NATO Undersea Research Centre
Partnering for Maritime Innovation

Annual Progress Report 2004

This document is approved for public release.

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.

ANNUAL PROGRESS REPORT 2004

A Few 2004 Indicators

Visitors

The Centre received 548 scientific and technical visitors, 229 visitors for meetings/conferences and 54 official visits (see page 91 for a listing).

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

Personnel Rotation

The Centre received 400 applications for 17 vacant posts in 2004. There were 10 visiting scientists from 5 nations, 6 research assistants, also from 5 nations, and 3 thesis or doctorate students (3 nations).

Ship Management Office (SMO)

NRV *ALLIANCE* was visited by 11 officers of flag rank, or their civilian equivalents, from 5 nations.

The ship operated jointly with RV *QUEST* (CA) and ITS *DA VINCI*, *PONZA* and *TAVOLARA* and sailed a total of 14 632 miles.

Engineering Technology (ETD)

ETD supported 13 SPOW sea trials and 4 military experiments.

An oceanographic instrumentation calibration capability has been developed over the years and is offered to member nations. nine organisations from 3 nations utilised this capability in 2004 for a total of 37 days.

The Science and Technology Office (STO) has 8 co-operative programmes at various stages of maturity. They are described in the ETD section.

Other significant activities in 2004:

- Shallow water Environmental Profiler in Trawl-safe Real-time configuration (SEPTR): completion of pre-production prototype testing.
- Ocean Explorer AUV (OEX): completion of navigation and control performance enhancement.
- Completion, demonstration and deployment of prototype Forward Eyes beach monitoring and surveillance system.
- Focused Acoustic Fields (FAF): Design, development and build of full scale FAF experimental system.

Contents

Target Military Capabilities

Thrust Area	Programme	1. Remote MCM	2. LFAS	3. Network-enabled surveillance	4. Marine mammal Risk Mitigation policy	5. Covert Undersea surveillance	6. Environmental prediction package	7. REA using AUVs and satellite	8. Tactical Decision Aids and CONOPS	9. Command and Operational Support	10. Expert exercise analysis	11. Defence against terrorism	12. Comms for REP
Expeditionary MCM and Port Protection	Mine-Ship Interaction	■							■	■		■	
	Minehunting With AUVs	■							■	■		■	
	MCM Decision Aids								■	■		■	
	Intruder Detection	■										■	
Undersea Reconnaissance, Surveillance and Networks	Multi-sensor Systems and Methods			■	■	■			■				
	Environmental Adaptation		■	■	■		■		■				
	Network-Enabled Capabilities			■	■								
	ASW Decision Aids		■	■	■				■	■			
Expeditionary Operations Support	High Resolution Environmental Modeling and Shallow Water Acoustics	■	■	■		■	■	■	■			■	■
	Data Collection For Battlespace Preparation		■	■	■	■	■	■	■			■	
	Data Management, Fusion, TDAs and Display	■			■		■	■	■	■	■	■	■
Command and Operational Support	Operational Support	■								■	■	■	

Foreword by the Director

This Report describes how the NATO Undersea Research Centre[*] discharged its mission in 2004. It is aimed at a wide audience and contains no classified material. The Centre's accomplishments in this period were achieved while the Scientific Programme of Work (SPOW) was being refocused on NATO's latest operational and transformational imperatives, which include expeditionary operations, support for the NATO Response Force and the defence of maritime forces and installations against terrorism. Achievements, therefore, include the culmination of a number of multi-year projects and realignment to face new challenges.

A few, sample highlights to illustrate the 2004 programme are:

- a demonstration of the potential of Autonomous Underwater Vehicles (AUVs) for operations in protection of ports.
- completion of the Focused Acoustic Fields (FAF) exploratory research.
- the release of the latest versions of 2 mine countermeasures software packages.
- the first demonstration of the deployable multistatic surveillance system in an operational context.
- the completion of the Anti Submarine Warfare (ASW) planning tool, PLANET.
- a test of new environmental assessment techniques off Portugal, with specific applications for expeditionary forces.
- the delivery of a satellite ground station for remote sensing of the environment.

In the course of refocusing the research, I selected 12 areas in which the SPOW targets shortfalls in military capabilities. The resulting matrix is shown on the facing page. A description of the 12 Target Military Capabilities can be found on pages 79 and 80.

Unfortunately, the Centre had to make unexpected reductions in the course of execution of the 2004 programme in order to meet emergent demands on the budget of the newly-established Allied Command Transformation (ACT). This resulted in the cancellation, or postponement of several sea-trials. We will deal with the impact in programming terms by making adjustments over the course of 2005 and beyond, and we will continue to foster relationships with our partners because they remain of prime importance to us in meeting the needs of NATO and the Nations.

A working group formed by SACT to consider the options for the future status, financing and organisation of the Centre met in August. As a result the operating flexibility of the Centre under ACT is being increased and the possibility of operating as part of the Research and Technology Organisation (RTO) is under consideration by the Research and Technology Board (RTB).

In these pages you will read of the continued success of, and output from, the Centre, notwithstanding the unusual challenges to programme execution and the prospect of a dynamic future.

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[*] formerly SACLANTCEN

Expeditionary MCM and Port Protection (EMP) Research Thrust Area

Operational Context

Modern NATO doctrine places emphasis on expeditionary forces that will be prepared to deploy and operate anywhere in the world. The NATO Response Force, for which a rapidly deployable efficient Mine Countermeaures (MCM) capability will be crucial, is a critical element of these operations. Additionally, for the NATO Conference of National Armament Directors (CNAD), the defence of maritime forces and installations against terrorist threats is the item of highest priority amongst those relating to maritime warfare.

Overview

This Thrust area develops sensors and procedures for:

- Employing quickly deployable, unmanned MCM systems with an emphasis on shallow water and the restricted environment of ports.
- Protecting maritime forces and ports against terrorist threats.

EXPEDITIONARY MCM AND PORT PROTECTION		
Mine-Ship Interactio	Mine Jamming (Proj. 3C1)	A. Gabellone
	Signature Sensitivity Study (Proj. 3C2)	A. Gabellone
MCM Modelling	Finite Element Model for Target Scattering (Proj. 3E2)	M. Zampolli
Minehunting with AUVs	Advanced Sonar for Minehunting with AUVs (Proj. 3G1)	M. Pinto
	AUVs for Counter-Terrorism MCM in Ports and Harbours (Proj. 3G2)	E. Bovio
Environmental Programme (MCM)	Environmental Characterization for MCM (Proj. 3H1)	E. Pouliquen
	Clutter Estimator Capability for MCM (Proj. 3H2)	E. Pouliquen
Focused Acoustic Fields (FAF)	Communications and ASW Applications of FAF (Proj. 6B1)	M. Stevenson
	A FAF Acoustic Barrier For Counter-Terrorism (Proj. 6B2)	M. Stevenson
MCM Planning, Evaluation and Decision Aids	MCM Tools (Proj. 5C4)	K. Bryan
	Minehunting Sonar Performance Model (Proj. 5C8)	G. Davies

The highlights of the 2004 programme (see Table above) were:

- Completion of the counter-terrorism project “AUVs for Counter-Terrorism MCM Operations in Ports and Harbours”. This successful project convincingly demonstrated the potential of small AUVs, such as the REMUS, for MCM operations in ports.

- Redirection of the MCM environmental programme. The two projects were reported at the November 2004 meeting of the Scientific Committee of National Representatives (SCNR) in and project completion reports are available.

- Completion of the Focused Acoustic Fields (FAF) exploratory research programme. The reporting on the counter-terrorism acoustic barrier (Proj. 6B2) has been postponed to October 2005, to incorporate the results of the October 2004 sea trial.

Vision

Medium Term The main thrust of the MCM work is on AUV-based MCM with direct application to both Expeditionary Warfare and Port/Force Protection. The scientific content covers a wide spectrum, from basic acoustic scattering theory applied to targets and the environment, to signal and systems applied to AUV and sensor technology for proud and buried mine hunting, and finally Tactical Decision Aids (TDAs) and operational research. The emphasis on TDAs will progressively move from tools for existing Mine Countermeasure Vessels (MCMVs) to tools for AUVs. In particular a new project will begin in 2005 on planning and evaluation of MCM operations with AUVs. This project will be supported by a new environmental acoustic project, which will emphasize the role of high resolution sonar imagery in minehunting bottom type and clutter estimation.

The mine-ship interaction work explores alternatives to minehunting, based on concepts of electronic warfare (e.g mine jamming). A simulation framework, including a generic mine model, will be developed to assist in the evaluation of the operational effectiveness of such concepts.

The Thrust Area's second contribution to maritime DAT is a capability to detect and track intruders such as divers or mini-submarines. The work done in 2004 on FAF-based barriers is preliminary work, exploratory in nature. The scope of this work will be expanded in 2005 in the frame of the new project entitled "Multi-sensor harbour protection systems".

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 on 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 and (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 (NAS) and possibly bistatic or multistatic sonar operations. There is a clear link between this work on NAS 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 of sensing systems. The underwater surveillance provided by the inner and outer layers must also be combined (data fusion) with above water surveillance (optical, radar and infrared sensors based on shore, airborne or spaceborne). All of these cues must be fused into a single port security picture that is available to both military and civilian authorities and is highly automated with low false alarm rates.

Targeted Military Capabilities

The mission of the Expeditionary MCM and Port Protection (EMP) Thrust Area is to address shortfalls in the following Military Capabilities:

- Remote MCM against modern and buried mines
- Defence of maritime forces and installations against terrorism
- Developing a common operating picture (COP) and integrated tactical decision aids (TDA).

Technical Accomplishments

1: Assessment of Commercial-Off-The-Shelf (COTS) AUVs for counter-terrorist MCM operations in ports and harbours

Port installations are an extremely challenging area within which to conduct MCM operations due to: shipping movements, very shallow water, turbidity, confined space, mine burial, and very high clutter density.

In March 2004 the project demonstrated the capabilities of AUVs for port protection to NATO Assistant Secretary General for Defence Investments and to the Italian Navy in the port of La Spezia. The REMUS AUV, provided by Hydroid, was configured with the Marine Sonic 900 kHz side scan sonar. The vehicle was launched and retrieved from an Italian Navy rigid hull inflatable boat (RHIB). In addition the PLUTO PLUS remotely operated vehicle (ROV) provided by GayMarine was equipped with the Widescan II side scan sonar provided by NURC.

At the beginning of 2004 HQ SACT provided funds to procure two REMUS vehicles and organized an experiment in the port of Rotterdam that was chosen because of its relevance to the world economy. Personnel from various organizations contributed to the conduct of the experiment: EOD divers and the support vessel “Hydra” from the RNLN, scientists from NURC, port authorities from the Port of Rotterdam, SACT personnel for Experimentation Analysis, engineers from Hydroid and SeeByte, which provided the post-mission analysis tool SeeTrack. The trial was conducted in two basins, Yangtze and Tennessee, of the EUROPORT (Fig. EMP.1). Both areas have the typical port bottom conditions with some mud and silt as well as burial of up to 50 cm.

Figure EMP.1 *Entrance to EUROPORT, Rotterdam, NL showing the two test sites TENNESSEE and YANGTZE where the REMUS surveys took place.*

The trials in the ports of La Spezia and Rotterdam showed that commercially available AUVs such as the REMUS, when used in conjunction with EOD divers, can significantly speed up clearance operations. However the difficulties encountered in highly cluttered areas suggest that the problem of protecting our ports and harbours is not completely solved. In particular, navigation in confined waters, detection and classification of partly and completely buried mines, are difficult problems which require more research (Fig. EMP.2).

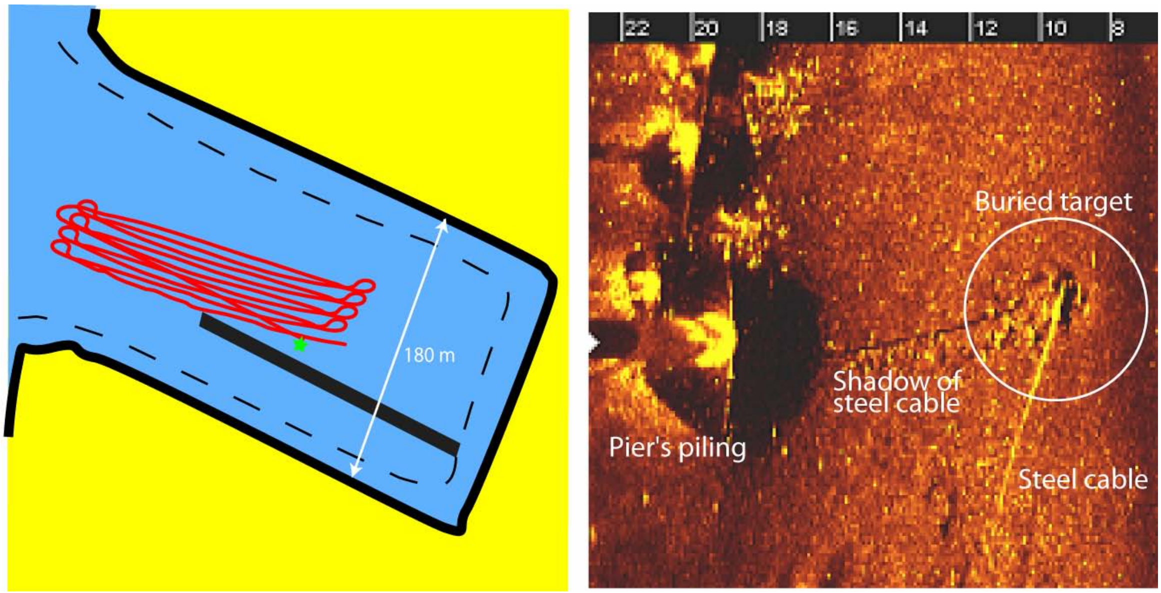

Figure EMP.2 *REMUS survey tracks in Tennessee harbour (left) and image (right) of the Marine Sonic sonar showing the pier's pilings, a buried target connected to the pier by a steel cable.*

2: Experimental demonstration of an AUV-based synthetic aperture sonar for buried mine detection and classification (Fig. EMP.3)

In March 2004, a sea trial was conducted in the Baltic Sea in collaboration with the German research establishment FWG to assess the performance against buried mines of the Centre's AUV-based 8-16 kHz bottom penetrating synthetic aperture sonar (SAS), deployed from R/V *ALLIANCE*. The gassy seabed in the Baltic is a notoriously challenging area for buried mine detection. The SAS performed consistently well, in both the side-looking and down-looking configurations, providing the expected tenfold gain in sonar cross-range resolution and the corresponding 10dB increase in echo to reverberation ratio. The down-looking SAS detected a deeply buried cylindrical target, covered by 1 m of hard sediment (sand) with 15 dB signal excess. Unfortunately the unexpectedly poor performance of the vehicle's dead-reckoning navigation suite limited the ability of the vehicle to do large scale surveys. An upgrade of the navigation package has since been put in place.

Figure EMP.3 *Ocean Explorer AUV equipped with the Low frequency Synthetic Aperture Sonar which was used in the Baltic in March 2004 for a buried object detection trial.*

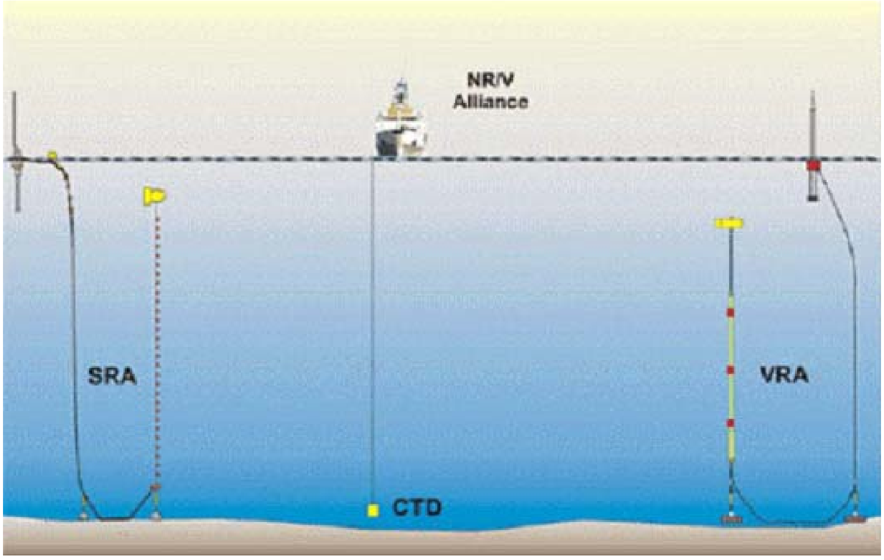

Figure EMP.4 *The schematic above illustrates the components of a generic TRM experiment. A probe source (PS), indicated by one of the rectangles on the vertical receive array (VRA), sends out a pulse that is received at the source-receive array (SRA). The dispersed signal with all its multipath structure is time reversed and retransmitted by the SRA. The resulting signal multipath structure collapses to a spatial and temporal focus (original PS pulse length) at the original PS position that is co-located in range with the VRA.*

3: Experimental demonstration of mine jamming concepts

Mine jamming consists of preventing a live mine from arriving at a firing solution, e.g. by interfering with its acoustic or magnetic target detection sensors, or its firing logic. It has generated considerable international interest and is the focus of a Joint Research Project supported by Australia (sponsored by Denmark under a MOU), Belgium, Canada, Denmark, Germany, Italy, Norway, the Netherlands, United Kingdom and United States. The 2004 study results were presented to the BE/NL Minewarfare School (EGUERMIN), the Italian Naval Academy, and the Mine Warfare Working Group and are included in the Mine Jamming Phase 2 Results, SR-414.

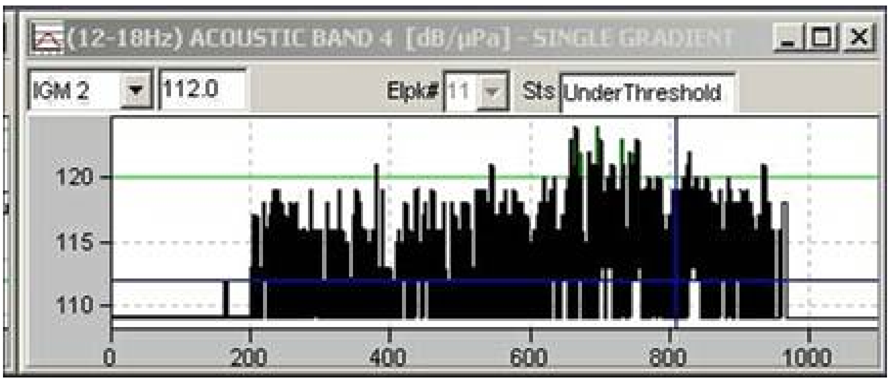

Figure EMP.5a and b *An example of acoustic environmental jamming. In thefigure above there is a sample of feedback - positive lock - of one acoustic logic channel (in the 12-18 Hz band) of an influence mine during a target-only run. In the figure below) there is feedback - no decision=jammed - of the same logic channel during a target+jam run. The target's signature is also masked by the jammer's signal*".

Figure EMP.6 *The ITS GRECALE crossing the experiment minefield protected by jamming equipment.*

In 2004 a joint trial 'Songs of Sirens' was carried out with the Italian Navy MCM Forces Command (COMFORDRAG) and the Commander in Chief (CINCNAV). COMFORDRAG provided the MW range facilities and two minehunters while CINCNAV provided a frigate, ITS *GRECALE*. Representatives from UK, BE and EGUERMIN took also part in the trial. NURC provided a set of acoustic transducer sources, which between them covered the frequency band 10Hz ÷ 20kHz. Using the TMSS (Total Mine Simulation System) software, different jamming concepts were evaluated and the ability to significantly reduce the risk to a transiting ship was proven. The trials results confirm and quantify the general rule that jamming is more effective against modern mines.

4: FAF sea trials for acoustic communications and intruder detection (Fig. EMP.4)

These sea trials have mostly been a cooperative effort between the scientific, engineering and ship staff of NURC and scientists and engineers of the Marine Physical Laboratory, U.S.A. Other collaborators have included the University of Pisa, Massachusetts Institute of Technology, the U.S. Naval Research Laboratory, and Woods Hole Oceanographic Institution.

The July experiment was conducted in approximately 100 m water depth at a centre frequency of 3500 Hz with 1000 Hz bandwidth. This geometry is well suited to assess the potential of FAF for undersea multiple-input-multiple-output (MIMO) communications, which are of interest both for AUV networks and the fixed sensor networks investigated in the Undersea Reconnaissance, Surveillance and Networkds (RSN) and Expeditionary Operations Support (EOS) thrust areas for ASW applications as well as oceanographic data collection. This assessment of potential will be made in a new project in 2005. In addition the experiment also considered reverberation nulling with a 2D array.

The November experiment was conducted at 11-19 kHz in about 10 m water depth. The aim was to assess the potential of FAF for a forward scatter acoustic barrier (tripwire) concept for intruder detection in a counter-terrorism port protection scenario. The waveguide length was about 160 m with one interface being an undulating seafloor. After establishing a focus at one end of the waveguide, stationary and moving objects were placed in the water column, including an autonomous undersea vehicle (AUV). The detection is based on before and after comparison of the received acoustic signal, including the temporal and spatial aberration of the focus. Several anomaly detection techniques were applied to the acoustic data in post-processing. The overall performance of the concept will be reported at the May 2005 SNCR meeting.

5: Assessment of space-time filters for acoustic communications

In the minehunting AUV programme, a comparison was performed between FAF and multi-channel adaptive equalization for two-way SIMO/MISO (Single Input Multiple Output/Multiple Input Single Output) underwater acoustic communications between a source-receiver array and a single transducer. This is relevant to long range shallow water communications between an AUV and a mothership. The study was based largely on a pre-print by M. Stojanovic (MIT) and showed that equalization allows much higher data rates to be achieved than FAF in the particular case, of practical significance, when inter-symbol interference induced by multipath is the limiting factor, rather than additive noise. The results of this study were also presented to the German research establishment, FWG.

6: Efficiency gains in finite element target modelling tool FESTA (Fig. EMP.7)

FESTA is capable of predicting the echoes of targets in realistic mine-hunting or harbour protection scenarios with a high level of structural detail. The price to pay is increased computation time which limits the maximum useable frequencies to typically less than 10 kHz. The addition to FESTA of a sophisticated computational technique called infinite elements, has made it possible to consider higher frequencies, in the range 10-15 kHz, which is the operating frequency range of the NURC buried mine sonar. Significant progress has also been made on an environment-independent technique for the characterization of elastic targets.

