SCIENCE AND TECHNOLOGY ORGANIZATION

ANNUAL REPORT
2012

Foreword

NATO'S SCIENCE AND TECHNOLOGY ORGANIZATION

• Supporting NATO Core Tasks

Foreword

It is my pleasure to introduce to you this Annual Report. It is a very particular one, since it addresses a year of transition and its associated structural changes. As a consequence, the report both addresses both the 'old' organizations, the Research and Technology Organization (RTO) and the NATO Undersea Research Centre (NURC), and the new organization, ***the Science and Technology Organization (STO), which was stood up on 1 July 2012***.

Under the STO umbrella, Nations, governments, industry and academia cooperate through and with NATO bodies to provide NATO Nations with a ***knowledge and technology advantage, supporting the core tasks of the Alliance: collective defence, crisis management and cooperative security***.

That cooperation, in the true spirit of ***Smart Defence***, is more relevant than ever. It enables Nations and NATO to focus on the future, on innovation and creativity, in times when the centre of gravity of NATO activities is shifting from the short-term to the medium- and long-term. It allows them to them to join forces and combine strengths, making the best use of the available resources, and to spread risk. Finally, it reinforces the Alliance: Nations share a common enterprise of benefit to all NATO Nations.

The past year was very productive for the RTO, the NURC and the STO. A very solid programme of work was delivered, which materialized in a wide variety of activities, all driven by Nations' and NATO priorities. Its leadership also continued to contribute to the definition of a way forward for the NATO Science and Technology Reform, and started, with the dedication of all involved, the implementation of that Reform, all of the targets of which were met in 2012.

Inside this Annual Report you will find an overview of what NATO S&T is (Part 1) and what the 2012 focus and achievements were (Part 2). Attention will be paid to the NATO S&T Strategy and its implementation.

You will also find an overview of the Programmes of Work that are delivered by the STO. You will find an overview of the Collaborative Programme of Work, inherited from the RTO (Part 3), introduced by the Director of the STO's Collaboration Support Office (Mr. René LaRose). Furthermore, you will find an overview of the Programme of Work of the

NATO Undersea Research Centre/Centre for Maritime Research and Experimentation (Part 4), introduced by the Director of the Centre for Maritime Research and Experimentation (Dr. Dirk Tielbürger).

The Collaborative Programme of Work is the output of a unique and dynamic network, the largest of its kind in the world. Thousands of scientists, engineers, administrators and managers participate, taking advantage of this proven forum to leverage the Nations' and NATO S&T investments and to develop S&T capabilities in areas critical to the Nations and to NATO. The holistic character of this work is truly distinctive in terms of Technology Readiness Levels, of areas of scientific expertise, of phases of the life-cycle of materiel, and of elements of operational capabilities.

The NURC/CMRE Programme of Work is the output of an unparalleled world-class research and experimentation centre focusing on the maritime domain, and the undersea domain in particular. Its Programme of Work addresses improvements in the areas of submarine detection, naval mine countermeasures, maritime situational awareness, and harbour protection.

Excellence is also addressed in this report (Part 5). Personal achievements will be highlighted and results, of particular importance, will be described. Resources used are also summarised (Part 6).

I trust this report will clearly demonstrate that the Science and Technology Organization is more committed than ever to serving the Nations and NATO with a vibrant NATO S&T Programme and with superb S&T activities supporting them.

The report mentions only a part of the results and thus is inevitably merely a snapshot. I invite you to consult our Websites (starting from www.sto.nato.int) to discover more.

I wish you a pleasant reading, and hope to have the pleasure of meeting you during one of our events.

Maj. Gen. (BE AF) Albert Husniaux, MSc (Eng.), Chairman Science & Technology Board and NATO Chief Scientist

TABLE OF CONTENTS

NATO Science & Technology

NATO S&T

NATO S&T is Science and Technology that Nations, NATO bodies and other participants elect to perform in a trusted NATO framework in order to serve Nations' and NATO's security and defence posture.

It covers a wide scope, and encompasses S&T programmes and activities that contribute to the generation and exploitation of scientific knowledge and technological innovation in support of NATO core tasks. It includes programmes and activities in NATO and in Nations (to the extent that they are made available in the NATO context), and spans the short-, medium- and long-term horizon.

NATO S&T results in activities such as consultations, studies, experiments, demonstrations and trials that can be used to develop capabilities and to deliver evidence-based advice to support decision-making. They are fundamental to cementing the trusted relationships NATO is built upon. NATO S&T is based on multinational collaboration and on NATO (as the collective of Nations) investments in S&T programmes and activities.

Multinational collaboration in the NATO S&T framework leverages Nations' efforts to develop capabilities, creates new knowledge, and builds and sustains Nations' S&T capacity. NATO S&T informs requirement definition and solution design, and lays the foundation to enhance interoperability among Allies and with partners. Furthermore, it can facilitate multinational capability development initiatives.

NATO's own S&T investment delivers collective benefits to Allies in areas such as planning and decision support, political consultation and partnerships, transformation, experimentation, interoperability, and capability development.

NATO S&T thus serves the Nations, both individually and as an Alliance, by generating added value. The collective nature of NATO S&T complements the Nations' efforts performed in other frameworks, and gives Nations a lever with which to achieve their objectives more efficiently through burden-sharing. This added-value generation maintains the momentum of NATO S&T. NATO S&T adds value by providing leverage, thus making participation attractive. It is this attraction, in turn, that maintains the leverage, creating a self entertaining dynamic, generating added value.

NATO S&T STAKEHOLDERS

NATO S&T stakeholders are all of those individuals or organisations that can affect NATO S&T (e.g., through guiding, funding or executing S&T activities) and those that can be affected by NATO S&T results (e.g., benefiting from, applying or exploiting the results of S&T activities). They cover a broad spectrum, comprising NATO staff, as well as national representatives or Subject Matter Experts (SMEs), and organise their activities through NATO committees, commands, programmes, agencies or headquarters staff.

A non-exhaustive list of NATO S&T stakeholders comprises (in alphabetical order): Allied Command Transformation (ACT), the Conference of National Armaments Directors (CNAD) and its subordinate structure (namely the Main Armaments Groups (MAG) and the NATO Industrial Advisory Group (NIAG)), the Consultation, Command & Control Board (C3B) and its subordinate structure, the Military Committee (MC), the NATO Communications and Information Agency (NCIA), the Science & Technology Organization (STO), the NATO Support Agency (NSPA), the Science for Peace and Security Programme (SPSP), and the supporting staff at NATO Headquarters.

NATO stakeholders are part of the rich and complex S&T demand – S&T supply landscape. The demand for S&T is expressed both individually in Nations and collectively in NATO. The supply of S&T is performed primarily by the Nations via their governments', industries' and scientific institutions' own investments, but also by NATO, as the ensemble of its Nations.

Due to the diversity of the stakeholders and of the product range of NATO S&T, the effectiveness of NATO S&T critically depends upon the close cooperation between all stakeholders: those that execute S&T activities and those that can apply their results, in Nations, among Nations, and between Nations and NATO.

NATO S&T REFORM

At the Lisbon Summit in Fall 2010, Nations acknowledged the evolving nature of the security environment and the increasing fiscal pressures on them. They subsequently directed far-reaching reforms of NATO's Command Structure and its Agencies in order to make the organization more effective and affordable.

This broader reform context provided the opportunity to launch the NATO S&T Reform. The goal of this reform is to make S&T activities more visible and accessible for senior NATO leadership, and to better link multinationally funded S&T activities with common-funded ones, while maintaining the highly appreciated quality of services and products provided. In order to achieve those goals, Defence Ministers in June 2011 directed the creation of a new NATO Science & Technology Organization (STO), integrating the functions of the former Research & Technology Organization (RTO) and the former NATO Undersea Research Centre (NURC).

The STO would be governed by a newly established Science & Technology Board (STB), providing unified governance of NATO S&T, and overseeing the work of the Collaboration Support Office (CSO), formerly the RTA, and the Centre for Maritime Research and Experimentation (CMRE), formerly the NURC.

Ministers also agreed to establish the new position of the NATO Chief Scientist, who would serve as the Chair of the STB and as the scientific advisor to senior NATO leadership.

These ministerial decisions gave birth to the Charter of the Science and Technology Organization, which was approved by the North Atlantic Council on 19 June 2012. The STO was subsequently stood up on 1 July 2012.

NATO S&T STRATEGY

Through the NATO S&T Reform, the Alliance expressed its strong commitment not only to maintaining its S&T activities at the same level of quality, but also to extracting more value by making them even more visible, exploitable and accessible.

To implement this increased level of ambition and to enhance the overall benefits of the investments in NATO S&T, a strategy for NATO S&T was developed which was approved by the North-Atlantic Council in January 2013.

The Strategy formulates a clear vision and defines the mission of NATO S&T as '**enabling and focusing the generation and exploitation of scientific knowledge and technological innovation in order to support the Alliance's core tasks.'**

The Strategy also identifies the three strategic goals for NATO S&T:

- To support military operations through capability development;
- To enhance security dialogue and cooperation via consultation and partnership in the development and execution of the collaborative program of work; and
- To support senior leaders in their strategic and operational decision-making process by providing timely knowledge, analysis and advice.

The NATO S&T Strategy and its elements position NATO S&T as a direct support to the Alliance core tasks, which are defined in the Strategic Concept as collective defence, crisis management and cooperative security. It addresses NATO top-level processes and initiatives, such as the NATO Defence Planning Process, Smart Defence and the Connected Forces Initiative.

Delivering to the mission will comprise the full spectrum of S&T activities, ranging from basic scientific research to generate new knowledge, through the development and maturation of technologies, all the way to the pull-through of innovative solutions to their practical exploitation.

The Strategy encourages the collaboration amongst Nations and between Nations and NATO to make the best use of the Nations' and NATO's investments in S&T, and to generate the best value for money for all. It aims at focusing NATO's own S&T investments in high-priority areas, informing the Nations' investment decisions in S&T to address Alliance core tasks, and exploiting external S&T activities whenever they are accessible and relevant to the Alliance.

The NATO S&T Strategy will be implemented by all stakeholders, with the Science and Technology Board in charge of maintaining the overall coherence of actions.

NATO SCIENCE & TECHNOLOGY ORGANIZATION (STO)

The STO is NATO's main venue to deliver Science and Technology, assisting NATO and Nations to have a knowledge and technology advantage that they can use for their security and defence postures.

The STO:

- Conducts and promotes S&T activities that augment and leverage the capabilities and programs of the Alliance and of the NATO Nations and the Partner Nations in support of NATO's objectives;
- Supports security- and defence-related capability development and threat mitigation in NATO Nations and Partner Nations, in accordance with NATO policies;
- Provides evidence-based advice to support decision-making in the NATO Nations and in NATO.

The STO is composed of a Board, Scientific and Technical Committees, and three executive bodies.

- The STB constitutes the highest authority in the STO. It exercises governance on behalf of the NAC, reporting to the NAC through the Military Committee and the Conference of National Armament Directors. It is chaired by the NATO Chief Scientist. The Board and its Chairman are supported by an executive body located at the NATO headquarters (HQ): the Office of the Chief Scientist (OCS);
- Scientific and technical committees, composed of national defence S&T managers and Subject Matter Experts (SMEs), are responsible to the STB for the planning and execution of the STO's Collaborative Programme of Work. They are supported by an executive body, the Collaboration Support Office (CSO). In Part 3 of this report, the collaborative programme will be addressed, highlighting the roles of all players as well;
- The CMRE is the executive body that uses its own facilities and staff to organise and conduct scientific research and technology development activities focused on the maritime domain. In Part 4 of this report, the CMRE Programme of Work will be addressed, highlighting the CMRE as well.

NATO S&T GOVERNANCE: THE SCIENCE & TECHNOLOGY BOARD

The STB membership is comprised of up to three leading personalities in defence S&T from each Nation. Members are chosen by the Nations and may be from government, academia or industry. STB members typically are senior S&T executives at the deputy under-secretary, deputy assistant secretary or deputy administrator level.

The STB also has ex-officio members, representing the stakeholders from the NATO structures.

The STB plays three interrelated roles.

- The STB is the governing body for the STO. It is therefore responsible for overseeing STO policies, management and programmes, and for guiding and directing the operations of STO technical committees and working groups, as well as its executive bodies;
- The STB is responsible for implementing unified governance of NATO S&T. This governance includes developing and implementing the NATO S&T Strategy, defining NATO S&T priorities, and serving as the focal point for the coordination of all S&T programmes and activities in NATO;
- The STB supervises the implementation of the NATO S&T Reform.

All stakeholders are represented in the STB, meeting in different formats to exercise its interrelated roles.

- NATO S&T Delivery: The S&T programmes of the STO;
- This report will focus on the S&T Programmes that are executed by the STO[1]. They are delivered through two distinct business models.

Using the 'collaborative S&T business model', Nations and other stakeholders collaborate to deliver S&T results and to promote information exchange. In what is 'smart defence avant la lettre', they use their own resources to generate the programme of work. The STO provides a forum and delivers executive support through the CSO, which is located in Neuilly-sur-Seine, France.

1 S&T activities, executed as part of Programmes of Work of other Stakeholders, are not described here, but are included in the yearly reports of the respective executive bodies.

Within this framework, the NATO Nations voluntarily contribute the efforts of some 3500 scientists and engineers, resulting in a portfolio of more than 150 activities on a yearly basis. National laboratories, industries, militaries and NATO staff participate, focusing their efforts on an ensemble of NATO and national priorities.

As already mentioned, the Collaborative S&T Programme of Work and its corresponding business model are described at greater detail in part three of this report.

Using a second business model, a classical 'research institute model', a dedicated NATO laboratory, the (STO) CMRE, which has its own personnel, specific capabilities and infrastructure delivers science and technology focused on the maritime domain and, in particular, the undersea. It is located in La Spezia, Italy, and operates on a customer-funding base as of 1 January 2013. Its main customer is NATO (through the ACT), which orders S&T focused on maritime capability development from the CMRE. Other customers are part of its portfolio as well.

As mentioned previously, the Programme of Work of the CMRE and its corresponding business model are described in greater detail in part four of this report.

2012 Focus and Achievements

OVERVIEW OF THE 2012 FOCUS AND ACHIEVEMENTS

The year 2012 proved a very intense on for NATO S&T. It was especially challenging for the RTO, the RTA, and the NURC (until 30 June 2012), and for the STO, the CSO, the CMRE, and the OCS (beginning 1 July 2012).

Many achievements related to implementing the NATO S&T Reform, executing STO governance and oversight, and executing NATO S&T unified governance were realized:

- The STO Charter was crafted, discussed and approved by the North Atlantic Council on 17 June 2012;
- The RTA and the NURC were transitioned to the STO on 1 July 2012.
- The OCS was set up in the NATO HQ on 1 July 2012;
- The personnel structure (Interim State Peacetime Establishment) of the STO was approved, paving the way for a formal approval of the personnel structure by the North Atlantic Council, and the manning of the organisation and of the OCS;
- Adjustments to the *modus operandi* of the STB have been being defined and implemented. This includes new STB meeting formats, extraordinary meetings to address particular events and sub-groups of the STB (in particular the Maritime Subgroup and the Finance and Audit Subgroup);
- The 2013 Business Plan of the CMRE, comprising a Financial Plan and the Programme of Work (PoW), was approved by the STB;
- Significant progress has been made in the elaboration of the steady-state of the research vessels of the CMRE;
- The CMRE was transitioned successfully to a customer-funded business model, starting to operate as of 1 January 2013;
- The NURC/CMRE 2012 Programme of Work was delivered according to plans.
- The 2012 Collaborative S&T Programme of Work was delivered according to plans by the scientific and technical committees, with the CSO continuing to provide superb executive support to them;
- The NATO S&T Strategy was delivered in December 2012 and subsequently approved by the North Atlantic Council, with the STB being tasked to oversee its implementation;
- A framework to generate a NATO Maritime S&T Business plan was defined by the STB;
- A study on the future of NATO's Operational Research and Analysis (ORA) capability was delivered in December 2012. its implementation to be defined in 2013;
- The S&T connectivity to the other stakeholders has been continuously improved, with the presence of the Office of the Chief Scientist in the NATO HQ proving its value.

In 2013 the STO will continue to face challenges:

- Continuing to deliver the STO Programme of Work while improving its visibility and its exploitation, as well as looking for increased coordination and synergies with other stakeholders;
- Implementing the NATO S&T Strategy (action plans, coordination plan, priorities).
- Producing a Maritime S&T Business Plan and the CMRE 2014 Business plan;
- Defining the solution of the steady-state of the NATO research vessels and the implementation of the retained solution;
- Implementing the conclusions of the ORA Study;
- Implementing STB governance.

• Implementing NATO S&T Reform

The main 2012 NATO S&T Reform objectives, defined by the Nations at the Ministers' level, were:

- To draft the STO Charter and to have it approved by the Council;
- To stand up the STO, i.e., to transition the existing structures to the STO and to create the new structures;
- To deliver a NATO S&T Strategy;
- To transition the CMRE to a new, customer-funded business model;
- To deliver a Maritime S&T Business Plan;
- To deliver a study on ORA in NATO.

All milestones were met. Highlights were, of course, standing up the STO on 1 July 2012, and the delivery, before the end of the working year, of the requested documents (strategy, business plan and ORA Study). This required an extraordinary meeting of the STB at the end of 2012, in addition to the Spring and Fall meetings of the STB earlier in the year.

The STO succeeded in doing so, using existing resources and without impairing the execution of the 2012 Programmes of Work of the 'legacy' Research and Technology Organization (RTO) and the NATO Undersea Research Centre (NURC).

The extraordinary efforts and the dedication of the Nations' STB members and of the implied NATO Staff merit being mentioned.

• Standing up the STO

On 1 July 2012, both the RTA and the NURC transitioned *in toto* into the new organisation, the STO, with the transition structures having been defined and approved by the RTB/STB and the implied bodies.

Also on 1 July 2012, the OCS was created in the NATO HQ. The OCS was able to deploy its activities right from the beginning, with very few personnel, thanks to the generosity and strong commitment of some Nations and individuals, the support of the 'legacy' organisations, and the availability of the NATO Chief Scientist.

During the second half of 2012, considerable time and effort were spent on addressing the formal approval procedure of the personnel structure ('peacetime establishment'):

- The personnel structures were audited and fine-tuned;
- An interim personnel structure (Interim Status Personnel Establishment, "ISPE") was endorsed;
- The further steps of the procedure were prepared, with the aim of having Council approval of the final personnel structure (End Status Personnel Establishment, "ESPE") before the summer of 2013.

With the full completion of the process a prerequisite, recruitment for the OCS was not possible in 2012, limiting its output power.

The other executive bodies were able to function on the basis of the manning of their legacy organisations, with only a limited number of vacancies.

• Establishing Governance

The STB, responsible for governing the STO and the NATO S&T, defined appropriate STB meeting formats and STB sub-groups to exercise its responsibilities. Following the first cycle of these meeting formats, their effectiveness will be evaluated.

The STB created STB Sub-groups and Expert Committees, composed of STB members, in order to address STB issues between STB meetings, and to prepare the decision-making process of the STB meetings.

Having the CMRE as a customer-funded part of the STO led the STB to create a Maritime S&T Sub-Group, led by Dr. Bryan Wells (GBR), to advise the board on Maritime S&T (CMRE) matters. Furthermore, the STB reinforced the Financial & Audit Sub-Group, led by ir. Jelle Keuning (NLD), to advise the STB on financial matters.

The STB also considered establishing a Maritime S&T Committee to assist the STB and the CMRE in the coordination of maritime-related work. This new entity would ensure timely scientific/technical interactions with national experts in maritime S&T and the CMRE, and stimulate proposals for new or expanded research activities for Nations or NATO entities.

• Transitioning the CMRE

One of the most relevant challenges of S&T Reform is the transition of the CMRE to the STO. This process is very complex and multi-faceted, including issues such as the departure of the Centre from the NATO Command Structure (which involved legal challenges such as the transition from the Paris Protocol to the Ottawa Agreement), the transition from a common-funded model to a customer- (or project-based) funding model, as well as the need to find a definitive solution for NATO's research vessels.

This required numerous interactions with several other Committees, including the Military Committee, the Defence Policy and Planning Committee, and the Resources Policy and Planning Board, and the presence of the Chief Scientist and his office proving to be an important success factor.

The successful transition of the CMRE to the customer-funding model was achieved as of 1 January 2013. The continuous support of ACT proved to be a key success factor in achieving this significant result.

At the end of 2012, the STB approved the first-ever Business Plan of the CMRE (the 2013 Business Plan), of which the 2013 Programme of Work and the Financial Plan are key elements. The STB also endorsed a framework for a NATO Maritime S&T Business Plan. This framework will be used to develop a Maritime S&T Business Plan for NATO, taking into consideration a number of additional elements, including:

- The strategic context for maritime S&T in NATO;
- The maritime elements of S&T Programmes of Work beyond those of the CMRE;
- The customer base of the CMRE in the Nations;
- The decisions pertaining to the future of the research vessels and the NATO S&T Strategy and its implementation.

This Maritime S&T Business Plan for NATO will be delivered in 2013.

In 2012, ground-breaking work was performed with regard to the definition of the future of the NATO research vessels the NATO Research Vessel (NRV) *ALLIANCE* and the Coastal Research Vessel (CRV) *LEONARDO*. The STB also jointly conducted a study on these research vessels, with the aim of defining proposals pertaining to a 'final' (or 'steady-state') solution.

In 2012, ACT commissioned an Independent Experts Team (IET) study to provide an evidence base, built on the experience of independent experts familiar with running these kinds of ships in a similar environment, the results of which were published at the end of the year. In parallel, the STB conducted a survey among Nations to obtain their views on the potential use of the research vessels for their own programmes.

In 2013, both results will be aggregated to formulate recommendations. Additional work will be required to explore legal issues.

In 2012, the STB, assisted by its Maritime Sub-group, defined policies regarding the customer base of the CMRE. It is indeed important, in a customer-based context, to clearly define the customer base of the CMRE. Using its HQ presence, the OCS also established the necessary relationships to facilitate the approval by the STB of CMRE projects involving non-NATO entities.

- **Implementing NATO S&T Unified Governance: Strategy and Priorities**

The development of the NATO S&T Strategy began in June 2012, as soon as the STO Charter was approved, and was brought forward by an ad-hoc Strategy Development Team led by Dr. Walter Jones (USA) and composed of representatives of all stakeholders. The STB's aim was to develop the NATO S&T Strategy, consulting extensively across the entire NATO S&T community.

As a result of these early consultations, the NATO S&T Strategy was endorsed by the Conference of National Armament Directors (CNAD) and the Military Committee (MC) in December 2012. The North Atlantic Council approved it in early 2013, tasking the STB to oversee its implementation.

Next steps are the implementation of the NATO S&T Strategy by all stakeholders, with the STB in charge of maintaining the overall coherence of actions.

Furthermore, the definition of NATO S&T priorities will require in-depth reflection and an extensive dialogue between all stakeholders involved. It will need to consider guidance expressed through the NATO Defence Planning Process (NDPP) and through NATO high-level initiatives such as Smart Defence and the Connected Forces Initiative.

It will also need to consider the perspectives of Nation's S&T experts, allowing for the identification of S&T challenges of interest to NATO and the Nations. Finally, it will finally need the STO network of technical experts to continually review emergent technologies of potential interest or concern.

- **Implementing NATO S&T Unified Governance: Coordination and Outreach**

The STO shall act as the focal point for coordinating the STO PoW and the S&T activities in the PoWs of other NATO bodies to ensure collective awareness, synergies, and collective avoidance of duplication and to insure NATO S&T Strategy and S&T priorities alignment.

This important task was taken into account during the standing up of the OCS, which has a Coordination & Outreach Section. The presence of the Chief Scientist and of an STO footprint at the NATO HQ has proved to be an important leverage for coordination and outreach. Indeed, it provided several new opportunities for coordinating with and reaching out to other NATO entities that have a stake in S&T.

In addition to the well-established coordination with the ACT and the CNAD sub-structure (mainly with the Main Armaments Groups and the NATO Industrial Advisory Group, both supported by the Defence Investment Division within the International Staff), new contacts have been established (and existing contacts have been reinforced) with an impressive number of stakeholders:

- The International Military Staff (supporting the Military Committee), in particular with the Logistics & Resources and the Intelligence divisions;
- The Emerging Security Challenges Division (ECSD) of the International Staff, in particular for matters regarding Cyber Defence, Energy Security and Counter-Terrorism;
- The Science for Peace and Security Program (also managed by the ESCD), especially through the STO membership of the Independent Scientific Evaluation Group (ISEG), in charge of reviewing and evaluating proposals for SPS multi-year projects, workshops and training, and making recommendations for approval by the Political and Partnerships' Committee;
- The new NATO agencies, in particular the NCIA and the NSPA;
- The NATO Centres of Excellence.

The membership of the Chief Scientist in the Capability Development Executive Board (CDEB) also contributed to enhancing the STO visibility in the Capability Development community. In this regard, the STO is becoming an active player in the NDPP, representing the S&T Planning domain in several key meetings and a workshop organized by the Defence Planning community.

A number of key meetings for engaging important stakeholders were organized in 2012, among which the most relevant were:

- A Roundtable for early engagement of industry in S&T, held in Paris in March 2012, that provided several significant inputs for the enhancement of the industrial commitment in S&T activities. The engagement with Industry was also reinforced by the setting up of a specific session on technology during the first NATO Industry Day (jointly organised by the ACT and the Defence Investment Division), held in October 2012, and moderated by the Chief Scientist;
- Two S&T Focus Sessions, held both with the Military Committee and with the National Armaments Directors Representatives at NATO HQ (NADREPs) in November 2012, which provided opportunities for high-level discussions on important topics (respectively Urban Operations and Autonomous Systems).

These events also were a starting point for building structured relationships, including the possibility to offer solicited and unsolicited advice, thereby increasing, if necessary, the frequency of the interactions.

Finally, in 2012, the Staff of the OCS also established a dialogue with the R&T Directorate of the European Defence Agency, aimed at ensuring, within the agreed frameworks, mutual awareness of the respective PoWs.

- **Implementation of NATO S&T Unified Governance: ORA (Operational Research & Analysis)**

A review of the ORA assets of NATO was also completed, with recommendations on how best to maximize this capability to the benefit of Nations and NATO.

The Collaborative Programme of Work

DIRECTOR'S INTRODUCTION

The 2012 edition of the STO Collaborative Program of Work (CPoW), while undergoing a significant transition of its governance, has continued to solidify its primacy as NATO's forum of choice for science and technology (S&T) co-operation among its member and partner nations. Utilising a long-standing and effective framework that had its origins in the merging of the early Advisory Group for Aerospace Research and Development (AGARD) with the NATO Defence Research Group (DRG), NATO and its partner nations have again worked together to build and expand the information and knowledge base that is essential for the Alliance to maintain its technological advantage and anticipate tomorrow's challenges.

Under this framework, the NATO Nations have voluntarily contributed the efforts of some 3500 scientists and engineers in activities covering the entire spectrum of environments – space, air, land, and sea – as well as S&T areas: vehicles, humans, sensors, information, concepts, analysis, and modeling and simulation. This has resulted in a portfolio of more than 150 activities in which representatives from national laboratories, industries, militaries and NATO staff have focused their efforts on an ensemble of NATO and national priorities, leveraging their own investments while also enhancing security dialog and cooperation. In the sections that follow, you will be exposed to a sample of the variety of activities that have contributed to the two main effects that the S&T investment is expected to deliver: the development of effective NATO capabilities and support to the decision-making process. While many of these activities have been significantly oriented toward one or the other of these effects, all activities contribute to both, in various degrees and at various times.

While all of these activities continue to contribute directly to making NATO a more effective Alliance, they have also allowed participating nations and organisations to not only augment and leverage their own S&T investments, but have also significantly contributed to expanding the shared information and knowledge base that will enable each nation to bring a higher level of coherence to its pursuit of effective collective capabilities.

The recently enabled NATO S&T Reform has established a Science and Technology Board to provide governance and oversight across the entirety of NATO S&T. As an integral component of that effort, the CPoW, aided by coordination and outreach provided by the Office of the Chief Scientist and the Collaboration Support Office team at Neuilly-sur-Seine, France, is well positioned to provide even more exploitable information, knowledge and coherence to NATO's combined S&T efforts in order to meet the current and future needs of the Alliance.

I look forward to working within this new structure, providing opportunities to enhance the value of our contribution to the Alliance, and invite you to consider that contribution in the pages that follow.

René LaRose, Director, Collaboration Support Office

CPOW OVERVIEW

Collaborative defence research within NATO has a long history. Soon after World War II, at the urging of Dr. Theodore von Kármán, NATO established the Advisory Group for Aerospace Research and Development (AGARD). Some years later, NATO also established the Defence Research Group (DRG). The two entities were subsequently combined in 1998 to create the Research and Technology Organization, comprised of the Research and Technology Agency (RTA) and overseen by the Research and Technology Board (RTB). As part of the NATO Science and Technology (S&T) Reform, the Science and Technology Organization (STO) was established, combining the on-going RTA structure and approach with NATO's Undersea Research Center (NURC), renamed the Centre for Maritime Research and Experimentation (CMRE). Given the goal of achieving additional efficiencies and effectiveness, Nations also made known their expectations that the reorganisation would both avoid disruptions to on-going work, and continue to deliver the high-value products that enhance and maintain NATO's collective capability.

