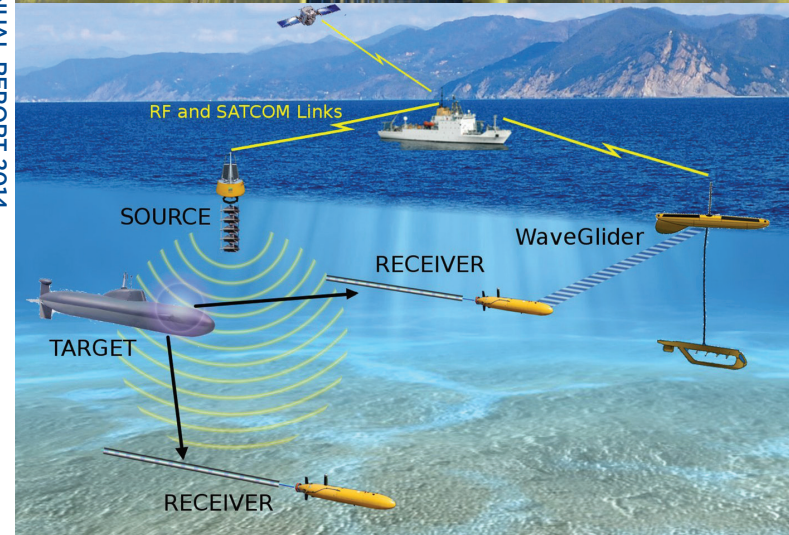
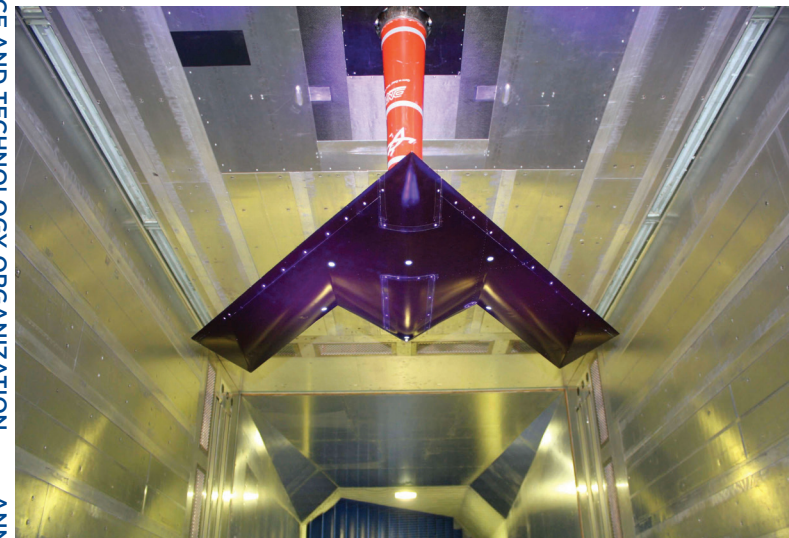




Science and Technology Organization ANNUAL REPORT 2014

NATO SCIENCE AND TECHNOLOGY ORGANIZATION ANNUAL REPORT 2014

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Supporting the Defence and Security posture of the Alliance and its Partners

Foreword

FOREWORD

THE NATO SCIENCE AND TECHNOLOGY ORGANIZATION (STO) SUPPORTING THE DEFENCE AND SECURITY POSTURE OF THE ALLIANCE AND ITS PARTNERS

In the foreword to his 2014 Annual Report, the NATO Secretary General states his priorities are to keep NATO strong, to work with Partners to help keep our neighbourhood stable, and to keep the bond between Europe and North America rock-solid.

The NATO Science and Technology (S&T) community, and the Science and Technology Organization (STO) in particular, are very well positioned to support NATO and the Nations in this respect and deliver to expectation.

NATO S&T is instrumental in the strategic awareness of future challenges and the innovation that NATO and Nations need to enable Defence and Security, today and tomorrow.

The focus on **supporting the Defence and Security posture of the Alliance and its Partners** is reflected in the Collaborative Programme of Work (CPoW) growing by 15 percent; the Centre for Maritime Research and Experimentation (CMRE) customer-funded programme delivering on time and within budget; and the STO delivering S&T results with multiple exploitation paths, including supporting the Wales Summit taskings.

In 2014, the Science and Technology Board's (STB) efforts toward **overseeing the STO** positioned the Executive Bodies to deliver the STO S&T Programme of Work (PoW), moving reform forward, including key dossiers such as defining the future of NATO's Research Vessels (NRVs) at CMRE.

On **issuing coherent guidance to NATO S&T**, the STB matured the framework for strategic guidance, which now includes NATO S&T Priorities and S&T Strategic Initiatives, while continuing to strengthen the engagement of the S&T planning domain across all steps of the NATO Defence Planning Process (NDPP).



Figure 1: Trond Karlsen, MGen (NOR AF), NATO IMS L&R Director and S&T Board Co-vice Chair; Albert Husniaux, MGen (BEL AF), NATO Chief Scientist and S&T Board Chair; Ernest J. Herold, NATO DI DASG and S&T Board Co-vice Chair.

With respect to **enhancing the co-ordination and synergy of NATO S&T** across NATO S&T stakeholders, the STB, through the STO, conducted extensive outreach activities both within NATO and with external NATO bodies.

Last, through the NATO Chief Scientist, the NATO S&T community **delivered knowledge, analysis and advice** to NATO leadership on a variety of topics, such as unmanned aerial systems, Modelling & Simulation (M&S) in support of training, autonomous systems, and elements related to process and analysis with the goal of enhancing the NDPP.

We are pleased to present this 2014 Annual Report. We trust it will provide an appreciation for the results delivered by NATO S&T and the STO in particular, a view of leading-edge scientific and technical accomplishments, and that it will encourage supporting the generation of the STO PoW and participating to it.

We hope you find it an interesting read. ■

Executive Summary

EXECUTIVE SUMMARY

The 2014 Annual Report of the NATO Science and Technology Organization represents the 2014 STO PoW, which consists of more than 200 activities that cover all Defence and Security areas of interest.

This report demonstrates that through extensive interaction across the Alliance, NATO S&T is aligned with the priorities of the Nations and NATO. It is intended not only for NATO's S&T stakeholders, but also to reach out to those across the globe who are interested in benefiting from and participating in NATO S&T.

In the section "Corporate Perspectives", the reader is invited to get acquainted with S&T in NATO, including its large community of stakeholders. The most important functions of the STO are addressed, including the fact that the organization encompasses the largest known collaborative network of Defence S&T experts in the world. This part concludes with the 2014 strategic focus and achievements, aimed at governing the STO and developing NATO S&T governance, and the 2015 preview.

The section "NATO STO Programme of Work" treats the reader to a representative set of S&T activities drawn from the extensive STO PoW. All those activities contribute to the three strategic objectives of NATO S&T – Supporting Capability Development; Fostering Consultation and Partnerships; and Delivering Knowledge, Analysis and Advice. The description of the activities includes explanations of S&T Achievements, Synergies and Complementarities, and Exploitation and Impact.

Within the STO PoW there are two executive bodies that play a major role in PoW delivery – the Collaboration Support Office (CSO) and the CMRE. Both are introduced by their respective Directors at the beginning of the PoW part of the report.

Last but not least, the focus is placed on excellence in NATO S&T.

The "Annexes" contain a more detailed description of the NATO STO and its functions, including facts and figures, and a list of acronyms. ■

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Corporate Perspective

NATO SCIENCE AND TECHNOLOGY

Defence Science and Technology or S&T, in the context of NATO, is defined as the selective and rigorous generation and application of state-of-the-art, validated knowledge for Defence and Security purposes. The term is broadly inclusive of the physical, engineering, information, human, medical and social sciences.

NATO S&T is comprised of activities that contribute to the generation and exploitation of scientific knowledge and technological innovation, addressing the short-, medium- and long-term horizon. NATO S&T includes programmes and activities that Nations, NATO bodies and Partners elect to perform within the trusted NATO framework. NATO S&T serves the Security and Defence posture of the Nations and NATO, and supports the core tasks of the Alliance as set out in the Strategic Concept. The vast majority of NATO S&T work is funded directly by the Nations.

NATO S&T is instrumental in enabling state-of-the-art Defence and Security capabilities, assessing the security impact of emerging (technological) threats, and serving public diplomacy by building

bridges. Facilitating knowledge generation and exchange in a NATO collaborative context, thereby injecting military relevance, positions S&T as a critical “force multiplier” for the Alliance. Influencing, enabling and leveraging S&T investments in the Nations and NATO will achieve a higher quality and impact at a reduced cost.

NATO S&T stakeholders comprise individuals, organisations, Partners, NATO Nations and NATO bodies that are able to guide, fund or execute NATO S&T activities, or that can benefit from its results without being actively involved. Due to this diversity, the effectiveness and efficiency of NATO S&T depends critically upon close co-ordination, co-operation and collaboration between all stakeholders.

Governing NATO S&T at the Alliance level, without prejudice to the responsibilities and authority of the stakeholders, is of vital importance to avoid unnecessary duplication while encouraging innovation to further improve synergies, and to seek complementarities for burden sharing.

STAKEHOLDERS

A non-exhaustive list of NATO stakeholders (in alphabetical order) is presented in the North Atlantic Council (NAC)-approved NATO S&T Strategy – Allied Command Transformation (ACT); the Conference of National Armaments Directors (CNAD) and its subordinate structure (namely the Main Armaments Groups (MAGs) and the NATO Industrial Advisory Group (NIAG)); the NATO Consultation, Command and Control Board (NC3B) and its subordinate structure; the Military Committee (MC); the NATO Communications and Information Agency (NCIA); the NATO Support Agency (NSPA); NATO’s Science for Peace and Security Programme (SPSP); the NATO Science and Technology Organization (STO); and the supporting staff at NATO Headquarters.

Other stakeholders include the Committee of the Chiefs of Military Medical Services (COMEDS) and its subordinate structure, NATO’s Defence Against Terrorism (DAT) PoW, the NATO Centres of Excellence (CoE), the NATO Defence College (NDC), the NATO Parliamentary Assembly (PA) and its sub-structure, the von Kármán Institute (VKI), research institutes, academia and industry.

This community of stakeholders is widening, reinforcing the drive to co-operate within the NATO framework.

NATO SCIENCE AND TECHNOLOGY ORGANIZATION

Defence Ministers created the NATO STO in 2012, with the aim of making S&T more visible and accessible to senior NATO leadership, and to better link multi-nationally and commonly funded S&T, while maintaining the quality of services and products.

The STO is built on two important preceding bodies – the NATO Research and Technology Organization (RTO) and the NATO Undersea Research Centre (NURC). This amalgamation brings together a legacy of co-operative S&T that dates back to Dr. von Kármán’s founding the Advisory Group for Aerospace Research and Development (AGARD) in 1952. It also encompasses the NATO in-house maritime research facility.

The mission of the NATO STO is to help position the S&T investments of the Nations and NATO as a strategic enabler of the knowledge and technology advantage for the Defence and Security posture of NATO, Nations and Partners.

The STO is the main venue to deliver S&T in NATO. It encompasses the largest network of Subject-Matter Experts (SMEs) of its sort in the world, working through the STB, Scientific and Technical Committees (STCs), and three executive bodies.

The STB, in which all NATO S&T stakeholders are represented, is the highest authority in the STO. It exercises governance on behalf of the Council, and reports to the Council through the MC and the CNAD. The STB’s main responsibilities are:

- **Governing the STO** – This includes overseeing STO policies, management and programmes, guiding and directing technical committees and working groups, the Knowledge/Information Management Committee (KIMC) and the three executive bodies.
- **Implementing NATO S&T unified governance** – This includes, without prejudice to the responsibilities and authorities of the stakeholders, developing and implementing the NATO S&T strategy, defining NATO S&T priorities and serving as the focal point for the co-ordination of all S&T programmes and activities within NATO.

The STB is chaired by the NATO Chief Scientist, who represents the STB to the Secretary General and the Council. The NATO Chief Scientist is also the senior scientific advisor to NATO leadership, and is responsible for the effective co-ordination of all NATO’s S&T programmes. The STB and its Chair are supported by three STO executive bodies.

The Scientific and Technical Committees, composed of national defence S&T managers and SMEs, are responsible to the STB for the planning and execution of STO’s CPoW. In the CPoW, Nations and other stakeholders work together to deliver S&T results and to promote information exchange. The STO provides the framework to deliver executive support through the CSO, which is located in Neuilly-sur-Seine, France.

Within this collaborative framework, approximately 3,500 scientists and engineers are active in a portfolio of more than 200 activities every year. In what is “smart defence”, NATO S&T stakeholders use their own resources to generate the CPoW, and focus their efforts on Nations’ and NATO’s priorities, together with NATO staff.

There are seven S&T content-driven collaborative committees in the STO. They encompass a broad spectrum of scientific fields and are designed to address every relevant military scientific and technological topic. Each committee is chaired, on a rotational basis, by a senior scientist or engineer from one of the participating NATO Nations.

These committees are the Applied Vehicle Technology (AVT) Panel, Human Factors and Medicine (HFM) Panel, Information Systems Technology (IST) Panel, NATO Modelling and Simulation Group (NMSG), Systems Analysis and Studies (SAS) Panel, Systems Concepts and Integration (SCI) Panel, and the Sensors and Electronics Technology (SET) Panel – see Annex A for more information.

The CMRE is STO’s customer-funded executive body; it is a maritime S&T facility particularly focussed on underwater. It carries out projects and experiments to deliver military-relevant, state-of-the-art, scientific Research and Technology (R&T) using its own capabilities, infrastructure and personnel. The Centre is located in La Spezia, Italy, and its main customer is NATO, through ACT.

The Centre's portfolio includes ocean science, Modelling and Simulation (M&S), acoustics, communication, signal analysis and other disciplines. It also contributes new technologies for enabling interoperability with unmanned systems that have the ability to sense, comprehend, predict, communicate, plan, make decisions and take appropriate actions to achieve mission goals. The Centre also provides S&T-based enhancements to unmanned (autonomous intelligent) systems and integrated defence systems.

Last, CMRE's customer-funded PoW enables Nations, NATO and Partners to work more effectively and efficiently together by leveraging national needs and focusing on military relevant S&T challenges, both within and outside of the maritime domain, in close collaboration with all stakeholders.

The Office of the Chief Scientist (OCS), located in NATO Headquarters (HQ) in Brussels, Belgium, supports the NATO Chief Scientist in his various roles. It is a key interface between NATO S&T and NATO HQ.



2014 STRATEGIC FOCUS AND ACHIEVEMENTS

In its two main roles, the STB provides executive governance of the STO, as well as direction and guidance of NATO S&T. The achievements in 2014 reflect a focus on delivering S&T to support Alliance objectives, and delivering a PoW that reflects the Nations' collaboration objectives.

DELIVERING S&T TO SUPPORT ALLIANCE OBJECTIVES

The STO is chartered to support the Alliance core tasks of collective defence, crisis management and co-operative security. The organisation fulfils this mission through three strategic objectives, which collectively support NATO's and the Nations' objectives – Supporting Capability Development; Fostering Consultation and Partnerships; and Delivering Knowledge, Analysis and Advice.

Supporting Capability Development – STO efforts included activities in support of the Wales Summit Defence Planning Package, such as joint intelligence, surveillance and reconnaissance. Other activities included munitions health management, social media analysis, M&S, future electronic warfare, force protection, space technology, robotic systems, big-data, anti-piracy tools, and human and medical sciences.

Fostering Consultation and Partnerships – STO's primary means of contributing to co-operative security is to open its activities to non-NATO Nations (approximately 70% of them are open). The STO has started to develop enhanced opportunities for the Partner Nations concerned.

Delivering Knowledge, Analysis and Advice – The NATO Chief Scientist delivered knowledge, analysis and advice to NATO leadership on unmanned aerial systems, M&S in support of training, autonomous systems, and process- and analysis-related elements to enhancing the NDPP.

In addition, links were strengthened with the Connected Forces Initiative (CFI) and Smart Defence. Examples are S&T contributions to harbour protection, future mission network and a potential new Smart Defence project on Munitions Health Management, endorsed by the CNAD Ammunition Safety Group (CASG).

STO CORPORATE GOVERNANCE

This governance addresses the supervisory tasks of the STO (comparable to an Agency Supervisory Board).

STO PROGRAMME OF WORK DELIVERY

The STO's CPoW is composed of S&T activities that Nations fund directly to perform within the STO framework. In 2014, this programme grew by more than 15% (from approximately 180 activities in 2013 to more than 210 in 2014). This demonstrates the relevance of STO activities in defence S&T collaboration to the Nations.

The STO's CMRE, customer-funded since 2013, has further diversified its PoW and customer base, while making significant advances in the key research areas of its largest customer, ACT.

The STO further aligned the collaborative S&T activities and customer-funded activities to produce an STO PoW that provides multiple exploitation paths, including the Wales Summit taskings, thereby increasing the leverage of the stakeholders' (mainly the Nations') S&T investments.

STO TRANSITION

Based on the STB-ACT joint proposal for the final solution for the future of NRVs (noted by Council in December 2013), a Task Force, reporting to the STB under the leadership of the Director CMRE, developed a draft report on the final solution. This report will be finalised early in 2015 with a view to seeking Council approval so that the proposed solution can be implemented by the end of 2015.

The STB developed a Maritime S&T Business Plan (BP) that provides a comprehensive long-term view on the Alliance's maritime S&T. To further improve the connection between the individual Nations and the CMRE, STO maritime experts conducted an analysis pertaining to the current status of the transition of technology from the CMRE to the individual NATO Nations, which will be used to inform future business planning of the CMRE.

The three Executive Bodies in the STO – CMRE, CSO and the Office of the Chief Scientist (OCS) – continued to progress, optimise and improve their mutual interactions and portfolios with the aim of enhancing the visibility and the exploitation of the STO's PoW. STO's business processes, including STO policies and directives, are under revision to further improve STO operations.

The work on implementing a NATO Operational Research and Analysis (OR&A) framework continued, including strengthening the existing Community of Interest (CoI), of which STO's SAS Panel, the NCIA and ACT are the cornerstones, through dedicated events such as symposia, a yearly conference and a Lecture Series.

STO EXECUTIVE BODIES

Centre for Maritime Research and Experimentation (CMRE)

In 2014, STO's CMRE successfully operated as a customer-funded entity, delivering its PoW within the boundaries of its financial plan, balancing planned income and expenses, and delivering a surplus that was used to offset previous financial obligations.

CMRE further strengthened its relationship with ACT as its current primary customer. In addition, the CMRE developed and formalised a formal relationship with Allied MARitime COMmand (MARCOM), signing a Letter-of-Intent for collaboration in July 2014.

Last, CMRE reached out to the relevant NATO CoE, NATO Nations' national autonomy programmes, and industry to further extend its knowledge base network and leverage S&T investments.

Collaboration Support Office (CSO)

STO's CSO continued to mature and refine the executive support it provides to the CPoW, responding to the need of the NATO S&T community for a collaborative environment that can handle information up to the classification level of NATO RESTRICTED. This resulted in travel and accommodation cost-savings for the Nations and NATO bodies.

In addition, the potential for a social network-based collaboration environment is being explored.

Office of the Chief Scientist (OCS)

The OCS provided support to the STB and its Chairman in fulfilling their mandate to exercise STO corporate and NATO S&T governance, supervising the S&T progress on implementing NATO reform, developing strategy and policy, exercising co-ordination and outreach, and providing dedicated advice to NATO senior leadership.

The OCS continued to act as the interface between the STO and the NATO structure. In 2014, the OCS focused on engagements within the NATO HQ (International Staff, International Military Staff and Committees' supporting structures) and the STCs of the NATO PA. These outreach activities have led to improved connections and exploitation paths for the STO PoW.

Last, through the NATO Chief Scientist, the NATO S&T community **delivered knowledge, analysis and advice** to NATO leadership on a variety of topics, such as unmanned aerial systems, M&S in support of training, autonomous systems, and process- and analysis-related elements to enhancing the NDPP.

NATO S&T GOVERNANCE

This governance addresses the guidance and co-ordination of NATO S&T.

NATO S&T STRATEGIC GUIDANCE

Building on the NATO S&T Strategy, which was approved by the NAC in January 2013, the STO advanced the framework of NATO S&T strategic guidance, to include NATO S&T Priorities and S&T Strategic Initiatives.

In 2014, the STB led the development of NATO S&T Priorities, which are expressed as medium-term guidance to NATO S&T. These Priorities are driven by the Long-Term Aspects (LTAs) of the Minimum Capability Requirements and S&T considerations (the Emerged/Emerging to Disruptive Technologies or E2DTs, and S&T Hard Problems or STHPs).

NATO S&T strategic guidance also includes S&T Strategic Initiatives, which will drive the collaboration on time-sensitive, high-relevance topics across NATO S&T stakeholders; the 2015 initiatives are Maritime Security and Horizon Scanning.

The NATO S&T community continued implementing the NATO S&T Strategy, committing to a set of implementation actions that will be reviewed in 2015.

NATO S&T PROGRAMMES CO-ORDINATION AND EXPLOITATION

With respect to **enhancing the co-ordination and promoting synergy of NATO S&T** across NATO S&T stakeholders, the STB, through the STO, conducted extensive outreach activities both within NATO and with external NATO bodies at the strategic and PoW implementation levels.

These co-ordination activities (referred to as Unified Governance in the STO Charter), exercised without prejudice to the responsibilities and authority of the stakeholders, are of vital importance to avoid unnecessary duplication, while encouraging innovation to improve synergies and seek complementarities for burden sharing.

The net result is a better connection between the various NATO S&T stakeholders, improved co-ordination (and synergies) pertaining to the various strands of the NATO S&T PoW and additional exploitation paths of the PoW, especially in areas where NATO as a collective expressed demand (needs).

The co-operation with the SPSP, building on a long history of fruitful co-operation, deserves particular attention. It comprises programmatic

co-ordination during the early phases of programme planning in order to ensure mutual awareness, synergies, complementarities and support. In addition, it encompasses, on a case-by-case basis, practical collaboration with concrete Science for Peace and Security (SPS) programmes such as “STANd-off Detection of EXplosives on suicide bombers in public transport” (STANDEX, with STO’s SET Panel) and “Towards the Monitoring of Dumped Munitions Threat” (Monitoring Of DUmpered Munitions (MODUM) with STO’s CMRE).

The STB reviewed its business cycle to generate a systemic approach to finding synergies and additional exploitation paths of NATO S&T. One of its meetings was transformed to an annual S&T Plans and Programme Event, in order to start co-ordination at the NATO S&T programming stage. The first meeting of this kind will occur in March 2015.

NATO S&T AS A PLANNING DOMAIN

The STO continued to engage in the NDPP, paying special interest to NATO’s S&T role with respect to the long term. In that light, the OCS has been continuously engaged in the staff-supporting efforts to enhancing the NDPP across all steps, including the development and articulation of political guidance and the improved understanding of fair burden-sharing and reasonable challenge, upon which target apportionment is based. ■

2015 PREVIEW

In 2015 the focus of the STB will shift from NATO S&T (the strategy and the priorities have been developed and are now being implemented) to the STO (including its PoW), developing a STO corporate plan. Continued attention will be paid to the planning, co-ordination and the exploitation paths of the various strands of the NATO S&T PoW.

DELIVERING S&T TO SUPPORT ALLIANCE OBJECTIVES

The main objective is to further increase the satisfaction of the Nations as stakeholders. Planning, co-ordination, connection of the stakeholders, links with NATO demands and clear exploitation plans of the STO PoW will be the focus of attention.

STO CORPORATE GOVERNANCE

The STB will focus on the key aspects toward finalising the STO transition; particular attention will be paid to define and implement the final solution for NRVs.

The STB will also work towards developing an STO Corporate Plan.

NATO S&T GOVERNANCE

In expressing strategic-level guidance for NATO S&T, the STB will put the emphasis on implementing the NATO S&T Strategy; refining the NATO S&T Priorities; and advancing the Strategic S&T Initiatives. In addition, the STB will support the further enhancement and execution of the NDPP and its advisory role, with special emphasis on NATO S&T's role for the medium and long term.

NATO STO
Programme
of Work

INTRODUCING THE COLLABORATION SUPPORT OFFICE

ENABLING NATIONS TO GET THE MOST OUT OF THEIR S&T INVESTMENTS



Figure 2: Mr. René LaRose, Director, STO-CSO.

I am very pleased to introduce this brief but representative sample of activities that the CPoW accomplished in 2014. During the year, our pool of over 3500 S&T resources, supported by the 42-strong team at the CSO, made significant inroads into furthering the recognition of the NATO S&T Collaborative Framework as “the framework of choice” for NATO and Partner Nations to conduct their collaborative Defence and Security S&T activities. While this framework has experienced tremendous success for more than 60 years, this last year has set a new record in accommodating the largest ever number of activities, including experimentation and demonstrations.

The examples that follow illustrate how the CPoW has delivered on all aspects of its mission. Whether in partnership with the ACT for the very successful articulation of the basis for the development of M&S as a service capability for NATO, or by

stimulating innovation through the demonstration of concepts like the Integrated Munition Health Management (IMHM), the CPoW has demonstrated its far-reaching ability to mobilise the Nations to support the development of interoperable approaches and technical solutions.

During 2014, the CPoW also demonstrated its ability to adapt to the most pressing needs expressed by NATO. In this year’s report, one can see the increased focus given to the human dimension, autonomy, cyber, space and affordability, among others. These have all been recognised as critical for the success of NATO.

We at the CSO are very proud to contribute to the success of NATO, NATO Nations and Partner Nations by offering a unique collaborative framework that enables all contributors to derive the best value for their investment.



Figure 3: The CSO Team.

INTRODUCING THE CENTRE FOR MARITIME RESEARCH AND EXPERIMENTATION

SCIENTIFIC ACCESS TO THE SEA

SUPPORTING CAPABILITY DEVELOPMENT

Since NATO's Undersea Research Centre (formerly NURC now CMRE) was established in 1959 in La Spezia, Italy, it has continuously served as the gathering place in NATO for scientists and engineers from the Alliance Nations to conduct collaborative research projects. The projects advance the basic understanding and naval capabilities needed to operate effectively and efficiently in the maritime domain, and facilitate interoperability in future naval systems, both conceptually and in practice.

Collaboration at the Centre is fundamental to reduce the significant expense associated with maritime research. By pooling the investment in infrastructure, the Nations can reduce the cost of innovative work to reduce life-cycle operation costs and improve performance of downstream systems.