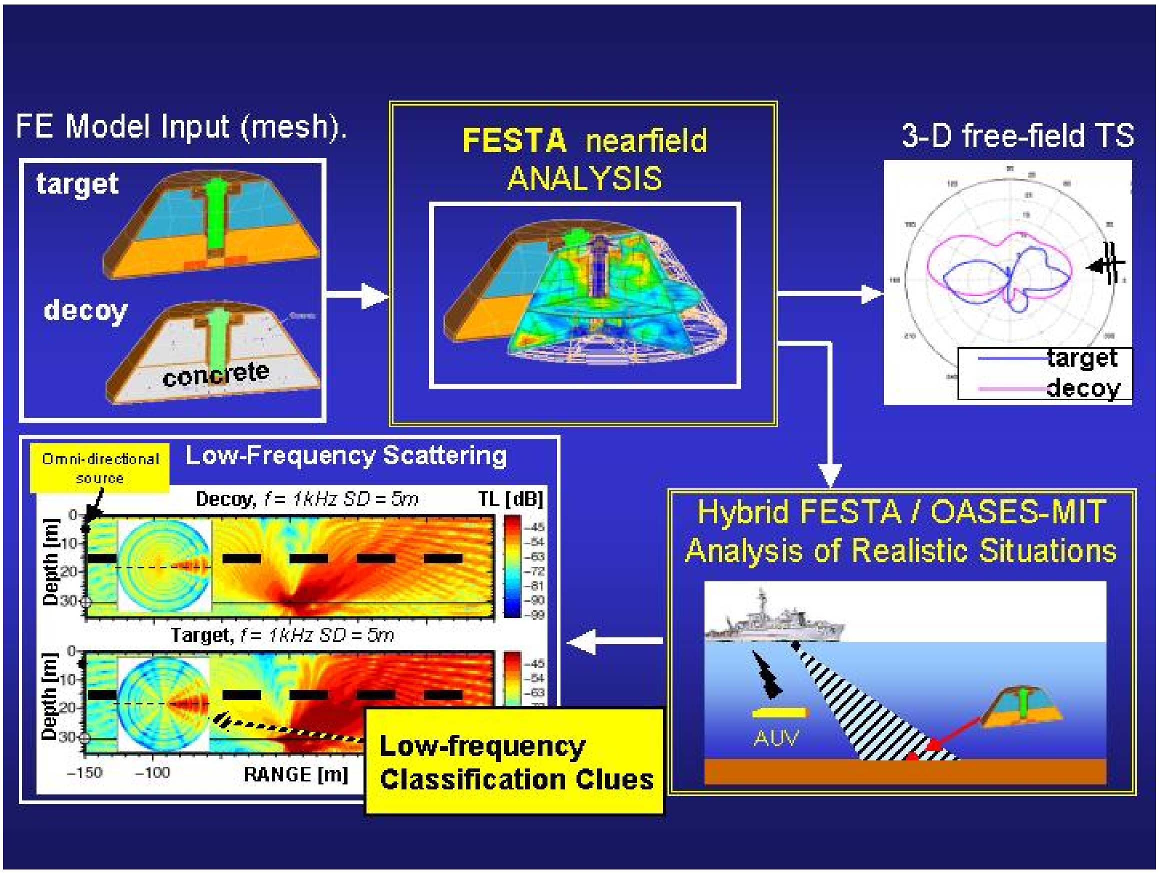

Figure EMP.7 *Example of the FESTA workflow showing two available options: (i) free-field analysis to study the relevant details of the target echo structure, and (ii) hybrid (or coupled) FESTA/OASES model for the simulation of realistic low frequency minehunting scenarios.*

7: Software releases of Version 2.0 of DARE (Decision Aid for Risk Evaluation) and of beta version of MCM sonar performance prediction tool ESPRESSO

DARE addresses the requirement for planning and evaluation methods for MCM operations that accurately assess the risk to follow-on traffic based on the MCM effort employed. The technical achievement in DARE 2.0 was a revised computational methodology, allowing for the calculation of much larger scenarios and providing a much faster and more reliable assessment of risk. NURC staff were onboard the MCM Command Ship in the exercise Blue Game 04 running DARE and provided an analysis of the use of DARE in the exercise. In April, 180 copies of DARE version 2.0 were distributed to NATO navies. DARE is developed under the operational guidance of the NATO Mine Warfare Planning Evaluation and Risk Assessment Panel (MW PERAP).

ESPRESSO addresses the military requirement of “performance assessment of MCM systems in real-time”. A beta version was released in February. Two versions of the software tool are available: a scientific version gives scientists and engineers a high degree of flexibility in algorithm choice, and a military version can be tailored to each sonar system for use in a military environment.

8: Algorithms and software for seabed classification and the modelling of scattering

There are numerous achievements within this programme, such as techniques for seabed segmentation using high-frequency multibeam systems, near normal classification of the seabed, inversion and mapping of seabed properties relevant to minehunting performance prediction. Work on reverberation amplitude statistics was performed in collaboration with Penn State University and ONR. The Centre stereo-photogrammetry device was deployed during the SAX'04 experiment in the US. The software tools developed include the segmentation tool SESAM, the high fidelity seabed scattering simulator BORISSA and a rough waveguide propagation tool BELLODDS. These tools are currently used by a large group of scientists in numerous NATO Nations. SESAM was tested during several Centre sea-trials and Centre and NATO exercises (NL 03, MREA 04, Blue Game 04) and was found very useful in planning and evaluating MCM operations. The two projects were reported at the SCNR meeting in November 2004 and detailed project completion reports are available.

Expeditionary MCM and Port Protection publications and presentations 2004

Peer reviewed journal papers

Canepa, G., Pouliquen, E., Figoli, A., Guerrini, P., Fioravanti, S., Lyons, A. SAPHO: Seafloor Automatic PHOtogrammetry. *IEEE Journal of Oceanic Engineering*.

Canepa, G., Pouliquen, E., Pace, N.G. Modelling and field measurements of bistatic scattering at high frequency. *Journal of the Acoustical Society of America*.

Canepa, G., Pouliquen, E., Ramoni, M. SESAM, a SEafloor Segmentation AlgorithM: theory and experimental validation. *IEEE Journal of Oceanic Engineering*.

Harrison, C.H., Nielsen, P.L. Plane wave reflection coefficient from near field measurements. *Journal of the Acoustical Society of America*, **116**, 2004:1355-1361.

Rixen, M., Ferreira Coelho, M. Operational surface drift prediction using linear and non linear hyper ensemble statistics on atmospheric and ocean models. *Journal of Marine Systems*.

Tesei, A., Zampolli, M., Stevenson, J.M., Fawcett, J.A. Prediction of the acoustic target strength of a scuba diver for anti-terrorism applications. *U.S. Navy Journal of Underwater Acoustics*.

Reports

Bovio, E. Autonomous underwater vehicles for port protection, SR-401 (NATO CONFIDENTIAL).

Rothenbach, M., Bovio, E., Yip, H., Gabellone, A. Unmanned Underwater Vehicle (UUV) Experiment in the Port of La Spezia, SR-399 (NATO CONFIDENTIAL).

Burnett, D.S., Zampolli, M. FESTA: a 3D finite element program for acoustic scattering from undersea targets, SR-394.

Canepa, G., Pautet, L., Pouliquen, E. BORIS-SSA: BOttom Response from Inhomogeneities and Surface using Small Slope Approximation. Version 1.0, M-152.

Canepa, G., Pouliquen, E., Figoli, A., Guerrini, P., Fioravanti, S., Lyons, A. SAPHO: Seafloor Automatic PHOtogrammetry, SM-424.

Canepa, G., Pouliquen, E., Pace, N.G. Modelling and field measurements of bistatic scattering at high frequency. SM-426.

Canepa, G., Pouliquen, E., Ramoni, M. SESAM, a SEafloor Segmentation AlgorithM: theory and experimental validation, SM-414.

Gabellone, A., Zampolli, M., Michelozzi, E. Mine jamming. Phase II results, SR-414 (NATO CONFIDENTIAL).

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

Law, J., Bovio, E., Bezemer, A. Preliminary guidance for the tactical use of AUVs in counter-terrorism MCM operations in ports and harbours, M-151 (NATO RESTRICTED).

Myers, V.L., Pinto, M. Information theoretic bounds of ATR algorithm performance for sidescan sonar target classification, SR-391.

Nielsen, P.L., Jensen, F.B. Prediction of low-frequency acoustic propagation in shallow water, SR-404.

Pouliquen, E. Modelling and field measurements of bistatic scattering at high frequency, SM-388.

Pouliquen, E. Near normal classification of the upper layer of the seabed, SM-421.

Pouliquen, E., Canepa, G., Pautet, L., Lyons, A.P. Variability of seafloor roughness properties and its impact on acoustic scattering, SM-422.

Pouliquen, E., Pautet, L., Guerrini, P., Tesei, A., Lyons, A.P. Detection of a partially buried object using a time-reversal technique, SM-427.

Tesei, A., Pautet, L. Using single-element time reversal mirror for echo enhancement, SM-431.

Wang, L., Munk, P., Bellettini, A., Pinto, M., Myers, V. Experimental studies on detection and classification of buried targets with synthetic aperture sonar on AUV, SR-423.

Conference presentations

Bellettini, A., Pinto, M.A., Munk, P., Myers, V. A new synthetic aperture sonar design with multipath mitigation. Invited paper presented at International Conference on Acoustics, Kyoto, Japan, April 2004.

Bovio, E. Autonomous Underwater Vehicles for port protection, Symposium on Systems, Concepts and Integration (SCI) Methods and Technologies For Defence Against Terrorism, SCI-158/ RSY, NATO Research and Technology Organisation, October 25-27 2004, London.

Burnett, D.S., Zampolli, M. A unified continuum mechanics approach for structural acoustic finite-element modelling of target scattering. *In*: Simons, D. G. *editor*. Proceedings of the seventh european conference on underwater acoustics, ECUA, 5-8 July 2004, Delft, University of Technology, 2004:pp.423-430 [ISBN 90-5986-079-9].

Burnett, D.S., Zampolli, M. Simulation of acoustic scattering from undersea targets in shallow water. In: Capabilities of acoustics in air-/ground and maritime reconnaissance, target classification and identification, Lerici 26-28 April 2004.

Isakson, M., Canepa, G., Pouliquen, E. A comparison of laboratory reflection coefficient data with predictions from a time domain model of sea floor scatter using the small slope approximation (BoRIS-SSA). Paper presented at Acoustical Society of America 148th Meeting, San Diego, California, 15-19 November 2004. *Journal of the Acoustical Society of America,* **116**, 2004:2576.

Canepa, G., Pouliquen, E., Pautet, L., Pace, N.G. Bistatic scattering from the seabed at high frequency. *In*: Simons, D. G. *editor*. Proceedings of the seventh european conference on underwater acoustics, ECUA, 5-8 July 2004, Delft, University of Technology, 2004:pp. 595-600 [ISBN 90-5986-079-9].

Hollett, R.D., Pouliquen, E. Modelling the pressure fluctuations of a shallow-water reverberant field. *In*: Simons, D. G. *editor*. Proceedings of the seventh european conference on underwater acoustics, ECUA, 5-8 July 2004, Delft, University of Technology, 2004:pp. 313-318 [ISBN 90-5986-079-9].

Ronald T. Kessel, Myers, V.L Discriminating man-made and natural objects in sidescan sonar imagery: human versus computer recognition performance.

Myers, V.L., Pinto, M.A. Information theoretic bounds of ATR algorithm performance for sidescan sonar target classification.

Crook, R.J., Pinto, M.A., Bennett, P., Bellettini, A. A new modular AUV sonar payload optimized for littoral operations, MINWARA – Canberra, Australia, 9-11 Feb 2004 and DSTO workshop Sydney Australia 12-13 February 2004.

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Undersea Reconnaissance, Surveillance and Networks (RSN) Research Thrust Area

Operational Context

Small submarines and submersibles, difficult to detect in the challenging shallow-water environment typically associated with expeditionary operations, pose a significant risk in this crucial area of NATO's operational focus. NATO maritime commanders recognise this and emphasise their requirement for an improved reconnaissance and surveillance capability in order to achieve and maintain an increased tactical advantage against submerged, mobile threats in littoral waters and choke-points. This is key to the success of expeditionary operations involving the NATO Response Force (NRF). Additionally, the Strategic Commanders' specific guidance notes that priority is to be given to the all-weather detection and localisation of threat submarines and secure identification and recognition of own submarines in littoral/shallow waters.

Overview

Distributed sensor technology and netcentric warfare concepts will be utilised to improve significantly the detection-classification-localization (DCL) of small to medium-size, slow motion, submerged vehicles and improve the associated tactics through the development of tactical planning and decision aids. Potential targets include all types of submarines including small exploration submarines, Unmanned Underwater Vehicles (UUVs), Remotely Operated Vehicles (ROV) and Autonomous Underwater Vehicles (AUV) but temporarily exclude torpedoes and swimmers.

UNDERSEA RECONNAISSANCE, SURVEILLANCE AND NETWORKS		
Advanced Shallow Water Surveillance and Tactical Active Sonar	Advanced Active ASW Sonar Technology (Proj. 4A1)	Vance Crowe
	Broadband Environmentally Adaptive Sonar (Proj. 4A2)	Georgios. Haralabus
	Multistatic Active Sonar (Proj. 4A3)	Doug Grimmett
Littoral ASW Environmental Acoustics	Geo-Acoustic Inversion (Proj. 4C1)	Mark Fallat
	Scattering and Boundary Interactions (Proj. 4C2)	Peter Nielsen
ASW Modelling	Performance Model for Multistatic Reverberation-Limited Sonar (Proj. 4E1)	Mark Prior
Marine Mammal Risk Mitigation	Sound Oceanography and Living Marine Resources (Proj. 4F1)	Mike Carron
Non-Acoustics	Undersea Surveillance Network (Proj. 4G1)	Stephane Jespers
ASW Planning, Evaluation and Decision Aids	PLANning Expert Tool (PLANET) Proj. 5C1	Handson Yip
	Area Search Tactical Planning Aid (ASTPA) Proj. 5C2	Craig Carthel

Vision

Medium Term , The Thrust Area's new structure in 2005 will consist of the following four main research themes:

1. "Multi-sensor systems and methods" focuses research into the underwater (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. "Netcentric 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 Anti Submarine Warfare (ASW) operations-friendly environmental sensing techniques supporting the prediction capabilities required to operate broadband LFAS systems optimally in littoral waters.
4. "ASW Decision Aids" studies and develops information products in support of operational requirements expressed by the military ASW community.

Long Term The shift from sensor-centric towards networked-enabled capabilities has forced a change of orientation in the scientific research on sensors. The fields of distributed sensor technology and data/information fusion will become the main components of tomorrow's applied UW research, underpinned by advances in UW communications, ad hoc or dynamic networking concepts and environmental modelling and assessment. Information superiority will be the driving goal for improvements in:

- detection power (using optimally distributed heterogeneous sensors),
- classification and identification effectiveness, through information processing techniques such as sensor management and data fusion with the use of acoustic and systems models (i.e. "model-based data fusion"),
- localization and tracking with the aid of geographically referenced sensor and environmentally compensated sensor contacts and track fusion methods.

Advances with space-time resolving methods and technologies will be exploited in UW applications. Each advance will be supported by related operational research to optimize performance and to support mitigation strategies in respect of environmental constraints and regulations.

Targeted Military Capabilities

Capabilities under the initiative of this Thrust Area:

- Broadband environmentally adaptive LFAS.
- Multistatic concepts for an adaptive netcentric shallow water tactical surveillance capability.
- Marine mammal risk mitigation policy and decision aids.
- Multi-sensor covert undersea surveillance.
- COP-integrated Tactical Decision Aids (and associated prototype CONOPS) for the planning and execution of current and future maritime expeditionary operations.
- Command and Operational Support
- Additionally, this Thrust Area, supports the Centre's contribution to:
- Environmental prediction packages for maritime NRF operations.

Technical Accomplishments

1: Demonstration of deployable multistatic surveillance and target tracking during DEMUS'04 seatrial

The successful planning and execution of the DEMUS '04 seatrial focused on the use of deployable multistatic systems against the Italian Navy submarine *ITS LEONARDO Da Vinci.* The sea trial was conducted during a three-week period in September 2004, in the shallow waters of the Malta Plateau, in a JRP with the U.S. (ARL/UT, APL/UW) and the U.K. The primary objective of DEMUS'04 was the evaluation of the effectiveness of deployed multistatic active sensors in ASW surveillance scenarios, such as for choke points, fixed barriers, the monitoring of ports for entry/exit, and for limited area search missions. Specific objectives were the collection of a data set for development of multistatic active data fusion/tracking algorithms, evaluation of sonar performance models and sensor placement methodologies, and evaluation of integrated passive/active sensors in a distributed field.

The DEMUS system experienced some reliability problems during the trial, which limited the amount of data collected. However, the data which was collected was of high quality, and sufficient data exists to evaluate the system's performance and apply multistatic tracking algorithms. Figure RSN.1 shows the output of a distributed two-stage, multi-hypothesis tracker (MHT)-based, multistatic tracking algorithm as applied to one of the DEMUS runs which utilized an echo-repeater for the target (trajectory shown in red). The DEMUS source insonifies the target and echoes are obtained by two DEMUS receivers (one of which is blanked by the direct blast arrival over a significant portion of the track), which are then fused in the tracking algorithm. It is clear that the fused system is effective in tracking the target in this case. Also shown are various false tracks, most of which are generated by fixed bottom reverberation features. This demonstration of successful multistatic surveillance and fusion methods is a starting point for the Centre's future moves towards evaluating netcentric ASW concepts.

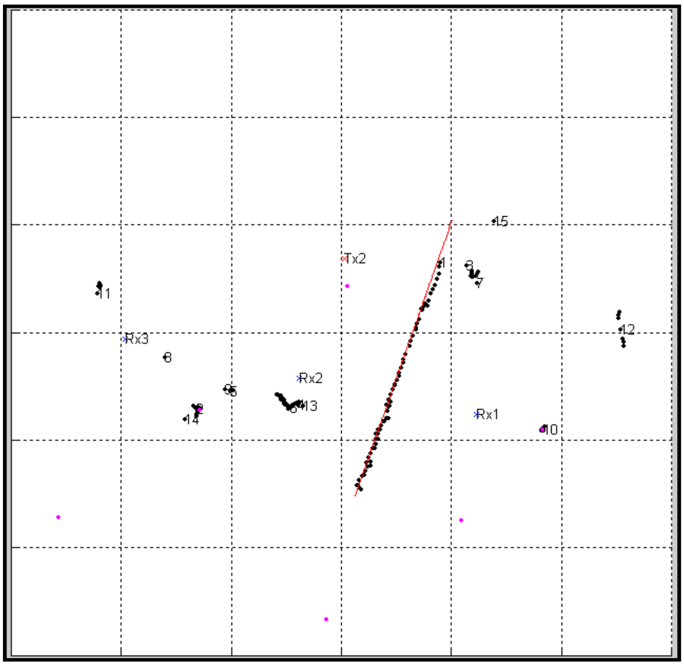

Figure RSN.1 *A multistatic tracker output during DEMUS'04.*

2: BASE'04 sea-trial in support of the broadband environmentally adaptive sonar concept development (Fig. RSN.2)

The successful planning and execution of the BASE'04 experiment included the participation of three vessels, namely NATO's Research Vessel *NRV ALLIANCE,* the Canadian Forces Auxiliary Vessel *CFAV QUEST,* and the Italian Navy submarine *ITS LEONARDO DA VINCI.* BASE '04 was conducted in a Joint Research Project (JRP) framework with the Defence

Research and Development CANADA (DRDC - Atlantic). The NAVSEA/NUWC and FWG laboratories in the USA and Germany respectively joined in the JRP work.

Figure RSN.2 *BASE '04 particating vessels. NRV ALLIANCE (left), ITS LEONARDO DA VINCI (centre), CFAV QUEST (right).*

As area diversity is important for this work, the experiment was conducted in three areas south of Sicily, namely, the Malta Plateau, the Adventure Bank and the Medina Bank. The data acquired are used for model validation in an effort to enhance the performance of broadband low frequency active sonar (LFAS) systems based on *in situ* environmental assessment coupled with real-time modelling forecast to identify sonar parameters that optimize detection performance in a specific environment. This accomplishment is an intermediate step in the development of the Broadband Environmentally Adaptive Sonar concept (target capability #2) to contribute to the reconnaissance and surveillance of slow moving submerged vehicles in shallow water, as the Centre merges ASW methodologies in a netcentric structure.

3: SUPREMO first-time use during sea-trial

The prototype version of the SUPREMO model was run at-sea during the BASE-04 experiment. On-the-day measurements of sea state and sound speed profile were used to augment archival data describing the Malta Plateau, Adventure Bank and Medina Bank areas; allowing real-time prediction of sonar performance, as quantified via signal-to-background ratio.

4: Environmental characterization

A Bayesian analysis of the MAPEX 2000 horizontal array data has been performed. This approach is based on a fast Gibbs sampling, which provides best estimates of geometric and geoacoustic properties and unbiased uncertainties of these parameters through matched-field inversion. The acoustic data covering a frequency band from 250 to 750 Hz were received on a 64-element and 250 m towed horizontal array. The acoustic track was around 10 km and has weakly range-dependent bathymetry and bottom properties. The 1-D marginal probability distributions for the water (black) and sediment (red) depth from 18 independent inversions along the acoustic track are shown in Fig. RSN.3.

The distributions are superimposed on a seismic profile acquired along the same track. The maximum value of the distributions indicates the water and sediment depth that results in the best match between model and data. The width of the distributions indicates the uncertainty of the inverted parameter. High uncertainty in the determined water depth is seen for the first 3 km. This is caused by the low sound speed in the sediment, which is almost transparent for the acoustic signals. The sediment depth in the same region is determined fairly uniquely as for the remaining part of the track. The water depth is determined more uniquely down range as the bottom sound increases and therefore strongly reflects the acoustic signal. The uncertainty analysis is planned for assessing the prediction capability of acoustic propagation in shallow water.

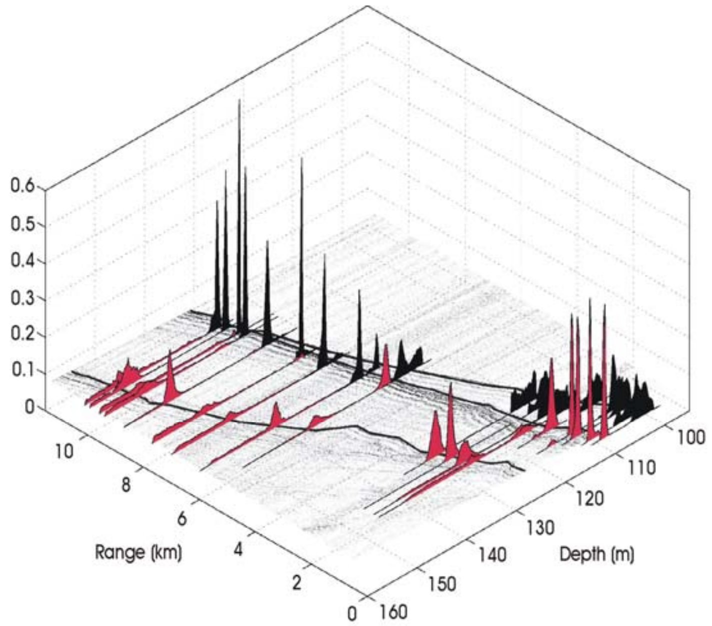

Figure RSN.3 *Marginal probability distribution of water depth (black) and sediment depth (red) along the 10-km acoustic track in MAPEX 2000.*

In May 2004 NATO Undersea Research Centre conducted the BOUNDARY'04 experiment which was part of a Joint Research Project with Defence Research and Development Canada, Applied Research Laboratory (Pennsylvania State University) and the Naval Research Laboratory (US) on the Malta Plateau in the Mediterranean Sea. The experiment involved 3 vessels: RV *ALLIANCE*, CFAV *QUEST* and ITS *TAVOLARA*. The objectives were to validate numerical algorithms to extract environmental information from acoustic measurements and demonstrate newly developed measuring techniques to enhance sonar prediction capabilities in high reverberation environments. All the objectives of the sea trial were met. Data analysis will continue in 2005 and during the coming years individually at each participating organization. The first meeting to discuss the BOUNDARY 2004 data analysis and results, and to present work in progress, is planned for September 2005 at NURC.

5: Marine mammals risk mitigation

This project facilitates the conduct of experiments and operational exercises, involving high-powered sonars, by developing a Centre (and NATO) policy for mitigating the risk to the marine environment and advising the nations on theirs. It is essential if international concern over the potential harm from sonar research and maritime exercises (to marine mammals), is to be addressed. In this programme, broad collaboration is a particularly significant feature of the research. In 2004 collaboration with the Woods Hole Oceanographic Institution (WHOI) who performed the tagging of sperm whales during earlier experiments aboard the NRV *ALLIANCE,* continued with tagging of beaked whales in the Ligurian Sea from a small whale watching vessel. This has resulted in the first ability to determine space-frequency bioacoustic properties of *Ziphius cavirostris* (Cuvier's Beaked Whale). Results will be published in 2005.

During the NRV *ALLIANCE* experiments the following organizations participated, in addition to WHOI:

- The Istituto Idrografico della Marina (Italian Naval Hydrographic Office)
- Università degli Studi di Genova (University of Genova - UNIGE)
- Centro Interdisciplinario di Bioacustica e Ricerche Ambientali, Università degli Studi di Pavia (Interdisciplinary Centre for Bioacoustics, University of Pavia, Italy - CIBRA)
- US Office of Naval Research, Naval Research Laboratory, the Naval Oceanographic Office, and Space and Naval Warfare Systems Center
- Naval European Meteorology and Oceanography Center (US) in Rota, Spain
- UK Defence Science and Technical Laboratory (Dstl) and QinetiQ
- Consiglio Nazionale delle Ricerche (CNR) Istituto per le Scienze Marine (ISMAR)
- Guardia Costiera (Italian Coast Guard)
- Museo Civico di Storia Naturale di Milano and Centro Studi Cetacei (CSC)
- Tethys Research Institute, San Donato Milanese
- Museo da Baleina (Whale Museum) , Madeira, Portugal
- Centre de Recherche sur les Cétacés (Centre of Research of Cetaceans), Antibes

6: Progetto Vulcano seatrial

Successful completion of multi-ship *Progetto Vulcano 04.* This experiment using CRV *LEONARDO*, Italian civilian R/V *UNIVERSITATIS*, and Italian Naval Hydrographic Office Vessel *GALATEA* surveyed the area north of Sicily in the Aeolian Islands performing oceanographic, acoustic, and visual surveys of marine mammals. The goal of *Progetto Vulcano 04* was to test habitat models being developed by the Marine Mammal Risk Mitigation Program in an area suspected to be an active habitat of *Ziphius cavirostris* (Cuvier's Beaked Whale), the marine mammal considered most at risk from naval sonars.

