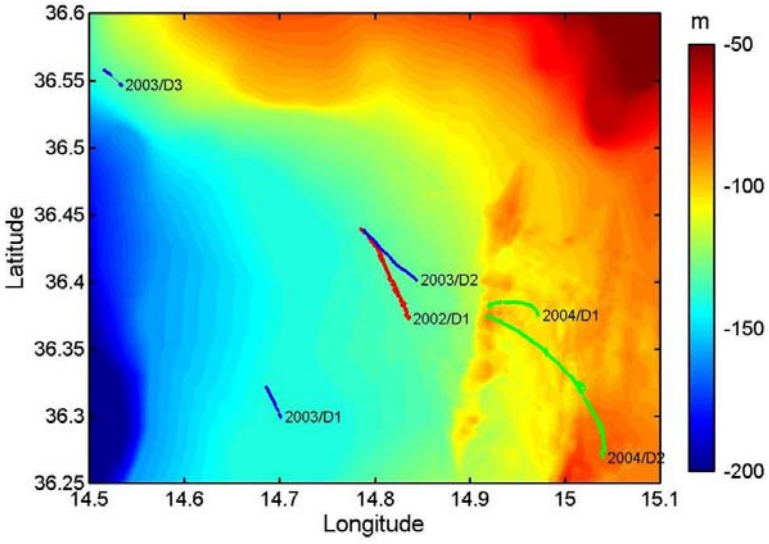

Figure EOS.6 *Map of VLA and MFA drifts to date. Important ones are 2003 on the Malta Plateau (blue) and 2004 on the Ragusa Ridge (green)*

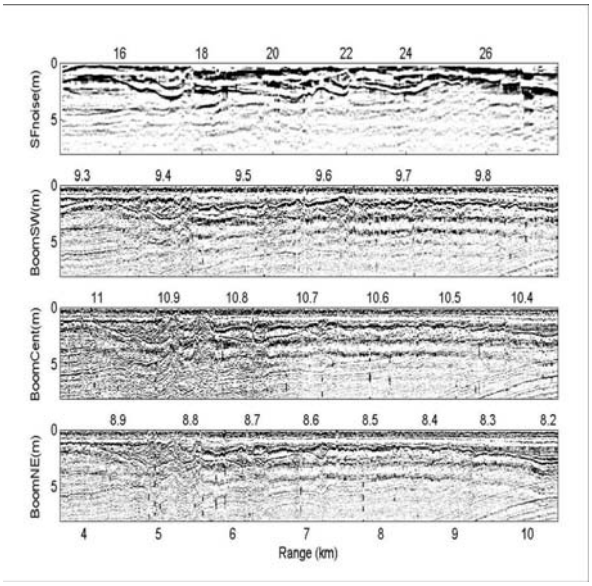

Figure EOS.7 *Comparison of processed noise during a 12 hour (6 km) drift with a seismic boomer. In the top frame is sub-bottom layers derived from noise using spectral factorization to get the phase, do the FFT, and then get a profile. The other frames are three boomer records with seabed shifted to zero depth along, and to either side of, the drift track.*

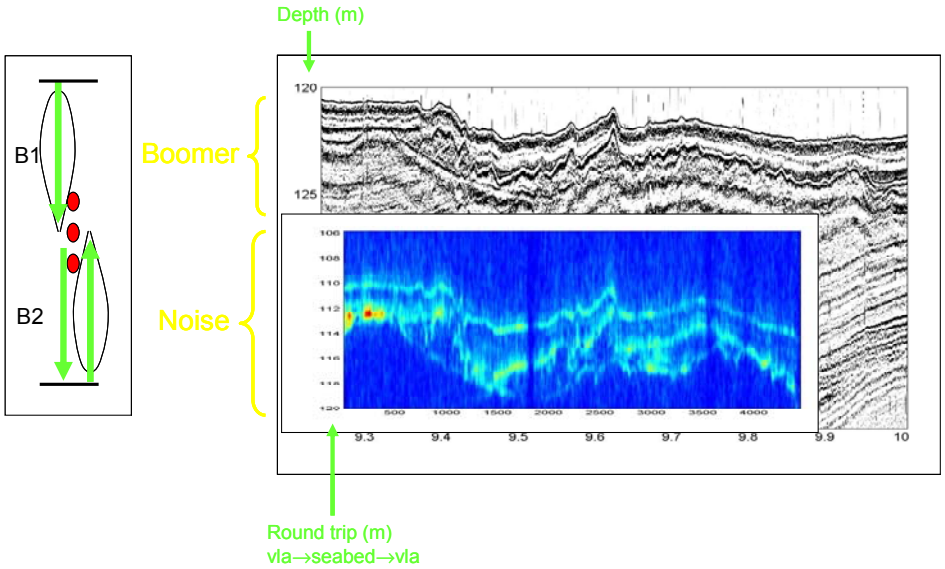

Figure EOS.8 *Comparison of the same noise and boomer but processed a different way so that the noise gets an absolute depth directly. The blue panel is the result of cross-correlating the time series received on a vertical upward beam with that on a vertical downward beam. The black and white is unaltered boomer.*

High Frequency Acoustic Propagation Studies: Processing the complementary data from partner experiments BARRIER04 (NURC) and DOREV05 (FR), allowed improvement of the Gaussian Ray Acoustic Beam simulation tools to be made to significantly increase the accuracy of the model outputs in very shallow waters below 20 kHz. These improvements have been validated during the FAF05 sea trial in Elba. As part of the ongoing HF Acoustics JRP, NURC personnel participated in the Makai05 cruise off Hawaii from September 15th to October 2nd 2005 to provide a comprehensive study of acoustic propagation in the 8-15 kHz band for diverse applications, from tomography to underwater communications. The structure of the received impulse functions shows strong variability although resolved arrivals are persistent in this highly dynamic environment.

Expeditionary Operations Support publications and presentations

Peer reviewed journal papers (published)

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Allen, J.T., Brown, L., Sanders, R., Moore, C.M., Mustard, A., Fielding, S., Lucas, M., Rixen, M., Savidge, G., Henson, S., Mayor, D. Diatom carbon export enhanced by silicate upwelling in the northeast Atlantic. *Nature*, **437**, 2005:728-73,doi:10.1038/nature03948.

Rixen, M., Ferreira-Coelho, E. Operational prediction of acoustic properties in the ocean using multi-model statistics. *Ocean Modelling*, **11**, 2006:428-440.

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Conley, D.C., Trangeled, A., Zappa, G., Gualdesi, L., Guerrini, P., Holman, R.A. REA in the nearshore. Submitted to *Journal of Marine Systems*.

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Harrison, C.H. Algorithms for ambient noise sub-bottom profiling. Submitted to *Journal of the Acoustical Society of America*.

Rixen, M., Ferreira-Coelho, E. The Multi-scale multi-model super-ensemble cocktail: brake, shake and mix. Submitted to *Nature Physics*.

Siebesma, A.,P., Soares, P.M.M., Teixeira, J. A combined Eddy diffusivity mass flux approach for parameterizing turbulent transport in the convective boundary layer. Submitted to *Journal of the Atmospheric Sciences*.

Teixeira, J., May, P., Flatau, M., Hogan, T.F. On the sensitivity of the SST from a global ocean-atmosphere coupled system to the parameterization of boundary layer clouds. Submitted to *Journal of Marine Systems.*

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Askari, F., Signell, R.P. RADARSAT mapping of BORA winds in the Adriatic Sea, SR-422.

Harrison, C.H. Nielsen, P.L. Plane wave reflection coefficient from near field measurements, SR-419.

Harrison, C.H. Experimental determination of seabed scattering law and environmental parameters from reverberation, SR-403.

Pennucci, G., Zanasca, P. A comparison of *in situ* measurements and satellite remote sensing of absorption coefficient, beam attenuation coefficient and horizontal diver visibility, IN-690.

Zanasca, P. Work performed in underwater visibility estimation, IN-689.

Conference presentations

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Ferreira-Coelho, E., Rixen M. Surface Drift Uncertainty Analysis Using an High Resolution Tactical Ocean Modelling System. LAPCOD Meeting, Lerici, June 2005.

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CD-ROM/DVD

Ferreira-Coelho, E., Rixen, M., Conley, D., Ranelli, P. MREA 2004 Workshop, DVD-4.

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Texeira, J. High-Resolution Coupled Coastal Prediction Workshop, NATO Undersea Research Centre 29 Nov. - 1 Dec. 2005, CD-90.