DELIVERING S&T TO SUPPORT THE OPERATORS

The Centre recently began to expand its influence by introducing emerging S&T into operational exercises and experimentation. The collaboration with the newly formed NATO MARCOM in Northwood, United Kingdom, has led to the Centre participating in the Maritime Enterprise led by MARCOM. A Letter-of-Intent was signed in July 2014 to signal a deeper engagement between emerging science and emerging naval operations and operational Commanders.

For the past two years the Centre has participated in the Coalition Warrior Interoperability exploration, experimentation, examination, eXercise (CWIX) trials to learn and demonstrate how to connect maritime data feeds and Centre-developed algorithmic insights into national and NATO networks. Working with MARCOM, the Centre is developing and testing new ways to explore and exploit the cascade of new maritime data sources without overwhelming either analysts or Commanders.

The key enablers in delivering S&T support to the operators are the NRV *Alliance* and Coastal Research Vessel (CRV) *Leonardo*. With year-round access to the ocean and state-of-the-art scientific laboratories, satellite communications and reconfigurable deck equipment, experimentation can range from concept development through to prototype demonstration in NATO and multi-national maritime exercises.

NEW ENGAGEMENT AREAS

Beyond defence science, the Centre has become more involved in the problems associated with civil security in the maritime domain, and this has in turn brought NATO into a closer collaborative posture with the European Commission (EC).

In 2014, CMRE once again successfully operated as a customer-funded entity. ACT remains the principal customer and the focus of the Centre's PoW; the relationship between the Centre and ACT has never been more effective than it is today.

CMRE will continue to develop and deliver its PoW in support of Alliance and Nations' objectives.



Figure 4: RAdm (ret.) Hank Ort, Director, STO-CMRE.

SUPPORTING CAPABILITY DEVELOPMENT

ENABLING NATIONS TO GET THE MOST OUT OF THEIR S&T INVESTMENTS

Capability development is supported by NATO S&T in bringing scientific knowledge and technological innovation to bear on the definition, development, demonstration, improvement, cost reduction and evaluation of sustainable, connected and interoperable Defence and Security capabilities for the benefit of the Nations and NATO, in line with NDPP, in the short, medium and long term.

The NATO STO PoW included activities in the areas of munitions, chemical-biological defence, human factors, Command and Control (C2), M&S, sensors and electronics, maritime warfare and security, autonomy and robotics, cyber defence, route clearance, Intelligence, Surveillance and Reconnaissance (ISR), and the medical and social sciences.

The following pages are a representative outline of the 2014 NATO STO PoW. 

ADVANCES IN RADAR WAVEFORM DIVERSITY AND SPECTRUM ENGINEERING (SET-204)

The need for studying Waveform Diversity (WD) is closely related to today's congested spectrum requiring spectrally confined waveforms.

Prof. Shannon Blunt, USA, University of Kansas; Prof. Hugh Griffiths, GBR, University College and Dr. Jans Klare, DEU, Fraunhofer FHR

BACKGROUND

There is an urgent need for greater design freedom in radar emissions in order to contend with the increasing complexity of the modern spectral environment. However, this need is offset by the growing global demand for that same fundamental spectrum resource. Two Research Task Groups (RTGs), SET-179 on "Dynamic Waveform Diversity and Design" and SET-182 on "Radar Spectrum Engineering and Management", have worked closely to address these intrinsically interconnected and competing issues.

OBJECTIVE(S)

The main objective of this Research Specialists' Meeting (RSM) was to foster the interaction and exchange of results between the SET-179 and SET-182 participants and the broader NATO community investigating Waveform Density (WD) and spectrum utilisation.

S&T ACHIEVEMENTS

The RSM provided the appropriate venue to discuss recent advances by SET-179, SET-182, and others on the dual problems of radar WD and spectrum engineering within the specific context of defence applications. Examples include spectrally compliant waveform design, mimicking of dolphin bio-sonar to discriminate linear and non-linear scattering, advances in multi-dimensional emission structures such as Multiple Input, Multiple Output (MIMO) and polarisation diversity, mimicking the spatial modulation of the human eye, waveform adaptivity for cognitive sensing, and various others. High-fidelity simulation and, in many cases, experimental results demonstrated the feasibility of these advances.

SYNERGIES AND COMPLEMENTARITIES

While much of the focus of this RSM was on the development of enhanced radar capabilities in a dwindling spectrum, of particular note was a thread introduced by Dr. John Chapin of Defense Advanced Research Projects Agency (DARPA) that emphasised the need for substantially improved compatibility between radar and commercial communications. In fact, in a congested spectrum, sharing between radar and cellular communications could be a win-win for both if the technical hurdles can be addressed. The latter is a significant contributor to economic growth and the prime driver behind the explosive growth in

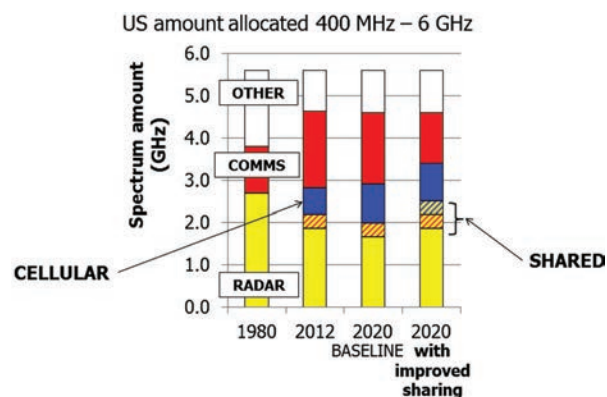


Figure 5: 400 MHz to 6 GHz frequency allocation - Potential benefit of improved sharing.

spectrum demand due in part to the underlying consumer demand for wireless video.

This dichotomy emphasises the imperative to determine ways in which spectrum can be shared effectively by the rather disparate users that include myriad radio-location, communication, navigation, and electronic warfare applications for civil, scientific and military systems.

EXPLOITATION AND IMPACT

As it becomes possible for new spectrally constrained waveforms and multi-dimensional sensing structures to be transitioned into operational capabilities, military radar will be able to address the increasingly complex threat environment. Further, the focus on physical emissions resulting from the interaction between the intended waveform and the distortion-inducing transmitter will facilitate realisable flexibility and enhanced sensitivity to deployed systems.

CONCLUSIONS

The twin pillars of WD and spectrum engineering, enabled by continued advances in high-fidelity waveform generation and high-performance computing for adaptive processing, while being externally driven by increased spectral demand, are changing the electromagnetic landscape for radar. The advances we are making in waveform design, emission structures and waveform adaptivity will enable radar to continue to provide the all-weather, day-or-night sensing capability in an increasingly congested and contested spectral environment.

INTEGRATED MUNITIONS HEALTH MANAGEMENT (IMHM) DEMONSTRATION: AVAILABLE AND READY FOR DEPLOYMENT – TODAY (AVT-212 CDT)

IMHM seeks to improve safety, reduce life-cycle cost, enhance reliability, increase availability, and enable interoperability both within and across NATO Nations. The AVT-212 Co-operative Technology Demonstration (CDT) showed that IMHM is available and ready for deployment today.

Dr. Robert A. Mueller, USA, BNet Corporation; Dr. Steven Wagstaff, GBR, Frazer-Nash Consultancy and Mr. Emmanuel Schultz, NATO MSIAC

BACKGROUND

The proper management of munitions involves management of risks that could result in failures and compromise the safety of our most critical assets. It is necessary to be aware of environmental exposure and the issues associated with aging and usage, which can force premature retirement and replacement, significantly increasing cost.

OBJECTIVE(S)

The objectives of IMHM are to improve safety, reduce life-cycle cost, enhance performance, increase availability and burden sharing, and enable interoperability both within and across NATO Nations and Partners. As part of the IMHM approach, pooling and sharing of capabilities is co-ordinated by adopting centralised requirements within the Alliance.

S&T ACHIEVEMENTS

Notable S&T achievements include a common framework for the use of sensors (technology) and in-service surveillance (people). This enables the measurement and monitoring of the chemical and mechanical effects of aging. Modelling allows assessments of the munitions' current state and more accurate prediction of safe service life. The same technology is able to automate munitions' storage and transportation management, and provides a deeper understanding of how to exploit condition-based maintenance.

SYNERGIES AND COMPLEMENTARITIES

This work is fundamentally centred on NATO's Smart Defence initiative – the linking and sharing of capability and co-operation of Nations to ensure the better use of technology for less money, by working together with more flexibility. Furthermore, the core IMHM framework supports interoperability through common goals, understanding, language and standards, while leveraging advances in technology. IMHM, as demonstrated in the Co-operative Technical Demonstration (CDT), encompasses infrastructure, personnel, logistics, and assets including platforms and associated munitions.

EXPLOITATION AND IMPACT

The IMHM CDT is the legacy of 12 years of collaboration between government, industry and academia across NATO Nations and Partners. Contributions included two Task Groups, a Symposium and a Lecture Series. These activities interfaced with other NATO bodies such as NSPA, CASG and Munitions Safety Information Analysis Center (MSIAC).

The demonstrated technology exploits international standards, dramatic advances in sensor and communications technology, and a deeper understanding of the physics of munitions failure. The resulting impact is – significant extension of safe service life; longer munitions replacement cycles; more efficient management of munitions storage, maintenance and transportation; and the ability to share munitions stockpiles across NATO Nations.

CONCLUSIONS

The CDT demonstrates that IMHM is a proven approach to identifying accelerated aging and unsafe munitions. The approach can also extend the safe service life of munitions and enables shared stockpile capability. Logistics benefit from improved efficiency of munitions storage and transportation management. Using current IMHM technology and methodologies demonstrates that IMHM is available and ready for deployment today.



Figure 6: MINERVE missile demonstrator with an implemented sensor system to measure the condition of the missile.

NATO'S CRITICAL ROLE IN BIOLOGICAL DEFENCE: THE LONG-TERM CHALLENGES OF MEDICAL COUNTER-MEASURES DEVELOPMENT (HFM-186)

NATO Nations' research in and development of medical diagnostics and counter-measures against biological agents or related highly contagious infectious diseases are key issues in military medical readiness.

Leonard Smith, PhD, USA, US Army Medical Research Institute of Infectious Diseases and John Wade, DVM, PhD, USA, Battelle Memorial Institute

BACKGROUND

With the emergence of highly communicable or difficult to treat diseases (such as Ebola), military medical personnel figure prominently as first responders, international co-ordinators, and occasionally as impacted Nations, in the face of disease outbreaks. Significant challenges exist in managing newly emerging or re-emerging infectious diseases, which are similar to, or closely related to, the anticipated challenges of classic biological agent defence.

OBJECTIVE(S)

This Task Group achieved two primary objectives. First, it compared the medical biological defence priorities and supporting Research, Development, Test and Evaluation (RDT&E) being conducted in the participating Nations. Second, the Group produced a final report which comprehensively describes a broad study of the mechanisms of biological agent-related infectious diseases, prophylaxis and therapy, and also provides a concise overview of the use of such agents in Chemical, Biological, Radiological and Nuclear (CBRN) defence.

S&T ACHIEVEMENTS

The final report describes achievements in various areas of interest such as – laboratory identification of biological threats; challenges and technological advances in vaccine development for biodefence; use of adjuvants for enhanced vaccine potency; genome-based tools to develop vaccines; therapeutic medical counter-measures, generic threat assessments and relative risks.

Specific biological agents and/or diseases covered in depth include – smallpox; Ebola and Marburg; Venezuelan, Eastern and Western Encephalitis; anthrax; plague; tularaemia; brucellosis; Q Fever; melioidosis; Glanders; typhus; and intoxication by botulinum neurotoxins, ricin and staphylococcal enterotoxin B.

SYNERGIES AND COMPLEMENTARITIES

The Task Group was fully integrated with the COMEDS BioMedical Advisory Committee (BioMedAC), and its working meetings were generally attended by members of this agency.



Figure 7: Success in the laboratory has direct application to NATO's understanding of how to cope with exotic diseases in real-world settings.

EXPLOITATION AND IMPACT

Activities generated renewed interest in infectious disease research and preparedness across the NATO medical community. They also emphasised the need for rapid identification of broad-spectrum counter-measures – both bacterial and viral – in the face of the global threat of re-emerging, difficult to treat infectious diseases. The unfolding Ebola Virus outbreak/epidemic demonstrates and reinforces the challenges inherent in the development and approval of vaccines for diseases that historically occur with a very low incidence.

Activities of this Task Group were the basis for a NATO HFM Symposium on “Medical Counter-Measures Against Potential Biological Warfare Agents”. Scientists from approximately one-third of the NATO Member Nations met to present and consider papers on threat assessment, vaccines, diagnostics, bacterial therapeutics and multi-drug resistance, anti-viral and anti-toxin therapeutics, animal models and pathogenesis.

CONCLUSIONS

The focus of defence research has shifted from vaccines to diagnostics and therapies as a focus for future efforts. Current biological threats to NATO forces are complex and less well understood than in the past; spontaneous natural outbreaks of highly virulent or difficult to treat pathogens could adversely impact military medical readiness in the same manner as a biological attack by an aggressor.

INFORMATION FILTERING AND MULTI-SOURCE INFORMATION FUSION (IST-106)

People and machines “speaking” the same language bridges the fusion gap. Automatic fusion relies on a common representation “language” for data/information regardless of source and process. The basis for this language is to be found in NMSG’s efforts on Battle Management Language (BML).

Dr. Wolfgang Koch, DEU, Fraunhofer FKIE – SDF

BACKGROUND

Having the right information at the right time supports effective decision-making and planning, resulting in military information superiority. Today, the amount of gathered intelligence is too vast and too complex for timely, hands-on analysis by intelligence experts. Nations need to be able to efficiently and accurately sift through vast amounts of structured and unstructured data coming from human- and device-based sources, fuse that information into actionable intelligence information, and exploit the results.

OBJECTIVE(S)

Information fusion is the combination, or fusing, of information from different sources to facilitate understanding or provide knowledge not evident from individual sources. Automatic fusion has been hindered by the fact that information from diverse sources may be represented in extremely diverse ways – structured, unstructured, numeric, text. Even when using multiple sources, most fusion systems are developed for combining just one type of data (e.g., positional data) in order to achieve a certain goal (e.g., accurate target tracking).

The objective of the IST-106 RTG was to investigate possible solutions for enabling multi-source, multi-level (low to high) fusion¹.

S&T ACHIEVEMENTS

An experimental scenario utilising multiple sensors as well as HUMAN INTelligence (HUMINT) was designed and successfully run in November 2014 in Wachtberg, Germany, with a resulting test bed of data demonstrating the promising use of Battle Management Language (BML) for data representation and fusion.

SYNERGIES AND COMPLEMENTARITIES

BML reports already have extensions for reporting both HUMINT and sensor data, a basis for multi-source fusion. Within the context of its work, IST-106 tested and expanded on NATO MSG-048

¹ The data fusion processes comprise five levels, which are categorised into two stages, the low-level fusion processes and the high-level fusion processes. The low-level fusion processes support data pre-processing, target discrimination and target tracking. The high-level fusion processes support situation assessment, threat (or impact) assessment and process refinement.

“ Information is of great value when a deduction of some sort can be drawn from it. This may occur as a result of its association with some other information already received.” (AJP 2.0, 2003)

and MSG-085 works on BML for standardised military communications to represent algorithmic results, thereby enabling multi-level fusion.

EXPLOITATION AND IMPACT

A common representation and description framework for all sources was seen to be the first step in enabling multi-source fusion algorithms. Much intelligence information including reliability of sources and credibility of information has representation based upon the Joint Command, Control and Consultation Information Exchange Data Model (JC3IEDM), and upon inspection. The approach to achieving the initial step toward the ultimate goal of multi-source and multi-level fusion via BML showed great promise.

CONCLUSIONS

IST-106 concludes that BML provides the solution to the issue of finding a common representation for data/information regardless of whether that information comes from a device, a human or an algorithm; this is an important step towards an effective NATO Network-Enabled Capability (NNEC).



Figure 8: Data generated by different sources is formulated in BML. (©Bundeswehr/Piz EinsFükdo)

C2 – SIMULATION INTEROPERATION AS AN ENABLER TO IMPROVE THE MILITARY (MSG-085)

Standardisation for Command and Control (C2)-SIMulation (C2SIM) interoperation applies to Systems-of-Systems (SoS) working together towards a common goal at different levels: within and across services and Nations in an Allied and/or Coalition context.

Mr. Lionel Khimeche, FRA, DGA

BACKGROUND

Force readiness, support to operations and capabilities development heavily lean on Command and Control (C2)-SIMulation (C2SIM). Developing standards that define common interfaces for the exchange of military information among C2 and simulation systems can lead to significant cost reduction and greatly facilitate systems integration.

OBJECTIVE(S)

The MSG-085 RTG objective was to assist in the validation and development of proposed C2SIM interoperability standards like the Military Scenario Definition Language (MSDL) and the Coalition Battle Management Language (C-BML) to support scenario initialisation and scenario execution.

S&T ACHIEVEMENTS

The C2SIM proof-of-concept was demonstrated. In addition, thanks largely to significant involvement from the operational community, a clearer scope and refined set of operational and technical requirements for C2SIM interoperability has been established. This was done through a series of experiments highlighting the C2SIM benefits for several military use-cases like training and collaborative distributed planning.

This proof-of-concept was demonstrated in December 2013 at the Mission Command Battle Laboratory (MCBL) at Fort Leavenworth in Kansas (USA), and featured six national non-US C2 systems and five national simulations. MSG-085 has raised the Technology Readiness Level (TRL) of national C2SIM interoperability products that implement current C-BML and MSDL standards, including their utilisation during multi-national or Coalition events.

SYNERGIES AND COMPLEMENTARITIES

The findings and learnings, rich in content from experimental work, provided a set of operational and technical requirements for C2SIM interoperation. These have proven to be useful for the Simulation Interoperability Standards Organisation (SISO) C-BML and MSDL standardisation activities, as well as informing the community via scientific papers selected,

for instance, at the International Command and Control Research and Technology Symposium (ICCRTS). In April 2014, SISO approved the initial version of C-BML, mainly based on the work of this Task Group.

EXPLOITATION AND IMPACT

A growing consensus among stakeholders is to merge the C-BML and MSDL activities to generate a unified, more manageable and easier to deploy C2SIM interoperability solution. Towards this goal, MSG-085 has already proposed an iterative, systems engineering approach to produce an operational relevant, technically mature, unified C-BML/MSDL standard. The approach proposes a sustainable, extensible process and production chain for building, maintaining and evolving C2SIM interoperability solutions.

CONCLUSIONS

Significant progress has been made in advancing standardisation of C2SIM interoperation, providing a capability to improve decision-making and training in Coalition military operations. Starting with a concept, the community involved in C-BML/MSDL, both in NATO and SISO, has achieved continued progress. The goal is for military Coalitions to benefit from interoperating C2 and simulation systems across all participating Nations.

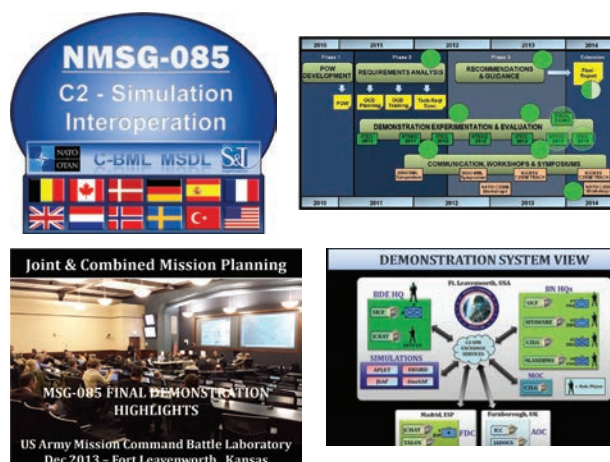


Figure 9: C2SIM concept through the development of interoperability standards.

MODELLING AND SIMULATION AS A SERVICE: NEW CONCEPTS AND SERVICE-ORIENTED ARCHITECTURES (MSG-131)

The combination of service-based approaches with ideas taken from cloud computing – known as “Modelling and Simulation as a Service” (MSaaS) – is a promising approach for realising next-generation simulation environments.

Dr. Robert Siegfried, DEU, Aditerna GmbH and Mr. Brian Miller, USA, US Army, CERDEC

BACKGROUND

To a great extent, future military training, analysis and decision-making capabilities will be provided by M&S. Two main barriers are cost and accessibility – hardware, software and personnel necessary to implement and utilise models and simulations can be both time and cost intensive. The situation is complicated by unknown validity and ad-hoc processes.

OBJECTIVE(S)

M&S products are highly valuable to NATO and military organisations; it is essential that M&S products, data and processes are accessible to as many users as often as possible. Therefore a new “M&S ecosystem” is required where M&S products can be accessed simultaneously and spontaneously by a large number of users for their individual purposes. This “as a Service” paradigm has to support stand-alone use as well as integration of multiple simulated and real systems into a unified simulation environment whenever the need arises.

The Nations active in MSG-131 were invited by ACT to conduct a survey on the topic of “Modelling and Simulation as a Service (MSaaS)” and to provide collective knowledge and experiences. Existing applications as well as simulation architectures were to be identified, and recommendations on the way ahead with regards to an MSaaS Reference Architecture to be made.

S&T ACHIEVEMENTS

Sixteen MSaaS applications and case studies from 12 Nations and two NATO bodies were identified and evaluated. For the first time, an exhaustive overview of service-based approaches used in the M&S domain was produced.

SYNERGIES AND COMPLEMENTARITIES

The S&T work relied heavily on web conferences to meet cost and time requirements. Within one year, 45 members held 23 meetings and produced more than 19 versions of the final deliverable. This rapid development cycle enabled qualified stakeholder



Figure 10: MSaaS concept and architecture provide a network of services model.

feedback and ensured that the S&T work finished in time, including delivery of a 108-page report.

EXPLOITATION AND IMPACT

Results were forwarded by ACT to the NC3B for consideration in future developments. Key findings were presented at the NATO Computer-Assisted eExercise (CAX) Forum, SISO events, and at national conferences. MSG-131 successfully prepared a follow-on RTG that is the focal point for all MSaaS activities within NATO. This RTG has already attracted some 53 members from 14 Nations and five NATO bodies.

CONCLUSIONS

MSG-131 was a highly successful STO activity that defined “M&S as a Service” in the NATO context and initiated a high-visibility RTG that will intensify MSaaS investigations.

“MSG-131 is the paradigm of the new NATO where collaboration between ACT and STO produces an extremely valuable product.” – *Angel San Jose Martin, ACT*

FUTURE ELECTRONIC WARFARE (EW) CONCEPTS (SCI-267)

The impact of future EW systems on NATO operations were considered and analysed, and recommendations for overcoming rapidly evolving threats were provided.

Dr. Nic Law, GBR, Dstl

BACKGROUND

Due to the fast evolution in off-the-shelf electronics technology, driven by commercial development, Electronic Warfare (EW) must evolve continuously to keep up with emerging trends and threats. NATO Nations need to develop concepts, systems and architectures that can maintain pace with the threat evolution and ensure NATO dominance of the electromagnetic spectrum. This work requires development of intelligent systems and architectures optimised to react quickly and efficiently to adversary threats, ensure trusted near-real-time data sharing and interoperability, and produce a common operating picture.

OBJECTIVE(S)

The objective of the Specialists' Meeting "Future Electronic Warfare (EW) Concepts" was to address systems, concepts, architectures and technological developments for future NATO EW systems.

S&T ACHIEVEMENTS

Participating Nations gained a solid understanding of the evolving threat assessment, National interests and existing efforts in next-generation EW, critical issues for future R&T efforts, and suggested areas for further NATO research activities. The Specialists' Meeting featured briefings and discussions from programme managers that produce the EW systems and members of the operational community that employ the EW systems.

The programme spanned seven session topics, which were - Electro-Magnetic Environment (EME) policy and challenges; operational experiences; interoperability and spectrum management; the threat; next-generation EW technology; cyber and EW; and NATO interoperability. Key issues for future consideration are hardware/software architectures, interoperability, operational concepts and training, real-time data transport, mission planning, and battle management tools that are tied to the ability to share data for a common operating picture.

SYNERGIES AND COMPLEMENTARITIES

Co-chaired by Dr. Nic Law (GBR) and Mr. Ray Irwin (USA), the Specialists' Meeting featured representatives from nine different Nations and two NATO agencies to include Canada, Germany, Netherlands, Norway, Poland, Spain, the United Kingdom, the United States, NATO Joint Electronic Warfare Core Staff (JEWCS) and NCIA. Sixty participants engaged in seven different sessions highlighted by five keynote addresses during the three-day meeting.

EXPLOITATION AND IMPACT

EW is a key enabler of Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) capabilities and critical to future battlefield success. SCI-267 facilitated the collaboration of EW experts and identified potential future NATO EW capabilities and the associated technologies to address fast-evolving threats.

The Specialists' Meeting conclusions and recommendations will allow Alliance Member Nations, participating non-NATO Nations and other NATO entities to make informed decisions concerning EW operations. In addition, the SCI Panel is pursuing a future activity involved in electromagnetic congestion effects on air operational and mission success. Links with military working bodies in NATO were also reinforced.

CONCLUSIONS

SCI-267 explored architectures that enable the ability to address fast-evolving threats, interoperability among NATO EW systems, and the ability to provide near-real-time sharing of data to enhance NATO EW capabilities. The results will inform leaders and guide EW planning and integration in future operations.

NATO Nations need to ... maintain pace with the threat evolution and ensure NATO dominance of the electromagnetic spectrum.

VISIBLE LASER DAZZLE - EFFECTS AND PROTECTION (SET-198)

This Task Group worked to develop and validate models of laser dazzle to predict its impact upon target discrimination tasks for human vision and visible waveband sensors. This is the summary of a field trial performed to gain data on dazzled sensors.

Dr. Bernd Eberle, DEU, Fraunhofer IOSB

BACKGROUND

The proliferation of laser illumination systems is generating concern for the protection of personnel and sensors. In order to understand in detail the impact of laser dazzling, i.e., visual disability resulting in reduction of operational capability, it is crucial to have the capability to model such situations.

OBJECTIVE(S)

The main objective of the Task Group was to develop a validated computer model to assess laser dazzling. This involved laboratory and field dazzling tests on sensors and humans, computer eye-dazzle modelling, automatic character recognition, and observer trials for validation of the algorithms. The Task Group also aimed to determine and characterise commercial state-of-the-art dazzling laser sources and commercial protection measures against laser dazzling.