The Collaborative Support Office (CSO), located in Neuilly-sur-Seine, France, host a small cadre of dedicated military and civilian defence science experts who facilitate the research coordination efforts of the Nations. As one of three executive bodies responding to the Board, the CSO follows the leadership exercised by the Board Chairman and Chief Scientist. The spectrum of defence S&T activities are addressed within six Technical Panels and a Modelling and Simulation Group.

AVT	Applied Vehicle Technology Panel
HFM	Human Factors and Medicine Panel
IST	Information Systems Technology Panel
SAS	System Analysis and Studies Panel
SCI	Systems Concepts and Integration Panel
SET	Sensors and Electronics Technology Panel
NMSG	NATO Modelling and Simulation Group

The membership of these Panels is comprised of technical experts from participating NATO Nations who voluntarily participate with the intention to align their nationally funded programmes in order to accelerate knowledge development, avoid technological surprise, and leverage each other's investments. These Panels respond to top-down guidance offered by the Board to respond to NATO concerns, as well as identify bottom-up emergent technologies of interest or concern. In addition, they offer reach-back to the Nations' experts, who assist in the execution of the Collaborative Programme of Work.

The research activities agreed to respond to the needs of both individual Nations and NATO, and take place in a variety of forms, including Task Groups, Workshops, Symposia, Specialists' Meetings, Lecture Series and Technical Courses. In 2012, over 160 activities were underway. The results of these activities are published by the CSO, as well as in peer-reviewed literature.

In 2012, over 2,300 scientists, engineers, and researchers participated in STO-sponsored collaborative technical activities. Of these, more than 2,100 were from NATO Nations, the rest coming from NATO's many Partner Nations. Additionally, almost 1,800 professionals and students from 50 nations attended STO-sponsored courses, lectures, and symposia. This outreach networked major actors from government, academia, and industry in and informed attendees of "entry" opportunities into NATO's collaborative network.

In total, NATO added 63 new technical activities to its CPoW in 2012. Coupled with the on-going activities, 2012's total programme consisted of 152 activities, the third highest in the history of the programme.

Task Groups represented almost three-quarters of the entire CPoW—of the on-going technical activities. The Task Groups enabled researchers in different nations to collaboratively work together in order to solve particular research and technology problems. Task Groups are just one of a number of types of activities in the CPoW "toolkit."

In the following section are provided specific examples of the Collaborative Programme of Work organised in response to the STO mission to help position the NATO Nations' and NATO's S&T investments as a strategic enabler of the knowledge and technology advantage for the defence and security posture of NATO Nations and Partner Nations, by:

- Conducting and promoting S&T activities that augment and leverage the capabilities and programmes of the Alliance and of NATO Nations and Partner Nations in support of NATO's objectives;
- Contributing to NATO's ability to enable and influence security- and defence-related capability development and threat mitigation in NATO Member Nations and Partner Nations, in accordance with NATO policies;
- Supporting decision-making in the NATO Nations and in NATO.

In many of these examples, one can clearly see the uniqueness of the NATO collaborative model. Where one Nation alone may have insufficient resources to explore a capability solution or advance its understanding of a fundamental problem, in concert with multiple trusted Partners it can accelerate knowledge development, advance interoperability and influence its partners to a common goal. It is the value Nations extract from this powerful mechanism that continues to drive their engagement, bring coherence to national investments and advance national and NATO capabilities.

Following these examples are brief descriptions of the Panels/Groups, their missions and scopes of work, as well as additional highlights.

RESPONDING TO THE MISSION

• Influencing Capability Development

S&T investments underlie current and future operational capabilities, and are fundamental to ensuring the continued advantage Alliance forces maintain over potential adversaries. Collaborating in the pre-competitive environment permits more rapid advancement in knowledge generation, information sharing, interoperability and concept development. It is this exploration of multiple research pathways, de-risking potential solutions, and identification of emergent challenges that serves to influence capability development within NATO. The following are offered as examples of these efforts from 2012.

• Supervisory Control of Multiple Uninhabited Systems: Methodology and Enabling Human-Robot Interface Technologies (HFM-170 and HFM-217)

OBJECTIVE: To develop and demonstrate supervisory control design practices and concepts for UV operations.

Uninhabited Vehicles (UVs) are at the forefront of current operations and future thinking. With increasingly automated UVs, the operator's role will become more supervisory in nature, overseeing the automated activation of planned events and managing unexpected changes that impact the automated mission plans. Future vehicles will also have the capability to make certain decisions independent of operator input and pre-defined mission plans. This capability of the UVs to 'decide' actions (i.e., to be autonomous) constitutes a whole new set of challenges for UV operators, as they will be required to rapidly judge the appropriateness of certain UV decisions and assess their impact on overall mission objectives, priorities, rules of engagement, etc. Moreover, there is a vision for a new control paradigm whereby a single operator will simultaneously supervise multiple autonomous UVs.

Unfortunately, there is a dearth of information as to how best to support the coupling of this intelligent autonomy with the unique capabilities and decision-making responsibilities of the operator so as to maximise mission effectiveness across a wide range of mission contexts. New interfaces that take into account issues associated with this automation management, as well as potential negative automation-induced impacts on the operator, are required.

Given the possibility that future operators may likely control many UVs simultaneously, additional human-factors challenges will include how best to maintain situational awareness, a reasonable workload level, and high system performance and safety across several managed assets. New principles for supporting the operator in such scenarios, which focus on supervisory control design methodologies, adaptive automation, and novel-situation assessment/decision-support aids, need to be developed and evaluated.

Additionally, standard operator interface design guidelines associated with UV supervisory control need to be identified so as to facilitate interoperability across unmanned platforms.

In response, this effort concentrated on the identification and demonstration of successful supervisory control methodologies and interface design practices for enabling single-operator control of multiple UVs. The applications addressed varied in degree of autonomy from manual robotic control to highly autonomous, swarming UVs. The Task Group developed and demonstrated pertinent supervisory control human-system interface design practices and concepts for UV network-centric operations through 15 specific technology demonstrations addressing:

- Supervisory control issues and methodologies;
- Human-automation challenges and mitigation techniques;
- Human-automation problem-solving/co-operative dialog;
- Networked telepresence;
- Manned/unmanned collaboration;
- Flexible (adaptive) level of automation;
- Optimisation of human/vehicle ratio;
- Heterogeneous systems;
- Control-station design – decision-support interfaces;
- Augmented remote world;
- Situation assessment aids, augmented feedback of action impact;
- Task-switching, -interruption and -prioritisation methods;
- Predictive/'look ahead' tools, anticipatory support;
- Intelligent aiding, time-critical decision making;
- Multi-modal interfaces, intuitive interfaces, natural-language speech-enabled interfaces;
- Commonality of supervisory control interface design components supporting interoperability;
- Operator knowledge, skills, and abilities.

These demonstrations focused on critical issues, including multi-vehicle control, manned-unmanned teaming, human-automation interaction, telepresence interfaces, delegation interfaces, vehicle hand-offs, operator workload-adaptive systems, variable levels of autonomy, authority sharing, situation-awareness aids, cognitive workload assessment, swarming interfaces, and dynamic mission management.

A Technical Report that summarised these 15 technology demonstrations, including a summary description of the activity, human-factors issues involved, results and lessons learned, was subsequently produced. The report also provides a discussion on the development of a supervisory control framework by which to characterise and communicate research and technology development occurring within the supervisory control domain.

This work directly leverages the completed HFM-078, which developed a comprehensive review of uninhabited military vehicle human-factors issues across a wide variety of human-effectiveness areas and potential military applications. Building off of this acquired knowledge, the Task Group concentrated on the identification and demonstration of successful supervisory control methodologies and interface technologies for enabled single-operator control of multiple UVs with varying degrees of autonomy (including highly autonomous UVs), whether the operator is within a stationary control station, a passenger in a manned vehicle, or operating a manned vehicle.

> Only within the STO's trusted collaborative environment could 16 members from 8 different NATO and Partner Nations jointly execute these technical demonstrations that set the course for doctrine development by NATO bodies, and provide a guideline for future research and development of this important future capability.

Figure 1. RoboLeader in a Multi-Tasking Environment.

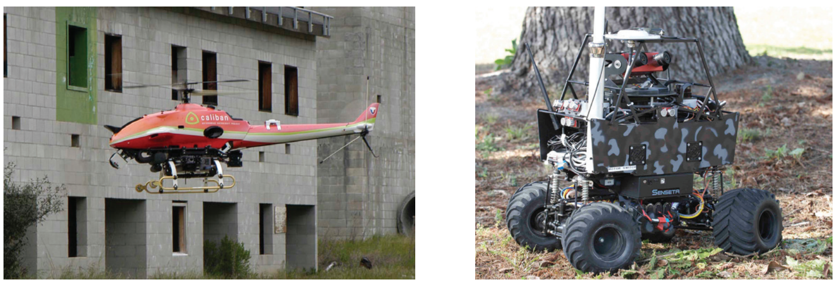

Figure 2. Live Yamaha RMAX Vertical Take-offand Landing (VTOL) AS (left) and and MAX over Unmanned Ground Vehicle (UGV) (right)

Figure 3. Vehicle with Towed Ground-Penetrating Radar and Several Electro-Optic Detection Systems.

• Detection and Neutralisation of Route Threats (SCI-193) and Route Threat and Clearance Technologies (SCI-256)

OBJECTIVE: To investigate the physical and operational potential and limitations of techniques for stand-off detection and neutralization of route threats, such as landmines and IEDs.

The threat of Improvised Explosive Devices (IEDs) is a critical vulnerability to NATO forces in the current operating environment. IEDs are a staple of enemy tactics in present operations current operation in Afghanistan. With world-wide attacks currently numbering 270 per month, terrorists and insurgents will continue to utilise these devices in asymmetrical operations in order to offset the Alliance's technological and material advantages. Consequently, it is vital to develop new technology, tactics, techniques and procedures to detect and defeat these devices.

The SCI Counter-Improvised Explosive Device (C-IED) Team, led by Dr. Arnold Schoolderman of the Netherlands, has executed a series of activities, including extensive field tests to evaluate, improve and eventually field systems to help forces detect these devices.

Starting with SCI-193, Detection and Neutralisation of Route Threats, scientists and engineers from eleven NATO and Partner Nations have collaborated to develop detection technology. Detection techniques considered included infrared, electro-optical and radar systems, and other emerging technologies. The sensor technologies were complemented with the appropriate signal- and data-processing techniques. Neutralisation techniques were matched to the detection techniques and the threat.

Testing took place in the United States in 2008 and in France in 2010. A wide range of systems was tested for effectiveness, including vehicle-towed ground-penetrating radar; counter-IED canines; command wire detectors; explosive detection systems based on the Raman effect; and dual-sensor detectors that included ground-penetrating radar and metal-detection technology.

This effort continued with SCI-256, Route Threat and Clearance Technologies. Expanding on the work done in the previous effort, the new activity emphasised a limited number of techniques that are potentially suitable for mounted stand-off detection. The work and initial trial held in the Netherlands in October 2012 focused on change-detection systems, and included both optical camera-based platforms and Light Detection and Ranging (LIDAR) technology used to create a synthetic 3D environment.

> The SCI technical team integrated multiple approaches to produce a promising field-tested technique for mounted stand-off detection.

The SCI-256 trial was funded in part by both the Conference of National Armaments Directors (CNAD) Voluntary National Contribution Fund and the STO Co-operative Planning Programme. This displays an important synergy within NATO to address the critical issue of defeating IEDs.

As SCI-256 moves forward, the Team will continue to look at detection, as well as advance neutralisation techniques. Some technologies considered for future tests include non-linear junction detection; high-power microwave for neutralisation; Unmanned Aerial System (UAS)-based detection; and the use of dogs and vapour detection.

The SCI Technical Team integrated multiple approaches to produce a promising field-tested technique for mounted stand-off detection. The Team will continue to translate these research advances into practical products to support Alliance operations. This will be accomplished through close co-ordination by the STO with other NATO bodies, including Allied Command Transformation, the Conference of National Armaments Directors, and the Counter-IED Center of Excellence.

• Design for Disposal of Present and Future Munitions and Application of Greener Munition Technology (AVT-179)

OBJECTIVES: To review the current environmental needs, capabilities and opportunities in munitions procurement and management, and to recommend ways for NATO and Partnership for Peace (PfP) Nations to improve their capabilities in these areas. This included: 1) identifying the critical issues for the effective Design for Disposal of Munitions, including explosives, pyrotechnics, initiators, missiles, gun propellants, and non-energetic weapons; 2) examining ways of producing and employing greener munitions; and 3) making recommendations on future policy, including identifying the critical issues for the effective Design for Disposal of Munitions, including explosives, pyrotechnics, initiators, missiles, gun propellants and non-energetic components; to examine ways of producing and utilising greener munitions, and make recommendations on future policy including assessing developing technology for applicability.

The forces of NATO and the PfP Nations possess large quantities of munitions. Weapons must be dismantled and the energetic materials destroyed or dealt with in a manner that does not harm the environment and that ensures safety. New disposal techniques that convert the munitions components, including energetic materials, to harmless bi-products that do not pollute the environment are required. In some instances, it is possible to reprocess materials for installation in new weapons or for alternative civil use. This is to be welcomed, from a sustainability perspective, but processes must still meet stringent environmental requirements. The safety and cost effectiveness of the process needs to be assured. *Design for Disposal* is a critical route to meeting the requirement for 'duty of care'.

Environmental control legislation is becoming tougher on emissions and disposal of residues. The design of new weapons must include disposal procedures and an environmental impact statement. The understanding of munition disposal is lagging behind this design requirement. It is important to fully understand the environmental issues so that they do not place undue constraints on the design of weapons. Equally as important, public opinion and pressure will have an impact on what is acceptable within NATO Nations, and this will have an effect on what is required for 'duty of care'.

Through appropriate utilisation of the STO collaborative network, the Task Group has brought together a group of scientists (22) from 10 Nations to address a persistent problem within NATO, that of the safe and environmentally friendly disposal of munitions. The methodologies and protocols developed by AVT-179 have the potential to save NATO Nations millions of Euros in range-cleanup and munitions-disposal costs. The recommendations developed from the information gathered by this Task Group will have an impact on reducing the health costs associated with medical problems encountered by military personnel regularly exposed to contaminants released during live-firing training exercises. Another important result of safer and easier disposal of munitions is the potential to reduce the risk of stored munitions falling into the hands of terrorists.

The methodologies and protocols developed by AVT-179 have the potential to save NATO Nations millions of Euros in range-cleanup and munitions-disposal costs.

The Group has successfully examined the scale of the problems and identified the key areas that were found to differ in many respects from the received wisdom. It is not merely a matter of synthesizing new improved materials, but also one of ensuring that manufacture, use and disposal are considered. This is much more complex, and, to assist in the study, the Group examined and tested the methodologies used both in defence and civilian applications for examining life cycles.

Two different models were discussed, that of the United Kingdom and a more detailed modeling approach as devised in France and Portugal. Both have strengths and weaknesses, and in order to attempt greater quantification, they were tested on a standard artillery shell. The results provided confidence in a baseline for examining new or changed materials. The approach proved sound, though the results indicate gaps and opportunities for future study.

Never before in the history of the AVT Panel have so many scientists and researchers gathered to produce such a comprehensive package of both field experiments and analytical data, or interacted with so many other NATO Armament Groups and Agencies. It is abundantly clear that AVT-179 is an excellent example of the mission of the STO to conduct co-operative research and information exchange, and exemplifies the mission of the AVT Panel to improve the performance, affordability and safety of vehicles through the advancement of technology. AVT-179 has produced a truly significant scientific contribution to the NATO knowledge base, one that will have a direct impact on defence costs and safety, with an outstanding level of international and intra-NATO collaboration.

• Characterisation of Bio-Inspired Micro Air Vehicle (MAV) Dynamics (AVT-184)

OBJECTIVE: Characterising the dynamics of bio-inspired MAVs and understanding key engineering principles related to different modes of Micro Air Vehicle operation.

The AVT-184 Task Group studied the flight dynamics of Micro Air Vehicles (MAVs) and used the acquired data to better understand how they fly. Researchers decided which dynamic quantities to characterize; selected a small number of existing vehicle configurations to test; determined how to characterize quantities of interest in a manner common to the different vehicles; compared and contrasted innovative experimental techniques and analysis methods; adopted a common nomenclature; defined operational metrics of merit (e.g., for efficiency, speed, agility); shared and collaboratively analyzed collected data; and disseminated key findings and lessons learned to the STO community through a Technical Report.

This study focused on MAVs fabricated at universities, where expert-led, enthusiastic students meld ingenuity with a wide range of engineering skills to develop and/or modify flight-worthy aircraft. Vehicles whose propulsion is produced by moving wings are of key interest. Like (birds, bats and insects) that inspire flapping MAVs, these craft have great maneuverability; the smallest may be highly suited to operation in built-up areas or confined spaces. Typical wingspans range from 10 cm to almost 1 m, as shown in Figure 8. The defence sector has a growing interest in the operational potential of MAVs to expand Intelligence, Surveillance, Target Acquisition and Reconnaissance (ISTAR) capability in urban operations, and to meet security needs for unconventional and/or asymmetric threat environments. The recent proliferation and evolution of MAV concepts is indicative of an early point on the S-curve for this form of robotic aerial technology, and is part of a broader upward trend in the larger Small Unmanned Aircraft System (SUAS) technologies.

The aerodynamic, aeroelastic, and flight-dynamic characteristics of MAVs are poorly understood. Very little data, e.g., instantaneous wing shape, power utilisation, body position and orientation, and gust handling, has been systematically collected. When feasible, this data is most beneficial when recorded while the vehicle is in free flight and can thus avoid constraint effects, (absence of rigid-body motion and potential mischaracterization of flight loads) whose impact on system behaviour may be significant. New diagnostic test techniques that are well suited for careful study of MAVs have appeared, and include: motion-capture technology to capture MAV dynamics during flight (see Figure 9), which shows reflectors affixed to vehicles); digital image correlation for recording instantaneous wing shapes; and 3D particle image velocimetry for capturing flow-field structures produced by flapping. Motion-capture technology, implemented indoors, enables MAV motions to be recorded with high accuracy in space (mm precision) and time (ms precision), and free of outdoor environmental uncertainties.

Piloted tests of flapping vehicles (DelFly III, two UA ornithopters, and two WSU flappers) conducted at the Air Force Research Laboratory (AFRL) at Wright-Patterson Air Force Base, Ohio (USA), revealed important wing-body couplings and aeroelastic changes in wing shape resulting from flapping flight.

By conducting this effort within the STO collaborative environment, AVT-184 was able to target the potential benefits of NATO technical exchange on definitions, testing procedures, and performance measures. This data will be used to develop vehicle autopilots, answer questions about vehicle stability during certain maneuvers, and conceive better wing-structure layouts for reducing power consumption. Proposed follow-on efforts include: investigating the utility of MAVs from a security/rescue perspective; studying MAVs in an ISTAR system context; validating computational aeroelastic models; characterizing MAV gust response; and continued development of autopilots for flapping MAVs.

• Cognitive Radio in NATO (IST-077)

OBJECTIVES: To review and synthesise the military applications of Cognitive Radio technologies explored within NATO Nations, and to review civilian technologies available for military Cognitive Radio both currently and in the mid- to long-term.

In multinational and coalition operations, frequency spectrum must be carefully managed in order to allocate channels to all participants. In NATO, frequency management is based on a static allocation of spectrum bands and frequencies. While this is effective for interference avoidance and is necessary for some users, it prevents dynamic reuse of allocated bands that are not in use. For modern radio systems that are more tolerant of interference, a more effective spectrum-access strategy would be to allow radios to adapt their operating frequencies in response to the changing propagation and interference environment. This strategy, which is the basis of the Cognitive Radio (CR) technology concept, is anticipated to provide a more effective use of spectrum in order to increase usable bandwidth in congested theatres of operation, and provide increased robustness in dynamic conditions.

The STO collaborative environment was particularly appropriate for examining the multi-national, coalition-based issue of cognitive radio. IST-077 agreed to review and synthesize the Research and Development (R&D) in CR technologies for military applications, and to investigate the technology and its implications for future NATO operations. It is particularly noteworthy that this activity is the first initiative to address the use of Cognitive Radio in NATO.

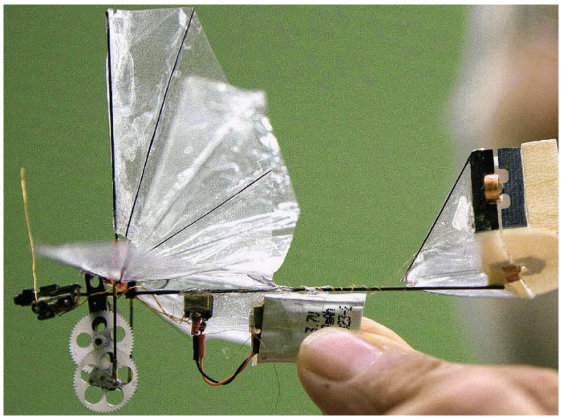

Figure 4. MAV Configurations: (left) Delft University of Technology (TU Delft) DelFly Micro (10 cm).

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Figure 5. MAV Data Collection: TU Delft DelFly III Marked with Reflective Tape and Hemisphere Markers; Wright State University (WSU)

The Group focused on the co-existence of coalition tactical networks operating in the same theatre (i.e., cognitive radio networks that are not centrally co-ordinated), and demonstrated the need for a common framework with which to provide a fair basis to compare different CR solutions in realistic simulations of operational scenarios. To this purpose, the Group has begun development of a new simulation methodology that considers the impact of spectrum use by each network on the others nearby, and the successful provision of necessary services within all networks simultaneously.

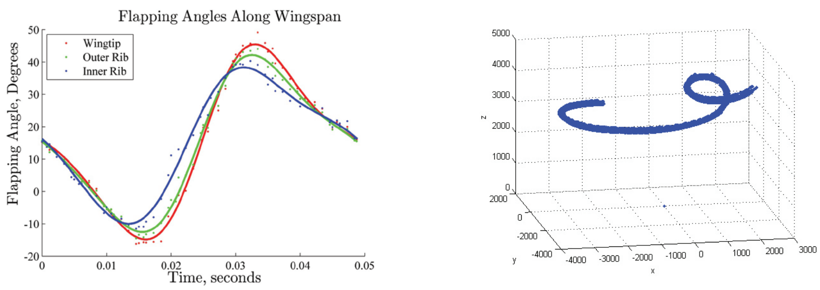


Figure 6. (left) Flight Trajectory of DelFly III; Wing Deformation of UA 25 cm Ornithopter while in Flight.

This simulation methodology is partly the result of cooperation within NATO, as it is based on the operational vignettes produced previously by the NATO Communications and Information Agency (NCIA). The chosen vignette considers preventing the hijacking of an aid convoy within a multinational coalition context.

The methodology, which can be applied to any of the current or future NATO vignettes, provides a framework with which to compare CR solutions, based on their ability to support a range of services, such as voice, data and video, and will be instrumental in helping to identify promising strategies for more effective spectrum access. Continuing efforts are needed to determine the most effective strategies and to evaluate the dynamic co-ordination of coalition networks.

• Impact of Lifestyle and Health Status on Military Fitness (HFM-178)

OBJECTIVES: To examine the underlying negative trends on military fitness; to identify and evaluate relevant data sources; to develop a database and tools for pre-employment screening, personnel planning, and design of equipment and workplaces; and to identify effective intervention strategies for education and training.

Soldiers must be physically and mentally fit for the job in order to withstand the rigours of today's missions. To date, soldiers have been considered relatively immune to sedentary lifestyle issues because physical selection and regular physical exercise are integral parts of military service. However, the past decade has shown that military recruitment and retention, military fitness and readiness, and medical consumption are strongly and progressively affected by the widespread and increasingly earlier establishment of unhealthy lifestyle behaviours among soldiers. In the last few years, medical encounters and work absenteeism among military personnel have risen sharply. Even more worrying, in particular for the military, is the phenomenon of presenteeism, in which substantial losses of performance and resilience, as well as a shrinking ability to perform under stress, occur in working personnel long before diseases become apparent, and the manner in which it is almost entirely disregarded. These creeping changes are affecting combat readiness at both the individual and the operational unit level.

The Technical Report produced from this effort represents the international agreement on evidence-based findings relevant for health and fitness promotion in the military. Each chapter provides recent evidence obtained by review of the scientific literature. A major limitation in the reviewing process has proven to be the widespread lack of structured collection, sampling, recording, and analysis of health- and performance-related data in military recruitment, physical training, and medical consumption. This 'black box' is a poor basis for supporting military decision-making processes regarding health and fitness promotion.

The considerable impact of adverse lifestyle habits on the military has grown significantly during recent years, fuelled by the on-going demographic changes, the further decrease in numbers of able-bodied and healthy service members, the reduced performance and resilience of soldiers, and the increasing financial burdens resulting from work presenteeism, absenteeism and medical consumption. Many areas, such as recruitment, training and education, and medical care – the main topics of the Technical Report – are directly affected by these negative changes. It can be taken from published literature and the existing data that previous countermeasures and initiatives have failed or have had no lasting impacts. The main reasons for these shortcomings are:

- The lack of sound baseline data and science-based concepts resulting in generalized and often unstructured (rather than individualized and targeted) interventions;
- No adequate infrastructure and tools for the long-term implementation of effective campaigns into daily military routine and organisations;
- Mostly non-existent reward-punishment systems for soldiers to maintain or increase their fitness and health.

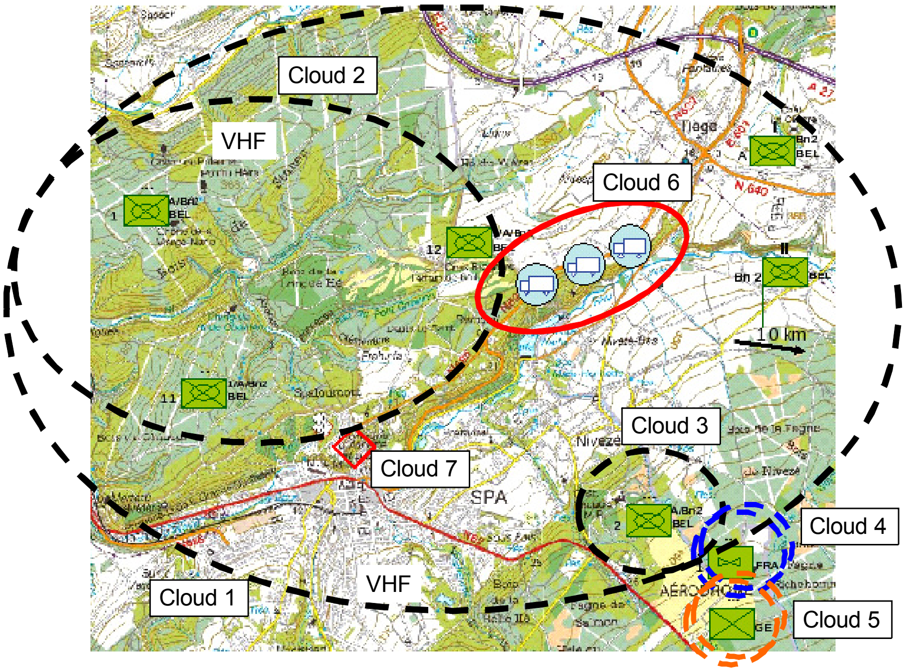


Figure 7. Mapping of the 'Preventing the Hijacking of Aid Convoy' Vignette into Clouds.

Based on the experiences of the 17 participating members from 9 different NATO and PfP Nations, as well as over 400 references from the scientific literature, this Report highlights a number of countermeasures that can lead to improvements in the main domains of interest, i.e., recruitment, training and education, and medical care. These measures concern, for example, the establishing of appropriate enrolment standards; preconditioning of military recruits to help them attain physical fitness requirements prior to their enrolment into basic training; and the use of state-of-the art training principles (e.g., differentiation and individualization) to anticipate the seemingly ever increasing inter-individual differences in the physical performance of today's recruits. Physical training and exercise can also be a powerful tool in tackling health-related fitness issues in older military age groups) if health programmes are built according to a number of key factors, including the proper use of tailored interventions, software-based tools, and state-of-the-art exercise guidelines.

It is clear that, if further negative effects are to be avoided, armed forces must identify and remove barriers to physical activity, promote physical activity and healthy behaviour in daily life, and motivate military members to engage in regular and effective physical activity. This requires considerably more funding and research, as well as strong links between experts from the operational field and from other disciplines such as exercise physiology, psychology, and medical care.

• Deployable Multi-band Passive/Active Radar (DMPAR) for Air Defence (SET-152)

OBJECTIVE: To study the capabilities of a future type of radar that would combine passive and active modes of operation, and use multiple radar bands for better performance in air defence applications.

Following the encouraging results of multi-band radar trials carried out by SET-078, the SET-152 Technical Team conducted a study on the capabilities of a future type of radar that would combine both passive and active modes. One outcome of the study was the development of a system concept for a Deployable Multi-band Passive/Active Radar (DMPAR). The DMPAR concept indicated the critical components, proposed solutions, specified performance expectations, and proposed new approaches for system performance verification.