7: Progress in underwater sensor methods and technology

This project started this year and NURC attended two trials involving submarines and surface ships in Norway's underwater range of Herdla near Bergen. Experiments conducted during trials were aimed at: submarine detection and tracking, investigation into cooperative remote sensors (data sharing over limited links), engineering tests of new and unproven components, vertical line array (VLA) *versus* horizontal line array (HLA) and electromagnetic (EM) communications. Some technology tests were also attempted and consisted of trying active/passive sensor systems such as UCARA 4 (Ultra-light Canadian Acoustic Research Array) rapidly deployable system (RDS), EM source and receivers, magnetic full-field magnetometers, Herdla's EM/acoustic/pressure network. Two sets of several gigabytes of data have been acquired and are now under study. Initial trial analysis results indicate good progress in noise figures of some magnetic sensor technologies. Target detection using EM fields and EM communications underwater is also making good progress. This project is part of international collaborative research called "NGAS" (Next Generation Autonomous Sensors). In this collaboration, NURC partners are: NO (FFI), CA (DRDC-Atlantic) and US (ONR/SSC-SPAWAR). Figure RSN.4 shows the UCARA canisters on the ship deck, prior to deployment on the bottom of the fjord.

Figure RSN.4 *RDS UCARA system.*

8: Development of PLANET and ASTPA (Fig. RSN.5)

Planning Expert Tool (PLANET-5C1) was completed in 2004. It is an operational planning tool designed for use by ASW planners to determine the most efficient force deployment for ASW area search, barrier, screening and safest route operations. PLANET combines high quality sonar modelling with sophisticated search algorithms to provide the possibility of planning proposed missions in advance.

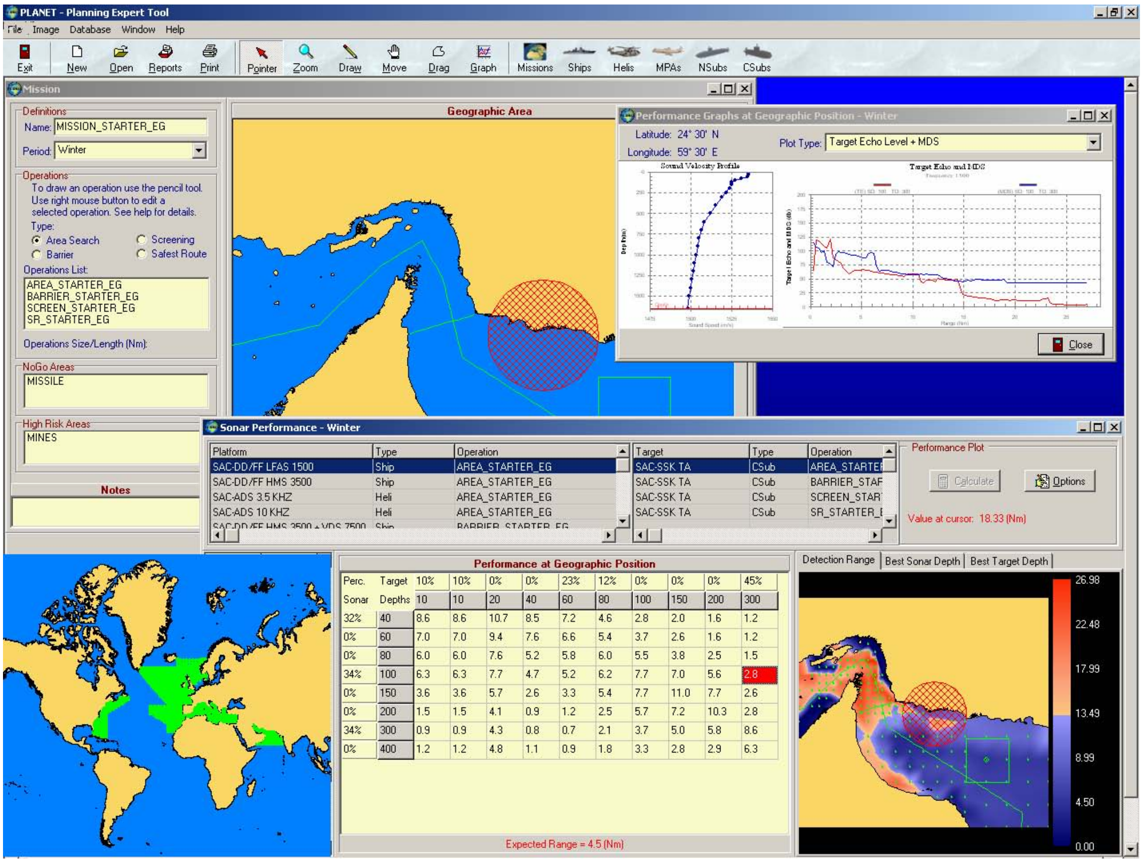

Figure RSN.5 *PLANET v 3.0 screenshot representing the available environmental areas, a mission and the performance of a specific sonar deployment.*

The Areas Search Tactical Planning Aid (ASTPA) will be completed in 2005. It is a tactical decision aid designed to provide the ASW Commander at sea with search tactics that maximise the effectiveness of the allocated ASW assets. ASTPA uses sonar sensor modelling, reacting target behaviour assumptions and kinematic state estimation algorithms in a Monte Carlo simulation to evaluate and optimize the effectiveness of ASW search and clearance plans.

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Stéphane Jespers *received the MS in Electrical Engineering from the Universite Catholique de Louvain in 1979. He then conducted statistical atmospheric impact studies on radio and television signals depolarization using radiometers and the European OTS satellite signals. In 1983, at the Centre he developed submarine target strength measurement techniques. Later he conducted VLF Active Sonar statistical performance analysis and led the design of an advanced real-time Active Sonar receiver prototype. In 1990, he was hired by Objectif SA Paris to lead the design and experimentation of Sonar Intercept demonstrator for French SSNs and SSBNs. He specialized in various Array Processing techniques, with application to towed array shape retrieval and Synthetic Aperture Sonar (SAS). In 2000, as Head of Department at the Centre he heading the RSN thrust area, in which the main focus is performance improvement of LFAS and deployable systems in shallow water, with emphasis on environmental limitations and impact of sound on marine life. Stéphane Jespers is a member of the IEEE, Signal Processing and Communications Societies. He is a member of the UDT conference Technical Programming Committee. He is an ex officio member of NATO/RTO/Sensors and Electronics Technology.*

Alberto Baldacci *graduated in Telecommunication Engineering and received a Ph.D. in Information Engineering from the University of Pisa in 1997 and 2000, respecttively. During this period his research focused on remote sensing for oceanography and target detection in infrared video sequences. In 2000 he joined the Centre as a consultant, where he worked on the integration of satellite derived parameters into ambient noise models, on geoacoustic inversion of ambient noise and participated in the development of a multistatic sonar performance model. In late 2002 he joined the ASW department, working on broadband environmentally adaptive sonars and multistatic active sonars. His main research interests are in digital signal and image processing.*

Michael Carron *graduated from the U.S. Naval Academy in 1968 with a B.S. in Oceanography and subsequently earned a M.A. and Ph.D. in Marine Science from the College of William and Mary, Williams-burg, VA and a M.A. in National Security and Strategic Studies at the Naval War College, Newport RI. He began in career at the US Naval Oceanographic Office (NAVOCEANO) in the Mathematical Modeling Group working on the development of ocean climatologies and the analysis of geophysical and oceanographic data from the GEOSAT program. He subsequently was an advisor to Sixth Fleet in Naples Italy. During the late 1980s he was head of NAVOCEANO's Physical Oceanography Department and his final position at NAVOCEANO was as Chief Scientist. He is presently a member of the IOC/IHO GEBCO Subcommittee on Digital Bathymetry and coordinator of the GEBCO Centennial World-wide Grid Project. The focus of his research at the Centre is to understand the effects of man-made noises, especially sonars, on marine mammals. This work is in support of the Centre's Acoustic Risk Mitigation Policy.*

Craig Carthel *received B.S. degrees in physics and mathematics (1988), M.S. degree in mathematics (1992) and Ph.D. degree in mathematics (1995) all from the University of Houston. From 1995 to 1997 he worked at the Institute for Industrial Mathematics in Linz, Austria on parameter identification problems associated with the steel industry. From 1998 to 2002 he worked in the Fusion Technologies and Systems division at ALPHATECH, Inc. in Burlington, MA on data fusion problems in radar and target tracking. He has been in the Command and Operational Support department since 2002 and is currently leading the development of NURC's Area Search Tactical Planning Aid.*

Stefano Coraluppi *received the B.S. degree in Electrical Engineering and Mathematics from Carnegie Mellon University in 1990 and the M.S. and Ph.D. degrees in Electrical Engineering from the University of Maryland in 1992 and 1997, specializing in estimation and control. From 1997 to 2002 he was with ALPHATECH Inc. in Burlington MA, where he worked on multi-sensor data fusion and target tracking for ground surveillance. He joined the Centre in 2002 and is working on multi-static sonar fusion and tracking.*

D. Vance Crowe *headed home to the East Coast of Canada after receiving MSc in Electrical Engineering from McMaster University, Ontario, Canada in 1973. He immediately started work in acoustic ASW at the Defence Research Establishment Atlantic (DREA). He worked on many projects: passive towed arrays, low frequency active sonar, high-speed signal processing and directional acoustic sensors. He has participated in and lead many multi-platform multi-national sea tests of R&D sonar systems. He worked at DREA until taking a leave of absence in September of 2001 to join the ASW Department at the Centre, where he developed the concepts of ASW acoustics using broadband active towed array sonar (BATAS) and active deployed systems (DEMUS).*

Mark Fallat *received the B.Sc. degree in Physics and Oceanography and the M.Sc. degree in Ocean Acoustics from the University of Victoria in 1997 and 1999 respectively. His M.Sc. research involved the inversion of ocean acoustic fields for geoacoustic parameters. In 1999 he worked for the Canadian aerospace company MacDonald Dettwiler and in 2000 he worked as the Director of Research for an internet company specializing in online gaming. He joined the Centre in late 2001 working on geoacoustic inversion employing a "through-the-sensor" approach.*

Odile Gérard *graduated from Ensi Caen in 1986. She obtained a Diplome d'Etudes Approfondies in Acoustics in 1987 and a PhD in Acoustics in 1991 from Marseille University. She then worked for 10 years for the French Navy Laboratory in Le Brusc on the measurement systems of submarines, particularly on ALHAMBRA. In 2001 she joined the Centre ASW team.*

Doug Grimmett *received the B.S. degree (1987) in electrical engineering from the University of Utah and masters degree in acoustics (1995) from the Pennsylvania State University. From 1987 to 1997 he worked with the SPAWAR Systems Center (and its predecessors) in San Diego, California, on signal and information processing in the area of bi/multi-static active sonar. In 1998 he joined the Centre where he leads the Advanced Shallow Water Tactical Active and Surveillance Sonar project.*

Georgios Haralabus *received his B.S. degree (1987) in mathematics from Aristotle University, Greece and the M.S. (1989) and Ph.D. (1993) in signal processing from Duke University, USA. The same year he worked as a Research Assistant at the Centre before joining the Hellenic Navy where he served as a sonar control petty officer. In 1995 he joined the Centre working on passive detection including merging multi-frequency matched field processing techniques with genetic algorithms. Subsequently he investigated active detection in order to enhance the effectiveness of low frequency broadband active sonar in coastal areas. He is the leader of the Broadband Environmentally Adaptive Sonar project. In 2004 he became a fellow of the Hellenic Institute of Acoustics, a member of the European Acoustics Association.*

René Laterveer *received the Ph. D. in theoretical physics from the University of Amsterdam in 1993 on a subject in elementary particle physics. From 1992 to 1995 he was at TNO Physics and Electronics Laboratory in the Hague, the Netherlands, working on active low frequency sonar. He has been at the Centre since 1996.*

Peter Nielsen *received the M.S. Mech. Eng. from Aalborg University in 1989 and the Ph.D. from the Technical University of Denmark in 1993. From 1993 to 1996 he was employed at the Technical University of Denmark on a European Union funded MAST-II project concerning develop-ment and validation of numerical models for sound propagation in the ocean. He joined the Centre in 1996 working on numerical modelling and experimental data analysis of time variability of received broad-band acoustic signals in shallow water. His interest is in numerical modelling of sound propagation in the ocean and geoacoustic inversion techniques.*

Mark Prior *received his B.Sc. in Physics from Birmingham University in 1988, after which he joined the Admiralty Research Establishment, Portland. As part of his work researching underwater acoustic propagation, he studied for an external Ph.D .in underwater acoustics with The Institute of Sound and Vibration Research at the University of Southampton, completing his Ph.D. in 1996. Remaining with A.R.E. through its transition to the Defence Research Agency and then the Defence Evaluation and Research Agency, he studied many aspects of underwater acoustic modelling with his main emphasis on propagation loss modelling and model validation using mathematical benchmarks and measured acoustic data. He joined the Centre in January 2001 and has worked on multi-static sonar modelling and the deduction of seabed properties from ambient noise.*

Marcel van Velzen *received a masters degree in theoretical physics from the University of Amster-dam in 1987 and until 1989 worked at the Netherlands National Institute for High Energy Physics (NIKHEFH). From 1989 to 1998 he was at the TNO Physics and Electronics Laboratory in the Hague, the Netherlands, where he worked on Synthetic Aperture Satellite Radar processing and from 1991 worked on real-time processing and data analysis for the Netherlands Low Frequency Active Sonar program. In 1999 he started at the Centre as a senior scientist working in the areas of signal processing and data analysis related to Active Sonar.*

Walter Zimmer *received his Ph.D. (Dr.rer.nat.) in physics at the Institute for Theoretical Physics, Uni-versity of Regensburg, Germany in 1978. From 1978 to 1982, he worked in the operation research department of the Industrie Anlagen Betriebs Gesell-schaft (IABG), Munich, in the field of air-to-ground reconnaissance perfor-mance modelling. From 1982 to 1987, he was principal scientist in the Centre Signal Processing Group working on high-resolution beam-forming techniques. In 1989 he became responsible for the real-time implementation of the active and passive sonar systems.*

Expeditionary Operations Support (EOS) Research Thrust Area

Operational Context

NATO operational planning centres on expeditionary forces that will be prepared to deploy and operate anywhere in the world. The NATO Response Force (NRF) is a critical element of such 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.

Overview

In 2004, the EOS Thrust Area shifted emphasis and technical focus to improve support to NATO's pursuit of "out of area" capabilities and to respond to the iMETOC implementation plan. The research goal is to develop the capabilities needed to enable the successful operational implementation of the iMETOC concept, with the ultimate objective of assisting the Combined Joint Task Force (CJTF) and maritime commander to exploit the environment to their strategic and tactical advantage.

EXPEDITIONARY OPERATIONS SUPPORT		
Littoral Ocean Modelling	Air-Sea Interaction Effects on Expeditionary Warfare (Proj. 1A2)	Richard Signell
	Surf Modelling (Proj. 1A3)	Daniel Conley
	NATO Tactical Ocean Modelling System (Proj. 1A5)	Emanuel Coelho
Data Collection for Battlespace Preparation	Seabed mapping with Autonomous Vehicles (Proj. 1B1)	Francesco Spina
	International Cooperation on AUV Technology (Proj. 1B3)	Edoardo Bovio
	Exploitation of High-Resolution Remote Sensing Imagery (Proj. 1B4)	Farid Askari
	Geoacoustic Inversion of Ambient Noise (Proj. 6E1)	Chris Harrison
Environmental Acoustic Modelling	Acoustic Modelling and Prediction Capability Development (Proj. 1C1)	Thomas Folegot
	Shallow Water Acoustic Tomography (Proj. 1C2)	Thomas Folegot
Data Fusion and Exploitation	Fusion and Exploitation of Geospatial Information (Proj. 1D1)	Farid Askari
	REA Exercise Support and Secure Communications (Proj. 1D2)	Alex Trangeled

NATO expeditionary operations are expected to increasingly take place in littoral environments where commanders will have inadequate knowledge of the environmental conditions affecting their missions. This includes a timely environmental picture of the littoral battlespace, which is an extremely dynamic and variable region complicated by the interaction of the ocean, atmosphere overland environments. In these volatile environments, rapid changes in meteorological and oceanographic conditions have often resulted in loss of life, platforms and weapons which become more detailed and time critical as an operation approaches.

Target Military Capabilities

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:

1. Remote and *in situ* data collection for battlespace characterization;
2. METOC prediction models for expeditionary operations support;
3. Data management and communications to support iMETOC in the Recognized Environmental Picture (REP) and Common Operating Picture (COP).

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 that assess environmental effects on weapons and sensors. The thrust area will continue to move into new technical areas to support NATO's plans for iMETOC, and expeditionary operations better. A more concentrated effort on the effect of air-sea interaction on operations in the littoral has begun. The principal effort will be devoted to the development of covert data collection using remote sensing and autonomous vehicles, improvement of methods for data analysis, prediction and effects along with expanded efforts in geospatial data services to provide timely exchange of METOC data and efficient use of the information technology infrastructure. Battlespace data collection will make maximum use of the new remote sensing ground station which will introduce advanced all weather, high-resolution satellite measurements to new oceanographic and acoustic models including assessment of their utility to ASW, MCM and amphibious warfare (AMW) and other expeditionary operations on tactical scales and timeframes. 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 through a series of sonar and programming upgrades for survey work aimed at the capacity for intelligent, covert shallow water surveys in unfamiliar waters.

Long Term 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 iMETOC support to expeditionary operations. The effect of air-sea interaction on operations will continue to be one of the major drivers for the thrust area and additional investigation into the coupling of air-sea-land effects may begin. 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 an iMETOC sampling network, 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

1: Development of tools for rapid environmental assessment (REA)

An extended inter-disciplinary sea trial (MREA04) was conducted off the western coast of Portugal in March and April 2004 to test new REA techniques under development as part of various collaborative efforts. This included contributions from 10 organizations from 7 countries, the RV *ALLIANCE*, the French Navy Hydrographic ship *BORDA* and a beach observations team. The trial included the following specific objectives:

- Testing of the NTOMS (NATO Tactical Ocean Modelling System) concept,
- Surface drift testing using automated met-ocean-wave model ensembling techniques;
- Small scale tactical numerical modelling (Mini-HOPS) testing using improved local data assimilation techniques;
- Testing of transmission loss estimation using non-hydrostatic ocean modelling;
- Training divers in the Forward-Eyes beach survey system prototype deployment;
- Test integration of oceanographic data collected by AUV missions,
- Real-time acoustic tomography testing to measure time variability of sound speed cross sections, between a ship and a ultra light drifting line array;
- Testing of geo-acoustic and tomography inverse methods using an array of standard sonobuoys.

A Maritime Rapid Environmental Assessment (MREA) workshop was held at the centre in December to report on developments in REA as a result of sea trials that the Centre has conducted including Linked Sea 2000, MREA-03, MREA 04, Adria-02 and Adria-03. Over 45 people from 10 nations participated in the workshop.

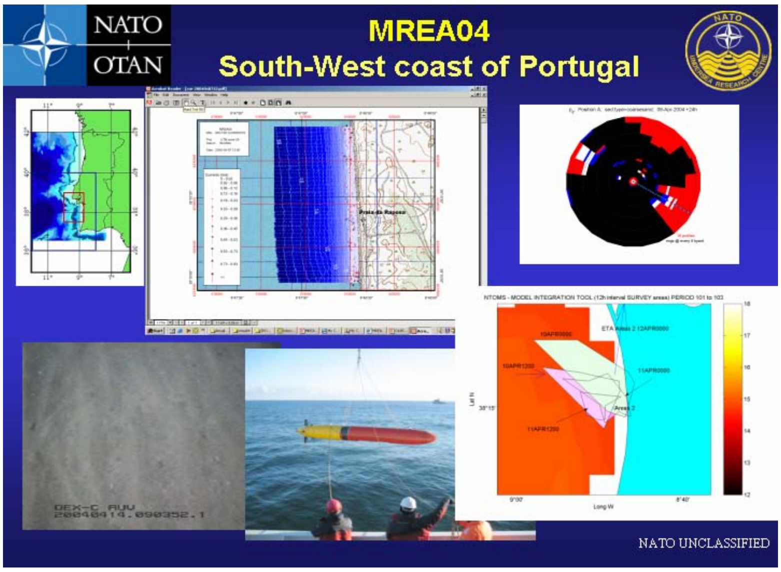


Figure EOS.1 *A summary of the MREA-04 sea trial showing clockwise from upper left (1) the operating area, (2) a beach survey combining laser bathy-metry, video measurements and model data, (3) plot showing variability in acoustic performance, (4) surface drift predictions using ensemble techniques, (5) launching the Ocean Explorer (OEX) AUV and (6) still photograph of the seabed taken from OEX video.*

2: Remote sensing X-band antenna ground station

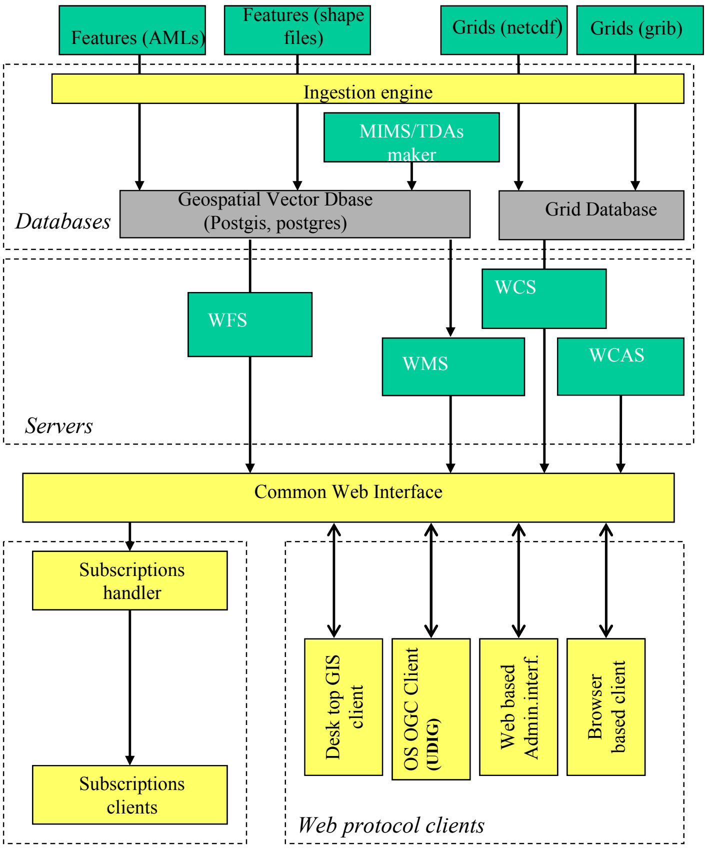
The Centre achieved a major milestone for upgrading the remote sensing capabilities in October with the delivery and acceptance of an X-Band Antenna Ground Station. The newly commissioned X-band ground station provides a unique capability within NATO and many Nations to receive satellite remote sensing imagery in real-time from the following: TERRA/MODIS, AQUA/MODIS, RADARSAT1, ENVISAT-ASAR, and ENVISAT-MERIS. Following the expected certification in 2005 of the ground station by RADARSAT International and the Canadian Space Agency CSA, NURC will belong to a family of networked ground stations around the globe which is certified to receive and disseminate RADARSAT-1 imagery to various users. NURC is also authorized by the European Space Agency (ESA) to receive and exploit the use of ENVISAT imagery for Earth observation and validation.