S&T ACHIEVEMENTS

Laser dazzle was assessed in a first step by using cameras to develop a set of concepts, methodologies and techniques that realistically represent and measure dazzling effects. A common field trial to generate dazzled sensor images was performed under controlled conditions; sensor data provide real-world input helping to develop representative eye models. In a second step these data were used to find an appropriate character recognition algorithm. In addition, laboratory observer tests were performed to validate the recognition algorithm, and in the third step, to support the development and the validation of the desired models of laser eye dazzle.

Test charts used were specially developed for these purposes.

SYNERGIES AND COMPLEMENTARITIES

The dazzling experiments were run over five days in a laboratory with controllable ambient light levels and another two days were spent on outdoor dazzling tests. All participating Nations supported the trial by providing equipment such as light and laser sources, cameras, lenses,

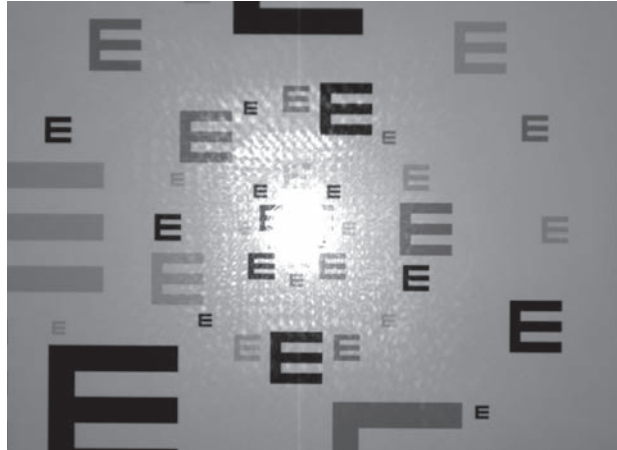


Figure 11: TV camera viewing one of the test charts, dazzled by laser light originating from the centre of the scene.

novel protection filters, test charts, recognition algorithms or eye models.

EXPLOITATION AND IMPACT

The impact of dazzling was studied in dependence of laser wavelength, laser power and camera type. An example of a dazzled camera image is shown above. Based on these data and the planned laboratory observer tests, it will be possible to optimise, and thus to validate the various character recognition algorithms taken into account.

The Task Group is planning future work to develop common test procedures, in co-operation with the NATO Army Armaments Group (NAAG) and the Land Capability Group (LCG)/6, and to provide input for NATO Standardisation Agreements (STANAGs).

CONCLUSIONS

The field trial generated dazzled sensor images and provided sufficient data to enable the development of a "character recognition" algorithm. This is progress in the development of an advanced laser-eye-dazzle model. A further trial is scheduled for April 2015 to produce a validated "eye and camera dazzle" model, which will be crucial to realistically represent and measure laser dazzling effects on human eyes. The aim is to minimise the operational impact of laser dazzling.

AUTONOMY FOR MINE WARFARE: UNMANNED VEHICLES PERCEIVE, PLAN, AND PERFORM (CMRE)

CMRE has designed, implemented, and demonstrated a series of autonomous behaviours for mine warfare AUVs. They give the vehicles the ability to react adaptively to their local environment, and generate more useful data sets for accomplishing the mine warfare mission compared to pre-planned sorties.

Dr. Warren Fox, Dr. David Williams and Dr. Samantha Dugelay, STO-CMRE

BACKGROUND

Over the past several years, CMRE has been working to add advanced perception and autonomy algorithms to Autonomous Underwater Vehicles (AUVs) for mine warfare applications. In the 2014 Multi-national AutoNomy EXperiment (MANEX '14), CMRE demonstrated multiple AUV behaviours at sea that have the potential to enhance the efficiency and effectiveness of stand-off mine counter-measures capabilities significantly.

OBJECTIVE(S)

The objectives of this research area are – to develop algorithms that allow AUVs to sense and interpret their environment using data collected through their acoustic sensors; to develop autonomy algorithms that act on the vehicle's perception to re-plan and collect the best data possible while on a given sortie; to demonstrate and validate the algorithms in real-world sea testing scenarios; and to quantify the improvements that advanced autonomy algorithms bring over the alternative of running completely pre-planned and non-adaptive missions.

S&T ACHIEVEMENTS

In the past, CMRE has demonstrated autonomy algorithms for mine warfare AUVs. One algorithm was for adaptive track spacing, where through-the-sensor estimates of system performance vs. range were used to automatically plan an efficient and effective initial survey. Another algorithm involved target revisit behaviour, where results of automatic target recognition processing obtained during the initial survey were used to design new tracks at orthogonal aspects to suspect targets. In the MANEX '14 sea trial, CMRE combined these behaviours with a newly implemented ripple adaptation behaviour, which estimates the dominant direction of an existing ripple field, and involves planning new surveys to minimise the impact of the ripples.

SYNERGIES AND COMPLEMENTARITIES

CMRE worked closely with other national researchers on topics of mine warfare autonomy, managing a joint research project on "Machine Intelligence for Autonomous Mine Search". During MANEX '14, the Centre hosted researchers from Norway on the NRV *Alliance*, who demonstrated their own autonomy algorithms and framework on their vehicle. On the same occasion, researchers from the Netherlands utilised the CMRE MUSCLE (Mine-hunting Unmanned Underwater Vehicles (UUVs) for Shallow-water Covert Littoral Expeditions) vehicle for autonomy studies, running their own algorithms on the vehicle and leveraging that NATO asset for their national programme.

EXPLOITATION AND IMPACT

Eventually, these types of autonomy algorithms will make their way into operational systems in order to improve the results of mine warfare operations. Careful testing, analysis and incorporation into doctrine are required in order to gain operator trust.

CONCLUSIONS

Several years of work have culminated in an advanced demonstration of autonomy for mine warfare AUVs. The experimental infrastructure and results are currently benefitting related national programmes. The customer for this work is ACT's Output, Autonomous Security Networks.

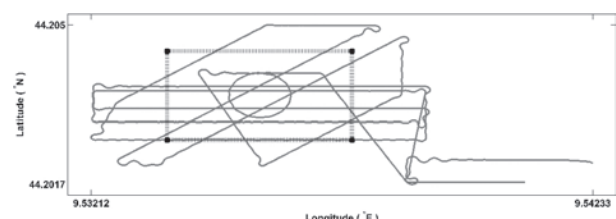


Figure 12: Reconstruction of an autonomous vehicle survey, covering the rectangular area. The vehicle planned all tracks itself – complete coverage of the area and adaptation to a ripple field.

FIRST TEST OF AN AUTONOMOUS SECURITY NETWORK WITH AN AIR-INDEPENDENT PROPULSION SUBMARINE (CMRE)

REP14-Atlantic was the first CMRE experiment where networks of underwater receivers deployed by AUVs were tested against the most modern type of Air-Independent Propulsion (AIP) submarines.

Dr. Kevin D. LePage, STO-CMRE

BACKGROUND

Autonomous security networks for Anti-Submarine Warfare (ASW) will deliver cost-effective, scalable solutions to address future ASW threats. ACT has been funding research and experimentation at CMRE directed towards developing the scientific building blocks necessary to demonstrate that autonomous ASW networks based on AUVs are feasible.

OBJECTIVE(S)

One of the most significant challenges to ASW operations is the latest generation of conventional submarines (SSK) with Air-Independent Propulsion (AIP). In a significant technology push, in the summer of 2014, CMRE participated in the REP14-Atlantic experiment with the Portuguese Navy to demonstrate networked autonomous ASW experimentation against one of the Portuguese Navy's newest generation AIP SSKs.



Figure 13: The NRP *Arpão* and the NRV *Alliance* during REP14-Atlantic. Insert: One of the AUVs used to track the *Arpão*.

S&T ACHIEVEMENTS

To address the challenges represented in performing networked autonomous ASW against the latest generation submarines, CMRE developed and deployed new advanced wideband continuous active sonar processors to improve detection and intelligent navigation of the autonomous assets. These newly developed behaviours allowed the AUVs to manoeuvre in an optimal way, based not only on their own detections, but also on the detections of their collaborators in order to

“ It was a privilege and a pleasure to have such a ship, NRV *Alliance*, in our home waters for trials as important as 3-dimensional awareness using AUVs.”
– *Chief of Staff Submarines, Portuguese Navy*

avoid duplication of effort and therefore improve area coverage. To achieve this, the behaviours considered future courses of action in their decision-making processes to subdivide the scene or, when favourable, to plan collaborative actions.

SYNERGIES AND COMPLEMENTARITIES

The Portuguese Navy has a very active national programme using unmanned vehicles for maritime operations. During the second half of the REP14-Atlantic experiment, interoperability between CMRE and the Portuguese Navy autonomous assets was demonstrated.

EXPLOITATION AND IMPACT

CMRE's developments in the field of networked robotic ASW, demonstrated during REP14-Atlantic for the first time in the Atlantic Ocean against the latest generation submarines, is leading to a change in perception within NATO and the Nations about how ASW missions may be conducted in the future. The scalable, inexpensive autonomous networks demonstrated during REP14-Atlantic offer the possibility of augmenting current ASW platforms, extending the detection range and area coverage, and deploying in forward or denied areas to provide expanded capabilities.

CONCLUSIONS

The REP14-Atlantic experiment, the first networked autonomous ASW experiments conducted by CMRE outside the Mediterranean, showed that CMRE can carry out networked autonomous ASW effectively against the latest generation of AIP SSK. A high-profile audience of ministers, national and NATO maritime operations Commanders and S&T leaders of a NATO Nation witnessed the results of significant investment in cutting-edge maritime technology and Research and Development (R&D). The customer for this work is ACT's Output, Autonomous Security Networks.

REAL-TIME MULTI-PLATFORM SONAR PERFORMANCE ASSESSMENT DEMONSTRATED AT SEA (CMRE)

CMRE demonstrated its ASW decision support tool at Dynamic Mongoose 2014 during which multiple geo-referenced sonar performance maps were generated in real time and displayed to sonar operators.

Mr. Christopher Strode, STO-CMRE

BACKGROUND

CMRE has developed a fast acoustic ASW decision support tool which was deployed at sea during NATO exercise Dynamic Mongoose. The tool may be used as a simulator to test tactics for both mono-static and multi-static sonar, as an exercise replay tool allowing for the correlation of the impact of platform decisions with expected sonar performance, and as a real-time sonar performance assessment tool for range-dependent environments.

OBJECTIVE(S)

The purpose of the deployment was to test the tool in an ASW decision support role. It was operated in real-time mode in which all platform positions were updated regularly with actual platform dispositions. Climatology forecasts were ingested in order to create realistic combined sonar coverage maps.

S&T ACHIEVEMENTS

The demonstration included the generation of geo-referenced sonar performance maps for multiple platforms operating heterogeneous sonar systems within a fully range-dependent acoustic environment. The resulting performance assessment provided the ASW Commander (ASWC) with a graphical representation of the combined sonar coverage of their Task Group. The tool quickly highlighted potential gaps in coverage against deep submarines during a screen operation. Additional graphical elements were added which allowed for fast range-depth slices of performance to be plotted anywhere on the map. These plots allowed operators to observe the impact of the climatology on the predicted coverage.

SYNERGIES AND COMPLEMENTARITIES

The tool builds upon 50 years of experience in acoustic modelling at CMRE and allows this expertise to be deployed at sea to assist ASW operators and planners to visualise and better understand the performance of their sonar systems. The advanced range-dependent acoustic engine may be quickly deployed, ingesting climatology information from CMRE oceanographic modelling or other sources.

EXPLOITATION AND IMPACT

In a modern ASW Task Group many different sonar systems will be deployed. Currently each Nation's ship uses its own acoustic tool for planning. This can

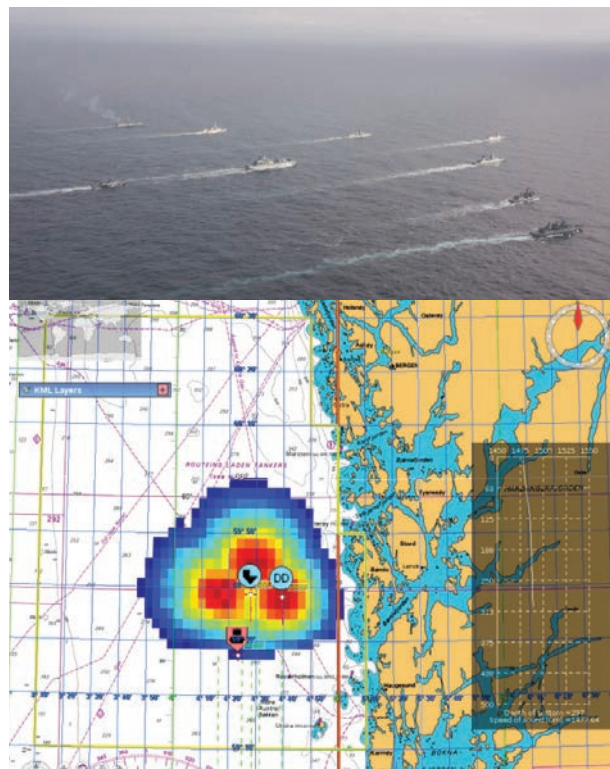


Figure 14: Real-time sonar performance maps generated during Exercise Dynamic Mongoose.

introduce inconsistencies, however, such that the ASWC will not be able to generate a common picture.

CMRE has created a NATO tool that is able to capture the performance of any sonar system accurately with consistent environmental parameters, providing the ASWC with a consistent and accurate picture of the performance of their Task Group. With this information they can then update tactics to better cover an area. The range-dependent nature of the predictions can highlight changes in expected sonar performance from one region to another – this information will allow planners to update sail plans in order to mitigate these effects.

CONCLUSIONS

CMRE's ASW decision support tool has been successfully demonstrated in real time during a NATO ASW exercise. Further development and testing will allow for a direct link to platforms C2, allowing fully automated positional updates. This functionality will be tested at the NATO CWIX exercise in 2015. The customer for this work is ACT's Output, Autonomous Security Networks.

NEXT-GENERATION AUTONOMOUS SYSTEMS FOR LITTORAL ANTI-SUBMARINE WARFARE (CMRE)

CMRE is pursuing heterogeneous autonomous sensor networks applied to littoral ASW. The potential network performance gains from data fusion and optimal autonomous behaviours may allow these networks to approach and even exceed the performance of conventional ASW assets.

Dr. Ryan A. Goldhahn, STO-CMRE

BACKGROUND

Modern submarines are extremely difficult to detect at long ranges. Heterogeneous networks of different types of autonomous sensors (e.g., Unmanned Surface Vehicles (USVs), AUVs and/or bottom nodes) are therefore useful in increasing the detectability of current submarines using multiple sensing modalities (e.g., active and passive acoustic, magnetic, electromagnetic), and lowering the number of false active sonar detections through the use of data fusion between sensors.

OBJECTIVE(S)

The NATO STO-CMRE is pursuing distributed autonomous sensor networks as a scalable, cost-effective solution to the anti-submarine warfare scenarios. These systems rely on the fusion of information from a large number of small, low-power platforms to obtain good network performance. The sensors may be autonomous, and thus able to make adjustments or re-deploy themselves based on observed data without human intervention. Furthering the signal processing, autonomous behaviours, data fusion, and other aspects of these vehicles is thus of interest to CMRE and the NATO Nations.

S&T ACHIEVEMENTS

A field of bottom-mounted sensors (developed by Canada, Germany and Norway) capable of making real-time passive acoustic and magnetic detections was deployed during a sea trial in 2014. The CMRE network of two AUVs and an off-board acoustic source was deployed concurrently, making multi-static active sonar detections and tracks on the SMG *Gazzana* (ITA). Information from each of these platforms was conveyed to topside C2 centres via acoustic and electromagnetic messages. Detections from the stationary bottom nodes were then used to cue the manoeuvrable AUVs, alerting the active sonar network of the possible presence of a target.

The trial was important in demonstrating and evaluating both the detection performance of the various sensing modalities and the collaboration possible among nodes in a heterogeneous autonomous sensor network.

SYNERGIES AND COMPLEMENTARITIES

The sea trial was conducted in collaboration with Canada, Germany, Italy, Norway, the United Kingdom and the United States. The joint work with CMRE and Member Nations was formalised in a Joint Research Project (JRP) which is in the process of being renewed for 2015.

EXPLOITATION AND IMPACT

The results and data collected during NGAS-COLLAB14 had an impact both within the CMRE Co-operative Anti-Submarine Warfare (CASW) programme and within the national programmes of participating Nations. This collaboration advanced the work in acoustic and magnetic detection performance and autonomy and will help direct future efforts in this area with the goal of eventual fleet deployment.

CONCLUSIONS

The NGAS-COLLAB14 experiment was a collaborative effort in which strides were made in autonomous behaviours, target detection and classification, and multi-sensor fusion. It demonstrated both the current efficacy and potential future impact of heterogeneous autonomous networks applied to the ASW problem. Future work will focus on technology, co-operation, scalability and other aspects of these solutions. The customer for this work is ACT's Output, Autonomous Security Networks.



Figure 15: The NRV *Alliance* and the UUV *Groucho* during NGAS-COLLAB14.

STEALTH ROBOTIC PLATFORMS AND REMOTE SENSING FOR LITTORAL RECONNAISSANCE (CMRE)

CMRE is developing capabilities for discreet and secure autonomous environmental data collection in denied or high-risk areas for use in the intelligence preparation of the battlespaces and ISR missions in expeditionary warfare contexts.

Dr. Emanuel F. Coelho and Dr. Alberto Alvarez, STO-CMRE

BACKGROUND

Timely collection, prediction, tailoring and integration of environmental information are part of counter-anti-access strategies in Assured Access / Area Denial (A2/AD) environments. Ocean gliders are small unmanned underwater platforms that use their change in density to glide through the upper oceans with long endurance times (in the order of 30 days) and therefore are well suited to perform under these constraints.

OBJECTIVE(S)

CMRE is developing glider smart sensing to collect information without redundant and unnecessary data acquisition and with sensor-level processing specifically designed for the application targeted.

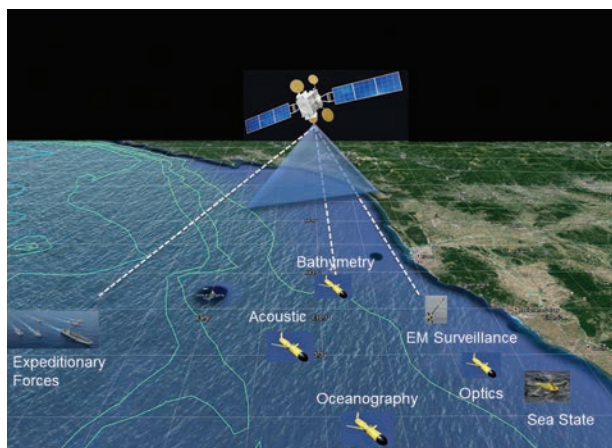


Figure 16: Glider fleet that operates a range of payloads capable of delivering complete discrete reconnaissance of remote seas.

S&T ACHIEVEMENTS

Glider sensing developed by CMRE samples variables of interest for diagnosing performance of sonar systems (reverberation, transmission loss, bottom properties and ambient noise levels). In particular, a novel smart sensor to measure surface wave non-directional spectra was developed and tested, combining inertial sensors and modelling of the dynamical response of a Slocum ocean glider while at the surface. An environmental sea-bed characterisation algorithm using acoustic sensors installed on ocean gliders was tested, and a methodology was developed to estimate signal excess performance surface uncertainty.

The stealth glider concept will improve NATO ability to analyse and characterise the underwater operating environment in remote and/or denied areas.

A compact volumetric array was designed for determination of sea-bed properties from a glider via ship-radiated noise.

SYNERGIES AND COMPLEMENTARITIES

The stealth glider measurements are to be complemented by remote sensing either through satellites or aircraft/Unmanned Aerial Vehicle (UAV). For this reason, a tool for site selection to calibrate and validate marine satellite remote sensing was developed and tested to guide the robotic platforms.

EXPLOITATION AND IMPACT

This project explores their endurance and manoeuvrability by developing solutions for a glider network, launched from offshore host platforms that transit into operational areas to conduct intelligent surveillance-reconnaissance missions, and then return to a retrieval platform. The collected data is reported in real time when the glider surfaces, using secure communications.

The stealth glider concept assumes a glider fleet that operates a range of payloads capable of delivering complete discrete reconnaissance of remote seas. Present development for payloads include antennas for electromagnetic activity monitoring, hydrophones for acoustic environments monitoring, ocean and surface wave sensing, echo-sounding and optical sensors to calibrate remote sensing imagery; and in the future, laser and sonar tools that could be used for mine warfare missions.

CONCLUSIONS

The stealth glider concept will improve NATO's ability to analyse and characterise the underwater operating environment, providing a solution for the intelligence preparation of the battlespaces within expeditionary warfare and A2/AD contexts. The customer for this work is ACT's Output, Environmental Knowledge and Operational Effectiveness (Maritime).

MARITIME SURVEILLANCE EXPLOITING DATA FUSION OF “GREEN” OVER-THE-HORIZON RADARS (CMRE)

Maritime surveillance can be enhanced by using multiple ultra-low-power (“green”) Over-The-Horizon (OTH) radars. Sophisticated algorithms are needed to benefit fully from the synergy of multiple radars operating in the same region.

Dr. Paolo Braca, STO-CMRE

BACKGROUND

Overall maritime situational awareness can be maintained only if non-co-operative sensors are used to confirm reports of positional information from transponder-fitted platforms, ensuring that all vessels required to do so are conforming to International Maritime Organisation (IMO) regulations. High-frequency radars, deployed for environmental monitoring, can be exploited as non-co-operative sensors to augment the capabilities of maritime surface traffic monitoring systems. In order to realise the benefit for surface ship tracking, algorithms must be developed which can detect and track surface vessels effectively using this challenging data source.

OBJECTIVE(S)

The objective was to develop ship tracking and data fusion algorithms for multiple High-Frequency Surface Wave (HFSW) radars in collaboration with NATO Nations.

Several Nations have installed or plan to install HFSW radars for environmental monitoring.

S&T ACHIEVEMENTS

CMRE partnered with Germany (Helmholtz-Zentrum Geesthacht (HZG)) and the University of Hamburg) to follow up on early HFSW radar experiments carried out at CMRE (2009) with a radar operating in the German Bight (2013). CMRE developed algorithms that exploit the signatures sensed by HFSW radars, while coping with the negative side effects of a technology not expressly designed for tracking. In particular, HFSW radars exhibit short-range, coarse azimuth resolution, high non-linearity and significant clutter, which must be taken into account.

CMRE demonstrated that the proposed approach reduces the detection false alarm rate by one order of magnitude. Further improvements in time-on-target, position and dynamic accuracy can be obtained by combining two HFSW radars. CMRE documented its efforts in several technical reports and peer-reviewed scientific articles.



Figure 17: An example of ship tracks resulting from 30 minutes of fused HFSW radar data collected on 1 August 2013.

SYNERGIES AND COMPLEMENTARITIES

Many NATO Nations are interested in following the potential of this technology. A Workshop on Over-The-Horizon (OTH) HFSW radar applications was held at the CMRE in October 2014 involving several Nations, academia, national laboratories and industry. The next step is the integration of the developed algorithms in a coherent framework including contextual information, such as sea-lanes, sea-state conditions, etc.

EXPLOITATION AND IMPACT

HZG is currently using the data fusion and tracking algorithms as well as environmental monitoring procedures in near real time. Several Nations have installed or plan to install HFSW radars for environmental monitoring. The developed algorithms can leverage this infrastructure for surveillance without requiring additional equipment expenditure, thereby multiplying the impact of NATO’s investment in scientific research.

CONCLUSIONS

Partnering with CMRE made it possible for others to develop the necessary algorithms that leverage existing and planned HFSW radar infrastructure for maritime surveillance. The customer for this work was ACT’s Output, Exploring Future Technology.

TACTICAL VIDEO SYSTEM FOR MARITIME SECURITY OPERATIONS BOARDING TEAMS (CMRE)

This was a demonstration of the Boarding Team Tactical Video System at the NATO Maritime Interdiction Operations Training Center (NMIOTC) at Souda Bay, Crete, in partnership with the US Naval Post-graduate School (NPS). The technical demonstration was developed at CMRE using Commercial-Off-The-Shelf (COTS) equipment as a proof-of-concept to address identified shortfalls in military capabilities.

Mr. Manlio Oddone, STO-CMRE

BACKGROUND

The collection of continuous high-definition camera evidence during Vessel Boarding, Search and Seizure (VBSS) missions can improve command confidence in progress of the mission, as well as enable significantly quicker response than when using radio communications alone. CMRE's project was oriented towards the specific operational challenge of a live-video and data transfer link between a naval Boarding Team (BT) and its command chain.

OBJECTIVE(S)

The goal was to create an open architecture live-feed video and data transfer capability, illustrating the ability to stream video from a mobile camera moving about a ship to the warship and the ground headquarters. Also to be investigated was interoperability with other VBSS-related systems such as biometric or CBRN data acquisition systems.

S&T ACHIEVEMENTS

A prototype portable, wearable Tactical Video System (TVS) was created to test the capability. Several vignettes simulated the main features of a routine VBSS mission using a training ship at the NATO Maritime Interdiction Operational Training Center (NMIOTC). Video streams, images and biometric files were shared concurrently across three levels of command. Mobile ad-hoc networking technology maintained a stable link between the BT Officer-in-Charge and multiple cameras moving deep inside the boarded vessel.

The video streaming was transmitted and stored at multiple locations representing the command chain, using SATellite COMMunication (SATCOM). Biometric data was encoded, transferred and decoded afterwards. The transfer reduced data latency from hours/days to seconds. Interoperability was demonstrated by transfer of TVS video and image files to the NPS website.

SYNERGIES AND COMPLEMENTARITIES

The Italian Navy contributed to the testing of the prototype and NMIOTC supplied the experimentation test site and operators, demonstrating a high degree of collaboration between the S&T and operational communities. The experimentation was performed concurrently with other NPS testing providing a larger audience and exchange of ideas.

EXPLOITATION AND IMPACT

Military operational utility was confirmed qualitatively by all officers observing the data flow from the warship and operational HQ. The results were published in a technical report and briefed to NATO's Above Water Warfare Working Group.