Command and Operational Support (COS) Research Thrust Area

Overview

In the course of 2005, the Command and Operational Support (COS) Thrust Area continued operational support activities (e.g. exercise support, support to the Defence Requirements Review). Efforts were made to streamline activities for exercise support. These activities are funded by the SPOW, apart from travel to support NATO exercises (funded by ACO). In 2005, COS developed plans to include activities for the defence against terrorism (DAT) into its operational research activities for 2006.

OPERATIONAL SUPPORT AND EXPERIMENTATION		
Operational Support	Exercise Support, Support to NATO meetings, Support to the Defence Requirement Review (Proj. 5D)	Handson Yip

Medium Term Vision

In 2006, COS will continue to support NATO Response Forces (NRF). DAT will be a key activity with two new projects. The following is the medium term vision:

- Conduct of operational research studies pertaining to the protection of ports and harbours. The development of capabilities for modelling threat behaviour will also take place.
- Continue to conduct and to analyze Percentage Clearance Trials for the Standing NRF MCM Groups in challenging mine hunting scenarios. COS will also explore concepts for using the PC trials in the NRF certification of the Standing NRF MCM Groups.
- Utilize opportunities in NATO exercises to validate the operational research concepts and algorithms associated with Tactical Decision Aids.
- Conduct exploratory research to facilitate the development of future decision aids that will provide decision superiority to the war fighter. The emphasis will be on scenarios of maritime force protection, expeditionary warfare, and defence against terrorism.

Long-Term Vision

The long term objective is to facilitate the transfer of operational experience to systems through military exercise analysis and to facilitate the transfer of scientific knowledge to operations through system requirement studies and measures of operational effectiveness. Over the next 5-7 years it is envisaged that the thrust area will include operations research to identify technologies and systems to meet NATO operational and transformational requirements. The support to the NRF in NATO exercises is expected to continue because the growing complexity of the future systems involved in operations will likely require more scientific support and analysis.

Technical Accomplishments

Percentage Clearance Trials

The Centre continued to support the planning, execution and operational analysis of challenging mine hunting 'Percentage Clearance' (PC) trials in 2005. These trials evaluate a broad range of mine hunting performance parameters and provide data to quantify the operational effectiveness of NATO's MCM Groups. In 2005, PC trials were conducted in Exercise CINQUE TERRE 05 (Bonassola-Levanto, Italy) and TRIDENT D'OR (South-east coast of Sardinia).

In the fall of 2005, a PC trial was conducted to support the Investigation and Capability Assessment of Modernized MCMVs (ICAM) program. HMNLS *Hellevoitsluis* participated in a PC Trial with its newly upgraded MCM system. A detailed analysis of the trial has been conducted and provided to the RNLN.

Figure COS.1 *False contact identified by HMNLS HELLEVOITSLUIS*

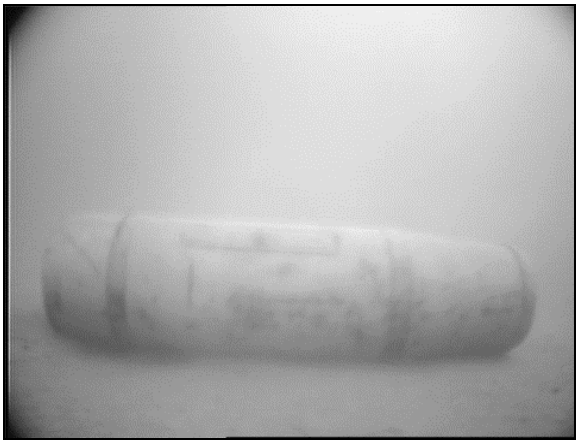

Figure COS.2 *MK36 Identified by HMNLS HELLEVOITSLUIS*

The results obtained from these trials continue to generate considerable interest and discussion in the NATO Mine Warfare community. COS staff contributed by providing expert exercise analysis.

Exercise Noble Marlin 05

This is an annual ASW exercise (EX DOGFISH) which the Centre has supported in the late 90's until 2003. Those activities started with operational analysis, which then lead to the development of the tactical analysis and rapid feedback (TARF) concepts. In 2005, the Centre collected target reaction data to evaluate one of its tactical decision aids during exercise Noble Marlin. COS was well positioned to use the opportunity offered by this NATO exercise to facilitate the development of products for the NRF.

Exercise Bell Bottoms: Synthetic MCM effort

Exercise Bell Bottoms is a bi-annual synthetic MCM exercise to train Naval Mine Warfare officers. The NRF MCM Group1 participated in analysis activities of Exercise Bell Bottoms 05. The analysis highlighted some issues with NATO interoperability, data exchange, and the

process for using existing NATO planning and evaluation tools. This was also an opportunity to test a new version of the tactical decision aid tool, DARE version 2.1 beta.

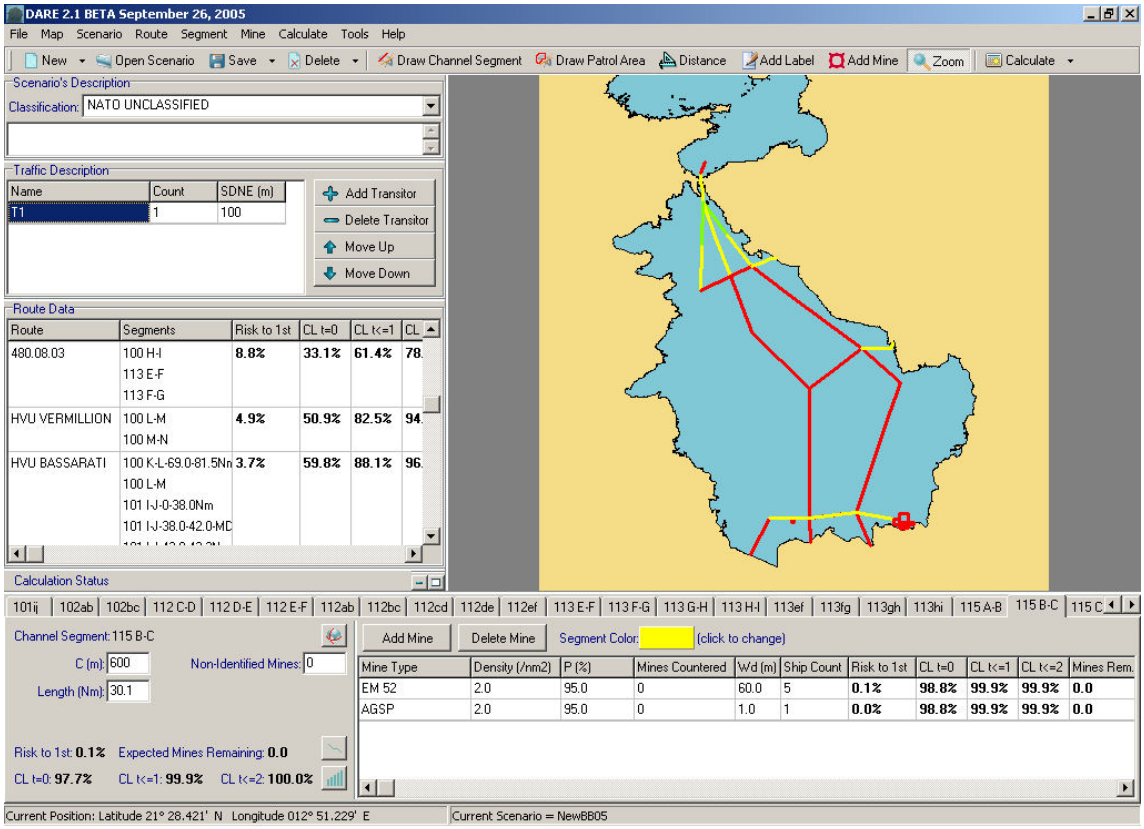

Figure COS.3 *DARE main window*

Electronic Minefield Referee System (EMIR)

EMIR is a software system connected to the Global Positioning System onboard Non-MCM units during a NATO exercise. Its purpose is to enforce Non-MCM units to respect the paper minefields during exercise play. The COS thrust area provided implementation and analysis support of EMIR in NATO exercises. In 2005, efforts were focused on streamlining the preparation and implementation of the paper minefields of the EMIR system for exercise areas on the coast of Denmark during Loyal Mariner 05. Quantitative analysis of EMIR during LOYAL MARINER 05 was conducted to assess the effectiveness of the paper minefields against the non-MCM units. This work provides operational support to NATO commands and agencies.