Figure EOS.2 *Ground station*

This station is capable of receiving in real time downlinks of numerous space-based sensors including synthetic aperture radar, multi-spectral and commercial high resolution imagery. Development of sensor fusion algorithms and user-friendly decision-support systems that can synthesize multiple data fields, and extract knowledge from data-bases in a concise and coherent manner is important for environmental centres dealing with information management and rapid multidisciplinary decision making. The real-time exploitation of remote sensing imagery for ocean prediction, as well as the use of web-based decision support systems for dissemination of information has important implications for civil emergency and disaster relief applications. Availability of satellite imagery in real-time is essential in the development of realistic tactical decision aids requiring time-critical environmental inputs and fast delivery-times.

3: Next generation geospatial data fusion server

In 2004, a re-design of the Centre's geospatial data server was completed and implementation is planned for 2005. The new server, named GEOS-II is a part of the research project to develop data processing, fusion and distribution methods and will support other Centre activities, such as sea trials and tactical decision aid development. The system is based on open source software and open GIS standards, allowing easy replication. It is composed of a collection of servers to process geo-referenced images, geographic data and charts and multi-dimensional gridded data. It has ingest engines for multiple data types and applications, and interfaces for all clients to be supported. The centralized database will be available immediately for each application, in a Common Data Format and connected to a tactical decision aids and other user defined tools. The use of innovative communications will result in a dramatic reduction of network band-width consumption and data redundancy.



Legend:
WFS: World Features server
WMS: World Map server
WCS: World Coverage server
WCAS: World Catalogue server

Figure EOS.3 *GEOS-II architecture.*

4: Sub bottom profiling using ambient noise

A novel technique has been developed for measuring the seabed reflection properties (as a function of angle and frequency) using only ambient noise from wind and shipping measured on a Vertical Line Array (VLA). In 2004, an important scientific objective was to check the results (reflection loss and bottom layer structure) against other well-known methods such as boomer, chirp sonar, local reflection measurements using a sound source. Several experiments were completed during BOUNDARY 2004. These were two noise drift experiments over the Ragusa Ridge, comparison chirp sonar runs along the same tracks and derivation of a scattering law from reverberation and propagation vertical directionality using a VLA. These checks need to be repeated in areas that are geophysically distinct, such as, sediment, rock, as well as different oceanographic and meteorological conditions.

A prototype VLA was designed and built by ETD as a system demonstrator. The VLA is a 64 element, three octave system (2, 4, 8 KHz) capable of measuring the noise vertical directionality. It can be either a buoyed or a bottom-moored system. In the final implementation, the necessary beam forming, averaging and data reduction will be done on board the buoy. The VLS was tested in October 2004, during the Focus Acoustic Fields experiments.

5: Surf zone modelling and beach monitoring system

Real-time surf monitoring was performed for the MREA04 field trial. Two independent wave-current meters were deployed in the surf-zone and data was transmitted to a shore laboratory *via* cable. Used to verify model simulations, this data was also confirmed the conclusions of the wave modelling work. Continued analysis of field data and testing of model simulations have been performed in 2004. A final publication, "Lessons for REA in the nearshore" was submitted for inclusion in the MREP conference proceedings which documented potential pitfalls associated with application of wave models for surf-zone modelling as well as effective techniques to avoid those problems.

Initial planning of SURF04 was completed in the spring of 2004 but subsequent cancellation of the field trial prevented further work following distribution of a preliminary trial plan. Later, the restoration of this trial required accelerated development of a revised trial plan for January 2005. As part of the preparation for the trial, a joint research project (JRP) was developed between the Centre and the Department of Environmental Engineering at the University of Genova. This project is directed towards developing an analytical boundary condition at the swash end of the surf-zone for more complete 3-D modelling efforts.

A video monitoring system was similarly deployed in MREA-04 and time-averaged images from this system were rectified, merged and geo-referenced in order to provide additional surf zone data as well as to verify model results Efforts have been expended on a remote, real-time covert monitoring package for the surf-zone to render it smaller, simpler and more reliable. Two field deployments have been performed during 2004. One involved deployment by Centre personnel under observation by Portuguese military divers during the MREA04 trial. Input from the divers was then utilized to render the system more operational. The revised system was then deployed solely by the Dutch Very Shallow Water dive team during NATO exercise Destined Glory '04. Final input from these users has then been used to design final system modifications.

6: Clutter estimation from side scan sonar

Clutter density is one of the factors that affects mine hunting and accurate knowledge of this factor allows better planning and better evaluation of the remaining risk. The data collected within the execution of project MX1 (Baltic sea, Oct 2004 trial) in a high clutter area have been used to test a collection of algorithms that use the extent and mutual consistency of echo and shadow to extract from the background the responses from small bottom objects, group them into objects (by features and position criteria) and calculate spatial objects density.

7: High frequency acoustic propagation studies

In 2004, an investigation was completed of the usefulness of environmental databases for performance predictions in high-variability littoral waters. To address this issue on a large geographical scale the allied environmental support systems (AESS) was used as the prediction tool and the NATO Standard Oceanographic Data Base (NSODB) as the environmental representation. To quantify prediction errors in selected shallow-water areas as a function of bottom type, water depth, season, frequency, sonar/target depth, etc., the Centre's vast broadband transmission-loss database established over the past 30 years was used as ground truth. Seven different geographical locations reaching from the Barents Sea in the north to the Strait of Sicily in the south, all representing typical operational scenarios for littoral ASW were examined. The AESS predictions are generally deemed *unsatisfactory*, due mainly to inaccurate environmental inputs from the NSODB. The bottom-loss information is found to be the weakest link, but also profile, bathymetry and sea state information can have adverse effects on the prediction accuracy.

The work is being expanded to investigate high frequency (5-50kHz) acoustic propagation in shallow water, as part of a JRP with US and FR. Under a successful collaboration with Atlantide (France), the “Laboratoire Ondes et Acoustique” (Paris) and ECA (Toulon), NURC has participated in a high frequency acoustics propagation experiment using a new rigid 24-element source receiver array. The experiment has taken place in a 10-meter depth and 50-meter long pool where both environmental and instrumental parameters were kept under control. The pool is equipped with a calibrated surface wave generator and Green’s Functions have been acquired to build a high frequency benchmark in several environmental setup. The data gathered will further our understanding of environmental factors affecting acoustic propagation in the 10-50Khz range and will make an important contribution to the development of advanced acoustic communications methods necessary for underwater networks and the development of tomographic capabilities.

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***Peter H. Ranelli** received his M.S. with Distinction in Meteorology and Oceanography from the U.S. Naval Postgraduate School in 1983 and his Ph.D. in Oceanography from Dartmouth College in 1991. His dissertation was a study of the circulation of the Arctic Ocean using a coupled ice-ocean model. He retired from the U.S. Navy with the rank of Captain. He served as Meteorology and Oceanography Officer, including Meteorologist for the USS New Jersey Battle Group and Fleet Oceanographer on the Staff of the Commander Sixth Fleet. He has been the deputy director for the Ocean and Atmospheric Sciences Directorate at the U.S. Naval Research Laboratory and the Assistant Chief of Staff for Plans and Programs for the Commander of the Naval Meteorology and Oceanography Command. Since 2003, he has been at NURC as the head of Military Oceanography Department, leading research activities in developing new methods for providing a Recognized Environmental Picture for NATO.*

***Farid Askari** received the B.S. (1977) degree in Engineering from Purdue University, West Lafayette, IN., the M.S. (1979) and Ph. D. (1985) degrees, respectively, in remote sensing and physical oceanography from the Ohio State University. During 1988-1997 he was employed by the U.S. Naval Research Laboratory (NRL) Washington, DC as a research physicist and head of the Ocean Measurements Section from 1991 to 1993. Since 1980 he has been working in the areas of remote sensing, image processing and pattern recognition and has served as principal investigator on several international projects. Since joining the Centre in 1997 his research interests have included microwave imaging of the ocean surface, sensor fusion and development of tactical decision aids for rapid environmental assessment.*

***Daniel C. Conley** received B.S. degrees in Geophysics and Ocean Engineering from Massachusetts Institute of Technology in 1980 and a Ph.D. in Oceanography from the Scripps Institution of Oceanography in 1993. From 1993-2000 he was assistant professor at the Marine Sciences Research Center of the State University of New York at Stony Brook. His research interests encompass nearshore and estuarine circulation, coastal sediment transport and processes of erosion and deposition in the littoral zone. He joined the Centre as a scientist in October 2000 where his work emphasizes surf-zone modelling and observation.*

***Emanuel M.M. Ferreira Coelho**, hydrographic engineer in the Portuguese Navy and associate professor at the University Lusofona, Lisbon, was Head of the Oceanography Division at the Instituto Hidrográfico, Lisbon, until September 2001. Prior to his appointment as Senior Principal Scientist in the REA Thrust Area, coordinating the Littoral Ocean Modelling Programme, CDR Ferreira Coelho obtained his MSc (1991) and Ph.D. (1994) in physical oceanography, with a minor in digital signal processing, at the Naval Postgraduate School, California. He has coordinated and participated in a number of oceanographic experiments and studies dedicated to mesoscale and sub-mesoscale processes; developed software for the processing, interpretation and analysis of acoustic data and acoustic tomographic methods for observing near-inertial internal wave propagation over irregular (finite) topography and non-linear internal wave generation and propagation.*

***Chris Harrison** received his MA in Natural Sciences from Clare College, Cambridge in 1968. Subsequently, at the Scott Polar Research Institute, Cambridge he studied radio propagation in ice and spent two summer seasons in the Antarctic, completing his Ph.D in 1972. He started work in acoustics at Admiralty Research Laboratory, Teddington and spent two years, from 1976 to 1978, as Exchange Scientist at Naval Research Laboratory, Washington where he worked on long distance reverberation and three dimensional propagation theory. Since 1978 he has worked as an acoustics consultant, mainly under contract to the UK MOD and DERA, in a software company, which is now a part of British Aerospace. One of his interests was the software generation of realistic waveforms for testing sonar systems in the laboratory. He joined the Centre's Acoustics Division in March 1999 where he has worked on rapid environmental assessment topics, particularly ambient noise directionality.*

***Michel R.M. Rixen** received M.S. degrees in Computer Science (1991), Oceanography (1995), Ocean Modelling (1996) Environment (1997) and a Ph. D. degree in Physical Oceanography (1999) from the University of Liège. He was awarded a Marie Curie fellowship by the European Union to conduct research at the Southampton Oceanography Centre from 2001-2003 and joined the Centre in 2003. In 2004 he was also appointed assistant professor at University of Liège. He served as an expert for IOC/IODE, the European Commission and the UK/NERC. His research interest and expertise is focused on operational oceanography (multi-model/super-ensemble models, data assimilation methods for nested and parallel ocean models, variational inverse models, objective analysis and cross-calibration techniques, operational optimization of sampling strategies, synoptic-scale and mesoscale processes) and climate variability - hydrographic and bio-chemical database and climatologies of the Mediterranean and the Black Sea, with a strong background in remote sensing (active and passive), ocean instrumentation, statistics, artificial intelligence (neural networks, genetic algorithms, fuzzy logic) and information technology.*

***Richard Signell** received the B.S. (1983) degree in Atmospheric and Oceanic Science from the University of Michigan, Ann Arbor, MI, the M.S. (1987) and Ph. D. (1989) from the Massachusetts Institute of Technology/Woods Hole Oceanographic Institution Joint Program in Physical Oceanography, Woods Hole, MA. During 1989-2000 he was employed by the U.S. Geological Survey as an oceanographer, measuring and modelling water, sediment and pollutant transport processes in the coastal ocean. He joined the Centre in January 2001 and conducted research in improving surface drift and turbidity modelling for MCM operations.*

***Francesco Spina** graduated in electronic engineering from the University of Genova in 1965. He worked for a short period with Elsag and joined the Centre in 1968 where he worked initially in the computing department in systems and applications software. Since 1995 he has been working in the fields of oceanography, seafloor classification and geographic information systems.*

Command and Operational Support (COS) Research Thrust Area

Operational Context

Exercise Support covers support to ASW and MCM components of NATO exercises. The thrust area utilizes quantitative assessment techniques for operational analysis, which accelerates the development of experimental tactics (EXTACs) and decision aids. The analysis of NATO exercises is briefed to the participants immediately after the exercise. Military experimentation facilitates the transformation of concepts and technologies developed in other thrust areas to support expeditionary force operations and the development of CONOPS for autonomous underwater vehicles, for example, for force and harbour protection against terrorism.

Overview

In the course of 2004, the following changes were implemented:

- Inclusion of Operational (Military) Experimentation. Due to the increasing number of operational experimentation projects being undertaken by the Centre for ACT, it was felt appropriate to nominate a single Thrust Area to report on the management of them. These projects are not funded through the Centre's core budget but directly from the ACT Experimentation budget.
- The projects concerned with the development of tactical decision aids for MCM and ASW were moved into the new thrust areas Expeditionary MCM and Port Protection (EMP) and Undersea Reconnaissance Surveillance and Networks (RSN), respectively.

The on-going operational support activities (such as exercise support, support to the Defence Requirements Review) have continued. These activities are funded by the SPOW, apart from travel to support NATO exercises (funded by ACO) and support to operational experimentation (funded by ACT, outside of the SPOW).

COMMAND AND OPERATIONAL SUPPORT		
Operational Support	Exercise Support, Support to NATO meetings, Support to the Defence Requirement Review (Proj. 5D)	Handson Yip
Military Experimentation	Forward Eyes; remote beach surveillance system (Proj. E1)	Daniel Conley
Military Experimentation	High Performance AUVs (Proj. E2)	Edoardo Bovio

Targeted Military Capabilities

The principal Operational Support capabilities to be delivered are:

- Provision of specialist operations research assistance in direct support of the NATO Commands and Agencies.
- Expert exercise analysis: provision of quantitative exercise analysis in direct support of the NATO Commands and NRF.

Other capabilities to which the thrust area contributions are:

- Remote MCM against modern and buried mines
  - Experimentation (High Performance AUVs); Exercise Support (development of MOEs)
- Environmental prediction packages for maritime NRF operations
  - Experimentation (Forward Eyes, Covert Remote Sensing)
- Remote REA of the expeditionary battlespace using AUVs and satellites
  - Experimentation (Covert Remote Sensing)
- COP-integrated Tactical Decision Aids and associated prototype CONOPS
  - Experimentation (High Performance AUVs, Forward Eyes, Covert Remote Sensing)
- Defence of maritime forces and installations against terrorism
  - Experimentation (High Performance AUVs); Exercise Support (development of MOEs)

Vision

Medium Term The thrust area will continue to support the NRF through interaction with other thrust areas. In the medium term:

- The thrust area will conduct and analyze Percentage Clearance Trials for the Standing NRF MCM Groups in challenging minehunting scenarios. However, efforts will be on utilizing the PC trial methodology to assess the operational effectiveness of minehunting AUVs in challenging environments. The thrust area will also explore concepts for using the PC trials in the NRF certification of the Standing NRF MCM Groups.
- The thrust area will utilize opportunities in NATO exercises to validate the operational research concepts and algorithms associated with Tactical Decision Aids (TDAs).
- The thrust area will provide scenario and experimental design and analysis for military experimentation with high performance AUVs and for SPOW projects from the EMP thrust area.
- The thrust area will explore operational research methodologies for the assessment of hazards from maritime Chemical Biological Radiological Nuclear (CBRN) scenarios. The emphasis will be on scenarios of maritime force protection, expeditionary warfare, and defence against terrorism. This work will be done in conjunction with the EOS thrust area and NATO nations.

Long-Term Over the next 5-7 years it is envisaged that the thrust area will grow to include operations research to identify technologies and systems to meet the NATO operational and transformational requirements. The support to the NRF in NATO exercises is expected to continue because it is an essential element to the thrust area.

Technical Accomplishments

1: Percentage Clearance Trials

The Centre has been supporting the planning, execution and operational analysis of minehunting 'Percentage Clearance' (PC) trials since 1997. These trials evaluate a broad range of minehunting performance parameters and provide data to quantify the operational effectiveness of NATO's two MCM Immediate Reaction Forces, MCMFORNORTH and MCMFORSOUTH. In 2004, the PC trials have focused on the evaluation of minehunting performance parameters in challenging environments. PC trials were conducted in Exercise BLUE GAME 04 and Exercise GALLURA 04 in 2004.

Concepts and technologies from the EMP thrust area were tested in the PC trial during exercise BLUE GAME 04. These concepts were aimed at improving the tactical planning of MCM clearance operations. The Centre collaborated with the Norwegian Navy and the Norwegian Defence Research Establishment (FFI) to test seafloor segmentation algorithms in the PC trial area. Figure COS.1 shows the backscatter properties of the seabed in relation to the minelay plan in the PC trial area south of Horten.

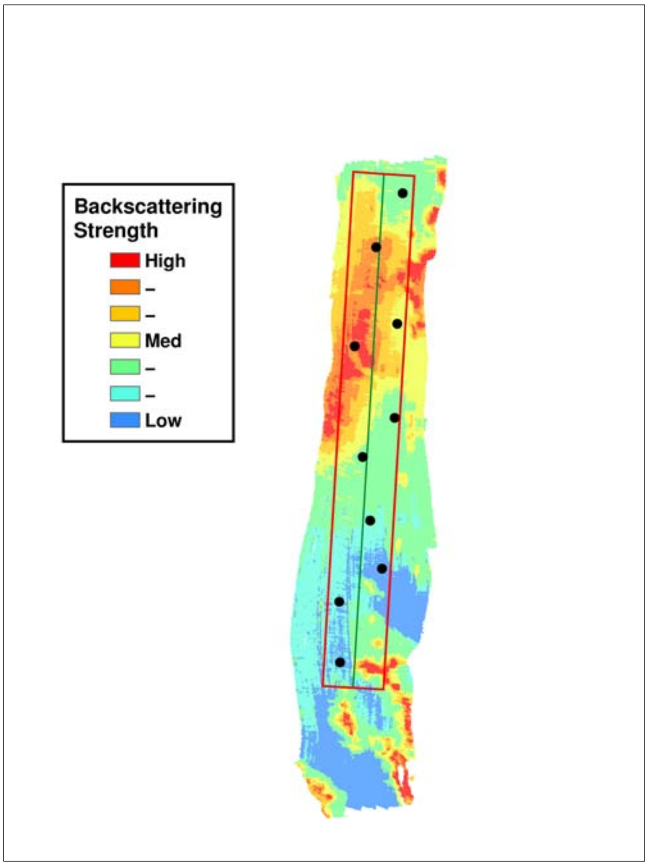


Figure COS.1 *Backscattering strength of the seabed in the PC trial area*

The PC trials in 2004 have also been adapted to assess the operational effectiveness of Commercial-Off-The-Shelf AUV technologies in an MCM role. The lessons learned and the measures of effectiveness from these trials provide guidance in the CONOPs for MCM operations with AUVs.

The operational analysis of the PC trials was presented to the exercise participants, the Minewarfare Working Group (MWWG), the Planning, Evaluation, and Risk Assessment Panel (PERAP), and to NATO MW Officers attending MW Courses and visiting the Centre. The results obtained from these trials continue to generate considerable interest and discussion in the NATO Minewarfare community. The work provides expert exercise analysis and addresses the capability for remote MCM against modern and buried mines.

2: Risk analysis after MCM effort

This activity also supported the quantitative analysis of EXTAC 858 in exercises. An analysis of EXTAC 858 was conducted during Exercise BLUE GAME 04. The analysis compared the military decision to open or to close Q-routes along the Norwegian coast with the results from a MCM risk decision aid. This work was carried out in collaboration with the MCM command unit in BLUE GAME 04 and the EMP thrust area. Lessons learned from the analysis and implementation of the Decision Aid for Risk Assessment and Evaluation (DARE) improved the decision aid. NURC briefed the analysis of EXTAC 858 in Blue Game 04 to the PERAP. This work provides expert exercise analysis and supports the development of tactical decision aids in the EMP thrust area.

3: 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 (virtual) minefields during exercise play. The thrust area provides implementation and analysis support of EMIR in NATO exercises. In 2004, efforts were focused on preparing and implementing the paper minefields of the EMIR system for exercise areas on the coast of Norway and Denmark during BLUE GAME 04. Quantitative analysis of EMIR during BLUE GAME 04 was conducted to assess the effectiveness of the paper minefields against the non-MCM units. Figure COS.2 shows a ship transiting across a paper minefield, and actuating a mine. This work provides operational support to NATO commands and agencies.

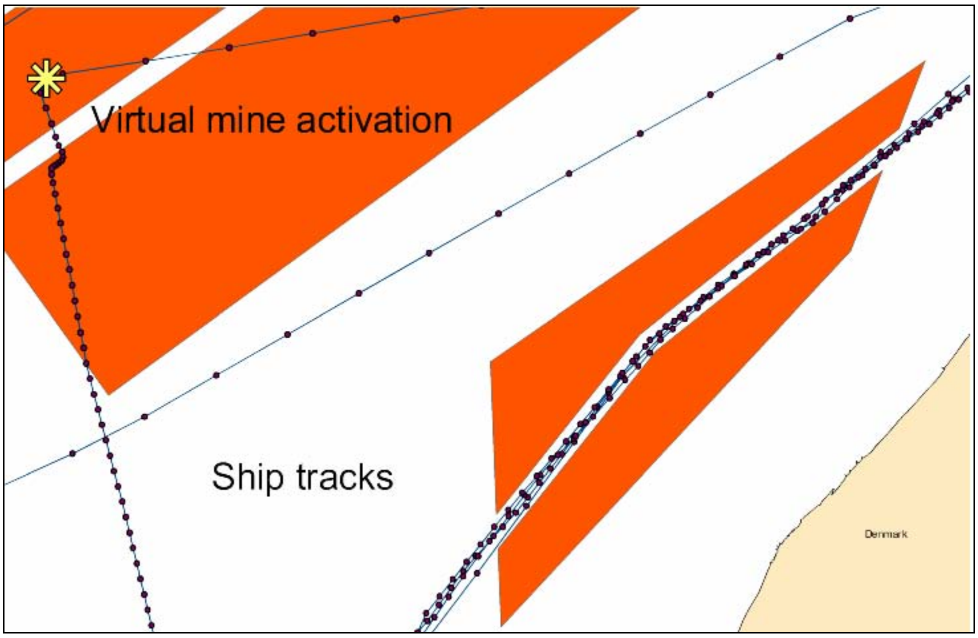


Figure COS.2 *Ship tracks from the EMIR system during Exercise Blue Game 04*

4: Support to the Defence Requirement Review

In 2004, this activity provided the measures of performance for a mixture of ASW systems and platforms in several defined planning scenarios. These MOP are used as input to estimate the required number of platforms. This activity was done in collaboration with NC3A using planning aids developed by the RSN thrust area of NURC. This work provides operational research assistance in direct support of NATO commands and agencies.

5: Support to key NATO meetings

The Centre continues to provide specialist support to the following NATO meetings during the year. Scientist and military staff from the Centre are asked to provide a range of services from program updates, to technical advice, and regular participation in the activities of the groups. A total of approximately 70 working days was devoted to:

- NATO Naval Armaments Group (NNAG)
- Naval Group 2 (NG2)
- Naval Group 3 (NG3)
- Naval Group 4 (NG4)
- 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

6: Forward Eyes military experiments

Project Forward Eyes is a suite of deployable sensors that provides very shallow water and beachhead real-time data to NATO's Recognized Environmental Picture (REP). In 2004, the proto-type Forward Eyes equipment was successfully deployed in the presence of Portuguese Navy dive team. The deployment of Forward Eyes in the field provided recommendations to modify the system to render it operational, and the deployment confirmed the utility of the measurements obtained from military users traditionally assigned to collect data by other means.

Figure COS.4 *Upgraded meteorological Sensor*

Shortly after the initial field deployment of the Forward Eyes suite, the hardware system components were upgraded. The following improvements were achieved:

a. smaller, more robust and unobtrusive meteorological sensor (Figure COS.4)

b. unified and integrated wave-current meter setup and instrument deployment alternatives

c. sensor reduction to single miniature imaging device in video monitoring system

d. low profile – sailor deployable satellite antennae for video monitoring system.

The upgraded Forward Eyes system was then successfully deployed by the Dutch Very-Shallow-Water Dive Team (Fig. COS.5). The military team deployed the instrumentation based on earlier training at the Centre.

Figure COS.5 *Military Deployment of upgraded Forward Eyes system*

The achievements in 2004 were carried out in close collaboration with the Portuguese Navy Dive Team, the Dutch Very-Shallow-Water Dive Team, and the Centre's engineering and technology department. The Forward Eyes system is a result of extensive work from 2 projects in the SPOW; 1A3 and 1D2 and provides military capability in several areas: environmental prediction packages for maritime NRF operations, and COP-integrated Tactical Decision Aids and associated prototype CONOPS.