CONCLUSIONS

The prototype capability was shown to address the basic requirements for video and data transfer links on a boarded ship. It includes the basis for an infrastructure interoperability that bridges the "last tactical mile" between the BT and the command chain. Mission adaptability through the use of biometrics in this rapid response has the potential to enable more effective concepts of operations for naval VBSS teams. The customer for this work was ACT's Output, Exploring Future Technology.

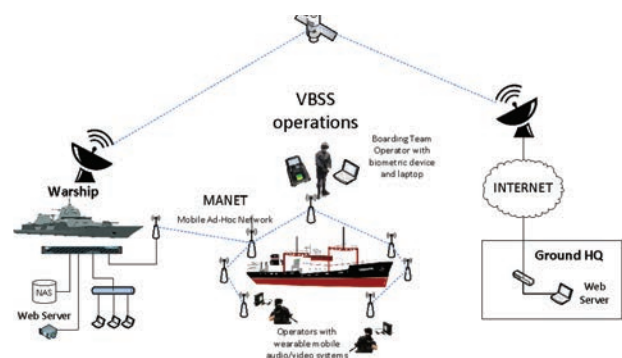


Figure 18: Diagram of the information flow of the Boarding Team Tactical Video System.

FOSTERING CONSULTATION AND PARTNERSHIPS

Consultation and partnerships objectives are supported by NATO S&T in conducting co-operative S&T activities between the Alliance and non-NATO Nations, in line with NATO's partnerships policy, and thus, over time, fostering strategic and technological interoperability. NATO S&T enhances the security dialogue and mitigates threats by building trusted relationships, even in situations where direct political dialogue is difficult.

The NATO STO successfully used two different approaches to contribute to co-operative security. STO's primary means is opening activities in the STO PoW for non-NATO Nations (approximately 70% of them are open). Secondly, the Emerging Security and Challenges Division (ESCD) funds individual S&T activities with non-NATO Nations through the NATO SPSP.

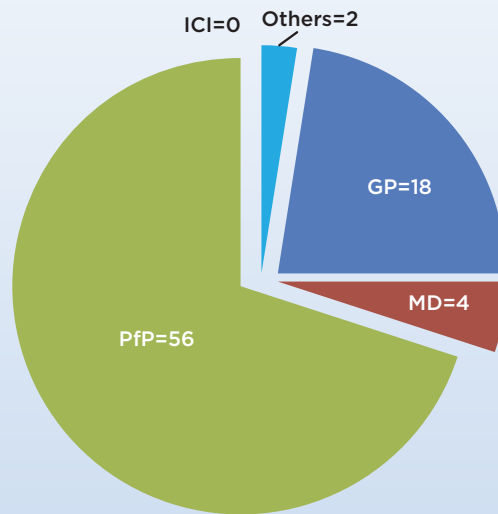


Figure 19: Partner Nation participation by partnership arrangement and number of activities.

M&S OF NEXT-GENERATION NATO GROUND VEHICLES (AVT-221)

This was a Specialists' Meeting on "Design and Protection Technologies for Land and Amphibious NATO Vehicles".

Dr. Michael Hönlinger, DEU, Krauss-Maffei Wegmann GmbH & Co. KG and Prof. Roger King, USA, Mississippi State University

BACKGROUND

The use of validated physics-based M&S methods during the design and development of land and amphibious vehicles is a critical enabler to allow development of robust platforms that meet mission needs while avoiding high development costs. To fully utilise physics-based models, a new design approach is needed to break out of the lengthy and expensive "build-test-fix" mode of development and implement more efficient "model-build-test" approach.

OBJECTIVE(S)

The objective of this RSM was to understand the value of current M&S methods and proposed concepts for advanced vehicle design to meet requirements for tactical and operational mobility.

Specific areas of emphasis included state-of-the-art simulation modelling from blast modelling to vehicle design and warfighter protection.

S&T ACHIEVEMENTS

The HFM Panel shared insights on "Challenges for Design and Protection Technologies Based on Operational Experience and Derived Requirements", whereas industry shared insights "On the Assessment of Amphibious Military Vehicle Design and Production". Specific recommendations from this RSM included the need to develop a set of verification and validation guidelines for simulations of blast-vehicle interactions. This was motivated by identification of the variety of codes used for this task. The RSM also identified a need for requirements and guidelines for NATO amphibious vehicles like those that already exist for ships or ground vehicles.

SYNERGIES AND COMPLEMENTARITIES

This RSM brought together experts in the field to review and assess the current state-of-the-art for M&S of next-generation NATO vehicles to include Australia, a non-NATO Partner. Two keynote presentations and 25 technical papers were

NATO Nations to break out of the lengthy and expensive "build-test-fix" mode of development and implement a shorter more efficient "model-build-test" approach.

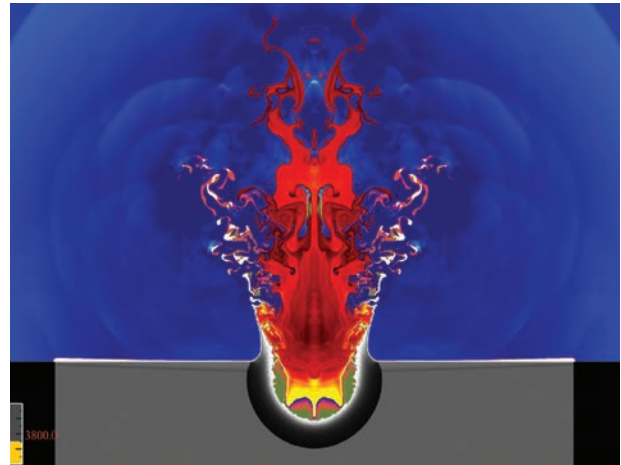


Figure 20: Simulated underbody blast.

presented. Participants included representatives from nine NATO Nations in military, academia and defence industry, and members of the HFM Panel.

EXPLOITATION AND IMPACT

The RSM sought to investigate best practices and concepts proposed for vehicles that are capable not only of land operations, but of facilitating manoeuvres throughout a larger theatre of operations including crossing rivers, tactical swimming in the sea and within littoral areas. The Task Group sought to assess the efficacy of using advanced technologies and materials, as well as advanced design and optimisation tools for new vehicle designs. Follow-on AVT activities have been established to address the specific needs identified for amphibious vehicle standards and innovative design approaches that will benefit the warfighter.

CONCLUSIONS

For the rapidly changing threat situations of the future, NATO vehicles must be upgraded or newly developed. The advanced M&S methods and tools identified in this RSM can contribute significantly to achieving the required capabilities. The RSM results contribute to fulfilling the military requirements of "Land Engagement Capability" and "Vehicle Mobility, Safety and Survivability".

SYNTHETIC ENVIRONMENT FOR ASSESSMENT (SEA) – THE FUTURE FOR DESIGN, TRAINING, AND MULTI-NATIONAL COLLABORATION (HFM-216)

Synthetic Environments for Assessment (SEA) is a modelling and simulation approach integrating models, simulators and operators to measure key system performance parameters in validated mission scenarios. It spans many training capabilities, including Live, Virtual and Constructive (LVC) simulations.

LCDR Brent Olde, PhD, CDR Joseph Coen and Dr. Rudy Darken, USA (all), Office of Naval Research

BACKGROUND

The Synthetic Environment for Assessment (SEA) allows both the S&T and the acquisition communities to use a common simulation environment to conduct trade-off analyses and to explore performance impacts of complex human system's designs. The SEA approach can impact system evolutions from early development to sustained incremental improvements in ways that could radically speed the adoption of new ideas that change the R&D process for warfare and national defence.

The HFM Panel's focus on this approach recognises that military capability derives from integrated use of hardware, software and human systems.

Both researchers and acquisition professionals can now explore and trade off a large number of potential solutions. The HFM-216 final report presents functional descriptions that identify key value-added capabilities, as well as issues requiring more S&T. Use-cases and demonstrations show how SEA could be used with significant benefit to various user groups.

OBJECTIVE(S)

The three objectives were to explore “what works” in synthetic environments for mission effectiveness assessment, to develop functional requirements for synthetic environments for assessment, and to develop a guide for assessing system and training readiness and the use of calibrated virtual environments during design and evaluation to maximise mission performance.

S&T ACHIEVEMENTS

Adoption of SEA processes by members from Canada, France, Germany, Italy, Netherlands, Ukraine, the United Kingdom and the United States is considered as a cost-effective approach to the use of Live, Virtual and Constructive (LVC) simulation technologies.

Future sharing and collaboration of SEA – LVC (RTG HFM-221) is underway. Using this collaborative infrastructure reduces costs, furthers inter-Panel/Group collaboration, and facilitates interoperability of training systems.

SYNERGIES AND COMPLEMENTARITIES

Seven NATO Nations and one Partner Nation (Ukraine) joined efforts along with the NMSG (MSG-107) to further explore architectures for facilitating synthetic environments for assessment.

EXPLOITATION AND IMPACT

Follow-on work is planned with NMSG and the IST Panel, as well as the NATO Training Group (NTG) Individual Training and Education Developments (IT&ED) Working Group who will continue to explore opportunities to work with NIAG in order to accelerate transition to industry. The RTG's report explores the way ahead, describes ongoing SEA activities, and offers uses for SEA that identify resources, models and systems, inputs, outputs, and potential user communities. Member Nation activities are also described, as well as their usage similarities and differences.

CONCLUSIONS

The SEA provides a valuable approach to enhance collaboration and measure mission performance using calibrated scenarios. The technical risks are small as most components have been developed and demonstrated in some form already (e.g., LVC). The ability of current and future synthetic environments to positively impact design and assessment for mission effectiveness is critical to NATO mission readiness.

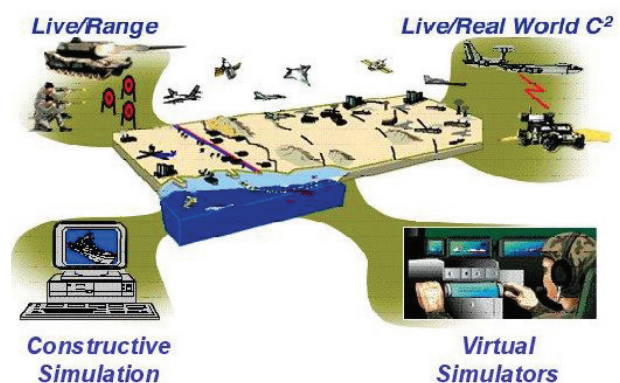


Figure 21: SEA overview seen as it complements LVC as a multi-mission and cross-Panel programme.

INFORMATION TECHNOLOGY AND CRISIS OPERATIONS (HFM-248)

Using NATO's critical role in humanitarian assistance as a backdrop, this effort demonstrates why social media analysis technology is critical to the success of NATO forces in crisis operations and takes specific steps toward operationalising social media analysis in NATO operations.

Dr. R. Goolsby, USA, ONR; Mrs. K. Woodward, GBR, Dstl; Dr. P. Pruulmann-Vengerfeldt, EST, University of Tartu; CAPT D. Apse, EST, NATO COE/Cyberdefence; Dr. M. Vanden Homberg, NLD, TNO; Dr. C. Heinze, AUS, DSTO and MAJ R. Galeano, NATO-Brunssum

BACKGROUND

Social media and Information Technology (IT) continue to be identified as a critical S&T concern to the NATO Alliance. Recent emphasis is on education and training, new methods and approaches for the development of new CONCEPT of OPERATIONs (CONOPS) that will improve data discovery, information sharing and analysis. Social media and their associated new technology advances are providing important new Situation Awareness (SA) capabilities and almost real-time information on current, local activities.

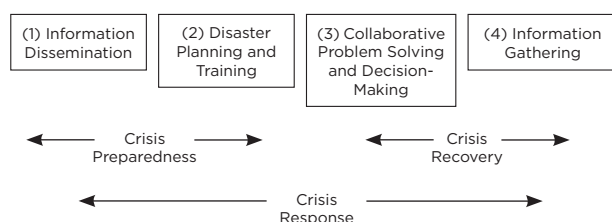


Figure 22: Social media functions for crisis management - Adapted from vanguard Risk Assessment and Horizon Scanning (RAHS) Think Centre; Jason Christopher Chan.

OBJECTIVE(S)

The objectives of HFM-248 are focused on influencing advancements in emerging education and training capabilities, to enhance and analyse online knowledge exchange, and promoting information sharing to accommodate NATO's use of social media streams during complex humanitarian operations, SA and real-time analysis.

S&T ACHIEVEMENTS

HFM-248, in collaboration with NATO-Brunssum, completed a report on the use of social media in Crimea, to be published in mid-2015. A follow-on data-collection activity will use planned field exercises and related Technical Courses on social media and complex humanitarian response for NATO. In addition, a "serious game" is being developed with the Netherlands for the creation of a virtual exercise with follow-on papers planned for 2015 in humanitarian technology.

SYNERGIES AND COMPLEMENTARITIES

Four NATO Nations and one Partner Nation (Australia) actively participated in this RTG. Inter-Panel collaboration is important to our outreach. For example, work was done with SAS-105 on their 8 November 2014 Symposium on Crimean experiences. RTG HFM-248 worked closely with NATO-Brunssum's social media cell, NATO's Centres of Excellence for Strategic Communication and for Cyber Defence, to identify and develop approaches to satisfy those requirements. Discussions were held in the Netherlands with NMSG and SAS to consider routes for pursuing synergies and complementarities.

EXPLOITATION AND IMPACT

New information exchange templates were created to facilitate discussion related to the new information environment, and to promote international engagements in research, education and concept development. This will be a step toward development of an online social media exploitation course for NATO's Allied Command Operations (ACO). International research efforts in information sharing, information discovery, new methods and techniques in analysing and exploiting open source data for crisis and disaster response are now forming. A Symposium is planned for 2016, based on a NATO capstone exercise in 2015.

CONCLUSIONS

HFM-248 continues to encourage additional collaborative research among the Alliance members. Active interest in the results from this Task Group has been expressed by NATO CoE and NATO ACO. The efforts thus far indicate excellent potential to achieve objectives, with significant milestones already completed.

GENERIC METHODOLOGY FOR VERIFICATION AND VALIDATION (GM-VV) TO SUPPORT ACCEPTANCE OF MODELS, SIMULATIONS AND DATA (MSG-073)

Verification and Validation (V&V) of M&S products is critical to the effective and efficient implementation of a viable M&S programme for NATO. This work establishes an internationally accepted standard to allow NATO and the Nations to justify that M&S products meet their intended purposes.

Dr. M. Adelantado, FRA, ONERA; Dr. A. Hikmet Dogru, TUR, Middle East Technical University; Mr. C. Giannoulis, SWE, Stockholm University; Dr. J-L. Igarza, FRA, Antycip Simulation; Mr. F. Jonsson, SWE, FMV; Prof. A. Lehmann, DEU, Universität der Bundeswehr München; Dr. Ir. M. Roza, NLD, NLR; Mr. D. Sebalj, CAN, CAE IES; Mr. A. Van Lier, NLD, DMO-SEC and Dr. J. Voogd, NLD, TNO

BACKGROUND

The NATO Modelling and Simulation Master Plan (NMSMP) calls for the application of M&S products for cost-effective defence planning, training, exercises, support to operations, research, technology development and armament acquisition. The application of Verification and Validation (V&V or VV) methods is essential to help assure that suitable and credible M&S products are available.

OBJECTIVE(S)

The primary objective of the MSG-073 RTG was to establish a Generic Methodology (GM)-VV framework that enables NATO to justify that particular M&S products serve their desired purposes. Its secondary objective was to establish an approved and published Simulation Interoperability Standards Organisation (SISO) standard.



Figure 23: Use-case “Heavy Weather Ship Handling” (NLD) applying GM-VV to determine if simulation is valid for training and doctrine.

S&T ACHIEVEMENTS

GM-VV was rapidly and actively applied by the participating Nations in different simulation projects; several Nations (Germany, Netherlands and Sweden) proposed specific use-cases.

In addition, a Lecture Series (MSG-123) was organised in 2014 to disseminate the GM-VV methodology and leverage its use.

SYNERGIES AND COMPLEMENTARITIES

Seven NATO Nations and one Partner Nation (Sweden) actively participated in this RTG and

worked together with the SISO GM-VV Product Development Group (PDG). Specifically, the RTG was charged with supervising PDG activities to guarantee NATO and Member/Partner Nation’s needs were addressed. For demonstration and validation of the GM-VV, two case studies were selected, both initiated by the Netherlands. The first case was the “Flashing Lights” case, a research experiment designed to handle traffic on a highway at an incident location. The second case was the “Heavy Weather Ship Handling” scenario.

EXPLOITATION AND IMPACT

The GM-VV standard has been established with SISO. It is expected to be an efficient V&V methodology that allows M&S practitioners to gain confidence in M&S results and minimise the risk of their use in decision-making. Because the SISO standards form the basis for validation of M&S systems across the domain, this work directly influences the quality and reliability of all future M&S developments in NATO and beyond.

The Lecture Series developed as a result of GM-VV reached a broad cross-section of experts in the field from Canada, Italy and Sweden, and beyond, and will lead to improved V&V of M&S products for NATO and the Nations.

CONCLUSIONS

Three standards documents representing the full GM-VV framework were developed by MSG-073 – SISO-GUIDE-001.1-2012 (approved in October 2012) provides a high-level introduction to GM-VV; SISO-GUIDE-001.2-2013 (approved in June 2013) is the implementation guide; and SISO-REF-039-2013 (approved in October 2013) is the reference manual. Through publication of these GM-VV standards by SISO, the MSG-073 RTG fully satisfied its initial objectives.

The SISO standard for GM-VV was rapidly and actively applied by the participating Nations in different simulation projects to evaluate usability and efficiency for multiple use-cases.

ROUTE THREAT DETECTION AND CLEARANCE TECHNOLOGIES (SCI-256)

New Improvised Explosive Device (IED) detection techniques and equipment to enhance soldier and equipment protection were tested and evaluated.

Dr. Arnold Schoolderman, NLD, TNO

BACKGROUND

The use of Improvised Explosive Devices (IEDs) is so widespread, their use will remain an enduring global threat. IEDs and other types of on- and off-route threats, such as landmines and emplaced explosive hazards, restrict freedom of manoeuvre and put both troops and equipment at risk. In order to combat the IED threat, many government, university and commercial organisations are developing a multitude of new counter-measures aimed at different IED defeat mechanisms to include detection, conformation and neutralisation, and emerging technologies (electro-optics, electromagnetic induction and scattering, X-ray and neutron backscattering and spectroscopy based on Raman scattering).

OBJECTIVE(S)

The objective of “Route Threat Detection and Clearance Technologies” was to investigate the potential techniques and their limitations for countering the on- and off-route threats encountered by NATO forces in current and future out-of-area missions.



Figure 24: SCI-256 Task Group members conduct field testing of Counter-IED (C-IED) equipment in the Czech Republic.

S&T ACHIEVEMENTS

In support of developing new IED defeat mechanisms, demonstrations and tests of detectors based on Non-Linear Junction Detection (NLJD) technology were conducted at the Czech Republic Army’s 15th Engineers Regiment home base. NLJD is a technology for the detection of electronic components which are often used in the sensors, initiators and remote control units

As the Task Group Chair notes “No single technology is capable of countering the IED threat. A combination of different technologies will be necessary.”

of IEDs. SCI-256 members investigated a number of hand-held NLJD detectors currently in use by NATO Nations for military search. In addition, three experimental, vehicle-mounted technology demonstrators were tested during the field trials.

Task Group members are analysing the vast amount of data gathered during the demonstrations and tests and will generate a report on their findings to help the Alliance shape tactics, techniques and procedures for countering IEDs.

SYNERGIES AND COMPLEMENTARITIES

Chaired by Dr. Arnold Schoolderman (NLD) of the Netherlands Organisation for Applied Scientific Research (TNO), the RTG included nine NATO Nations and one Partnership for Peace (PfP) participant (Sweden). Participating Nations continue to provide test objects, equipment and sites to support research activities.

EXPLOITATION AND IMPACT

SCI-256 is assessing the potential and limitations of existing and emerging technologies for the detection and clearance of IEDs, and investigating techniques for countering the on- and off-route threat as encountered by NATO forces. The results of SCI-256 RTG are expected to have a significant impact on a number of techniques that are potentially suitable for mounted and dismounted stand-off detection, confirmation and neutralisation using hand-held and vehicle-mounted technologies. These techniques will further enhance IED-defeat concepts and protect NATO personnel and equipment conducting on-going and future operations.

CONCLUSIONS

Enhancing detection techniques and equipment is critical to maintaining force protection and saving lives. SCI-256 continues to demonstrate that implementing new evaluation techniques and approaches to IED detection are essential to protect NATO forces and equipment.

AUTOMATIC TARGET RECOGNITION WORKSHOP: TEACHING COMPUTERS TO FIND SEA MINES (CMRE)

CMRE hosted the latest in a series of Workshops aimed at cross-fertilisation of ideas in the NATO scientific community in the area of Automatic Target Recognition (ATR). Working in a collaborative environment, the participating scientists took back to their national programmes' lessons learned about how to improve the overall NATO capability in this area.

Dr. Warren Fox and Dr. David Williams, STO-CMRE

BACKGROUND

CMRE manages an international Joint Research Project (JRP) entitled "Machine Intelligence for Autonomous Mine Search". An important application of this area is the speeding up of mine warfare operations by analysing sonar data automatically for the presence of mine-like contacts, both in post-mission analysis and real-time autonomous operation. As part of this JRP, CMRE has hosted Workshops on Automatic Target Recognition (ATR) for the past three years.

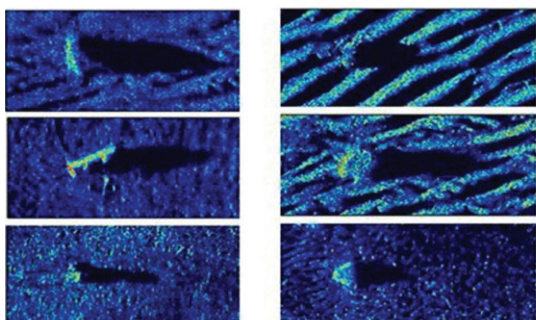


Figure 25: Six examples of target "snippets" are shown. Experienced operators can discern the difference between mine and non-mine targets. ATR algorithms are catching up to human performance.

OBJECTIVE(S)

The objectives of the Workshops are to bring together NATO researchers working in the area of automating algorithms for detecting and classifying mines in high-resolution sonar imagery, to have them work on common data sets using the algorithms and computer code developed individually. The interactions promote the sharing of ideas and approaches.

S&T ACHIEVEMENTS

In previous years, the data sets to be analysed were provided solely by CMRE, generated by CMRE sea-testing activities using the NATO-owned MUSCLE autonomous underwater vehicle equipped with state-of-the-art synthetic aperture sonar. In the 2014 edition, a standard data format was defined in advance by CMRE, while participating Nations (Canada, Germany, Norway, the United Kingdom and the United States) brought example data sets from national systems, supplementing the CMRE data sets. This provided

a unique opportunity to examine algorithm robustness across the various dimensions of target types, environments and sonar system parameters.

SYNERGIES AND COMPLEMENTARITIES

As computing speeds continue to increase, and critical advances are made in machine learning, the potential of ATR technologies for aiding mine warfare missions has been recognised in many NATO Nations. The series of Workshops provided a forum where once disparate national efforts can be focused, researchers can discuss and actively generate lessons-learned, and best practices can be defined and adopted NATO-wide.

EXPLOITATION AND IMPACT

ATR has obvious application to post-mission analysis tasks, where large amounts of data brought back to operators after a vehicle sortie must then be analysed to locate potential mine threats. As computing, sensing and vehicle technologies advance, these algorithms are also being run on the vehicle in-mission, with real-time target detections influencing autonomy algorithms to allow better and more complete data collection during a sortie.

CONCLUSIONS

The 2014 version of this ATR Workshop provided researchers the opportunity to quantify the performance of their developmental algorithms across a range of systems and mine-hunting environments. This collaborative working experience provided information on how the various algorithms can be improved, thus improving the collective capability. It also highlighted the important role of CMRE as a host for collaborative efforts. The customer for this work is ACT's Output, Autonomous Security Networks.

Sitting side-by-side, analysing real-world data from a variety of NATO sonar systems in a collaborative environment, the participating scientists took back to their national programmes lessons learned about how to improve the overall NATO capability in this area.

“24/7” COVERT ACOUSTIC SURVEILLANCE OF SURFACE SHIPS USING AN UNDERWATER GLIDER (CMRE)

For the first time at CMRE, an underwater glider was equipped with an acoustic surveillance capability, working in real time onboard the platform’s payload, enabling covert operations with continuous coverage.

Dr. A. Tesei, Mr. B. Cardeira, Mr. B. Garau, Mr. D. Galletti, Dr. D. Cecchi and Mr. R. Been, STO-CMRE

BACKGROUND

The European Commission’s Framework Programme 7 (FP7) project PERSEUS addresses the protection of European seas through the intelligent use of surveillance.

OBJECTIVE(S)

The overall objective is to design and develop an integrated surveillance system consisting of distributed sensors, installed either on moving platforms (sea gliders, unmanned aircraft, patrol boats, etc.) or on land. CMRE’s contribution consisted of creating an underwater acoustic surveillance capability onboard an unmanned system and linking the system’s output to the PERSEUS C2 centre.

For the first time at CMRE, an underwater glider has been equipped with an eight-element, wide-band, passive acoustic antenna, the data of which have been processed in real time on-board the glider for detection and localisation of small boats.

S&T ACHIEVEMENTS

For the first time at CMRE, a Teledyne Webb Research Slocum glider was equipped with a fully CMRE-designed acoustic payload including a wide-band passive acoustic antenna of eight, low-self-noise hydrophones. Acoustic data were acquired and analysed simultaneously in real time onboard the glider by high-performance, fast array-processing algorithms implemented on an embedded computer. Processing capabilities allow the detection, localisation and classification of small boats. Particular features of the demonstrator system are reactive behaviour (detection-driven surfacing), very low power consumption, persistence and covertness. The system prototype was demonstrated successfully during the final demonstration exercise of the project (Ikaria Island, Greece, September 2014).

SYNERGIES AND COMPLEMENTARITIES

Underwater gliders have been in use at CMRE for a number of years and CMRE currently has a fleet of nine, plus a C2 station and calibration facilities; all this has been set up for the primary application of the gliders, which is environmental

characterisation. The development of the acoustic surveillance ‘add-on’ will influence and facilitate the development of smart sensors that can be carried on-board this type of autonomous system, such as those that measure sea waves and characterise sea-bottom properties using the inversion of ambient sea noise. The Nations with whom CMRE interacts chiefly are France, Greece and Spain.