Figure COS.4 *Paper minefields in the EMIR system during Exercise LOYAL MARINER 05*

Support to the Defence Requirement Review

In 2005, COS worked on developing a plan to include Autonomous Underwater Vehicles into the DDR 07. This work is done in collaboration with NC3A, who is the lead agency for the Maritime element of the DRR 07.

Support to EGUERMIN Minewarfare Gaming System

This activity falls under the cooperative agreement between the NURC and EGUERMIN. In 2005, data from past NATO Percentage Clearance trials were used to develop models of mine hunting activities. These models are useful for future upgrades to the EGUERMIN Minewarfare Gaming System, which is a system used to train Naval Minewarfare officers. The NRF participates in synthetic exercises bi-annually with the EGUERMIN Minewarfare Gaming System.

Support to NATO meetings

Specialist support was provided to the following NATO meetings during the year.

- NATO Naval Armaments Group (NNAG)
- Naval Group 2 (NG2)
- Naval Group 3 (NG3)
- MAROPS Working Group
- Area Search and Screening Working Group (AS2WG)
- NATO Mine Warfare Working Group (MWWG)
- NATO Mine Warfare Conference
- MILOC Main Group
- MILOC Sub Group

Command and Operational Support publications and presentations 2005

Clemente, C. Modelling Minehunting Target Classification/Identification Efficiency, SR-434 (NATO CONFIDENTIAL).

Yip, H., Cimino, G.P. Electronic Minefield Referee (EMIR) in LOYAL MARINER 05 (NATO CONFIDENTIAL).

Yip, H., Strode, C. Analysis of Percentage Clearance Trials in Trident D'Or 05 (NATO RESTRICTED).

Yip, H. ICAM 05 PC Trial Analysis compiled by (NATO CONFIDENTIAL), Dec 05.

Bryan, K., Clemente C. Exercise Bell Bottoms 05 Analysis Report: AO3. Quantitative and qualitative analysis of EXTAC 858 (DARE) compiled 2005 (NATO RESTRICTED).

CD-ROM

DARE Decision Aid for Risk Evaluation. Version 2.1, CD-89.

Davies G.L. ESPRESSO version 1.0, CD-91.

Presentations

Yip, H. AUVs in Blue Game 04 PC Trials, presented at AD HOC Drafting Team – NATO EXTAC, Portsmouth, UK 26-27 Jan 2005.

Yip, H. Cinque Terre 05 Percentage Clearance (PC) Trial, presented at PXD CT05, COMFORDRAG, La Spezia, 21 Feb 2005.

ICAM 05 PC Trial FIR, presented onboard HMNLS HELLEVOITSLUIS, 17 Oct 05, La Spezia.

Grignan, P. NURC Command and Operational Support, presented at Mine Warfare Working Group Technical Panel Meeting, Bruxelles, 28 September 2005.

Progress in Engineering and Technology

Context

NATO, and SACT in particular, has a requirement for an ongoing programme of research to generate and support transformational concepts, which will enable NATO to respond to the modern threat in an increasingly efficient manner.

In the maritime area NURC is the prime research establishment used by SACT to supply this underpinning research and to demonstrate new concepts in a military context.

The Engineering and Technology Department (ETD) within NURC has a unique capability, developed over more than 40 years, to invent, design, develop, produce and support new equipment that allows the leading scientists in the field of maritime research to investigate new scientific principles, to demonstrate their applicability in the military context and to assist in the transition of new concepts into the military arena.

Vision

The specialized capability developed over a period of 40 years within ETD provides a world class capability to invent, design, develop, produce and support novel solutions to meet the requirements of a scientific programme of work.

However as the tools needed to support the SPOW increasingly evolve from individual equipments to system level solutions, greater expertise in the area of technical management during system development or procurement is needed.

ETD has adapted its organization to this new requirement in order to offer a balanced capability in support of the SPOW. It is now growing its capability to technically manage the procurement of complex, technically advanced equipment with a view to providing a more assured route to the provision of the necessary technical infrastructure to support the SPOW. This will undoubtedly involve planning on a multi-year basis.

Overview

The role of ETD at NURC is to:

- Support the execution of the Scientific Programme of Work (SPOW) by designing, procuring and operating state-of-the-art measurement systems.
- To transition experimental concepts arising form the SPOW into the more directly applicable arena of military experimentation.
- To initiate and coordinate programmes of collaboration with the host countries research community.
- To maintain a “technology watch” identifying future trends in technology that could assist the implementation of the SPOW.

The highlights of the 2005 were:

- Preparation and operation of measurement systems in support of more than 14 separate experiments, involving 138 days at sea with NRV *ALLIANCE* and CRV *LEONARDO* plus other days onboard vessels from collaborative Nations.

- Completion of an improvement programme to the DEMUS system to ensure improved reliability during all subsequent deployable multi-static sonar trials.
- Production of a proven set of SEPTR units with enhanced capability. These units will support the Centres SPOW in 2006 in programmes being conducted by both EOS and RSN.
- A series of deployments of ACT's REMUS AUVs in support of SACT operations including the first simultaneous deployment of up to four vehicles, all under control working in a collaborative manner.
- The completion and successful deployment of Forward Eyes; a suite of prototype sensor systems providing operators with the ability to monitor a beach environment in real time in support of amphibious landings
- Under the coordination of the STO (Science and Technology supporting initiatives Office) several programmes of collaboration with the host country research community have been activated, continued or extended. Such cooperation builds up synergies and sharing of resources in support of the SPOW. Most of them are summarized in the table below.
- Provision of a calibration facility for oceanographic instrumentation in support of several NATO navies and research establishments.

Project	Activity	Benefit to NATO	Partner
04-F *01-A* *01-B* *ETD*	*Implementation of the cooperation with DIPTERIS (University of Genova) in the following areas:* *1. SOLMAR project* *2. SEPTR project*	*Support to SOLMAR project including, data collection /analysis, participation to SIRENA cruise 2005*	University of Genova (DIPTERIS)
		Long term field test for the SEPTR unit in the Portofino Marine Protected Area (MPA)	
		Thesis work in support of the SEPTR project for field validation of optical sensors - one man/year additional resource	
01-A *04-F*	*Agreement in progress for ocean engineering and other infrastructures (MOU)* *A Letter of Interest from the Centre has been issued*	*Alliance chartering, ocean engineering developments, acoustic monitoring station*	INFN (National Institute of Nuclear Physics)
06-B	*Cooperation with Pisa University for conducting a field experiment in Pianosa island marine protected area*	*Authorization to operate in the marine protected area*	University of Pisa
ETD	*Activity in progress aiming to set-up a natural lab in Pianosa island through a cooperation with several Italian institutes*	*Support to 06-B and AUV experimentation*	University of Pisa CNR IBIMET (Firenze) ICRAM
01A-2 *01A-5*	*explorative initiative for possible synergies in support of the SPOW with the Italian project RIMA (Rete Integrata Mediterranea ed Accesso ai dati)*	*Technology transfer and data sharing*	INGV ENEA IMC
	Explorative initiative for possible inclusion of the Centre as an Observer in the Italian Oceanographic Commission (COI)	*Technology transfer and data sharing*	COI

Technical Accomplishments

Accomplishment 1: SEPTR

In May 2003 the Centre entered into a cooperative programme with NRL to enhance both establishments' capabilities in real time monitoring of the littoral ocean environment. The primary objective was the provision of timely data that can be assimilated into numerical models that traditionally require boundary condition information to be effective.

This work builds on previous development at NURC of the BARNY trawl-resistant system which is placed on the sea-bed, is resistant to trawler activity, and collects Acoustic Doppler Current Profiler (ADCP) data over a long period of time. The enhanced concept is to augment a "BARNY like" system with a profiler buoy. This buoy periodically rises to the surface where it transmits via satellite communications the ADCP data and additional water column data it collects en route to the surface. The buoy then returns to the seabed where it is docked within the trawl safe body providing it with a long term survival capability. This complete concept is known as a Shallow water Environmental Profiler in Trawl-safe Real-time configuration (SEPTR).

The design objective was to provide a system that could be deployed in water depths of up to 100m, would perform four profiles a day and would operate unaided for a period of not less than one month. During 2004 initial design and development of the new system was completed including a completely new composite material based construction technique. In 2005 following a successful Critical Design Review the new design was transitioned to production and components for 5 systems procured assembled and tested.

The first production system was deployed for an extended period where it operated, unaided, for a period of 32 days. Figure ETD.1 below shows the unit prior to deployment (without the cover) and the temperature data set collected (Fig. ETD.2). Lessons learnt from this deployment were incorporated into the later production models as well as being retrofitted into the first unit.