7: High performance autonomous underwater vehicles (Figs. COS.6 and 7)

In the fall of 2004, NURC successfully conducted its first military experimentation with two REMUS AUVs in an MCM role in the Baltic Sea. The REMUS system is shown to be able to detect and to classify ground mines in the Baltic Sea. The REMUS's high frequency sonar system was also shown to be effective in the re-acquisition mine targets. The performance of various navigation systems was also assessed; the performance of the LBL navigation system was compared with that of the GPS.

The military experimentation was conducted in collaboration with the German Navy, ACT, and SeeByte. The methodologies for the experimentation were developed from the extensive efforts in the SPOW Project 3G2 – AUVs for Defence of Ports and Harbours.

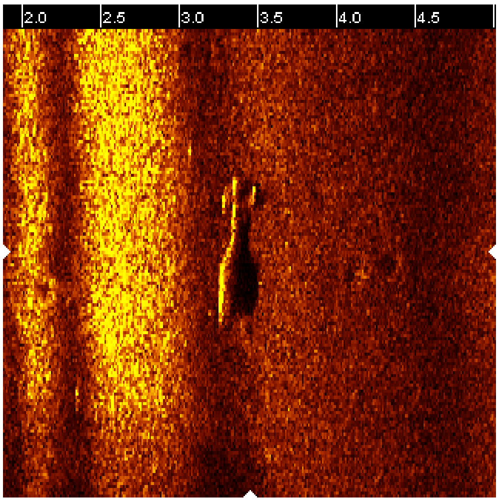


Figure COS.6 *Side scan image of a HEDGEHOG*

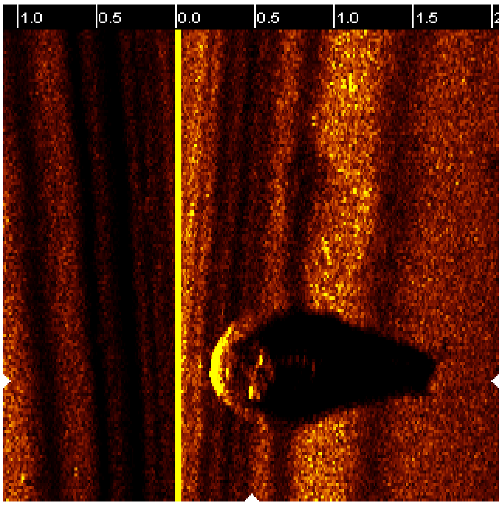


Figure COS.7 *Side scan image of a MANTA*

The military experimentation efforts with AUVs provides military capability in three areas: COP-integrated tactical decision aids and associated prototype CONOPS, defence of maritime forces and installations against terrorism, and remote MCM against modern and buried mines.

Command and Operational Support publications and presentations 2004

Signell, E.P., Bryan, K. DARE Version 2.0 User Guide, M-153.

Yip, H., Pouliquen, E., Canepa, G., Davies, G. Minehunting percentage clearance trials in BLUE GAME ’04, SR-409 (NATO CONFIDENTIAL).

Conference Presentations

Clemente, C. Analysis of DARE in Exercise Blue Game 04, Presentation at the PERAP, La Spezia, Italy, 21-24 June 2004.

Yip, H. BLUE GAME 04 Percentage Clearance (PC) Trial. Presentation at the PXD, Frederikshavn, Denmark, 14 May 2004.

Yip, H., Davies, G. GALLURA 04 Percentage Clearance (PC) Trial. Presentation at the PXD, Caglari, Italy, 22 March 2004.

Yip, H. Percentage Clearance Trials, Presentation at the PERAP, La Spezia, Italy, 21-24 June 2004

CD-ROM/DVD

NATO Undersea Research Centre. COS Department PLANET Version 3 - Volume I discs 1 and 2 - Volume II discs 3 and 4, CD-76 (NATO CONFIDENTIAL).

NATO Undersea Research Centre. DARE Decision Aid for Risk Evaluation. Version 2.0, CD-71.

Handson Yip *received a PhD in Applied Mathematics from the University of Western Ontario in 1988. After graduation, he worked as an independent contractor modelling atmospheric dispersion of toxic gases. In 1989 he joined the Operational Research and Analysis Establishment in Ottawa as a defence scientist working in the field of Maritime Operational Research and Logistics. In 1997 he joined the Operational Research Division of MARLANT in Halifax as an analyst conducting operational studies of Above-Water-Warfare systems. He joined the Centre in 2000 as a senior scientist conducting analysis of NATO ASW and MCM exercises and systems. He is currently responsible for providing operational support to the NRF and NATO commands and agencies.*

Chris Strode *received a B.Sc (hons) degree in physics from Nottingham University in 1996. He worked for GEC-Marconi on the Stingray torpedo project as a trials analyst. In 1999 he moved to the Defence Evaluation and Research Agency as an operational analyst. Here he became involved in many aspects of underwater warfare including tactical development and sonar performance assessment. He joined the Centre in 2004 as a member of the Command and Operational Support department where he is currently working on tactical decision aids, and support to NATO commands and agencies.*

Brief biographies of the following scientists, who are members of the Command and Operational Support Department, are included amongst those in the EMP and RSN Thrust Areas:

Karna Bryan *(EMP)*
Gary Davies *(EMP)*
Craig Carthel *(RSN*

Progress in Engineering and Technology

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.

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.
- Transition experimental concepts arising form the SPOW into the more directly applicable arena of military experimentation.
- Initiate and coordinate programmes of collaboration with the host countries research community.
- Maintain a "technology watch" identifying future trends in technology that could assist the implementation of the SPOW.

The highlights of the 2004 were:

- Preparation and operation of measurement systems in support of 13 separate experiments, involving 250 days at sea with NRV *ALLIANCE* and CRV *LEONARDO*.
- Completion of a series of performance enhancements to NURC's Autonomous Undersea Vehicle so that's its navigation and control performance meets the foreseeable requirements of the SPOW.
- Deployment of a pair of REMUS AUVs in support of ACT's experimentation programme
- Design, development and build and demonstration of a pre-production standard sensor suite providing military operators with the ability to monitor a beach environment in support of amphibious landings.
- Provide a calibration facility for oceanographic instrumentation in support of several NATO navies and research establishments.

The Science and Technology Supporting Initiatives Office of ETD initiated and facilitated a series of cooperative programmes in support of the SPOW:

a. Signed a Memorandum Of Agreement (MOA) with the Central Institute for Scientific and Technological Research Applied to the Sea – Italian Ministry of the Environment (ICRAM) that extended the cooperation defined in the previous Letter of Intent (LOI) to other activities including:

   - Oceanographic, biochemical and acoustic data acquisition and processing in cooperation with the marine mammal risk mitigation project

- Environmental ocean characterization and sensor development
- Exchange of expertise in remote sensing and GIS

This enables the provision of environmental advice for marine protected species and advanced optical and acoustical tools for the characterization of marine sediment transport.

b. Implementation of the cooperation with DIPTERIS (University of Genoa) in the areas of Marine Mammal Risk Mitigation (MMRM) and the Shallow Water Environmental Profiler in Real Time (SEPTR), thus enabling:

   - Support to the MMRM project including, data collection /analysis, participation of the vessel *UNIVERSITATIS* in the SIRENA 2004 sea trial.
   - 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 acoustic/optical sensors - one man/year additional resource.

c. MOU with National Institute of Nuclear Physics (INFN) for ocean engineering and other infrastructures, offering potential *ALLIANCE* chartering and ocean engineering developments.

d. Cooperation on Ph.D. work (hydraulic engineering - University of Trieste) in support of work on sediment core analysis.

e. Cooperation with Pisa University for the conduct of a field experiment in the Pianosa island MPA. This enabled Centre operations in the marine protected area (MPA) and data exchange on biological aspects of characteristics of the sea floor.

f. In initial exploratory activity aiming to set up a natural laboratory on Pianosa island through cooperation with several Italian institutes, University of Pisa, CNR IBIMET (Firenze) and ICRAM.

Vision

Medium Term 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 procurement is needed. In the medium term ETD is adapting its organization to this new requirement in order to offer a balanced capability in support of the SPOW.

Long Term In the longer term ETD intend to grow their capability to manage technically 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.

Technical Accomplishments

1: SEPTR

In May 2003 the Centre entered into a cooperative programme with U.S. Naval Research Laboratory (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 development of the new system was completed including a completely new composite material based construction technique. The figures below show an early prototype SEPTR based on the original BARNY design manufactured with conventional materials and the final design solution in CAD format, made almost exclusively from composite material, which removes any long term corrosion problems.

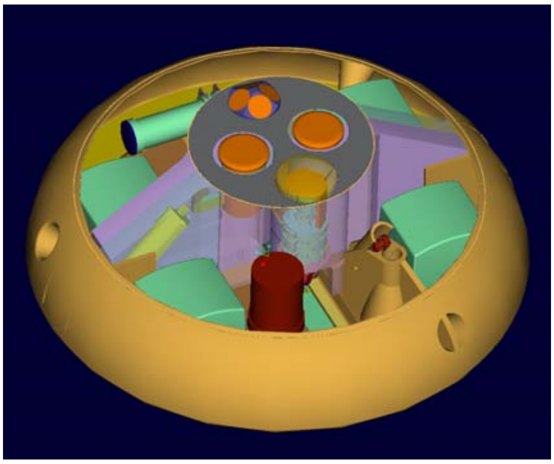


Figure ETD.1 *An early prototype SEPTR based on the original BARNY design.*

During the year a prototype system was deployed for an extended period in the Portofino Marine Protected Area where it operated, unaided, for a period of 88 days. Data from this prototype deployment is shown below.

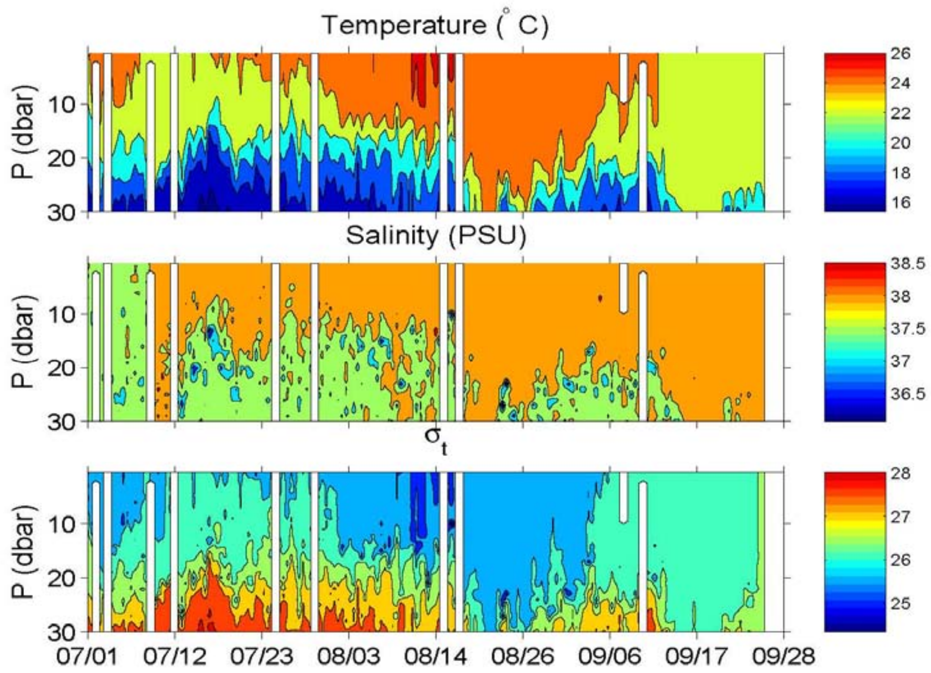


Figure ETD.2 *Time-depth contour plot of salinity, temperature and density collected over a period of 88 days in Portofino Marine Park (note that one dbar equates to one metre).*

The year concluded with a partially populated pre-production unit undergoing final testing in La Spezia bay prior to the release of the design for final production.

2: Forward Eyes beach surveillance system

As part of the SPOW, this programme has shown the value to operational commands of near real time environmental data in support of amphibious landings. As part of ACT's military experimentation programme NURC was contracted to build on the output. 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 prototype systems clearly demonstrated that the equipment could eventually be procured by individual nations *via* their normal defence equipment procurement processes.

The three primary sensors to be deployed were an in-water current meter, a meteo station and a camera system. All systems needed to be rugged and lightweight for ease of deployment, be relatively covert once deployed, and possess an endurance of approximately two weeks. Each sensor required a significantly different data transmission bandwidth. The in-water system offered the additional challenge of requiring a specialized deployment technique to ensure it remained securely but covertly *in situ* for the duration of any deployment.

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 sensor 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 versions of each sensor were designed, developed and constructed. In April early prototypes were tested and in October military personnel deployed updated systems during an exercise in Sardinia. Each prototype met or exceeded its fundamental design aims. During the latter part of 2004 additional features to enhance covertness were developed, tested and proven with the objective of producing delivery in the spring of 2005.

The figures show the prototype current meter being deployed in the surf zone by military divers, and two views demonstrating the complex engineering involved within this sensor system.

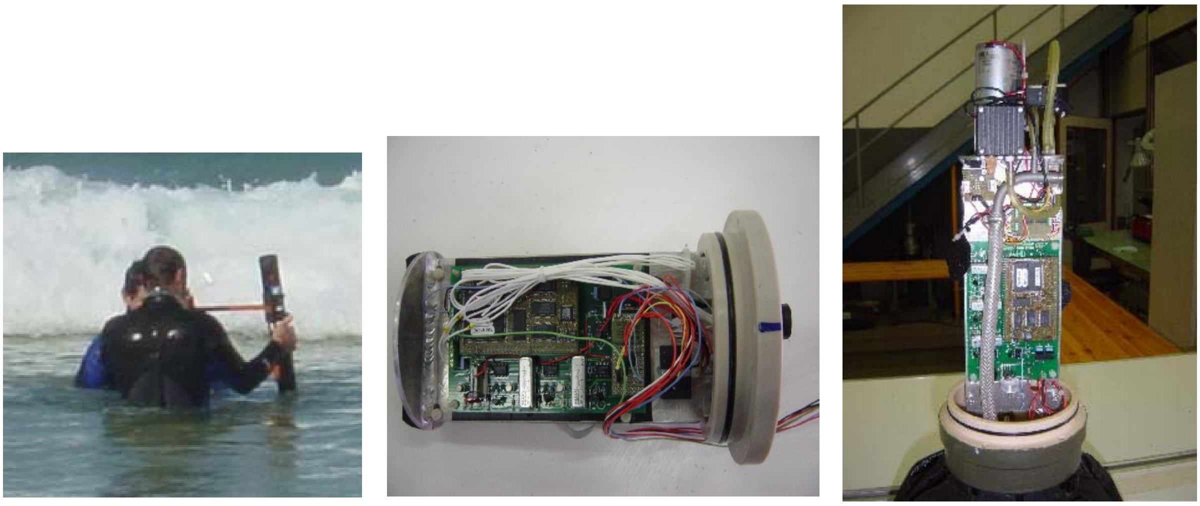


Figure ETD.3 *Deployment of the prototype current meter in the surf zone by military divers.*

3: AUV hydrodynamic and navigational improvements

At the end of 2003 it was evident that the navigation and hydrodynamic performance of the OEX vehicle as delivered was insufficient to meet the requirement of scientific projects requiring its use. Consequently an improvement programme was initiated. The initial objectives were:

- Navigational accuracy: ±1% of distance travelled between GPS fixes or ±1m, whichever is the greater.
- Heading stability: ± 1 degree (later modified to +/- 2.5 degrees)
- Depth `stability: ± 0.5m
- Track keeping ability: ±2m
- Roll stability: ± 1 degree

Navigational performance

An Inertial Navigation System (INS) was installed into the OEX-C AUV. The core of the new navigation module was the HAIN Inertial Navigation System. The system uses the navigation sensors already installed on the vehicle. INS software runs in a separate processor connected to the main CPU by means of an Ethernet UDP link with a newly developed software interface running on the main CPU in order to handle the data flow and control the HAIN system.

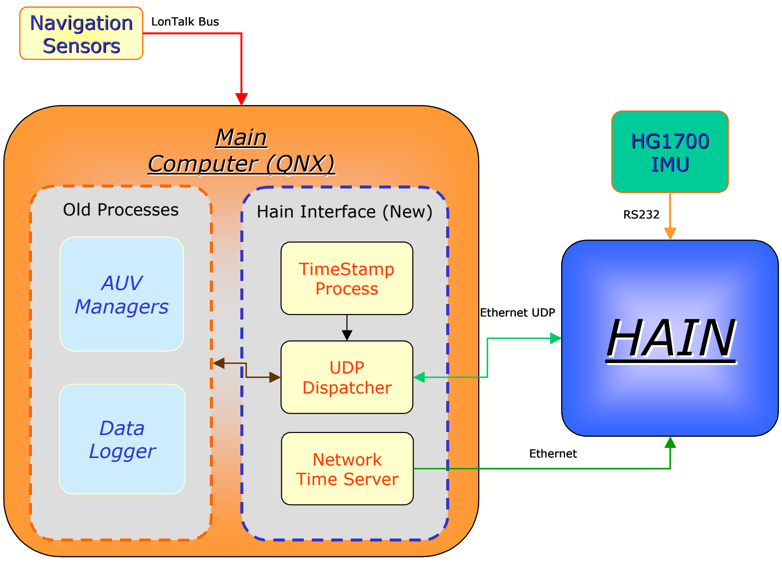


Figure ETD.4 *Revised Navigational Processing*

Much effort was devoted to the development of a robust time management subsystem because of a recognized interaction between time synchronization errors amongst the navigational sensors and the resultant navigation error.

The HAIN was aligned at the beginning of a mission by running the vehicle for about 10 minutes following a “star” pattern. The navigation accuracy was then estimated using an overall mission length of 10Km (almost 5 hours). At the end of the mission the overall error was in the order of 10m (0.1% travelled distance error).

Further experimentation is still required to assess the navigation performances under more general operational conditions. However, simulations carried on with the current data predict a worst-case accuracy better than 1% of the distance travelled.

Hydrodynamic performance

A series of engineering tests were performed in both confined waters and in the open sea. Achieved results are well explained in the following figures:

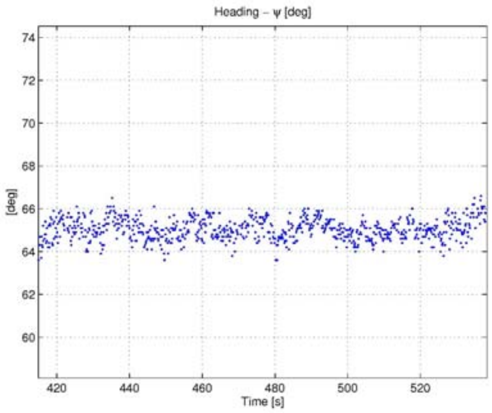


Figure ETD.5 *Constant heading test.*

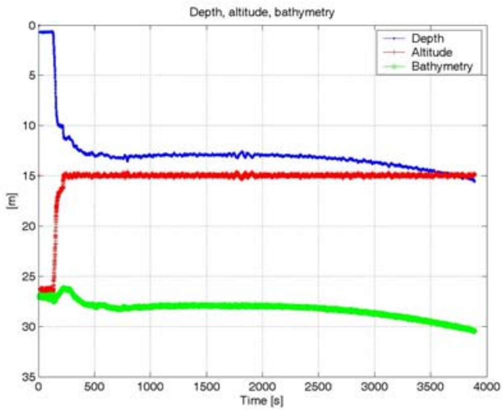


Figure ETD.6 *Constant altitude test-open sea.*

Figure ETD.5 shows a portion of a constant heading test. The set point is tracked with an error of approximately ±1 degree. Figure ETD.6 shows the result of a constant altitude test in the open ocean. The performance was good (±20 cm error) if the sea bottom was quite regular. The performance was similar during a constant depth test. However in constant altitude mode in presence of a sharp variation in bottom depth the vehicle dynamics was unable to maintain the desired altitude and a transition phase occurred where the error became large. More generally during constant altitude and depth tests, when the vehicle was programmed to turn the depth error was always limited to approximately ±25 cm.

The table below shows the achievable performance at the end of 2004. Some further analysis is required to extract information regarding roll and track keeping performance but it is believed this will also now be within specification.

Test	Requirement	Performance (error)
Navigational Accuracy	± 1%	± 0.1%
Heading Stability	± 1 degree	±1 degree
Depth Stability	± 50 cm	±20 cm (constant depth)
		±20 cm (constant altitude)
		±25 cm (overall)

Engineering and Technology Department publications and presentations 2004

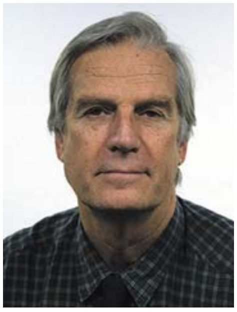
Reports

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.

Conference Presentation

Ruggieri, N,. de Strobel, F., Grandi, V., Gualdesi, L., Carta, A., Fioravanti, S., Cattaneo-Vietti, R., Castellano, M., Doglioli, A., Povero, P. New system for marine coastal monitoring in real time configuration (SEPTR): application in a marine protected area (Portofino, Italy, IV Convegno Nazionale di Scienze del mare del CONISMA, 18-22 October 2004.

Peter Enoch *graduated from Birmingham University with an MSc in 1972. He subsequently worked at the Admiralty Research Laboratory, Teddington, in the field of underwater acoustics, and submarine sonars in particular, before transferring to the Defence Research Agency, (subsequently DERA), Portland where he worked on the fundamental physics involved in towed array self noise and the array construction techniques needed to reduce this effect. He then joined the Centre as Head of the Low Frequency Active Programme (Project 20) before returning to the UK in 1990 to take up a post in industry, becoming the Technical Director, Ultra Electronics Ocean Systems in 1992. During this period he also joined the faculty of Bournemouth University where he taught courses on "Advanced Sidescan Sonar" and "Towed Array Technology". In 2003 he re-joined the Centre as the Head of ETD.*



Federico de Strobel *graduated from the University of Rome, Italy, with a degree in electronic engineering with acoustic specialization. Since joining the Centre in 1969, he has worked mainly in buoy technology, oceanographic instrumentation and CTD calibration at different levels of responsibility from scientist in the physical oceanography group to Head of the Ocean Engineering Department. In 1999, he became the head of the Centre Science and Technology Office. He has spent sabbaticals at Woods Hole Oceanographic Institution, Woods Hole, MA and Scripps Institution of Oceanography, La Jolla, CA. He teaches "oceanographic measurements" at the Italian Navy Hydrographic Institute and the University of Genoa. Dr de Strobel received the Marine Technology Society's International Compass Award in 1992.*

Pier Angiolo Boni *received his BS in Electronics in 1963 in La Spezia, Italy. He joined the Centre in 1964. He is responsible for Real Time data acquisition and pre-analysis in all Yellow Shark, Rapid Response, Scarab, Boundary, Ascot, Base, Adults, Barrier cruise experiments.*

Vittorio Grandi *received his masters degree in Electronic Engineering from the University of Pisa. He joined the Centre in 1993 as Head of the Sensors Branch of the Engineering Technology Division, after many years in state and commercial industries, as analogue and digital designer. He has participated in numerous sea trials requiring analogue and digital system development for oceanographic and acoustic instrumentation.*

Lavinio Gualdesi *graduated from the Naval Academy, Livorno (IT) in 1967. He was awarded the naval architect masters degree at the University of Trieste. Having resigned from the Navy in 1978 with the rank of Commander (Engineering Corps), he contributed to the design for fibreglass mine counter measure vessels as the Technical Director of the Intermarine Shipyard in Sarzana. He has been Head of the Underwater Technology Branch in the Ocean Engineering Group since 1982, working mainly on buoy technology and towed body design.*

Piero Guerrini *received a masters degree in Electronic Engineering from the University of Genoa (Italy) in 1978. He worked in digital communication systems at Marconi Italiana. In 1981 he joined the Electronic Engineering Department at the Centre working mainly in the design of acquisition systems and acoustic arrays. He has been involved in a variety of projects and he has spent more than 1200 days at sea during scientific trials. He is the Head of the Engineering Group in ETD.*

Bruno Miaschi, *Head of the ETC Array and Cable Branch, graduated from the Technical Institute of La Spezia in mechanical engineering in 1961 and was awarded a M.Sc in marine engineering from the University of Los Angeles in 1991. He was employed by Olivetti Ivrea (Turin) from 1961 to 1965 as a robotic machinery designer. Since joining the Centre in 1965 he has specialized in the design and development of underwater research instruments.*

After graduating as a siv.ing. from the University of Trondheim, Norwegian Institute of Technology in 1992, ***Per Arne Sletner*** *worked as a special investigator (computer fraud) and trained police investigators at the Police Academy in Norway. Before joining the Environmental Acoustics Branch of the Engineering Technology Division in 1996, he worked for Geco Defence, Økokrim and Simrad Subsea.*

Richard Stoner *graduated from Birmingham University with a master's degree in underwater communication. His industrial career started in 1985 with GEC Sonar Systems Division, commissioning and developing passive towed array sonars for the Trafalgar class submarine. In 1988 he moved to Ferranti ORE as a research engineer working on payload design feasibilities for AUVs. In 1991, he joined the Acoustic and Sonar Group at Birmingham University, as trials coordinator and research engineer where his research focused on shallow water communication using HF wide band and parametric techniques. He has been Head of the Oceanography Branch of ETD at the Centre since 1997.*

After graduating from the University of Bath with a BSc in physics, ***Luigi Troiano*** *was a design engineer for a multibeam imaging sonar system, at Ulvertech Ltd. Since joining the Centre in 1987 he has provided engineering support to scientific sea-trials in the fields of low frequency active sonar, mine counter-measures and environmental acoustics*

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Progress in Communications and Information Systems

Context

In 2002 NATO recognized the need to adapt national concepts such as Network Centric Warfare (NCW) or the Network-Enabled Capability (NEC) by developing the NATO Network-Enabled Capability (NNEC).

