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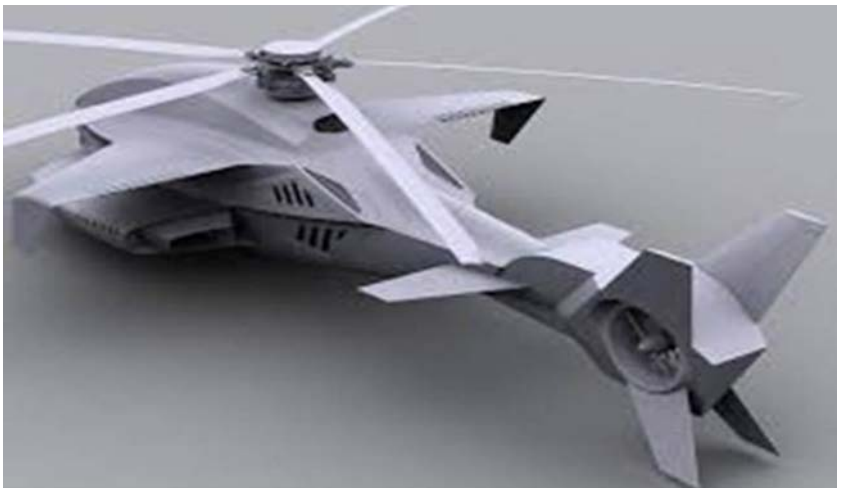

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Structural Health Monitoring of Military Vehicles

Reference Number	Activity Type	Activity Start Date	Activity End Date
AVT-220	Lecture Series	01 Sep 2013	31 Dec 2016
Publication Reference https://www.sto.nato.int/publications/STO Educational Notes/STO-EN-AVT-220			

Technical Team Leader(s)

Prof. Alfredo GUEMES , Spain , Universidad Politécnica de Madrid
Prof. Afzal SULEMAN, Portugal, Instituto Superior Tecnico

Abstract

The objective of this Lecture Series was to inform experts on SHM systems on the transition issues for implementing SHM technologies in military vehicles. Its aim was to describe and explain current research, areas of application and tendencies for the future of this technology including various design issues being involved. During the Lectures, all the theory and techniques important for understanding the covered topics was addressed. This Lecture Series gathered experts actively working on various SHM techniques in order to cover the main SHM disciplines that are based on piezoelectric transducers, elastic wave propagation phenomenon, Fiber Bragg Gratings and structure vibrations analysis.

Background

Structural Health Monitoring (SHM) is a multidisciplinary technology devoted to development and implementation of methods and systems that realize inspection and damage detection by integration with structures. It also includes a variety of techniques being related to diagnostics and prognostics. SHM emerged from the wide field of smart structures and laterally encompasses disciplines such as structural dynamics, materials and structures, fatigue and fracture, non–destructive testing and evaluation, sensors and actuators, microelectronics, signal processing and possibly many more.

SHM in its own has now been around for more than two decades. Much of the science developed has been generated in either the academic or industrial environment. Numerous institutions and industries being involved specifically in aerospace and civil engineering have been involved, as well as those dealing with the more engineering and physics based disciplines mentioned above. The large number of publications, attendance in conferences and workshops, research projects and R&D groups dealing with SHM is a significant proof that this technology has gained wide interest, not only in the engineering world but also in physics, electronics or computer science, to just name a few.

NATO, in particular, is making a concerted effort to implement condition-based maintenance as a means of reducing the life cycle costs and improving availability of various weapon platforms. Despite this effort, the majority of installed health monitoring systems are limited to rotating machinery such as engines, transmissions, and other gear boxes. The goal of this Lecture Series is to bring together representatives from military, industry, and academia covering the spectrum from hardware developers to end users and platform managers and have them discuss issues that must be addressed as structural health monitoring systems mature to the point that decision makers will implement them.

Objectives

The objective of this LECTURE SERIES is to inform experts on SHM systems on the transition issues for implementing SHM technologies in military vehicles. Its aim is to describe and explain current research, areas of application and tendencies for the future of this technology including various of the design issues being involved. During the course, all the theory and techniques important for understanding the covered topics will be addressed. This course gathers experts actively working on various SHM techniques in order to cover the main SHM disciplines that are based on piezoelectric transducers, elastic wave propagation phenomenon, Fiber Bragg Gratings and structure vibrations analysis.

Future Technological and Operational Challenges Connected with Application of Synthetic Fuels

Reference Number	Activity Type	Activity Start Date	Activity End Date
AVT-225	Task Group	01 Jan 2014	31 Dec 2016
Publication Reference https://www.sto.nato.int/publications/STO Technical Reports/STO-TR-AVT-225			

Abstract

In recent times, factors such as climate change, the finite nature of oil reserves, and concerns over political security in the oil-producing regions have triggered a broad effort in the search for new sources and conversion processes for the production of alternative fuels. The increasing availability of such liquid alternative fuels, and their mixing with conventional petroleum-distillate fuels have led to a need for NATO member nations to more closely coordinate to study and (if possible) mitigate any negative effects of the introduction of such fuel blends on their military vehicles and systems (air, land or naval) as well as operational procedures. Working closely with the Petroleum Committee, this Technical Group will build upon previous fuel-related activities of the NATO RTO such as AVT-ET-076 (2006), AVT-159 (2008-2011), and most recently AVT-ET-128 (2012) to evaluate the opportunities and threats posed by emerging fuels on NATO vehicles and systems (air, land or naval). Based on the Petroleum Committees Vision on Future Fuels (1st-edition supplied in 2007, and later revised in 2010), the recently concluded AVT-159 focused on the near-term threat of the introduction of biodiesel-blends in ground vehicles. The present Technical Group being proposed will focus on the next priority, and undertake work to identify and rank the impact of emerging synthetic fuel blends on NATO military vehicles and systems.

Figure 1: (Synthetic Fuels. globalthermostat.com)

DOTMLPFI

Technical Team Leader(s)

Mr. Shaji MANIPURATH , CAN , National Research Council of Canada
Mr Peter HOPKINS, GBR, Defence Equipment and Support

Background

Working closely with the Petroleum Committee, this Technical Group will build upon previous "fuel"-related activities of the NATO RTO such as AVT-ET-076 (2006), AVT-159 (2008-2011), and most recently AVT-ET-128 (2012) to evaluate the opportunities and threats posed by emerging synthetic fuel blends on NATO vehicles and systems (air, land, and naval).

Objectives

To identify and prioritize the opportunities and threats for vehicles (air, land, and naval), and their equipment associated with the introduction of synthetic fuels and their blends. A risk-matrix methodology will be used to rank their impact on vehicle operation and mission, as well as on hardware and maintenance characteristics.

Synergies and Complementarities

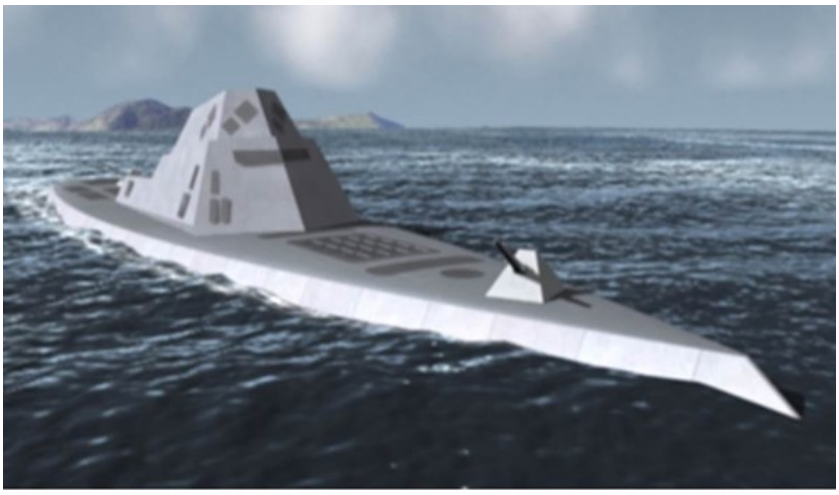
Potential outcomes of this Task Group to the military user include a ranking of potential negative effects of the introduction of synthetic fuel blends, and related recommendations on vehicle maintenance and operation, fuel procurement, fuel storage and fuel handling.

Eliminating Thermal Limitations through Validated Design

Reference Number	Activity Type	Activity Start Date	Activity End Date
AVT-226	Task Group	01 Jan 2014	01 Dec 2016
Publication Reference (when published) https://www.sto.nato.int/publications/STO Technical Reports/STO-TR-AVT-226			

Abstract

Consideration of thermal management for military platforms typically occurs late in the development cycle and is often based on un-validated component and subsystem models, resulting in underperforming thermal systems. Thermal design must occur early in the development cycle using validated tools in order to ensure full operational capability, optimize platform efficiency, and avoid costly fixes.



DOTMLPFI

Author information

Dr. Mark Spector, USA, Office of Naval Research (ONR)
Ir. Bart Eussen, NLD, National Aerospace Laboratory (NLR)

Background

Increasing thermal loads are found to be an operationally limiting constraint for military air, land, and sea vehicles. Electrical power levels have continued to grow exponentially with nearly 70% of the power eventually dissipated in the form of waste heat. Often, thermal problems surface only after a new system has been fielded and will tend to force restrictions on the platform's operational capabilities.

Objective

The objective was to assess thermal model validation methodologies in order to strengthen design practices for future military platforms. The goal was to understand and quantify the uncertainty in thermal models through experimental validation of a representative thermal management system.

S&T Achievements

AVT-226 has designed and fabricated a common test bed which is being circulated among national laboratories for experimental characterization. The test bed is a single-phase fluid loop that represents a common design of power amplifier liquid cold plates. Various thermal models of the test bed are being formulated. Comparison between models and measured performance will lead to improved understanding and quantification of uncertainty as it influences the validation process.

Synergies and Complementarities

The RTG brought together 21 experts in thermal system design and modelling from six NATO Nations. Three test beds and four modelling approaches were implemented independently in academic institutions, government laboratories, and private companies. By comparing the approaches of these organisations, the team developed standards for best practices in thermal
design and validation..