Future deployable air surveillance and defence solutions may no longer use a variety of radar systems optimized for specific tasks, but rather employ multi-function radars that are able to meet the requirements of multiple military scenarios and challenges. Such deployable radar sensors should utilise all technical and technological capabilities that are expected to become available in the next 15-20 years. Passive radar concepts, which allow the use of a large variety of remote transmitters and active multi-band radars, and which are designed to exploit the best properties of different bands for different tasks, share a number of common technical and system features. Furthermore, they have the potential to be mutually complementary concerning their surveillance capabilities, such as low-level coverage, anti-stealth, high update rate, high resolution, and non-co-operative target identification.

> The composition of members from academia, industry, and the military, enabled solutions that would have been far beyond the capabilities of a single entity to perform outside the NATO STO environment.

The DMPAR system concept, which has been proposed and validated by functional and performance simulations, consists of four integrated components covering frequency bands from Ultra High Frequency (UHF) to X-band. Active, as well as passive modes of operation, which exploit broadcast emissions, are implemented in order to optimize sensor performance dependent on the threat scenario. A sketch of the integrated system indicating its components is shown in Figure 11.

When transporting the DMPAR system, the entire antenna structure can be collapsed into the lowermost antenna, as depicted in Figure 11. The circular dipole antennas of the Low Frequency Passive Radar portion can be located inside the sensor platform.

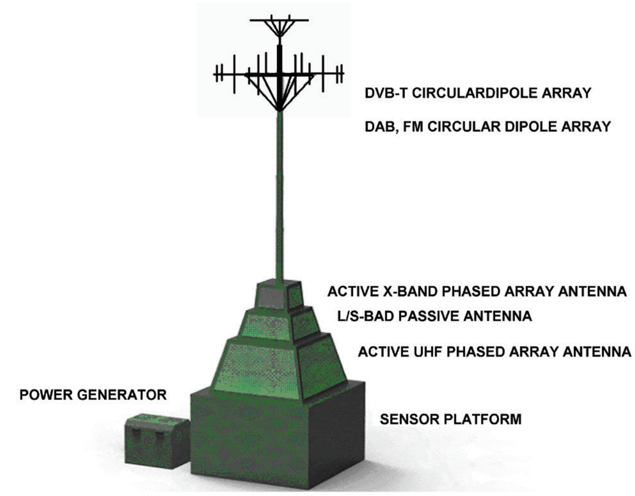


Figure 8. DMPAR System Design Proposal.

In addition to the DMPAR system concept, architecture and component design, with a realisation horizon beyond 2020, short- and mid-term solutions approximating the performance of a DMPAR were also proposed.

As mid-term perspectives, the joint co-located operation of active and passive systems with a common data-fusion processing approximating the centralised DMPAR approach and a joint Passive Emitter Tracking (PET) and Passive Coherent Location (PCL) processing were considered.

The development of a conclusive system concept that respects not only the algorithmic background of new processing schemes and procedures, but that also takes into consideration system realisation aspects and hardware constraints, has been a great challenge for this multinational team. The composition of members from academia, industry, and the military, and the dedication of all involved, enabled solutions that would have been far beyond the capabilities of a single entity to perform outside the NATO STO environment.

• Support Decision Making

One pillar of the STO Charter addresses the expectation of the STO to support decision making in the Nations and in NATO. The products and processes researched within the CSO collaborative environment serve to influence decision makers at multiple levels. Knowledge is developed and shared in order to inform policy, provide standards, and identify future concerns for consideration and decision. Contributions that affect current operational concerns and serve to influence Nations' investment strategies are also made. The following are offered as examples of these efforts from 2012.

• Factors Affecting Attraction, Recruitment and Retention of NATO Military Medical Professionals (HFM-213)

OBJECTIVE: The objective was to collect, and assess information about national efforts to attract, recruit and retain specialised medical personnel. Current demographic change and increasing competition for these personnel on the civilian health market necessitate creation of a 'best practice-based' toolbox with targeted measures to mitigate critical shortfalls in the medical arena. This was achieved by a social-scientific assessment of contributing Nations' situation reports.

For several years, available medical capabilities, including Multinational Medical Support, Aeromedevac, and Deployable Medical Facilities, have been identified as being insufficient to meet NATO's level of ambition.

Efforts and plans to mitigate these shortfalls are in progress, and Nations are encouraged to implement the proposed steps. A key factor in the delivery of such capabilities is the availability of suitably qualified medical personnel. At the informal Defence Ministers' meeting in February 2010, the issue of the recruitment and retention of specialized medical personnel was addressed as a pressing concern for several Nations. Military medical services, however, are increasingly in competition with their national civilian health systems for qualified medical personnel. For this reason, the attractiveness of serving as a medical officer or non-commissioned officer (NCO) is a key issue for meeting NATO's requirements.

As requested by the Committee of the Chiefs of Military Medical Services (COMEDS) in 2010, the NATO STO HFM Panel established the HFM-213 Task Group on 'Factors Affecting Attraction, Recruitment, and Retention of NATO Military Medical Professionals'. This Task Group has undertaken a social-scientific assessment of personnel situations in the military medical services of contributing Nations, including existing or expected shortfalls, and measures already taken or initiated to overcome them.

The study was conducted primarily through the use of questionnaires presented to specialists in the recruitment and retention of medical personnel in participating Nations. In this way, all NATO Nations and PfP Nations were invited to support the work of the Task Group, which was supported by the German Bundeswehr Institute of Social Sciences (BISS).

The topics that were covered in the Technical Report were:

- Environmental factors (e.g., demography, situation in civilian health market);
- Attraction factors of serving (e.g., public image, political support);
- Recruitment advantages and disadvantages (e.g., education, adventure, health care versus bureaucracy, payment);
- Retention advantages and disadvantages (e.g., safe employment, pension versus deployment, limited career);
- Applicable tools to compete with the civilian health market for qualified medical personnel.

The findings of the Task Group can be grouped into seven basic measures of recruitment and retention:

- Financial incentives;
- Flexible forms of service and employment status;
- Compatibility of career and family;
- Career planning and professional development;
- Training measures;
- Advertising;
- Other measures.

Without cooperation from NATO and its Partners, comprised of nine members from eight different Nations this activity would not have been possible. Within NATO, this Technical Report can be used as a guideline for adapting the findings and advice to military medical recruitment and personnel systems. Nations are encouraged to implement the proposed steps, as the study clearly showed that countries that do, encounter fewer problems in the recruitment and retention of military medical personnel.

• Missionland: A Universal, Generic Multi-Spectral Simulation Environment Database (MSG-071)

OBJECTIVE: To construct a coherent dataset from which environmental databases for a wide scope of simulators can be constructed. These environmental databases are generally needed for visual out-of-the-window and sensor views, but terrain servers and computer-generated forces applications often make use of such databases as well.

Distributed simulation and training exercises are growing in importance within the NATO community, as the requirement to respond rapidly to changing world events means that rapid and flexible multinational forces are needed for a variety of purposes, ranging from peace-keeping and emergency relief to preparation for contingent military operations.

Previous distributed simulation exercises have demonstrated a requirement within NATO for a single environmental dataset to be used for these exercises, as the creation and correlation of synthetic environments is both expensive and time consuming.

The STO MSG-071 Task Group 'Missionland' was established in 2008 to investigate the requirements for and to ultimately produce a non-geospecific (generic) environmental dataset for use in distributed multinational simulation and training exercises within NATO and PfP Nations.

The scope of this Task Group was to provide a static, sensor-capable, environmental representation of a substantial geographical area containing different geologies, climates, and feature types in order to enable use within a wide range of simulation systems.

Enabled by the STO collaborative environment, the eight-nation Task Group worked for four years, using a mixture of innovative and established technologies, to produce a

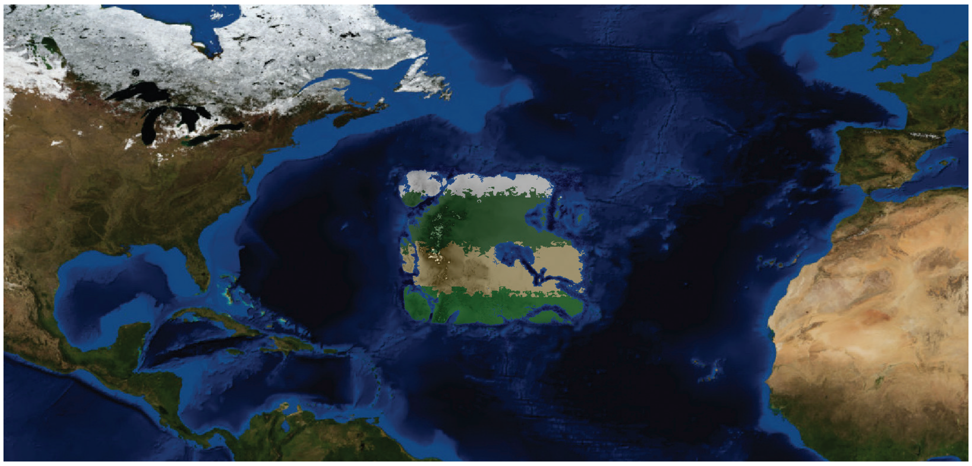


Figure 9. Missionland.

coherent and consistent dataset comprised of four million km² of terrain (approximately the size of Western Europe) set in the middle of the North Atlantic Ocean. The Group overcame significant technical problems and solved non-technical issues regarding intellectual property rights, the re-use of data, and capability development issues to add new data in order to improve functionality.

Despite the technical innovation required, the Task Group's activities were successful in generating the Missionland dataset, which can now be used. For maximum utility, however, further work is required to ensure that the data is safely stored and distributed, tools are maintained, users of the dataset are adequately supported, and specific improvements for exercises using Missionland are added.

The Technical Report is not the sole result of the Task Group's activities. Tangible items such as the dataset and associated software tools, as well as definitions for conditions of use and a contribution guide that will allow future additions, were additional successful outcomes.

• Psychological and Physiological Selection of Military Special Operations Forces Personnel (HFM-171)

OBJECTIVE: To improve the validity of SOF personnel selection processes, including both psychological and physiological elements and their interaction.

In light of current global issues, NATO has received an increasing number of requests to deploy military forces to unstable regions. Special Operations Forces (SOF) units are the 'force of choice' for counter-terrorism and asymmetrical warfare. In these multi-national operations, cooperation and trust are essential. However, there is limited sharing of knowledge within NATO regarding the psychological and physiological qualities required of SOF personnel. Each Nation has its own selection methods that, to date, remain confidential. Accordingly, a forum to allow for the exchange of selection methodology and research results is required. This will facilitate and optimize the efficient identification and measurement of the attributes required to maximize SOF performance. The ultimate objective is to ensure that SOF personnel possess the necessary competencies to achieve mission success.

The operational deployments of NATO Special Operations Forces demand a high level of performance in counter-terrorism and asymmetrical warfare. This requires SOF personnel to be extremely fit both mentally and physically. NATO Nations have each developed methods to ensure SOF units attract, select and retain the best performers.

The overall objective of this Task Group was to establish guidelines to improve the selection processes for SOF personnel derived from best practices and evidence-based research, including both psychological and physiological elements and their interaction. This is done by identifying physical and psychological attributes that are required in order to maximize SOF performance and mission success. The most appropriate methods for measuring these attributes are detailed in this report.

> [This Technical Report] can be used as a source for NATO Nations interested in designing a SOF assessment and selection system, or for those wishing to strengthen an existing system.

During the International Military Testing Association meeting in Kingston, Canada, in October 2006, the Dutch delegation proposed inter-NATO co-operation in which research methods and results could be exchanged with respect to the psychological selection of military SOF personnel. Subsequent discussions identified the need to integrate the physiological aspects of personnel selection. Various Nations have identified the requirement to exchange best practices and selection research. The objective to improve personnel selection processes derived from evidence-based research. HFM-171 focused on the process of selection, and expands on the work of HFM-107 on recruitment and retention of military personnel, which was completed in 2007.

In the final Technical Report, the following topics were covered:

- A description of SOF selection procedures in terms of Western industrial-psychology guidelines. The development of a valid SOF assessment and selection system is documented step-by-step, with an emphasis on job analysis and multiform assessment. This document can be used as a source for NATO Nations interested in designing a SOF assessment and selection system, or for those wishing to strengthen an existing system;
- A review of available research on physical aspects of SOF soldier-selection and physical-performance challenges that is presented to SOF candidates by NATO Nations during selection;
- New trends in research and development in the selection testing of SOF operators are reported. For success on the battlefield in the next decade, it is essential to identify the future requisite SOF competencies and the appropriate measurement techniques. While current diagnostic methods are viewed as successful, selection procedures should be as efficient as possible. Personnel selection must be cost-effective, particularly in today's resource-constrained environment.

Without the STO collaborative environment and the cooperation of 18 members from 11 different NATO and PfP Nations, this activity would not have been possible. Within NATO, this Technical Report can be used as a guideline for constructing and improving the selection process for SOF personnel.

• Interactive Visualisation of Network Dynamics (IST-085)

OBJECTIVES: To compare the utility of various interactive visualisation styles for providing the user knowledge of the dynamics of a network, and to develop the required experiments to provide insight into which characteristics of interactive visualisations are most likely to aid the military user in determining and predicting the types of change happening within a network.

Visualization, a means by which people make sense of complex data, can be seen as a human activity supported by technology. A key element of visualization is the interface through which the human interacts with the data. It includes not only the 'how', but also the 'what, when, where, and why' of information presentation and control. For successful network discovery, simulation and prediction supporting adaptive operations, political effects, public health and other security issues, uncertain environments, and abstract concepts, one needs to understand how to visualize the changes taking place within a network (the dynamics) and the trends within that change.

The human is part of the process of producing and refining the presentations that support decision making. Military applications of Interactive Visualization of Network Dynamics are extremely broad and include Network Common Operational Picture (NetCOP), an essential tool in Network-Based Operations (NBO) and in understanding network interdependencies. Of increasing interest are applications to cyber warfare, special operations, urban warfare, and counterterrorism. Utilizing these techniques to visualize threat networks of relationships, including causal or probabilistic networks, gives insight that can influence the planning of military and civilian protection operations.

IST-085's goals were to understand the visualization of all types of networks, not only those of computers, and to examine:

- representations of networks;
- the best methods for visualizing the network structure;
- dynamic network representation (e.g., if a network changes over time, how can this be represented?);
- methods for optimizing various networks and combining them;
- developing tools to maintain linkages no matter the structure.

Enabled by the STO collaborative network, IST-085 Task Group engaged with various organisations, including the National Visualization and Analytics Centre (NVAC), the Vancouver Institute for Visual Analytics (VIVA), the UK Visual Analytics Consortium (UKVAC), and the Visual Analytics for Command Control and Interoperability

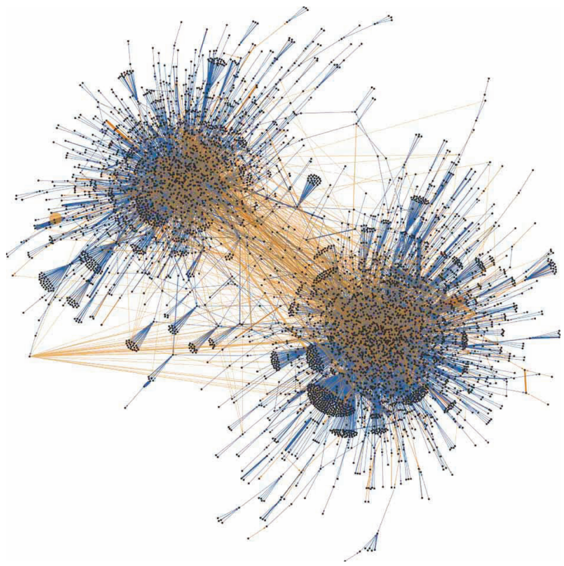


Figure 10. Visualization Captures Interrelationships Within Dynamic Layered Networks.

Environments (VACCINE) Centre, which assisted in the instigation of technology creation and the evaluation of developed technology, and engaged in technical exchanges in order to further NATO goals and objectives.

Among the key accomplishments of the IST-085 Task Group was the progress that was made on forwarding a unified framework for network analysis that includes Visualization of Dynamics. By advancing fundamental research and furthering interaction with the global technical community, the Group helped to:

- focus the attention of other researchers on problems that require additional effort;
- ensure that issues of importance to NATO objectives and military missions were addressed;
- open new areas of research.

The next steps for the follow-on Group will be to focus on visual analysis, and to develop candidate implementations of previous results in a Web-demonstration format in order to aid in transition to military users.

• NATO Education and Training Network (MSG-068)

OBJECTIVE: To assess the distributed simulation and learning capabilities that NATO and Partner Nations, schools, and agencies have that could contribute to the development of a NATO Education and Training Network (NETN) capability. The Task Group will recommend a way forward for interoperability, technical standards, and architectures to link these training and education centres in order to provide a persistent capability. The Task Group will also identify and recommend roles and responsibilities of the NATO and Partner-Nation organisations responsible for distributing and maintaining M&S and Advanced Distributed Learning (ADL) capabilities within the scope of NETN.

In recognition of current and anticipated operations, NATO established the need for, and initiated the development of, a distributed and networked education and training capability subsequently titled the NATO Education and Training Network (NETN). The NETN was created in order to integrate and enhance existing national capabilities, and to focus on the education and training of NATO Operational and Tactical Headquarters' staffs and NATO forces preparing to execute NATO Response Force (NRF), Combined Joint Task Force (CJTF), International Security and Assistance Force (ISAF) and other future NATO missions. For these missions, NATO provides and trains combined headquarters, and NATO Nations assign trained tactical forces. Therefore, the training of the combined headquarters is the responsibility of NATO, while Member Nations are responsible for the tactical training of the assigned forces. An NETN comprised of a persistent infrastructure, distributed training and education tools, and standard operating procedures not only supports the training of NATO headquarters, but also enables the Nations to collaborate with each other to train their tactical forces and headquarters. NETN promises a more efficient and less costly capability for these purposes, as well as broader and deeper interoperability. It also introduces an opportunity to integrate the training of NATO headquarters with the tactical forces, when needed, for short-notice, mobile mission-rehearsal training and other integrated exercise requirements.

> NETN promises a more efficient and less costly capability, as well as broader and deeper interoperability.

Current and emerging operational requirements increase the need for a highly available, agile, flexible and cost-effective NETN. Existing capabilities, such as the NATO Airborne Early Warning and Control (AEW&C), and enhanced capabilities, such as UASs, joint intelligence, surveillance and reconnaissance, Friendly Force trackers, C-IED, and cyber defence are being integrated into ISAF and NRF operations and preparations. New capabilities such as Air Command and Control Systems (ACCS), Airborne Ground Surveillance (AGS), and Active Layer Theatre Ballistic Missile Defence (ALTBMD) are also in development. In addition, NATO is increasingly operating alongside non-NATO military forces, as well as Non-Governmental Organizations (NGOs), placing further new demands on current NATO tactics, techniques, and procedures. This combination of enhanced capabilities and evolving operational requirements exerts force on NATO to ensure that it and its national command and control systems, weapon systems and tactics, techniques and procedures are all interoperable with each other and, where appropriate, with other coalition allies, from the highest levels of the NATO Command Structure (NCS) to the lowest levels of the NATO Force Structure (NFS). For these reasons, there is an essential need for a common NATO training and education distributed environment in which both the NCS and the NFS, as well as NATO Nations and Partners, can routinely train 'as they fight' in order to boost standardization and interoperability, while at the same time reducing duplication of effort and enhancing the efficient use of resources.

To meet this operational demand, the ACT requested that the NATO Modelling and Simulation Group (NMSG) start a technical activity in 2006. NMSG tasked an Exploratory Team (ET-025) to analyse the requirement and begin a technical activity. ET-025 formed Modelling and Simulation Group 068 (MSG-068 NETN) for this purpose in 2007. The NATO Joint Warfare Center assigned the chair for MSG-068. In addition to the NATO JWC, the Headquarter Supreme Allied Command Transformation (HQ-SACT), the Joint Forces Training Center (JFTC), the NATO Consultancy, Command and Control Agency (NC3A) (now the NATO Communication and Information Agency (NCIA)), and 13

Nations, supported MSG-068. The MSG-068 NETN Task Group assessed the distributed simulation and learning capabilities that could contribute to the development of an NETN capability. The Task Group (TG) makes recommendations on and demonstrates a way forward for interoperability, technical standards, and architectures to link the NATO and the national training and education centres in order to provide a persistent capability. It also identifies and recommends the roles and responsibilities of NATO and its Partner- and Contact-Nation organisations within the scope of NETN.

The MSG-068 NETN Task Group conducted a distributed stand-alone experiment between 25 October and 05 November 2010 to validate proposed solutions; the MSG-068 Technical Report includes the results from this experiment. MSG-068 also conducted a distributed demonstration during I/ITSEC 2010, which elicited strong interest from many Nations.

• Code of Best Practice for Judgement-based Operational Analysis (SAS-087)

OBJECTIVES: To develop a Code of Best Practice (CoBP) for judgement-based Operational Analysis (OA). This CoBP will take the perspective of the client regarding his/her needs for OA support (and expectations of the validity of that support) as starting points, and aims to: a) set 'rules of the road' for analysts when conducting judgement-based analysis for military clients; b) create focus and clarity in available findings; c) promote a multi-methodology approach in which hard and soft, qualitative and quantitative, subjective and objective approaches are used in complementarity; d) create understanding of what predominantly judgement-based approaches can and cannot achieve; and e) increase credibility and, thereby, acceptance of judgement-based OA.

The SAS-087 Task Group on 'Code of Best Practice for Judgement-based Operational Analysis' was formed to provide a state-of-the-art resource that described the field of judgement-based OA and best practice in its application to the many difficult problems faced by military decision makers. The goal of the Team was to demonstrate that even though an issue may be extremely complex, sufficient guidance and insights from a study may be presented to decision makers in order that that sound and defensible decisions can be made.

This Task Group created a CoBP for judgement-based OA. The CoBP was established to take a military client's needs for support – to include expectations of the validity of that support – as a starting point, and:

- Set 'rules of the road' for analysts when conducting judgement-based analysis for military clients;
- Promote a multi-methodology approach in which various approaches are considered and used based on the needs of the specific issue being addressed;
- Create an understanding of what a judgement-based approach is and what it can and cannot achieve;
- Create a roadmap for decision makers that will enable them to identify the type of problem they are facing and which OA methods should be used to solve it.

The Task Group bridged the gap between academia and the military in a very effective and efficient manner. Recent advances in practical uses of judgement-based OA in the academic and industrial fields have been successfully adapted and tailored for use within the defence arena. By specifically addressing military problems – with problem situations at tactical, operational and strategic levels – it was possible for the TG to create an inventory of existing methodological approaches, which were then assessed to determine their ability to deal with this problem spectrum.

> Enabled by the STO collaborative environment, the scientific research undertaken by the SAS-087 TG allowed them to tailor the CoBP into three separate documents, customized for myriad levels of supervision and leadership that can be utilized throughout NATO Nations and bodies.

However, the current approach overly relies on the use of human judgement to resolve complex problems, and as such the SAS-087 Team was able to effectively cull information and study results from previously accomplished research done by NATO and non-NATO Nations, in both academic and military fora, as well as from short case studies, in order to analyses the relevance and applicability of the work.

Enabled by the STO collaborative environment, the scientific research undertaken by the SAS-087 TG allowed them to tailor the CoBP into three separate documents, customized for myriad levels of supervision and leadership that can be utilized throughout NATO Nations and Bodies.
These documents are:

The Analyst-Oriented Volume

This document, the most extensive volume of the three, sets the 'rules of the road' for analysts. Subjects covered are:

- The nature of judgement-based OA and the type of problematic situations which require this type of analysis;
- How to achieve validity, credibility, and acceptance of judgement-based OA studies;
- The roles and responsibilities of individuals involved in a judgement-based OA study;
- The design of a study, the design of the study's (multi-)methodology, and how to recognise and cope with problematic situations;
- How to deal with data, subject matter experts, bias, and aspects related to Workshops;
- How to communicate the results to the military client.

The Client-Oriented Volume

This 58-page document explains judgement-based analysis and what can be expected from it, addressing potential questions from military clients. The document's chapters address questions that military clients are likely to ask:

- What is judgement-based OA?
- Which problematic situations require judgement-based OA?

- How does judgement-based OA add value?
- What does a judgement-based OA study look like?
- What is expected of me, the client?
- What does the analyst bring to achieve validity, credibility, and acceptance?
- How can a CoBP protect the client from threats to the study?

The High-Level, Executive Decision Maker-Oriented Volume

This document is a concise, folded A3-format brochure carrying the sub-title 'Judgement-Based Operational Analysis for Improved Defence Decisions'. It summarises the client-oriented document and is written for executive defence decision makers, including high-ranking officers. It addresses the following issues, which decision makers are likely to find relevant:

- What is judgement-based OA?
- How can defence decision makers be supported?
- When should judgement-based OA be used?
- What can you do with facilitated Workshops?
- What are the value and the benefits of judgement-based OA?

• Mission Effectiveness of Denial and Deception (SCI-200)

OBJECTIVES: Expand NATO's traditional view of Camouflage, Concealment and Deception (CCD) to include the overarching doctrine of Denial and Deception (D&D); Thoroughly research, study and evaluate military operations where D&D tactics and techniques were employed; Determine how to statistically and comparably evaluate the effectiveness of D&D tactics in military operations; Develop criteria or guidelines for NATO to continue to evaluate the effectiveness of D&D tactics; Investigate methods to determine the value of D&D in an operational context; Increase awareness and understanding of adversarial D&D capabilities.

NATO-led air campaigns in the former Yugoslavia and in Libya required the Alliance to confront and counter Denial and Deception (D&D) techniques used by its adversaries. While NATO maintains strong technological advantages, D&D tactics, techniques, and procedures can be effective in limiting operational success and misallocating operational resources. The SCI-200 Task Group on 'Mission Effectiveness of D&D' sought to determine how to evaluate the effectiveness of adversarial D&D tactics against the Alliance, and to develop a process whereby D&D operations can be effectively predicted and countered.

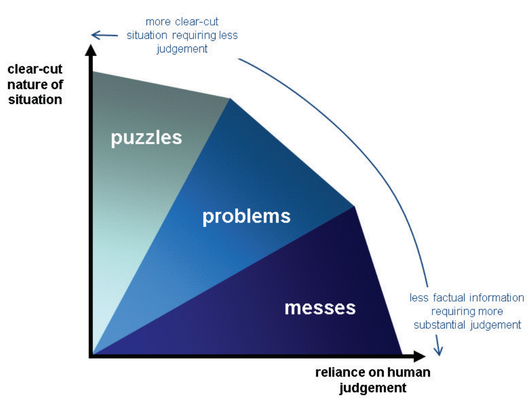


Figure 11. A Spectrum of Problematic Situations and Their Clear-Cut Nature versus Reliance on Human Judgement.

The Task Group, led by Ms. Rosemary Pierce of the United States, includes participation from eight NATO Nations. The effort has been carefully co-ordinated with a number of NATO organisations, and culminated with field trials as part of Unified Vision 2012, which was executed over 10 days in June 2012 in Ørland, Norway.

Figure 12. Inflatable Tank Decoys at Unified Vision 2012.

The purpose of the exercise was to demonstrate improved coalition information integration and sharing across an allied network in order to deliver Joint Intelligence, Surveillance and Reconnaissance (JISR) to warfighters and decision makers. The exercise included more than 1250 personnel from 17 Nations.

Canada, Norway and the United States contributed D&D materials, including inflatable tanks, fighter aircraft, and logistical vehicle decoys, to the trials. A total of 29 different D&D assets were used, tested, and analyzed over the course of 29 scenarios and vignettes.

> The Task Group provides a model for synergy between the operational community and the STO.

The Task Group's focus for the trial extended beyond the material aspects of D&D, such as camouflage nets, decoys, and obscurants, to a holistic analysis including the enemy's intent, as well as the technical and informational aspects of denying and deceiving within this definition.

Initial reports from the trials indicate that the deception efforts were extremely effective. The Task Group is now completing detailed data analysis to determine how best to educate collectors and analysts in order to minimize enemy D&D, and ultimately to develop NATO doctrine to support senior leaders' decision-making efforts in strategic and operational environments. The Task Group had an opportunity to demonstrate the value of its work to a number of high-ranking NATO and national officials at the Unified Vision 2012 Visitor's Day.

The Task Group provides a model for synergy between the operational community and the STO. The participation of a collaborative team of technical experts in a NATO exercise is a key element to ensuring that the scientific community is meeting the needs of the Alliance's military leadership.

THE TECHNICAL PANELS AND GROUP

• The Applied Vehicle Technology (AVT) Panel

THE AVT MISSION: The Applied Vehicle Technology Panel strives to improve the performance, affordability and safety of vehicles through advancement of appropriate technologies. The Panel addresses vehicle platforms and propulsion and power systems operating in all environments (land, sea, air, and space), for both aging and future vehicle systems.

• Scope of the AVT Panel

In fulfilling this mission, the Panel is focused on two broad technology areas:

- Vehicle and platform technologies, including: vehicle and platform design; configurational fluid dynamics and fluid mechanics; stability and control; noise and vibration control; structural loads and dynamics; smart structures; structural materials and manufacturing processes; affordability, availability, survivability and supportability; reliability, maintenance and repair; environmental impact; and testing; Propulsion and power technologies, including: air-breathing engine design (piston, gas turbine, ramjet/scramjet); rocket motors and rocket-based combined cycles; electric propulsion (including hybrid systems); engine control and thrust vectoring; power generation and storage; fuels and combustion; power-plant materials and structures; propellants and explosives; operation, health monitoring, reliability, maintenance and affordability; environmental impact; and testing.