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.

CIS (Communication and Information Systems) 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 (NRF), ensuring interoperability, security and performance across the NNEC.

Overview

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

The highlights of the 2004 were:

- Development of a new high performance Local Area Network inside the Centre, with full mobility support to the NATO research vessels *ALLIANCE* and *LEONARDO*. The architecture enables seamless integration of Network Enabled Capabilities based experimentations and rapid integration of new information technologies.
- Support to Sea Trials, providing ad-hoc networking solutions in response to scientific requirements and ensuring smooth operations and on-site assistance during sea trials.
- Successful preliminary experiments using asymmetric networks to provide high bandwidth download capacity (up to 30 Mb/sec) to NURC ships and remote laboratories.
- International collaboration within the NATO Research and Technology Agency (IST Panel and NecSec Task Group) and with the NATO C3 Agency.
- Installation and system acceptance of the new earth observation satellite ground station procured under the NATO Security Investment Programme.

Vision

Medium Term The specialist knowledge available in the CIS Office will be more directly applied to scientific activities from 2005 onwards, with the involvement of CIS personnel in full project lifecycles (i.e. 2005 Project 4G2 “Netcentric Concepts for Surveillance of the Undersea Battlespace”).

In the medium term it is envisioned that work will be conducted together with NC3A, the European Space Agency and partners in the Nations to develop techniques for 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 purpose would be to build experience to be shared with the Nations, providing a realistic evaluation of the 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 drive NURC scientists in their decisions on how much “intelligence” in terms of data reduction and processing should be put in sensors deployed at sea. The amount of data that can actually be transferred from the field to shore and vice versa is one of the most signficant factors in the development of the new Maritime Network Enabled Capabilities.

Long Term The role of CIS is to be the enabler of all Centre projects requiring the integration of complex Communication and Information Systems. A constant technology watch will continue to be performed, 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 the 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

1: New high performance Local Area Network inside the Centre, with full mobility support to the NATO research vessels

CIS is committed to provide the most efficient and flexible IT environment to support the scientific community. New state of the art technologies (Network, Security, Communications, Systems, Cryptography) have been used to increase efficiency and flexibility, reducing ownership costs. The new network (Gigabit to the desktop) is designed to easily integrate emergent technologies and any future requirement for new research activities.

In consideration of the specific requirements in the SPOW for the exploitation of network-centric capabilities, the network incorporates advanced features such as simplified central management, IP mobility support, community of interest separation, NATO crypto, scalability to multi-ship and multi-sensor experiments.

Connections with ships or shore laboratories are provided through several commercial satellite providers (e.g. EUTELSAT, INMARSAT, IRIDIUM, GLOBALSTAR, etc), commercial asymmetric Networks (e.g. ASTRA, EUTELSAT) and line-of-sight radios for both voice and data transmission. All exchanges of information can be cleared up to NATO SECRET level.

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

Scientific experiments are getting more complex. Multiple satellites, mobile telephony and line of sight communication devices are joined to enable seamless communications between several sites, ships and sensing equipments.

With an average of 20 new ad-hoc network designs and implementations each year, the CIS team has achieved a NATO-wide recognized experience in Maritime Ad-Hoc Networking. This experience is of utmost importance to pursue Network Centric Challenges in the future.

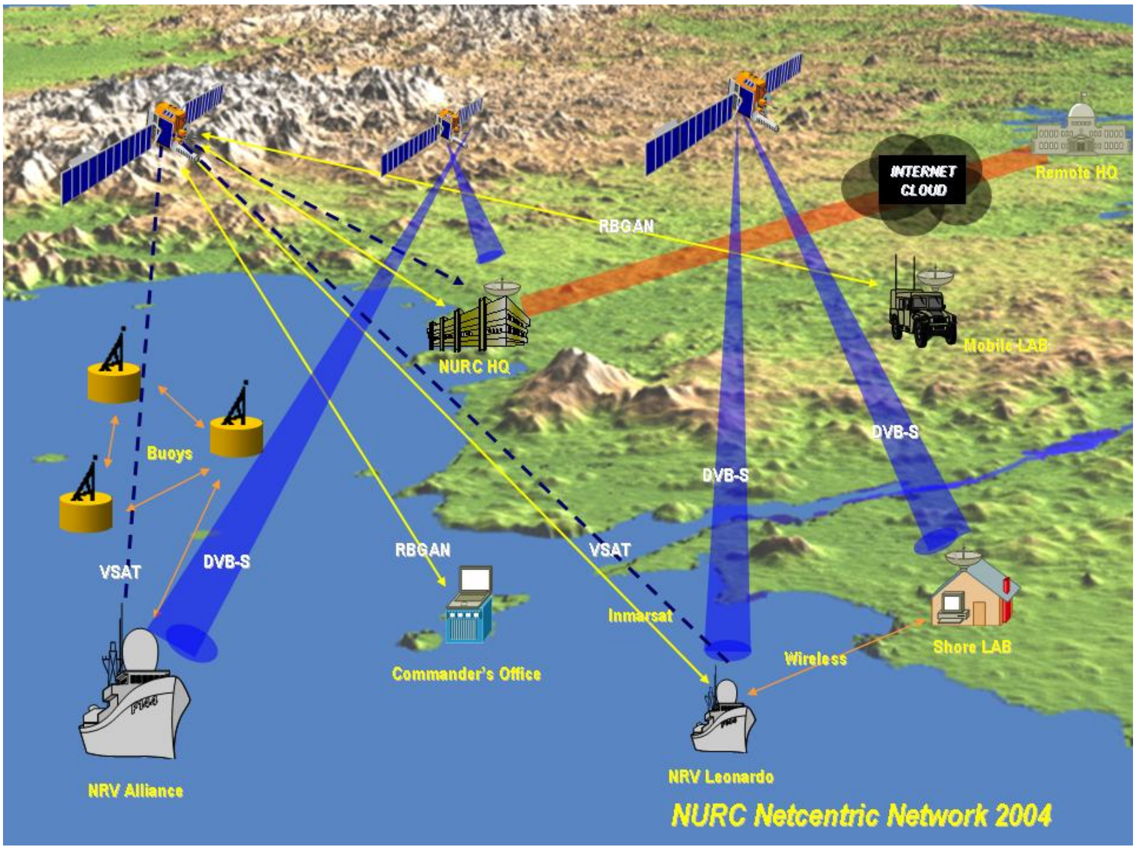


Figure CIS.1 *The 2004 NetCentric Framework of the NURC*

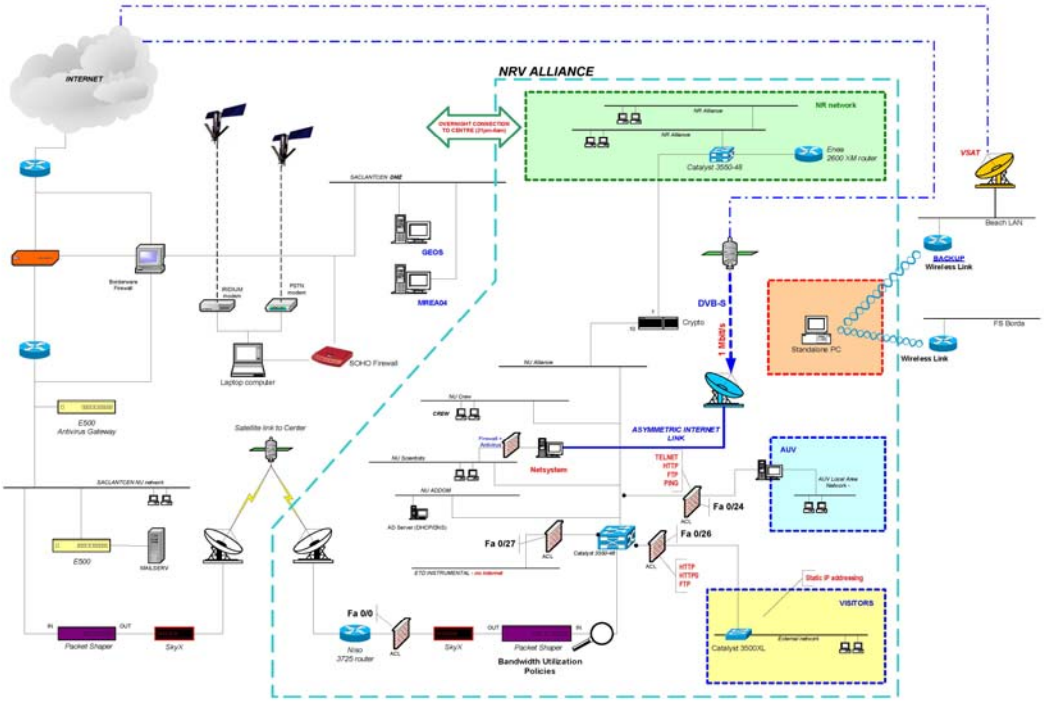


Figure CIS.2 *An example of Maritime Ad-Hoc Network developed by CIS for the MREA04 experiment.*

3: Dissemination of data and remote control of mobile autonomous covert sensors: a low cost approach using COTS IPSEC VPN over public networks.

To stay covert, a sensor must be able to communicate only when it is needed. To do so, it must be able to initiate trusted communication through security defences of the intended recipient in order to communicate vital information. CIS has developed a proof of concept allowing a remote sensor to take advantage of any communication technology (Internet, GSM, WLAN, etc) available to perform this duty.

For example, the possibility of extending the Virtual Private Network (VPN) concept to data services delivered using GPRS (data through GSM technology) or Inmarsat Regional BGAN (data through Satellite) offers to the scientific users the possibility of accessing state-of-the-art Commercial-Off-The-Shelf (COTS) communications media to enable the environmental covert sensors they develop. Since the solution proposed is based on published standards ensuring confidentiality and integrity, it will be possible to apply it to other applications or systems with minimal effort.

In technical terms, the proof of concept addresses the possibility of extending the COTS architecture (IPSEC VPN) 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 NURC report describing this concept will be published early in 2005.

4: Performance evaluation of SkyWAN Satcom TDMA system

NATO and the Nations are currently considering the DEBRA (Dynamic Efficient Bandwidth Resources Allocation) mechanism. The main objective of the DEBRA mechanism is to optimize the required resource (bandwidth and power) when transmitting over a geo-synchronous transponded payload while maintaining Quality of Service for network centric applications.

A campaign of tests has been conducted on the NURC SATCOM network in conjunction with the CIS Division of NC3A to assess the technology. The collaboration had the objective of understanding and testing the combination of:

- A Satcom bandwidth efficient mechanism based on SkyWAN technology:
  - Accessing Satcom resources *via* on-demand multi-frequency TDM/TDMA,
  - Interfacing to an IP router *via* frame relay based on real time and non real time provision of service,
- TCP/IP and UDP encapsulated applications.

At the time the trials were run, no "IP modem" was available, therefore an equivalent approach was achieved by combining an IP router, a TCP-IP accelerator and the SkyWAN Satcom bandwidth efficient sub-system, developed by the German company ND-SATCOM.

The results have been documented in a joint NC3A/NURC report.

5: Coordination of the installation and system acceptance of the new satellite ground station (X-Band – 5.4m) procured under the NATO Security Investment Programme.

CIS has supported the acquisition, installation and commissioning of the new satellite ground station, in line with the Infrastructure Committee authorization, and has provided operational and administrative support for its CIS component.

Communications and Information Systems publications and presentations 2004

Reports

Gauvry, O., Machalica, M., Terrasse, A., Berni, A., Leonard, M., Merani, D. NC3A-NURC joint trials of the SkyWAN Satcom TDMA system, SR-407.

Conference presentations

Berni, A., Leonard, M. Merani, D. INSC applications for undersea research. Proceedings of the Symposium on Interoperable Networks for Secure Communications, NATO C3 Agency, The Hague, 2004.

Leonard, M., Berni, A., Merani, D. Architectures for network centric operations in undersea research. RTO Meeting Proceedings RTO-MP-SCI-137 – AC/323(SCI-137)TP/68 - “Architectures for Network-Centric Operations”, Athens, Greece, 2004.

Leonard, M., Berni, A., Merani, D. Automated Anti-Virus Deployment. RTO Meeting Proceedings RTO-MP-IST-041 Adaptive Defence in Unclassified Networks, Toulouse, France.

Merani, D., Berni, A., Leonard, M. Dynamic virtual LANs for adaptive network security. Submitted to RTO IST-041/RSY-013 symposium on Adaptive Defence in Unclassified Networks.

Merani, D., Berni, A., Leonard, M. Dynamic virtual LANs for adaptive network security, RTO Meeting Proceedings RTO-MP-IST-041 - Adaptive Defence in Unclassified Networks, Toulouse, France, 2004.

Merani, D., Leonard, M., Berni, A. Multi Node Network Systems: an overview of COTS technologies to build tomorrow’s network centric communications infrastructure”, Proceedings of the Maritime Rapid Environmental Assessment (MREA) Workshop, NATO Undersea Research Centre, 2004.

Participation in NATO Expert Groups

Leonard, M. RTA/IST Experts Task Group on Network Enabled Capability Security (NECSec), NATO IST-045/RTG-017.

Michel Leonard *is the Head of the CIS Office, where he is responsible for the application of communications and information systems with a large focus on NATO's maritime research. He holds Master Degrees in Computer Science, Marine Science, Management and a Ph.D. in Applied Mathematics. Before joining NATO, Dr. Leonard was Head of the Computer Department at the Liege Space Centre in Belgium, a co-ordinated facility and Excellence Centre of the European Space Agency (ESA).*

Alessandro Berni *has been working at the Centre since 2000. He is responsible for the development and implementation of communications solutions in support of the Scientific Programme of Work. Prior to his employment at the Centre, he was a member of the University of Genoa team which built the first interconnection of an Italian University to the Internet and subsequently a founder and network architect at ITnet S.p.A., the first commercial ISP in Italy, until the company merged with Wind S.p.A. in 1999. He holds a Master of Science degree in Electronic Engineering from the University of Genoa and is a member of ACM, AFCEA and of the Internet Society*

Progress in Ship Operations

NRV ALLIANCE

During the first half of 2004, *ALLIANCE* had a full scientific schedule with a period operating outside the Mediterranean. Her work area extended from the Baltic Sea to the Atlantic off the coast of Portugal. As well as being extremely successful from an operational and scientific point of view, the work in the Baltic also gave the opportunity for the Flag State (Germany) to visit the vessel. This enabled much dialogue that led to beneficial changes to the Memorandum of Understanding (MOU) with the German government that came to fruition later in the year. One of the highlights of the deployment outside the Mediterranean was the ships visit to the Oceanology exhibition at the Excel Conference Centre in London. NURC had a stand at the exhibition and *ALLIANCE* was berthed outside the main hall. The ship was undoubtedly one of the major attractions of the exhibition and received much attention from the delegates. Many useful contacts were made for future charter work.

ALLIANCE had a quieter second half of the year due to unexpected NURC budget reductions, but still completed two major scientific cruises and a charter period to the Italian and Greek Navies in July and also to the Italian Navy again in November. These charters led to valuable cost return to the Centre which helps offset maintenance and running costs.

NRV *ALLIANCE* is an impressive platform for promotion of the Centre's work and numerous VIP visits were hosted during the year. The list included Admiral Giambastiani, SACT, Admiral Sir Mark Stanhope, DSACT, as well as a number of senior NATO and scientific dignitaries.

Along with the *LEONARDO*, the *ALLIANCE* took part in the Centre's family day in December and took 70 family members to sea during a short cruise in the Gulf of La Spezia area.

During 2004 the *ALLIANCE* spent a total of 124 days at sea on Programme of Work projects and 27 days on charter.

Although now 16 years in operation, the *ALLIANCE* is still performing very well, backed up by the professional attitude of officers and crew. There are some areas that will need considered investment in the near future, especially in navigation and machinery automation. With the necessary targeted investment the ship can look forward to many more years of scientific support work.

CRV LEONARDO

During 2004 *LEONARDO* continued to provide a very capable platform for coastal research operation. Although some minor technical problems inherent from a new ship design remain to be solved, the ship has now evolved into a very versatile unit. The dedicated and experienced ship's staff enabled *LEONARDO* to achieve full availability for all planned operations during 2004. The highly automated and advanced control and scientific systems on board have allowed the ship to be fully integrated into the scientific programme as a true extension of the shore side laboratory.

As the less expensive platform to operate, *LEONARDO* was able to continue with much of her programme of work activity throughout the year and did not suffer as much uncertainty in her programme as *ALLIANCE*. The annual dry docking was carried out in November with no major defects discovered. The hull was cleaned and painted and the annual class inspections were carried out. This docking utilized a local shipyard and was carried out by lifting the ship out of the water by a synchrolift and physically carrying the hull across the yard before placing it on the blocks.

Along with the *ALLIANCE*, the *LEONARDO* took part in the Centre's family day in December and took 12 family members on a short cruise of the Gulf of La Spezia area.

The ship remains fully certified and classed by the American Bureau of Shipping and is now the first ship to fly the flag of a Public Vessel of the Government Registry of Italy.

In summary, 2004 has yet again proved to be a very busy and exciting year for both ships with a diversity of operational requirements being fully met and has underlined a core capability of the Centre which is to provide seamless availability for scientific research from the deep ocean to the shoreline.

Figure SMO.1 *LEONARDO coastal operations*

Accomplishments

1: ALLIANCE deployment outside of the Mediterranean 9th February – 19th April 2004

ALLIANCE sailed from La Spezia on the 9th of February on a two month deployment outside the Mediterranean which took her to Germany, the UK and Portugal.

Figure SMO.2 *ALLIANCE leaving La Spezia*

Figure SMO.3 *ALLIANCE alongside at Oceanology, London*

The transit to Kiel in Germany encountered none of the expected February weather and instead *ALLIANCE* experienced perfect conditions for most of the voyage and at times achieved a speed not seen since her younger days.

Her time in Kiel was spent preparing for the ASAP 04 cruise which involved operating Autonomous Underwater Vehicles (AUV) and carrying out official visits and receptions in connection with the German FMoD who are the Flag State for the vessel. An opportunity was taken to take advantage of an invitation by the FMoD to conduct crew safety training at their sea training centre in Neustadt. Fire drills were also carried out on board under the supervision of German Navy firefighters. This was a rare opportunity to experience realistic training in a smoke filled ship and was much appreciated by all on board.

The opportunity for the Flag State to be welcomed on board helped prepare the way later in the year, for a change in the MOU between the German Government and NURC regarding chartering opportunities for the *ALLIANCE*.

ASAP 04 was carried out in the coastal water areas of Warnemuende and Tromper Wiek in the Baltic Sea and was a joint project between FWG Germany and NURC.

From Kiel, *ALLIANCE* went to London and was a star attraction at the 2004 Oceanology exhibition held at the Excel Exhibition Center in the Docklands. During the exhibition, ship staff carried out ship tours twice daily and great interest was shown with a large number of people visiting the ship during the time at the exhibition.

Figure SMO.4 *ALLIANCE ready for visitors*

Figure SMO.5 *ALLIANCE - night at Excel,London*

After departing London on the 23rd March, *ALLIANCE* arrived in Lisbon three days later to prepare for the MREA 04 cruise. This project was a Rapid Environmental Assessment carried out with several other collaborating organizations in the waters outside Lisbon and the bay south of Cab Espichel. The weather during this time was very variable and *ALLIANCE* experienced severe storms, having to seek shelter in Lisbon on one occasion. However as has been experienced in the past, *ALLIANCE* proved to be an excellent sea ship and all work was completed successfully with no damage to any equipment.

After completing MREA 04, the *ALLIANCE* departed Lisbon on the 12th of April and arrived back in La Spezia on the 19th April.

This extended deployment outside the Mediterranean once again highlighted the wide ranging reach of the *ALLIANCE* and demonstrated the excellent asset she is to the NURC, to NATO and to the Nations.

2: Equipment updates for NRV ALLIANCE

2004 also saw a number of equipment updates on the ship. The long awaited replacement crane was installed on the after deck, a new workboat was fitted and a major update completed to the multibeam sonar. This restored a very important scientific capability and has proved to be a reliable and accurate system.

3: Retrofitting of CO2 and FM200 fixed fire fighting system to replace the Halon 1301 system

This was a technical project to replace the existing Halon 1301 fixed fire fighting system with an environmentally acceptable system that complied with the Montreal Protocol and all the European directives regarding ChloroFluorocarbons (CFCs)

The original Halon system on *ALLIANCE* was extensive and as well as covering the machinery spaces, also protected various storage areas and store rooms. An acceptable alternative to Halon was FM200. FM 200 was developed to replace Halon and is more ozone friendly having an Ozone Depletion level of zero as well as having a high level of personnel safety and absence of toxicity. However the cost involved covering all the areas on *ALLIANCE* was prohibitive and a compromise was reached, using CO2 for the general storage areas and FM200 for the machinery spaces.

Installation was contracted to Siemens Fire Systems and to allow the continued operation of the vessel while installation took place, the time of installation was spread over a number of maintenance periods and was finally completed in September 2004.

Due to the complexity of the original system, the logistics of the change over were complicated, but the technical managers of the vessel saw through the project within budget.

***Ian Sage** joined the Centre in March 2002 and became Head, Ship Management Office in September 2002.Before this, Ian had spent 21 years as an officer in the UK Royal Navy in a variety of ships and submarines throughout the world. He became a specialist Hydrographic Surveyor and ultimately commanded the survey vessel HMS Bulldog. Since joining the Centre he has been involved in numerous research vessel projects and is a member of the U.S. Research Vessels Operators Committee.*

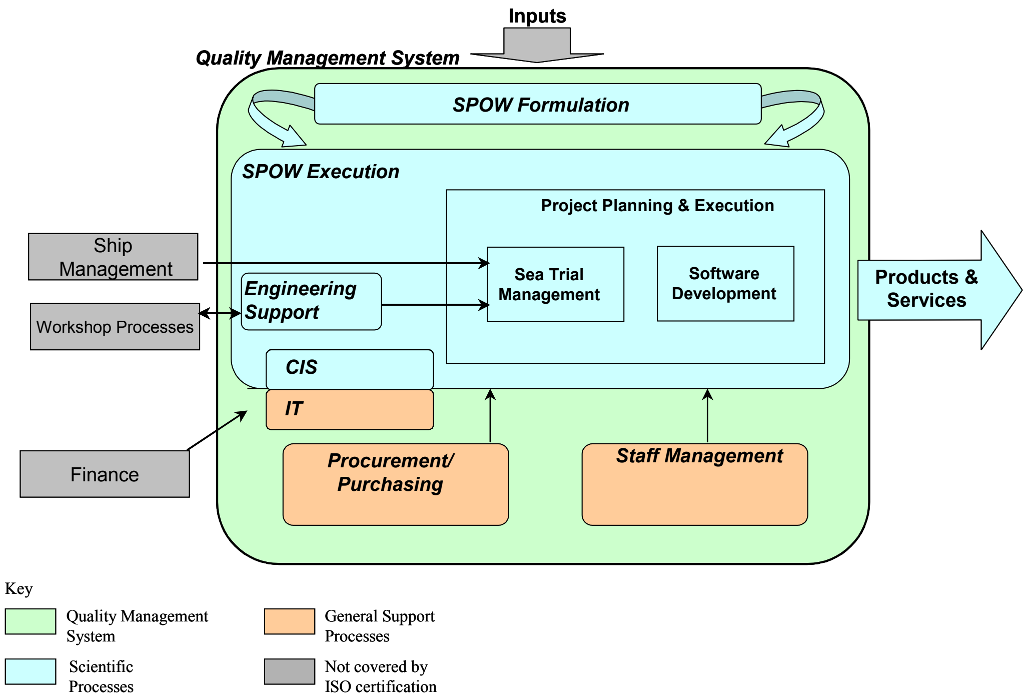
Progress in Quality Management

Centre Certification – Background

The decision to establish a Quality Management System at the Centre was taken in 2000 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.