Exploitation and Impact

This work led to validated thermal models, which are needed to ensure operational platforms meet their design specifications once fielded. Early consideration of thermal design helps to avoid the imposition of operational restrictions based on poorly-understood thermal limits and enhances platform efficiency. Dissemination of the results of this effort educates practitioners and decision makers on the best practices for the validation of thermal analysis tools.

Conclusions

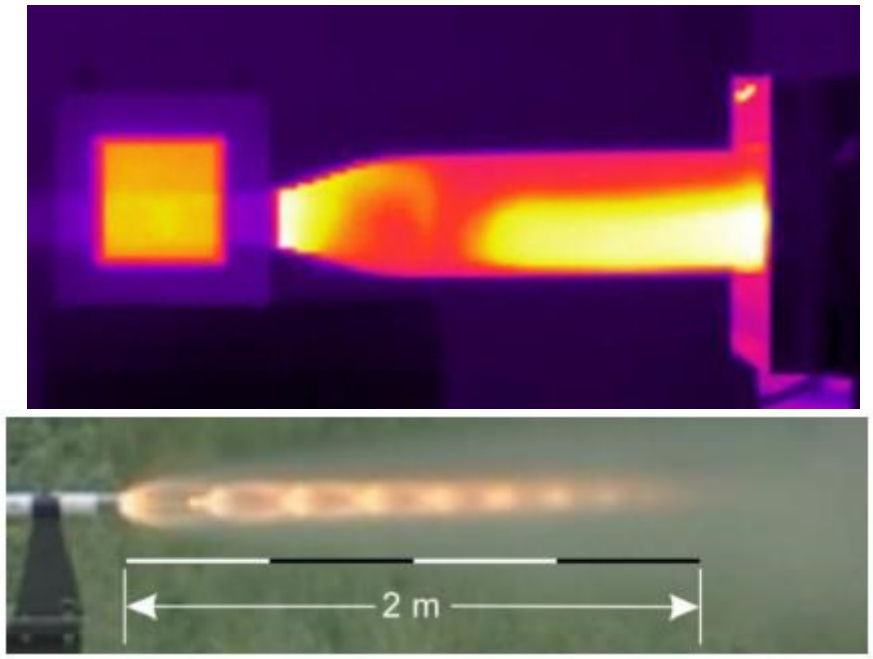
A statistically based experimental design methodology for thermal model validation has been developed and is being implemented using a common test bed. A workshop is planned for Fall 2017 (AVT-270) to disseminate results and formulate recommendations for follow-on activities.

Joint Exercise on Infra-Red Signature Prediction

Reference Number	Activity Type	Activity Start Date	Activity End Date
AVT-232	Task Group	01 Jan 2014	01 Dec 2016
Publication Reference https://www.sto.nato.int/publications/STO Technical Reports/STO-TR-AVT-232			

Abstract

Infra-Red signature model accuracy directly impacts electronic warfare self-protection, intelligence threat assessment, and signature management specifications and design. This activity provides a means to validate methods and understand the propagation of uncertainty from models and inputs through to operational decision making .



Experimental test cases used in the quantitative validation of plume structure and radiance tools as a part of IR signature prediction.

Author Information

Dr Nigel Smith, AUS, DST Group, Department of Defence
Dr Martin Fair, GBR, Dstl, Ministry of Defence

Background

Vehicles and weapons are sources of infra-red (IR) radiation -- IR signatures are routinely used to detect, track and identify these systems. The accurate understanding and modelling of IR signatures is essential to the militaries of partner-nations in meeting operational requirements for stealth, surveillance and

electronic warfare survivability. This exercise seeks to establish the current state of validation and verification of IR signature prediction tools and identify capability gaps and uncertainties.

Objectives

To investigate key technical aspects of IR signature prediction for aerospace systems with the primary focus being on validation and verification of the techniques, and the sharing of best practice, algorithms, codes and supporting techniques.

S&T Achievements

The end-to-end prediction task has been broken into model components: gaseous exhaust plume structure and radiance, surface radiance, and atmospheric propagation. Quantitative test cases, from five partner nations, with corresponding blind predictions have been employed to examine the each element individually and in an overall sense.

A validation methodology and signature prediction framework has been articulated. Together, these concepts allow the identification of uncertainties in each model component, as well as the propagation of uncertainties through the end-to-end prediction process.

Synergies and Complementarities

No one partner nation has had access to all the requisite test case data necessary to make a full assessment -- different nations have provided test cases specific to different model elements. The synergy of all these test cases and the subject matter experts from each nation has provided a rare opportunity to definitively assess the state of the art of IR signature prediction and its impact on the military user.

In order to gain useful inputs and deliver useful outputs, AVT-232 has also established links with other groups: NATO Air Capability Group 3 / Sub Group 2 /Threat Warning Tech Team, SET-211 (Naval Platform Protection in the EO/IR Domain) and AVT-251 (Multi-disciplinary design and performance assessment of effective, agile NATO air vehicles).

Exploitation and Impact

AVT-232 will provide evidence of the validation status and uncertainties of IR signature prediction models, which impacts Doctrine and Materiel in the DOTMLPFI acronym.

Signature model confidence impacts military doctrine in susceptibility applications (EW protection measures) and threat modelling for intelligence applications. It impacts materiel in providing *a priori* methods to specify and design signature management requirements for military systems.

Conclusions

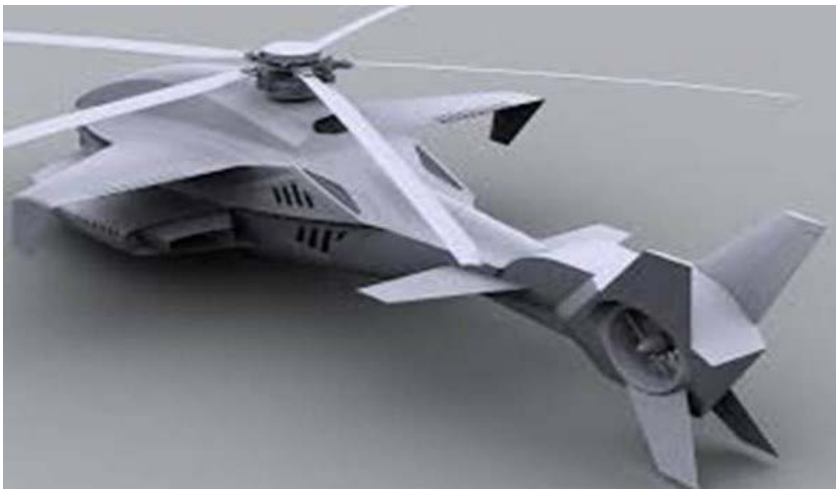
The test cases have been completed and comparisons made. Final analysis is being conducted with the findings of AVT-232 to be reported in December 2016. A preliminary finding has been to extend the aerospace focus of the AVT-232 to a cross-domain application in a follow-on activity (AVT-281).

Understanding Requirements for the Next generation of Rotorcraft

Reference Number	Activity Type	Activity Start Date	Activity End Date
AVT-245	Specialists Meeting	01 Mar 2014	01 Dec 2016
Publication Reference https://www.sto.nato.int/publications/STO Meeting Proceedings/STO-MP-AVT-245			

Abstract

The importance of helicopters in military operations is widely recognized. Research has advanced the state of available technology such that much greater capability is now achievable. The Applied Vehicle Technology panel sponsored an activity to gain an understanding of the future military requirements for rotorcraft, to explore what activities and ideas are present across NATO and to form a strategy to realize these capabilities.



Technical Team Leader(s)

Mr. Patrick W. COLLINS , GBR , Helicopters Operating Centre

Mr. Marc Hoefinger, DEU, Deutsches Zentrum für Luft- und Raumfahrt

Background

Many of the helicopters operated by NATO countries can trace their origins back to designs produced 30 or more years ago with the basic configuration not changing significantly in that time. The most dramatic recent change in rotorcraft has been the development of tilt-rotor technology. Technologies are emerging which offer the potential to overcome many of the current limitations.

Objectives

AVT-245 recognise that to realize advanced capabilities, technology development alone is not sufficient. Force structure, doctrine, operational concepts, and procurement strategies must all be developed, analyzed and enacted to foster cooperation across those communities.

S&T Achievements

AVT-245 organised a Specialists Meeting between 12th and 15th October 2015 in Prague, Czech Republic. A total of 19 papers were presented during the week over a senior keynote and four themed technical sessions to an audience of 60 persons from 10 NATO Nations.

A novel approach was adopted with considerable time devoted to facilitated workshop sessions involving a combination of panel discussions and wide ranging audience debate.

Synergies and Complementarities

AVT-245 brought together representatives from organizations involved in researching the next generation of rotorcraft together with a significant number of major rotorcraft manufacturers. An enhanced proceedings document providing direction for future research activities that will inform the definition of future common rotorcraft requirements will be issued in 2016. AVT-245 will foster a close working relationship with the JCG-VL (Joint Capability Group – Vertical Lift); part of the NATO Army Armaments Group, the HISWG (Helicopter Inter Service Working Group) and ACT (Allied Command Transformation).

Exploitation and Impact

AVT-245 recommends the formation of a Pan-NATO activity to work across the operator, procurement and S&T communities to develop and execute the analysis, planning, and development necessary for success. AVT-245 also recommends three technical activities to develop and mature critical capabilities that clearly require further research these being:

- development of airworthiness strategies for complex systems
- reducing helicopter maintenance by 80%.

further analysis of high speed rotorcraft capabilities for military concepts

Conclusions

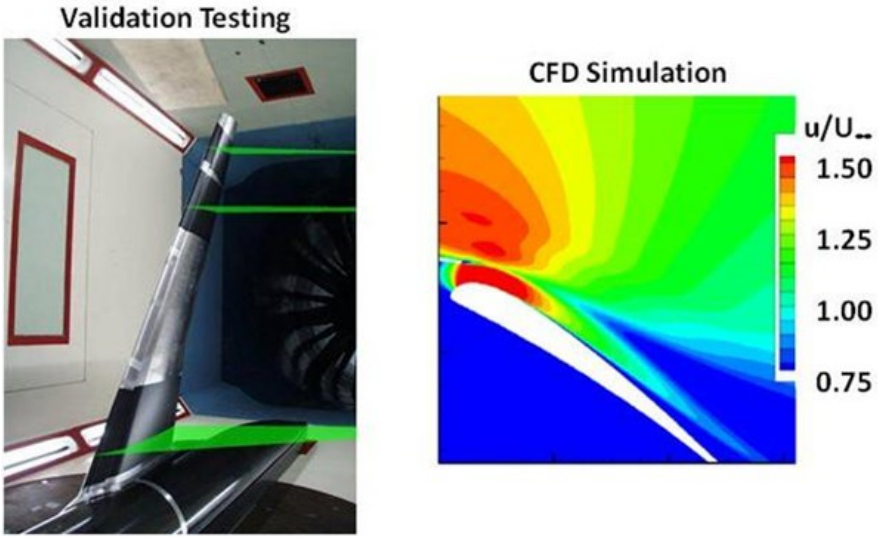
AVT-245 brought together a group of rotorcraft technology professionals to debate the issues relating to future requirements and identified key areas requiring greater understanding in order to provide decision makers with the evidence required to support future procurement strategies.