Taking advantage of the delay in conducting the DART 05 cruise the year ended with plans being finalized to conduct an extended reliability test on a final production unit in the Portofino Marine Protected Area.

Figure ETD.1 *Complete SEPTR unit without cover.*

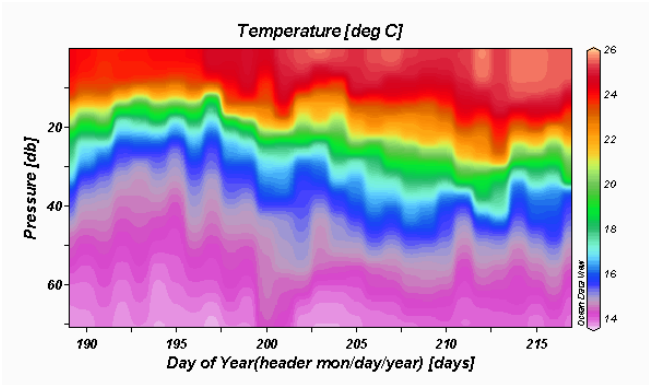

Figure ETD.2 *Ocean temperature as function of depth and time.*

Accomplishment 2: Forward Eyes Beach Surveillance System

As part of the SPOW, the 01A programme has shown the value to operational commands of near real time environmental data in support of amphibious landings. As part of SACT's military experimentation programme NURC was contracted to build on the output from 01A. The objective was to produce an equipment suite (3 sensor systems), which replicated the functionality of the scientific equipment used to monitor the immediate beach environment, but which was to be presented in a covert form that could be deployed unaided by military personnel. In addition it was required that the systems developed clearly demonstrated that the equipment could eventually be procured by individual nations via their normal defence equipment procurement processes.

The immediate challenges were to miniaturise the individual systems, provide them each with a means of collecting, storing and transmitting data and to reduce the required power to a level that was sustainable for a period exceeding 14 days.

The three sensors systems were each based on a Commercial Off The Shelf (COTS) primary sensor integrated with bespoke data collection and local processing, combined with a variant of satellite communications.

During 2004 initial prototypes of each sensor were designed, developed and constructed. These initial prototypes were deployed by military personnel in October 2004 in a successful military operation. Despite this success the sensor suite still lacked some of the miniaturisation features needed to demonstrate truly covert operation and some technical enhancements were called for to improve usability.

These improvements were incorporated in early 2005, transitioned into production and a pre-production sensor suite, consisting of a meteo station, a camera system and an in-water current meter were produced, tested and deployed by a Spanish operational team during Loyal Midas 05.

Figure ETD.3 shows the pre-production current meter deployed in very shallow water for demonstration purposes. When deployed by military divers the water depth is approximately 10m.and the complete assembly is submerged.

Figure ETD.3 *Complete current meter showing three components of the system.*

Publications

Peer reviewed journal papers (submitted)

Pautet, L., Tesei, A., Guerrini, P., Pouliquen, E. Target echo enhancement using single-element time reversal mirror, Submitted to *IEEE Journal of Oceanic Engineering*.

Bartolotti V., Gombia M., Cernich F., Michelozzi E. and Fantazzini P. A preliminary study to apply nuclear magnetic resonance porosity measurements to seabed sediments. Submitted to *International Journal of Marine Geology, Geochemistry and Geophysics.*

Centre reports

Baralli, F., Hagen, O.K., Biagini, S., Cecchi, D., Chiarabini, R., Christenson, R.A., Fioravanti, S., Mazzi, M., Sapienza, A., Sletner, P.A. Inertial Navigation System for the OEX-C AUV: Integration and Performances SR-412, in progress.

Cecchi, D., Baralli, F., Biagini, S., Chiarabini, R., Christenson, R.A., Fioravanti, S., Mazzi, M., Sletner, P.A. OEX-C Autonomous Underwater Vehicle control system: analysis and tuning, SR-446, in progress.

Conference presentations

Grandi, V., Carta, A., Gualdesi, L., de Strobel, F., Fioravanti, S. An overview of SEPTR: Shallow water Environmental Profiler in Trawl-safe Real-time configuration. The IEEE/OES/CMTC Eighth Current Measurement Conference, Southampton Oceanography Centre, Southampton, UK June 2005.

Gualdesi, L. Seminars on the following subjects: Selección de materiales y problemas de resistencia en ambiente marino; (A selection of materials withstanding with marine environment); Diseño de fondeos y comprobación experimental (Mooring design and their experimental validation); Una introducción al SEPTR (A SEPTR platform introduction). "Primero Curso de Experto en Ingenieria de Puertos y Costas (First Course for Expert in Harbour and Coastal Engineering), Departamento de Ingenieria Civil, Universidad de Las Palmas de Gran Canaria, Spain

Gualdesi, L., Guerrini, P., Conley, D. Satellite data link buoy for wave-current measurement in very shallow waters, Proceedings. OCEANS 2005 MTS/IEEE Conference,18-23 September 2005, Washington D.C.,USA.

Fioravanti, S., Grandi, V., de Strobel, F., Gualdesi, L., Carta, A., Dogliosi, A., Cattaneo-Vietti R., Castellano, M., Ruggieri, N., Povero, P. SEPTR a new systems for marine coastal monitoring in real time configuration: applications in a marine protected area (Portofino, Italy) International Ocean Research Conference, Paris, France, 6-10 June 2005.

Cecchi, D., Fioravanti, S., Caiti, A., Baralli, F., Bovio, E. Target detection using multiple autonomous underwater vehicles. International Workshop on Underwater Robotics, Genova, Italy, 9-11 November 2005.

CD-ROM/DVD

Stevenson, M., Guerrini, P., Akal, T., Kuperman, W., Hodgkiss, W., Cavanna, A. FAF05 Focused Acoustic Field Studies, CD-83.

Progress in Communications and Information Systems

Context

The Communications and Information Systems (CIS) Office at NURC focuses on the "adaptation layer" between the concepts and systems developed by the Scientific Departments and the customers, such as SACT or the NATO Response Force, ensuring interoperability, security and performance across the NATO Network Enabled Capabilities (NNEC) Architecture.

NNEC is one of the key concepts at the heart of NATO transformation. It is more about people, organizations and countries being empowered to work together in new, more dynamic, flexible and effective ways than it is about technology. Yet it is technology that provides information with the scope, speed and richness necessary to enable this transformation to take place. Therefore, organizational and technological innovation and change must work hand-in-hand to achieve transformation.

Overview

The role of CIS at NURC is to support the execution of the Programme of Work by designing, procuring and operating leading-edge technologies in computing and networking, ensuring interoperability with Joint Research Partners as well as the protection of intellectual and corporate assets, and of NATO classified information.

The specialist knowledge available in the CIS Office has been applied more directly to scientific activities in 2005, with the involvement of CIS personnel in full project lifecycles, including the design of complex data processing and data exchange architectures used both at the Centre and during Centre trials. New areas which are being addressed relate to underwater communications and to new concepts for sensor data networking, including interoperable repositories for secure data exchange across the NNEC architecture.

The highlights of the 2005 were:

- Support provided to 10 Centre trials (both at sea and ashore), providing ad-hoc networking solutions in response to scientific requirements and ensuring smooth operations and on-site assistance during sea trials when required.
- Support provided to the Experimentation Programme of Work (Forward Eyes during Loyal Midas '05, Covert Remote Sensing and CWID '05).
- Activation of High Performance Computing cluster.
- Activation of a new CIS infrastructure to improve communications between NURC and other NATO Commands and Agencies (high data rate NSWAN, VTC, secure voice).
- International collaboration within the NATO Research and Technology Agency on topics of interest to the SPOW (IST Panel, Military Communications and Network Enabled Capabilities Security), and to improve the visibility and accessibility of Centre products (publications of Centre reports on RTA web site, private web for SCNR members).
- Collaboration with the NATO C3 Agency (Satellite communications, Information Management, Information and Communications Security).

- Activation of a new Local Area Network to support Joint Research Partners during collaborative work performed at the Centre, to provide seamless data exchange facilities while protecting NATO assets in compliance with the policies in force.

Vision

Medium Term In the medium term it is envisioned that work will continue together with NC3A, the European Space Agency and partners in the Nations to develop techniques that support the seamless transmission of very large amounts of data (including raw satellite imagery) from the sensors at sea to maritime units and data processing centres ashore, and vice versa. Some key technologies to be exploited would be, but not limited to, at-hoc wideband wireless networks at sea (buoys, ships), high data rate SATCOM (VSAT, DVB-RCS), STANAG 5066, and emerging personal communications systems.