The Panel carefully reviews proposed future activities to ensure the coherence and balance, as well as the relevance, of its programme. In this process, specific emphasis is placed on NATO's long-term requirements and on-going programmes, such as Defence Against Terrorism (DAT). In this way, researchers are constantly aware of NATO's current and future needs when they provide their contributions to its capabilities.

The trend of addressing subject areas common to all theatres of military operations, as well as application-oriented technology, has thus been successfully adopted. It encompasses an intense consideration of NATO's needs, and works in close cooperation with the ACT and all relevant elements of the structure under the Conference of National Armaments Directors (CNAD).

• Panel Programme of Work

The challenges that NATO faces today require innovative technologies in vehicle design in order to achieve larger payloads, wider ranges, higher speeds, improved deployability, and increased versatility, to name only a few. The AVT Panel is dedicated to investigating and providing suitable technologies, such as:

- Health management/monitoring of propulsion systems;
- Compact high-power density prime movers, energy generation, and storage;
- Drag reduction for sea and air vehicles;
- Morphing aircraft;
- Design for disposal of munitions;

- Self-healing materials and damage repair in the field;
- Lightweight armour for both vehicles and personnel.

A substantial amount of research is done on nanotechnology for applications in military vehicles (such as stronger/stiffer materials, coatings) and power systems for military applications (e.g., reduced fuel consumption, and lightweight and man-portable alternative sources such as fuel cells). Presently, the most visible application of a large number of these new technologies is in unmanned vehicles for air, sea, and land, covering all aspects of their aerodynamic and structural design, and control and power supply, including Micro-unmanned Aerial Vehicles (MAVs), and in the design and application of greener munition technology.

• Highlights

In 2012, more than 900 scientists, engineers, and representatives from NATO and its Partner Nations attended the Spring and Fall AVT Panel Business Meeting Weeks in San Diego, California (USA) and in Biarritz (FRA).

During these meetings, more than 40 Technical Teams and Programme Committeess held their meetings at the same time as the Business Meeting of the AVT Panel and the respective technical and strategic committees.

Furthermore, six major events, including Workshops, Specialists' Meetings and Symposia, have been held in conjunction with and around the AVT Panel Business Meeting Week.

Two symposia, on 'Technical Advances and Changes in Tactical Missile Propulsion for Air, Sea and Land Applications' (AVT-208) and 'Modeling, Simulation and Validation of Advanced Materials for Extreme Military Environment' (AVT-187), were accomplished.

Furthermore, three Specialists' Meetings, covering 'Hypersonic Laminar-Turbulent Transition' (AVT-200), 'Advanced Lubrication Systems for Gas Turbine Engines' (AVT-188), and 'Catalytic Gas Surface Interactions', were executed during the week. A Workshop on 'Energy-Efficient Technologies and Concepts of Operation' (AVT-209) was also held and is described below.

• Energy-Efficient Technologies and Concepts of Operation (AVT-209)

OBJECTIVE: To bring together researchers and operators from commercial and military communities in order to discuss technologies for energy-efficient vehicles and operations. Topics included environmentally friendly, energy-efficient vehicle concepts, as well as operational concepts capable of providing significant reductions in fuel burn, emissions, and/or noise.

Approximately 60 participants took part in the three-day 'Energy-Efficient Technologies and Concepts of Operation' Workshop at the Instituto Superior Tecnico in Lisbon, Portugal, and at the Portuguese Air Force Academy in Sintra. Twenty-six papers and three keynotes were presented by experts from ten NATO Nations. The co-chairs were Prof. Afzal Suleman and Prof. Robert Canfield, and the technical evaluator was Dr. Hector Climent from Airbus Military in Spain.

Technical experts from NATO were provided a forum in which to share recent technological developments in order to enable environmentally friendly air vehicles and energy-efficient concepts, as well as operational concepts capable of providing significant reductions in fuel burn, emissions, and/or noise. Several key topics, including novel air vehicle configurations and propulsion concepts, structures and materials (weight reduction), aerodynamics (drag reduction), concepts of operation, and systems energy balance methods, were covered.

It is noteworthy to mention the paper on formation flight indicating that a 10% saving can be achieved in a novel operational scenario which could be implemented in a short time. Boeing and Airbus, the two aircraft manufactures, presented interesting proposals for aircraft greening during the Workshop. The Boeing Blended Wing Body is a disruptive concept, with potential savings up to 20%. Airbus presented the open rotor concept with a potential saving of 10% at a cost of reduced speed. Other papers also indicated interesting solutions to achieve greener aircraft in the short- and long-term.

Societal drivers with respect to worldwide restrictions on emissions of carbon dioxide and water vapour, continuously rising fuel prices, and increasingly restrictive noise regulations, combined with the potential doubling of airline traffic over the next 15 years, are resulting in increased efforts to make both commercial and military transports and their operations both more energy efficient and more environmentally friendly. At present, the commercial transport sector is leading the way in the quest for efficiency and environmental compliance. Numerous on-going programmes are targeting technologies that possess the potential to provide significant reductions in fuel burn, emissions, and noise. While the commercial transport sector may lead the way in its focus on efficiency, the military has become much more active in seeking improvements in fuel burn and reductions in emissions and noise.

The NATO STO provided the optimum forum for Alliance members to co-ordinate their ideas and approaches to an increasingly important topic. Driven by Nations' concern with fuel burn, emissions, and noise reduction at the vehicle level, a meeting between researchers and builders of commercial and military air vehicles to discuss game-changing technologies, vehicle concepts, and operations for improved efficiency demonstrated the responsiveness of the STO to these concerns. Experts from NATO Nations shared their knowledge on energy-efficient technologies and concepts of operation. In the coming decades, this topic will become an increasingly important design driver for military vehicles in order to reduce costs in these areas.

• The Human Factors and Medicine (HFM) Panel

THE HFM MISSION: The mission of the Human Factors and Medicine Panel is to provide the science and technology base for optimising health, human protection, well-being, and performance of the human in operational environments with consideration of affordability. This involves understanding and ensuring physical, physiological, psychological, and cognitive compatibility among military personnel, technological systems, missions, and environments. This is accomplished by the exchange of information, collaborative experiments, and shared field trials.

The Scope of the HFM Panel

The scope of the HFM 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 HFM Panel:

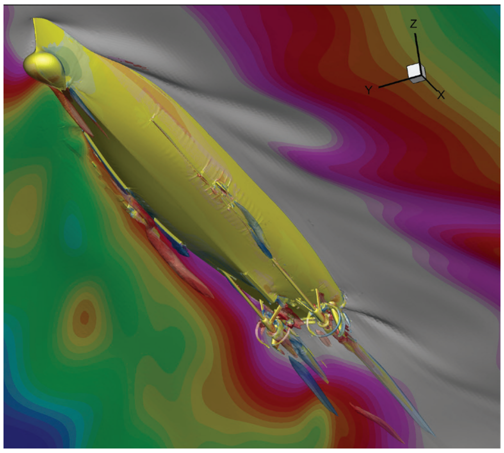


Figure 13. Turbulent and Vortex Structures Generated by Self-Propelled 5415M in Irregular Beam Waves.

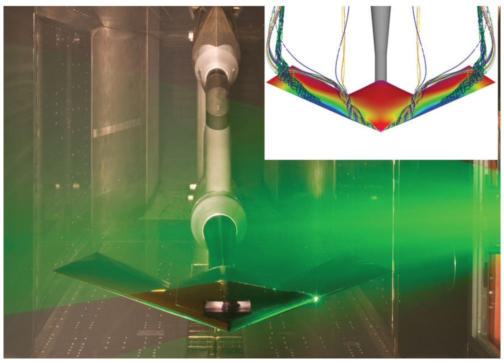


Figure 14. Computation of the Vortical Flow Around a Generic Unmanned Combat Air System (UCAS) Configuration and the Corresponding Experimental Model in the Wind Tunnel.

- The Health, Medicine and Protection Area provides the scientific basis for establishing an operationally fit and healthy force, restoring health, minimising disease and injury, and optimising human protection, sustainability and survivability. This encompasses research in the fields of military medicine, physiology, psychology, and human-protection technology. Areas of interest include, among others, medical diagnosis, prevention, treatment and evacuation. HMP also focuses on enhancing human-protection research on physiological and physical influences, e.g., of cold, heat, air pressure, noise, motion, vibration, ionising and non-ionising radiation, chemical and biological effects on the human body, acceleration, and developing appropriate counter-measures;
- The Human Effectiveness Area optimises individual readiness and organisational effectiveness by addressing psycho-social, organisational, cultural, and cognitive aspects in military action. Contributions on individual readiness cover values and ethics, leadership, multinational operations, and coping with new demands on the individual. Contributions on organisational effectiveness encompass human resource management, training, interoperability, shared decision-making, synchronised situational awareness, understanding terrorism, psychological operations, and coping with new demands on military organisations;

- The Human System Integration Area optimises the performance of human-operated technical systems by addressing the human-machine interactions, processes, tools and measures of effectiveness. Specific contributions cover complexity, total life-cycle affordability, human-error and fatigue management, intelligent agent, human-system communication, human cognitive and physical resources management, anthropometry, interface, design of information displays and controls, human-human communications and teamwork, performance enhancement and aiding, and training and function allocation in automated systems.

HFM Programme of Work

The HFM Panel portfolio of research is predominantly focused on human performance enhancement, organisational effectiveness, medical preparation and after-care for missions, and the integration of human factors.

In 2012, the Panel continued to conduct research in the areas of advancements in distributed learning, training technologies, medical technologies, mental health, and human modelling.

Cooperation within NATO and with Partners

The Human Factors and Medicine Panel fosters co-operative research in behavioural sciences and medicine among NATO Nations. The HFM Panel reaches these goals by setting up cooperative demonstrations of technology and shared experiments, based upon international cooperation between, for instance, the ACT and the NATO Committee of the Chiefs of Military Medical Services (COMEDS) on behavioural sciences and medicine. Ex-officio members of ACT and COMEDS join the Panel Business Meetings of the HFM Panel.

Within NATO, the Public Health, Food and Water Group (PHFW), the former Joint Medical Committee (JMC), advises the Senior Civil Emergency Planning Committee (SCEPC) on civil matters affecting NATO. PHFW also acts as the co-ordinating body for the SCEPC regarding all medical policies, procedures, and techniques.

In an endeavour to be more open in their Programme of Work (PoW), the HFM Panel has made their symposia available to participating PfP nations, Mediterranean Dialogue (MD), Global Partners (GP), and selected contact countries.

The Specialists' Meeting and Symposium planned for 2012 were HFM-201 on 'Social Media: Risks and Opportunities in Military Applications', held in Tallinn, Estonia, in the spring, and HFM-223 on 'Biological Effects of Ionising Radiation Exposure and Counter-Measures: Current Status and Future Perspectives', held in Ljubljana, Slovenia, in the autumn.

• Highlights

Safe Ride Standards for Patient Evacuation Using Unmanned Aerial Vehicles (UAVs) (HFM-184)

OBJECTIVE: To develop an evidence-based reference resource that can be used by UAV developers to ensure that the Artificial Intelligence (AI) programmes used to control UAVs will be able to support the use of these airframes in a casualty evacuation role. Absolute G tolerances of casualties with various injuries were investigated, as were rates of G-onset. The majority of this work was done through literature search and co-ordination with regulatory/scientific agencies.

Aeromedical evacuation has been carried out routinely in both fixed- and rotary-wing environments since the 1920s, and has become the 'gold standard' for evacuation mechanisms. The increasing use of Unmanned Aerial Vehicles (UAV) has raised the question as to whether they can be used to safely move patients. The HFM-184 Task Group was established to attempt to answer this question.

The issue is both operationally and clinically relevant. The use of UAVs has shown great progress in recent years in multiple roles, and it appears evident that logistics UAVs capable of carrying casualties will be present on the battlefield in the forces of several Nations within the short- to medium-term. Many doctrine developers have begun to plan for the use of these aircraft for casualty extraction or evacuation on 'back-haul', after the UAVs have delivered their cargo. Although initially skeptical about such potential usage, the HFM-184 Task Group has come to believe that these aircraft will be used for casualty movement soon after their appearance on the battlefield, with or without doctrinal guidance. NATO and national Special Operations Forces have clearly indicated their interest in such use, when regular aerial evacuation means are either not available or are operationally undesirable, as have several nations' conventional military forces. Potential use of these vehicles for this purpose will likely be far-forward, and will involve the transport of freshly wounded, unstable patients who may be more susceptible to the stresses of flight than would be stabilised patients.

If UAVs are to be used in a casualty evacuation role, it is necessary to have an agreed set of physiological, flight, and materiel parameters which can be used by decision makers to decide whether or not a casualty is suitable for evacuation by means of a UAV, or conversely, if a specific UAV is suitable for evacuation use.

> In the near future, the use of these aircraft for evacuation without medical control or treatment in flight, will be both feasible and practical, and is likely to happen even in the absence of doctrine controlling such use.

The Task Group was charged to develop such an evidence-based reference resource that can be used by:

- UAV developers to ensure that the AI programmes used to control both the flight and the internal aspects of the aircraft (i.e., not just piloting, but also such issues as environmental controls, C2, etc.) will be able to support the use of these airframes in the casualty evacuation role;
- Operational users (both military and medical) to determine when and under what circumstances such aircraft can successfully be used to move casualties.

A Technical Report with recommendations regarding the potential use of UAVs for the transportation of casualties was produced. Development of these recommendations has involved a review of all aspects of this type of vehicle, the legal and ethical considerations for such use, the operational and clinical considerations, and the development of possible scenarios in which such use could be beneficial to the casualty.

A full technical study of the UAVs that might soon have this capability has been carried out through co-ordination with several producers of UAVs, and both their capabilities and limitations have been carefully researched from the viewpoint of potential users. Team members were able to investigate this aspect of the problem from many viewpoints, as they and their guests included physicians (including those with extensive air ambulance experience), pilots (including test pilots and air ambulance pilots, as well as active UAV pilots), research personnel working with both UAVs and medical research, safety and standardisation experts, aircraft developers, policy developers, and operational personnel from all services.

The Task Group chose to approach the problem by asking the question 'Given the availability of a UAV with adequate capability to move a casualty in Casualty Evacuation (CASEVAC) mode, how can the unit commander on the ground analyse the relative risks and make a determination on an individual case as to whether or not to use such a vehicle?' The Task Group also emphasised the use of generic principles, rather than prescriptive SOPs, to assist in making those determinations. In addition to the previously mentioned aspects, the Task Group developed a number of criteria for casualty preparation and selection that should be considered before making the decision to evacuate a casualty by these means. These criteria include:

- The aircraft must meet all of the same safety-of-flight requirements as do current manned rotary-wing aircraft;
- Environmental standards in the casualty compartment (e.g., noise, vibration, acceleration factors, air quality) must be met in accordance with current standards;
- Some provision must be made to fix the casualty to the aircraft (e.g., litter tie-downs);
- Carriage of the casualty must be internal to the aircraft.

The final conclusion of the Task Group is that the use of UAVs for casualty evacuation can be fully justified in some circumstances. In the near future, the use of these aircraft for evacuation without medical control or treatment in flight, will be both feasible and practical, and is likely to happen even in the absence of doctrine controlling such use.

Their use for Medical Evacuation (MEDEVAC), i.e., evacuation under medical control as part of the treatment continuum, with treatment in flight provided by medical personnel, is not possible at this time or in the near future, though the Task Group saw no reason why this use will not be possible in the medium to longer term.

This activity conducted within the STO environment enabled the production of a report containing a set of recommendations for future research and development to support such potential usage, as well as a number of recommendations for doctrine development by various NATO bodies and clinical guidelines for such usage. With 191 widely discussed references, the Technical Report can be used as 'the handbook' for future research (technical and medical), development (technical and medical), policy making, and operational and medical planning, as well as decisions on legal and ethical issues.

Medical clinicians and planners within NATO and the Nations are now called upon to follow the technological development and to bring their expertise and knowledge to bear in ensuring that such potential use will be able to benefit the soldiers whom we serve.

Within NATO, we cannot afford to disregard such a potentially life-saving technology.

• The Information Systems and Technology (IST) Panel

THE IST MISSION: The mission of the Information Systems Technology Panel is to implement, on behalf of the Science and Technology Board, the STO mission with respect to Information Systems Technology, namely, to advance and exchange techniques and technologies to provide timely, affordable, dependable, secure and relevant information to warfighters, planners and strategists, and to advance and exchange techniques and enabling technologies for modelling, simulation and training.

• The Scope of the IST Panel

The Information System and Technology Panel activities cover four main themes: architecture and enabling technologies, communications and networks, information and knowledge, management, and Information Warfare and Information Assurance.

IST Programme of Work

The IST Panel portfolio of research is predominantly focused on how to advance and exchange techniques and enabling technologies in order to improve Command, Control, Communications and Intelligence (C3I) systems, with a special focus on interoperability and cyber security. In 2011, the Panel continued to conduct research in the areas of Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR), interoperability, information fusion, and cyber defence.

• Highlights

Service-Oriented Architectures (SOA) for Real-Time and Disadvantaged Grid (IST-090)

OBJECTIVES: To identify improvements and demonstrate how to make SOA applicable at the tactical level in military operations. Particular attention was paid to battlefield disadvantaged grids in 'near real time' including:

- Communication paradigms;
- Mechanisms to reduce needed bandwidth;
- Mechanisms to improve reliability;
- Security.

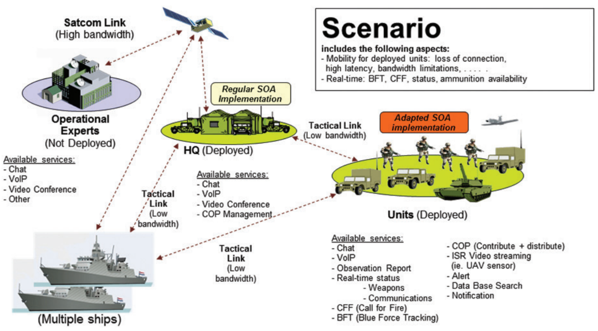


Figure 15. The Service-Oriented Architecture (SOA) Scenario.

The SOA approach has been chosen by the NATO Consultation, Command and Control Board (NC3B) as the recommended method to achieve information interoperability in NATO. This technology, however, was originally designed for civilian use over robust, high-bandwidth networks, and it was not clear that it could function properly in the deployed military environment, which in many instances suffers from inadequate or unstable connectivity.

The work of IST-090 was a significant step in extending the very valuable and flexible SOA to the tactical level. The group has successfully achieved its goal, capping the work with an excellent series of demonstrations on:

- Web services across disadvantaged networks;
- Data Distribution Services (DDS) at the tactical level;
- enhanced communication using common distributed databases; and
- improved communication performance by exchange of status information between Command, Control and Information System (C2IS) applications and network protocol layers (cross-layer design). These demonstrations showed, for example, that information could be shared among different levels (tactical and brigade), that interoperability could be achieved using SOA (even though the independent systems were using different technologies to implement the SOA), and that significant cost savings and flexibility could be provided when combining national systems.

The suite of solutions developed by IST-090, once made operational, will make it quick and easy for an administrator to choose and apply the best solution for the case at hand in order to optimize support to the military forces.

In addition to the participating Nations, IST-090 was fortunate to have both industrial and NCIA membership. NCIA brought a stronger link to actual NATO systems, and the results of the Group have been captured in NCIA reference documents and Technical Reports. Moreover, connections were established with the Multilateral Interoperability Programme (MIP) and the Multi-sensor Aerospace-ground Joint ISR Interoperability Coalition (MAJIIC) project.

The STO environment enabled a unique opportunity for multiple NATO and national entities to address a fundamental issue of interoperability. The suite of solutions developed by IST-090, once made operational, will make it quick and easy for an administrator to choose and apply the best solution for the case at hand in order to optimize support to the military forces. The involvement of NCIA in this work enhances the pathway to operational utilisation of the technologies developed here. Thus IST-090 has left a very positive legacy for NATO and the Nations. The SOA concept is now well known within NATO and, partly due to the work of previous IST Task Groups, it is being used in portions of the Afghanistan Mission Network (AMN).

• The NATO Modelling and Simulation Group (NMSG)

THE NMSG MISSION: The mission of the NATO Modelling and Simulation Group is to promote cooperation among Alliance bodies and NATO Nations and Partner Nations to maximise the efficiency with which Modelling and Simulation (M&S) is used. Primary mission areas include M&S standardisation, education, and associated science and technology. The activities of the Group are governed by a strategy and business plan derived from the NATO M&S Master Plan. The Group provides M&S expertise in support of the tasks and projects within the STO and other NATO bodies.

The Scope of the NMSG

Modelling and Simulation (M&S) is today a revolutionary technology providing powerful tools that assist the search for improved operational effectiveness and yield value for money within NATO. The ability to represent and examine the behaviour of equipment and the military capability of armed forces continues to increase, particularly with the advent of simulations carried out over a distributed network that can include humans and live (real) equipment. M&S contributes to important savings in lives, time and money, and to better preparing the war fighter, both more quickly and more inexpensively.

The role of the NMSG is to function as a management body in which a full and balanced range of M&S interests can be represented, and to promote the coherent management and co-ordination of M&S across all Alliance activities in the principal application areas of defence planning, technology development, and armaments acquisition. The scope of activity under the NMSG is:

- M&S Policy Management – Promoting exchange between the NATO Nations and Alliance organisations on M&S standards and best practices, which will co-ordinate and harness individual M&S capabilities and activities for the long-term systematic benefit of NATO. This exchange must be responsive to varied interests and to NATO roles and missions;
- Management and Co-ordination of M&S Activities – Developing, maintaining and integrating a co-ordinated, long-term strategy for NATO M&S activities; identifying and co-ordinating opportunities for M&S activities across the whole of the Alliance, including the NATO military authorities, the international staff, technology development organisations, and application development organisations; developing M&S project work-plans and associated resource requirements for forwarding to NATO budget authorities via the STB; in co-ordination with the director of the CSO, overseeing the expenditure of resources by the Modelling and Simulation Co-ordination Office (MSCO) during the execution of M&S projects.

NMSG Programme of Work

As part of its mission to fulfil the objectives established in the NATO M&S Master Plan, a three-year effort to update the Master Plan was completed and formally endorsed by the NATO Science and Technology Board in their Fall 2012 meeting. The revised plan is composed of a strategic plan and an implementation plan. The strategic plan addresses the linkages between NATO M&S customers, users, and suppliers, and outlines objectives. The implementation plan amplifies this information with specific stakeholder roles and responsibilities in fulfilling these objectives in a time-phased manner. The NMSMP v 2.0 is freely downloadable from the MSG section of the NATO CSO Website www.cso.nato.int.

The NMSG PoW is divided into 'Common Service' programmes that address training, standardisation and education under the lead of members of the MSCO, and 'Technical Activity' programmes managed by Task Groups. The MSCO works in conjunction with the CSO's Information Management Systems Branch (IMSB) to provide the community with common services for the development, use and re-use of M&S by means of a NATO Simulation Resource Library (NSRL).

NMSG continues to develop its relationship with the NATO ACT, assisting in the development of M&S-based ADL courses and supporting major projects such as the NETN.

From its inception in 1998, the NMSG has been keen to involve the Partner Nations in its Programme of Work. Currently, most NMSG activities are open for partner participation.

• Highlights

Coalition Battle Management Language (MSG-048)

OBJECTIVE: To develop a complete software language that permits the interaction of Command and Control (C2) systems and simulation systems, permitting them to work together in distributed simulations.

The work focused on providing a NATO Coalition Battle Management Language (C-BML) specification by analysing and adapting the currently available specifications and implementations from the Simulation Interoperability Standards Organization (SISO) or other NATO Nations. This technical activity assessed the operational benefits for NATO C2 and M&S communities by conducting experiments, and concluded with a final demonstration with existing systems that have been made compliant with this specification.

> C-BML will provide the necessary interoperability not only between C2 and M&S systems, but among NATO and Partner national systems in operations as well.

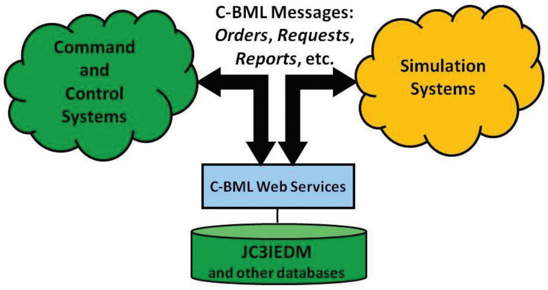
The main goals for NATO's C-BML are:

- To standardise and improve M&S/C2 interoperability for automatic, rapid and unambiguous command and control;
- To develop a standard representation of digitised C2 information, such as orders and plans, to be understandable by military personnel, simulated forces, and future robotic forces;
- To provide a situational awareness common operational picture through digitised reports and returns.

A Battle Management Language (BML) is an unambiguous language used by Command & Control (C2) forces and systems conducting military operations. BML, which digitises C2 information such as orders and plans in order to be understandable for military personnel, simulated forces and future robot forces, is being developed as an extension of standardised representations. It provides the capability to exchange the required context through digitised reports and returns from situational awareness and a shared common operational picture.

BML is particularly relevant in a network-centric environment for enabling mutual understanding. BML must also facilitate C2-simulation interoperability in an environment in which multinational distributed and integrated capabilities are becoming increasingly common and gaining importance. BML is a means of representing doctrine, while not standardising it; the vocabulary must be well defined in the context of the respective application domain in order to unambiguously generate executable tasks at the end of the process.

Figure 16. C-BML Allows C2 Systems to Communicate with Simulation Systems.



BML must model these aspects so that underlying information systems (M&S or C2 systems) can exchange information and make sense of the results. It must also specify the underlying protocols for transferring BML information. National studies have shown that BML information can be transferred using internet- or Web-based open standards such as eXtensive Markup Language (XML).

Ten Nations voluntarily contributed to NATO's C-BML development through participation in several demonstrations.

The STO served as the optimal forum in which Alliance partners could develop C-BML as a particularly relevant asset in a network-centric environment for enabling mutual understanding. C-BML will provide the necessary interoperability not only between C2 and M&S systems, but among NATO and Partner national systems in operations as well.

The need for C2-simulation interoperability in coalition operations is even greater than that of national or joint operations, as coalitions must be able to function despite barriers created due to significant differences between doctrine and human language.

BML also constitutes a natural bridge between the scientific and technical worlds and the operational domain. It will enhance the interrelationship and mutual understanding of these domains, and will likewise facilitate the creation of better environments and products, and add to the development of Live Virtual Constructive (LVC) environments as C2 systems used in real operations.

C-BML implementation will have a direct application for the training of NATO forces by enhancing their operational capabilities. It will also enhance the interoperability among NATO Nations and Partner forces and the future development of LVC systems and future robotic commanded forces. It will favour a better design and development of future NATO and national C2 systems.

Figure 17. Development of Standards for Distributed Simulations Systems and their Verification, Validation and Accreditation (VVA).

Exploiting Commercial Games for Military Use (MSG-117)

OBJECTIVE: To explore the possibilities of the use of commercial games in the defence domain, including being integrated in distributed simulations.

Many NATO, PfP and Global Partner Nations are now exploiting, or planning to exploit, commercial games technology and techniques for military training and analysis activities. Such an approach offers clear advantages, as such games are easily accessible and relatively inexpensive when compared with the more traditional developed military simulations. However, there are obstacles to the exploitation of commercial games, including that such games may not sufficiently adapt to military requirements. In addition, the economics of the military market are quite different from those of the commercial market. A clear identification of how best to extract value from this market will help to identify both advantages in their use and new lines of development/adaptation in order to be used efficiently in the defence domain.

A successful series of Workshops have already been organised, and preparations have also been made to continue the series during 2013.

The objectives of these activities include the establishment of a common forum for sharing national experiences and best practices, and the identification and elimination of barriers to further exploitation.

Opportunities for further collaboration among NATO, PfP Nations and Global Partners are also being sought, and will specifically include:

- Current applications;
- Future technical opportunities and challenges;
- Cost-effectiveness;
- Industrial and/or economic issues;
- Impact of commercial games in military training and other operational uses;
- Establishment of military requirements;
- Cultural issues within existing military organisations;
- Acquisition/procurement issues.

Within the STO environment, the NMSG possesses wide experience in the analysis and development of standards for distributed simulation and the Verification Validation and Accreditation (VVA) of simulation systems, as well as a deep knowledge of the use of distributed simulations for training, rehearsal, and preparation for operations. Through this cooperation mechanism, NATO and the Nations can share knowledge and skills that accelerate the adoption and application of emerging capabilities.

• The Systems Analysis and Studies (SAS) Panel

THE SAS MISSION: The mission of the System Analysis and Studies 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 the SAS Panel

The System Analysis and Studies Panel portfolio of research is predominantly focussed on exploring how operational capability can be enhanced through the exploitation of new technologies, new forms of organisation, or new concepts of operations.

SAS Programme of Work

In 2012, the Panel continued to conduct research in its areas of strength, including support to operations and capability development, long-term defence planning, and methodological improvements, as well as command and control theoretical development coupled with practical guidance. The Panel's 2012 PoW marked a re-emphasis on bringing the NATO Nations' Operational Analysis/Operational Research (OA/OR) expertise to bear on operational issues currently facing NATO.