Progress and Challenges in Validation Testing for Computational Fluid Dynamics

Reference Number	Activity Type	Activity Start Date	Activity End Date
AVT-246	Specialists Meeting	01 Jan 2015	01 Dec 2017
Publication Reference https://www.sto.nato.int/publications/STO Meeting Proceedings/STO-MP-AVT-246			

Abstract

Aerospace and marine systems are becoming increasingly reliant on advanced numerical simulation for their design and development processes. This specialists meeting will provide an opportunity for technical experts to assess the state of the art in experimental testing to guide the development and validation of Computational Fluid Dynamics (CFD) simulation methods pertinent to military air and sea platforms.



Validation Testing for high-lift aerodynamics

Author information

Dr. James M. Luckring, **USA**, NASA LaRC
Dr. John A. Benek, USA, AFRL
Dr. Trevor J. Birch, GBR, DSTL

Background

There is an increasing demand that the CFD and related physics-based simulation methods be validated so that they produce simulations of vehicle performance based upon accurate modelling of the critical underlying flow physics. Validation philosophy has been established, and several groups are working within their respective disciplines to perform this new form of validation testing.

Objectives

The objectives of the meeting are to:

- Establish the baseline of current experimental practices as they apply to the development and validation of high-fidelity Computational Fluid Dynamics,
- Identify the strengths and challenges within the current state of the practice, and
- Identify key areas requiring further research and development.

Contributions will include experimentation and closely coupled interactions among numerical simulation, design, and analysis of the experiments.

S&T Achievements

The specialists meeting is designed to address validation testing over a hierarchy of problem complexity to include (1) Unit Problems; (2) Combined-Unit (or Component) Problems; (3) Subsystem Problems; and (4) System Problems. Unit problems are fundamental in nature; System Problems are fully representative of actual vehicles.

Synergies and Complementarities

23 papers and one Technical Evaluation are scheduled for presentation from 5 countries over two full days of meetings. Cross education will occur among specialists from diverse disciplines to include fluid dynamics, aerodynamics, acoustics, aero-structural heating, and hydrodynamics. Planning leverages came from AVT-191, and outcome leverages will be provided to ET-168.

Exploitation and Impact

Future air and sea military vehicles will increasingly rely on simulation for part of their deisgn. Advances in validation testing will further enable simulation-based design activities. The specialist meeting will facilitate networking among the subject matter experts and help ensure that facilities are used effectively for future validation testing.

Conclusion

AVT-246 will provide a unique opportunity for specialists from several disciplines to share their experiences toward the common interest in validation testing for advanced Computational Fluid Dynamics. Improved validation processes will increase confidence in CFD simulation and enable its further penetration to the military vehicle design process.

Pull Quote

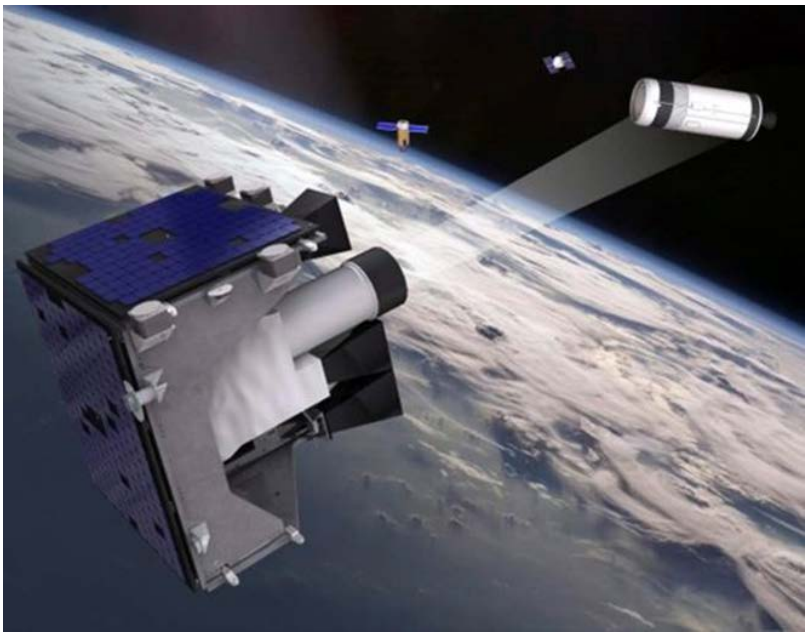
W.L. Oberkampf, and B.L. Smith, “Accuracy and reliability of M&S results are particularly important in the design, performance, and safety analyses of large-scale and high-consequence systems that could impact public and environmental safety, and national security,” AIAA paper 2014-0205.

Best Practices for Risk Reduction for Overall Space Systems

Reference Number	Activity Type	Activity Start Date	Activity End Date
AVT-257	Specialists Meeting	01 Jan 2015	01 Dec 2016
Publication Reference https://www.sto.nato.int/publications/STO Meeting Proceedings/STO-MP-AVT-257			

Abstract

NATO is critically dependent upon space capabilities to conduct missions in a responsive and efficient manner. Smallsats offer potential benefit to the war-fighter through responsive systems for a range of missions at reduced cost. However, proper assessment of risk, reliability and performance is necessary to maximize the benefits. New techniques and approaches must be developed to achieve these savings in cost and time.



Author Information

Dr. David Zimcik, CAN, Bell
Prof. Dr. Alim Rustem ASLAN, TUR, Istanbul Technical University

Background

NATO critically depends on space capabilities for global security, out-of-area peace-keeping missions with rapid reaction forces, and asymmetric warfare. Operational requirements such as secure point to point communications, extended ISR (Intelligence, Surveillance, and Reconnaissance) and geographical positioning require a responsive and resilient space capability at affordable cost. Smallsats are significantly cheaper than larger platforms and can be launched quickly at low cost. Moreover, Smallsats enable the

deployment of constellations or formations of space assets that can perform tasks with increased resolution, repeat cycle and higher performance.

Objective

The AVT-257 Technical Team (TT) will investigate the most effective means to enhance the projected performance of Smallsats for NATO missions while achieving savings in cost and schedule. Based on past investigations through AVT-210, three issues will be addressed: i) Subsystem Compatibility and Integration Simplification, ii) System Implementation Opportunities, and iii) Verification and Validation Rationalization. The objective is to review and assess the current state-of-the-art in these areas, identify the gaps in technology and define the required next steps to enhance the value to be derived from Smallsats.

S&T Achievements

A Specialist Meeting has been organized for Sept 2016 to address selected technology areas. TAVT-257 will identify viable new approaches and techniques, consistent with risk and budget associated with Smallsats in order to access their benefits to the warfighter.

Synergies and Complementarities

Smallsats provide hardware implementation for mission concepts under the Systems Concepts and Integration Panel as well as space platforms for instruments for communications, remote sensing and ISR instruments under the Sensors Electronics Technology Panels.

Exploitation and Impact

Smallsats have the capability to advance NATO space competence and enhance performance with reduced cost and schedule while directly impacting two areas of Long Term Aspects (LTAs) of the Minimum Capability Requirements namely the “Intelligence Surveillance and Reconnaissance (ISR) Collection Capability” and “Space Capability Preservation”, and one area of the Emerged/Emerging Disruptive Technology: “Microsats” as defined in the 2014 STB Science & Technology Priorities.

Conclusion

This work advances technology to enhance the capability and availability of Smallsats for NATO missions to improve their performance and cost effectiveness. AVT-257 will assemble the results of this Specialist Meeting in a report to identify the current technologies and provide recommendations to enhance the value to be derived from Smallsats.

Pull Quote

Smallsats offer potential benefit to the NATO warfighter through responsive systems to support a range of NATO missions at reduced cost.

Additive Manufacturing for Military Hardware

Reference Number	Activity Type	Activity Start Date	Activity End Date
AVT-258	Specialists Meeting	01 Apr 2015	01 Oct 2016
Publication Reference https://www.sto.nato.int/publications/STO Meeting Proceedings/STO-MP-AVT-258			

Figure 1: (Additive Fertigung von Metallteilen. 3Druck.com, November 18 2015)

Technical Team Leader(s)

Dr. Ludmila T'HOEN-VELTEROP , NLR, TNO

Dr. Priti Wanjara, CAN, NRCC

Background

Cost efficiency drives the maintenance and repair process and the quest for more efficient and environmentally friendly methods to accomplish maintenance and repair is always of interest to the NATO community. The specialist meeting of AVT-139 “Cost Effective Manufacturing via Net Shape Processing”, May 2006, had identified additive technology as a viable tool for use during manufacturing and repair of military hardware. In addition, additive manufacturing for repair was investigated in AVT-163 “Additive Technology for Repair of Military Hardware”. Additive manufacturing can also be used for manufacturing of spare parts. This is especially useful when damage is beyond currently available repair. If Powder Bed Fusion Technologies can be applied for manufacturing of spare parts this would have the advantage of short lead times for spare parts without the need for large stock volumes.