The objective is to build experience to be shared with the Nations, providing a realistic evaluation of technologies using maritime assets (e.g. NATO Research Vessels *ALLIANCE* and *LEONARDO*). This knowledge of the possibilities offered by today's leading edge technologies would influence NURC scientists' decisions on how much "intelligence" in terms of data reduction and processing should be put in sensors deployed at sea. The data volume that can actually be transferred from the field to shore, and vice versa, is a major constraint in the development of the new Maritime Network Enabled Capabilities.

Long Term The role of CIS is envisioned to be the enabler of all Centre projects requiring the integration of complex communication and information systems. A constant technology watch will continue, with the objective of applying leading edge Commercial-Off-The-Shelf technologies to scientific research, with a special focus on high-performance computing, information protection and wireless communications. Adherence to the NATO C3 Technical Architecture will play a key part in transferring the Centre products to NATO operational customers. Coordination will continue with NC3A and RTA, with the assistance of the SACT Office of Security for all security policy compliance issues.

Technical Accomplishments

Accomplishment 1: Support to Centre trials, providing ad-hoc networking solutions in response to scientific requirements and ensuring smooth operations and on-site assistance during sea trials.

10 trials were supported in 2005, a decrease in comparison with previous years following the unavailability of NRV *ALLIANCE* during the second half of the year.

The trend towards increased complexity in experimental setup was evident in 2005 as new requirements were presented by scientific projects. Today's ad-hoc networks mix different types of satellite communications to wireless local area sensor networking to enable seamless communications between several sites, ships and sensing equipments.

In 2005 new communications technologies were evaluated and developed, to improve the interconnection of remote sensors and systems as part of the Centre contribution to NATO's Network Enabled Capabilities.

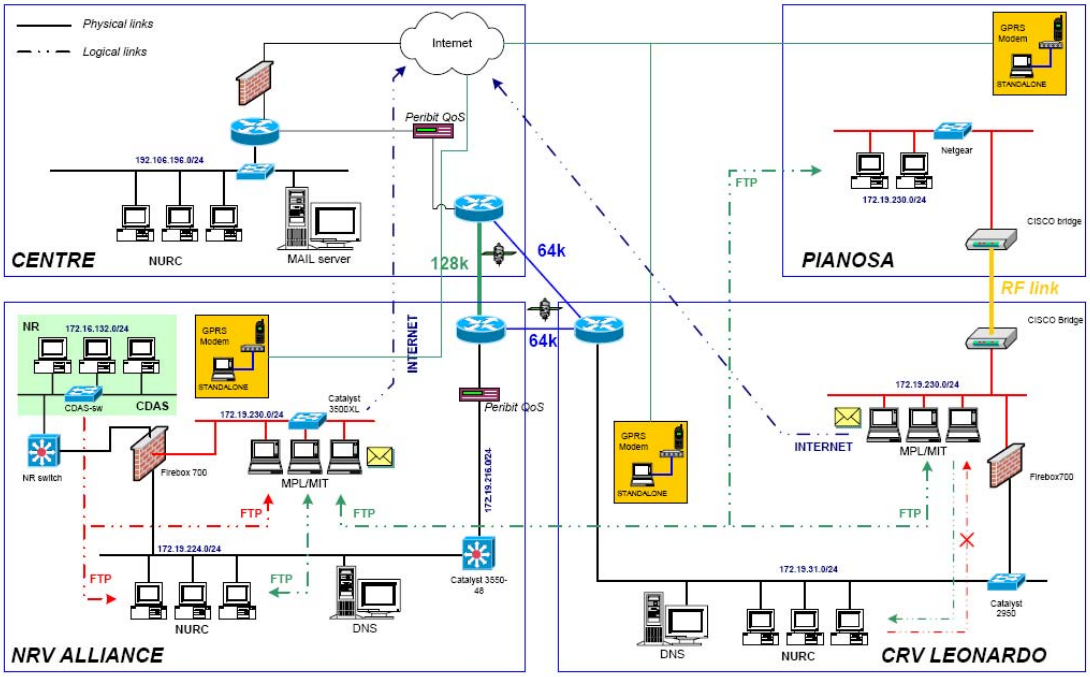

Figure CIS.1 *An example of a complex Maritime Ad-Hoc Network developed by CIS for the FAF05 experiment.*

Accomplishment 2: Support to Real-time Pre-landing Beach Monitoring System Experimentation (Forward Eyes)

As part of the Forward Eyes experimentation project, CIS developed a solution to set up Virtual Private Network (VPN) links using IPSEC between remote sensors or mobile terminals and a central site.

This solution offered as side benefit, the possibility of extending the IPSEC VPN concept to mobile terminals and sensors that not only are connecting with dynamic (e.g. variable over time) IP addressing, but that are also "hidden" behind a gateway or a firewall that performs network address translation of port address translation (NAT/PAT). This is the typical case of terminals connected using dial-up IP, or GPRS, or the Inmarsat Regional BGAN (RBGAN) service.

The ability to extend this VPN concept to data services delivered using GPRS or RBGAN offers scientific users the possibility of accessing state–of-the-art communications media to provide proof of concept of the environmental sensors developed at NURC. Since this solution is based on published standards, deploying it to other applications or systems can be done with minimal effort.

Accomplishment 3: Support to Covert Remote Sensing in Support of Expeditionary Operations

In 2004, NURC procured a Satellite Ground station operating in the X-Band, which provides a unique capability within NATO to receive real-time satellite remote sensing imagery (e.g. RADARSAT, ENVISAT).

A test deployment was conducted in the scope of the 2005 EPOW, to exercise the mobile and transportable features of the system under controlled conditions. CIS contributed this project by designing and implementing the SATCOM network connecting the mobile laboratory to NURC.

The resulting architecture can support two different routing schemes: in the first scheme, the two sites communicate directly via satellite, via a satellite relay station, while in the other the mobile laboratory communicates only with the satellite hub, and all subsequent communications take place using the Internet as a carrier.

Figure CIS.2 View of deployable DVB-RCS SATCOM system used during covert remote sensing experiments – the NURC X-band ground station can be observed in the background.

The applicability of the two solutions varies according to the application to be supported. In general terms, the direct SATCOM communication of the first scenario appears to be the one that matches more closely NATO's deployable forces requirements.

During the experiment a number of tests were conducted, to test the applications and services required by the covert remote sensing operations. Infor-mation protection was ensured at all times using commercial-off-the-shelf or NATO- approved encryption systems.

A performance assessment was made with different topologies and encryption systems, to derive useful information on the impact of the configuration change on the applications that have to be supported. The results will be published in Centre reports.

Accomplishment 4: Activation of new High Performance Computing cluster

The new 16-CPU HP-Itanium High Performance Computing (HPC) cluster, was installed and made available to Centre users in 2005.

The first application to be tested was developed by Project 3E2, to calculate the far field backscattered echo from elastic shells immersed in water. This type of forward problem is computationally intensive, as hundreds of millions of independent solutions may have to be computed. The availability of the HPC cluster has enabled the reduction of typical processing times from 12 days (using a 1-CPU high-end workstation) to only 17 hours. This reduction in processing time enabled the completion of tasks which would otherwise have been unaffordable.

The next application scheduled to be run on the HPC cluster is the Coupled Ocean/Atmosphere Prediction System (COAMPS) for Project 1A2, which has recently been ported to the new architecture with the assistance of the Marine Meteorology Division of the US Naval Research Laboratory.