• Highlights

Operational Analysis Support to NATO Operations (SAS-089)

OBJECTIVE: To recommend common procedures, structures, technical training, and tools that would improve the use of OA in both NATO and national deployed HQs.

The SAS-089 Task Group on 'Operational Analysis (OA) Support to NATO Operations' was formed to address a growing concern that, although many NATO operational leaders and decision makers recognise that OA has significantly contributed to the success of operations, there still is no common NATO-wide approach and not enough acceptance of this capability.

OA has proven useful in supporting commanders' decision-making processes (e.g., allowing faster and more robust decisions, using fewer resources, accounting for less collateral damage and losses), and in recent years, NATO HQs and Nations have introduced different procedures and organisations to provide OA support. Yet without a common understanding of how to provide OA support to NATO operations, senior military leaders face discrepancies in organisational structures, procedures, technical training, and tools that lead to reduced effectiveness, interoperability, and sustainability.

Thus this Task Group, enabled by the STO SAS Panel and composed of representatives and experts from twelve Nations, as well as from six NATO organizations, examined the current practices of OA support to operations (in NATO and NATO Nations) and elaborated a desired (i.e., ideal) situation, as well as recommendations, for its implementation in order to support the decision-making process during preparation, execution and post-processing of NATO operations.

Through their analytical work, this team was able to construct a final report that describes an employment concept for OA support to NATO operations. It outlines the roles and responsibilities of OA, describes where operational analysts should be positioned in deployed HQs, and makes proposals with regard to the function and role of a NATO reach-back capability, as well as the qualification, selection and training of OA personnel. It identifies gaps between the current and desired situation, and provides recommendations to fill these gaps and for the implementation of the proposed concept.

Figure 18. NATO SACEUR Adm. James Stavridis (U.S. Navy) Meets Troops During a Visit to Combat Outpost Sperwan Ghar, Afghanistan.

The Task Group was then able to outline a 'desired solution' for OA in NATO operations, specifically that:

- There would be a common understanding of applying OA in NATO, to be described in appropriate publications;
- OA would become directly embedded into staff functions and/or organisations at all levels of the NATO command structure;
- OA has direct access to the decision maker;
- A Senior OA Representative would promote and co-ordinate the application of OA in NATO;
- OA would be enhanced by the creation of a NATO reach-back organisation;
- OA posts are filled with qualified, trained and experienced personnel.

After determining this 'desired solution', the Task Group devised a list of recommendations for implementation that would seek to solve these important issues.

- Develop a 'Conceptual Document for OA Support to NATO Operations' in the form of an Allied Joint Publication (AJP) or ACO Directive;
- Create a Senior OA Representative post at SHAPE to implement this conceptual document, and to act as a liaison between the OA community and operational leadership;
- Generate processes and procedures for the formation and education of future deployed analysts;
- Create a NATO OA reach-back capability to provide support to operational analysts in static and deployed NATO HQs before, during and after operations.

As a result of the work done by this Task Group, a follow-on activity was established: a Military Application Study (MAS) on a NATO 'Pre-Deployment OA Course', designed to ensure that operational analysts (both civilian and military) deploying into NATO operations are well prepared for their OA mission by creating a pilot course at the NATO school that will provide theatre-specific OA training.

With continued investigations and focus on the strengths of OA in NATO operations, the benefits of this work, the labours of which have been underpinned by the diligent efforts of the SAS-089 Team, will be felt for years to come.

• The Systems Concepts and Integration (SCI) Panel

THE SCI MISSION: The mission of the Systems Concepts and Integration Panel is to further knowledge concerning advanced systems concepts, integration, engineering techniques and technologies across the spectrum of platforms and operating environments to assure cost-effective mission-area capabilities.

The Scope of the SCI Panel

The scope of the Panel activities covers a multi-disciplinary range of theoretical concepts and design, development and evaluation methods applied to integrated defence systems, including air, land, sea and space systems, both manned and unmanned. Associated weapon and counter-measure integration are also covered.

SCI Programme of Work

The Panel relies on scientists, engineers, military officers and industry experts from across NATO and PfP Nations to accomplish its mission. Task Groups and Exploratory Teams focus on a broad range of topics, including:

- Space awareness and operations;
- Flight test and unmanned aerial vehicles;
- Camouflage and force protection;
- Route-clearance and C-IED operations;
- Directed-energy weapons;
- Electronic warfare.

• Highlights

Symposium on Port and Regional Maritime Security (SCI-247)

OBJECTIVES: The Port and Maritime Security conference focused on methods and tools for NATO to engage both the symptoms and the underlying causes of disorder at sea. These fell into three categories, as described in the SCI-247 programme:

- Detecting illicit activity: 'Disorder at sea - evident in piracy, irregular immigration, illegal fishing and industry, environmental destruction, and clandestine entries and shipments ... '.
- Technologies that support maritime governance: 'Disorder at sea ... can occur when nations are weakened by civil unrest or economic decline, when competition for limited resources and ocean exploitation increases, and when terrorists perceive vulnerabilities in the maritime domain.'
- Technologies that support direct action: '... countermeasures to such global maritime problems require multinational responses, supported above all by information sharing, by increased surveillance persistence and coverage, and by the combination of these into overall Maritime Situational Awareness often reaching far beyond any single nation's territorial waters.'

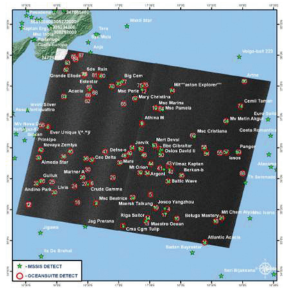


Figure 19. Automatic Identification System Off the Coast of Sicily in 2012.

NATO has assumed a major role in maritime security, contributing in a global sense to the foundations and policy underpinnings, partnership and capacity building, and protection of operational forces in this important domain. This Symposium focused on littoral waters, ports and harbours, with particular attention paid to the unique problems of maintaining situational awareness in an environment rich in small vessels, and to understanding threats to both maritime and ashore activities. It served as a venue in which to share information among NATO scientists, engineers, and practitioners engaged in expanding maritime security capabilities with new and improved technologies, analytic methods, and operational concepts. It also served to hone the focus of those engaged, revealing where complementary efforts might produce synergy, as well as where gaps exist in the maritime security R&D investment portfolio could be addressed.

The Port and Maritime Security Symposium (SCI-247) achieved its major objective. An international understanding of the need to collaboratively build a global Maritime Situational Awareness system was fostered through the presentations, demonstrations, and discussions among the 90 participants, representing 19 NATO Nations.

The STO collaborative environment served a critical role in providing a forum for Alliance members and Partner Nations to share their best concepts and technologies to support port and regional maritime security. It is now incumbent on the participants to engage in collaborative activities that produce synergies beyond the scope of their individual research activities.

• The Sensors and Electronics Technology (SET) Panel

SET MISSION: The mission of the Sensors and Electronics Technology Panel is to foster co-operative research, the exchange of information, and the advancement of science and technology among the NATO Nations in the field of sensors and electronics for defence and security. The SET Panel addresses electronic technologies, as well as passive and active sensors, as they pertain to Reconnaissance, Surveillance and Target Acquisition (RSTA), Electronic Warfare (EW), communications and navigation, and the enhancement of sensor capabilities through multi-sensor integration and fusion.

The Scope of the SET Panel

The SET Panel research activities predominantly address the phenomenology related to target signature, propagation and battle space environment, Electro-optic (EO), Radio-frequency (RF), acoustic and magnetic sensors, antennas, signal and image processing, components, sensor hardening, electromagnetic compatibility, and all other phenomena associated with sensors and electronics that assist NATO war fighters during future warfare and peace-keeping scenarios.

The SET Panel is partitioned into three Focus Groups:

- RF Technologies (RFT);
- Optical Technologies (OT);
- Multi-Sensors and Electronics (MSE).

The main purpose of each Focus Group is to provide a convenient and efficient forum for in-depth technical discussions during the SET business weeks. The Focus Groups review updates of NATO guidance and their applicability to the SET Task Groups, the Exploratory Teams and the on-going activities of the Technical Teams, examine and propose new activities, discuss Technology Watch topics, and propose award nominations.

Technology Watches are performed by the SET Panel as part of its normal business, in order to monitor the development and emergence of new technologies and to review and analyse their potential impact on military capabilities. The Panel identifies various on-going programmes regarding enabling technologies and initiates discussions on areas related to emerging technologies. The activities undertaken by the Panel embrace phenomenology, sensors and electronics.

The SET Panel currently is comprised of more than 50 national representatives and top scientists from 24 of the 28 NATO Nations, including four members-at-large with exceptional expertise in specific topic areas. In addition, ex-officio members from the NC3A and the ACT participate in the Panel Business Meetings.

Traditionally, the Panel covers the entire spectrum of STO activities (Symposia, Specialists' Meetings, Lecture Series, Workshops, Courses, Exploratory Teams, Task Groups), with a special emphasis on Task Groups. Many Task Groups are closed in order to allow participating Nations to work on sensitive technologies. The Technical Team members are comprised of more than 700 scientists from both NATO and non-NATO Nations.

In 2012, the SET Panel supported 49 activities, including 34 Task Groups, seven Exploratory Teams, four Lecture Series, and four Symposia, Specialists' Meetings and Workshops.

• SET Programme of Work

SET Contribution to Military Requirements

The SET Panel community focuses its work on science and technology (S&T) that is relevant to NATO military requirements. The technologies that are addressed in SET activities may be beneficial to the capability gaps identified by the ACT, with a horizon that spans from the short to the long term. Specifically, the SET Panel was assigned as the 'Lead Body' of the C-IED Long-Term Capability Requirement, and the SET-161 Task Group was established for this purpose.

Additionally, according to the established NATO S&T priorities, the Panel is running several activities that are focussed toward discovering implementable solutions and fieldable technologies that mitigate, and possibly overcome, the technical challenges currently facing NATO operations. To that end, the Panel is addressing issues in the following areas:

- Persistent EO/IR surveillance;
- Low-cost night vision;
- Fibre lasers with high average power;
- UCASs with autonomous surveillance, reconnaissance, and target recognition capabilities;
- Total situational awareness: Active Electronically Scanned Arrays (AESA);
- Robust, quick and ready display of information to soldiers;
- Biology-based solutions;
- Novel power sources;
- New sensing.

The SET Panel identifies various on-going programmes regarding enabling technologies and initiates discussions on areas related to emerging technologies. According to the SET areas of interest, the current Technology Watch topics are:

- Black silicon;
- Flexible displays;
- Graphene;
- Multi-function apertures for Active Electronic Scanning Antennas (AESA);
- Plasmonics for decreasing IR detector size;
- Multiple Input Multiple Output (MIMO) radar;
- Quantum cryptography;
- Femtosecond laser applications for defence and security.

• Highlights

Mitigation of Ship Electro-Optical Susceptibility against Conventional and Asymmetric Threats (SET-144)

Military ships face increasing threats from missiles with infrared seekers and asymmetric threats such as small surface targets. There is an urgent need to investigate the susceptibility and vulnerability of ships to such threats. Advanced infrared seekers, including low-cost imaging seekers with powerful image-processing algorithms, are being developed by many countries. Small craft have proven to be an asymmetric threat to naval ships, and have demonstrated their destructive capability when used by terrorist groups. Consequently, in order to investigate infrared research topics relating to infrared ship susceptibility, the focus of the SET-144 Task Group was the conducting of the SQUIRREL Trial, with the major objective being the testing of the IR signature and susceptibility properties of a ship (the CFAV Quest) with an IR Ship Signature Management System (SMS), as well as the performing of propagation measurements and small-target detection.

SET-144 was an unqualified success. The results of the trial demonstrated conclusively that the SMS not only reduced signature, but would reduce missile acquisition range and improve the seduction effectiveness of off-board decoys. The participating countries

Figure 20. The Canadian Forces Auxiliary Vessel (CFAV) *Quest*, a Research Vessel, Deploying IR Decoys.

combined their results into a comprehensive database, which is available to benefit NATO navies. The insights gained from this effort facilitated the follow-on activity, SET-154, to advance capabilities in order to manage ship signatures.

Signature Management System for Radar and Infra-red Signatures of Surface Ships (SET-154)

The signature of a ship is crucial in determining the range at which it is detected by a threat and the effectiveness of countermeasures. A ship's signature is not a fixed entity; it can vary depending on the ship configuration and motion, environmental conditions and threat parameters. SET-154 has considered the information and tools required to develop a ship Signature Management System (SMS). This will provide awareness of the ship's exposure to specific threats, advice to the ship's command on its current signature, and awareness of the implications of actions on board the ship to its signature. The SMS will actively aid the ship's company to optimise the vessel's signature and allow better-informed operational decisions to be made.

SET-154 has concentrated on radar signature, although close cooperation has been maintained with the IR ship signature group SET-144, including a number of joint sessions at meetings and collectively running the Surendorf QUest Infra-Red and Radar Evaluations in the Littoral (SQUIRREL) trial. The opportunity of the Radar Infra-red electro-Magnetic Pressure Acoustic Ship Signature Experiments (RIMPASSE) 2011 trial, organised by the Centre for Ship Signature Management (CSSM) in Kiel, Germany, and at Defence Research and Development Canada (DRDC) in Ottawa, Canada, was used to enhance SQUIRREL. Liaison has been maintained with SET-143 on 'Radar and Infra-red Synergy for Military Situation Awareness', with SET-166 on a 'Signature Management System for Underwater Signatures of Surface Ships' and with the CSSM. These liaisons ensure shared data, where possible, and compatibility between different signature domains. SET-154 has attended three signature-management conferences organised by CSSM.

In addition to sharing national data and lessons learned, SET-154 organised a Workshop to obtain operator and command input into the functional requirement for a ship SMS. Attendance at this Workshop was not restricted to Member Nations of SET-154; there was also representation from many Nations' navies and tactical schools, as well as scientific attendance from the infra-red and underwater signatures communities. The Workshop concluded that there was significant military benefit in a signature management system.

The SQUIRREL trial provided excellent data to validate models, investigate radar signatures and propagation effects, and assess the impact of an infra-red signature-suppression system on the ship's radar signature.

Figure 21. Canada and Germany Both Provided Ships and Support Boats.

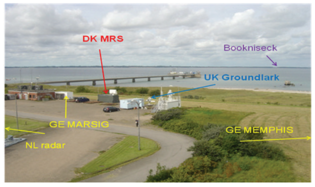


Figure 22. Denmark, Germany, the Netherlands and the United Kingdom Participated in the Trial with Instrumentation Radars.

The close cooperation between SET-154 and SET-144 has allowed environmental data to be shared by the two groups. The transient nature of the environment and the rate at which the propagation can change lead to rapid changes in apparent signature, as observed during measurements taken of corner reflectors during the SQUIRREL trial. This has consequences in defining the update rate for an operational SMS.

Additional study is proposed in the drive to provide a reliable tool for operational command. The accuracy, sensitivity and confidence level of an SMS will be pursued using models of propagation, signatures and threats. The pursuit of this objective through the STO environment allows the sharing of ideas and trials data in order to accelerate our understanding and enable the development of an effective response.

The Centre for Maritime Research and Experimentation Overview

DIRECTOR'S INTRODUCTION

The Centre for Maritime Research and Experimentation (CMRE) is the 'in-house' research centre of NATO's new Science and Technology Organization (STO). In line with our mission, we will organise and conduct scientific research and technology development, and deliver innovative and field-tested Science and Technology (S&T) solutions to address the defence and security needs of the Alliance, i.e. the needs of NATO and the NATO Nations.

The CMRE and its predecessors, the Supreme Allied Commander Atlantic Anti-submarine Warfare (SACLANT ASW)/Undersea Research Centre and the NATO Undersea Research Centre (NURC), look back on more than 50 years' experience in seagoing research in support of NATO's needs for maritime science and technology. The Programme of Work (PoW) has always been defined predominantly in close cooperation with NATO Nations, often with in-kind contributions to specific projects.

The sea has always been the focus of the North Atlantic Alliance in order to ensure the freedom of the sea lines of communication in the huge area of the ocean for which NATO is responsible. Energy security and the protection of critical infrastructure at sea are of crucial importance to our global societies now more than ever. Littoral environments and the ever-present and indispensable assets therein need to be protected in a changing world with diverse asymmetric threats, including both inter-state and sub-state actors. Only naval forces will address these security challenges in the open sea, and thus are the guarantors for defence against all manner of maritime challenges.

Our mission, therefore, is centred on the maritime domain in which we sustain core capabilities, particularly for the undersea environment. Conformant with the policy guidance we receive from our governance body, the Science and Technology Board (STB), we may extrapolate in other directions in order to meet the demands of our stakeholders and customers.

In addition, we must recognise the highly challenging nature of the maritime environment, particularly for sensors and systems, which is most pronounced in the underwater domain. Sensors such as radar and communication via radio waves cannot work adequately because of the underlying physics of electromagnetism. The salt water in the sea behaves like a short, making these well-known means, utilised in all other environments, useless. Acoustics must instead be applied, as sonar and underwater acoustics are the substitutes for radar and electromagnetic waves. The physics of underwater acoustics add considerable complexity, however, and sensing and communication are major and on-going challenges in this environment.

Systems and sensors must be tested; new concepts and models will work only if they are validated against the peculiarities of their environment. The final test must be exposure to naval exercises, with the inherent procedures and overall scenarios of threats and own assets. A seagoing capability is indispensable for this kind of work. The CMRE has access to two vessels with excellent capabilities: the NATO Research Vessel (NRV) *ALLIANCE* and the Coastal Research Vessel (CRV) *LEONARDO*. Their capabilities are complementary: *ALLIANCE* serves as a global seagoing platform, while the focus of *Leonardo* is on inshore and confined waters. The excellent engineering capability of the CMRE is the required and well-established link between NATO's seagoing capability and the research that is conducted by the world-class scientists from the NATO Nations.

NATO's S&T Strategy focuses on three distinct areas. Capability Development is the predominant area to which the CMRE contributes, as new capabilities will serve NATO or the NATO Nations directly. The second area is our contribution to NATO's knowledge base. NATO decision makers and the Nations have access to the outstanding knowledge the Centre has collected over the years. Partnering, the third pillar of the S&T Strategy, is well in line with NATO's Strategic Concept, and is both indispensable for maritime security and an integral part of the networking character of the CMRE as a science and technology centre.

The CMRE utilises a business model of customer funding in order to ensure that the prioritised requirements of NATO and NATO Nations are addressed. The CMRE's customer base also includes other clients on a case-by-case basis. NATO's Supreme Allied Commander Transformation (SACT), who leads the organisation in the area of military transformation, is currently a major customer for the services of the CMRE, developing new capabilities that are expected to be at the forefront of optimisation, interoperability and rationalisation. These are challenges for NATO and for NATO Nations in general, and are addressed by the CMRE with their capabilities, portfolio and PoW.

Autonomous reconnaissance and intervention, robotic characterisation of the battle space, and the management of abundant information have been identified as the key areas that will underpin the transformation of maritime defence and security capabilities, as well as deliver more assured results at lower sustained costs. The associated technologies required to achieve this vision form the basis of the CMRE PoW. The warfare disciplines they support represent applications of the concept of 'Data to Decision', the supply chain of information at the heart of CMRE's programme, with systems such as autonomous (robotic) vehicles that sense their physical environments, search for and classify targets, interpret their signal environment, and take actions following autonomous interpretation. The advances in system science, acoustic signal processing, control theory, and algorithm development that make these accomplishments possible all are constrained by attempting them in the enduringly difficult ocean environment. In such an environment, success is possible only through knowledge of the physics of the sea, including acoustic propagation and scattering, and the support of a world-class ocean engineering capability.

Much of this involves the preparation and use of synthetic environments in which authoritative and accredited databases, algorithms, models and simulations form the building blocks from which such environments can be created. Tactical decision aids, training systems, simulators and, increasingly, serious games all are potential delivery mechanisms. As these synthetic environments become increasingly sophisticated, they begin to offer a legitimate cost-saving alternative to fleet deployments for training or mission preparation, and thus are an opportunity for NATO Nations to lower operating costs, including those for fuel and personnel.

In this report you will find examples of CMRE's core competencies in state-of-the-art scientific research and experimentation in:

- Underwater acoustics
- Ocean prediction
- Exploitation of remote sensing at sea
- Autonomy in the maritime domain
- Underwater communications engineering
- Sensors and signal processing
- Modelling and simulation in the maritime domain
- Ocean physics
- Computation and data management
- Hydrographic systems
- Oceanographic instrumentation, platforms, and systems
- Portable sensors in the maritime domain
- Sonars, transducers and arrays
- Ocean engineering
- Seagoing capability (see Research Vessels below)
- Autonomous vehicles (AUVs, USVs, gliders)
- Operations research
- Calibration

ACT's planning activities as part of NATO's Defense Planning Process (NDPP) highlight the need for new and additional capabilities in the areas of Joint Intelligence, Surveillance and Reconnaissance; Command and Control; and Deployment and Sustainment in particular. In this exceedingly complex maritime domain, the CMRE contributes to each of these areas of military requirements with our expertise, assets and experience. Our S&T work is at the forefront, providing new ideas, concepts and opportunities that enable NATO's capability advancement. The CMRE is well prepared to address these challenges and to respond to requirements from NATO and NATO Nations, in particular to the NDPP and to tasks resulting from the Connected Forces Initiative or the Smart Defense concept.

Dr. Dirk Tielbuerger, Director, Centre for Maritime Research and Experimentation

CMRE OVERVIEW

In 2012, the NATO Undersea Research Centre (NURC) transitioned from the chain of command under the Supreme Allied Commander Transformation (SACT) to become the Centre for Maritime Research and Experimentation (CMRE) under the newly formed NATO Science & Technology Organization (STO). At the same time, SACT declared its intention to remain a major customer for the CMRE in the coming years. Staff designed a number of new deliverables requiring S&T support, while calling for a smooth redirection of those to which the NURC had contributed in recent years. The scientific achievements of the NURC/CMRE are described fully in the first Annual Report of the STO.

• NRV *ALLIANCE* and CRV *LEONARDO*

In 2012, the *ALLIANCE* spent 106 days at sea, including participating in exercises Proud Manta and Noble Mariner. Between exercises, the ship undertook her fifth American Bureau of Shipping classification survey and dry dock period, including propulsion and navigation system upgrades, as well as the fitting of a HiPaP 500 acoustic positioning system. The *LEONARDO* spent 120 days at sea supporting the CMRE programme and the Italian Navy.

• Robotic Undersea Surveillance and Intervention (specifically for mine hunting applications)

Robotic technologies are advancing quickly, with machines now truly able to perform complex jobs that are undesirable or too dangerous for humans. In naval mine warfare, the use of remote systems to 'remove the man from the minefield enhances safety while increasing the operations tempo. In 2012, CMRE addressed the full spectrum of mine-hunting operations through use of autonomous systems for: a) detection, classification and localisation of suspected mine targets; b) delivery of a small package to the location of a suspected mine in order to identify it; and c) facilitating the disposal of the bomb. In addition, technical issues related to advancing NATO doctrine for the use of such systems in joint operations are also addressed. In the near future, the CMRE will focus on perception and autonomy methodologies that allow such systems to operate effectively in increasingly difficult environments. The CMRE will also focus on rigorously quantifying the performance of these systems, ensuring they can be confidently used in operations.

• Maritime Security (from global maritime networks to non-lethal responses for port protection)

The Maritime Security Programme contributes to the CMRE value proposition of building maritime knowledge superiority. Highly modular algorithms that enable information sharing and address interoperability, and that inform the development of future Command and Control (C2) systems, are under development. The CMRE is also creating valuable information layers that add intelligence to decision support. A significant achievement in 2012 was a virtual exercise comprised of escalation-of-force scenarios for military and critical infrastructure protection in ports and harbours that used the CMRE's *OpenSea* Tactical Theatre Simulator for serious gaming, which simulated emerging non-lethal technologies in collaboration with the NATO Defence against Terrorism Programme of Work.

- **Active Sonar Risk Mitigation (preservation of military freedom of action)**

In 2012, the Active Sonar Risk Mitigation (ASRM) project continued to support naval exercise planners with risk assessment and mitigation for marine mammals. This included exercises Proud Manta and Noble Mariner, as well as experimentation in other CMRE programmes. These efforts for specific operational scenarios ranged from information and training on marine mammal distribution patterns, strandings, conservation status and concerns to spatially explicit risk assessment studies using best available information. It also provided a risk assessment and risk mitigation framework by identifying both critical-risk scenarios that could require adjustment of sea-trial plans, and minimum-risk scenarios from the operational options available to exercise planners within trial plans.

Networked Littoral Intelligence, Surveillance and Reconnaissance (leading-edge technologies to enable the detection of quiet targets in difficult environments such as littoral waters)

The CMRE demonstrated an off board, autonomous, multi-static Anti-Submarine Warfare ASW capability during Exercise Proud Manta, NATO's largest ASW exercise, which is held annually in the Ionian Sea east of Sicily. Later in the year, a sea trial in which 12 communication nodes were deployed from the NRV *ALLIANCE* saw a number of significant technological advances in networked underwater communications, an approach that others now seek to replicate. A two-pronged approach to tactical analysis of multi-static operations, employing both traditional surface platforms and Autonomous Underwater Vehicles (AUV), allowed for rapid analysis and feedback by the Proud Manta in-stride debrief team on board the HNLMS De Ruijter, the flagship of Commander Standing NATO Maritime Group 1.

- **Ocean Engineering (rapid field testing of new systems and concepts to accelerate exploitation)**

In addition to routine support for projects in the SACT-sponsored Programme of Work, the particular achievements of the CMRE Engineering and Technology Department include:

- The introduction of Graphics Processing Unit (GPU) technology for real-time synthetic aperture sonar processing on-board AUVs, a key enabler for robotic systems;
- Advances in technologies for persistent autonomous underwater surveillance, a key enabler for littoral Intelligence, Surveillance and Reconnaissance (ISR), including improved endurance, optimised bandwidth for underwater communications, and more efficient recovery systems;
- The development of next-generation echo repeaters, including both moored and AUV-borne systems, in addition to the traditional towed version, another key enabler for littoral ISR.

- **Environmental Knowledge and Operational Effectiveness (from data to decision making in crisis situations)**

To enable NATO forces to characterise denied or hostile areas and gain a tactical advantage, the CMRE uses autonomous underwater platforms (gliders) and remote-sensing technologies, combines *in situ* measurements with numerical models to extrapolate forecast conditions, and fuses the information in order to achieve decision superiority through an integrated picture. In Exercise Noble Mariner 2012, data from the autonomous vehicles fed numerical models that were used to forecast oceanographic conditions and derive products that were made available on the Websites of the CMRE and the French navy. The Regional Ocean Modelling System generated four-dimensional (space and time) forecasts as an input to tactical decision aids such as the Multi-Static Tactical Planning Aid.

Techniques have been developed to fuse data from autonomous underwater platforms with satellite remote-sensed sea-surface temperatures in order to obtain synoptic views of the ocean volume, including temperature and salinity, and derived products, such as sound speed and ocean currents. In addition, algorithms to execute campaigns with multiple gliders in an optimised manner that allows 'sampling on demand' have been developed. The tactical prediction activities include numerical ocean modelling to forecast the impact of the underwater environment on the performance of acoustic systems (i.e., sonar), and on warfare disciplines that rely upon clarity/turbidity of the water column (e.g., diver visibility for mine countermeasures and Special Operations).

TRANSITION CHALLENGES

Since its inception as a research centre in the command structure, the CMRE has been supported by NATO common funds, which provide stable income for the development and delivery of its Programme of Work. HQ SACT documented shortfalls in NATO military capabilities and audited the proposed programme for military relevance with the assistance of the Scientific Committee of National Representatives (SCNR).

In 2012, this process underwent a fundamental change. In response to the ministerial call for the Centre to be funded on a project-by-project basis, HQ SACT designed new deliverables and CMRE responded with detailed project management plans for all new work, including that for HQ SACT. These plans formed the basis for Firm Fixed Price proposals that were screened and agreed to under the terms of a Memorandum of Agreement (MOA) signed between CMRE and HQ SACT in late December 2012.

The preparation of fixed price proposals required a thorough review of the CMRE cost structures and processes, with the concepts of billable days and charge-out rates becoming part of the vocabulary, and the customer taking on a new and specific role.

In 2013, each project will be run as a unique activity and tracked for performance and cost. The shift from input-based budgeting to a project-based financial culture has required complete review of policies and procedures. The results will be incorporated into the ISO 9001 system, which will be re-certified in 2014 under the new business model.

In the customer funding model, cash is a resource that must be managed, and cash flow is a critical factor in accepting any new work. Processes and procedure for seeking and accepting new business are changing significantly, and the requirement for speed and agility in all processes has become explicit. This is particularly evident in hiring processes, which previously had taken up to one year due to the length of time required for security clearances to be granted. Work is now packaged in order to minimise the requirement for clearances, which not only reduces response time, but improves the protection of classified information. The use of a temporary and contract workforce has expanded the skills base and reduced risk.

NRV *ALLIANCE* AND CRV *LEONARDO*

Figure 23. The NRV *ALLIANCE*.

Figure 24. The NRV *ALLIANCE* in dry-dock.

The CMRE operates two research vessels in support of NATO's maritime S&T Programme of Work. The vessels are an integral part of the scientific research, and enable the CMRE to provide field-tested and validated solutions for NATO. The vessels are wholly owned by the NATO Nations, and are operated by the CMRE on behalf of the nations through flagging and custody arrangements with Germany, Italy and HQ SACT.