EXPLOITATION AND IMPACT

Exploitation possibilities of the project achievements are – integration into a heterogeneous sensing solution fusing above-water and underwater sensing; environmental monitoring (noise pollution, marine life); obstacle avoidance by gliders while surfacing; scalability of the concept to wide-area coverage; and adaptation to fit other unmanned platforms and the extension to improved antennas in order to increase system performance (detection ranges).

CONCLUSIONS

Acoustic surveillance of surface vessels was demonstrated successfully at sea through an undersea glider equipped with passive acoustic antenna and real-time, on-board data processing capabilities. The PERSEUS project has been extended by half a year by the European Commission in order to expand the exploitation and dissemination activities, based on the outstanding results achieved.

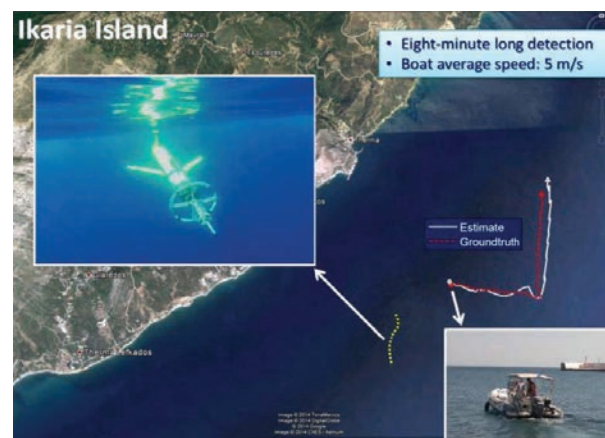


Figure 26: Example of experimental results achieved at sea during PERSEUS final demo (16 September 2014). During one of its missions the glider detected and localised a small boat crossing the area.

ROBOTIC TOOLS FOR SAR OPERATIONS (ICARUS) (CMRE)

ICARUS is an EU-FP7-sponsored project in the field of unmanned Search And Rescue (SAR) operations. CMRE is involved in the project with the goal to design and build a sensor suite to be installed on the U-RANGER Unmanned Surface Vehicle (USV) and to provide the high-level software for enhanced intelligent autonomy.

Dr. Stefano Fioravanti, Dr. Stefano Biagini, Dr. A. Grati and Mr. M. Stipanov, STO-CMRE

BACKGROUND

Autonomous robots participating in Search And Rescue (SAR) operations offer a valuable tool for speeding up the SAR process and ultimately saving lives. They need to be able to execute a critical set of autonomous behaviours to ensure both mission success and safety. CMRE's work will allow the level of autonomy of the robotic assets for SAR operations to be increased.

OBJECTIVE(S)

In previous years, CMRE identified and tested some key devices for the sensor suite of SAR robots. Work in 2014 concentrated on the integration of those devices into the Unmanned Surface Vehicle (USV) and the software running on the vehicle, Mission-Orientated Operating Suite (MOOS), with the ICARUS common Command, Control, Communications, Computers and Intelligence (C4I) and network infrastructure.

S&T ACHIEVEMENTS

CMRE has completed the integration of sensors and the coding of the USV behaviour set into the U-RANGER USV. The main obstacle-avoidance sensor is a gyro-stabilised laser scanner developed by CMRE for applications at sea; it has been integrated into an advanced obstacle avoidance behaviour. Excellent results have been obtained with the laser scanner, with detection ranges up to 200 m for small objects achieved.

The front-seat/back-seat interface has been validated and the stabilised obstacle avoidance sensors and detection/presence sensor pool (thermal and daylight camera, radar, loud hailer, weather station) has been tested. In addition, the USV behaviour set (basic waypoint navigation, obstacle avoidance, go to deployment position and release unmanned capsule) has been tested at sea. A MOOS-JAUS (Joint Architecture for Unmanned Systems) wrapper that allows the integration of the U-RANGER C2 station into the common ICARUS Command, Control and Intelligence (C2I) has also been implemented. During the trial, three robots were able to exchange data in support of the SAR mission (set of contacts, position, status, etc.).

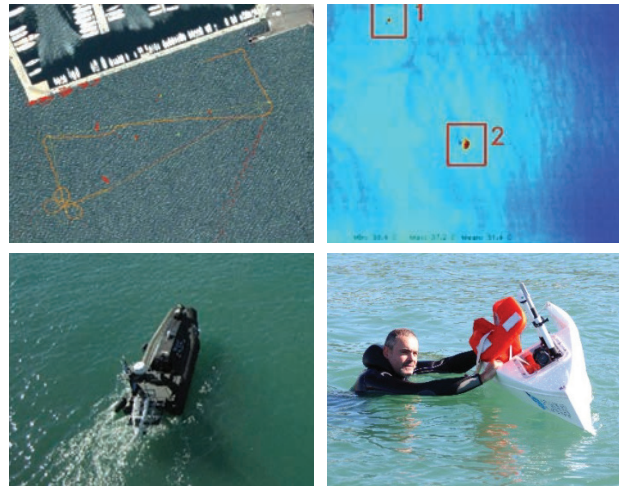


Figure 27: (a) U-RANGER obstacle avoidance mission showing laser data; (b) Real-time object detection from UAV (by ASCAMM - Associació Catalana d'Empres Constructores de Mòtilles); (c) U-RANGER with UCAP (Unmanned CAPsule); (d) UCAP delivering salvage kit.

SYNERGIES AND COMPLEMENTARITIES

The ICARUS project is a perfect environment for testing synergies and interoperability of multiple robotic systems. The robotic tools used within the project span from land robots and aerial systems (both fixed-wing/long-range avionic systems and small drones/quadcopters) to specialised autonomous surface vessels. Interest from EC Partners (Belgium, Italy, Portugal and Spain) in adopting and improving standards for the interoperability between these systems (STANAG 4586, JAUS, etc.) is also of primary interest for NATO.

EXPLOITATION AND IMPACT

The project will end at the beginning of 2016 with land and sea demonstrations. The use of robotic tools for SAR operations is expected to improve the effectiveness, safety and rapidity of SAR operations.

CONCLUSIONS

Results obtained during the trial at sea show that CMRE has achieved a high degree of autonomy and integration into the ICARUS network. Excellent results have been obtained with reliable obstacle avoidance supported by a CMRE-designed sensor suite and software.

NATO SCIENCE FOR PEACE AND SECURITY PROJECT MODUM GOES TO THE MEDITERRANEAN (CMRE)

NATO SPSP funded the MODUM team to attend the MANEX '14 trial for training and familiarisation on unmanned systems operations during sea-going experiments.

Mr. Robert Been and Mr. Per Arne Sletner, STO-CMRE

BACKGROUND

The NATO SPS MODUM project investigates the use of Autonomous and Remotely Operated Underwater Vehicles (AUVs and ROVs) for a monitoring network for the dump sites of chemical warfare materials in the Baltic Sea. CMRE's focus was to give the MODUM team an opportunity to learn and operate their vehicles onboard NRV *Alliance*, and assist the team during their experiments in the Baltic Sea by operating the CMRE sub-bottom profiler. The MODUM team would operate their ROVs and AUVs, the latter carrying a towed magnetometer with a side-scan sonar capability.

OBJECTIVE(S)

NATO SPSP funded the MODUM team's attendance at the MANEX '14 trial with the objective of training and familiarising them both with CMRE's unmanned system operations and MODUM's newly acquired Iver AUV.

“... discarded munitions are a major human health risk and have an environmental impact” – *Terry Long*
(www.underwatermunitions.org)

S&T ACHIEVEMENTS

Participating in a larger trial meant the MODUM team could train for mission preparation, programming and analysis in a more controlled environment than usual when working with small AUVs.

In addition to the standard targets for the Mine Counter-Measure (MCM) part of the trial, specific targets of interest for dumped munitions monitoring were deployed by CMRE. Known objects similar in size and shape to dumped munitions and targets that would allow quality assessment of the Klein side-scan images were deployed at the start. A string of targets with a known mass of iron (from 50 – 150 kg) were also laid on the sea floor to get representative conditions for the magnetometer. The resulting data allowed calibration of the AUV's on-board magnetometer. Also, tools were provided to estimate the AUV's navigational accuracy. The existing infrastructure on board NRV *Alliance*



Figure 28: The Iver AUV being deployed during the MANEX '14 trial off the coast of La Spezia, Italy.

allowed the operation of up to four AUVs simultaneously, making optimal use of the time at sea.

SYNERGIES AND COMPLEMENTARITIES

CMRE has experience working with AUVs since 1998 and is currently operating 10 from different manufacturers within NATO. The MANEX '14 trial already had much of the infrastructure required for the MODUM team, so little effort was required to adapt the trial to accommodate their scientific requirements.

EXPLOITATION AND IMPACT

The first year of CMRE involvement in the NATO SPS MODUM project, through the provision of training and familiarisation, has been highly efficient. The model of multi-national, multi-team, multi-sponsor sea trials can be further applied as a means to share experience and cost optimally with the Alliance S&T programmes.

CONCLUSIONS

The CMRE/MODUM teaming was highly successful. The MODUM team was offered a sea-trial opportunity to train, to learn from CMRE's experience and to operate their AUV with full NRV *Alliance* support, resulting in a very high quality data set. In 2015, CMRE will support the MODUM team by bringing a sub-bottom profiler to the Baltic Sea trial.

MULTI-NATION COLLABORATION IN OCEANOGRAPHIC AND UNDERWATER ACOUSTICS RESEARCH AND EXPERIMENTATION TO COUNTER SUBMARINE TACTICAL ADVANTAGES IN ASW OPERATIONS (CMRE)

CMRE conducted the REP-14-MED sea trial along with 20 Partners from six NATO Nations to deliver major reference data sets for ocean and underwater acoustics research and experimentation.

Dr. Emanuel F. Coelho and Dr. Reiner Onken, STO-CMRE

BACKGROUND

The Intelligence Preparation of the Battlespace (IPB) requires knowledge of underwater environments to assist NATO operators and warfighters in achieving operational effectiveness and minimising risks.

OBJECTIVE(S)

The objective was to produce cost-effective, re-locatable, on-demand, discreet and secure autonomous data-collection technologies and highly portable and interoperable performance algorithms and modelling tools capable of characterising and predicting the underwater environment over regions of interest, through the collaboration with NATO and Nation's stakeholders.

Among other experiments, the sound created by the ship itself and from a towed source was recorded continuously by a glider to assess bottom-bed properties. In another experiment, a glider detected a signal identified as "of interest", initiated a behaviour to retrieve a full profile of Received sound Levels (RL), transmitted the results, waited for new missions, and then resumed a search status. These measurements can be delivered and mapped to key variables of interest such as Transmission Loss (TL) and Bottom Loss (BL) in tactically relevant timeframes.

SYNERGIES AND COMPLEMENTARITIES

The capabilities demonstrated can expedite operational real-time measurements of in-situ RL/TL/BL over depth and range, as well as in-situ benchmarking of actual performances of sonar systems or other sound sources. The retrieved data can also be used for data assimilation into models, correcting the overall sonar performance estimates in a region, complementing environmental surveys.

EXPLOITATION AND IMPACT

This capability would provide operators the same information that any submarine in the area would observe, thus countering the implicit tactical advantage of the submerged platform. Remaining challenges include expediting the data processing and deployment/recovery so that these missions can be performed organically.

CONCLUSIONS

The REP14-MED trial used the CMRE scientific, technical and sea-going expertise to study and develop major concepts capable of delivering information that provides tactical advantages to the modern NATO tightly connected forces. The customer for this work was ACT's Output, Environmental Knowledge and Operational Effectiveness (Maritime).

A capability is being developed to deliver to the ASW operators the same information that any submarine in the area would be observing, thus countering the implicit tactical advantage of the submerged platform.

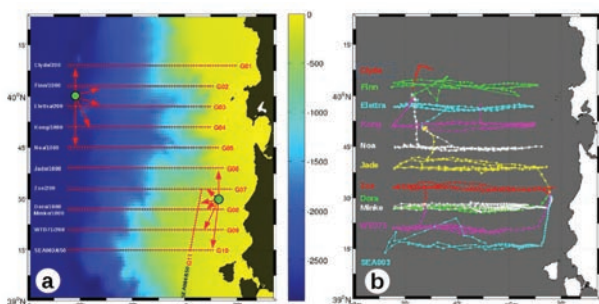


Figure 29: (a) Nominal tracks (red dashed) and deployment positions (green dots) of all gliders launched at the beginning of the REP14-MED sea trial. The names of the gliders are written at the western/southern end of their respective tracks, and the number behind the name stands for the pressure rating in dbar. The red arrows indicate the redirection of the gliders from their launch positions to their assigned tracks. (b) Actual tracks of the gliders dedicated for the oceanographic survey.

S&T ACHIEVEMENTS

An interdisciplinary sea trial (REP14-MED) was conducted in the Mediterranean Sea off the west coast of Sardinia in June 2014. This trial, led by CMRE, was supported by 20 participants from six NATO Nations. Two research vessels from NATO and Germany, a fleet of 16 ocean gliders and ocean-acoustics instrumentation were used to collect high-resolution interdisciplinary data. Results provided ocean and environmental acoustics reference data to the participants.

OPERA: OPTICAL PHYSICAL AND ECOSYSTEM REGIONAL ASSESSMENT (CMRE)

CMRE and Partner organisations have been working on coupling optical measurements into an ecosystem-physical model to improve ocean properties evaluation and prediction.

Dr. Charles C. Trees and Dr. Violeta S. Calzado, STO-CMRE; Dr. Sukru Besiktepe, TUR, Dokuz Eylul University and Dr. Georges Fournier, CAN, DRDC

BACKGROUND

A fully coupled ocean optics-ecosystem-physics model that uses satellite-based or in-situ measurements of hyper-spectral or multi-spectral water-leaving radiances to predict near surface optical fields has been developed and validated. This requires forward and inverse radiative transfer models to estimate the absorbing and scattering components to initialise the OPERA model. Most ecosystem models use either carbon or nitrogen as the model's currency, whereas this work proposes to initialise the OPERA model with optical properties.

OBJECTIVE(S)

The objective was to improve the prediction of ocean properties through – realistic estimates of the radiant light flux in the water column; the use of satellite and in-situ data to initialise the model by inverting ocean colour into absorption and scattering properties; and deconvolution of these properties into the optically active components in the water column to provide a future prediction of their distribution.

S&T ACHIEVEMENTS

OPERA represents the first fully coupled optical-physical-ecosystem model initialising with ocean colour satellite and in-situ optical data.

SYNERGIES AND COMPLEMENTARITIES

This effort has been funded jointly by NATO's ACT and the EC for the past three years. Tactical prediction is focused on coastal oceans; the dynamics in these areas are very complex, and involve a variety of processes, scales, forcing functions, and include multiple interactions. Model prediction skills are inevitably limited, as affected by inaccurate representations of the initial ocean state, scale-limited parameterisation of ocean physical processes and inherent uncertainties in the driving forces at the lateral boundaries and the air/sea interface. The coastal coupled optical-ecosystem model OPERA will constrain and improve environmental assessment and prediction.

EXPLOITATION AND IMPACT

Results from this approach can be used to predict water clarity in the absence of remotely sensed ocean colour data, or to fill in gaps in satellite data caused by cloud cover for the evaluation of diver visibility, airborne-based bathymetry and detection of submarines. Further, they can improve the physical models of heat absorption in the upper ocean layers that will then constrain the ecosystem thus changing the sound speed structure.

CONCLUSIONS

The OPERA solutions are studying and developing concepts that deliver information to improve the intelligence preparations of the battlespace, and will provide tactical advantages to the modern NATO tightly connected forces. The customer for this work was ACT's Output, Environmental Knowledge and Operational Effectiveness (Maritime).

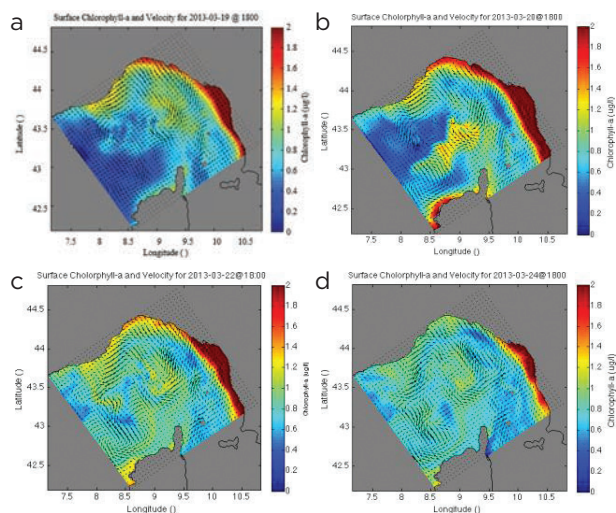



Figure 30: OPERA output during the Ligurian sea Lidar and Optical Measurement Experiment 2013 (LLOMEx'13) sea trial in March 2013 in which satellite and in-situ data were assimilated with bio-optical modelling results to estimate the chlorophyll distribution; a, b, c and d, respectively (overlaid are the modelled velocity vectors).

DELIVERING KNOWLEDGE, ANALYSIS AND ADVICE

NATO S&T supports providing targeted and timely evidence-based knowledge, analysis and advice in response to requests; or proactively using and developing appropriate tools to contribute effectively to political and military planning and decision-making across the full spectrum of NATO and Nations' activities.

The NATO S&T community demonstrated its ability to respond to the objective of delivering knowledge, analysis and advice; in particular drawing on its strengths in operations research and strategic analysis.

The following pages contain a representative outline of the 2014 NATO STO PoW. 

IMPACT OF SCARCITY OF STRATEGIC MATERIALS ON NATO MILITARY CAPABILITIES (AVT-196)

A joint ACT/AVT effort to develop mitigation strategies based on an innovative supply risk and consequence assessment.

Mr. Daniel Chaumette, FRA, Dassault Aviation

BACKGROUND

At the request of the STB, the AVT Panel began studying the possible impact of the scarcity of materials and products on NATO forces in 2008. After a number of unrelated events (e.g., the closure of the rare earth mine in the United States, the sale of a magnet production plant to China and its subsequent closure), by 2005 the entire supply chain for rare earth permanent magnets resided in one non-NATO Nation. In August 2009, the Chinese government tightened export control over rare earth minerals. The ensuing “rare earth crisis” confirmed the risk of scarcity of strategically relevant materials. AVT has since reinforced its investigations, recognising that this crisis was predictable and avoidable.

military supply chains are not in mining operations, but in specialised facilities producing materials or components. This fact must be considered in any evaluation of supply risk and its consequence. “Rare earth” magnets, for example, are a critical component in weapons systems. Also to be considered is the unique nature of military procurement – for example a neutral country may decide not to deliver a needed supply for military use.

This Task Group developed an original method for supply risk and consequence assessment. Testing on several scarcity cases demonstrated that the method has predictive capabilities.

SYNERGIES AND COMPLEMENTARITIES

ACT organised a Workshop for the Task Group to obtain further comments and data from industry, academia, NATO and NATO Nations. The meeting generated additional ideas for potential mitigation strategies.

EXPLOITATION AND IMPACT

Among the different solutions discussed, the development of alternative technologies was considered the most promising approach. Such new developments were covered by the Specialists’ Meeting on “Scarcity of Rare Earth Materials for Electrical Power Systems” which was attended by NATO and Partner Nations. Building on various AVT results, STO policy advice is being formulated.

CONCLUSIONS

Scarcity of strategic materials is an important issue for the Alliance that could have negative impact on military systems providing capabilities and consequently affect future operations. The AVT Panel maintains a very active presence in this field. The AVT activities in this area will conclude in 2015, and recommendations for future actions will be provided as STO policy advice.

The “rare earth magnets” crisis of 2009 was predictable and avoidable!

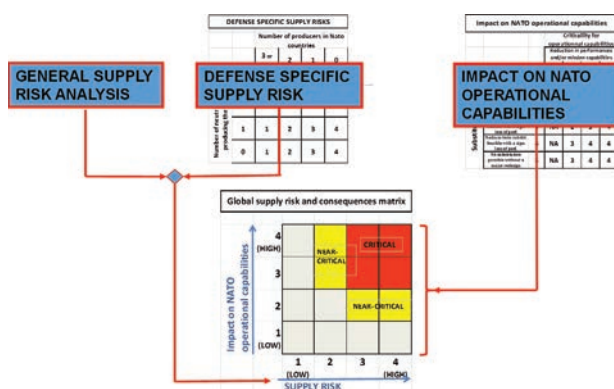


Figure 31: Supply risks and consequences assessment process.

OBJECTIVE(S)

The objectives were – to evaluate the risks of non-availability of materials, components and spare parts for NATO Nations’ military systems; to evaluate the consequences of disruption of supplies on NATO operational effectiveness; and to identify possible mitigation and risk reduction actions.

S&T ACHIEVEMENTS

A survey of potentially critical materials used in military systems revealed that the weak links in

SHARING THE BURDEN OF COMMUNICATION INFRASTRUCTURE THROUGH PCN (IST-103)

Sharing the burden of communication infrastructure can be achieved through implementation of Protected Core Networking (PCN). The initial technical analysis of PCN delivered the functional requirements for an Interoperability Specification (ISpec). IST-103 moved PCN closer to reality by mitigating some of the outstanding technical issues with Quality of Service (QoS), scalability, federated management and risk assessment, and provided guidance on the transition to PCN.

Mr. Roland Schutz, FRA, Thales Communication & Security

BACKGROUND

The fact that defence budgets are diminishing is one of the driving forces for the Alliance to not only share responsibilities, but also provide and invest in communication and information services. Protected Core Networking (PCN) is a federated approach to interoperable transport services.

OBJECTIVE(S)

The key technical issues to be studied in the context of PCN were Quality of Service (QoS), scalability, federated management and Real-Time Automated Risk Assessment (RTARA).

The RTG also sought to provide guidance for the application of PCN and to illustrate operational benefits.

S&T ACHIEVEMENTS

Significant advances were made in addressing issues relating to the federation of autonomous network segments. The concept of Protected Core Communities (PCCs) was further developed. This allowed differentiated information exchange models for federated management purposes, between members of PCCs and Protected Cores (PCores), to help address scalability issues related to the PCN concept. Particular focus was placed on the exchanges relating to QoS and RTARA to support the federated capability provided by these functions. Much of the completed work was presented at renowned international conferences.

SYNERGIES AND COMPLEMENTARITIES

Close collaboration with the TActical interoperable COMmunications Standards + (TACOMS+) Consortium² led to a strong convergence of works done by the two groups. Based on PCN principles, TACOMS+ is addressing the networking and service layer required for the Federated Mission Network (FMN) Spiral 2. IST-103 synchronised with the draft PCN Interoperability Specification (ISpec) through collaboration with the ISpec owner, NCIA. Finally, the work complements STANAG 4711 on Internet Protocol (IP) QoS, currently undergoing ratification procedures.

² The TACOMS+ consortium is a Memorandum of Understanding (MoU)-based project among 13 NATO Nations.

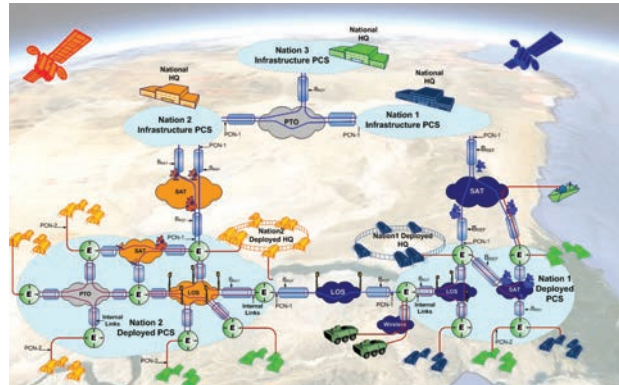


Figure 32: Sharing the responsibility for providing a flexible and secure networked battlefield.

EXPLOITATION AND IMPACT

The PCN approach is aimed at communication transport interoperability among NATO and its Partners at both fixed and higher echelons of deployed networks through the provision of a PCore. The plan is to base the imminent NATO Communications Infrastructure (NCI) upgrade and FMN Spiral 2 on PCN principles.

Evolution of NCI and FMN, along with national fixed and deployed projects, will realise the full capability offered by PCN thanks to the efforts of IST-103. Ultimately, users from any Nation in the Alliance will seamlessly connect to the PCore and be confident in the continued provision of transport services across the PCore according to agreed Service-Level Agreements (SLAs). With PCN equally applicable to fixed and deployed networks, the PCore has worldwide applicability to support protected interoperable networking.

CONCLUSIONS

The technical analysis of the PCN concept is now complete. The next step is to evolve the specification and put the concept into practice to deliver on the Connected Forces Initiative.

EXECUTIVE SEMINAR FOR DECISION-MAKERS IN THE APPLICATION OF OPERATIONAL ANALYSIS (SAS-103)

An executive seminar presented case studies from NATO operations, demonstrating the real-world value of operational analysis.

CDR Harold Pietzschmann, DEU, Bundeswehr Planning Office

BACKGROUND

Throughout their careers senior personnel of NATO Nations and their institutions receive high-level, high-quality training and education in a wide range of academic disciplines. The need for high-quality analysis to support decision-making in military acquisition, force development and employment, and in management of national military and NATO organisations, compels continued emphasis on practical applicability of modern decision support methodologies. Operational Research and Analysis (OR&A) provides evidence-based support to decision-making using a wide range of quantitative and qualitative methodologies.



Figure 33: Representation of a visualisation technique utilised by operational research analysts. This technique was demonstrated during the SAS-103 Technical Course.

OBJECTIVE(S)

This Technical Course was designed to achieve three objectives – first, to create an understanding of what OR&A is and what it could offer senior leaders; second, to show how operational analysis has helped decision-makers in the past and how it can be utilised in the future; and finally, it aimed to foster confidence and trust of senior decision-makers in integrating OR&A into their decision-making.

S&T ACHIEVEMENTS

OR&A contains a number of quantitative and qualitative scientific methods to support senior

This Technical Course presented case studies from previous NATO operations and demonstrated the real-world value of operational analysis.

decision-makers by providing valid and credible data in a world of growing complexity. Among these methods are data visualisation, risk assessment, optimisation and simulation. Each of these methods supports decisions in various areas, such as determining the distribution of resources and helping to develop an understanding of unapparent connections.