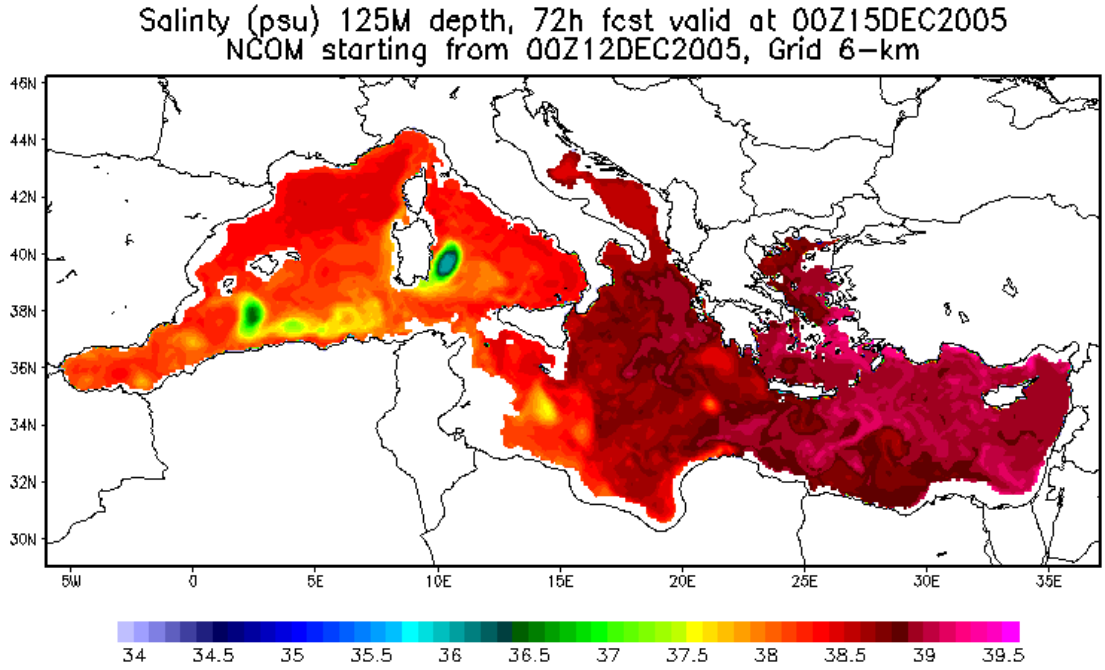

Figure CIS.3 *Sample output from the COAMPS model - 72h forecast of salinity at 125m depth over the Mediterranean, starting from 00Z December 12, 2005 (Image courtesy of NRL Monterey).*

Accomplishment 5: Activation of a new CIS infrastructure to improve communications between NURC and other NATO Commands and Agencies, and with Joint Research Partners.

A new classified link has been activated to improve the connectivity to other NATO Commands and Agencies for services such as voice/data communications and video-teleconferencing (VTC). The availability of the VTC facility ensures easier communication between Centre personnel and ACT, reducing the need for transatlantic travel. New network setups have also been activated to support Virtual Private Networks with Joint Research Partners using the Internet as a bearer.

Accomplishment 6: International collaboration within RTA and with NC3A

CIS personnel have continued their active participation to joint activities with RTA and NC3A, giving presentations to symposia and conferences and participating in working groups in the field of Military Communications (IST-54) and Security for Network Enabled Capabilities (NECSEC).

Communications and Information Systems publications and presentations

Conference presentations

Berni, A., Merani, D., Leonard, M. The challenges of internetworking unattended autonomous sensors. Submitted to the RTA IST Panel Symposium on "Military Communications" 18-19 April 2005 Rome, Italy.

Progress in Ship Operations

The year has been dominated by the grounding of the vessel in July 2005 and the subsequent salvage and repair period. A detailed summary of those unfortunate events can be found in the article below.

ALLIANCE started the year at sea on passage to the Netherlands where she was to undertake a major dry dock period. The Netherlands ship repair yard at Vlissingen was selected after a rigorous international competition and the work package included hull painting, deck machinery refurbishment, recertification and the replacement of one main propulsion generator.

The dock period was completed on schedule and a newly refurbished vessel arrived back in La Spezia in mid February ready to commence scientific work. Unfortunately, due to continuing funding constraints, the scientific programme of work at sea did not commence until July when the focused acoustic fields trial (FAF 05) commenced.

The first part of the FAF05 trial was very successful with both CRV *LEONARDO* and NRV *ALLIANCE* performing extremely well. On the evening of the 23rd July *ALLIANCE* was underway off the Island of Pianosa. The vessel had just completed a boat transfer to exchange scientists between the island and the ship when she struck a charted submerged rock at a speed of approximately 7 knots. The collision with the rock caused substantial damage below the waterline and the vessel very quickly started to flood. It became evident that the pumps were not able to cope with the large ingress of water and the Master took the decision to beach the vessel in an area of soft shallow sand to prevent the ship from sinking. CRV *LEONARDO*, near-by at the time of the incident, used her boat to guide her big sister to a safe grounding position.

Figure SMO.1 *ALLIANCE aground at Pianosa Island, July 2005.*

With the initial emergency stabilized, plans were made to evacuate the scientific team from the ship and the full incident management team was assembled at NURC and the ship management company, Anglo-Eastern (UK). Although badly damaged, the vessel did not lose any fuel, no pollution or damage to the environment was caused and perhaps most importantly, no injuries were sustained. Preventative measures were immediately taken to ensure the continued safety of the environment in the sensitive area of the island.

Figure SMO.2 *Damage control measures in the engine room after the flooding.*

Figure SMO.3 *Watertight door on Alliance during flooding (note water ingress).*

Although now in a reasonably stable condition the next problem was how to recover the ship from this predicament. After assessing the options it became evident very quickly that an international salvage effort would be required to safely retrieve *ALLIANCE* whilst ensuring that no further damage or pollution occurred. The flooding was extensive with the auxiliary machinery space completely flooded and the main generator room partially flooded. There is no doubt that the damage control efforts of the crew had saved the ship.

Figure SMO 4 *NRV Alliance – underwater hull damage.*

The contract went to San Giorgio yard in Genoa and a lengthy repair period commenced in early August. The damage was significant and the repairs involved not only the obvious hull damage but replacement or refurbishment of a large proportion of the auxiliary and main machinery. The repair period was scheduled to be completed in November and through careful oversight by the ship's technical staff and management all of the milestones were achieved and the ship was declared ready for sea exactly on schedule.

Figure SMO 5 *Hull repairs to NRV Alliance.*

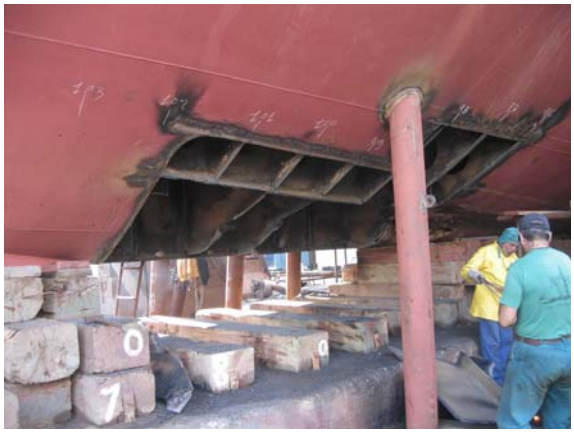

Figure SMO 6 *Hull repairs to NRV Alliance.*

A period of sea trials followed during which all aspects of the ship's operation were thoroughly checked before making the transit to Germany where the noise signature was measured. The purpose of the noise measurements was to ensure that the very quiet acoustic signature of the vessel had not been adversely affected by the repairs. With this successfully completed *ALLIANCE* made her way back to La Spezia, arriving on 21 December, and was declared fully ready again for scientific operations. This was a remarkable achievement in the timescale and *ALLIANCE* is now ready for a full year of operations in 2006.

The costs for the repairs were significant but will be largely covered by the commercial insurers of the ship. NATO has had to pay a proportion of these costs (insurance deductible, scientific equipment salvage fee) but in overall terms the financial costs to the Centre have been minimized. The loss of *ALLIANCE* had a significant effect on SPOW sea trials but through careful re-planning, moving trials into 2006 and an increased use of CRV *LEONARDO* where possible, these effects have been negated as far as possible.

In summary, 2005 was an extremely difficult year for the ship and all involved with her but the final outcome has proved positive with *ALLIANCE* emerging from it all in better shape than for many years.

CRV LEONARDO

LEONARDO continued to provide a very capable platform for coastal research operations. The vessel started the year with an extended trial in Sardinia supporting the MILOC department in surf and wave monitoring. The conditions were very rough for a large proportion of the trial but a successful outcome was achieved.

A quiet spring period was followed by a very busy schedule for the remainder of 2005. After the *ALLIANCE* grounding the Centre transferred as much work as possible to *LEONARDO* to enable the at sea SPOW to continue. The ship and crew performed admirably throughout this period and recorded over 160 sea days in support of centre projects which included a large proportion of EMP work, Marine Mammal mitigation and SACT experimentation.

The annual dry dock was postponed because of the rearranged programme but a slightly longer period is planned in 2006 to account for this.