The NATO Research Vessel (NRV) *ALLIANCE* is a global-class, 93 m vessel capable of worldwide operations, having the capacity and endurance to take up to 25 scientists and engineers to sea for protracted lengths of time. The vessel is flagged by Germany as a German naval auxiliary vessel, and is manned by a civilian contract crew under a management arrangement with a ship management company based in the United Kingdom.

In 2012, the ship was employed at sea for 106 days in support of the Programme of Work. Highlights included participation in the NATO exercises Proud Manta 2012 Noble Mariner 2012, during which many new technologies and scientific processes were introduced to the operational community.

> The vessels are an integral part of the scientific research, and enable the CMRE to provide field-tested and validated solutions for NATO.

Commissioned in 1988, the ship marked a significant milestone in its maintenance history when it entered its fifth special-classification survey and dry-dock period this year. The survey involved extensive inspection and testing to ensure the vessel is seaworthy and meets the standards required for classification by the American Bureau of Shipping (ABS). The results were very good, with measurements from the hull indicating that the vessel will remain seaworthy for many more years.

In order to avoid a very costly mid-life refit, the ship has been maintained and upgraded on a rolling programme throughout its life. The 2012 dry-dock period continued this process, with completion of the propulsion system upgrade, as well as navigation system updates and the fitting of a HiPaP 500 acoustic positioning system. All of these updates allow the *ALLIANCE* to remain as a state-of-the-art research vessel able to support advances in technology and modern maritime scientific research.

The NATO Coastal Research Vessel (CRV) *LEONARDO* is the second wholly owned ship. The 28 m vessel is used predominantly for inshore and coastal area research, providing the CMRE a capability with platforms from the near-shore to the deep ocean. The ship is operated under a sharing arrangement with the Italian navy, which provides both the flag and significant support by crewing and maintaining the vessel. When not in use by the CMRE, the ship is made available to the Italian navy.

Figure 25. The CRV *LEONARDO*.

In 2012, the *LEONARDO* spent 71 days at sea supporting the CMRE programme, and 49 days supporting the Italian navy. This arrangement provides a cost-effective solution for NATO, and a highly effective and specialised platform for the Italian navy, when required.

• Evolving Customer Base

NATO

NATO is the CMRE's principal customer, and the Centre is committed to delivering an outstanding work product. At present, most of the CMRE's projects are sponsored by HQ SACT, mainly their Capability Development Division and the Future Solutions Branch. The new customer-supplier relationship between HQ SACT and the CMRE was begun on 01 January 2013, with both organisations quickly fulfilling their roles and responsibilities. The CMRE's programme managers have engaged decision makers in this command, and new requirements for monthly reporting have been implemented and are being met. Efforts are underway to re-engage with HQ SACT's Concept Development and Experimentation (CD&E) Branch. There had been significant interaction on projects of mutual interest between CD&E and the NURC prior to 2010, and it is envisioned that this interaction will be reinvigorated.

> The relationship between CMRE and NATO Nations will continue to strengthen.

The CMRE foresees that funding from Allied Command Operations (ACO) will increase significantly over the next three years, and that a significant portion of this work will involve Operations Research (OR). 'The Centre previously possessed a significant OR capability, and intends to place renewed emphasis on this work, which will enable accelerated application of S&T solutions to ACO problems. The CMRE will be with ACO at the mid-grade scientist and analyst level throughout the following months.

The NATO Security and Investment Programme (NSIP) is a key mechanism to improve NATO's defence capabilities and promote the interoperability between the 28 Allied Nations. The Centre has a successful history of managing NSIP funding, in particular for HQ SACT. The NSIP finances the provision of key military capabilities, and the CMRE is in a unique position to provide programme management for these enhancements. For example, Autonomous Underwater Vehicles (AUVs) and gliders are likely to undertake a greater role in future NATO operations. Interoperability will require communications both above water and under the sea surface, and the CMRE is a leader in providing AUV and glider services to NATO exercises. The CMRE also foresees, at the request of the Commander of Allied Maritime Command Northwood, an increase in social science research, including for example the application of data fusion capabilities in support of NATO operations.

Enlarging the Customer Base

In order to thrive under the new customer-funded regime, the STB encouraged the CMRE to seek ways to expand its customer base, while acknowledging its specific situation. To that effect, the STB approved a customer-base policy that defines the conditions under which the Centre could engage with customers from industry, international organisations, or non-NATO Nations.

Long-Term and Sustainable Funding for Experimentation at Sea

The CMRE (and its predecessor organisations) have for many years had an effective at-sea experimentation programme. The *ALLIANCE* and the *LEONARDO* provide NATO with a unique, world-class capability to test equipment, including robotic underwater and surface vehicles, to demonstrate techniques, such as multi-static sonar for ASW, and to validate algorithms, such as those that can predict oceanographic weather. These capabilities are used to support NATO maritime strategy, tactics and training. Another example of the unique role of the ships is the participation of the Alliance in the NATO exercises Proud Manta and Noble Mariner during the past several years. With the *ALLIANCE* and the *LEONARDO*, NATO is able to deploy and recover underwater gliders that provide oceanographic and biological data to the exercise commander. These ships also allow the introduction of the latest technology in underwater robotics to NATO air, surface and sub-surface combatants. In addition, the ships support individual NATO nation goals such as submarine noise measurements by the Italian Navy. On a space-available and cost-reimbursable basis, industrial customers from NATO Nations may use the ships to support their research and development requirements.

Long-term and sustainable funding for the ships will be attained through the following measures:

- Increased participation of the *ALLIANCE* and the *LEONARDO* in NATO exercises such as Proud Manta and Noble Mariner. Obtaining the needed funding through ACO, with assistance from HQ SACT, and through NATO agencies. This will require a dedicated marketing campaign with key decision makers within ACO;
- Increased collaboration with individual NATO Nations for use of the ships on a cost-reimbursable basis. This will require focused marketing efforts towards key decision makers within the nations;
- Increased cooperation with industrial partners for use of the ships on a cost-reimbursable basis. This will require a marketing campaign with key decision makers in the industries.

The *ALLIANCE* and the *LEONARDO* provide NATO with a unique, world-class capability to test equipment.

ROBOTIC UNDERSEA SURVEILLANCE AND INTERVENTION

Technologies in the general field of robotics are advancing quickly, such that machines are now reaching the state where they can perform complex jobs that are undesirable or dangerous for humans to undertake. In the field of naval mine warfare, a generally agreed goal is to 'remove the man from the minefield', i.e. utilising remote systems to the greatest extent possible in order to both ensure the safety of human operators and increase the operations tempo.

In 2012, the CMRE undertook an interrelated set of projects under the Autonomous Naval Mine Countermeasures (ANMCM) programme in order to extend NATO capabilities in this area. The programme addresses the full spectrum of mine hunting operations, using autonomous systems for the detection, classification and localisation of suspected mine targets, for the delivery of a small package to the location of the suspected mine for identification, and for potential disposal operations. In addition, the programme addresses technical issues related to advancing official NATO doctrine for the use of such systems in joint operations.

• Underwater Perception

One important area of research for enabling autonomous systems to perform such missions, versus the use of underwater mines, is improved perception, i.e., providing to the robotic system data about its environment, such that it can perform its mission and make intelligent decisions on how best to operate. Because acoustic energy propagates underwater better than electromagnetic energy, sonar systems are typically used to provide autonomous perception in this field.

> The CMRE has played a significant role in the development of Synthetic Aperture Sonar (SAS) technologies. They operate at acoustic frequencies on the order of 100 kHz, and maintain a demonstrator system, the MUSCLE, that consists of an integrated Autonomous Underwater Vehicle (AUV) and an SAS payload.

In 2012, the CMRE SAS processing software chain and raw data were distributed to several nations in order for them to leverage the development in their own national programmes. In addition, the CMRE installed a new hardware processing module in the MUSCLE vehicle, with a state-of-the-art Graphical Processing Unit (GPU) and specialised software, allowing the SAS imagery to be processed during the vehicle's mission time in the water. This new module provides high-resolution acoustic imagery to other on-board algorithms for follow-on processing, a capability that was demonstrated during the ARISE'12 sea trial in October 2012.

Figure 26. The multi-national ARISE'12 sea trial took place near Elba Island from 15 October to 03 November 2012, with participation of the CMRE and representatives from four national research programmes. The MUSCLE vehicle (foreground) and the NRV *ALLIANCE* are pictured.

Other perception-related research took place in a parallel project related to using lower frequency acoustics, approximately 10 kHz. The goal of this research is to provide information about the seabed and potential foreign objects that may not be available in the higher frequency acoustic data, thereby reducing false alert rates for search missions. CMRE is also investigating the use of very high frequency (i.e. 1 MHz) Commercial Off the Shelf (COTS) imaging sonar systems for reacquiring previously located objects and optimally employing their fields-of-view for delivering small packages to potentially dangerous objects. This capability was ably demonstrated in the ANT'12 series of experimentation. The overall programme, through utilisation of acoustic systems over a broad frequency range, must leverage the core competencies of underwater acoustics, signal and image processing, and ocean engineering that are maintained at the CMRE.

• Autonomous Behaviours

As truly autonomous robotic systems periodically perceive information regarding their mission and operating environment, they must then employ programmed intelligence that utilises this information to perform the mission efficiently and effectively. Another key research area undertaken in the ANMCM programme is autonomous behaviours related to mine-countermeasure missions. Several examples can be found in the project related to the MUSCLE vehicle. As high-resolution acoustic imagery data is processed on board the vehicle, it is analysed for performance of the system versus cross-track range from the vehicle. By keeping a record of areas that have been covered by high-quality acoustic imagery, efficient coverage plans can be generated to ensure that the entire area of responsibility is effectively interrogated in the minimum amount of time. More complex autonomous behaviours with respect to Automatic Target Recognition (ATR) algorithms that are run on the same data are being explored. As targets are detected and assessed in order to determine their identities (i.e., are they mines), additional interrogations at different aspect angles can be planned in an efficient way in order to gain the most effective amount of new data. In this way, target classification confidence can be maximised. The objective is for the vehicle to gather the best data possible while on sortie, and return that data to human operators for further review and higher-level tactical decision making.

The project concerning reacquisition of previously located targets utilises complex collaborative autonomous behaviours involving multiple vehicles. The base experimental system is an Autonomous Surface Vehicle (ASV), which moves to a contact point and initialises an autonomous reacquisition search (using a small imaging sonar) for the

Figure 27. The Gemellina ASV poised to launch the Goldrake 'slave' package. Repeated successful remote-guiding missions were accomplished during the ANT'12 experimentation from 28 May through 18 June and from 17 October through 4 November 2012.

suspected target found by the MUSCLE system. Upon reacquiring the target, a small inexpensive 'slave' vehicle is launched. After the slave vehicle is acquired in the imaging sonar field of view, it is guided by the master to the suspect object using messages sent via acoustic communications. The current test version of the slave vehicle has an optical camera, allowing pictures to be taken and relayed to the ASV via acoustic messaging. This master-slave 'remote guiding' approach was developed with the idea that the slave package may later be used as a disposal device. The primary sensors and computers running the autonomy algorithms are therefore located on the ASV, which can be moved to a safe range should disposal become necessary. Multiple successful landings near targets were achieved in the ANT'12 experiments.

• Planning and Evaluation

As well as providing technology in order to generate increased autonomous capability, the CMRE also performs studies on new planning and evaluation methods that will be required in order for autonomous systems to be used in a seamless way in joint NATO mine-countermeasure operations. To this end, the CMRE participates in NATO MINEX exercises, both in helping to baseline current operational performance and in collecting data with the autonomous systems in order to compare performance and develop the proper tools for performance evaluation. The CMRE works closely with the NATO operational community, and provides scientific support to the NATO Mine Warfare Working Group (NMWWG) and its Tactics and Tools Evaluation Panel (TTEP). The CMRE also provides scientific representation to the Mine Warfare Syndicate of the Underwater Warfare Capability Group (UWWCG). These activities help inform the NATO Nations' operational representatives of the capabilities that can be brought with new technologies, and ensures that CMRE researchers stay abreast of operational requirements.

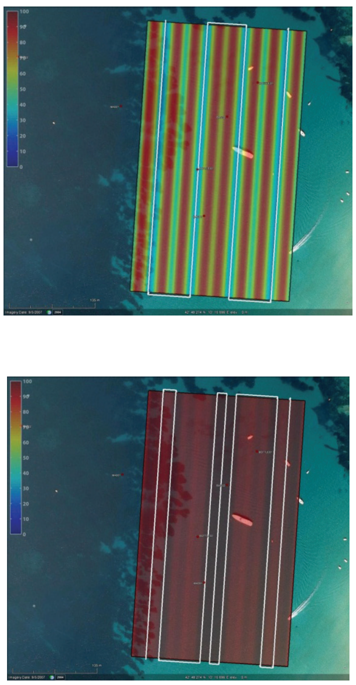


Figure 28. Examples of mission plans from ARISE'12 that achieve different levels of coverage (red indicates successful sonar mapping). New techniques are being developed for planning with pre-programmed systems, as well as for post facto evaluation of mission performance for these systems and more autonomous versions that plan their own missions in the field.

• Looking Forward

In the near future, CMRE research in this area will focus on several particular areas. These include the development of perception and autonomy methodologies that allow such systems to operate effectively in increasingly difficult environments, primarily with respect to cluttered sea bottom conditions, as well as the rigorous quantification of the performance of these systems in order for them to be used confidently in real-world operations. The CMRE will continue to work closely with researchers in NATO Nations, allowing them to leverage the data sets and algorithm developments that are produced.

THE FUTURE OF NETWORKED ASW IN A MULTINATIONAL CONTEXT

Through an underwater network of intelligent sensors, this programme demonstrates persistent littoral surveillance of submarine targets. It develops and tests technologies that support the creation of ad-hoc communication networks between maritime assets (autonomous, manned, submerged, and on or above the surface) and the associated decision support tools.

• ASW Sensing

In 2012, the NRV *ALLIANCE*, with two Autonomous Underwater Vehicles (AUVs), participated in Exercise Proud Manta, NATO's largest ASW exercise, held in the Ionian Sea east of Sicily, to demonstrate the concept of off-board multi-static ASW. The results from this and other trials were shared exclusively with the U.S. Naval Research Laboratory, the Hellenic Navy, the Norwegian FFI Laboratory, the Italian Navy, the NATO Underwater Warfare Working Group, MC Naples, and MC Northwood. All offered opportunities to brief national navies, laboratories, NATO specialist teams, and the NATO ASW exercise community about the compelling end-to-end demonstrations made against real targets by the CMRE systems.

• Communication and Networks in the Maritime Environment

The Littoral Ocean Observatory Network (LOON), a 'modem farm' in the Gulf of La Spezia that enables the latest developments in underwater mobile acoustic networking to be tested without research vessel support, has been extended in response to strong international collaborative demand. It featured subsequently in an intensive experimental sea trial with five different collaborating research organisations represented on board the NRV *ALLIANCE*, conducting the most ambitious networking and routing experiments attempted anywhere previously. A total of 12 communications nodes were deployed, with up to 10 operating at any one time, hosted on a wide range of platforms, including bottom-mounted fixed nodes, two types of small AUVs, shown in Figure 31, gateway buoys, and an Autonomous Surface Vehicle (ASV). Cross-platform communications using different modems were also tested.

Figure 29. AUV deployment in Exercise Proud Manta.

Figure 30. Aft deck of the NRV *ALLIANCE* with winch for Low Frequency Active (LFA) Variable Depth Sonar (VDS).

Figure 31: Two 'Folaga' AUVs being prepared for deployment.

Figure 32. 'Mission Control' during CommsNet 12, with teams from the universities of Rome 'La Sapienza', Padova, and Porto, as well as EvoLogics and the CMRE.

Work continues on developing these platforms and payloads, specifically for the Proud Manta exercises, to provide an autonomous surface gateway for the CMRE AUVs.

In addition to the intense field trials conducted this year, significant effort was invested in hosting an international conference and workshop on underwater channel estimation and validation for communications (http://www.UComms.net). The UComms conference attracted 74 participants from 31 research organisations across 15 countries, with significant sponsorship both from ONR and several commercial underwater communication equipment manufacturers. The objectives of the conference were to reach consensus on the physics needed to model the underwater acoustic communications channel effectively, the modelling approaches that represent the best practices, and the benchmarks that can be established for the purposes of predicting communications performance. The product of this work will be published in a special issue of the IEEE Journal of Oceanic Engineering and as a CMRE report in 2013.

Significant progress was also made in the refinement and promotion of JANUS, the digital underwater coding standard developed at the CMRE and adopted as a NATO Standardization Agreement. A workshop was held in October that brought together a number of the main stakeholders and, more specifically, a strong representation from Germany, due to outstanding concerns and differences that had surfaced between the current standard definition and German preferences. All differences and concerns were addressed at the workshop and resolved. The result is an improved standard version 3 that all parties are comfortable with and that is now being submitted. A revised set of technical documentation has now been produced and posted on the JANUS community wiki site at http://www.januswiki.org.

• Decision Support

This project provides tactical analysis of multi-static operations employing both traditional surface platforms, in support of Smart Defence, and cutting-edge AUVs. A two-pronged approach combines the development of the tactical decision aid with analysis of multi-static tactics. The Multi-static Tactical Planning Aid (MSTPA) was further improved on during 2012 with the addition of enhanced acoustics and validation against the Advancing Multi-static Operation Capability (AMOC) TTCP collaboration. MSTPA was used in Exercise Proud Manta 2012 for both acoustic prediction and as a tactical replay tool, comparing well with on board software. The replay facility was well received on board and has prompted further development.

The MSTPA tool was a central feature of the ASW TDA workshop held at the CMRE, which saw more than 70 scientists and military personnel attend. Two days were devoted to presentations that included discussions on tools and tactics, as well as the need for multi-static tactical development and doctrine. The presentation phase was followed by real-time red-on-blue simulations employing multiple MSTPA simulations linked to the OpenSea virtual maritime environment. This allowed participants to drive surface platforms in multi-static configurations, deploy air-dropped sonobuoys, and pilot submarine threats.

Following the workshop, there has been increased interest in the MSTPA tool, which has been used by the Canadian Maritime Warfare Centre for another tactical workshop. This collaboration has resulted in the proposal of a Joint Research Project (JRP) in which MSTPA will be used on board Canadian military platforms for the planning and analysis of multi-static exercises. It is likely that this JRP will include Norway.

'This workshop convinced me that I will use MSTPA in my future work. It is an excellent tool for modelling and demonstrating the prowess of multi-static and multi mono-static operations.' – FFI (NOR)

[Relative to MSTPA and its serious gaming capabilities]: 'I see it being quite useful in multinational prototype and new NATO conops transitions, moving down the development risks and identifying interoperability issues prior to expensive operational testing tasks.' – NRL (USA)

'I must start by congratulating you and all the team involved in running a very successful workshop and demonstration that captured different aspects of the systems while obtaining operators inputs and opinions.' – NRL (USA)

ENVIRONMENTAL KNOWLEDGE AND OPERATIONAL EFFECTIVENESS (EKOE)

• 'Data to Decision Making' in Crisis Situations

Faced with a mission in a denied or hostile littoral area, how will NATO forces obtain the environmental information they require in order to characterise the battle-space, gain a tactical advantage over their adversaries, and ensure the safety of their operations? Addressing this question is at the heart of the on-going research in the EKOE programme at the CMRE.

A focal point for activities in 2012 was Noble Mariner 2012 (NOMR12), a NATO Response Force Exercise in the Gulf of Lion in which Rapid Environmental Assessment (REA) was an objective. The CMRE participated, with gliders serving as discreet REA units and with the NRV *ALLIANCE* evaluating oceanographic and acoustic prediction tools. The trial involved collaboration with Geographic, Meteorological and Oceanographic Center GEOMETOC personnel at Maritime Command Northwood, military and civilian organisations in France, and representatives from an additional five national research programs in Italy and the United States. To demonstrate the 'data-to-decision' paradigm, data from the autonomous vehicles was collected in order to characterize the environment and feed numerical models to forecast oceanographic conditions, and derive products that were made available to the fleet on the CMRE and French Navy Websites. The high currents near the coast tested the capability limits of the underwater gliders, with pilots frequently consulting a decision-support tool developed at the CMRE that predicts glider trajectories based on ocean current forecasts.

Battle-space Characterisation

Battle-space characterisation employs remote-sensing technologies in order to develop techniques to characterise the battle space discreetly.

> The long endurance of undersea gliders presents significant potential for them to function as mobile 'nodes' that are cost effective, scalable to an area of interest, re-locatable, and rapidly deployable.

Techniques have been developed to fuse data from the gliders with satellite remote-sensed sea-surface temperature in order to obtain synoptic views of the ocean volume, including temperature and salinity, and derived products, such as sound speed and ocean currents. In addition, algorithms have been developed to execute campaigns with multiple gliders in an optimized manner that allows 'sampling on demand', i.e., a series of waypoints (and the minimum number of gliders) that are required to achieve the performance stipulated by a mission planner. With Spain, France, Italy and the United States, research in 2013 will extend the network to platforms such as gliders, profiling buoys, and ships, and introduce a continuous feedback of information from the data fusion engine for adaptive mission planning.

Additionally, novel sensor payloads to evaluate gliders for Intelligence, Surveillance, and Reconnaissance (ISR) roles are being developed.

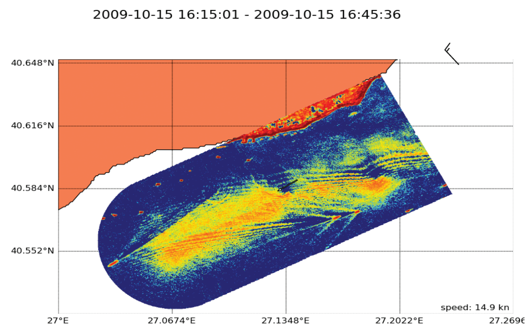


Figure 33. Internal wave signatures using an X-band marine radar and SuFMoS software.

New sensing modalities, including marine radar and ocean optics, are also being evaluated. Development of the Surface Feature and Monitoring System (SuFMoS) was completed in 2012. The specialised processing allows a ship-based X-band marine radar system to monitor ocean surface features within a radius of approximately 4 km, revealing winds, waves, currents, and internal waves that would otherwise have been hidden in the sea clutter. In 2013, the real-time observational capabilities of SuFMoS will be demonstrated in trials in Italy, Germany and the United States. The LIDAR Observations of Optical and Physical Properties (LOOPP) workshop hosted at the CMRE in late 2011 identified significant potential for Light Detection and Ranging (LIDAR) systems that originally were developed for applications such as shallow-water bathymetric mapping to measure a suite of vertical oceanographic properties (e.g., temperature, salinity, vertical currents, and optical properties), which collect vastly more data at a fraction of the cost of existing instrumentation options. As a result, in 2012 plans were made for a field trial, scheduled for early 2013, which will be the first attempt at assessing whether this potential can be realised in practice. The research will be undertaken with representatives from 10 national research programmes in the United Kingdom, France, Italy, Turkey and the United States.

Tactical Prediction

Tactical Prediction combines in situ measurements with numerical models to forecast conditions in time and space, information that is critical for selecting the time and/or location of a mission, reducing the vulnerability of NATO forces, and employing assets most effectively and efficiently. In 2012, the CMRE extended the Regional Ocean Modelling System (ROMS) to enable the assimilation of data from gliders, and to provide stochastic forecasts. These forecasts may generate products directly, such as for NOMR12 (Figure 34 and 35), as an input to tactical decision aids such as the Multi-Static Tactical Planning Aid (MSTPA), and more generally as an input to the Goal-Oriented Decision Support

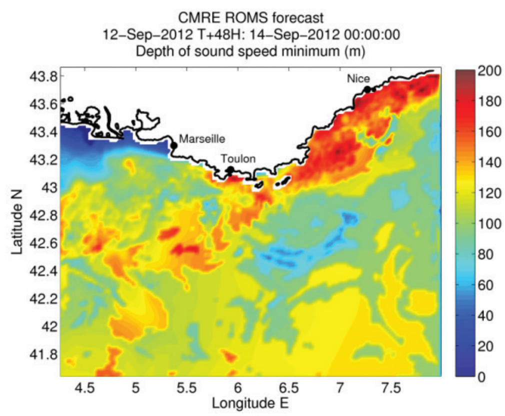


Figure 34. ROMS forecasts during NOMR 2012. Sea surface temperature and currents at depth of 25m.

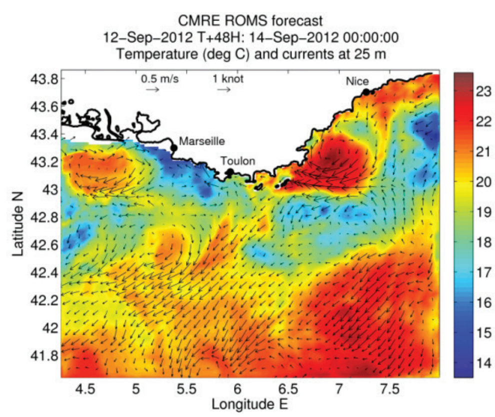


Figure 35. ROMS forecasts during NOMR 2012. Depth of the sound speed minimum, a sample product for ASW operations.

System, which is described in the next section. The CMRE's partners represent five national research programmes in Canada, Italy and the United States.

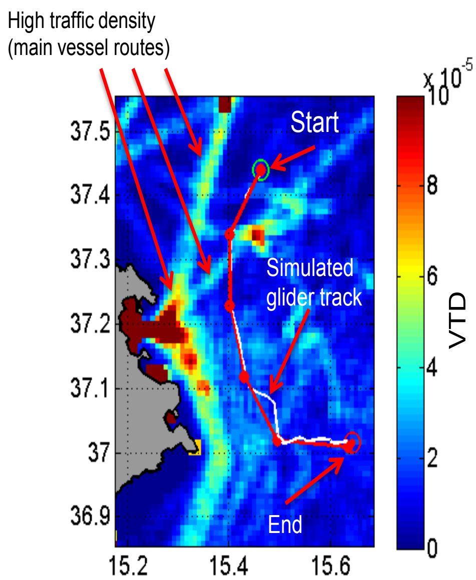


Figure 36. Waypoints for a glider mission (red dots) optimized to avoid areas of high vessel density (colour coded map with red indicating high traffic) and to minimize the mission duration.

Decisions in Uncertain Ocean Environments

Decisions in Uncertain Ocean Environments fuses a large amount of information in order to achieve decision superiority by providing an integrated picture, enhancing an operator's cognitive capabilities by assessing and portraying risk, and incorporating the uncertainty of Meteorological and Oceanographic (METOC) forecasts. In 2012, the CMRE continued the development of a Goal-Oriented Decision Support System (GO-DSS) framework to increase the automation and effectiveness of information fusion, environmental impact, uncertainty assessment, and decision-making processes. The framework also includes tools for advanced machine learning and optimisation. These tools can be modularly combined to support a large spectrum of operation-planning tasks involving optimal asset deployment in the presence of conflicting objectives. The DSS capability is generic, and is intended to support NATO maritime operations in many warfare disciplines.

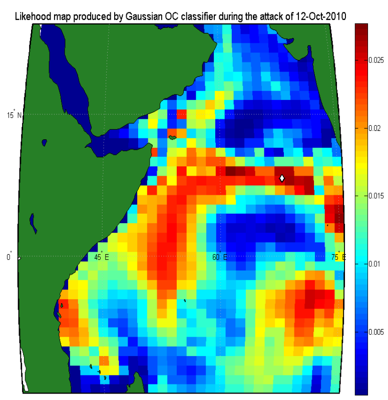


Figure 37. Geographical distribution of the likelihood that MetOc conditions are suitable for a pirate attack (red is high likelihood) based on. The position of the actual attack is represented by the white dot.

An application utilized in 2012 provided support for glider operations during exercises POMA 2012 and NOMR 2012, Since slow-moving gliders are deeply impacted by the environment, the GO-DSS must incorporate forecasts of wave heights, wind speed, currents, vessel traffic density, kinematics of the glider, and geometric constraints in order to anticipate forces acting on the glider and propose an optimal set of waypoints for a set of objectives including mission time, vehicle endurance, and collision avoidance while on the surface to telemeter data (Figure 36).

Another application of the DSS sought to improve the quality of piracy-attack risk maps (based on METOC parameters) by introducing machine learning in order to train a classifier to identify suitable conditions for an attack rather than relying on 'crisp' thresholds (Figure 37). The research was undertaken in conjunction with MC Northwood, and with representatives from national research programmes in the United Kingdom, the Czech Republic, and the United States.

Collaborative Projects

Gliders for Research, Ocean Observation, and Management (GROOM) – European Commission FP7 consortium agreement

GROOM is striving to ensure interoperability between European glider fleets through the standardisation of data formats, data-processing and quality-control routines, and mission-planning tools. It will establish the necessary infrastructure and protocols for EU nations to make most effective use of the pool of gliders owned and operated by those nations. These topics are also pertinent to ensuring the interoperability necessary for NATO use of this technology in military oceanography.