This Technical Course presented case studies from previous NATO operations and demonstrated the real-world value of operational analysis. It provided an overview of OR&A and demonstrated a selection of tools available to improve flag and general officers' decision-making processes.

SYNERGIES AND COMPLEMENTARITIES

This Technical Course cost-effectively built on two previous activities of the SAS Panel – SAS-089, which analysed the use of OR&A in NATO operations; and SAS-098, which developed the case studies presented here. Preparation and conduct of the course featured close and high-level co-operation of professors from Australia, Europe and the United States.

EXPLOITATION AND IMPACT

Advanced understanding of OR&A was developed through this course due to prior knowledge in the targeted (senior level) audience. It was widely appreciated that the examples given proved OR&A had supported the Commanders in decision-making.

CONCLUSIONS

The Technical Course improved the understanding of OR&A by senior decision-makers. The level of participation and feedback provided indicated that there was significant value in this course. The SAS Panel will continue pursuing aspects of this Technical Course in its future activities.

INFORMATION OPERATIONS FOR INFLUENCE (SAS-105)

This was a Symposium on asymmetric advantage and exploitation of the information environment by state and non-state actors.

Mr. Matthew A. Lauder, CAN, Defence R&D and Mr. Peter J. Tiggelman, NLD, Civil and Military Interaction Command

BACKGROUND

Two key trends impact the contemporary operating environment. First is the increased appearance of and involvement by Non-State Actors (NSAs) in violent conflict, whether as the primary instigator of violence or as a proxy for a state-based adversary. The second is the exploitation of the cyber domain, in particular social media (Web 2.0), to shape and manage the narrative and conduct information warfare. It can be argued that we have entered a new phase in the evolution of warfare, in which the Information Environment (IE) is the contentious ground where communication is preferred over kinetic approaches to achieve desired effects.

OBJECTIVE(S)

The 2014 Information Operations for Influence (IOI) Symposium provided an environment for the defence S&T community, academics, SMEs and operators to discuss issues and share knowledge related to the exploitation of the IE by various adversaries, as well as extant and future Blue Force capability gaps and requirements to conduct operations in the IE.

We have entered a new phase in the evolution of warfare – one in which the IE is the contentious ground.

S&T ACHIEVEMENTS

Outputs of the Symposium included an enhanced understanding of extant and emerging threats in the IE, as well as the identification of new techniques for conducting target audience analysis and methods for measuring effect. Several S&T challenge areas were also identified, including intelligence support, role of culture, M&S, deception detection, selection and training criteria, non-verbal communication and engagement, and non-kinetic targeting.

SYNERGIES AND COMPLEMENTARITIES

In total, 16 speakers, representing seven Nations (Canada, France, Germany, Netherlands, Norway, the United Kingdom and the United States) participated in the Symposium. Topics ranged from the use of street art as an influence activity through the evolution of Russian

cyber-influence capabilities and the potential for using mistrust to disrupt threat networks. Several new insights were gained, in particular the use of psychological profiling techniques to support message design, the psychological impact of kinetic activities on target audiences, and the strategic effects of Russian information warfare. In addition, the brainstorming sessions aided in the identification of S&T challenges in support of information and influence capability development.

EXPLOITATION AND IMPACT

Outputs of the Symposium are expected to be broadly exploited by NATO, in particular to inform future doctrine and joint information operations capability development. Based on the findings of the Symposium, a three-year RTG follow-on activity has been approved. This activity will focus on the examination of emergent adversary influence capabilities and the development of a guidebook and a training course for operators to counter adversary influence.

CONCLUSIONS

There were two key takeaways from the Symposium. First, the IOI S&T challenge areas are incredibly diverse, cutting across social and applied science disciplines. Second, a significant number of deficiencies exist in capability and knowledge, requiring significant investment in order to close the Blue Force capability gap in IE operations.



Figure 34: Coalition officers speak to village elders in Afghanistan. (Photo credit: DND)

ANALYSIS SUPPORT TO DECISION-MAKING IN CYBER DEFENCE (SAS-106)

This Symposium provided a platform for sharing views and knowledge about requirements for decision support in cyber defence, and identified a gap between the technical side of cyber and the strategic/operational decision-makers, prompting the notion of cyber resilience over cyber defence.

Ms. Melanie Bernier, CAN, DRDC and Ms. Piret Pernik, EST, International Centre for Defence Studies

BACKGROUND

The rapidly evolving environment of cyber threats against the Alliance and Member Nations requires renewed focus on the development of cyber defence policy, strategies and capabilities. The aim of a NATO cyber defence capability is to ensure NATO's permanent and unfettered access to cyberspace and the integrity of its critical systems. The Symposium investigated where NATO and national (operational) analysts could support decision-makers regarding cyber defence.

OBJECTIVE(S)

The purpose of this NATO STO Symposium was to share knowledge and expertise across Nations, and present and discuss requirements for decision support, methods available for use, data availability, suitable measures of merit and case studies. It set out to increase the visibility of novel approaches to the study of cyber defence.

S&T ACHIEVEMENTS

The cyber domain is highly integrated into other domains in that cyber aspects fulfil main or auxiliary functions at each level of the decision-making processes at strategic, operational and tactical levels. An important gap was identified between the technical side of cyber and how the cyber domain is perceived by strategic decision-makers. Bridging this gap could be achieved by – improving awareness and decision-making capabilities of strategic entities; developing decision support systems that process and transform technical data into decision alternatives; and reinforcing the impact of decisions at all levels by creating, maintaining and revising appropriate metrics.

As cyber threats increase in sophistication, it is likely that our networks will not be fully free of security incidents. The conclusion was that we need to integrate cyber resilience within our defensive measures.

SYNERGIES AND COMPLEMENTARITIES

The Symposium promoted NATO STO inter-group collaboration within cyber defence and presented and discussed applicability of situational awareness, visualisation and M&S. Although synergies exist between all groups,

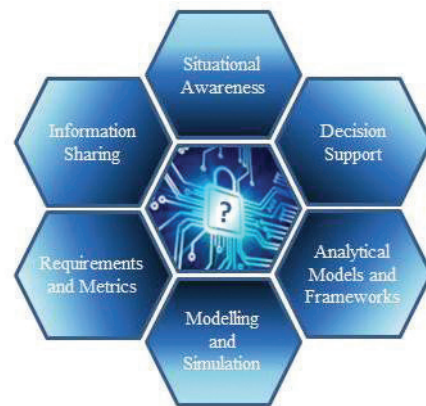


Figure 35: Diagrammatic representation of Symposium topic areas.

a strong correlation was identified between decision support and situational awareness that supports follow-on collaboration in cyber defence/resilience research.

EXPLOITATION AND IMPACT

The results from the Symposium will be advanced through a follow-on RTG that will investigate the notion of cyber resilience versus cyber defence and its effects and influence on strategic level decisions. The SAS Fall 2014 Panel Business Meeting resulted in a recommendation that the Symposium outcomes be presented to the NC3B which could foster a paradigm shift to revolutionise how the Alliance looks at cyber defence. This presentation will be co-ordinated in 2015.

CONCLUSIONS

The Symposium outcomes indicate cyber activities have an increasing impact in all aspects of military operations and can no longer be regarded as solely a technical issue. They also support that cyber resilience must be a priority for future NATO S&T work.

Although perceived as a technical issue, cyber security is not well considered through narrow focus. It requires decisions at all levels – strategic, operational and tactical.

NATO SPACE: SCIENCE AND TECHNOLOGY DEVELOPMENTS TO ENHANCE RESILIENCY AND EFFECTIVENESS OF NATO OPERATIONS (SCI-268)

Concepts were explored to improve NATO's resiliency and capability to conduct space operations and offered solutions for improved survivability and availability of NATO-critical space functionality.

Dr. Don Lewis, USA, The Aerospace Corporation

BACKGROUND

NATO is significantly dependent upon space services to conduct its military missions and related responsibilities. NATO's ACT established an LTA for Space Capability Preservation, to stimulate development of cross-NATO technical and non-technical solutions leading to improved survivability and availability of NATO-critical space functionality.

OBJECTIVE(S)

The objective of the Specialists' Meeting on "NATO Space: S&T Developments to Enhance Resiliency and Effectiveness of NATO Operations" was to develop a shared awareness of NATO's future space capability needs to include capability resilience, and identify key scientific and technical challenges.

S&T ACHIEVEMENTS

The results of SCI-268 identified several areas that will enhance NATO's resiliency in space to ensure comprehensive mission success in the domain. The Specialists' Meeting Chair noted, "... the meeting yielded increased shared awareness of the challenges NATO must overcome to maintain its operational and technical advantages in space, as well as the identification of the most appropriate technical investments for the NATO Nations to consider underwriting in the STO collaborative programme."

SYNERGIES AND COMPLEMENTARITIES

Co-chaired by Dr. Don Lewis (USA) and LtCol-Dr. Giovanni Sembenini (ITA), the Specialists' Meeting brought together eight Allied Nations - Canada, France, Germany, Italy, Portugal, Turkey, the United Kingdom and the United States - and one PfP Nation (Sweden). One of the important components of the meeting was the opportunity for cross-domain and cross-Panel collaboration. Panel representatives from AVT, IST and SET presented on-going space activities that each of their Panels are conducting. Also, representatives from the Joint Air Power Competence Centre (JAPCC) informed the participants of their on-going activities.

The breadth of the anticipated solutions and concepts for more resilient NATO space capabilities significantly benefited from the extensive base of technical experience resident in several of the STO Panels and fellow NATO organisations.

EXPLOITATION AND IMPACT

Space experts generated fresh and innovative ideas to enhance resiliency in space operations. The Specialists' Meeting conclusions and recommendations will allow the Alliance and participating Partner Nations to take informed decisions involving space resiliency. Also based on the results of the Specialists' Meeting, the SCI Panel will conduct a Symposium involving space-enabled capabilities in 2016.

CONCLUSIONS

The Specialists' Meeting provided the basis for a shared awareness in space resiliency and identified the most appropriate technical investments for the Alliance. These investments, if made by the Nations, will provide NATO with a more resilient space capability for future operations.

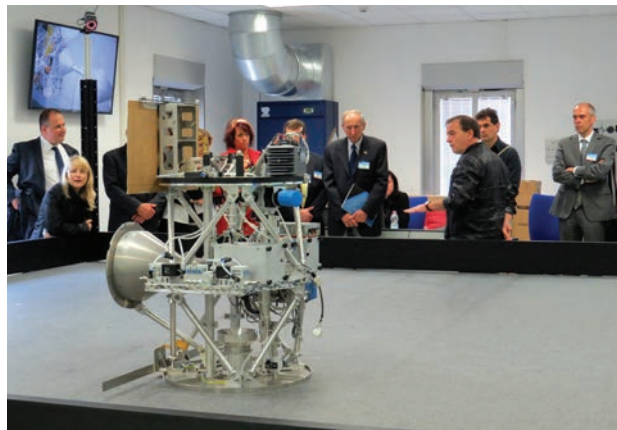


Figure 36: SCI-268 participants observing ongoing space technology research at Thales Alenia Space in Torino, Italy.

ITALIAN MINEX 2014: SCIENTISTS AND OPERATORS BROUGHT TOGETHER (CMRE)

CMRE performed a sea trial as part of the 2014 Italian MINE counter-measures eXercise (MINEX), utilising autonomous underwater vehicles for mine counter-measure operations. Valuable data were collected for research purposes, while at the same time generating lessons learned for the tactical deployment of these types of systems in an operational setting.

Dr. Warren Fox, STO-CMRE

BACKGROUND

CMRE brought scientists and naval operators together during the 2014 Italian MINE counter-measures eXercise (ITMINEX), examining issues related to the tactical use of autonomous vehicles for performing stand-off MCM missions.

OBJECTIVE(S)

CMRE performed a joint scientific and operational sea trial during the ITMINEX. The scientific objectives were to collect data to support research for raising TRLs of advanced sensor systems on AUVs for MCM and (operational) to deploy AUVs in a tactically useful way for MCM in accordance with a recently developed experimental tactic, and to provide lessons learned based on these deployments.



Figure 37: The Italian vessel *Vieste* in the foreground with mine-hunting AUV on the stern. The *NRV Alliance* is seen in the background.

S&T ACHIEVEMENTS

Hosted onboard the *NRV Alliance*, teams from CMRE, Germany, Italy and the United Kingdom made numerous vehicle sorties over target fields with a variety of experimental and operational systems. The acoustic data collected is being used in CMRE and national programmes for advancing the TRL of automatic target recognition technologies, and the development of autonomy algorithms that allow the vehicles to perceive their environment through their own sensors and to make autonomous decisions about how to achieve the missions. These data are also being used in

studies for quantifying the performance of these more modern sensors, so that interoperability can be achieved with legacy ship-based systems.

SYNERGIES AND COMPLEMENTARITIES

Many NATO Nations are looking at using AUVs for MCM operations, since they provide a stand-off capability, effectively removing the man from the mine field. While the data and results generated by CMRE are available to all NATO Nations, the sea-going capability of CMRE with *NRV Alliance* also allowed multiple national groups of scientists and naval operators to interact in a collegial environment of research and operational deployment, exchanging experiences and knowledge to grow the overall capabilities of NATO. CMRE's access to sea, and sea-going equipment and data-collection infrastructure, are key leverage points for Nations investigating these topics.

EXPLOITATION AND IMPACT

AUVs have shown exceptional promise for transforming the way Nations perform MCM, but the speed of technological advance has outstripped the development of rigorous doctrine to utilise AUV systems properly with high-resolution sensors in MCM operations. The joint scientific/operational flavour of CMRE's participation in the ITMINEX will help all of NATO to make the best possible use of these new and exciting technologies.

CONCLUSIONS

The 2014 ITMINEX was a very successful naval exercise, with the attendant CMRE sea trial being an integral part. *NRV Alliance* acted as command platform for an AUV Task Group during the exercise, bringing scientists and operators together to address emergent issues related to how best to employ newly available technologies for achieving stand-off mine counter-measure capabilities. The customer for this work was ACT's Output, Autonomous Security Networks.

Many NATO Nations are looking at using AUVs for MCM operations, since they provide a stand-off capability, removing the man from the mine field.

SETTING NEW STANDARDS FOR UNDERWATER COMMUNICATIONS (CMRE)

The increasing number of autonomous submerged assets motivates the requirement for underwater communication networks. A severe barrier for interoperability may soon be broken with the introduction of the first standard for digital underwater communications – a result of the collective work of NATO, CMRE and the Nations.

Dr. João Alves, STO-CMRE

BACKGROUND

Exchanging data underwater is inherently challenging. Sound is typically the preferred means to communicate wirelessly below the surface, but currently no standard exists on how to translate information from bits to sound (and vice-versa). With the increased number of autonomous platforms and sensor networks being deployed underwater, the ability to support even rudimentary networking tasks is paramount – for that, standards are required.

OBJECTIVE(S)

CMRE has been working for more than six years to establish a protocol that could serve as the common language for underwater systems allowing them to talk between themselves regardless of their origin or manufacturer. This new language is called JANUS, from the Roman god of portals and transitions. The JANUS communications protocol is now in the final stages of documentation towards promulgation as a NATO STANAG.

S&T ACHIEVEMENTS

During 2014, major steps were taken towards JANUS adoption and community engagement – an open-access document with the fundamental aspects of the standard was generated for the UComms 14 (Underwater Communications) Conference; a NIAG was established involving key players in the sub-sea industry with the mandate of preparing the next stages of JANUS adoption such as defining application scenarios and compliance tests; and a revised specification document was delivered via the NATO Standardisation Agency.

Another key JANUS activity in 2014 was the REP14-Atlantic sea trial where it was tested alongside the existing analogue underwater telephone standard. The data collected will allow CMRE to assess qualitatively the intelligibility of underwater telephone communication with and without interfering signals, as well as to generate the first field evidence of the advantages of the digital counterpart JANUS. These trials were particularly important as they were performed in collaboration with the German Defence Agency WTD 71 and the Portuguese Navy which participated in the tests transmitting both JANUS and traditional analogue signals from the underwater telephone of the NRP *Arpão*.



Figure 38: CMRE's heterogeneous underwater networking concept.

SYNERGIES AND COMPLEMENTARITIES

Working together with the Nations is critical for an underwater communications standard to be adopted and employed to solve the problem of force interoperability. Several Nations have worked together with CMRE on the topic of underwater communications – Germany, Netherlands, Norway and the United States have been very active in supporting joint experimentation and providing technical feedback.

EXPLOITATION AND IMPACT

The underwater communications world is entering the era of interoperability. For the first time, civilian and military end-users will be able to network below the surface by using JANUS-capable equipment. Manufacturers will be able to provide JANUS as an interoperability enabler without compromising their own efforts and developments.

CONCLUSIONS

JANUS is close to becoming NATO's digital underwater communications standard for enabling interoperability and ad-hoc underwater networking. Being an open standard, it will fulfil the requirements of a broad user base of private, public, academic, industrial and military institutions. Through JANUS, CMRE aims to advance the network-enabled capabilities of the Alliance. The customer for this work is ACT's Output, Autonomous Security Networks.

INTEROPERABILITY, STANDARDS AND PERSISTENCE FOR FUTURE UNMANNED MARITIME SYSTEMS-OF-SYSTEMS (CMRE)

In 2014, the NATO STO-CMRE started an S&T project entitled “Persistent Autonomous Reconfigurable Capability (PARC)” to address the technology and engineering aspects related to unmanned Systems-of-Systems (SoS) in NATO’s future maritime domain.

Mr. Robert Been, Mr. Keith Van Thiel, Mr. Gabriel Grenon, Mr. Vittorio Grandi, Mr. Alessandro Carta, Dr. Alberto Tremori and Dr. Alain Maguer, STO-CMRE

BACKGROUND

NATO STO-CMRE has been actively involved in unmanned maritime system S&T for over 15 years. In line with this effort, CMRE started a multi-year project for ACT in 2014 entitled “Persistent Autonomous Reconfigurable Capability (PARC)” in order to assist NATO in preparing the future in this domain.

OBJECTIVE(S)

The objectives of PARC include increasing unmanned maritime Systems-of-Systems (SoS) persistence, interoperability, scalability, capabilities and addressing standardisation, information assurance and cost aspects.

S&T ACHIEVEMENTS

A scoping review has been conducted, i.e., an assessment of the current state of the maritime unmanned system domain and its deficiencies has been made relative to the topics listed above. The insights gained have been used to propose focus areas for future S&T at CMRE, laid down in PARC’s 2015 – 2019 roadmap document.

This product aims at the articulation of a vision and strategy for continued involvement in standards development, hardware- and software-in-the-loop M&S, data and technology security, prototype development, experimentation and sustainment of unmanned SoS technology at CMRE.

The challenge of energy replenishment in unmanned SoS was also addressed. A wireless power transmitter, (hardware) interoperable by design, was conceived by members of the PARC team and demonstrated in December 2014. Patenting of the technology and its design is being pursued.

SYNERGIES AND COMPLEMENTARITIES

The S&T within the PARC project is beneficial at all levels of CMRE, the Nations and greater NATO, as they share the same objectives – interoperability, increased capabilities for the warfare areas, affordability and cost-effective solutions.

EXPLOITATION AND IMPACT

The roadmap presents a vision and strategy for the period leading to 2019, with capstone demonstration and experimentation in that fifth and final year, which are both achievable and realistic. Finally, the SoS approach and the products resulting from the actions taken will provide building blocks that may evolve into a maritime unmanned systems test and evaluation range that will aid the transition of such assets into the fleets of NATO Nations.

CONCLUSIONS

The first year of PARC was focused on scoping and developing a roadmap detailing the S&T for unmanned maritime systems. In addition to the continuing efforts relative to standards, engineering hard problems, cost aspects, technology and data security in 2015, PARC will start the development of a hardware- and software-in-the-loop simulation capability that will be used to test systems prior to being deployed at sea, address scalability and provide a S&T platform to cover counter-measures and cyber aspects related to unmanned maritime systems. The customer for this work is ACT’s Output, Autonomous Security Networks.

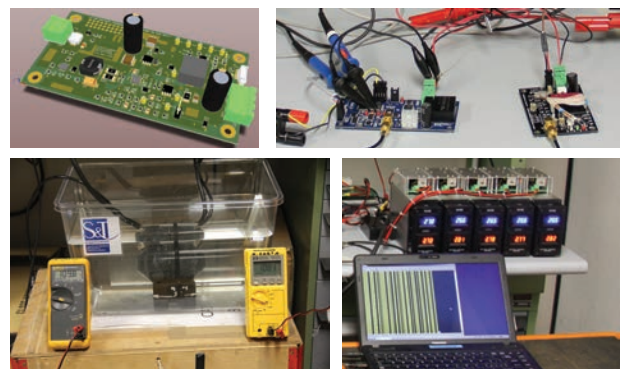


Figure 39: Elements of the hardware-interoperable Wireless Power Transmission (WPT) capability as designed, built and demonstrated by CMRE.

DECISION SUPPORT SYSTEMS (DSS) DRIVEN BY ENVIRONMENTAL CONSTRAINTS, ASSESSED RISK AND SENSOR PERFORMANCES (CMRE)

CMRE is developing research and experimentation to provide a representation of the environment, evaluate potential courses of action based on environmental conditions and uncertainty, and assess when and where additional data collection would provide more informed decision-making.

Dr. Emanuel F. Coelho and Dr. Raul Vicen, STO-CMRE

BACKGROUND

NATO maritime operational and tactical planning calls for accurate and relevant environmental and intelligence products to be delivered to NATO and Allies in a timely manner.

OBJECTIVE(S)

The CMRE-EKOE (Environmental Knowledge and Operational Effectiveness) programme is studying and prototyping concepts and fusion algorithms in a maritime context that process and filter the available databases, models and new observations to provide critical inputs to planning and decision support systems used by NATO forces.

S&T ACHIEVEMENTS

The CMRE-EKOE team demonstrated asset allocation Decision Support Systems (DSS) driven by environmental risk in the Indian Ocean by NATO operators via web services by generating Piracy Activity Group (PAG) maps. The EKOE programme also developed a new DSS, MVIS (METOC (METeological and OCeanographic)-driven Vessel Interdiction System)). This is based on last-generation METOC-driven vessel routing algorithms and is designed to assist decision-makers and planners on interdiction operations under a diverse range of environmental conditions.

The results from this CMRE-EKOE work will enable the access to information that increases the probability of mission success and reduces identified risks on personnel, platforms and equipment.

SYNERGIES AND COMPLEMENTARITIES

The CMRE-EKOE programme has been involved in baseline work to provide a dynamic stability analysis of ocean environments in different regions of military interest to assist the set-up of Rapid Environmental Assessment (REA) requirements. Within this scope, the EKOE will be using a long-range stochastic predictions system being developed by the EKOE and ocean modelling partners, exploring cloud computing and parallelisation schemes.

The EKOE team is also developing tools to expedite access to worldwide databases relevant

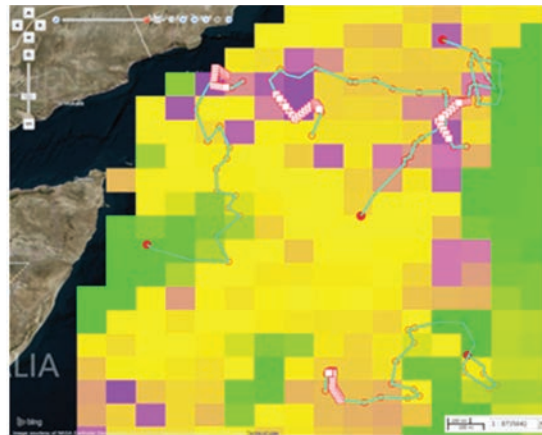


Figure 40: This example shows in the background a map at a given time with the METOC-driven risk of piracy activity. The green lines show the planned tracks minimising the risk along time.

to NATO. These will also allow the interface of CMRE data formats of ocean observations and numerical results with these databases such as those under the Ocean Data Interoperability Platform (ODIP), which includes organisations from the Australia, Europe and the United States. This work complements the CMRE data repository and allows CMRE to interoperate, in a bi-directional manner, with these repositories for routine and/or real-time applications.

EXPLOITATION AND IMPACT

NATO operators will be able to interact with decision-makers with large data sets and filter the relevant information according to operational and tactical planning requirements. In line with this, the programme participated in the NATO-CWIX exercises as client and provider, using different products developed by the programme, to experiment the interoperability of the present algorithms being developed and pre-prototype products that will be included in future NATO exercises for experimentation and demonstration.

CONCLUSIONS

The results from this work will enable the access to information that increases the probability of mission success and reduces identified risks on personnel, platforms and equipment. The customer for this work was ACT's Output, Environmental Knowledge and Operational Effectiveness (Maritime).

NOVEL GAMES TO BETTER UNDERSTAND MILITARY DECISION-MAKING (CMRE)

In November 2014, CMRE presented three games as a Table-Top-Exercise (TTX) to both support NATO work in Harbour Protection (HP) and give CMRE scientists valuable exposure to the military decision-making process.

Mr. Jonathan Locke, STO-CMRE

BACKGROUND

The oft quoted “Data-to-Decision” sound-bite suggests that the connecting processes should all be given due consideration. In general, it is common to linger in the “Data” comfort-zone where the problems are governed by the laws of physical science. Defence S&T has struggled to demonstrate the same application to the “Decision” end of the spectrum. Staff at the CMRE, however, have been working to better understand how (semantic) information impacts on the decision-making of the warfighter/peacekeeper.

OBJECTIVE(S)

The main objective of the Table-Top eXercise (TTX) for the Specialist Team on Harbour Protection (STHP) was to test the HP doctrine – but for CMRE the objective was also to expose S&T staff to the military decision-making and collect data through a set of novel games. In order to provide a broad and deep analysis of the problem space, three distinct games were developed : the “Matrix Game”; the “Information Game”; and the “Risk Game”.



Figure 41: “X marks the spot” – Decision-making under uncertainty, tested during the “Risk Game” at CMRE.

S&T ACHIEVEMENTS

HP is about providing a surveillance and response capability so that the Sea-Lines-Of-Communication (SLOC) and critical infrastructure may be protected.

Harbour Protection (HP) is about providing a surveillance and response capability so that the Sea-Lines-of-Communication (SLOC) and critical infrastructure may be protected.