There are many challenges in current state of additive manufacturing technologies. With due consideration of the diverse additive manufacturing platforms (e.g. laser, electron beam, wire, powder), an alternative strategy is the development of a deposition process in an “open” environment that has potential for enabling fabrication and repair of an unbounded part geometry. Developments involve realizing concept to prototype fabrication or repair using powder fed coaxially with a laser heating source and localized shielding protection of the molten pool and deposit. Also knowing the intrinsic challenges for attaining affordable high-quality powder feed, full density consolidation of the deposit that is more easily assured using a laser or electron beam deposition process with wire feeding. Though a drawback of electron beam

wire deposition technology is the requirement of a vacuum environment, the ability to modify the beam spot size during the process can enable integration of post-processing operations such as thermal treatments for relieving residual stresses or improving the surface finish. Hence both the “open” environment laser wire or powder deposition technologies as well as the “secure” environment electron beam wire deposition technology merit consideration for additive manufacture of high quality military hardware.

Recent developments in these additive manufacturing technologies have enabled the manufacture of parts with complex geometries and different alloys. However, the properties of such manufactured parts are still highly dependent on the processing parameters and currently there is not enough knowledge to enable the consistent manufacturing of high quality parts that have properties similar to those made with conventional techniques. Additional developments are required to assess the influence of process parameters and the optimization of the post-treatments that are independent of operator experience and machine manufacturer, to produce highest quality components.

This NATO-STO-AVT Specialist Meeting on additive manufacturing will provide a forum to scan all environments, seek out common technology gaps, and provide advice on best practices to enhance the manufacturing of future weapon systems and the maintenance of legacy weapon systems. This activity is linked to AVT-163 symposium (additive technology for repair of military hardware). SM results will contribute to fulfilling the NATO Science Technology Hard Problem #14 – Mitigate Strategic Resource Scarcity – as the need for raw materials is much less in additive manufacturing than in conventional subtractive manufacturing.

Objectives

This Specialist Meeting will conduct an analysis of the state of art in additive manufacturing for repair and fabrication of components in military platforms for air, land, sea and space. The technology gaps will be identified that are compromising the application of additive manufacturing for military components.

Exploitation and Impact

• Recommendations to AVT Panel on future activities to support the application of additive manufacturing for military hardware

Porous media in high temperature and high speed flows

Reference Number	Activity Type	Activity Start Date	Activity End Date
AVT-261	Lecture Series	01 Sep 2015	01 Dec 2016
Publication Reference https://www.sto.nato.int/publications/STO Educational Notes/STO-EN-AVT-261			

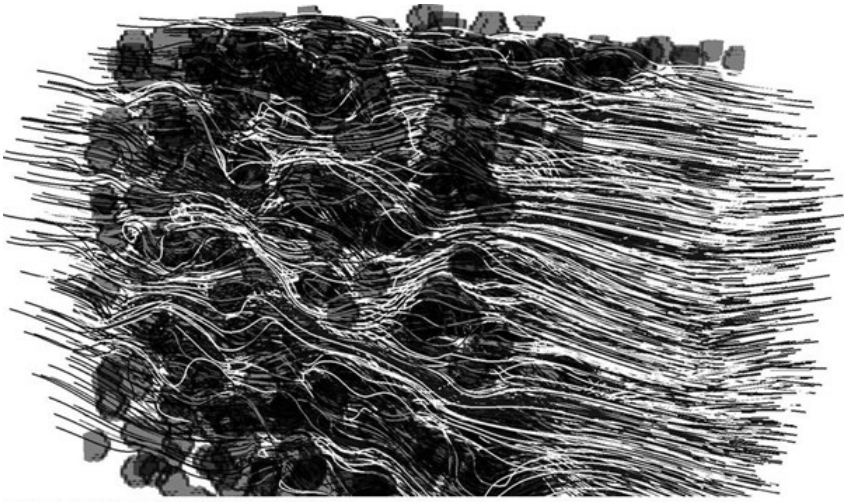


Figure 1: (Three dimensional porous media flow. ift.uni.wroc.pl)

Technical Team Leader(s)

Assoc. Prof. Olivier CHAZOT , France , von Karman Institute for Fluid Dynamics

Mr. Francesco Panerai, USA, NASA

Background

Porous media are ubiquitous in our lives. We find them in biological systems, insulations, filters, subterranean rocks, and several other fields of science and technology. In hypersonic, the characteristics of carbon-based porous and fibrous materials are very attractive. Their microscopic properties, their performance under high temperatures, and the possibility of tailoring their weight and density to very diverse applications, make them ideal solutions for heat shielding and thermal protection. State-of-the-art entry systems use carbon/carbon composites or carbon/phenolic materials among others, to face the aerothermal heating arising during high-speed maneuvers. The ensemble of thermal, chemical and mechanical processes that allow handling entry loads is defined as ablation. Ablative Thermal Protection System (TPS) are actively developed as solutions to handle high-speed re-entry which represents a current challenge for aerospace programs as well as for military activities. During the re-entry phase, the radiative, diffusion and convective heat fluxes at the surface of the probe are the result of complex physical phenomena taking place through the shock layer up to the wall's TPS. Ablation and pyrolysis at the wall have direct influence on the convective heat fluxes because it strongly changes the state of the boundary layer, but also affect a lot the material and the surface roughness. The underlying physics in this severe aerothermodynamics and aerothermochemistry is poorly known and makes the design process of the thermal protection system a difficult exercise. In top of this the coupling effects between those phenomena is still to be investigate and can lead to new paths for the TPS design and the re-entry maneuver strategy.

The last decade has witnessed a tremendous effort by space agencies, research centers and universities to tailor high performance ablators for entry environments. In parallel, physics based models for simulating heat and mass transport phenomena within the porous structures of ablative materials have been developed. Today, thanks to improved knowledge and availability of high-end computational resources, they allow higher and higher fidelity predictions of the material response to high enthalpy flows. Knowing better the properties of such porous material under high temperature and high speed flows will open more potentialities for military and defense development as they will find new applications in space missions.

Objectives

Objectives of the special course are to give a state-of-the-art on the investigations of porous material used in for aerospace applications and to offer an overview on the challenges that they represent. The course program will address in particular the coupling effects between the high enthalpy flows and the material response in the context of a re-entry situation. It will be tailored for students and engineers from aerospace industry, agencies and defense programs to provide the current knowledge over the research and application fields.

Space Debris Reentry and Mitigation

Reference Number	Activity Type	Activity Start Date	Activity End Date
AVT-262	Lecture Series	01 Dec 2014	01 Dec 2016
Publication Reference (when published) https://www.sto.nato.int/publications/STO Educational Notes/STO-EN-AVT-262			

Figure 1: (Space debris increasing at alarming rate, say scientists. Agencies , April 20 2017)

Technical Team Leader(s)
Dr Jean Marie MUYLAERT , BEL , VKI

Mr Thierry Magin, BEL, VKI

Background

Space debris from launcher stages and satellites at end of life are more and more a threat for satellite and space systems such as the space station or observation Satellites but also a threat for mankind when undestroyed debris impact the earth.

More than 5,500 tons of debris is cluttering space around the earth as a result of 50 years abandoning spacecraft leading to a threat of collision to any manned or unmanned spacecraft. Debris flux is increasing exponentially due to collisions even when no further objects are added into Low Earth Orbit (LEO). The United Nations proposed a 25 year de-orbit requirement for all LEO satellites. Growth mitigation strategies, active and passive removal of space debris will be covered in this activity. Mastering of space debris is not only important for preserving integrity of present space infrastructure for observation and communication but is also fundamental as part of the rapid growth of micro Sat and CubeSats upcoming constellations for security and network commands and communication.

Objectives

The course will provide a forum for discussion on design and validation of prediction tools for debris demise as well as disseminate information on ongoing and future projects associated with In Orbit Demonstration (IOD) for debris mitigation. The course will be tailored to provide professionals and students from supporting industries, space agencies, and defense programs the state-of-the-art in this rapidly progressing field of research.

Electric Propulsion Systems: From Recent Research Developments to Industrial Space Applications

Reference Number	Activity Type	Activity Start Date	Activity End Date
AVT-263	Lecture Series	01 Oct 2015	01 Dec 2016
Publication Reference (when published) https://www.sto.nato.int/publications/STO Educational Notes/STO-EN-AVT-263			

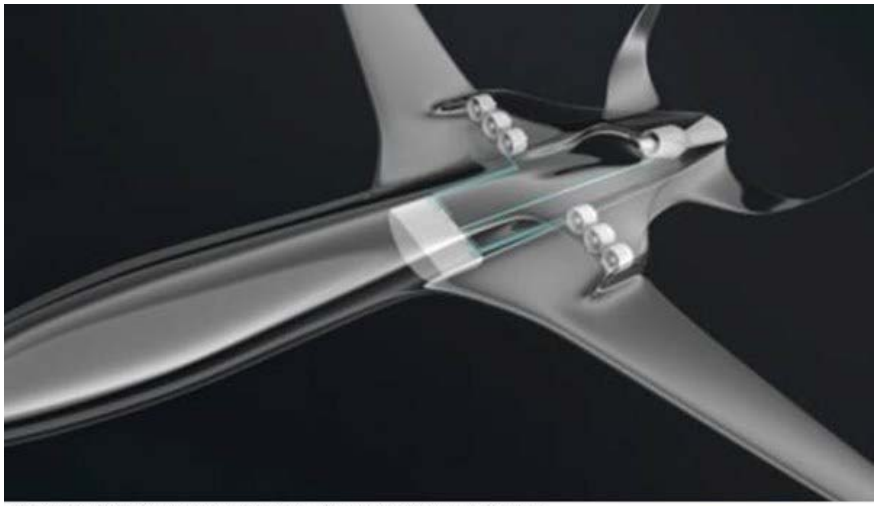


Figure 1: (Para el 2030, Airbus y Siemens crearán el primer avión eléctrico. embarcado.net, April 15 2016)

Technical Team Leader(s)

Mr. Thierry MAGIN , Belgium , von Karman Institute for Fluid Dynamics

Background

In the commercial telecommunication space arena, the strong competition among satellite manufacturers is a major driver for advancements in the area of Electric Propulsion (EP), where increased performance together with low prices are required. The use of electric propulsion will enable to use cheaper launchers or extend the life of current telecommunication spacecraft. Furthermore, new scientific and Earth observation missions dictate new challenging requirements for propulsion systems and components based on advanced technologies such as micro Newton thrusters. Moreover, new interplanetary missions in the frame of exploration will require sophisticated propulsion systems to reach planets such as Mars and in some cases bring back to Earth samples from these planets. A future colonization of Mars will require large cargo missions using EP.