Ocean Strategic Services Beyond 2015 (OSS2015) – European Commission FP7 consortium agreement

OSS2015 will provide nowcast, forecast, and climatology of the biogeochemical properties of the ocean mixed layer by fusing satellite ocean colour data (multispectral radiance of the sea surface) and *in situ* measurements (buoys, drifters, gliders, etc.) through two different methodologies: geo-statistical models and numerical, biological and biogeochemical models. CMRE research on the vertical optical properties of the water column is being coupled with physical oceanographic and biogeochemical models of consortium partners. The ultimate goal is a predictive capability of ocean optical properties, a goal of interest to NATO for sensor systems and operations that depend on water clarity.

Glider Acoustic Sensing of Sediments (GLASS) – US Office of Naval Research (ONR) Global

Seafloor properties in littoral areas can have a profound impact on sonar performance. Techniques to measure these properties typically require a ship, and are costly and time consuming. Gliders have been demonstrated to be a cost-efficient solution to the measurement of seawater properties such as temperature, salinity, and optical properties. Their potential as a discreet and cost-effective means to measure seafloor properties has yet to be assessed. To that end, techniques that use the vertical structure of the ambient noise intensity field measured with vertical arrays of hydrophones to determine seafloor properties are being adapted to use a compact hydrophone array mounted on a glider.

ACTIVE SONAR RISK MITIGATION

The conduct of active sonar exercises is essential for training naval forces to counter the threat from submarines. This requirement is at risk because of legal and public pressures deriving from temporal and spatial correlations between several atypical marine mammal stranding incidents (Canary Islands in 2002 and 2004, the Bahamas in 2000, and Greece in 1996) and the operation of tactical active sonar by NATO naval forces. The CMRE has for many years been closely involved in the development and application of best practices for mitigating risk to marine mammals in the presence of active sonar. Since 2011, The CMRE has provided a formal reach-back capability to maritime exercise planners.

• Effects of sound on marine mammals

As atypical mass-stranding incidents of cetaceans, especially beaked whales, have been associated with the operation of military Mid-Frequency Active (MFA) sonars, it is of utmost importance to learn about the effects of sounds on beaked whales. Recent studies suggest that behavioural responses to MFA sonar play an important role in the series of events that lead to such strandings (Cox et al. 2006). An initial series of Controlled Exposure Experiments (CEEs) and opportunistic studies have begun to provide data on behavioural responses to MFA sonar by species including Blainville's beaked whales (*Mesoplodon densirostris*) (Tyack et al. 2011).

Although Cuvier's beaked whales (*Ziphius cavirostris*) constitute the majority of fatalities in MFA-associated strandings (D'Amico et al. 2009), only very recently two Cuvier's beaked whales were exposed to simulated MFA sonar during the 2010-2011 Southern California Behavioural Response Study (SOCAL-BRS)(Southall et al. 2012). DeRuiter et al. (in preparation.) observed intense, consistent, long-lasting responses by two *Ziphius cavirostris* to simulated MFA sonar at short ranges. One of the whales, however, did not respond similarly to MFA sonar from a distant naval exercise with comparable received levels, suggesting that, in addition to received level, other contextual factors (e.g., sonar-whale range, increase of received level during ramp-up, reverberation, previous experience to MFA sonar) may moderate the whale's response to MFA sonar.

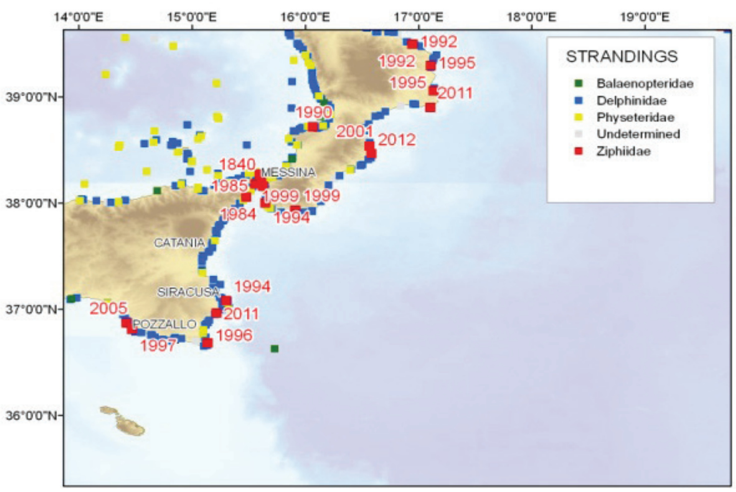


Figure 38. An example of material provided to exercise planners for risk assessment

• Estimation of the presence of marine mammals

Knowledge of animal presence is paramount for effective active sonar risk mitigation. In 2011, the ASRM programme carried out Sirena11, a cetacean survey in the Ligurian Sea to test not only the passive acoustic monitoring capability of the CMRE, but also to gain insight into the seasonal distribution of the Cuvier's beaked whales. The three phases were carried out in July, October, and December, and confirmed the year-round presence of Cuvier's beaked whales, with somewhat greater distribution during the summer (B-Nagy and Zimmer, in prep), as shown in Figure 39.

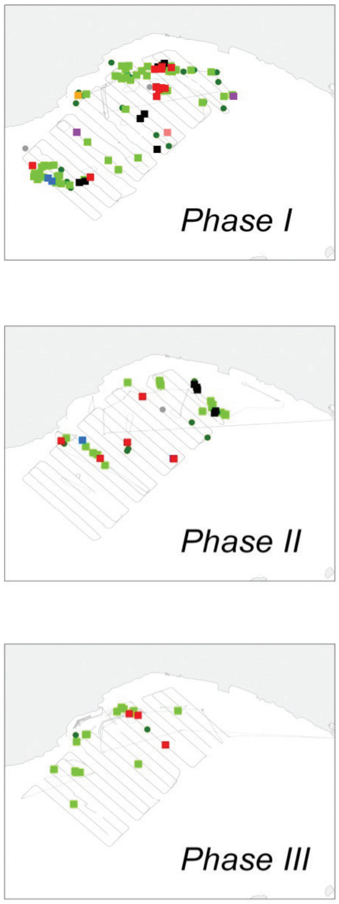


Figure 39. Sightings of marine mammals during the three phases of Sirena 11. The colours represent different species.

The Sirena 11 sea trial validated the CMRE's capability for visual and acoustic monitoring of marine mammals, and, in 2012, the data collected was used to expand the CMRE's marine mammal database and to update habitat suitability models for cetacean species of interest (particularly beaked whales), which are a critical component of the CMRE's marine mammal risk assessment and mitigation effort. (Figure 40). The combination of acoustic- and visual-monitoring techniques enabled us to compare their effectiveness, and highlighted both opportunities and challenges in generating robust presence and density estimates for marine mammals.

> Knowledge of animal presence is paramount for effective active sonar risk mitigation.

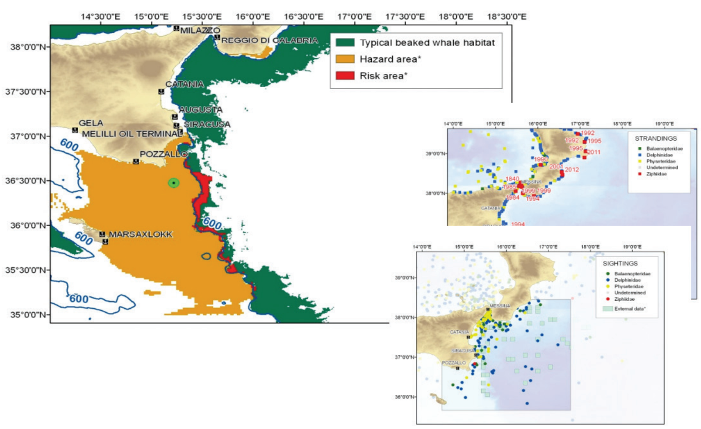


Figure 40. An example of material provided to exercise planners for risk assessment.

• NATO ASW exercises and marine mammals

In 2012, the ASRM project continued to support naval exercise planners in order to provide risk assessment and risk mitigation for marine mammals. This support covered both CMRE and wider NATO naval exercises (e.g., Proud Manta, Noble Mariner), and ranged from providing updated information and training on marine mammal distribution patterns, strandings, conservation status and concerns to spatially explicit risk assessment studies using best available information for specific operational scenarios (Figure 40). The ASRM effort seeks to provide a risk assessment/mitigation framework by identifying critical risk scenarios that could require the adjustment of sea trial plans, as well as minimum risk scenarios from the operational options available to exercise planners within trial plans.

> Monitoring the acoustic impacts of military activities underlines the commitment of NATO to mitigate risks to marine animals.

• Summary

The goal of the ASRM programme is to maintain the capability to carry out active sonar experimentation, and to allow NATO exercises to be carried out by providing the best scientific information on the effects of sound on marine mammals, as well as possible mitigation measures. The emerging results from controlled-exposure experiments and opportunistic studies indicate that the observed negative impact of active sonar on marine mammals is very much context dependent. It therefore seems essential that more effort be dedicated to assessing *in situ* the actual effects of active sonar sound on marine mammals in general, and on beaked whales in particular. Such monitoring of the acoustic impacts of military activities not only would quantify the real effect of sound on marine mammals, but would also underline the commitment of NATO to mitigate risks to marine mammals. Considering the successful development of mitigation procedures and tools by the ASRM program, the CMRE has positioned itself as strong partner for continuing support to NATO in its role as an environmental steward.

MARITIME SECURITY

NATO Nations enjoy many benefits from today's global economy, and maritime transport networks serve as an important backbone for the supply chain, carrying roughly 90 percent of world trade. Piracy, terrorism, and the use of maritime routes for illicit activities are concerns that threaten these important trade networks. The technical focus has been in the areas of automation in support of information exploitation, technology demonstration, and the use of war-gaming to evaluate the effectiveness of evolving tactics and techniques.

• Maritime Situational Awareness (MSA): Global Maritime Networks and Current Challenges

The maritime environment is largely unconstrained, both physically and politically, and threats tend to hide within normal activity while moving freely between the open oceans and territorial waters of a number of different nations. Collaboration and information sharing have become top priorities, as no single nation or organization has the mandate or resources to enable the desired level of stability. The high-tech industry is driving innovation with powerful mobile devices, network-based solutions, and the ability to consume and store massive amounts of information. The CMRE MSA project focusses on how to bring the best of academia and industry to operational users for information exploitation within a federated environment.

In 2012, the CMRE introduced a prototype to demonstrate 'Fusion-as-a-Service' (FaaS)" as a means of handling the abundance of information and enabling effective exploitation. Historically, track correlation algorithms follow a 'black box' approach, and many C2 systems are manually intensive with growing operator workload. Legacy systems simply do not support the demands of the amount of data available today from a variety of providers and sources.

The CMRE 'Collaborative Multi-Sensor/Source Fusion and Tracking' (CoMSSoFT) framework provides the structure and interfaces for fusion services, and is made available to NATO using the ACT Tidepedia site as a collaborative point of reference and repository. The goal is to advance fusion and tracking with modern and open software engineering standards that satisfy future C2 systems and provide robust and interoperable solutions based on common NATO service standards. This places considerable attention on scalability and the processing demands of global vessel traffic (as shown in Figure 41). The CoMSSoFT framework will be tested during the 2013 Coalition Warrior Interoperability eXploration, eXperimentation, eXamination, eXercise (CWIX), which will bring together several nations and NATO entities.

> Another significant accomplishment in 2012 was the development of unsupervised machine learning techniques to extract maritime traffic routes from historical positional data.

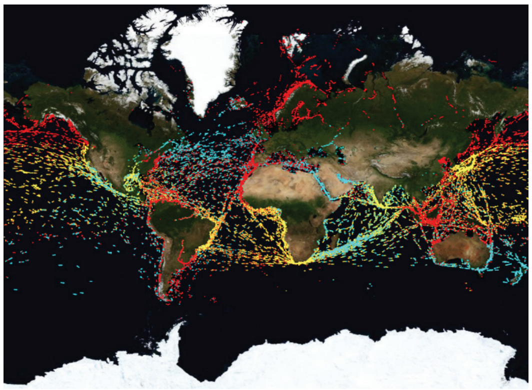


Figure 41. Twenty-four hours of global ship AIS tracking data from multiple providers as indicated by varying colours.

Significant progress has been made on the 'Traffic Route Extraction and Anomaly Detection' (TREAD) model, which will assess the capability to provide automated maritime traffic route anomaly detection. The first step in this development has been to provide an automated route-extraction technique, useful in its own right, to inform the understanding of patterns of life in the maritime domain. The NATO Shipping Centre (NSC) and MC Northwood response to initial results has been very positive. (Sample extracted routes in the La Spezia, Italy, area are shown in Figure 42). In 2013, the CMRE will continue to work with the NSC and with Allied Maritime Command MARCOM to assess the operational utility of automated route extraction techniques, and to better understand the follow-on requirements for route anomaly detection. The process of evolving and automating new decision-support analytical tools will require significant interaction with operators to ensure that useful intelligence is added to the operating systems.

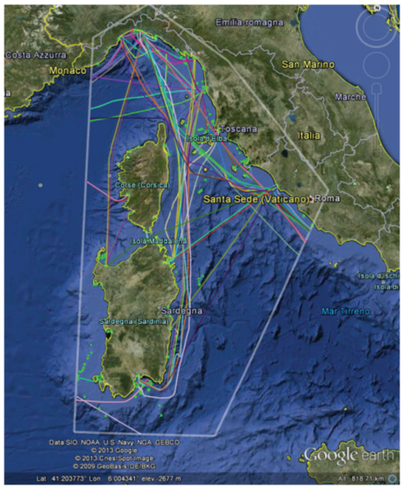


Figure 42. Traffic routes extracted automatically from historical AIS data from October – November 2012.

• Harbour Protection Table-Top Exercise

In March 2012, the CMRE hosted the Harbour Protection Table-Top Exercise (HPT2E), a virtual escalation-of-force scenario for military and

Figure 43. Participants in the HPT2E exercise of non-lethal capabilities.

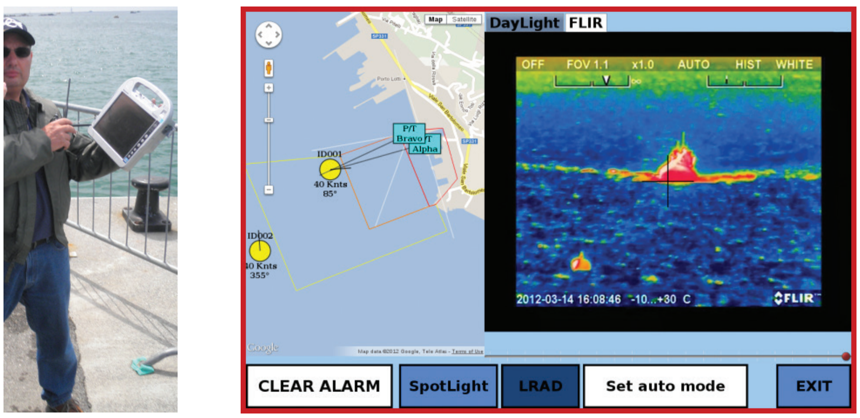


Figure 44. The TALON-12 hand-held controller (left) is shown together with the TALON12 tactical map (right) and the FLIR camera view of small-boat contact automatically detected, tracked, warned, and designated for security personnel on patrol.

critical infrastructure protection in the NATO Defence against Terrorism Programme of Work (DAT PoW). HPT2E used the CMRE's Maritime Tactical Theatre Simulator for serious gaming that simulated emerging non-lethal technologies (see Figure 43.) These technologies fill the response gap between 'shouting and shooting' in order to reduce both the risk to individuals and of litigation. A realistic simulation of security sensors and non-lethal response technologies was based on first-hand experience of the CMRE with the technologies exercised under controlled conditions. Thirty people from nine nations participated.

Non-Lethal Response in Port Protection

The CMRE demonstrated a new concept for rapid contact designation and warning for countering small-boat threats in ports in the TALON12 trial in May 2012 (see Figure 44). Security personnel engaged in integrated detection and response in their own environment (i.e., on patrol, rather than behind computers in an ops-room container), with better human-machine division of labour (i.e., automated contact designation and low-risk first response, as well as human intervention for escalation of force in the face of non-cooperative contacts and event resolution). Two stand-alone sensor-effector 'clusters' were integrated with automatic and manual operations through wireless Web-based handheld devices. A Quick-Pointing Device (QPD) demonstrated the intuitive and rapid manual contact designation for query and response for close engagements. More than 120 people, including military and civilian, technical experts, attended waterside demonstrations. A follow-on trial in 2013, TALON13, will incorporate findings from the TALON12 demonstration and include an underwater sensor-effector module for countering underwater intruders. The Port Protection project will continue collaboration with other communities of interest, including the SAFEPORT project, led by Portugal, and the general non-lethal community. As the project moves forward, it will look toward force protection and new concepts such as joint sea-basing operations.

• Collaborative Projects

Maritime security relies on international and inter-agency cooperation, and, in line with this collaboration theme, the CMRE Maritime Security Programme participates in a number of the European Commission's Framework Programme 7 (EC FP7) co-funded projects. These projects provide additional resources to existing CMRE projects and promote interoperability between NATO and other organizations, as well as with industry. These include the New Service Capabilities for Integrated and Advanced Maritime Surveillance (NEREIDS consortia, and Integrated Components for Assisted Rescue and Unmanned Search Operations (ICARUS).

In 2012, the CMRE and its partners successfully completed the 4-year SECTRONIC project for ship, port, and off-shore platform surveillance and response, with grant funding provided by the European Commission. The CMRE's role included survey, test, and evaluation of emerging dual-use (i.e., civilian and military) non-lethal response technologies and measures.

Elements of the project have already been transitioned into commercial products by industry.

The CMRE is participating in the NAVTRONIC consortia to address both the rising cost of fuel and global warming by reducing fuel consumption and emissions in the maritime shipping industry, in line with NATO's new Smart Energy Team (SENT) initiative. The NAVTRONIC methodology will integrate ship-propulsion and METOC data to optimize sail plans for a next sailing. Both the project and on-going trials will be completed in 2013.

For the NEREIDS consortia, running from mid-2011 until mid-2014, the CMRE has an opportunity to further develop and test the data fusion and anomaly-detection work from the MSA project. NEREIDS will produce new service capabilities for integrated and advanced maritime surveillance by combining Earth Observation sensors with other available maritime data sources in order to identify anomalous behaviour in the maritime domain.

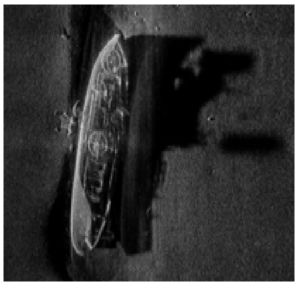
The ICARUS project is focused on unmanned search-and-rescue systems that integrate the responses of unmanned aerial, land, and sea vehicles under hazardous conditions during coastal crises. The role of the CMRE is to supply an autonomous sensor and behaviour-control payload for an ocean-going Unmanned Surface Vessel (USV) in order to provide situational awareness and deliver smaller life-saving equipment. The project will finish in 2015 with a joint land-sea-air demonstration.

OCEAN ENGINEERING

The CMRE Engineering Technology Department (ETD) has a unique capability, developed over 50 years, to invent, design, produce and support equipment that allows scientists in the field of maritime research to investigate new scientific principles, to demonstrate their applicability in a military context, and to assist in the transition of concepts into the military arena. The principle role of ETD is to support the execution of the Programme of Work, transition experimental concepts arising from the PoW, initiate and coordinate programmes of collaboration, and identify future trends in technology.

• Real-time Synthetic Aperture Sonar Processing On-board AUVs

In researching robotic undersea surveillance, the CMRE is introducing ground-breaking capabilities by integrating new processing and decision-making technologies into an AUV in order to create detailed images of the seafloor.



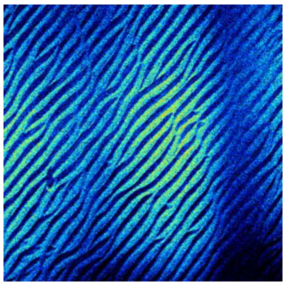


Figure 45. Synthetic Aperture Processing image of ship lying on the seafloor as measured with MUSCLE sonar (left); MUSCLE vehicle (middle); Synthetic Aperture Processing image from bottom as measured with MUSCLE sonar (right)

The primary engineering challenges are to harness techniques from machine intelligence in order to develop AUV behaviours, and to develop Automatic Target Recognition (ATR) algorithms that can increase confidence that an object is classified correctly. The goal is to perfect the capability to process the sonar data on-board the vehicle in near real-time, producing detailed acoustic images of the seabed that are analysed 'on the fly' by the vehicle's computers to make, completely autonomously, decisions on the best way to continue the mission in order to meet the specific objectives. Such algorithms are computationally demanding. However, the processing requirements must be evaluated carefully with respect to the space and the power available on-board the AUV. Moreover, the scientific nature of the project involves constant updates and fine tuning of the code, which should therefore be implemented in a language that allows for maximum maintainability and usability.

> The CMRE Engineering Technology Department (ETD) has a unique capability, developed over 50 years, to invent, design and produce the equipment necessary to execute and support maritime research.

Figure 46. OEX-C original propeller design (left) and the new design (right).

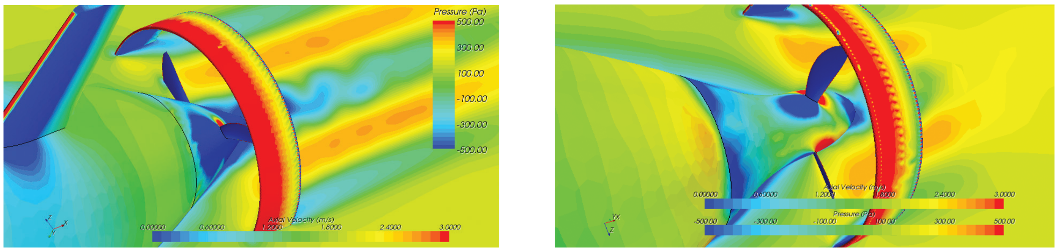


Figure 47. OEX-C hull pressure distribution: original (left) and new propeller (right) .

Figure 48. Deployment of a LOON tripod.

The CMRE began to look at these requirements, including the necessary sonar and computer technology, in 2008. Now, the new version of the software is capable of running in near real-time in the AUV. This was one of the key elements of a recent sea trial which was a huge step forward from the basic approach where the AUV performs missions following pre-programmed paths, collecting raw sensor data to be analysed at the end of the survey, with no ability to adapt to unexpected environmental conditions and/or sonar performance. The tests involved a multinational team of scientists and engineers aiming at finding out the best technologies that could be used by nations in joint NATO mine countermeasures missions. The focus is now on the integration of the newest generation of technology.

• Advances in Technologies for Persistent Autonomous Underwater Surveillance

The use of unmanned systems, in conjunction with ships, planes and shore stations, in maritime defence and security is increasing consistently among the NATO Nations. As global maritime trade faces threats from both above and below the sea surface, the use of unmanned platforms can compensate for the limited number of manned platforms undertaking maritime tasks, such as anti-submarine warfare, mine countermeasures, air defence, counter-piracy, and the protection of ports and choke points. For this purpose, the CMRE has long been considering the use of such vehicles, including underwater gliders and unmanned surface vehicles, for the evaluation of new concepts, especially in the field of autonomous underwater persistent surveillance. However, there are several technological hurdles to be surmounted before these vehicles can be used for such a challenging task.

> The CMRE is introducing ground-breaking capabilities by integrating new processing and decision-making technologies into an AUV in order to create detailed images of the seafloor.

Figure 49. AutoLARS design and during at-sea trial.

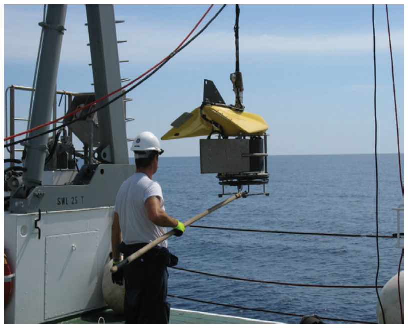
1. **Endurance. The operational requirements for unmanned vehicles translate** increasingly into demand for greater endurance. Higher energy is needed both for the vehicles themselves and for the increasingly power-hungry, more complex sensor payloads. Furthermore, greater autonomy will require higher computer capability, which in turn means a greater energy requirement. In order to improve endurance without reducing the platform speed or increasing its size, innovative solutions must be found, while increasing the available energy or the propulsion efficiency. The CMRE has sought to improve these two specific aspects with the design of a new propeller, and has made significant advances. Figures 46 and 47 illustrate the OEX-C propeller's original and new designs, and the pressure distribution on the hub. A large reduction of the wake's turbulent flow and associated drag can be seen on the figures between the two designs that yield much higher efficiency for the new design Work on battery technology is on-going, and performance improvement should be measured in 2013.
2. **Underwater Communications.**
   Underwater (UW) communication is essential in order to link command and control with autonomous vehicles and systems. Radio waves and light (including lasers) attenuate rapidly underwater, leaving acoustic energy as the only pragmatic means to communicate; acoustics, however, also has its limitations. Therefore, the CMRE is creating an inclusive community of users, researchers and manufacturers interested in ad-hoc networks of sensors for which both coding standards and new protocols will be required. In 2012, the CMRE successfully tested such a protocol, and was invited by the Internet Engineering Task Force to draft a proposal for a global standard. As noted elsewhere, the CMRE Littoral Ocean Observatory Network (LOON) has been deployed and is now available online to collaborators, who can test protocols at sea from their desks around the world. This has proven an extremely valuable and much sought-after facility, with several collaborators joining the CMRE in an EU proposal to federate the idea, and create four additional such test beds across Europe in order to provide wider access to diverse at-sea environments. As CMRE technologies mature, they are finding their way into research customer's hands. The Cooperative ASW project, which now uses a mobile surface communications gateway, developed by the Communications and Networking Project at the CMRE, with multi-hop communication capability to keep track of two AUVs remotely from the support ship, is just one such example.

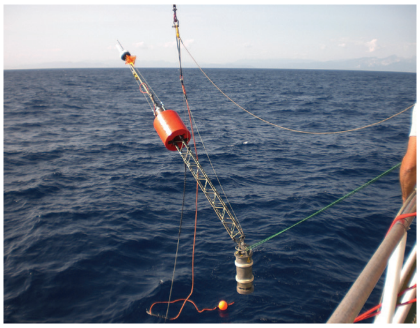
3. **Launch and Recovery**
   The challenge of any recovery system does not end with the initial capture of the vehicle, but involves mechanisms to secure and connect it for data transfer and recharging. The CMRE goal has been to eliminate the modifications for capture and retrieval required by current systems, while acknowledging that data and power transfer will remain invasive. Many parts of a fully automated generic Launch and Recovery System (LARS) are now in place; however, a mobile, non-stationary, automated means to make contact with an AUV does not yet exist. This is a critical component for a range of future systems, including USV operations and automated sub-sea gateway nodes. In response, the CMRE has developed the AutoLARS (Autonomous Launch and Recovery System) and, more particularly, an automated initial contact system that will capture a wide range of small AUVs.
   AutoLARS is a mobile, active-recovery system that requires minimal modification to any AUV or glider beyond affixing a generic transponder. The recovery method involves a free-swimming, ROV-like capture hoop whose position is actively guided by asynchronous tracking of an AUV. At the end of a mission, an AUV must be programmed to steer a constant heading and maintain a constant depth. The capture hoop, acting like a baseball catcher's mitt, adjusts to position itself in front on the free-swimming AUV using multiple thrusters mounted on the hoop. This was demonstrated successfully at sea in March 2012.

Separately, in order to allow the AUV to 'hibernate' and sit on the seabed until conditions are suitable for recovery, a Variable Buoyancy Device (VBD) has been engineered and manufactured at the CMRE. Further, because the vehicle is not designed to lie on the sea floor due to the various features protruding out of its cylindrically shaped body, a structure has been designed primarily to form stable landing gear (two parallel sleds) and proper protection for its acoustic transducers, control surfaces and propeller.

> This has proven an extremely valuable and much sought-after facility, with several collaborators joinig the CMRE in an EU proposal to promote the idea further.

Figure 50. MERAS buoy and acoustic section during deployment.





- **The development of 'next generation' echo repeaters including moored and AUV-borne, in addition to the traditional towed version**

A key component in the development and evaluation of new concepts for littoral ISR has been the Echo Repeater (ER), which serves as an artificial target that returns a synthetic echo by receiving a signal and retransmitting it, and therefore can be substituted for a real target (for training or research purposes). The use of an ER provides highly calibrated measurements, which allows for the extrapolation of results to the real anti-submarine case and for a careful assessment of new operational concepts. When the two previous systems became outdated, the CMRE went for new cutting-edge technology. The decision was driven also by the need to understand better the sensitivity of operational performance of underwater systems to seabed/water column parameters. CMRE quantified the differences between models and measurements at sea while including techniques to reduce uncertainty in the input data. In order to limit the uncertainty, an ER that could be moored on the bottom in order to limit signal fluctuations due to its motion, was introduced. This was also more efficient because no towing ship was required.