Upgrades and equipment updates

It has been a long held ambition to upgrade and replace the navigation and automation control system in *ALLIANCE*. The funding for this project has not been available in the past but as a result of the manufacturers' inability to further support the current equipment a decision was made by ACT to fund its replacement. After a detailed technical study and international competition the contract has been awarded to Kongsberg Maritime of Norway to replace both of these systems.

The new equipment will provide seamless integrated navigation and power management for the vessel and will ensure *ALLIANCE* remains as one of the most capable research platforms afloat.

Progress in Quality Management

The Centre Quality Management System has been in place since 2002. The system was established with the aim of assuring good business practices, providing a stable procedural framework in an environment with a high level of personnel and management turnover, assuring customer satisfaction, and achieving continuous improvement in business process performance and effectiveness.

During the first three-year period a number of changes were made to the original structure, and procedures were subject to frequent tuning to capture continuous improvement. The system was fully recertified in 2005.

New processes - Supplementary Work Programme planning and execution and Financial Support - are being included in the Quality Management System. Concepts of monitoring, objective setting and continuous improvement will therefore be applied to these activities as well.

Most Business Goals set for 2004 and 2005 have been accomplished or considerable progress was made, as such, the list has been significantly revised and streamlined for 2006.

Attention has been drawn to Business Goal #3 (Increased Staff and Partner satisfaction), with particular reference to strengthening staff development and establishing an annual performance management system.

The Quality Management System has proven to work effectively and to be a valid reference for existing and newly-recruited Staff.

On the occasion of the Alliance grounding in summer 2005, in particular, a robust Sea Trials preparation and execution procedure has allowed the Centre to respond promptly to all external inquiries, and to demonstrate adequacy of the established arrangements.

Finally, the system in place for managing issues, and more generally to turn actual and potential nonconformities into opportunities for improvement, has provided a valid framework for the “Lesson learned” process.

Indicators

Issues management

Management of issues raised by Staff and auditors has improved in the past year.

Issues are normally resolved within the agreed deadlines (average delay < 1 week) and a review of the actions taken shows effectiveness. In addition to this, the number of issues raised has significantly increased (+140%), whereas the rate of issues raised outside the audit cycle has moved from 48% to 60%, showing a higher participation of Staff to the effort towards continuous improvement. 100% of actions taken have been found to be effective.

Performance measures

Each Process Owner monitors efficiency and effectiveness of the process through a set of metrics: the degree of achievement of targets is reported in turn on a bi-weekly basis (i.e. several times per year for each process).
The second cycle of reports has been completed and targets are being refined.

Internal Audits
The internal audit cycle has been completed according to the approved plan.

External Audit
The external re-certification audit by DET NORSKE VERITAS took place in November and December 2005.

It was a major audit, and all the ISO 9001:2000 standard clauses and all Centre processes were assessed.

The system was found to be in compliance and gave adequate confidence in the internal organization and procedures: the auditor therefore recommended that the certificate validity be confirmed.

Two minor nonconformities and four observations were raised. Actions to resolve the nonconformities were defined and forwarded to DET NORSKE VERITAS for consideration.

A Few 2005 Indicators

Visitors

The Centre received 738 scientific and technical visitors and 545 visitors for meetings / conferences.

Publications	2005	2004	2003	2002	2001	2000	1999
Peer reviewed journal papers:	15	16	12	12	23	13	18
Centre reports:	20	24	24	23	20	17	24
CD-ROM/DVD:	14	12	9	—	—	—	—
Conference presentations:	39	102	56	28	53	25	41

Staff Evolution

In 2005 the Centre received 370 applications for 21 vacant posts. During the year, there were 4 visiting scientists from 2 nations, 13 research assistants from 7 nations, 6 thesis or doctorate students from 2 nations, and 16 consultants from 5 nations.

Between 2000 and 2005, the average age of serving staff members decreased by almost 4 years and the length of NATO service decreased by over 7 years. In the same period, the average number of years of formal education of all serving staff members increased by approximately 1½ years, rising from a bachelor degree to a master degree level.

Purchasing & Contracting

In 2005 the Centre placed approximately 1150 purchase orders/contracts for a value corresponding to some 5.1 million Euros. About 60% of the value of the purchase orders/contracts was for specialized scientific and engineering equipment and communication and information systems.

Ship Operations

NRV ALLIANCE was visited by 92 officers of flag rank, or their civilian equivalents, from 10 nations.

The ships operated jointly with RV *SWIFT* (US) and the Italian vessels *ARETUSA, STENELLA, KRILL* and sailed a total of 11 139 miles.

Engineering Technology

- Through the Science and Technology Office 6 new cooperative agreements have been formalized or commenced.
- Oceanographic Calibration was performed for 13 different NATO/European Institutes.
- Support to 138 days of SPOW seagoing activity involving more than 1000 man days at sea.

DIRECTORATE

Director :	S.E. Ramberg (USA) (until Oct 2006) F.R. Martin Lauzer (FRA) (from Nov 2006)
Deputy Director :	K. Pye (GBR) (until Oct 2005) D. Todoroff (USA) (from Nov 2005)

OFFICE OF THE DIRECTOR

Naval Advisor	Cdr R. Robichaud, USAN (until May 2006)
Security Officer	Cdr D. Pilepich, ITAN

PLANNING OFFICE

Head, Planning Office:	D. Bennett (USA)
Quality Systems Manager:	A. Barbieri (ITA)
Scientific Coordinator:	VACANCY
Health & Safety Oficer:	R. Molteni (ITA)
Financial Coordinator:	M. Rios (USAN)

FINANCE OFFICE

Controller:	G. Cozzolino (ITA)
Fiscal Officer:	E. Stewart (USA)
Budget Officer:	M. Rios (USAN)

PERSONNEL & ADMINISTRATION OFFICE

Head, PAD	R. Albini (ITA) (until Oct 2005) L. Parise (ITA) (from Dec 2005)
Purchasing and Contracting	VACANCY
Information Services	L. Gassie (USA) (from November 2005)

COMMUNICATION AND INFORMATION SYSTEMS OFFICE

Head, CIS	M. Leonard (BEL)
Senior Systems Engineer	A. Berni (ITA)
Senior ADP Systems Spec	P. Colucci (ITA)
Systems Engieneer (Net-centric)	D. Merani (ITA)
ADP Security Officer	Ensign R. Gonzalez (USAN) (from June 05)

SHIP MANAGEMENT OFFICE

Head, SMO	D.I. Sage (GBR)
Senior Engineer (Ship Manager)	G. Hutton (GBR)
Research Vessel Captain	A. Iacono (ITA)

CHIEF SCIENTIFIC DIVISION

Deputy Director, Chief Scientific Division (twinned post):	K. Pye (GBR) D. Todoroff (USA) (from Nov 2005)

MILITARY OCEANOGRAHY DEPARTMENT (MILOC)

Senior Principal Scientist, Head, MILOC	P. Ranelli (USA)
Senior Principal Scientist	E. Ferreira-Coelho (PRT)
Principal Scientist	VACANCY
Principal Scientist	C. Harrison (GBR)
Senior Scientist	J. Texeira (PRT)
Senior Scientist	T. Folegot (FRA)
Senior Scientist	M. Rixen (BEL)
Senior Scientist	D. Conley (USA)
Scientist	A. Trangeled (DNK)
Scientific Specialist	F. Spina (ITA)
MILOC Survey Officer	R. Schmidt (Civ. DEU) (from June 2005)

COMMAND AND OPERATIONAL SUPPORT DEPARTMENT (COS)

Senior Principal Scientist Head, COS	P. Grignan (FRA) (from Aug 2005)
Principal Scientist	R. Wathelet (BEL)
Principal Scientist	H. Yip (CAN)
Senior Scientist	G. Davies (GBR)
Senior Scientist	C. Carthel (USA)
Scientist	C. Strode (GBR)
Scientist	K. Bryan (USA)

ENGINEERING TECHNOLOGY DEPARTMENT (ETD)

Senior Principal Scientist Head, ETD	P. Enoch (GBR)
Principal Engineer (Head, STO)	VACANCY
Principal Engineer (Head, ENG)	P. Guerrini (ITA)
Senior Engineer	L. Gualdesi (ITA)
Senior Engineer	L. Troiano (GBR) (from Dec 2005)
Mechanical Engineer	S. Biagini (ITA)
Engineer	V. Grandi (ITA)
Engineer	B. Miaschi (ITA)
Engineer	P. Sletner (NOR)
Engineer	R. Stoner (GBR)
Engineer	S. Fioravanti (ITA) (from Nov 2005)