The advantages of electric propulsion with respect to the chemical propulsion is the high specific impulse that implies a significant saving in propellant mass, and the capability of a very good controllability due to the possibility of generating very low thrust and very small impulse bit. During the last decade, EP systems have become a prominent solution in controlling commercial and military satellites in Earth orbit. Prior to 1998, electric propulsion was implemented in 3% of the launched satellites, including scientific space missions. This corresponds to only a total of around 200 EP systems. Today, 20% or 227 out of 1084 active satellites (excluding classified ones) operate with EP systems and the trend in industry is now towards all EP

platforms. The window for EP applications is increasing fast: at the smallest scale the trend is now to develop small micro-propulsion systems to control small satellites or CubeSats (positioning control and de-orbiting at end of life) whereas at the upper scale high-power thrusters (of the order of kW) are developed for all electric systems including orbit rising.

The relevance for NATO is found in the direct application of this topic for propulsion systems of space platforms, in particular satellites. One Long Term Capability Requirement to be supported by this RLS is Communication, Surveillance and Navigation.

Objectives

The course will provide a forum for discussion on current technological challenges in the field of electric propulsion, together with a review on relevant physico-chemical models and computational methods for engineering prediction, experimental facilities and measurement techniques, flight data, as well as disseminate information on ongoing and future projects associated with communication, scientific, and military satellites, and space exploration. The course will be tailored to provide professionals and students from supporting industries, space agencies, and defense programs the state-of-the-art in this rapidly progressing field of research.

Design, Manufacturing and Application of Metallic Lightweight Material Components for Military Vehicles

Reference Number	Activity Type	Activity Start Date	Activity End Date
AVT-264	Specialists Meeting	01 Jan 2015	01 Dec 2016
Publication Reference https://www.sto.nato.int/publications/STO Meeting Proceedings/STO-MP-AVT-264			

Figure 1: (Aluminium-Warmumformung für automobilen Leichtbau. schulergroup.com, November 19 2015)

Technical Team Leader(s)

Mr Robert BONDARUK , United States , UES Inc

Dr Wieslaw BERES, CAN, NRCC

Dr John Rodgers, CAN, Innovative Materials inc.

Background

The AVT-264 Specialists' Meeting on "Design, Manufacture and Application of Metallic Lightweight Material Components for Military Vehicles" was held in Tallinn, Estonia, 25-27 April 2016. The meeting provided a NATO forum to discuss recent advances in lightweight metallic materials and structures for all military environments. Seventeen papers were presented from military, government, industry and academic organizations in 9 countries. Over 50 people attended with good representation from across the NATO regions. The meeting was divided into sessions focused on manufacturing, modelling and design. Papers discussed examples where substituting a stronger alloy with the same base can reduce weight by up to about 10%, or replacing a dense alloy such as steel with a lighter alloy, say titanium, has the potential of up to 40% weight saving, but some redesign would probably be needed with an increase in cost. Very significant weight saving can be achieved by using multi-material designs. That usually requires the joining of dissimilar metals. Joining technology was highlighted as a key enabler for lightweight structures. Additive manufacturing offers the potential for lower cost novel lightweight designs. All of these developments are being accelerated by the application of materials modelling. However, these models require a lot of data which may not be available. The sharing of data was identified as an important barrier to wider application

of modelling into manufacturing, support and repair. This report concludes with a list of recommendations to AVT for future activities on metallic materials.

Background

Military organizations are constantly seeking to balance performance, protection, affordability and payload. Reducing weight of military vehicles has been of interest for military organizations for decades. Lightweight components play major role in achieving enhanced system performance, greater energy efficiency, and lower life-cycle cost. Lightweighting of military aircraft, land vehicles, maritime vessels and space assets is motivated by the desire to reduce fuel consumption and costs and also by the need to improve vehicle transportability whilst, at the same time, improving vehicle performance. Lightweighting encompasses the design, development, and implementation of lightweight materials, components, and other technologies, as well as the capability to manufacture and produce such materials and components at reasonable cost. Advancing a systems-level approach for the design and manufacturing of lightweight material, structures and components will provide the technological leadership for defence efforts of the NATO nations.

NATO-STO-AVT Specialist Meeting on lightweight materials will provide a forum to scan all military environments, seek out common technology gaps, providing advice on best practices to enhance the design of future systems and also optimize support of the current systems. This activity is based on the conclusions of the AVT-187 Symposium. SM results will address the fulfilment of the NATO Science &Technology Hard Problem #14—Mitigate Strategic Resource Scarcity—as usage of lightweight materials decreases requirement for energy in operation of military platforms.

Objectives

This Specialist Meeting will conduct an analysis of usage of lightweight material components in military platforms for air, sea, land and space, identify the technology gaps that are compromising their availability and support for current and future military platforms and systems. Application of lightweight materials and components should be viewed as a mean of achieving a variety of desirable features:

• Improve vehicle performance through increased speed, mobility, maneuverability, range, and payload capacity;

• Improve operational survivability, maintainability, reparability, durability, transportability.

• Improved fuel economy that will reduce energy expenditures and the logistical support needed to supply fuel to forces deployed in remote and hostile locations.

Exploitation and Impact

• Recommendations to AVT Panel on future activities to support application of lightweight materials in military systems

Integration of CBRN Physical Protective Measures to Lessen the Burden on Personnel

Reference Number	Activity Type	Activity Start Date	Activity End Date
HFM-199	Task Group	01 Jan 2010	01 Nov 2016
Publication Reference https://www.sto.nato.int/publications/STO Technical Reports/STO-TR-HFM-199			

Abstract

Participation in military operations is accompanied by the threat of exposure to Chemical, Biological, Radiological, and Nuclear (CBRN) agents. Historically, focus has been on the acute health effects of exposure to chemical weapons, and the specter of the use of biological, radiological and nuclear weapons. This Task Group addressed integrated CBRN protection strategies. This report focused on outlining technologies that lower the burden on the individual by using a layered approach consisting of contamination avoidance, physical protection, hazard mitigation response, containment and recovery. In this report there are many new emerging technologies that are outlined that will be able to contribute to enhanced warfighter safety related to CBRN risks and events, while reducing the physiological burden. The challenge will be to build appropriate systems to use and balance all available options against the missions that are to be expected and planned.

Technical Team Leader(s)

Dr Charles BASS , United States , Defense Threat Reduction Agency

Background

Participation in military operations is accompanied by the threat of exposure to Chemical, Biological, Radiological, and Nuclear (CBRN) agents. Historically, focus has been on the acute health effects of exposure to chemical weapons, and the specter of the use of biological, radiological and nuclear weapons. From WWI till today impressive research and development efforts have been devoted to passive defense against CBRN agents comprising relevant elements such as threat analysis, various means of detection and identification, diagnosis, protection (both physical and medical), decontamination, and medical countermeasures. In recent years the awareness of the importance of health hazards resulting from exposure of other toxic materials encountered during military operations has grown steadily. Whereas the end of the Cold War may have lowered the threat of large-scale attacks of classical CBRN weapons, the new era brings new types of operations, mostly out-of-area in a wide range of environments, where attacks can be isolated with predominantly local effects. Attacks could be unexpected, uncertain or initially unrecognized as a result of intended and unintended releases of classical, new and improvised agents, toxic industrial materials (TIMs) including the likelihood of CBRN terrorism.

Focus will therefore be more along the lines of consequence management versus general battlefield readiness. Doctrine is changing from “fighting dirty” to relocate, isolate the area and restore operations. The changing threat requires dual-use and integrated solutions rather than unique dedicated CBRN defense capabilities. Finally, casualty acceptance under these circumstances will be far less than when all-out CBRN warfare was anticipated during the Cold War. Nowadays, civilian occupational health regulations and standards will play a more predominant role.

Past HFM panel and its predecessors have focused on the toxicology as well as the medical counter measures against first chemical warfare agents (HFM041), the operational toxicology of military relevant

toxic hazards in general (HFM057), later the broader spectrum of chemical toxic agents (ET078) and also medical counter measures against biological agents (ET091). Other elements of the so-called CBRN passive defense chain such as threat analysis, detection, reconnaissance, physical protection (either individual or collective) as well as decontamination of people and materiel have not been given the research and technology attention in the same manner.

If doctrine and operational practice need to change as a result of the changing general picture shown above, the capabilities of current and emerging technologies should be made known to the proper communities in NATO (ACT, ACO, and CBRN-WG). In the materiel community (NAAG/JCG-CBRN and its sub-groups as well as DAT) much attention is given to equipment requirements, but scientific support to all this is lacking throughout NATO (except for some) with limited attention given by the RTO SET and RTO AVT panels.

It is therefore recommended that the issues listed above be addressed in a single activity, enabling a more integrated approach to CBRN protection.

Justification for the activity is apparent from the statement that an increased level of protection of military personnel under operational conditions will improve combat readiness and effectiveness, and therefore the probability of successful mission completion.

Objectives

Task Group will address integrated CBRN protection strategies. These will focus on lowering the burden on the individual by using a layered approach consisting of contamination avoidance, physical protection, hazard mitigation response, containment and recovery.

The specific goal of Task Group is to facilitate the communication and coordination of research on CBRN protection among the participating nations. This goal will be realized by regular meetings of the Task Group, a Specialist Meeting half term and preferably a Symposium at the end of its lifetime. More specifically, the Task Group will address the following topics:

• Define current and emerging systems for integrated protection.

• Explore, describe and assess existing operational concepts and determine key contributing technologies.

• Assess value and maturity of emerging enabling technologies.

• Facilitate dialogue with operational and technical communities.

• Facilitate technical cooperation and data sharing.

Synergies and Complementarities

Justification for the activity is apparent from the statement that an increased level of protection of military personnel under operational conditions will improve combat readiness and effectiveness, and therefore the probability of successful mission completion.