In early 2001, a working group was established to identify key / support processes throughout the Centre. For each process a Process Owner was appointed as the "function with the highest interest in having the process efficiently managed".

Processes and interactions between them can be represented as follows:



Each process was then documented in Quality Procedures (QP) and – where appropriate – Quality Instructions (QI) to define methods and responsibilities for the execution of activities. A Procedure Owner was appointed for individual QPs and supporting QIs.

After a start-up period, the Centre Quality Management System was officially assessed by DET NORSKE VERITAS in October 2002 to be compliant with ISO 9001:2000 standard.

Centre quality management system

Certification is only a starting point, as all processes are subject to change considering the evolving needs of the Centre and its customers and stakeholders. Continuous improvement of the overall performance, efficiency and effectiveness is one of the key factors in an ISO 9001-orientated QMS.

Appropriate measures are therefore to be put in place to:

- Ensure that operation of processes is effective and compliant with the established rules.
- Evaluate process effectiveness.
- Define appropriate indicators to measure performance.
- Evaluate results of measurements in order to achieve the planned goals and obtain the continuous improvement of processes.

The Centre has set up a multi-level internal analysis and assessment process, which, together with the mandatory external audit scheme, enables Management and Process Owners to identify and correct problems, assess opportunities for improvement and take the necessary actions in an organized and co-ordinated way.

Internal Process

Internal audits

An Internal Audit programme is defined each year by the Quality Manager and approved by the Director. All areas and processes are audited to ensure that they are operating in accordance with the established procedures and that they are effective.

Audit reports are submitted to auditees and management for analysis and action.

Management of issues

A system is also in place to capture and address issues like actual/potential nonconformities and suggestions for improvement.

Issues may be generated as an output of the planned internal audits, or by initiative of any Staff Member: actions to resolve the issues are defined at the appropriate level and their status is reported to the Director and Management on a bi-weekly basis. Effectiveness of any action taken is assessed.

Indicators

Performance indicators are identified and monitored at two levels:

- **At management level**, a number of Quality Objectives have been set to achieve the overall business goals listed in the Centre Quality Policy. Progress towards objectives is periodically measured and forms the basis of management's performance assessment.

- **At process level**, each Process Owner identified a numbers of measurable indicators to monitor efficiency and effectiveness of the process. Targets are agreed with process customers and the degree of achievement is routinely reported.

Quality Management Review

A Quality Management Review takes place at least once a year, to ensure suitability, adequacy and effectiveness of the overall QMS and to assess opportunities for improvement.

External Assessment

Assessment and maintenance audits

The Centre is also subject to periodic auditing by DET NORSKE VERITAS for the three years of validity of the certificate. Maintenance audits are scheduled according to a pre-defined plan to assess all areas in a cycle and on a sample basis. The outcome of such audits includes observations (O) or nonconformities (NC): where a serious NC is raised, the certificate validity cannot be confirmed.

Three maintenance audits have taken place so far (June 2003, May 2004 and October 2004). Auditors did not raise any Nonconformities, and the number of Observations shows a significantly decreasing trend (7 during the first assessment audit in October 2002, 4 in June 2003, 1 in May 2004 and none in October 2004). Actions taken to address observations were assessed by the auditors and found to be satisfactory. The next audit will re-assess the whole QMS, of course with higher expectations on the auditors' side, and begin a further 3-year certification cycle.

Alessandra Barbieri *received her MS degree in Economy and Business from the University of Genova, Italy, in 1995. She was then awarded a European Union grant for a postgraduate master in Budgeting, Accounting and Internal Auditing. She joined the Centre in 2000 and was appointed Quality Manager/Internal Auditor in 2004.*

Synopsis of Target Military Capabilities

1. Remote Mine Countermeasures

This capability is a step change in the performance of automatic detection and classification of modern and buried mines with AUV systems. Together with the complementary work on mine-ship interaction, this contributes both to Expeditionary Warfare and Maritime DAT.

2. Low Frequency Active Sonar

This system concept optimises the detection range of mono-static LFAS in littoral waters. It will apply in expeditionary warfare areas where local variability of environmental conditions can provide a tactical advantage to opposing forces.

3. Network-Enabled Surveillance

This system concept is designed to offer a tactical advantage for towed LFAS and/or deployable surveillance platforms within a network enabled force. It applies to the protection of transiting forces and to covert multistatic surveillance.

4. Marine Mammal Risk Mitigation Policy

This is policy and operational support to help planners determine areas of low environmental impact for the conduct of acoustic trials for NATO's peacetime operations and to assist commanders at sea with on-scene monitoring devices for deployment prior to and during operational exercises involving undersea acoustics.

5. Covert Undersea Surveillance.

This utilises a distributed sensor field, combining acoustic and non-acoustic sensor technologies. Preferred options will use passive sensors, low probability of intercept communications and stealthy bottomed platform designs.

6. Environmental Prediction Packages.

New methods for data analysis and prediction of the littoral environment on expeditionary operations will be provided. New ensemble ocean modelling systems will provide environmental support to the performance of tactical systems and expeditionary operations.

7. Remote REA Using Autonomous Vehicles and Satellite Systems.

Real time battlespace characterization using autonomous vehicles and satellite based remote sensing will be provided. A long-term goal is to fuse battlespace characterization with the environmental prediction package to assist maritime commanders to exploit the environment to their strategic and tactical advantage.

8. Tactical Decision Aids and associated prototype CONOPS.

A suite of prototype software aimed at the commander at sea for planning the tactics of allocated platforms to meet the military objective, will be provided. There will be increasing emphasis on integrating the TDAs into the Common Operating Picture.

9. Command and Operational Support.

This capability provides OR support to the NATO Commands, Agencies and operational community in the area of underwater warfare, including guidance on the planning of exercises and operations, operational performance assessment and input to the development of CONOPS.

10. Expert Exercise Analysis.

This capability provides quantitative exercise analysis techniques to facilitate improvements in NATO C4I and to accelerate the development of NATO tactics and tactical decision aids.

11. Defence Against Terrorism.

A multi-sensor harbour protection system based on the concept of layered defence with an inner ring to detect divers and other small, mobile threats, and an outer ring to detect swimmer delivery vehicles and mini-submarines. A long term goal is to fuse underwater and above water surveillance.

12. REA Communications

Geospatial data services in a timely exchange of METOC data and efficient use of the information technology infrastructure will be delivered. It will provide near real-time-fused battle space picture with integrated tactical decision aids in support of expeditionary operations for planning and execution of missions.

Annual Bibliography of Centre reports with abstracts

M-143
Baldacci, A.
EST: an Environmental Scoping Study Tool

The Environmental Scoping study Tool (EST) has been developed to support trial planners who need predicted sound propagation properties for the area of interest, in terms of transmission loss (TL). The usefulness of such predictions is twofold: the knowledge of transmission loss helps the trial planner to investigate the scientific aspects of the experiment to be conducted; moreover the estimated received levels at all locations can be used in the framework of a marine mammal risk mitigation policy. The aim of EST is to provide an easy to use interface between the (possibly non expert, in terms of modelling) user and transmission loss models. EST takes care of creating the necessary input files for the TL model, running the models, reading TL model output files, and finally presenting the estimated TL tables as a set of convenient graphical and numerical results.

M-151
Law, J., Bovio, E., Bezemer, A.
Preliminary guidance for the tactical use of AUVs in counter-terrorism MCM operations in ports and harbours.

NATO's present capability to deal with a terrorist threat to our ports and harbours is slow, laborious, dangerous, and inefficient. Port and harbour installations are an extremely challenging area within which to conduct MCM operations due to several factors: shipping movements, very shallow water, turbidity, confined space, mine burial due to muddy/silty conditions, and very high clutter density. Due to the requirement to limit disruption to shipping, MCM operations in ports and harbours are extremely time critical with the added burden of having to be carried out to a close to 0% remaining risk.

The shortfall in NATO's ability to deal with this problem was recognised in the 2002 Bi-SC UWWSOR which gave the highest priority to MCM for Force Protection and Counter-Terrorism.

The recent availability of small, rapidly deployable, relatively inexpensive AUVs equipped with a variety of acoustic, optical, and magnetic sensors for shallow water operations, can contribute significantly to improving the current limitations of conventional assets. The use of AUVs working in conjunction with MCMVs and divers has several advantages: significantly faster search rate, reduced danger to divers, rapid deployability, and ability to carry out sonar searches in confined and very shallow areas. This document is based on the use of one such vehicle, REMUS, currently operational in the US Navy and UK Navy. Reference is also made to capabilities that REMUS does not currently have but which are under development. Other vehicles of similar performance and characteristics are becoming commercially available and will further increase the speed and efficiency of a counter-terrorist AUV MCM operations.

This document is a result of the work that was undertaken at the NATO Undersea Research Centre and its aim is to provide tactical guidance for the use of current AUV technology in counter-terrorism Mine Countermeasure operations in ports and harbours.

M-152
Canepa, G., Pautet, L., Pouliquen, E.
BORIS-SSA: Bottom Response from inhomogeneities and Surface suing Small Slope Approximation. Version 1.0.

The description of a software tool simulating, in the time domain, the acoustic backscattering from various seafloor types is presented: this package is an upgrade, with various new features, of `BORIS-3D`. The model underlying the `BORIS-SSA` software is capable of computing the full time response from the seafloor for various sonar types. The parameters of the model are the sonar directivity and pulse shape and the geometrical and physical characteristics of the seafloor. The package is platform independent and user friendly. This report is intended as a detailed description of the implementation on a source code level. A short introduction to the model underlying the package and a comprehensive demonstration program are also given.

M-153
Signell, E.P., Bryan, K.
DARE Version 2.0 User Guide.

After Maritime Mine Countermeasures (MCM) have taken place, MCM Commanders require an assessment of the remaining risk posed to transiting vessels or naval operations. DARE - Decision Aid for Risk Evaluation - is a software tool providing risk assessment for multiple mine types, multiple route segments and multiple routes. This User Guide provides documentation for the user functionality in DARE version 2.0. The User Guide is intended to serve both as an introduction for new users of the DARE software and as a reference for experienced users.

SM-388
Pouliquen, E.
Modelling and field measurements of bistatic scattering at high frequency.

The few bistatic scattering models reported in the literature are either empirical or simplified extensions of widely accepted backscattering models. Given the complexity and cost of measurements, few bistatic data sets have been collected to validate those models. Sea and tank experiments have shown that high frequency bistatic scattering is not only closely linked to parameters such as the carrier frequency and incident and scattering angles, but also to the pulse shape and the footprint created by the incident acoustic beam. The usual definition of the "steady-state" scattering strength is no longer meaningful for practical applications requiring short duration and high frequency signals. BORIS-SSA, a three-dimensional bistatic scattering model including these aspects as well as the three-dimensional properties of seafloor surface and volume has been developed. IT is a time domain model using the small slope approximation for interface scattering. The model is presented and successfully compared with high frequency (118 kHz) bistatic scattering data acquired on a sandy seabed off the Island of Elba (Italy).

SM-421
Pouliquen, E.
Near normal classification of the upper layer of the seabed.

Acoustic time series acquired at normal incidence from typical echosounders are highly dependent on the distance (also called "depth") between the transducer and the mean seabed level. As several classification systems use the seabed signal shape and energy, its depth dependence needs to be compensated for before processing. Without depth correction, a bias in the classification and inversion procedure is introduced. This paper describes the steps required to produce quasi depth-independent echoes for a given seabed type, that reduce the bias in the classification process. The proposed method is applied to data acquired in Nova Scotia on a geo-acoustically complicated area. Variability and reliability associated with this classification process is also investigated.

SM-422
Pouliquen, E., Canepa, G., Pautet, L., Lyons, A.P.
Variability of seafloor roughness properties and its impact on acoustic scattering.

Underwater environmental statistical properties are variable, both in time and space. Spatial variability is particularly important in shallower regions where near-bottom current and biological activity are significant. Temporal non-stationarity is also significant but traditionally given less attention, especially as far as the seabed roughness properties are concerned, as it is often believed to be negligible for short time scales. During two sea-trials conducted in July 2001 near Halifax, Canada, and in May 2003 at the Island of Elba, two specific studies were carried out to quantify seabed roughness spatial and temporal variability. At Halifax stereo-photos were acquired at various locations a few meters distant from each others. At the Island of Elba a stereo-photography system was deployed on a 10 metre deep sandy bottom. It acquired pairs of stereo-photos at the same location every 10 minutes continuously for 10 days. For both experiments, within a few metres distance and within a few minutes intervals important changes of the seabed roughness properties were observed. On one hand, biological patchiness and sand ripples are believed to be the main causes of spatial variability. On the other hand, two competing mechanisms - near-bottom currents and biological activity - are believed to play the most significant role in temporal variability. During calm days, small organisms living in the sediment are mainly responsible for reshaping the interface by creating local depressions (funnels) and excess of sand (mounds) and perturbating the underlying volume with burrows. The combination of sunlight, heat and micro-turbulence contribute via photosynthesis to the primary production within the sediment and to saturated oxygen O2 near and within the sediment and in turns to the appearance of bubbles. These phenomena mostly happen during daylight. During rough weather, near-bottom currents dominate the process and create sand ripples, eliminating roughness and bubbles caused by marine animals. Roughness spectral properties obtained from the computed roughness height field are used as direct input to a high frequency acoustic backscatter. Significant and sudden variations of backscatter (larger than 10 dB) over periods shorter than hours are expected at high frequency. These findings suggest solutions for improving the methods employed to retrieve seabed properties and to best use them in MCM prediction models like ESPRESSO.

SM-423
Prior, M.K.
A scatterer map for the Malta Plateau.

A method is described by which reverberation data gathered on a cardioid array can be processed to produce a 'scatterer map' of an area. Such a map shows the locations of strong seabed scatterers and gives a qualitative estimate of their strength. The method cannot give absolute values for scattering strength but its output is nonetheless useful in describing the locations of strong scatterers in an area.

Low-Frequency Active Sonar (LFAS) data gathered in the Malta Plateau are presented and the physical causes of observed strong scatterers are described, along with an assessment of the degree of certainty to which these causes are known.

SM-427
Pouliquen, E., Pautet, L., Guerrini, P., Tesei, A., Lyons, A.P.
Detection of a partially buried object using a time-reversal technique.

Time reversal and focalisation techniques offer new possibilities for communication and detection in highly reverberant and confined environments that are traditionally perceived as unfavourable. Instead of being hindered by multiple paths and reverberation this method exploits the m and is able to produce long virtual arrays and strong focusing at long range. A simple bistatic time reversal technique is applied to the detection of a low tar-get strength sphere half buried in sand in a narrow ocean waveguide, using an omnidirectional source and one hydrophone placed successively at various locations. Despite the high ambient noise level, the low accuracy of the hydrophone positions and the low target strength of the sphere, this bistatic time-reversal technique succeeded in detecting it unambiguously. This demonstration suggests numerous possibilities of using time-reversal methods with the appropriate frequencies and arrays for detecting objects located on or in the seabed.

SM-428
Fallat, M., Nielsen, P.L., Dosso, S., Siderius, M.
Through-the-sensor inversion and uncertainty analysis of MAPEX 2000 horizontal array data.

This paper examines the inversion of data from a towed acoustic source and towed horizontal array collected over a region with range-dependent geoacoustic properties. The inversion technique combines the results from a series of short-range, range-independent inversions to form a range-dependent representation of the environment. The acoustic data are taken from the MAPEX 2000 experiment conducted in the Malta Channel, Mediterranean Sea. Two inversion algorithms are used, Adaptive Simplex Simulated Annealing (ASSA) and Fast Gibbs Sampling (FGS). The results of the ASSA inversions are combined to characterize the range-dependent environment. The FGS results provide estimates of the uncertainties associated with the various geoacoustic parameters. The results agree favourably with a high-resolution seismic profile and measurements from several core samples.

SM-431
Tesei, A., Pautet, L.
Using single-element time reversal mirror for echo enhancement.

Iterative Time Reversal (TR) procedures have been demonstrated to be successful in detecting scatterers even in a highly reverberant medium. The success of the method is attributable to a Time Reversal Mirror (TRM) consisting of an array of transceivers that allows to reconstruct and reverse-propagate wavefronts of interest. This paper deals with the limit case of a TRM reduced to a single transceiver, tested using a tank experiment with three scattering objects in free-field conditions. It is shown that it is possible to excite a resonance between the TR operator and the strongest mode of the target in the bandwidth of insonification. A simple free field scattering model is used to study the mechanisms of convergence.

SM-432.
Baldacci, A., Grimmett, D.
Effects of source and receiver positional offsets in multistatic range determination.

During the Adults'03 sea trial (a joint research project between NATO URC and TNO-FEL, The Netherlands) a number of experiments were conducted to investigate the effects of equipment offsets in multistatic range determination. The analysis presented in this report is based on data collected during experiment P02b where the two participant ships, both towing an LFAS source-receiver pair, were arranged into an in-line configuration and proceeded with same speed and heading. The direct blast arrivals are used to acoustically calculate the distance between sources and receivers. The comparison between the expected arrival times (according to the geometry) and the measured arrival times gives an indication on how equipment offsets, latencies, positional errors and unknown sound speed effect range determination.

SM-433
Bouchage, G., Nielsen, P., Ferreira Coelho, E.
Effects of the internal waves on the acoustic propagation.

A simple 2D model called SOFIA has been developed in order to predict sound-speed fluctuations in the water column due to linear internal waves. It is based on solving the equation governing the vertical particle velocity associated with the internal waves, using a modal decomposition of the internal wave field. The main feature of the model is the use of experimental data: the Brunt-Väisälä profile is calculated from the density profile registered by the CTD cast, the amplitudes of the normal modes are determined using ADCP data and the spectrum is deduced from the thermistor chain measurements. The effects of the linear internal waves on the acoustic propagation were studied through several numerical simulations using some sound-speed profiles predicted with the SOFIA model. The acoustic simulations were performed with the REVPA model, based on a wide-angle approximation of the parabolic equation (PE) method. Through these simulations, the possible relation between the influence of the internal waves and different values of the environmental parameters was assessed. The environmental parameters considered in this study were the source depth, the acoustic frequency and the sediment properties.

SM-434
Harrison, C.H.
Drifting MF vertical array measurements in the 'noise-notch'.

Ambient noise data were collected on three occasions with a drifting medium-frequency vertical array (MFA) during the strongly downward-refracting conditions of BOUNDARY2003 on the Malta Plateau. The noise directionality shows a pronounced 24° wide, frequency-independent, noise-notch which at first sight is modified by passing shipping. Other features, whether acoustic or electronic, are revealed by the very low noise level in the notch. These include weak white noise and harmonics of 600 Hz at exactly horizontal. All features are investigated in detail by displaying the noise as a function of all combinations of two out of the three dimensions: angle, frequency, and time.

SR-391.
Myers, V.L., Pinto, M.
Information theoretic bounds of ATR algorithm performance for sidescan sonar target classification.

Autonomous underwater vehicles (AUVs) are receiving considerable attention as platforms to carry real or synthetic aperture sidescan sonars capable of classifying mine-like targets on the seafloor. As research begins to focus on the independent decision-making capabilities and behaviour for these vehicles, some effort is being spent on developing automatic target recognition (ATR) algorithms that are able to operate with high reliability under a wide range of scenarios, particularly in areas of high clutter density, without human intervention. Because of the great diversity of pattern recognition methods and continuously improving sensor technology, there is an acute requirement for objective performance measures that are independent of any particular sensor, algorithm or target definitions. This paper approaches the ATR problem from the point of view of information theory in an attempt to place bounds on the performance of target classification algorithms that are based on the acoustic shadow of proud targets. The information that can be used for classification found in sidescan sonar imagery is examined and common information theory relationships are used to derive properties of the ATR problem.

SR-393
Coraluppi, S., Carthel, C.
Distributed multistatic sonar tracking.

This report introduces a decentralized multi-hypothesis tracking algorithm for multistatic sonar. The algorithm performs single-sensor tracking on data from each source-receiver pair in the multistatic network. Single-sensor tracks are then combined with an automated track fusion capability that operates in a recursive, real-time mode as single-sensor track are produced. A key advantage of the decentralized approach is that it is robust to the fading effects exhibited in multistatic detection data, whereby targets fade in and out of view as a function of source-target-receiver geometry and environmental effects. The result of the decentralized approach is an overall surveillance picture that outperforms the capability of centralized, single-stage tracking algorithms.

SR-394
Burnett, D.S., Zampolli, M.
FESTA: a 3D finite element program for acoustic scattering from undersea targets.

Since 1999 the MCM thrust area has been actively involved in the development of a state-of-the-art, high-fidelity, finite-element, 3-D structural acoustics code for modelling the scattering of sonar signals by undersea mines located in or near the seabed. Several preliminary and intermediate codes were developed in 2000 and 2001. The first version of the structural acoustics code, named FESTA (for Finite Element STructural Acoustics), was released in Jan. 2003. Since then code development has included several enhancements, new functionalities and further code verifications. Today's FESTA is a sophisticated, reliable and useful modelling tool. This report describes the theoretical basis of FESTA, which includes the underlying physics and continuum mechanics and the mathematical development of the two types of finite elements used in the code – an elastodynamic and an acoustic element. The report also briefly discusses code implementation issues and demonstrates the modelling capabilities with both verification and realistic application problems.

SR-395
Askari, F.
A fuzzy approach for multisensor fusion and detection of eddy-induced upwelling.

Expert systems (ES) emulate the decision-making ability of a human expert by utilizing specialized knowledge. The recent alliance of fuzzy logic with ES has led to new systems that are more powerful than conventional ES. Here we describe a fuzzy-based ES that was developed for assisting in the detection of ocean upwelling using satellite remotely sensed ocean surface parameters/signatures. The satellite sensors include the Advanced Very High Resolution Radiometer (AVHRR), TOPEX/POSEIDON/ERS-2 (TPE) altimeter, Sea Wide Field of View Sensor(SeaWIFS), and QuikSCAT scatterometer. The oceanic parameters: sea surface temperature (SST), chlorophyll concentration, sea surface height (SSH), current vorticity and wind stress curl are used in formulation of the rule base that drives the ES inference engine. The ES provides the end-user with upwelling likelihood maps on the basis of satellite remote sensing measurements.

SR-397
Coraluppi, S.
Performance modelling and validation for distributed multistatic tracking.

This report develops a distributed multi-sensor tracker performance model that accounts for the target fading effect that we observe in sea trial data. We study model-based performance as a function of key tracker parameters, the choice of tracker architecture, and the number of distributed sensors. We validate the fidelity of the model by comparing model-based performance with actual tracker performance based on simulated contact data.

SR-398
Trangeled, A., Zappa, G., Conley, D.C.
Embedded Maritime Acquisition and Control System.

Real time oceanographic data in remote areas are required to support oceanographic scientists working on Rapid Environmental Assessment for NATO. To address this issue, an embedded system with integrated satellite link with near worldwide coverage has been implemented. An important advantage to this approach is the possibility of combining data retrieval with full remote control. Control is achieved using the telnet protocol. Data retrieval is accomplished by using web browser or an ftp client. A dial-in facility based on TCP/IP protocol suite is provided using PPP dial-in via satellite using a standard PSTN modem on one end and an Iridium/Globalstar satellite modem on the other.

This report presents the implementation of an embedded package for real-time oceanographic data monitoring, providing a limited set of standard UNIX commands for both remote control and data retrieval. Software has been developed for on-board data collection, processing and storage that are interfaced with oceanographic sensors aboard buoys, or submerged, providing real time data acquisition and control. Past development and future plans are presented.