UNDERSEA RECONNAISSANCE SURVEILLANCE AND NETWORKS DEPARTMENT (RSN)

Senior Principal Scientist, Head, ASW	S. Jespers (BEI)
Senior Principal Scientist	M. Carron (USA) (until Apr 2006)
Principal Scientist	D. Grimmett (USA) (until Jan 2006)
Principal Scientist	VACANCY
Principal Scientist	M Stevenson (USA) (until Sep 2006)
Senior Scientist	P. Nielsen (DNK)
Senior Scientist	S. Coraluppi (USA)
Senior Scientist	D. Hughes (GBR) (from Jan 2006)
Scientist	A. Baldacci (ITA)
Scientist	O. Gerard (FRA)
Scientist	M. Prior (GBR)
Scientist	J. C. Le Gac (FRA) (From Oct 2005)
Scientist	G. Haralabus (GRC)
ASW Programme Officer	CDR D. Uhde (DEU)
Scientific Specialist	W. Zimmer (DEU)

EXPEDITIONARY MCM AND PORT PROTECTION DEPARTMENT (EMP)

Senior Principal Scientist Head, EMP	M. Pinto (FRA)
Senior Principal Scientist	F. Jensen (DNK)
Senior Principal Scientist	R. Kessel (CAN) (from Jul 2005)
Principal Scientist	E. Bovio (ITA)
Principal Scientist	A. Gabellone (ITA)
Senior Scientist	VACANCY
Senior Scientist	VACANCY
Senior Scientist	B. Evans (GBR) (from Aug 2005)
Senior Scientist	M. Zampolli (ITA)
Scientist	P. Munk (DNK) (until Jul 2006)
Scientist	L. Pautet (FRA) (until Feb 2006)
Scientist	A. Bellettini (ITA)
Scientist	V. Myers (CAN)
Scientific Specialist	R. Hollett (GBR)
MW Programme Officer	LCDR R. Cornick (GBRN) (from Oct 2005)

Scientific personnel by nationality

Country	*Scientific complement (31 Dec 2005)*	*Total scientist man years (1959-2005)*
Belgium	3	102
Canada	3	112
Denmark	4	155
France	6	176
Germany	0	132
Greece	1	35
Italy	6	269
Netherlands	0	139
Norway	0	103
Portugal	2	17
Spain	0	3
Turkey	0	38
UK	6	348
USA	11	421
Total	42	2055

Visitors and meetings

January	Mr A. Bocconcelli	Woods Hole Oceanographic Institution
	DART 05 cruise planning meeting	
	Dr P. Narum, NO Ir P J Keuning, NL RADM L. Accardo, IT	RTB Study Group
	EGUERMIN MSOC-N Staff Officers Course	
	Dr J. Haun	ONR, London
February	US Naval Research Advisory Committee	
	NIAG SG 82 UUVs for Port and Harbour Protection	
	AS2WG meeting	
	Dr G. Jackson	Dstl, UK
	Senator L. Forcieri	
	Dr W. Alpers	University of Hamburg
March	Dr R. Signell	Woods Hole Oceanographic Institution
	Mr J. Piskor	NEMOC ROTA
	Italian Navy Academy Livorno	
	BGEN E. Mažeikis R/ADM E. Lyutskanov LTC E. Pucko CDR R. Strimaitis MGEN Frank Hye LTCDR B. Bachand, USN	Military Representative of Lithuania to NATO Military Representative of Bulgaria to NATO Military Representative of Latvia to NATO Military Representative of Latvia to NATO SACTREPEUR SACTREPEUR
	Prof P. Willett	University of Connecticut
April	VADM F. Sanfelice di Monteforte	Commander, Allied Maritime Component Command, Naples
	Mr G. Denny	Alaska Native Technologies
	Remote Sensing Symposium	
	VADM H.J. Stricker, GEN,	DCOS Transformation, HQ SACT
May	Intergovernmental meeting on the effects of sound in the ocean on Marine Mammals	
	LTGEN J.O.M. Maisonneuve	Chief of Staff, HQ SACT
	NIAG Meeting	
	Dr D. Cato	Australian Defence Science and Technology Organisation
	LtCdr S. Cole	RAN Environment Manager
	AUV Planning and Evaluation Workshop	
	Thrust Area Review Meeting	
	86th Meeting Scientific Committee of National Representatives	
	Mr E. Simeone	Flyby Srl - Livorno
June	TNO JRP meeting	
	Colonel Z. Vehovar LCDR S. Dekleva, LTSG T. Sullakatko, LTJG R. Saimla,	Deputy Military Representative of Slovenia to NATO Responsible for the Logistic Naval Detachment, Slovenia Chief, CIS Dept, Estonian Navy Staff Chief, Mine Warfare Data Centre, Estonia
	DEMUS JRP final meeting	
	Dr E.J. Sullivan	SAIC, Rhode Island
July	NIAG meeting	
	Cdr J. Orr and Cdr C. Gabrini	
	Swiss Television Preliminary Meeting	

Visitors and meetings

August	Dr M. Witek	Dept of Physics, Warsaw University
	Dr M. Siderius	Science Applications International Inc.
	Mr. W. Ianding	University of Connecticut
	Capt A. Mucedola Capt T. Paparella Cdr O. Bauer, LTC G. Sirks	
September	RADM Federico Solari	Commander, COMFORDRAG
	Dr J. Osler Dr P. Hines	DRDC Canada
	BOUNDARY JRP meeting	
	Dr D. Lane	
	Mr D. Wilhelmsen	General Manager NC3A
	NIAG NG86 progress (Integrated Harbour Barrier Systems)	
	RADM J.-L. Kérignard, FCRT,	SACT
	HPT06 Meeting	
	MARISTAT Italy Representatives	
	SG/21 & NG/2 MeetingSG/21 Meeting	
	Mr M. Palsetia	Vexcel Corporation, CA
	ST - MBPES meeting (Mine Burial Prediction Expert System)	
	NG/2 Meeting	
	Mr V. Kerbaol	Boost Technologies, France
	Mr W. Van Cappellen Mr S. Wallace	NC3A
	Mr J. Turk	NRL Monterey
October	Mr B. Nordgren Ms J. Salmon	Firelab
	Mr C. Trees	San Diego University Foundation
	87th Meeting Scientific Committee of National Representatives	
	Dr Y. Stephan Dr D. Jourdan Dr Y. Morel Ir G. Casagrande	Centre Militaire d'Océanographie (CMO) and Service Hydrographique de la Marine (SHOM)
November	Mine Detection and Classification JRP Meeting	
	Prof. W. Alpers	Hamburg University
	Mr R. Soukup	NRL, Washington
	NATO Workshop on Multistatic Operations Research	
	High resolution coupled coastal prediction workshop (01A2 kick-off) meeting	
December	Mine Jamming Meeting	
	Mine Models for Electronic MCM	
	SSTAG Space Science and Technology Advisory Group Meeting	
	EGUERMIN group visit	
	German Officers from the Ship FGS Mecklenburg-Vorpommern	

NATO Undersea Research Centre Scientific Committee of National Representatives National Liaison Officers and Observers

BELGIUM
National Representative 2004
CDR Sg **Stefan VERBOVEN, BELN**
Head of Naval Capabilities - Plans Division

CANADA
National Representative 2003
Dr **James L. KENNEDY**
Chief Scientist
Defence R&D Canada - Atlantic

CANADA
National Liaison Officer (1998) 1999
Dr **Dale ELLIS**
Defence R&D Canada - Atlantic

DENMARK
National Representative 2005
Mrs **Charlotte LANG**
Branch Chief Oceanography
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Annual Progress Report 2005.

Abstract

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This Progress Report describes the Centre's unclassified technical accomplishments and outputs realised under the Scientific Programme of Work (SPOW) for 2005. The Centre conducts maritime research in support and anticipation of NATO's operational and transformational requirements via the SPOW and via a number of military experiments under sponsorship of Allied Command Transformation (ACT).

We maintain extensive partnering to expand output, to promote maritime innovation and to foster more rapid implementation of the research products. Partners include similar organisations, capability providers in the nations, and users of these capabilities throughout the alliance. Several indicators of recent partnering activities follow the section on Progress in Quality Management along with a few other overall activity indicators. Details and results of partnering can be found in the body of this Report and are often termed Joint Research Projects (JRPs).

This Progress Report reflects a continuing evolution of the research in support of maritime operations for joint, expeditionary forces across a wide range of mission types as described in the Bi-SC document, Strategic Vision: The Military Challenge.

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