Live-Virtual-Constructive (LVC) Training to Enhance Performance Effectiveness

Reference Number	Activity Type	Activity Start Date	Activity End Date
HFM-221	Task Group	09 May 2012	31 Oct 2016
Publication Reference (when published) https://www.sto.nato.int/publications/STO Technical Reports/STO-TR-HFM-221			

Abstract

Over the past several years, there has been exponential growth in the combined application of live, virtual, and constructive systems, tools, and technologies in support of training and mission rehearsal. Combat systems are becoming more complex and interactive at the same time that the cost of training on the live systems exclusively continues to escalate. At the same time there has been a continued lack of understanding regarding what “L” and “V” and “C” actually can and should be and there are a variety of definitions regarding what constitutes “live”, “virtual”, and “constructive” players. Moreover, there is not a common language for the underlying architecture and tools necessary for the interoperability of these players in support of training and mission rehearsal. There is also a strong technological push rather than a human pull in many of the current LVC efforts. In order to deliver successful LVC applications, human factors issues have to be identified and addressed. Finally, many Governments and agencies are involved in LVC activity, but there is no current mechanism to promote crosstalk and collaboration regarding lessons learned and potential new solution sets to increase the application space and persistency of LVC.

The ongoing international trend of decreasing defense budgets have contributed to a situation where warfighters rarely are exposed to training situations that demand them to fully explore and use the potential of their systems at an appropriate level of credibility and security for the user. Economy is one strong factor behind this but also the availability of the number of assets needed to create a satisfactory level of dynamics and complexity of scenarios. The effect is that many warfighters do not get a sufficient amount of challenging live training under the circumstances and conditions they are expected to operate.

Technical Team Leader(s)

Dr Winston BENNETT , United States , 711 HPW/RHAS

Background

Over the past several years, there has been exponential growth in the combined application of live, virtual, and constructive systems, tools, and technologies in support of training and mission rehearsal. Combat systems are becoming more complex and interactive at the same time that the cost of training on the live systems exclusively continues to escalate. At the same time there has been a continued lack of understanding regarding what “L” and “V” and “C” actually can and should be and there are a variety of definitions regarding what constitutes “live”, “virtual”, and “constructive” players. Moreover, there is not a common language for the underlying architecture and tools necessary for the interoperability of these players in support of training and mission rehearsal. There is also a strong technological push rather than a human pull in many of the current LVC efforts. In order to deliver successful LVC applications, human factors issues have to be identified and addressed. Finally, many Governments and agencies are involved in LVC activity, but there is no current mechanism to promote crosstalk and collaboration regarding lessons learned and potential new solution sets to increase the application space and persistency of LVC.

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Objectives

One of the expressed goals for the RTG is to explore what it takes to develop a continuous learning environment that integrates various live, virtual, and constructive capabilities seamlessly for persistent training, rehearsal, and exercise, with real time and continuous assessment and performance tracking. The aim is to demonstrate that learning and proficiency can be accelerated, as well as mission readiness contribution in a variety of National, Joint, and Coalition mission contexts and domains, and that strategies can be developed and validated that might inoculate learners from the ravages of skill and proficiency decay.

The RTG will outline a report related to current LVC developments and applications. The report, which will be one of the products of the RTG, will identify and elaborate opportunities and continuing challenges, both in terms of policy and in terms of technology, that impact or limit additional and more widespread applications of LVC for training and mission rehearsal.

Synergies and Complementarities

There are numerous examples where the various military services have developed their own language, definitions, and integrating architecture for their LVC instantiations. One common element is a shared assumption that the sum is greater than the parts with respect to the integration of L, V and C for future training, development, and rehearsal. However, at the present time there is limited empirical data to make this case. What is not common is the desired aim for such integration. The ET has outlined a set of activities for the exploration of a shared understanding and agreement on the core underpinnings of LVC in Joint and Coalition air, land, and maritime applications, its current promise, and its longer term potential, and in what domains the promise and potentials can best be demonstrated.

With this background LVC is – from a technical, economical, methodological, and pedagogical perspective – potentially one of the most important opportunities for next generation training. Some examples of the questions and challenges that we will review and explore are: What happens when live systems, manned virtual simulators, and computer-generated forces act together simultaneously – does it affect the reliability and validity of the conclusions? How does the addition of live components change the “traditional features” of simulations with virtual and constructive components? How does LVC affect the conditions and opportunities for learning? In what ways have LVC training events been managed, scheduled and training needs prioritized and deconflicted - what strategies or methods should be in place to do so? What sort of feedback loops need to be put in place to ensure validity of the training environment and to enable continued development and evolution of the capability? Are the needs and requirements homogenous across platforms, roles, and communities, and if not, what are the important differences and how do they effect the development and application of LVC?

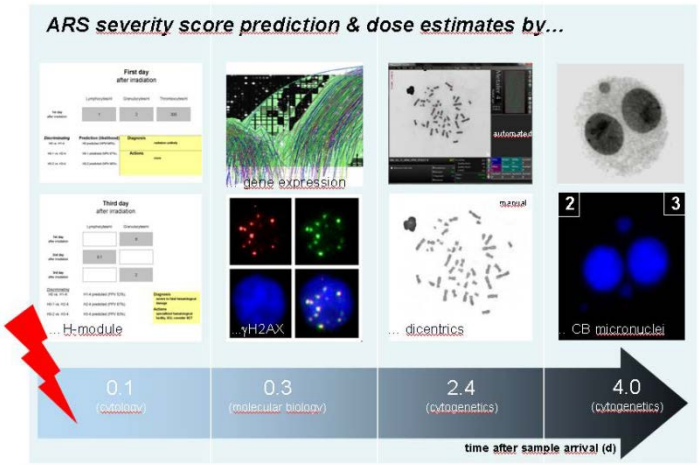
Ionizing Radiation Bioeffects and Countermeasures

Reference Number	Activity Type	Activity Start Date	Activity End Date
HFM-222	Task Group	14 May 2012	01 Jul 2016
Publication Reference https://www.sto.nato.int/publications/STO Technical Reports/STO-TR-HFM-222			

Improving medical countermeasures against radiological / nuclear threat from diagnosis to treatment.

Abstract

The HFM-222 RTG carried out two operational exercises (biological and clinical dosimetry) aimed at improving triage in the case of a malevolent large-scale radiation incident. Deployable medical planning tools were also developed. Moreover, RTG members contributed to the FDA approval of cytokines for treatment of patients with radiation-induced myelosuppression.



Author information

CZE: Major Dr Jaroslav Pejchal (Faculty of Military Health Sciences), DEU: Colonel Pr Michael Abend, (German Army Institute of Radiobiology), FRA: Colonel Dr Michel Drouet (French Army Biomedical Research Institute), GBR: Dr Kai Rothkamm (Public Health England), ITA: Colonel Dr Florigio Lista (Army Medical and Veterinary Center), NLD: Dr Tjerk Kuipers (Ministry of Defence), POL: Dr Ewa Nowosielska (Military Institute of Hygiene and Epidemiology), USA: Dr Alexandra Miller, (Armed Forces Radiobiology Research Institute), Chair : Dr Francis Hérodin (FRA), Panel Mentor: Pr Marek K. Janiak (POL).

Background (≈15%)

Based on the heritage of previous HFM-RTGs dedicated to improving knowledge on radiation bio effects, eight NATO leading nations gathered their expertise and resources to better cope with medical issues of the multiform and unexpected radiological/nuclear (RN) threat. HFM-222 RTG consists of nineteen radiation biologists recapitulating cutting-edge research, field experience, and knowledge of interoperable CBRN defense capabilities.

Objective(s) (≈10%)

Elaborate the state-of-the-art on medical countermeasures (MCM) against adverse health effects of low and high levels of ionizing radiation by focusing on biological dosimetry (diagnostic and predictive indicators), radioprotectors, mitigators, treatment of acute radiation syndrome (ARS) and prevention of late effects. Implement NATO exercices (ARS diagnosing and medical management) and propose recommendations. Mature medical products from planning to treatment.

S&T Achievements (≈20%)

High TRL: two exercises aimed at radiological triage improvement: (i) twelve institutions assessing dose estimate on irradiated irradiated blood samples using biodosimetry tools. The dicentric chromosome assay was confirmed as the gold standard biodosimetry method (estimate within 2.4 days), but emerging rapid molecular assays may become useful triage tools, (ii) diagnosing exposed individuals requiring specific treatment (e.g., cytokines) within the first days after radiation event using the METREPOL organ specific grading. The NATO initial (rapid) biodosimetry capabilities were assessed and TRL for emerging diagnostic technologies was updated; deployable medical planning tools were developed; recent preclinical research contributed to translating filgrastim and peg-filgrastim for treatment of severely irradiated patients. Sixty-six peer-reviewed articles published.

Lower TRL: mesenchymal stem cell (MSC) therapy was improved as the gold standard for cutaneous radiation syndrome (CRS), but uncertainties as to efficacy of cell banking remain. Gene therapy for H-ARS and CRS is being explored. Epidermal Growth Factor is under investigation for mitigating Gastrointestinal Syndrome. A better knowledge of MultiOrgan Dysfunction Syndrome was acquired. STO Annual Brochure Real-one Pager Version 23 September 2015

Synergies and Complementarities (≈20%)

Tight links between HFM-222 experts and networking (WHO, IAEA, EU) have been most useful. Strong brain storming and exchanges and several bilateral experimental efforts in biodosimetry, pathophysiology, therapeutics, and modeling have been successful. Some members who are also delegates to Nato Standardization Office medical working groups facilitated the translation of interoperability requirements into operational exercises to check common capabilities.

Exploitation and Impact (≈20%)

Additional work is needed to translate current biomedical research into gold standard procedures (e.g, rapid and reliable radiation diagnosis, deployable devices for better allocation of scarce medical resources). Harnessing role 4 capabilities (treatment following medical evacuation) is also a concern to the RTG. Combined injuries, including trauma, B/C agents, irradiation and contamination remain as challenges to be overcome.

Conclusion(s) (≈15%)

Radiobiologists of the NATO HFM network made significant progress into the development of new methods, bioassessment tools, and medical strategies for preventing, diagnosing and treating injuries associated with ionizing radiation exposure. Multiparameter biodosimetry and clinical dosimetry have been validated, planning tools have been developed and therapeutic strategies for ARS and CRS have been refined.

Civilian and Military Personnel Work Culture and Relations in Defence Organisations

Reference Number	Activity Type	Activity Start Date	Activity End Date
HFM-226	Task Group	23 Feb 2012	23 Feb 2016
Publication Reference https://www.sto.nato.int/publications/STO Technical Reports/STO-TR-HFM-226			

Abstract

Defence organizations are comprised of military and civilian personnel working together in a variety of contexts. This RTG provides insight into collaboration and integration of these workforces and offers recommendations for developing strategies, practices, and policies to enhance the quality of military-civilian personnel collaboration.