The “Matrix Game” enabled experts to provide a broad view of the problem at the operational and strategic level in a structured conversation. In the “Information Game”, simulation at the operational level based on Instant Messaging (JCHAT – Java 2 client/server CHAT module), experts played the parts of various organisations engaged in HP. It uncovered the social, information and task networks, it enabled an understanding of the flow of information and identified points of information overload and bottlenecks. Finally the “Risk Game”, at the tactical level, explored how information quality and in particular “uncertainty” has an impact on a single expert’s ability to provide a fit-for-purpose risk assessment of the scene. The work will culminate in a LIVE eXperiment (LIVEX) sometime in June 2015.

SYNERGIES AND COMPLEMENTARITIES

The STHP was established by Portugal to develop the doctrine and technical specifications for the HP element of NATO expeditionary operations. Following the successful TALON HP demonstrations and the 2013 Joint Main armaments groups Initiative (JMI) TTX, CMRE was chosen to deliver a TTX to test the doctrine and de-risk a 2015 LIVEX.

EXPLOITATION AND IMPACT

Both the “Information Game” and the “Risk Game” were developed at the CMRE specifically for the TTX. They are general in their approach and may therefore find application across all problems associated with military decision-making.

CONCLUSIONS

All three games were executed successfully during the TTX. A quick-look analysis was presented to the STHP on the final day, while a formal CMRE report for each game will follow in 2015. The customer for this work was ACT’s Output, Exploring Future Technology.

EXCELLENCE IN NATO SCIENCE AND TECHNOLOGY

NATO's STB recognises the value of S&T excellence within the Alliance. The quality of S&T, the breadth and depth of the collaboration within NATO, and the potential impact and exploitation are the key elements for displaying its recognition.

Every autumn, the STB grants NATO S&T awards – the von Kármán Medal and the Scientific Achievement Award (SAA). These landmarks of excellence will be granted when the STB considers that appropriate candidates were nominated. The NATO Chief Scientist, in his capacity as Chair of the STB, ceremonially presents the achievements to the successful candidates during the STB meeting in the autumn.

The von Kármán Medal is the most prestigious scientific and technological award; it is a personal prize that recognises either the whole STO *oeuvre* or a single outstanding STO achievement of the laureate. Exemplary service and significant contribution to the enhancement of progress in S&T collaboration among NATO, NATO's Nations and Partners within the STO are key. The medal is presented together with an accompanying citation, signed by the STB Chair.

The SAA can be awarded to a person or a team; it recognises excellence and originality of scientific and technical work, as well as outstanding results in terms of military benefit over recent years. The SAA consists of a certificate and an accompanying citation, signed by the STB Chair.

In 2014, the STB awarded one von Kármán Medal and six Scientific Achievement Awards.

THE 2014 VON KÁRMÁN MEDAL

The 2014 von Kármán Medal was awarded to Mr. Robert Hintz for his exceptional service to the NATO scientific and technical community over the past 30 years.

During this long and distinguished tenure, Mr. Hintz spearheaded the development of multiple, novel LAsER raDAR (LADAR) capabilities, including terrain following and obstacle avoidance, long-range eye-safe laser range finders, rescue systems, combat identification, automatic target recognition, Doppler velocimetry, and multi-target laser designation.

Mr. Hintz is recognised for his exceptional dedication and outstanding contributions in support of the NATO mission through his principal leadership of numerous world-class research and development activities that have pioneered this new sensing technology within a NATO context, providing enduring value to the Alliance.



Figure 42: Mr. Robert Hintz receives the 2014 von Kármán medal from the NATO Chief Scientist, MGen Albert Husniaux (BEL AF).

THE 2014 SCIENTIFIC ACHIEVEMENT AWARDS

Scientific achievements are one of the cornerstones that allow the Alliance to innovate and be prepared for unforeseen and unexpected challenges.

The STO is the impetus for creating a collaborative environment that invites scientists to excel.

The 2014 SAAs are described on the next pages. ■

QUALIFICATION AND STRUCTURAL DESIGN GUIDELINES FOR MILITARY UAVS (AVT-174)

Design guidelines leading to significantly reduced cost of acquisition and reduced operational cost due to a higher deployment ratio, more time on-station, and reduced maintenance costs in the field.

Mr. Charles Saff, USA, The Boeing Corporation

BACKGROUND

The global political arena is rapidly changing, and military requirements now differ significantly from the last decade. To meet new and changing demands, it is imperative that the development of new weapon systems should be affordable and reliable, as well as meeting the requirement for a quick and thorough assessment of the design space. Modern UAVs cover a variety of different capabilities which make these platforms important and indispensable for military operations. The qualification and admission of these systems is still a challenge with unsolved issues.

OBJECTIVE(S)

The aim of this RTG was to establish a set of guidelines for design criteria and structural qualification for UAVs tailored to reduce the level of effort required, specifically testing requirements.

S&T ACHIEVEMENTS

The scientific approach conducted by AVT-174 considering general UAV design requirements, structural design criteria as well as validation approaches, led to a guideline which would reduce the level of effort required to qualify a UAV platform, specifically testing requirements based on STANAG 4671. The challenge for the AVT-174 team was building a set of design guidelines for a relatively new breed of air vehicles, where there were significant gaps in the existing technology, and a diverse range of requirements based on vehicle application. A mix of existing knowledge and the development of new methodologies was used to produce a better understanding of the unique requirements.

UAVs cover a broader range of the flight spectrum than manned vehicles; the Task Group delivered a major innovative strategy based on different guidelines developed by AVT-174 for qualifying a system across the panorama of flight from vehicles weighing just grams to those crossing the sky at re-entry velocities, from vertical take-off and landing vehicles, to vehicles that remain airborne for weeks at a time. This proved to be an enormous challenge.

SYNERGIES AND COMPLEMENTARITIES

The team was a well-balanced group comprising members from UAV manufacturers and users, airworthiness authorities, with participants from

industry, military and academia backgrounds. Led by the Chair, Mr. Charles Saff, 13 Nations collaborated in this STO activity.

EXPLOITATION AND IMPACT

The results generated by the RTG were directly and immediately exploited within NATO and NATO Nations as they had been specifically requested by various industry and research institutions. The French Ministry of Defence has already used the load guidelines to qualify a prototype UAV for flight testing. Special requests for the results were also received from Boeing, the US Air Force Structural Integrity Program and the NATO Joint Capability Group on Unmanned Aircraft Systems (JCGUAS) programme – and the RTG was successful in satisfying their demands.

The guidelines will result in a significant reduction in the cost of UAV acquisition, reduced operational cost due to a higher deployment ratio, more time on-station, and reduced maintenance costs in the field.

CONCLUSIONS

As the Exploitation and Impact section highlights, AVT-174 produced a contribution to NATO and the NATO Nations within the field of UAV qualification. Future UAV systems fielded by the Nations and employed by NATO may be produced with lower acquisition and operations costs resulting from the principles derived by AVT-174 that will lead to improved availability rates over the system life-cycle.



Figure 43: Chairman of AVT-174, Mr. Charles Saff, receives the 2014 Scientific Achievement Award from NATO Chief Scientist, MGen Albert Husniaux (BEL AF).

C2 AGILITY AND REQUISITE MATURITY (SAS-085)

Cyber resiliency through a richer understanding and appreciation of the importance of C2 agility for NATO, its Member Nations and its Coalition Partners.

Dr. David S. Alberts, USA, Agility Advantage Corporation

BACKGROUND

Current and future NATO missions will involve NATO and non-NATO military Coalitions, inter-agency Partners, international organisations, host governments, private industry, non-governmental organisations, local authorities and leaders. How these complex endeavours can be effectively organised and managed over time is a crucial issue for future mission success. The complexity inherent in these operations makes it imperative that we understand how to deal with highly uncertain and dynamic situations. The changing nature of these missions highlights the need to recognise that different C2 approaches may be needed in order to succeed, as well as the need to understand that the appropriateness of each approach option is a function of the situation.

OBJECTIVE(S)

The goal of SAS-085 was to develop and foster a richer understanding and appreciation of the importance of C2 agility for NATO, its Member Nations and Coalition Partners. In order to accomplish this goal, SAS-085 had three objectives. The first was to understand and validate the implications of C2 Agility (or a lack of C2 Agility) for NATO missions. The second was to match the characteristics of alternative C2 Approaches (options) to situational attributes (e.g., complexity, dynamics) to support the selection of an appropriate C2 approach given the mission and circumstances. The final objective was to support the dissemination of C2 Agility concepts by providing educational materials including case studies and descriptions of experiments and related findings.

S&T ACHIEVEMENTS

SAS-085 significantly advanced the field of C2 by developing a way of quantifying differences between and among C2 Approaches. In the past, C2 Approaches were simply put into a few categories. This advance enables researchers and practitioners to more accurately represent nuanced differences that make a real difference in outcomes. Previously many different variants were indistinguishable from one another and this led to ambiguous and confusing results. For the first time, SAS-085 provided the C2 community with a scientifically valid way of comparing and integrating case-study and experimental findings. This greatly improves the community's ability to leverage empirical data across a wide variety of



Figure 44: Chairman of SAS-085, Dr. David S. Alberts, recipient of the 2014 Scientific Achievement Award.

missions and circumstances and makes it possible to explore the richness of agility.

SYNERGIES AND COMPLEMENTARITIES

SAS-085 leveraged the work of 12 Nations already completed in SAS-065 research. SAS-065 defined agility to be the ability to proactively maintain mission effectiveness in the face of changing circumstances and stresses, including the ability to conceptualise, design, create and deploy a successful endeavour. While SAS-065 adequately demonstrated that C2 Maturity and C2 Agility are related, more research and practical applications were needed to expand upon these two concepts. In all, SAS-085 has taken advantage of the collaborative work of 16 NATO and non-NATO Partners.

EXPLOITATION AND IMPACT

The success of SAS-085 has led to a follow-on activity entitled "C2 Agility: Next Steps". Not only is this effort expanding on SAS-085 research, but it is partnering with military organisations to develop the capability to employ more than one approach to C2 and to provide evidence-based advice on how to adopt the most appropriate approach as a function of the mission and circumstances.

CONCLUSIONS

C2 Agility, the ability to recognise and adopt an appropriate approach to C2 based upon the situation, is a critical capability that can and should be pursued by NATO, its Member Nations and Coalition Partners. These concepts and practices are mature enough to be incorporated into education, doctrine, exercises and, as Commanders and staff learn how to apply these concepts, they will be ready to be employed.

MITIGATION OF SHIP ELECTRO-OPTICAL SUSCEPTIBILITY AGAINST CONVENTIONAL AND ASYMMETRIC THREATS (SET-144)

This activity addressed ship signature management in Infra-Red (IR) and other threat detection modalities.

Mr. Douglas Fraedrich, USA, Naval Research Laboratory

BACKGROUND

The threat of Infra-Red (IR) homing missiles against ships is significant because of low-cost, high-performance imaging seekers and the striking contrast of the ship and its contours against the ocean background. In addition, the threat of asymmetric threats to ships such as highly manoeuvrable small watercraft has increased significantly in recent years.



Figure 45: Chairman of SET-144, Mr. Douglas Fraedrich, receives the 2014 Scientific Achievement Award from NATO Chief Scientist, MGen Albert Husniaux (BEL AF).

OBJECTIVE(S)

The main purposes of this Task Group were – to design and run co-operative field measurement programmes to validate on-going M&S efforts of radiometric signatures of maritime targets for large combatants and smaller craft; to integrate these modelling assets into IR ship signature management systems; to assess the detection capabilities of shipboard IR sensors against low-altitude point sources and small surface targets against land backgrounds; and to collect field data in the littorals for the purposes of validating components of susceptibility models.

S&T ACHIEVEMENTS

The major focus of the Task Group was the joint at-sea experiment called SQUIRREL (Surendorf QUest Infra-Red Radiometric Experiment in the Littorals) in Surendorf, Germany, on the Baltic Sea. This trial, executed in September 2011, represented the state-of-the-art in scientific instrumentation and analytical techniques.

The SET-144 Task Group successfully demonstrated how IR ship decoy effectiveness can be improved through ship signature management. This demonstration was accomplished by conducting and analysing the SQUIRREL trial, which showed that the IR ship signature management system was able to make moderately priced IR ship decoys effective, which can be used to improve survivability and reduce life-cycle costs.

SYNERGIES AND COMPLEMENTARITIES

The SET-144 Task Group of IR scientists from the various NATO Nations had worked together for many years, which facilitated mutually beneficial collaboration. Several members of the combined delegation were naval officers, who significantly helped the SET-144 scientists focus on operationally beneficial research and the scientists correspondingly educated the naval officers as to what the difficult scientific questions are. Finally the SET-144 Task Group served as a bridge between several STO activities related to naval signatures and other sensing modalities.

EXPLOITATION AND IMPACT

Each NATO Navy obtained an assessment of ship susceptibility against IR-guided anti-ship missiles. Moreover, the collaboration within the NATO STO forum enabled each Navy's experts not only to understand the details and signature features of infra-red ship decoys, but also to learn which decoy features are desirable and which are not.

CONCLUSIONS

SET-144 provided an extraordinary contribution as the Task Group tested the effectiveness of an IR ship signature management system to make threat missile target acquisition significantly more difficult, and improved the effectiveness of off-board decoys against terminal-phase threat missiles.

In addition, the extension of these results to signatures from other sensing modalities (radar, acoustics, optical, etc.) has set the foundation for merging all ship measurements into a comprehensive ship signature system and database. Comprehensive ship signatures for all sensing modalities enable NATO ships to adapt their signatures for optimal protection against a wide range of threats.

GROWING NATO CAPABILITY THROUGH DATA FARMING (MSG-088)

The report from this activity presents a codified process for data farming, ready to support NATO decision-making.

Dr. Gary Horne, USA, Blue Canopy Group

BACKGROUND

“Data Farming” combines the rapid prototyping of simulation models with the exploratory power of high-performance computing to rapidly generate insight into “what-if?” questions. Data farming focuses on a more complete landscape of possible system responses, rather than attempting to pinpoint an answer. This “big picture” approach is an invaluable aid to the decision-maker in light of the complex nature of the modern NATO battlespace. While there is no such thing as an optimal decision in a system where the enemy has a vote, data farming allows the decision-maker to better understand the landscape of possibilities and make better-informed decisions. Data farming also allows for the discovery of outliers that may lead to findings so that decision-makers are no longer surprised.

OBJECTIVE(S)

MSG-088 achieved the ambitious objective of assessing the data farming capabilities worldwide that could contribute to the development of improved decision support to NATO forces.

S&T ACHIEVEMENTS

Methods and techniques of data farming have been developed and documented in various ways since the inception of the idea in 1997. However, MSG-088 produced the scientific details and solutions to the challenge of putting all six of the domains of data farming together in a cohesive and codified collaborative framework.

SYNERGIES AND COMPLEMENTARITIES

Experts in all six domains of data farming and whose countries have begun practicing the art and science of data farming were brought together to advance the technology to the point where it is useful for decision-makers. These six domains include rapid scenario prototyping, model development, design of experiments, analysis and visualisation, high-performance computing, and collaborative processes.

EXPLOITATION AND IMPACT

Case-study explorations involving questions and models of interest to NATO Nations were undertaken by MSG-088 to exploit the power of data farming. These areas were humanitarian assistance and force protection. Also, the impact



Figure 46: Chairman of MSG-088, Dr. Gary Horne, receives the 2014 Scientific Achievement Award from NATO Chief Scientist, MGen Albert Husniaux (BEL AF).

of this work will be expanded as the results are now being applied to two very important NATO context areas – cyber defence and operation planning.

CONCLUSIONS

MSG-088 recommended and demonstrated a way forward for implementing data farming methods and processes to support NATO decision-making in several contexts. This development has taken advantage of the multi-national approach and the wide previous experience of the Task Group members.

These methods are now being exploited in the work of MSG-124 and to support NATO decision-makers and Commanders in their responsibilities and functions in the near future.

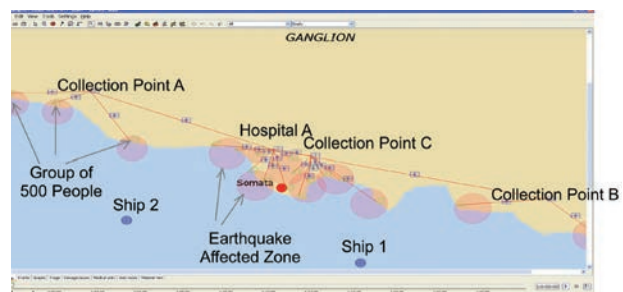


Figure 47: The humanitarian assistance scenario from MSG-088.

ELECTRONIC WARFARE (EW) ISSUES OF SOFTWARE-DEFINED RADIO (SCI-222)

The report from the activity significantly improved NATO software-defined radio technology approaches.

Dr. Jan Punt, NLD, TNO

BACKGROUND

Recent developments in radio technology enable the concept of Software-Defined Radio (SDR), which allows for a much more flexible use of radio systems. SDR enables communication radio systems to be reprogrammed to collect signals while not in use for communication. This concept allows radios not dedicated to Electronic Warfare (EW) missions to be involved in EW support measures data collection, and to be reprogrammed into an electronic counter-measure role. Introducing new functionality on existing platforms to enable reprogramming of radio systems is a challenge facing the NATO Nations and presents many unresolved issues.

OBJECTIVE(S)

The objective of SCI-222 “Electronic Warfare (EW) Issues of Software-Defined Radios” was to explore the potential application of EW functions using SDR development approaches and included the exploration of new capabilities in multi-function systems and networked sensors and jammers. In this context, the Task Group explored potential solutions for dealing with electromagnetic interference created between communication and electronic warfare system using well-developed SDR architectures, interfaces and standards.

S&T ACHIEVEMENTS

SCI-222 derived potential advantages and disadvantages to leveraging SDR development techniques and architectures in electronic warfare system design. These results included strategies for implementing multi-function systems capable of simultaneously supporting EW and communication functionality with assessment of important considerations that should be given to such system designs. The work of SCI-222 is a definite improvement in potential capability for NATO and Partner Nations as IEDs remain a weapon of choice in current and future operating environments.

SYNERGIES AND COMPLEMENTARITIES

Chaired by Dr. Jan Punt (NLD) of the Netherlands Organisation for Applied Scientific Research (TNO), the RTG included nine NATO Nations and one PfP participant (Sweden). Participating Nations provided complimentary test objects, equipment and sites to support research activities.

To support the SCI-222 study and assessment, a multi-national experiment was conducted in Oslo, Norway, with participation from across

the international Partners within SCI-222. The experiment included SDR hardware and systems provided by a variety of national participants and implemented as Electronic Surveillance (ES) detection systems.

The effort demonstrated networked data detection and distribution and proved the potential for SDRs to support EW applications. In addition, the experiment provided valuable real-world application results to support the study assessment.

EXPLOITATION AND IMPACT

SCI-222’s results and conclusions included strategies for implementing multi-function systems capable of simultaneously supporting EW and communication functionality with an assessment of the important considerations for the design of these systems. The results generated by the Task Group were directly exploited within NATO and the NATO Nations as they were specifically requested by various industry and defence institutions for presentation at the Wireless Innovation Forum Europe and the European Defence Agency in 2013. SCI-222’s exceptional findings will enable multi-function systems to support simultaneous EW and communication operations for both Counter Radio-Controlled Improvised Explosive Devices (C-RCIEDs) and distributed ES operations.

CONCLUSIONS

SCI-222’s derived strategies significantly impacted software-defined technology approaches. The strategies enable multi-function systems to support simultaneous EW and communication operations within both C-RCIEDs and distributed ES operations. SCI-222’s essential contribution in this domain is a critical product for NATO’s continued dominance of the electromagnetic spectrum.



Figure 48: Chairman of SCI-222, Dr. Jan Punt, receives the 2014 Scientific Achievement Award from NATO Chief Scientist, MGen Albert Husniaux (BEL AF).

UNDERWATER GLIDERS FOR DISCREET AND COST-EFFECTIVE INTELLIGENCE PREPARATION OF THE BATTLESPACE (CMRE)

Through a series of practical experiments at sea over four years, supported by theoretical development, code implementation and data analysis, a CMRE team demonstrated the feasibility of underwater gliders for the characterisation of the environment for naval operations.

Dr. John Osler, STO-CMRE

BACKGROUND

Through a series of practical experiments at sea over four years, supported by theoretical development, code implementation and data analysis, a CMRE team, led by Dr. John Osler, demonstrated the feasibility of underwater gliders for the characterisation of the environment for naval operations. This initiative, which began with the acquisition of the gliders in 2009, called for several engineering and scientific challenges to be met. Originality, innovation and creativity permeated all aspects; this has been documented in 31 CMRE reports and 25 peer-reviewed journal publications. In addition, CMRE hosted the first Workshop on Military Applications of Underwater Glider Technology in 2013, with representatives of six Nations representing the military, industry and defence science sectors.

OBJECTIVE(S)

In the course of the project, gliders were used for battlespace preparation and marine mammal detection in Exercises Proud Manta 2011 and 2012, and for discreet rapid environmental assessment in Noble Mariner 2012. Six major scientific experiments at sea investigated oceanographic characterisation tied to sonar performance, glider fleet operations in a high current regime, data assimilation into a numerical model, with comparison of measured versus modelled acoustic signal excess, real-time operation of a forecast system including assimilation, adaptive mission planning, and incorporation of gliders into a heterogeneous data-collection network comprising gliders, ships, buoys and remote sensing.

S&T ACHIEVEMENTS

Theoretical developments explored techniques for data assimilation, and an evaluation of algorithms for optimal sampling and safe navigation was undertaken. Analysis involved comparison of numerical ocean forecast predictions while code development included the data processing chain for gliders, correction of platform attitude and dead-reckoning navigation, automated quality control, and multiple representations of the data and situational awareness to assist pilots to conduct glider missions and for decision-makers to exploit their information.

SYNERGIES AND COMPLEMENTARITIES

The potential of underwater gliders for preparation of the battlespace was recognised in a study of



Figure 49: Dr. Osler receives the 2014 Scientific Achievement Award from NATO Chief Scientist, MGen Albert Husniaux (BEL AF).

maritime unmanned systems by the Combined Joint Operations from the Sea Centre of Excellence and in the report from first Workshop on Military Applications of Underwater Gliders. The system developed by CMRE will enable underwater monitoring and information dominance in denied areas to counter anti-access and area denial operations. After Exercise Proud Manta 2011, the Exercise Director remarked that “the environmental information provided by the gliders has proved valuable and helped everyone in that very difficult job of finding submarines that don’t want to be found.”

EXPLOITATION AND IMPACT

Scientists from six Nations and the military staffs from two NATO commands, France and Italy, joined CMRE staff, contributing personnel, equipment for field trials, and forecasts from their numerical models. The combination of these national contributions with CMRE’s capabilities (and funding from NATO ACT), enabled progress more rapid and cost-effective than any individual Nation could have achieved, or would have ventured to undertake.

CONCLUSIONS

The work progressed according to an ambitious schedule, with several objectives addressed in parallel, from acquisition of underwater gliders by CMRE in 2009, through to the first Workshop on Military Applications of Underwater Glider Technology in 2013. For their exceptional work, with a result of significant operational relevance, the 2014 S&T Achievement Award was presented to the CMRE Environmental Knowledge and Operational Effectiveness Programme.

Annexes

ANNEX A – NATO SCIENCE AND TECHNOLOGY ORGANIZATION

The NATO STO is a NATO subsidiary body to the North Atlantic Council or NAC, to which the NAC granted a clearly defined organisational, administrative and financial independence by approval of the Charter of the STO on 1 July 2012. It was established with a view to meeting, to the best advantage, the collective needs of NATO, NATO Nations and Partner Nations in the fields of S&T.

The STO conducts and promotes S&T activities that enable the Nations and NATO to cost-effectively augment and leverage their S&T investments in support of the core tasks of the Alliance.

The STO comprises organisational bodies and committees on three levels – governance, programmes and activities. The governance level is represented by the STB. The programmes level reports to the STB; it is composed of the STCs and the CMRE. Last, the activities level, on which experts do the actual S&T work, reports to the programmes level. In addition, there are several supporting and co-ordinating committees, and executive bodies within the STO, to ensure smooth and transparent operation.

THE SCIENCE AND TECHNOLOGY BOARD

The STB, in which all NATO S&T stakeholders are represented, is the highest authority in the STO. It exercises governance on behalf of the Council and reports to the Council through the MC and the CNAD. The STB's main responsibilities are governing the STO and implementing NATO S&T unified governance.

The membership of the STB is comprised of up to three leading senior defence S&T representatives from each NATO Nation, one of those being the principal board or voting member. Decisions of the STB are taken by unanimous consent. STB members are appointed by the Nations and may come from government, academia, institutes or industry. In addition the STB has also ex-officio members, representing the other stakeholders including the NATO structures and industry. The STB is chaired by the NATO Chief Scientist.

The inter-related nature of the main responsibilities of the STB introduces the necessity for the STB to meet in different formats. To that end, the STB

meets twice a year, in spring and autumn. In the spring session the STB has three different formats – Plans and Programmes; Strategy and Policy; and Executive. In the autumn the STB meets in Executive format only, together with Partners.

The STB is supported by several sub-groups, all consisting of STB members.

CHAIRMAN'S ADVISORY SUB-GROUP (CASG)

The CASG is the think-tank and soundboard to the STB Chair; it provides recommendations pertaining to all issues requiring formal executive action by the STB.

FINANCE AND AUDIT SUB-GROUP (FASG)

The FASG provides recommendations to the STB pertaining to the financial governance of the STO and STO's executive bodies, including audits and risk aspects.

MARITIME S&T SUB-GROUP (MASG)

The MASG provides recommendations to the STB pertaining to NATO maritime S&T and the CMRE.

SCIENTIFIC AWARDS SUB-GROUP (SASG)

The SASG provides recommendations to the STB pertaining to the yearly selection of those to receive the von Kármán Medal and the STO Scientific Achievement Award.

SCIENTIFIC AND TECHNICAL COMMITTEES

The STCs are responsible for the planning and execution of STO's CPoW. They are composed of national defence S&T managers and SMEs from all stakeholders, i.e., government, academia, institutes and industry. The STO provides the framework and delivers executive support through the CSO, which is an executive body of the STO and is located in Neuilly-sur-Seine, France.

There are seven STCs in the STO. They encompass a broad spectrum of scientific fields and are designed to be able to address every relevant military scientific and technological topic. Every committee is chaired, on a rotational basis, by a senior scientist from one of the participating NATO Nations.