SR-399
Rothenbach, M., Bovio, E., Yip, H., Gabellone, A.
Unmanned Underwater Vehicle (UUV) Experiment in the Port of La Spezia (NATO CONFIDENTIAL).

This document reports on the experiment in the Port of La Spezia that was undertaken by the NATO Undersea Research Centre to assess the feasibility and effectiveness of using a commercially available Unmanned Underwater Vehicle (UUV) and Remotely Operated Vehicle (ROV), both equipped with side-scan sonar, to counter mines in ports, particularly in confined spaces that are inaccessible to conventional MCMVs. The experiment allowed to measure the effectiveness of these systems in detecting and classifying mines in a highly cluttered sea bed and to determine the feasibility of detecting and classifying Improvised Explosive Devices (IED).

SR-400
van Velzen, M., Leutelt, L.
Evaluation of radial receive array performance (NATO RESTRICTED).

The DUSS (Deployable Underwater Surveillance System) is a transportable sonar system comprising one transmitter buoy and three receiver buoys. A DUSS receiver consists of 9 arms at 40-degree spacing where each arm contains 7 hydrophones. One hydrophone is positioned in the centre. The beamforming of these Radial Receive Arrays is shown to be in agreement with theoretical predictions. Shading coefficients to improve beamforming are determined by using genetic algorithms to search the 64 dimensional space spanned by the hydrophone data. It is shown that this shading reduces the highest sidelobe level by 5 dB while the average sidelobe level remains unchanged. An alternative "Cross Receive Array" is proposed, showing improved sidelobe levels for simulated data if beamforming similar to cardioid array processing is applied.

SR-401
Bovio, E.
Autonomous underwater vehicles for port protection (NATO CONFIDENTIAL).

This document reports the experimental work that was undertaken at the NATO Undersea Research Centre (NURC) during the period November 2002 – June 2004 under Project 03G-2 of the Scientific Program of Work, the technical lessons learned and guidance for using AUVs for MCM operations in ports and harbours. Five experiments were conducted in the ports of La Spezia, Stranraer and Rotterdam. The capabilities of the REMUS and the Ocean Explorer (OEX) were demonstrated in November 02 to the NATO Naval Group 3 (NG3). In March 03 NURC participated to the Cinque Terre exercise organized by the Italian Navy to simulate terrorist mining of Carrara and La Spezia harbours. During exercise Northern Light 03, the OEX and the REMUS surveyed part of Loch Ryan. A demonstration of the concept to NATO Assistant Secretary General took place in March 04 in the harbour of La Spezia. A final demonstration took place in June 04 in the harbour of Rotterdam, with the participation of REMUS. The experience gained during the exercises helped to develop a concept of operations and to identify the technical improvements required.

SR-402
Rixen, M., Ferreira Coelho, E.
Operational surface drift prediction using linear and non linear hyper ensemble statistics on atmospheric and ocean models.

Multimodel superensemble forecasts, which exploit the power of an optimal local combination of individual models usually show superior forecasting skills when compared to individual models because they allow for local correction and/or bias removal. Deterministic approaches to the problem of surface drift are often limited by strong assumptions on the underlying physics. Here we apply linear and non-linear statistical methods to generate optimal hyper-ensembles from combined atmospheric and ocean operational models and local observations that were made available during the MREA04 field experiment along the West coast of Portugal. Optimisation methods are based on a training/forecast cycle and include linear regression, neural networks and genetic algorithms methods. The performance and the limitations of the hyper-ensembles and the individual models are discussed. Results suggest that our statistical methods reduce the position errors by 20 to 50% for 12 to 48 hours forecasts and hence compete with pure deterministic approaches.

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

Simple theory shows that one can extract the scattering law angle dependence from ratio of reverberation to one-way propagation intensity measured on a vertical array (VLA). An experiment was carried out during BOUNDARY2003 and repeated during BOUNDARY2004 using an FM sweep as sound source first to measure vertical angle-dependent monostatic reverberation then to measure angle-dependent propagation loss as the ship mounted source moved away from the VLA. Both scattering and reflection properties are deduced in several ways without the need for modelling.

SR-404
Nielsen, P.L., Jensen, F.B.
Prediction of low-frequency acoustic propagation in shallow water.

In September/October 2000 NATO Undersea Research Centre conducted the SWEEP2K experiments collect environmental and low-frequency acoustic data in shallow waters. Data were collected from 3 sites with water depths ranging from 15-85m and varying bottom properties. Seismic surveys were performed along the acoustic tracks, and core data were available from previous sea trials conducted in the same area. Acoustic tones were transmitted from a towed source in the frequency band 6-100 Hz, and the data were acquired on a bottom moored array with 4 hydrophones covering most of the water column. The maximum propagation range was around 500m on both sides of the array. The numerical propagation model OASES was used to assess the feasibility of predicting acoustic propagation at low frequency in shallow water. This assessment was achieved by comparing the results to the data at several frequencies and source-receiver geometries. The best match between the model and data was obtained by manually adjusting the bottom properties for the model input. In general the agreement between the model and data is good for all sites and for the considered frequencies and source-receiver geometries. However, this is only achievable by using the correct propagation model and by estimating the underwater environment. The low-frequency and short-range propagation requires that the prediction model includes the full spectrum solution (continuous, discrete and evanescent spectrum) and support shear properties in the bottom. The deep layering structure and acoustic properties of the bottom are of particular importance for predicting the low-frequency transmissions.

SR-406
Rixen, M., Ferreira Coelho, E.
A note on operational prediction of acoustic properties in the ocean using multi-model statistics.

Super-ensemble multi-model forecasts exploit the power of an optimal local combination of individual models and usually show superior forecasting skills when compared to individual models because they allow for local correction and/or bias removal. Here we use multi-model statistics to optimise the forecast skills from an ocean model run operationally at two different resolutions during the MREA04 field experiment along the West coast of Portugal. The method is based on a training/forecast cycle and uses a linear regression optimisation. The performance and the limitations of the super-ensemble and the individual models are discussed. Results suggest that in forecast mode, our statistical method reduces the errors on sound velocity by 20 to 80% for 24 hours lead time.

SR-407
Gauvry, O., Machalica, M., Terrasse, A., Berni, A., Leonard, M., Merani, D.
NC3A-NURC joint trials of the SkyWAN Satcom TDMA system.

The report documents the trials conducted by NURC and NC3A in spring 2004. Trials were to assess the real time performance of a Satcom TDMA mechanism called SkyWAN in conjunction with end-to-end IP applications. That mechanism is currently used by NURC to support its operational communication links with its two NATO research vessels when at sea. In order not to disturb these operational links, NURC negotiated with Eutelsat additional Satcom bandwidth to support those experimental trials.

The major points of interest reported in that note are the description of the NURC VSAT characteristics, the configuration architecture and setting related to the NURC-NC3A trials, the basic end to end performance and a preliminary conclusion on the use of the SkyWAN mechanism.

SR-408
Haralabus, G., Baldacci, A., van Velzen, M., Laterveer, R.
BASE '02 sea trial: cardioid broadband data analysis for ambiguity resolution with variable bandwidth processing for real time performance enhancement, (NATO CONFIDENTIAL).

During the BASE '02 sea trial, the Centre;s low frequency active sonar system is used for the first time in a submarine detection scenario. The inherent advantages of broadband processing in reverberation-limited conditions are exploited. Frequency agile, sub-band processing techniques are proposed to identify efficient combinations of frequency and bandwidth in real time. The detection performance comparison between single-line (ambiguous) and cardioid (unambiguous) towed array receiver underlines the advantages of the latter. Examples that indicate upper limits in broadband detection performance as a function of bandwidth (case-depended) are provided.

SR-409
Yip, H., Pouliquen, E., Canepa, G., Davies, G.
Minehunting percentage clearance trials in BLUE GAME '04 (NATO CONFIDENTIAL).

MCMFORNORTH participated in the mine hunting percentage clearance trials in Exercise Blue Game '04 south of Horten in the Oslo Fjord. The main trial objective was to compare the reported percentage clearance with the minehunter's achieved percentage clearance. The mine hunting scenario was very difficult; high MILEC density, zero-to-low underwater visibility, large number of non-mine Minelike Bottom Objects (NOMBOs). Five MANTA and five ROCKAN shape mines were laid in the PC trial route; two MANTAs were countered and one ROCKAN was misclassified as non-mine by at least one unit. With the exception of one unit, the minehunting units' reported percentage clearance were much higher than their achieved PC. Measurements from the sonar conditions check indicated that the cross-track detection widths used for planning and evaluation were over-estimated. The large number of false contacts in the PC trial route also made it difficult for the sonar operator to select the contact for classification. Seabed classification algorithms using data from a multi-beam echo sounder survey conducted 4 weeks before the trial estimated areas of the seabed where the detection of mines would be a formidable task for the minehunters. Two mines were laid in this difficult area estimated by the seabed classification, no mines were detected by any units. The REMUS AUV conducted a search of a small area in the northern part of the PC trial route. Only one mine was available in that small area; this mine was positioned in the area with large back-scattering strength. The mission planning of the REMUS AUV did not achieve full coverage over the intended portion of the PC trial area. The BPAUV conducted a search of the southern section of the PC trial route. The track-spacing for the BPAUV did not allow for complete coverage of the intended area with its sonar's sweet-spot. However, it detected one MANTA.

SR-410
Young, V.
Using a vertical line array and ambient noise to obtain measurements of seafloor reflection loss.

Bottom reflection properties can be obtained from ambient noise directionality. The new results obtained at six sites in 2002 with the Centre's 62m VLA are summarised. At four of the sites the VLA was moored, in order to study a single seafloor environment, while at the other two sites the VLA was allowed to drift, in order to study geographical changes in the seafloor environment. Several variants of the measurement and processing techniques are investigated here. Firstly, rather than using only the uniformly spaced central section of a nested vertical array (VLA), one can expand the useful size of the array to about three quarters (rather than one half) of the full array length by padding out the array's correlation matrix. The padding makes the apparently good assumption that the noise cross-spectral-density matrix is Toeplitz. Thus the initially sparse matrix for the outer sections of the array (with wider hydrophone separations) can be filled out with values from elsewhere in the true matrix. This provides better angular resolution which is beneficial for the method. Secondly, the possibility of synthesising a VLA with a pair of hydrophones is investigated. The benefit of a synthetic aperture would be the lower cost of the equipment in an operational context. For the process to work (without extremely long integration times) the noise source spatial distribution needs to be stationary.

SR-411
Ferreira Coelho, E., Rixen, M., Signell, R.
NATO Tactical Ocean Modelling System Concept Applicability.

Although the available ocean forecast schemes include a broad range of scales, they usually cannot account accurately for higher frequency ocean phenomena (sub-mesoscale to small scale) due to the uncertainty on the forcing fields and its initial phase. To overcome this uncertainty at present, extensive oceanographic data collection is required, which is very expensive and likely it will not be feasible to obtain on a sustained and substantial basis. To overcome these limitations at tactical level the NTOMS methodology is here proposed. It starts by running a model ensemble based on local available observations, builds robust statistics and introduces feature and high resolution modelling as a way to reduce uncertainty and increase systems performance. An implementation example during the trial MREA03 showed for surface drift related products that efficiency can increase by 20% and reliability can increase from 70 to 85%. Embedded feature modelling and the Mini-HOPS concepts are also outlined to locally improve the representation of the sub-mesoscale dynamics. It was concluded NTOMS approach to produce short term, locally more accurate oceanographic field estimation, accounting for the tactical modelling requirements.

SR-413
Grasso, R., Spina, F., Hagen, P.E., Halvin, B.
Side scan sonar image segmentation through multi-resolution texture features: a case study over the Luce Bay site during Northern Light 2003.

The segmentation of a sidescan sonar (SSS) dataset acquired in the Luce Bay site during the Northern Light'03 exercise, by a Hugin autonomous underwater vehicle (AUV) mounting an Edge Tech sensor, is presented and discussed. The segmentation was performed through the analysis of the image texture by means of a set of un-decimated wavelet transform features followed by classif cation using a supervised classif er based on the Mahalanobis distance in the feature space. During the classif er training, four ain seaf oor classes were revealed, including low and high ref ectivity sediments and sand ripples at two different wavelengths, which are well discriminated in the feature space. A simple post-processing with GIS tools was applied to smooth the data and convert pixels into polygons for a f nal output in AML/S57, the format adopted for data upload in CCIS. The f nal thematic map showing the classif cation of the whole dataset, contains two distinct areas, the f rst in the so called inner leg (IL), showing no appreciable variations in the seabed characteristics, and the second, namely the outer leg (OL), having more variability.

SR-414
Gabellone, A., Zampolli, M., Michelozzi, E.
Mine jamming. Phase II results, (NATO CONFIDENTIAL).

This report describes Phase II of a study into Mine Jamming. It discusses the main characteristics of current threat mine and how some Mine Jamming concepts may be effective. Possible techniques are suggested and were experimentally investigated in two extensive sea trials. The results analysis shows that Mine Jamming successfully caused most mines to take a wrong decision. Old or simple mines are swept by jamming signals in the same way conventional mine sweeping devices simulate the target signatures. However modern or intelligent mines were mostly confused by jamming signals, which, at the same time, masked the transiting targets' signatures while eliminating or reducing the risk. This report concludes that Mine Jamming could be a realistic and effective risk reduction measure to support the traditional active MCM techniques (like mine sweeping). Finally new efforts into the Mine Jamming research should focus on investigating other mine jamming techniques for Port Protection and developing a Concept of Operations document for planning MCM operations that include Mine Jamming.

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

The plane wave reflection coefficient for all angles and frequencies is a unique descriptor of the acoustic properties of a seabed, but it is difficult to measure directly in shallow water. However, one can calculate the point receiver result by a plane wave expansion given the plane wave reflection coefficient. In this report we show that it is also possible to perform the more useful inverse operation of calculating the plane wave reflection coefficient given point source and receiver measurements. This means that it is possible to make propagation predictions in the presence of complex bottom structure using short range reflection measurements but without ever determining the detailed geoacoustic parameters. Simulations show that the method works for multiple isospeed layers and also continuously varying sediment sound speed profiles. The feasibility of experimental determination of plane wave reflection coefficient is addressed.

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Senior Scientist	M van Velzen (NL)
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Scientist	O. Gerard (FR)
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Scientist	M. Fallat (CA) (until November 2004)
Scientist	VACANCY
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Scientific Specialist	W. Zimmer (GE)

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Senior Principal Scientist, Head, EMP	M. Pinto (FR) (until October 2004) Vacancy
Senior Principal Scientist	F. Jensen (DA)
Principal Scientist	E. Bovio (IT)
Principal Scientist	D. Burnett (US) (until April 2004)
Principal Scientist	A. Gabellone (IT)
Principal Scientist	M. Stevenson (US) (to RSN from March 2005)
Principal Scientist	E. Pouliquen (FR)
Senior Scientist	A. Tesei (IT) (from November 2004)
Senior Scientist	L. Wang (UK) (until Mar 2005)
Senior Scientist	M. Zampolli (IT)
Scientist	P. Munk (DA)
Scientist	L. Pautet (FR)
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Scientist	V. Myers (CA)
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Visitors and meetings

January	EGUERMIN Staff Officers Course	
	VADM M. Galliccia, ITN	Commander in Chief, MARIDIPART La Spezia
	MREA04 Sea Trial Planning meeting	
	Dr R. Gisiner	CNR Arlington, US
February	Capt. J. Besch, GENA	Head of URC SPOW Coordination Section, HQ ACT
	Prof. E. Claudio Mr M. Fisenda	University of Genova, IT
	Prof. H.-P. Kuchenbecker Prof. K. Jobman	University of Hannover, GE University of Hannover, GE
	Dr J. Haun	Office of Naval Research, IFO
March	Dr P. de Theije	TNO The Hague, NL
	Prof. R. Holman	Oregon State University, US
	Italian Navy Academy	
	Next Generation Autonomous Sensors Workshop	
	Dr D. Abraham Dr P. Willett	Office of Naval Research, US University of Connecticut, US
	Mr M. Billingslea RADM M. Bartoli, ITN CAPT(Ret.) A. Simi Ambassador M. Moreno RADM M. Host, ITN VADM Q. Gramellini, ITN RADM D. Nascetti, ITN RADM L. Spagnuolo, ITN RADM R. Paperini, ITN CAPT M. Cassotta, ITN CAPT A. D'Andrea, ITN CDR P. Maggiani, ITN CDR D. Martini, ITN CDR O. Molino, ITN CDRE J. Welch, UKN	Ass. SECGEN for Defence Investment, NATO HQ Deputy Ass. SECGEN Defence Investment Head, Naval Armament Section, NATO HQ Italian Permanent Representative to NATO Military Counsellor, NATO HQ CINCFLEET Chairman,NNAG Commanding Officer COMFORDRAG Commanding Officer, COMSUBIN MARIDIPART Italian Representative to SCNR 4° SMM, Rome COMFORDRAG COMFORDRAG DACOS/frct, ACT HQ
	Dr W. Fox	Office of Naval Research, US
	DEMUS JRP Planning Meeting	ONR, US, Dstl and QinetiQ, UK
April	Dr G. Williams Dr D. Abraham Dr F. Ehlers	Dstl, UK ONR, US FWG, GE
	Capt L. McCullough	Deputy Legal Director, SACT
	VADM K. Donald, USN RADM S. Stanley, USN	COMSUBLANT Commander Submarine Allied Naval Forces South
	RTO-SET Symposium Meeting and RTO SET Panel Business Meeting	
May	NCOS Kick-Off Meeting – Task Group on Network Centric Operations Security	
	Thrust Area Review Team	ACT, ACT SEE and National Representatives
	84th Meeting Scientific Committee of National Representatives	
	RADM X. Paitard, FRN	DACOS Future Capabilities, Research and Technology, ACT
	Mr J. Shea	TED Services (SPAWAR), US
	Dr B. Whitehouse	OEA Technologies, CA

Visitors and meetings

June	Professor P. Jumars	University of Maine, US
	ADM E. P. Giambastiani Jr	SACT
	Mr J. A. Vogel	Director, TNO The Hague
	NATO Naval Mine Warfare Planning, Evaluation and Risk Assessment meeting	
	Mr N. Dazzi Mr P. Traverso	Fincantieri, IT
	NATO Mine Warfare PERA Panel	
	Dr M. Siderius Dr M. Porter	Science Applications International Inc., US
	Dr J. W. Book	NRL SSC, US
	DART 05 Pre-cruise planning meeting Mr S. Carniel Mr N. Russo Mr M. Orlic	 CNR Venezia, IT CNR Ancona, IT Univeristy of Zagreb, Croatia
	TAB Meeting Admiral Sir I. Forbes, UKN RADM X. Paitard, FRN Dr Ahmed Ucer Brigadier-General U. Manetti Brigadier-General J. Maj RADM M. Bartoli Mr B. Reedijk	 DSACT ACT HQ RTA NC3A NSA IS-DI (APPP) DASG, NATO HQ APP-PPS, NATO HQ
	Workshop for AUV Planning & Evaluation Tools	
	13th Mine Jamming JRP Meeting	
	Dr D. Bradley Dr E. Liszka	Applied Research Laboratory, Pennsylvania State University, US
	Dr J. E. Skjervold Mr J. Johnsen	Norwegian Defence Establishment
	Dr J. DeCorpo	US Office of Naval Research Global
July	NGAS 3rd JRP Trial Planning Meeting	
August	Multistatics technical demonstration	
	Dr G. Jackson Dr N. Prince Dr M. Donnelly	Dstl, UK Systems Engineering & Assessment Ltd (SEA)
	Professor L. F. Pratson	Duke University, US
	Dr J. Newcomb	Naval Research Laboratory, US
	CDR P. Vanderbeeck LT E. Depoorter CPO F. Degrieck CPO E. Lesabel	EGUERMIN Gaming Minewarfare System Department, NL
September	Destined Glory Final Planning meeting	
	DEMUS04 JRP participants meeting	
	Professor M. J. Perry	University of Maine, US
October	Professor P. Willett	University of Connecticut, US
	Mr R. Simpson	ACT
	Prof. J.-P. Hermand Prof. F. Absil	 Royal Netherlands Navy College
	ACO Civilian Personnel Officers Conference	

	TTCP ASW Systems and Technology Panel Meeting	
	The First Geospatial Maritime Working Group Meeting	
	NATO 35th MILOC Sub Group Meeting & NMESS User Group Meetings	
	Dr P.-M. Poulain Dr E. Mauri	Osservatorio Geofisico Sperimentale, Trieste, IT
	NATO MILOC Sub Group Meeting - NATO Maritime Environmental Systems User Group (NMESS UG)	
November	Dr P.l de Theije Mr P.l Van Walree	TNO, NL TNO, NL
	Ing. E. van der Spek, NLN	Senior Executive, Directorate of Materiel Royal Netherlands Navy
	CDR G. Spalton, UKN Mr R. Simpson CDR K. Carter, UKN CDR A. Lochrane	SHAPE ACT ACT MOD UK
	Mine Detection and Classification JRP Meeting	
	85th Meeting Scientific Committee of National Representatives	
	Broadband Environmental Adaptive Sonar (BASE) collaborative work follow-up meeting	
	Dr Raffaele Esposito	Vice Chairman NIAG
	ADM Sir Mark Stanhope, KCB OBE, UKN	Deputy SACT
	Mr John Laugerud, NOCiv.	Chairman SRB
December	Dr Fabio Di Felice	INSEAN Italian Ship Model Basin, Rome
	MREA04 Workshop	
	CDR Fernando Cerutti, ITN	MARISTAT

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Head of Naval Capabilities - Plans Division

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Chief Scientist
Defence R&D Canada - Atlantic

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Defence R&D Canada - Atlantic

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Royal Danish Administration for Navigation and Hydrography

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Chef du Département Lutte Sous la Mer
Service des Programmes Navals

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FWG

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Member of Submarine Section
Federal Ministry of Defence

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Head of Physical Oceanography Department
Hellenic Navy Hydrographic Service

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Hellenic Navy General Staff

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Centro Interforze Munizionamento Avanzato (CIMA)

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MARISTAT

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Ministero Difesa Marina

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Head, Underwater Acoustics Group
TNO Physics and Electronics Laboratory

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Head Underwater Sensor- and Weapon Systems branch
Dept. of Weapon and Communication Systems

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Maritime Systems Division
Norwegian Defence Research Establishment (FFI)

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Norwegian Naval Training Est

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Akademia Marynarki Wojennej

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Instituto Hidrográfico
Divisão de Oceanografia

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LTCDR **Juan Ramon CONFORTO SESTO**
CC Chefe de la Seccion Oceonografia
Instituto Hidrografico de la Marina

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SCNR Chairman
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Head of the Department of
Navigation, Hydrography and Oceanography

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ENG CAPT **Hakan BAŞARAN**
Arastirma Mrk K.ligi
Akustik Arastirma Grp.Bsk

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Mr **David VOGWELL**
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Dstl Winfrith

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LCDR **Piers MOORE**
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Director (Acting) Sensing and Systems Division
Ocean, Atmosphere and Space Dpt - Office Naval Research

UNITED STATES

National Liaison Officer
CDR **Robert HEADRICK**
Sensing and Systems Division Military Deputy
Ocean, Atmosphere & Space Dpt - Office Naval Research

SECGEN NATO

Representative
RADM **Mario BARTOLI**
Director
Armaments Defence Investment Division

NAMILCOM

Representative
COL **Tadeusz KRZYWDA**, PLAF
Staff Officer for Research & Technology
Logistics and Resources Division

SACT

Representative
RADM **Xavier PAITARD**, FRN (TC-70)
Deputy Assistant Chief of Staff
Future Capabilities Research and Technology
Headquarters, Supreme Allied Command Transformation

SACT

Liaison Officer
CAPT **Joerg BESCH**, GEN (TC-7410)
Section Head, URC SPOW Coordination
Headquarters, Supreme Allied Command Transformation

ACO and ACT SEE

Branch Head
CAPT (ITN) **Andrea MUCEDOLA**
Branch Head
Maritime Defence Planning, ACT SEE

Scientific Personnel by Nationality

Country	Scientific complement (31 Dec 2004)	Total scientist man years (1959-2004)
Belgium	2	99
Canada	2	110
Denmark	4	151
France	5	171
Germany	0	132
Greece	1	34
Italy	6	263
Netherlands	2	138
Norway	0	103
Portugal	1	15
Spain	0	3
Turkey	0	38
UK	7	342
USA	10	411
Total	40	2013