1. **Towed Echo Repeater (TERAS).** TERAS has been designed to be towed even by small ships with limited deck capability. It has its own winch for maximum flexibility, but the cable can be spooled onto any suitable winch.
2. **Moored Echo Repeater (MERAS). MERAS,** which was fully developed and tested in 2012, consists of a moored surface buoy and a bottom-moored transducer assembly connected by electro-mechanical cable in a classical U-shaped mooring configuration. The buoy hosts the control electronics and is battery powered by high-efficiency lithium cells. Battery replacement can be effected without the need for recovery of the buoy. The buoy is connected via radio link to a remote computer for control, monitoring and configuration purposes. Particular care has been taken to minimizing the energy consumption of the system in order to reduce the impact of the maintenance schedule on the experiment during operations at sea.
3. **AUV Echo Repeater**
   Finally, to reduce sea trials costs and to give more options for operational scenarios to be tested at sea, plans are being made to integrate the echo-repeater functionality into an AUV. The development of this system was taken into consideration in the design of the moored echo repeater and will use technology already developed at the Centre such as the receiving towed array (BENS) and the transmitting acoustic source (TOSSA). The *AUV Echo Repeater* was conceived as a target simulator payload for the Ocean Explorer (OEX) AUVs and will bring space and energy savings.

INFORMATION LABORATORIES

In 2012, the Centre engaged in a review of the essential Information Technology (IT) components required for the execution of the Programme of Work (PoW), focusing on the identification of targeted and cost-effective solutions that are scalable and adaptable to changing project requirements, enabling collaboration and cross-fertilisation among different projects.

A Network-Enabled Futures (NEF) Integrated Project Team (IPT) was established to support this endeavour by developing a roadmap for future development, and by demonstrating new IT-sourcing approaches in the context of project activities. During Noble Mariner 2012, the initial core of a scientific network was activated in order to enable the demonstration of interoperable and data-driven information services as part of the Maritime Security Programme, as well as of ship-to-shore, end-to-end capability, from in situ data acquisition to delivery of products to customers.

• Enabling Large Data Research

The ever-increasing availability of data sources, extremely valuable in scientific terms and in delivering operational advantage, drives the need for new approaches in the delivery of the 'information supply chain'. Specifically, a new generation of technologies must be developed in order to extract value from very large heterogeneous datasets through high-speed capture, discovery and analysis.

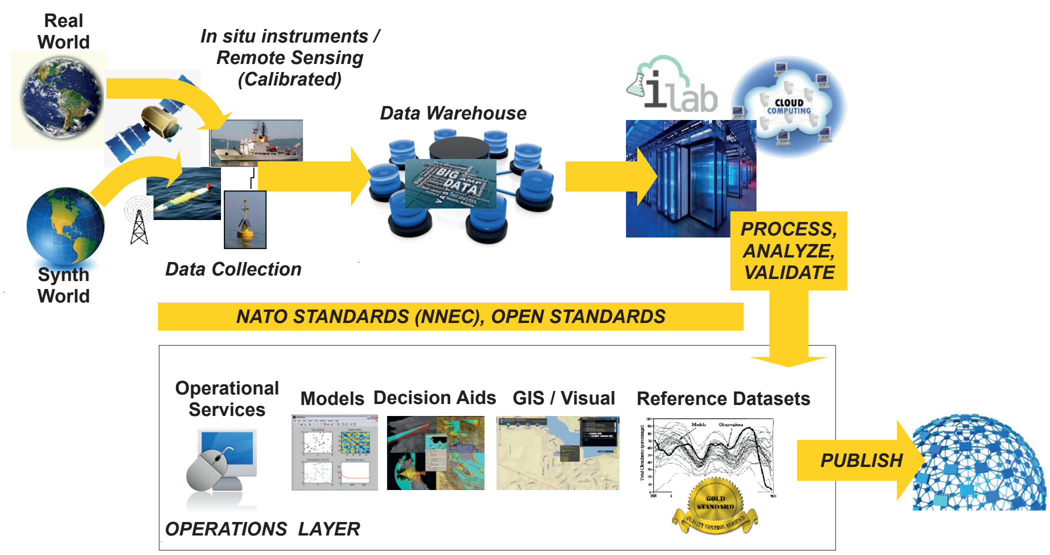


Figure 51. Depiction of CMRE's Network Enabled Futures (NEF) framework.

As an initial step in this transformation, scientific IT in the Centre has been redesigned in a data-centric perspective to enable experimentation and collaboration with NATO, NATO Nations and academia in a manner that is compatible with comprehensive approaches in which the traditional concept of 'need to know' evolves into a 'need to share'.

The resulting infrastructure can support all of the different stages of the data-curation lifecycle, i.e. data acquisition (in situ, remote sensing, other sources), warehousing, processing, and publishing (provision to end-users of operational services, models, decision aids and 'gold standard' reference datasets).

The quantity and quality of scientific data need to be supported properly by performing flexible upgrades as a function of evolving project needs and technological advancements. As an example, the development of 'Fusion as a Service' (FaaS) within the Maritime Security Programme required a dedicated high-performance database engine that is able to cope with a growth rate in excess of 200% per year (21 billion records as of December 2012). Activities in long-term data preservation, however, essential in sustaining the information base used to 'mine' patterns and insights with large data analysis techniques, will require additional work on the semantics of information and on metadata, ensuring interoperability across the various data providers and users.

• Networking at the Speed of Light

Broadband networks constitute the nervous system of today's world-class research. With fast and stable bandwidth available, concepts and processes that typically are delivered on Local Area Networks (LAN) can now be extended to a global scale. Approaches that were ruled out previously because the supporting technology was not available or because it was considered too expensive appear suddenly to be affordable, opening new roads to respond to today's and tomorrow's challenges. For example, transfers of large datasets that previously were considered unfeasible (or that at most could be accomplished by shipping storage media with an express courier) can now be supported online, opening new avenues to collaborative international research. In a similar manner, computing power can be rented from supercomputing centres or from providers of utility computing packages, offering 'Infrastructure as a Service' (IaaS) or 'Platform as a Service' (PaaS) solutions.

On this important front, the CMRE has finally broken its 'digital divide' gap, acquiring a dark fibre to connect to the Italian National Research Network GARR-X. The all-optical backbone of GARR-X allows on-demand establishment of an unlimited number of virtual networks or dedicated circuits with counterparts worldwide, enabling the establishment of distributed research teams underpinning critical projects that would previously have been impossible.

Figure 52. Roadworks to lay the fibre-optic cables connecting the CMRE.

Connectivity with the rest of Europe and with the world is ensured through the GEANT network, which brings together 40 million users in research institutions across 40 countries, across a 50,000 Km dedicated network.

With this connection, the Centre is provided with unprecedented flexibility in how the network connectivity is managed, with a choice between general purpose research internet carrying multiple users' traffic, and virtual 'private' network paths carrying the traffic of individual projects that have specific requirements relating to aspects such as quantity, security or accuracy of the data. The use of dark fibres makes this new infrastructure 'future proof', providing all necessary flexibilities required to meet the most demanding applications. This is made possible by the combination of two aspects. First, it is possible to combine different wavelengths on the same fibre in order to provide, in a prompt manner, the additional bandwidth required. Second, it will be possible to incorporate future developments in photonic technologies by upgrading the transceivers at the two ends of the dark fibre. While the standard operating speed of today's carriers is in the order of 1-10 Gbit/s, a 50-fold upgrade of the GEANT backbone is already being implemented in order to reach a speed of 2,000 Gbit/s by 2020, enough to transmit the entire Web library of the Library of Congress in just 30 minutes.

Excellence in NATO S&T

SCIENCE AND TECHNOLOGY ORGANIZATION AWARDS

Each year, the STB recognizes excellence within its community by granting two prestigious awards: the von Kármán Medal and the Scientific Achievement Award.

The selection of these awards is based on the quality of the work delivered, the breadth of the collaboration involved, the potential impact and the relevance of that work, and the dedication of the fine individuals and teams involved. They showcase what NATO S&T can deliver, and clearly illustrate how NATO S&T makes a difference.

In 2012, the STB awarded one von Kármán Medal to acknowledge personal achievement, and three Scientific Achievement Awards to recognize outstanding collaborative S&T performed in the NATO context.

• 2012 von Kármán Medal

The von Kármán Medal is awarded for exemplary service and significant contribution to the enhancement of progress in research and technology cooperation among the NATO Nations that is carried out in conjunction with STO activities. The von Kármán Medal consists of a silver copy of the gold medal presented to Dr. Theodore von Kármán at NATO Headquarters in Paris in July 1962, on the occasion of the tenth anniversary of the formation of the Advisory Group for Aerospace Research and Development (AGARD).

On 12 October 2012, during the Fall Science and Technology Board (STB) Meeting, held in Norfolk, Virginia, USA, Dr. Michael Winstone (GBR) was awarded the 2012 von Kármán Medal.

Dr. Winstone received the von Kármán Medal from the British AVT Principle Panel Member, Mr. Guy Powell, and the AVT Chair, Prof. Cord Rossow, from Germany, in a ceremony during the AVT Fall 2012 Panel Business Meeting.

Dr. Winstone's service was truly exemplary, in the spirit of Dr. von Kármán's vision, striving for international S&T collaboration, and NATO S&T collaboration in particular, at every step of his distinguished career.

Dr. Winstone has been an active member of the NATO S&T community for more than 16 years, both as a researcher and as an influential research leader and manager, first in AGARD, then in the RTO and finally in the STO. A long-standing member of the AVT Panel, he chaired numerous Task Groups and provided crucial support to many others as their Panel Mentor. Through his unprecedented presence in industry, university, and the MoD, he effectively bridged the gap between requirements and solutions sides, achieving the ideal of Prof. von Kármán: a close and mutually beneficial interaction between scientists and the military.

Figure 53. Dr. Michael Winstone (middle) accepted the von Kármán Medal from Mr. Guy Powell (UK AVT Principle Panel Member, right) and Prof. Cord Rossow (AVT Panel Chair, Germany, left) on behalf of the STO Board.

Dr. Winstone is also an exceptional scientist. During his long and distinguished career, he has consistently produced significant scientific contributions in the field of aerospace materials, to the benefit of the NATO S&T community. As an internationally renowned metallurgist, he has published more than 70 papers and holds several patents, including one for a heat-resistant nickel super-alloy that he developed and tested. He was a pioneer in developing single-crystal turbine blades, and investigated design issues for reducing the support and operating costs, as well as the wear and time to obsolescence, of military platforms. In addition, he has championed the field of methods in order to overcome the problems associated with ageing aircraft materials.

Dr. Winstone's work has a huge impact on the security and defence posture of the NATO Nations. His work has considerably contributed to increasing the service-life and operational envelope of military platforms, while reducing the maintenance requirements. His work on ageing aircraft materials has significantly helped many NATO Nations maintain legacy fleets, saving millions of dollars/euros/pounds in replacement costs and increasing the flight safety.

Dr. Winstone exemplifies the mission of the STO: transferring knowledge and scientific information, and leveraging the effort of individual nations to a greater and common result.

• 2012 Scientific Achievement Award

• Assessment of Stability and Control Prediction Methods for NATO Air and Sea Vehicles (AVT-161)

Developing air and sea vehicles is a very costly, lengthy and risky enterprise. Therefore, efforts to replace costly experiments and tests through computer simulations, allowing for a significant reduction in acquisition cost, schedule and risk, are undertaken all over the world.

Figure 54. Mr. Andreas Schütte and Prof. Russell M. Cummings (AVT-161 Co-Chairs, left and right), with Maj. Gen. Albert Husniaux (STO Chief Scientist, middle), receiving the 2012 STO Scientific Achievement Award.

Computational Fluid Dynamics (CFD) is one of the methodologies used to predict the performance behaviour of air and sea vehicles. While these tools are very performant, future capability requirements for air and sea vehicles can be met only if CFD tools evolve to an unprecedented level of accuracy.

Within the framework of NATO's STO, and building on the strength of the network to an unprecedented extent, a group of 46 CFD experts from 12 NATO Nations, as well as Sweden and Australia, converged to evaluate the potential of high-accuracy CFD tools for the design of future air and sea vehicles. Between 2008 and 2011, these experts collaborated on the design, execution, and evaluation of CFD tools and validation experiments. The results they obtained will significantly contribute to setting a new standard for CFD tools in defence and security.

The team performed true world-class scientific research in the field of CFD and achieved significant technological progress. By comparing results from different Nations and establishments, they implemented a benchmarking process that no individual research lab – and no single Nation – could have achieved. This successful benchmarking is indeed key: it ensures the validity and the accuracy of these new design tools.

The team also strengthened the network, establishing a solid pool of expertise across the Alliance, extending this network into valued Partner countries.

The impact of the results of this Group on the development of future NATO air and sea platforms is significant. The validated CFD capability will significantly reduce the number of ground tests required to verify vehicle concepts, and will likewise reduce the risk of performance anomalies that were not adequately predicted prior to full-scale vehicle development. War fighters will benefit from these results in terms of better-performing and less expensive air and sea platforms.

On behalf of the AVT-161 Task Group, the Co-Chairs, Prof. Russell M. Cummings (USA) and Mr. Andreas Schütte (DEU), accepted the STO Scientific Achievement Award from Maj. Gen. Albert Husniaux, NATO Chief Scientist and Chairman of the Board of the newly established NATO STO during the Board's meeting in Norfolk, Virginia, USA.

• Utilization/Dynamic Control of Adaptive Camouflage Materials (SCI-179)

The development of surveillance and acquisition devices is proceeding at an ever-increasing rate and poses a rising threat to NATO forces engaged in worldwide operations. To counter this threat, Camouflage, Concealment and Deception (CCD) measures are applied to mimic targets into the operational background across all relevant spectral bands. Due to NATO's need for forces to deploy in a wide variety of climates and terrain, variants designed for temperate, arctic and desert environments are necessary.

The SCI-179 Task Group investigated the opportunities for the Utilisation and Dynamic Control of Adaptive Camouflage Materials for CCD purposes. The Task Group was composed of scientists, engineers and military officers from 11 NATO and Partner Nations, building on one of the unique strengths of the STO: its immense network of experts with highly diverse scientific and operational backgrounds.

The science and technology work was impressive. Task Group members performed theoretical work in order to select the most promising and feasible techniques, and achieved a proof of concept.

They explored and applied leading-edge technologies in material science, conducting a wide range of simulations, and selecting and/or developing adaptive materials to meet their requirements.

To create an adaptive screen, they successfully applied to flexible screens concepts formerly limited to rigid surfaces. They also created pattern-generating software packages, developed a computer interface to the adaptive screen, and created on the screen the pattern generated by the software. The potential impact of the study on military operations is enormous. A target camouflaged with the screen developed by the team can adapt automatically to all types of backgrounds. This means that no additional materials (nets, paints and screens) are necessary, resulting in a sizable relief in costs, manpower and logistics. Dr. Pieter Jacobs, the Task Group Chair, and his team are applauded for this significant contribution and for their dedicated collaborative effort to achieve it. For their work, they received the 2012 STO Scientific Achievement Award.

Dr. Jacobs accepted the award on behalf of his team at the Fall 2012 Science and Technology Board meeting in Norfolk, Virginia, USA.

• Allied Information Sharing Capability (SAS-091)

In April 2010, the International Security Assistance Force (ISAF) Headquarters (HQ) requested assistance in the development and implementation of a plan to encourage a consistent approach to the collection of population data among the ISAF Nations, and the provision of a mechanism for the sharing of that data in easy-to-use formats.

Figure 55: Dr. Pieter Jacobs receives the 2012 STO Scientific Achievement Award.

In response, the SAS Panel rapidly and successfully convened a Specialist Team (SAS-091 'Allied Information Sharing Capability') with the aim of improving data collection and sharing in Afghanistan.

In July 2010, ISAF HQ and Joint Force Command Brunssum (JFCBS) requested that the scope of the project be expanded to include the development of metrics, with suggested data sources, to support decision-making for the transition of responsibilities from the ISAF international community to the government of Afghanistan.

Figure 56. SAS-091 Chairman Mr. Jim Bexfield receives the 2012 STO Scientific Achievement Award.

Finally, at the request of JFCBS, the scope of the final report was further expanded to include the development of a case study for use in training courses for personnel assigned to NATO assessment organizations.

The resulting study was organized according to ISAF's four Lines of Operation (LOOs): security, governance, rule of law, and economic development. It included recommended metrics for each line of operation, a Best Practices Guide, and suggestions for improving data collection and sharing, including an enduring Data Cards project used to identify data sources.

This effort by the SAS Panel is remarkable in many ways. It shows responsiveness to an operational request, and demonstrates that the operational and scientific communities can closely cooperate in order to achieve a significant impact on the operational theatre. In addition, it demonstrates the value of scientific evidence for decision making.

This exceptional team effort, resulting in outstanding and highly original security and defence science and technology advancements to the benefit of the NATO military, was recognized with a 2012 STO Scientific Achievement Award.

Facts and Figures

THE EXECUTIVE BODIES

The STO comprises three executive bodies: the CMRE, the CSO and the OCS. The resources used for all three of these executive bodies are described below. It deserves mentioning that the newly created executive body, the OCS, was only partially staffed in 2012. Its current resource figures are therefore not representative of the steady state of that office.

• CMRE - People

In 2012, the CMRE conducted a fundamental review of its staffing and made significant changes in order to position the organisation to embrace project funding. The major changes are:

- The establishment of a new Strategic Development Office to assess and address the current and potential requirements and opportunities associated with our major customers;
- A unified Research and Engineering Division to rationalise and streamline project work and to create a more agile response to customer requirements. Within this division, the Centre has significantly reduced the number of scientific assistants, and placed all technical support within the Engineering Department in order to improve flexibility and facilitate long-term professional development;
- An integrated Resources Division to provide coherent, coordinated support to the organisation.

The 2013 Personnel Establishment consists of 142 civilian and 9 military positions. This represents a reduction of 16 civilian positions when compared to the 2012 establishment.

In 2013, the CMRE will move from a fixed establishment consisting of ceiling positions to a flexible establishment that responds to work-load. The range of NATO International Civilians (NIC) positions is set out below. The Financial Plan is based on 140 NIC full-time-equivalent staff, and provides for up to 145 NICs should the additional workload warrant.

• CMRE - BUDGET AND FINANCE

2012 was a preparation and transition year as the CMRE put in place the processes and procedures required to work under the customer-funding business model. After extensive preparation – and in close cooperation with its major customer, the ACT – the CMRE produced its first Financial Plan and charge-out rates for STB approval at its meeting in September 2012. In late 2012, the CMRE made its first formal price proposals for the 2013 ACT Programme of Work. These were well received, and contracts were signed in early 2013.

A part of the CMRE Business Plan, the 2013 Financial Plan, submitted to and approved by the STB in December 2012, was based on a conservative income total of 28.1 million Euros. This total comprises the work ACT had submitted to the Budget Committee in its Consolidated Resource Proposal, and the European Commission (EC) consortia work already on contract. The CMRE also set a ‘Business Goal’ for 2013 that is a higher estimate

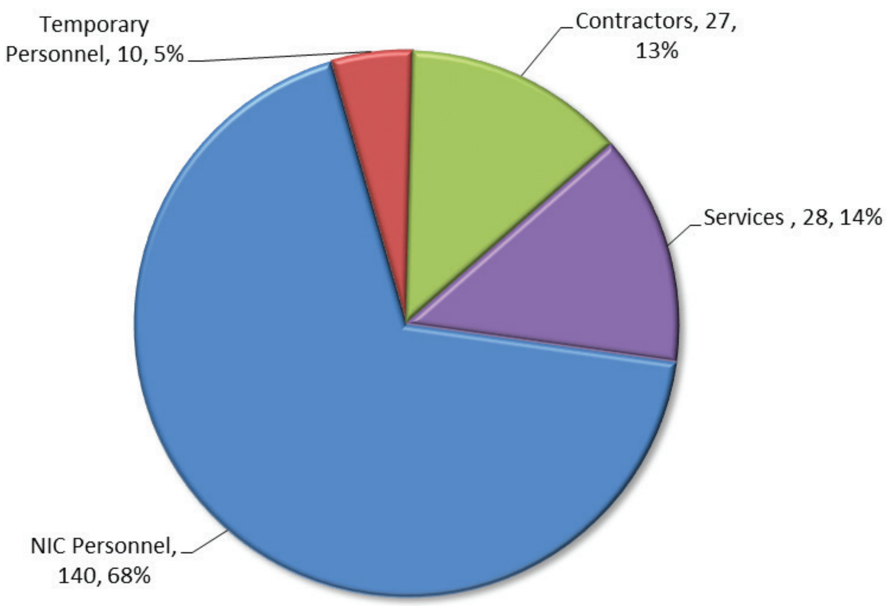


Figure 57. 2012 NURC/ CMRE Workforce

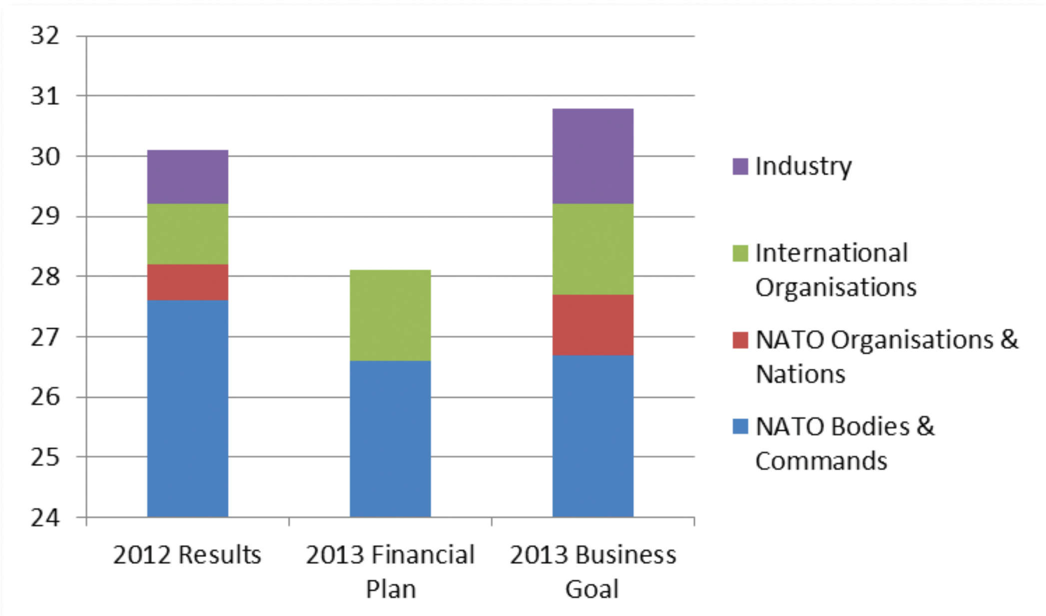


Figure 58. 2012 NURC/ CMRE Revenue

based upon current experience, as well as an early indication from the marketing outreach. The various figures can be seen in the exhibit below.

HQ SACT will remain the CMRE's largest financial sponsor in terms of Programme of Work and financial contribution over the next few years. To date, the CMRE has conducted two comprehensive project execution reviews under the new customer-funded business model, and the results have been positive. Project execution and revenue are in line with plans, and cash flow is adequate to support the total level of activity.

The International Board of Auditors for NATO (IBAN) audited the CMRE 2012 financial statements in April 2013. In 2012, the CMRE's financial activities were consolidated within ACT, and the auditors will issue their opinion at ACT level. There were no significant observations on the CMRE activities.

• CSO - People

The CSO workforce consists of a combination of military and civilian staff from multiple NATO Nations, with different backgrounds and statuses. Approximately one-third are NATO International Military Personnel (IMP) voluntarily contributed by the Nations; the others are NICs. The IMP positions, at the post-graduate level, are directed at supporting the Scientific Panels, and are vital to the execution and continuous monitoring of the STO Collaborative PoW. The NICs are employed in support and services functions.

The pie chart below shows the detailed distribution of the 58 posts of the Peacetime Establishment (PE) as of 31 December 2012. Six are vacant, while two have twin functions.

The ongoing development of the STO PE will result in a decrease of six positions at the CSO. The 52 positions identified on the proposed new PE for the CSO include two with twin functions and one shared with the International Military Staff (IMS). This was developed with due consideration to the Ministerial guidance in order to preserve the level and quality of the executive support provided to the execution of the Programme of Work. It also accounts for the standing up of the OCS.

Further developments remain to be seen, as decisions pertaining to the NATO Shared Services and savings objectives will be made.

The number and high level of quality of the staff provided by Nations is a key factor to the success of the STO/CSO. The smooth implementation of the new PE will largely depend on the continuation of this support by Nations.

• CSO - Budget and Finance

The CSO is a member of the IMS Budget Group, and the sole source of funding for all of its operations comes from the Military Budget. The CSO also has a delegation of funds from the IMS for its S&T-related PfP and MD activities. The financial activities of these programmes are managed by the CSO under the supervision of, and in close coordination with, the STO/IMS Financial Controller's office.

For all financial operations of the Military Budget funds, the CSO uses the NATO Automated

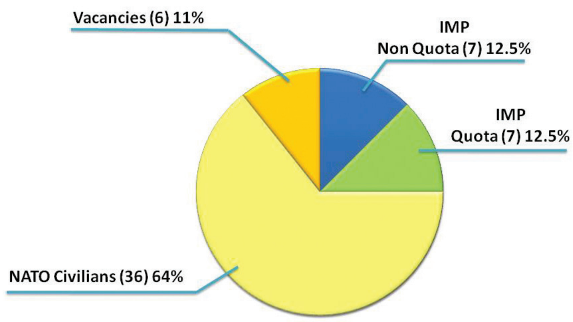


Figure 59. Staffing Situation – 31 Dec. 2012

Financial System (NAFS), which has been in use at the CSO since the Fall of 2003 because it provides the various means of control required by the NATO Financial Regulations (NFR).

The CSO, as with the rest of NATO, has begun to account for and report on its financial activities according to the International Public Sector Accounting Standards (IPSAS), and has prepared financial statements in accordance with these standards.

The CSO continues to strive for improved efficiency and effectiveness in conducting its overall operations. Contracting efforts have led to efficiencies in various areas throughout the budget, supporting the CSO's continuous efforts to add more value to NATO's and to the Nations' S&T community in conducting the mission and the S&T Collaborative Programme of Work.

IBAN audited the RTA 2011 financial statements and issued an 'unqualified' opinion on these accounts in January 2013.

The audit of the 2012 accounts by the IBAN will be conducted in September 2013.

• CSO - Collaborative Environment

Fundamental to the functioning of the STO is a secure collaborative environment. The Web-based environment forms the backbone of the operations of the STO, and has been developed through large-scale collaboration between the CSO, the CMRE and the STO Community.

The STO Website provides a window into the Websites of both the CSO and the CMRE, where traditional services, such as news and access to STO collaborative activities, event information, and the downloading of scientific publications, continue to be used extensively. The environment is a toolset for both participants in the STO and those involved in its operation, e.g., the STO National Coordinators.

Further, the SharePoint collaborative workspace continues to provide a secure remote environment for the S&T community. At the time of writing, there are over 3300 users, mainly scientists, working across more than 300 collaborative workspace environments. The current capabilities include file management, messaging, discussions and Wiki-based services.

Work is currently underway to upgrade the on-line collaborative environment in order to provide improved collaboration tools for scientists, including on-line editing, publishing tools, connecting people, and participant search and cross-site search capabilities. Additionally, work is progressing on a classified environment in which our scientists can collaborate at the NATO Restricted (NR) level. This solution is being tested, with a plan to provide it to the community before the end of 2013. Regarding scientific publications of the STO, the overall intent is to move to a single S&T repository in order to allow for better

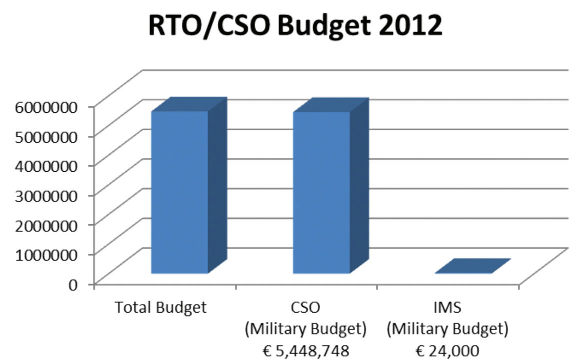


Figure 60. A Brief Overview of the 2012 CSO Finances (in k€).

distribution and exploitation of reports in electronic format against a wide range of competing requirements. Further, discoverability of the reports is paramount, and to this end the STO is working closely with institutions such as the Institute of Electrical and Electronics Engineer (IEEE) and EBSCO Publishing to make STO reports available in their respective libraries.

• OCS - People

The OCS is the only newly created executive body in the STO. It was created by transferring positions, some them vacant, out of the CSO and the CMRE.

To set up this office, the NATO personnel procedures were executed. At the end of 2012, and after an intense auditing phase, the ISPE was approved. This paved the way for the second part of the procedures: obtaining the approval by the Council of the ESPE.

Since Council approval is needed to recruit, the office was only partially staffed in 2012. At the end of the year, the OCS counted five staff, 10 of which were foreseen. Belgium, Italy and NATO bodies, including the RTA/CSO and IS (DI) generously staffed the OCS despite the structure not yet having been approved.

The IMS also agreed to accept that the IMS Financial Controller would be the STO Financial Controller, operating out of the NATO HQ.

It is expected that, by the end of 2013, the OCS will be at nearly 100 percent strength.

• OCS - Budget and Finance

In 2012, the OCS budget was essentially a transition budget with which to stand up the office. The recruitment of personnel was not possible, and personnel costs were largely covered by those Nations and NATO bodies providing staff.

Therefore, the 2012 level of expenses of the OCS totalled 30,000 €.

In 2013, this figure will significantly increase, as the staffing level will reach its expected end state and personnel costs will increase accordingly.