APPLIED VEHICLE TECHNOLOGY (AVT)

The mission of the AVT Panel is to improve the performance, affordability and safety of vehicle, platform, propulsion and power systems through the advancement of appropriate technologies.

The scope of this Panel is to address technology issues related to vehicle, platform, propulsion and power systems operating in all environments (land, sea, air and space), for both new and aging systems. The areas of interest are grouped into two main areas, i.e., vehicle and platform technologies, and propulsion and power technologies.

HUMAN FACTORS AND MEDICINE (HFM)

The mission of the HFM Panel is to provide the S&T base for cost-effectively optimising health, protection, well-being and performance of the human in operational environments. This involves understanding and ensuring the physical, physiological, psychological and cognitive compatibility among military personnel, technological systems, missions and environments. This is accomplished by exchange of information, collaborative experiments and shared field trials.

The scope of this Panel is multi-disciplinary and encompasses a wide range of theory, data, models, knowledge and practice pertaining to Health, Medicine and Protection (HMP), Human Effectiveness (HE) and Human System Integration (HSI). These three domains are complementary and represent the three “Area” committees of the Panel.

INFORMATION SYSTEMS AND TECHNOLOGY (IST)

The mission of the IST Panel is to advance and exchange techniques and technologies in order to improve Command, Control, Communications and Intelligence (C3I) systems – with a special focus on interoperability and cyber security – and provide timely, affordable, dependable, secure and relevant information to warfighters, planners and strategists.

The scope of this Panel includes the information warfare and assurance, information and knowledge management, communications and networks and architectures, and enabling technologies.

NATO MODELLING AND SIMULATION GROUP (NMSG)

The mission of the NMSG is to promote co-operation within the Alliance, together with Partner Nations, to maximise the effective utilisation of M&S.

The NMSG has been designated by the NAC to supervise the implementation of the NMSMP and to propose updates.

The scope of this group includes M&S standardisation, education and associated S&T including support to customers, users and suppliers in the five areas of simulation – operations; capability development; mission rehearsal; training and education; and procurement.

SYSTEM ANALYSIS AND STUDIES (SAS)

The mission of the SAS Panel is to conduct studies and analyses of an operational and technological nature, and to promote the exchange and development of methods and tools for Operational Analysis (OA) as applied to defence problems.

The scope of this Panel includes studies, analysis and information exchange activities that explore how operational capability can be provided and enhanced through the exploitation of new technologies, new forms of organisation or new concepts of operation, as well as activities to develop and promote improved analysis methods and techniques to support defence decision-making.

SYSTEMS CONCEPTS AND INTEGRATION (SCI)

The mission of the SCI Panel is to advance knowledge concerning advanced system concepts, integration, engineering techniques and technologies across the spectrum of platforms and operating environments to assure cost-effective mission area capabilities. Integrated defence systems, including air, land, sea and space systems (manned and unmanned), and associated weapon and counter-measure integration are covered. Panel activities focus on NATO and national mid- to long-term, system-level operational needs.

The scope of this Panel includes a multi-disciplinary range of theoretical concepts, design, development and evaluation methods applied to integrated defence systems. Areas of interest are – integrated mission systems

including weapons and counter-measures; system architecture/mechanisation; vehicle integration; mission management; and system engineering technologies and testing.

SENSORS AND ELECTRONICS TECHNOLOGY (SET)

The mission of the SET Panel is to foster co-operative research, the exchange of information, and the advancement of S&T in the field of sensors and electronics for Defence and Security. To fulfil this mission, the Panel has three focus groups - Radio-Frequency Technology (RFT); Optical Technology (OT); and Multi-Sensors and Electronics (MSE).

The scope of this Panel includes topics pertaining to Reconnaissance, Surveillance and Target Acquisition (RSTA), EW, communications, and navigation and the enhancement of sensor capabilities through multi-sensor integration and fusion.

CENTRE FOR MARITIME RESEARCH AND EXPERIMENTATION

The CMRE is located in La Spezia, Italy, and is an executive body of the STO. The Centre is STO's customer-funded S&T facility. It carries out projects and experiments to deliver military relevant state-of-the-art scientific S&T. For that purpose it has its own capabilities, infrastructure and personnel. The main customer is NATO, through the ACT.

The Centre's portfolio includes ocean science, M&S, acoustics, communication, signal analysis and other disciplines. It also contributes new technologies for enabling access to unmanned systems that have the ability to sense, comprehend, predict, communicate, plan, make decisions and take appropriate actions to achieve mission goals.

The CMRE has an engineering department to design, build and modify maritime advanced platforms and (underwater) sensors, including the required signal processing and communication. This important department of the Centre is also capable of providing S&T-based enhancements to unmanned (autonomous intelligent) systems and integrated defence systems.

NATO owns two research vessels, which are both operated by CMRE's Ship Management Office (SMO) - the NRV *Alliance* and the CRV *Leonardo*.

The NRV *Alliance*, designed especially for underwater acoustic research, is capable of operating in all the oceans of strategic importance to NATO and the NATO Nations. It is equipped with extensive and sophisticated navigation, communications and computer equipment, winches, cranes, loading frames and other deck machinery for the deployment, towing and recovery of a variety of sensor arrays and oceanographic instrumentation in all sea conditions. A sophisticated windows-based integrated navigation system, which utilises Differential Global Position Systems (DGPS), includes the ARCS (Admiralty Raster Chart Service, an electronic chart system) and ensures that the ship's position is logged with great precision to provide precise time-tagged navigation strings to other fixed vessel sensors such as the Swathe Mapping System and the Acoustic Doppler Current Profiler.

NRV *Alliance* enables scientists from the Centre to conduct a wide range of experiments. The vessel has been designed for eight different noise states; the quietest one operates on batteries to minimise the noise generated by the ship in order to reduce interference with the environmental measurements and acoustic experiments.

The CRV *Leonardo* has been designed to provide a stable yet flexible sea-going scientific platform suitable for operations in shallow waters. Like NRV *Alliance*, CRV *Leonardo* has a state-of-the-art communication and navigation system as well as substantial deck handling equipment. The vessel has significantly enhanced NATO's capabilities, especially in shallow seas. It has one very silent low-speed condition and enjoys the benefits of diesel electric propulsion driving twin azimuth thrusters and one azimuth pump jet bow thruster controlled by fully automated Dynamic Positioning (DP) and a power management system.

STO SUPPORTING AND CO-ORDINATING COMMITTEES

The smooth and transparent operation of the STO is supported by the following bodies and committees.

LEVEL TWO CO-ORDINATION COMMITTEE (L2CC)

The L2CC supports the STB and its Chair in co-ordinating the optimisation of the NATO STO CPoW by seeking synergies and complementarities while avoiding unnecessary duplication. The L2CC

meeting is composed of the STC Chairs and STO staff and is chaired by the Director of the CSO.

NATIONAL CO-ORDINATORS COMMITTEE (NCC)

The NCC consists of government representatives who support their STB members and facilitate the participation and smooth running of the STCs by effective planning, co-ordination, administration and publication including public relations matters. The NCC is chaired by the Deputy Director of the CSO.

MARITIME SCIENCE AND TECHNOLOGY COMMITTEE (MSTC)

The mission of the MSTC is to provide solicited and unsolicited scientific advice in the maritime domain, including seeking leverage between CMRE's and Nation's maritime S&T activities.

The scope of this committee includes NATO and its Nations' maritime S&T, with a particular focus on the activities of the CMRE. The MSTC is composed of S&T experts and customers from the Centre and the Nations and is chaired by a senior scientist from one of the NATO Nations on a rotational basis. The MSTC reports to the STB through MASG.

KNOWLEDGE/INFORMATION MANAGEMENT COMMITTEE (KIMC)

The mission of the KIMC is to provide expert advice to the STB, its Chair and the STO on knowledge, information management, technology and policy matters for supporting effective and secure exchange of knowledge and information within the STO. The KIMC also supports the development of mechanisms to facilitate the discovery and secure exchange of NATO and shared national information.

The scope of this committee includes processes and mechanisms that touch the entire life-cycle of information and knowledge, including its creation and acquisition, security, processing, retrieval, storage, exchange, distribution and disposition. This includes facilitating information and knowledge exploitation and exchange between the Nations regardless of the form it is exchanged in.

NATO STO EXECUTIVE BODIES

NATO STO is composed of three executive bodies – the CMRE; the CSO; and the OCS.

CENTRE FOR MARITIME RESEARCH AND EXPERIMENTATION (CMRE)

The CMRE is described above.

COLLABORATION SUPPORT OFFICE (CSO)

The CSO is located in Neuilly-sur-Seine, France, and is an executive body of the STO. The primary responsibility of the CSO is to provide executive support to the STCs, and to prepare the CPoW for STB approval. The Director of the CSO attends all STB meetings and chairs the L2CC to co-ordinate cross-cutting activities between the STCs.

OFFICE OF THE CHIEF SCIENTIST (OCS)

The OCS is located in NATO HQ. It is an executive body of the STO which supports the STB chairman, the STB and its sub-groups. The NATO Chief Scientist is the Chair of the STB and the Director of the OCS. Furthermore, the OCS supports the NATO Chief Scientist in his responsibilities within NATO, as senior scientific adviser to NATO senior leadership and decision-makers, and is a focal point for NATO-wide S&T co-ordination and outreach.

ANNEX B – FACTS AND FIGURES

NATO STO

The STO has three executive bodies, the CMRE, the CSO and the OCS, which enable the organisation to function smoothly and effectively.

RESOURCES

Resources for the STO encompass human and financial resources related to STO’s executive bodies. In 2014 the NATO Security and Investment Programme (NSIP) was not used by the STO.

HUMAN RESOURCES (STAFF)

Centre for Maritime Research and Experimentation (CMRE) – In 2014 the customer-funded CMRE employed 169 people (effective 31 December 2014):

- 163 NATO International Civilians,
- 6 NATO International Military Posts (voluntarily contributed by Nations).

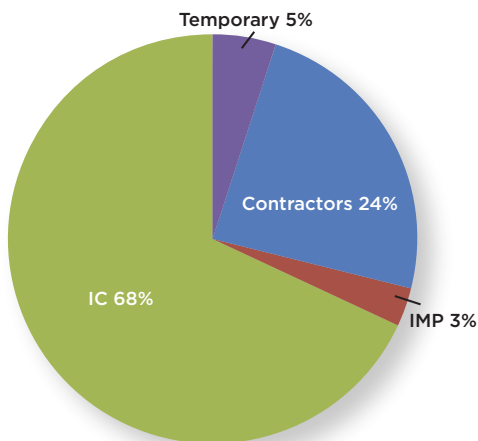


Figure 50: 2014 CMRE workforce.

Collaboration Support Office (CSO) – In 2014 the CSO employed 42 people (effective 31 December 2014) and had recourse to external services:

- 32 NATO International Civilians,
- 10 NATO International Military Posts (voluntarily contributed by Nations).

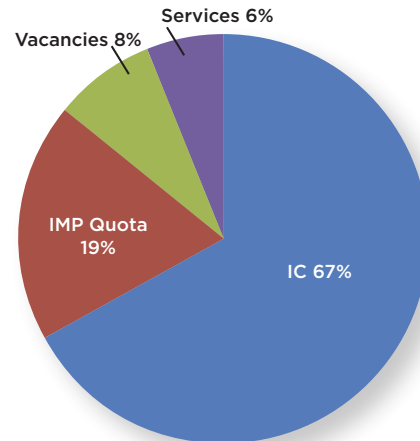


Figure 51: 2014 CSO workforce.

Office of the Chief Scientist (OCS) – In 2013 the OCS employed 9 people:

- 6 NATO International Civilians,
- 3 NATO International Military Posts (voluntarily contributed by Nations).

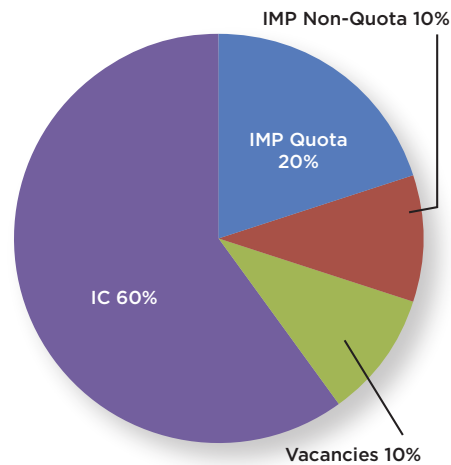


Figure 52: 2014 OCS workforce.

FINANCIAL RESOURCES

Centre for Maritime Research and Experimentation (CMRE) - The 2014 overall customer-funded financial volume was 29,20 MEuro. No NSIP funds were used in 2014.

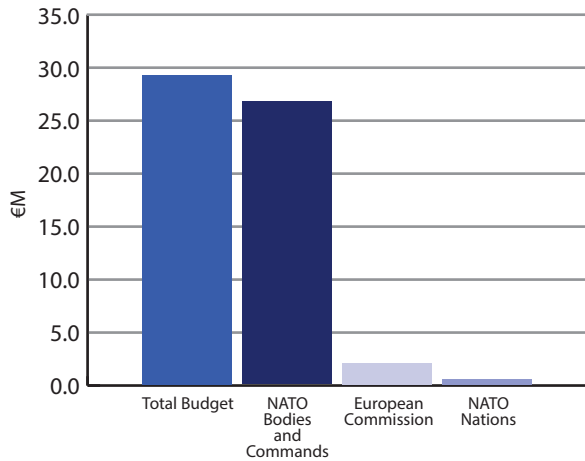


Figure 53: 2014 CMRE revenue.

Collaboration Support Office (CSO) -The 2014 overall common funded budget was 5,485 MEuro.

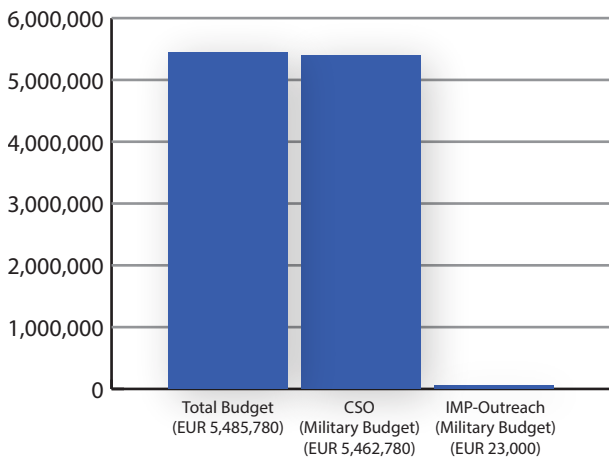


Figure 54: 2014 CSO budget.

Office of the Chief Scientist (OCS) - The 2014 common-funded budget was 0,76 MEuro.

ACTIVITIES PORTFOLIO/DISTRIBUTION STO SCIENTIFIC AND TECHNICAL COMMITTEES

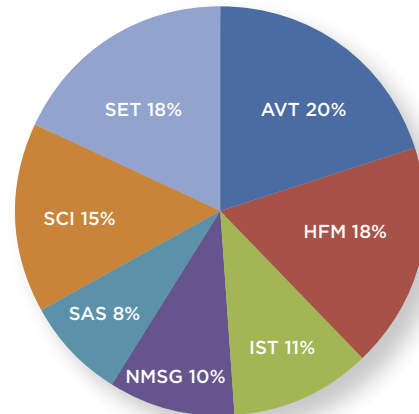


Figure 55: 2014 Distribution of activities per S&T committee.

CMRE

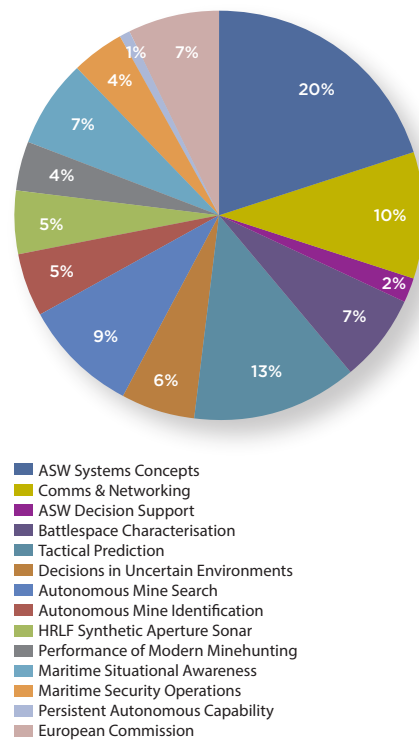


Figure 56: 2014 Distribution of activities over the CMRE portfolio.

ANNEX C – LIST OF ACRONYMS

A2/AD	Assured Access / Area Denial	CDR	Commander
ACO	Allied Command Operations	CDT	Co-operative Technical Demonstration
ACT	Allied Command Transformation	CERDEC	Communications-Electronics Research Development and Engineering Center
AF	Air Force	CFI	Connected Forces Initiative
AGARD	Advisory Group for Aerospace Research and Development	CMRE	Centre for Maritime Research and Experimentation
AIP	Air-Independent Propulsion	CNAD	Conference of National Armaments Directors
ARCS	Admiralty Raster Chart Service	CoE	Centres of Excellence
ASCAMM	Associació Catalana d'Empreses Constructores de Motlles	CoI	Community of Interest
ASW	Anti-Submarine Warfare	COMEDS	Committee of the Chiefs of Military Medical Services
ASWC	Anti-Submarine Warfare Commander	CONOPS	CONcept of OPERATIONs
ATR	Automatic Target Recognition	COTS	Commercial-Off-The-Shelf
AUS	Australia	CPoW	Collaborative Programme of Work
AUV	Autonomous Underwater Vehicle	C-RCIEDs	Counter Radio-Controlled Improvised Explosive Devices
AVT	Applied Vehicle Technology	CRV	Coastal Research Vessel
BEL	Belgium (Belgian)	CSO	Collaboration Support Office
BioMedAC	BioMedical Advisory Committee	CWIX	Coalition Warrior Interoperability exploration, experimentation and examination eXercises
BL	Bottom Loss	DARPA	Defense Advanced Research Projects Agency
BML	Battle Management Language	DASG	Deputy Assistant Secretary General
BP	Business Plan	DAT	Defence Against Terrorism
BT	Boarding Team	DEU	Germany
C-BML	Coalition Battle Management Language	DGA	Direction générale de l'armement
C-IED	Counter-Improvised Explosive Device	DGPS	Differential Global Position Systems
C2	Command and Control	DI	Defence Investment
C2I	Command, Control and Intelligence	DP	Dynamic Positioning
C2SIM	Command and Control – SIMulation	DRDC	Defence Research and Development Canada
C3I	Command, Control, Communications and Intelligence	DSS	Decision Support Systems
C4I	Command, Control, Communications, Computers and Intelligence	Dstl	Defence Science Technology Laboratory
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance	E2DTs	Emerged/Emerging to Disruptive Technologies
CAN	Canada	EC	European Commission
CAPT	Captain	EKOE	Environmental Knowledge and Operational Effectiveness
CASG	Chairman's Advisory Sub-Group	EME	Electro-Magnetic Environment
CASG	CNAD Ammunition Safety Group		
CASW	Co-operative Anti-Submarine Warfare		
CAX	Computer-Assisted eXercise		
CBRN	Chemical, Biological, Radiological and Nuclear		

ES	Electronic Surveillance	IST	Information Systems Technology
ESCD	Emerging Security and Challenges Division	IT&ED	Individual Training and Education Developments
EST	Estonia	IT	Information Technology
EU	European Union	ITA	Italy
EW	Electronic Warfare	ITMINEX	ITalian MINE counter-measures eXercise
FASG	Finance and Audit Sub-Group	JAPCC	Joint Air Power Competence Centre
FMN	Federated Mission Network	J AUS	Joint Architecture for Unmanned Systems
FP7	Framework Programme 7 (European Commission)	JC3IEDM	Joint Command, Control and Consultation Information Exchange Data Model
FRA	France	JCGUAS	Joint Capability Group on Unmanned Aircraft Systems
GBR	United Kingdom	JCHAT	Java 2 client/server CHAT module
GHz	Gigahertz	JEWCS	Joint Electronic Warfare Core Staff
GM	Generic Methodology	JMI	Joint Main armaments groups Initiative
GM-VV	Generic Methodology for Verification and Validation	JRP	Joint Research Project
GP	Global Partner	KIMC	Knowledge/Information Management Committee
HE	Human Effectiveness	L2CC	Level Two Co-ordination Committee
HFM	Human Factors and Medicine	LADAR	LAser RaDAR
HFSW	High-Frequency Surface Wave	LCDR	Lieutenant-Commander
HMP	Health, Medicine and Protection	LCG	Land Capability Group
HP	Harbour Protection	LIVEX	LIVE eXperiment
HQ	Headquarters	LTA	Long-Term Aspect
HSI	Human System Integration	LtCol	Lieutenant-Colonel
HUMINT	HUMAn INTelligence	LVC	Live, Virtual and Constructive
HZG	Helmholtz-Zentrum Geesthacht (Germany)	M&S	Modelling and Simulation
IC	International Civilians	M	Million
ICCRTS	International Command and Control Research and Technology Symposium	MAGs	Main Armaments Groups
ICI	Istanbul Co-operative Initiative	MAJ	Major
IE	Information Environment	MANEX	Multi-national AutoNomy EXperiment
IED	Improvised Explosive Device	MARCOM	MARitime COMmand
IMHM	Integrated Munition Health Management	MASG	Maritime S&T Sub-Group
IMO	International Maritime Organisation	MC	Military Committee
IMP	International Military Posts	MCBL	Mission Command Battle Laboratory
IOI	Information Operations for Influence	MCM	Mine Counter-Measure
IP	Internet Protocol	MD	Mediterranean Dialogue
IPB	Intelligence Preparation of the Battlespace	METOC	METeorological and OCeanographic
IR	Infra-Red	MGen	Major General
ISpec	Interoperability Specification	MHz	Megahertz
ISR	Intelligence, Surveillance and Reconnaissance	MIMO	Multiple Input, Multiple Output

MINEX	MINE counter-measures eXercise	OA	Operational Analysis
MODUM	Monitoring Of DUmped Munitions	OCS	Office of the Chief Scientist
MOOS	Mission-Oriented Operating Suite	ODIP	Ocean Data Interoperability Platform
MoU	Memorandum of Understanding	OPERA	Optical Physical and Ecosystem Regional Assessment
MSaaS	Modelling and Simulation as a Service	OR&A	Operational Research and Analysis
MSDL	Military Scenario Definition Language	OT	Optical Technology
MSE	Multi-Sensors and Electronics	OTH	Over-The-Horizon
MSIAC	Munitions Safety Information Analysis Center	PA	Parliamentary Assembly
MSTC	Maritime Science and Technology Committee	PAG	Piracy Activity Group
MUSCLE	Mine-hunting UUV for Shallow-water Covert Littoral Expeditions	PARC	Persistent Autonomous Reconfigurable Capability
MVIS	METOC-driven Vessel Interdiction System	PCCs	Protected Core Communities
NAAG	NATO Army Armaments Group	PCN	Protected Core Networking
NAC	North Atlantic Council	PCore	Protected Core
NATO	North Atlantic Treaty Organization	PDG	Product Development Group
NC3B	NATO Consultation, Command and Control Board	PfP	Partnership for Peace
NCC	National Co-ordinators Committee	PoW	Programme of Work
NCI	NATO Communications Infrastructure	QoS	Quality of Service
NCIA	NATO Communications and Information Agency	R&D	Research and Development
NDC	NATO Defence College	R&T	Research and Technology
NDPP	NATO Defence Planning Process	RAdm	Rear Admiral
NIAG	NATO Industrial Advisory Group	RAHS	Risk Assessment and Horizon Scanning
NLD	Netherlands	RDT&E	Research, Development, Test and Evaluation
NLJD	Non-Linear Junction Detection	REA	Rapid Environmental Assessment
NMIOTC	NATO Maritime Interdiction Operational Training Centre	ret.	Retired
NMSG	NATO Modelling and Simulation Group	RFT	Radio-Frequency Technology
NMSMP	NATO Modelling and Simulation Master Plan	ROVs	Remotely Operated Vehicles
NNEC	NATO Network-Enabled Capability	RL	Received sound Level
NPS	Naval Post-graduate School (USA)	RSM	Research Specialists' Meeting
NRV	NATO Research Vessel	RSTA	Reconnaissance, Surveillance and Target Acquisition
NSAs	Non-State Actors	RTARA	Real-Time Automated Risk Assessment
NSIP	NATO Security and Investment Programme	RTG	Research Task Group
NSPA	NATO Support Agency	RTO	Research and Technology Organization
NTG	NATO Training Group	S&T	Science and Technology
NURC	NATO Undersea Research Centre	SA	Situation Awareness
		SAA	Scientific Achievement Award
		SAR	Search And Rescue
		SAS	System Analysis and Studies

SASG	Scientific Awards Sub-Group	SWE	Sweden
SATCOM	SATellite COMmunication	TACOMS+	Tactical interoperable COMmunications Standards +
SCI	Systems Concepts and Integration	TARDEC	Tank and Automotive Research, Development and Engineering Center
SDR	Software-Defined Radio	TL	Transmission Loss
SEA	Synthetic Environment for Assessment	TNO	Toegepast Natuurwetenschappelijk Onderzoek (Netherlands Organisation for Applied Scientific Research)
SET	Sensors and Electronics Technology	TRL	Technology Readiness Level
SISO	Simulation Interoperability Standards Organisation	TTX	Table-Top eXercise
SLA	Service-Level Agreement	TUR	Turkey
SLOC	Sea-Lines-Of-Communication	TVS	Tactical Video System
SMEs	Subject-Matter Experts	UAV	Unmanned Aerial Vehicle
SMO	Ship Management Office	UCAP	Unmanned CAPsule
SoS	Systems-of-Systems	UComms	Underwater Communications
SPS	Science for Peace and Security	USA	United States of America
SPSP	Science for Peace and Security Programme	USV	Unmanned Surface Vehicle
SQUIRREL	Surendorf QUest Infra-Red Radiometric Experiment in the Littorals	UUV	Unmanned Underwater Vehicle
STANAG	Standard NATO Agreement	V&V (or VV)	Verification and Validation
STANDEX	STANd-off Detection of EXplosives	VBSS	Vessel Boarding Search and Seizure
STB	Science and Technology Board	VKI	von Kármán Institute
STC	Scientific and Technical Committee	WD	Waveform Density
STHPs	S&T Hard Problems	WPT	Wireless Power Transmission
STHP	Specialist Team on Harbour Protection		
STO	Science and Technology Organization		