Author information

Irina Goldenberg PhD & Angela Febbraro PhD – Defence Research and Development Canada

Background

Defense organizations are unique in that they are comprised of integrated military and civilian personnel working in partnership, including at headquarters, on bases, on missions, and in academic military institutions. Indeed, civilian personnel represent a significant proportion of defence workforces in most nations – usually comprising between one-fifth and one-third of personnel, with some notable exceptions. Many defence civilians are supervised by military managers, while others are themselves responsible for managing military personnel. However, despite high levels of integration, military and civilian personnel are governed by very different personnel management systems, and have highly distinct cultures. These factors can affect the nature of collaboration between these integrated workforces and influence personnel outcomes and organizational effectiveness.

Objective(s)

This research task group (HFM RTG 226) was established to address the significant knowledge gaps in this area and to identify challenges and enablers of effective collaboration between integrated military-civilian workforces. The RTG reviewed existing data sources, policies and directives that guide the management of military-civilian integration. Moreover, a comprehensive survey was designed to examine key aspects of military-civilian working relations and dynamics and was administered to large samples of military and civilian personnel across 10 nations.

Exploitation and Impact

This research has informed the size, nature, and roles of civilian workforces across a range of Western defence organizations and provided insight into existing approaches and policies for managing defence civilians. The multinational personnel survey demonstrated that optimal management of military-civilian work integration predicts important employee outcomes for both military and civilian workforces across nations. Notably, analysis was extended to a variety of contexts beyond national defence organizations, including SHAPE as a multinational headquarters study, NATO KFOR as a multinational operational study, Organization for Security Cooperation in Europe (OSCE) as a ‘security’ (versus ‘defence’) organization study, and leveraging a RAND project examining the key topic of operational deployment of civilians.

Conclusion(s)

Defence organizations draw upon the expertise of military personnel who have specialized skills and knowledge related to military and operational functioning, as well as civilians trained in a variety of occupations and possessing a range of expertise in order to meet defence mandates. This RTG provides STO Annual Brochure Real-one Pager Version 23 September 2015 pragmatic recommendations for optimizing military-civilian personnel collaboration – the implementation of which will have a positive impact on the integration of defence forces, personnel well-being, and organizational effectiveness.

Development of Depository of fast and reliable Detection Methods for Zoonotic Agents

Reference Number	Activity Type	Activity Start Date	Activity End Date
HFM-230	Task Group	30 May 2012	30 May 2016
Publication Reference (when published) https://www.sto.nato.int/publications/STO Technical Reports/STO-TR-HFM-230			

Abstract

Zoonotic diseases are defined as diseases transmitted from animals to humans. Several reasons may be responsible for the acceleration of the emergence of new zoonotic pathogens during the past decades: the ever growing human and livestock animal populations that in turn induce increasingly close contact of people and animals by cheer numbers, increased travel and transportation speed making it today possible to go around the globe in less than the incubation period of most infectious agents, human-induced ecological, econiche and environmental changes. Bioterroristic activities (supported by rogue governments or originating from educated amateurs) become increasingly likely. A multitude of parameters might contribute to the emergence of a new zoonotic disease: mutation, natural selection, and evolutionary progression of viruses and bacteria; acquired (natural or induced) immunity, behavioral features as well as ecologic and climatologic factors. During the past two decades a number of new virus infections have (re-)emerged. They can be divided into two categories, those that are transmitted to humans directly from vertebrate animals (like rodents, foxes, bats and birds) and those that are primarily transmitted by arthropods (mosquitoes, ticks, sandflies). Most of them have appeared in subtropical or tropical regions (e.g. Sin Nombre and Andes hantaviruses, SARS coronavirus, avian influenza, Nipah and Hendra viruses). In 1999 West Nile virus reached the New World, Dengue viruses are rapidly spreading to new areas and infections by several of these viruses may result in high mortality. Tick-borne encephalitis virus is also spreading to new areas as a result of climate and environmental changes. These viruses also deserve attention because they are potential bioweapons. An increased risk of exposure to certain pathogenic bacteria was induced by 20th century animal and human diet changes. The number of human food-borne infections due to the ingestion of pathogenic bacteria, such as Campylobacter, enterohemorragic Escherichia coli (including E. coli O157:H7) or Salmonella (in particular S. Enteritidis or S. Typhimurium DT104) has dramatically increased with the development of large scale industrial food processing and the emergence of fast-food restaurants. Foodborne infections caused by zoonotic agents have become more frequent throughout the last decades.Increasing populations of production animals and wildlife, together with modern breeding methods for domestic animals favored the spread of pathogens such as Mycobacterium bovis, Brucella spp. or Francisella tularensis. The increased number of pets in developed countries and the luxury problem of exotic pets has resulted in the emergence of new viral and bacterial infections or parasitic infections. Population displacement (human or animal, voluntary or not) or translocation via game release in zoological or safari parks have led to the emergence of bacterial zoonoses. Increased human contacts with wildlife reservoirs, associated with military operations as well as with leisure activities (hunting, fishing, tourism) may expose humans to bacteria excreted by healthy animal carriers, such as F. tularensis, Leptospira spp. and Bartonella spp. or to arthropods that are vectors of bacteria, such as Borrelia burgdorferi (Lyme disease) or Coxiella burnetii (Q fever).

Technical Team Leader(s)

Ms Christel COCHEZ , Belgium , Belgian Ministry of Defense

Background

A zoonosis is any infectious disease that can be transmitted from non-human animals, both wild and domestic, to humans. Zoonoses have been known since early historical times (i.e. plague, anthrax). Of the 1415 pathogens known to affect humans, 61% are zoonotic. The interdisciplinary field of human and veterinary medicine is already largely concerned with zoonoses as outbreaks of (re-)emerging pathogens regularly occur (e.g. Ebola, Lassa, Nipah, Hendra viruses, new Influenza strains, EHEC strains, some Salmonella strains). Zoonoses are of military interest because they are often emerging or even unrecognized diseases, or have increased virulence in populations lacking immunity. Moreover, one of the major factors contributing to the appearance of new zoonotic pathogens in human populations is increased contact between humans and wildlife. Deployed troops are thus at risk for zoonotic diseases, while the risk of pathogen transfer from a deployment area to the nation of origin is also a concern. Infectious diseases acquired in the operation zone do still account for more military hospital admissions than battlefield injuries. Whilst these arguments are valid for natural acquired pathogens, consideration should be given to the use of zoonotic agents as a possible biological weapon, the list of agents that can be a candidate biological weapon consists for 70% of zoonotic pathogens. The easy access to these agents in nature is a serious problem for biological weapons proliferation and is increasing the probability of a serious bio-terrorism incident. Concerted action for detection and surveillance is thus of importance, together with dissemination of data and information between NATO partners.

Finally, zoonotic parasitic diseases are transmitted to humans by ingesting spores, cysts, oocysts, ova, larval and encysted stages, but mainly by eating raw or undercooked meat containing infective tissue stages. Humans can be final, intermediate or accidental hosts. While the transmission of some of these zoonoses can be directly (e.g. by human-animal contact or through contact with contaminated faeces, soil, etc), they can also be transmitted through contaminated water and food. Water and food can be sources of infection. The water-food connection for parasite zoonoses has faeces as a major vehicle for many environmental transmissive stages, only few pathogens (e.g. Encephalitozoon cuniculi and Schistosoma haematobium) contaminate the environment via urine. The contamination by the various stages can be direct or indirect. The disposal of animal (and human) waste in many countries remains a significant operational problem. Water is the major route for parasites, and by direct consumption or by the use of contaminated water it is an important source of infection for humans.

Objectives

The RTG will define standards for first line (“in the field”) and second line (“in the lab”) detection and identification methods for viral and bacterial zoonoses. The RTG will also review the outbreak alert system and on-sight surveillance and create a list of pathogen collections of which items can serve as positive control or for validation purposes.

Synergies and Complementarities

Bacterial, parasitic and viral zoonoses have had their influence on military campaigns throughout history, at times playing an important role in determining the result. Bacterial and viral gents for possible use in biological warfare include the organisms causing anthrax, plague, tularemia, brucellosis, glanders, melioidosis, various food borne illnesses, cryptosporidiosis, cryptococcosis, Q fever, psittacosis, dengue fever, smallpox, viral equine encephalitides, and the viral hemorrhagic fever group. Except for smallpox and dengue fever, all are commonly found in animals. A report in the Journal of the American Medical Association concluded that 80% of the pathogens likely to be used in biowarfare are zoonoses. As a rule, only basic microbiological skills and equipment are needed to produce and use bioweapons. The potency, the cost-effectiveness, and ease of use guarantees that zoonotic agents remain a constant threat to public health in the form of bioweapons. Another detrimental effect of the use of zoonotic agents as weapon definitely is they can persist in the environment (in the soil, water, or air) and especially wildlife is the first and foremost victim of this release, thus serving as sentinels. Sentinel animals could provide an early warning to humans if clinical signs could be detected before human illness emerged, or soon enough to allow preventive measures to be initiated active surveillance for sporadic illness in animals could help

detect ongoing exposure risks. Migrating birds, commercially shipped livestock, and wild animals targeted in the pet trade (local or international)l could play a role in maintaining and spreading an epidemic over large distances, i.e. from an operation theater to the country of origin (or vice versa). It should be emphasized that what is valid for forced outbreaks- is equally valid for natural outbreaks. Zoonoses currently affect the operational capability of deployed troops in all operation theaters and all nations make considerable efforts for prevention already. Particularly because of their stability in aerosols, their virulence and infectivity if acquired through inhalation (e.g. Y. pestis, C. burnetii, F. tularensis), several zoonotic pathogens are among the most likely biological weapon threats. Several hundred cases of tularemia that occurred in Kosovo in 1999-2000 for instance highlight the military relevance of this zoonotic agent. Aerosols can also be self-inflicted as for instance propellers and engine motors can bring massive quantities of infected dust in the air in specific endemic regions. In order to enable fast and reliable identification of pathogens that could or actually do- pose a danger to deployed troops, a standardized depository of available diagnostics in military/civil environment and the follow-up of technical progress and the distribution of these data amongst NATO members could thus be beneficial. In relation to the previous it would also be useful to acquire knowledge concerning available pathogen collections in various nations in order to serve (if made available) as positive controls/test evaluation material. The practical use of the previous could be assessed during sample missions in connection with in-the-field identification of pathogens in the collected samples.

Sensitive Equipment Decontamination Technologies

Reference Number	Activity Type	Activity Start Date	Activity End Date
HFM-233	Task Group	05 Nov 2012	01 Jul 2016
Publication Reference https://www.sto.nato.int/publications/STO Technical Reports/STO-TR-HFM-233			

Abstract

The DOTMLPF-I approach has been largely neglected in the scientific community. This study lays the ground for taking into consideration the whole bandwidth of this schematic and its consequences in capability planning and –develoment.

Author information

Dr. Schneider, Dr. Grabowski , DEU, Bundeswehr Research Institute for Protective Technologies; D. Sinault, FRA, DGA Maitrise RNBC; Dr. Claesson, SWE, FOI, Swedish Defence Research Agency; B. Pedersen, NOR, FFI, Forsvarets Forsknings institutt; LtCdr A. McVey, GBR, MOD. **Editor:** Dr. Grabowski

Background

More and more mission-critical, e.g. electronic, equipment is not hardened against the effects of CBRN-weapons, rendering it useless after classic decontamination. Hence, it is critical to ensure the availability of technologies capable to decontaminate such sensitive equipment. Rapidly evolving equipment technology requires a qualified look into present and future capabilities in order to not let capability gaps emerge.

Objective(s)

To support the capability-planer and –developer by providing an outlook on (future) available technologies and the challenges their fielding would provide on Doctrine, Organization, Training, Materiel, Leadership, Personnel, Facilities, and Infrastructure in the force structure. That way, the materiel developer is in a position to develop requirement-tailored equipment in a timely and cost-effective manner.

S&T Achievements

This study is a review and not aimed at producing new data. It does collect, organize and manage scientific data to the extent that NATO's CBRN community now has a comprehensive document that provides the knowledge needed to identify actual and future capability gaps as well as to appropriately close these gaps.

Synergies and Complementarities

The synergies result from the co-operation of the scientific, the materiel developer's, and the user communities. These synergies are clearly visible in the work of the Joint CBRN Defence Capability Development Group that has emerged from the synthesis of these communities and has initiated this study.

Exploitation and Impact

The outcome of this study is of high relevance to the capability planner, allowing him to decide which capability to be developed by the materiel developer based upon the exact knowledge his decision will have on the whole spectrum of DOTMLPF-I; e.g., whether there are additional budgetary requirements for the construction of facilities or special training requirements for the personnel who would execute this capability. This will contribute to repel the main threats of the use of WMD, e.g. area denial, obstruction of movement, and reduction of physical performance.

Conclusion(s)

This study, an outcome of the fusion of all communities in charge of CBRN defence aspects in NATO, produces an extremely valuable tool allowing future, threat- as well as budget- and consequence-oriented capability planning.

Environmental Toxicology of Blast Exposures: Injury Metrics, Modeling, Methods and Standards

Reference Number	Activity Type	Activity Start Date	Activity End Date
HFM-234	Task Group	01 Jul 2013	01 Jul 2016
Publication Reference https://www.sto.nato.int/publications/STO Technical Reports/STO-TR-HFM-234			

Abstract

The HFM Research Symposium on Blast Injury (HFM-207) revealed a need for continuing NATO-wide research cooperation on the environmental toxicology of military personnel in blast exposure environments. Blast Injury is a significant source of casualties in current NATO operations and the spectrum of blast injuries and their consequences is broad. To address the research issues posed by the wide spectrum of battle injuries, a scientific interdisciplinary approach will be required. While HFM-207 provided an initial assessment of current state of relevant interdisciplinary science, it was appreciated that the hard problem of understanding and mitigating blast injury will require a specific NATO technical activity devoted to the environmental toxicology of blast exposures. Some of the scientific issues include a need for bio medically valid computational models of primary blast injury that incorporate biomechanical and physiological responses, the establishment of common animal models of blast exposure and the resulting injuries, and an understanding of non-penetrating blast injuries to the brain which are manifest in a host of symptoms whose etiology is at best vague. In effect HFM-207 served as a HFM Exploratory Team in identifying a significant opportunity for a new RTO Technical Activity.

Technical Team Leader(s)

Mr Michael LEGGIERI , United States , US Army Medical Research and Materiel Command

Background

The HFM Research Symposium on Blast Injury (HFM-207) revealed a need for continuing NATO-wide research cooperation on the “environmental toxicology” of military personnel in blast exposure environments. Blast Injury is a significant source of casualties in current NATO operations and the spectrum of blast injuries and their consequences is broad. To address the research issues posed by the wide spectrum of battle injuries, a scientific interdisciplinary approach will be required. While HFM-207 provided an initial assessment of current state of relevant interdisciplinary science, it was appreciated that the hard problem of understanding and mitigating blast injury will require a specific NATO technical activity devoted to the “environmental toxicology of blast exposures”. Some of the scientific issues include a need for bio medically valid computational models of primary blast injury that incorporate biomechanical and physiological responses, the establishment of common animal models of blast exposure and the resulting injuries, and an understanding of non-penetrating blast injuries to the brain which are manifest in a host of symptoms whose etiology is at best vague. In effect HFM-207 served as a HFM Exploratory Team in identifying a significant opportunity for a new RTO Technical Activity.

Objectives

The RTG will establish a framework for a new interdisciplinary research area – the environmental toxicology of blast. In addition the RTG will:

- build an evidence-based outline for NATO standards for blast injury analysis;

- examine opportunities for improvements in the standards of medical care for blast injury;

- explore advancing the state-of-practice in computational modeling of blast injury in relevant operational environments; and,

- explore standardized animal models and toxicology research protocols that could be adopted by R&T programs across NATO.

Synergies and Complementarities
The proposed technical activity has significant implications for advancing approaches to the design of protection systems (e.g., vehicle design, protective vests, helmets) through the interdisciplinary coupling of medical research with physics and engineering sciences. The core contribution of this multidisciplinary cooperation effort will be protocols for setting the metrics and methods for the environmental toxicology of blast environments which can lead to new NATO standards both for mitigating blast effects and, if mitigation fails, for improvement in medical care of injuries.

Assessment of Intelligent Tutoring System Technologies and Opportunities

Reference Number	Activity Type	Activity Start Date	Activity End Date
HFM-237	Task Group	20 Mar 2013	20 Mar 2016
Publication Reference https://www.sto.nato.int/publications/STO Technical Reports/STO-TR-HFM-237			

Abstract

The NATO Training Groups (NTG) working group on Individual Training and Educational Development (IT&ED) has found substantial instructional efficiencies in terms of both reduced costs and enhanced effectiveness to be readily achievable through the use of computer-based tutoring technology. However, most of these effects concerned memorization, understanding, and application of relatively straightforward facts, concepts, and procedures. Although the basic capabilities produced by such instruction are vital to successful accomplishment of military operations, they are not sufficient. Military operations, especially those characteristic of current irregular warfare environments, require, among other things, improvisation, rapid judgment, and the ability to deal with the unexpected. They go beyond basic instructional objectives and require education and training focused on higher order cognitive issues such as analysis, evaluation, creativity, and rapid synthesis of novel approaches that must intersperse judgment with the automatic responses provided by training involving memorization and straightforward applications. These capabilities can make the difference between success and failure in operations.

Technical Team Leader(s)

Dr Ray PEREZ , United States , Office of Naval Research, US Navy

Background

The NATO Training Group's (NTG) working group on Individual Training and Educational Development (IT&ED) has found substantial instructional efficiencies in terms of both reduced costs and enhanced effectiveness to be achievable through the use of computer technology. However, most of these effects concerned memorization, understanding, and application of relatively straightforward facts, concepts, and procedures. Although the basic capabilities produced by such instruction are vital to successful accomplishment of military operations, they are not sufficient. Military operations, especially those characteristic of current irregular warfare environments, require, among other things, improvisation, rapid judgment, and the ability to deal with the unexpected. They go beyond basic instructional objectives and call for education and training focused on higher order cognitive issues such as analysis, evaluation, creativity, and rapid synthesis of novel approaches – approaches that must intersperse judgment with the automatic responses provided by training involving memorization and straightforward applications. These capabilities can make the difference between success and failure in operations.

Instruction to produce these capabilities requires interaction with 'intelligent' systems that rapidly adjust to individual learner abilities, prior knowledge and experience, and, to some extent, misconceptions. As with basic instruction, technology is required to make this education and training affordable and effective at the scale required for military personnel. This technology has long been the goal of approaches earlier labeled intelligent computer assisted instruction (ICAI) and, more recently, intelligent tutoring systems (ITS). Research at various universities (in Europe, North America, and elsewhere) and some commercial enterprises has produced effect sizes in excess of 1.00 (roughly an increase of learner performance from the 50th to the 84th percentile) and, occasionally, 2.00 (roughly an increase from the 50th percentile to the

98th). Recent research on digital tutoring by the US Defense Advanced Research Projects agency (DARPA) has found effect sizes of 3.00 and 4.00 for one of their efforts. ITS may offer NATO substantial and unique opportunities for developing instruction that addresses critical cognitive capabilities needed for military operations. The nature, extent, availability, and feasibility of these opportunities should be identified, reviewed, and assessed for NATO applications.

Objectives

This effort will review and provide an analysis of the nature, extent, availability, and feasibility of opportunities presented by ITS for conducting NATO education and training.

Synergies and Complementarities

Instruction to produce these capabilities requires interaction with intelligent systems that rapidly adjust to individual learner abilities, prior knowledge and experience, and, to some extent, misconceptions. As with basic instruction, technology is required to make this education and training affordable and effective at the scale required for training military personnel. This technology has long been the goal of approaches previously known as intelligent computer assisted instruction (ICAI) and, more recently as intelligent tutoring systems (ITS) and computer-based tutoring systems (CBTS). Research at various universities and some commercial enterprises has shown effect sizes in excess of 0.3 sigma with an average of about 1 sigma. ITS may offer NATO substantial and unique opportunities for developing instruction that addresses critical cognitive capabilities needed for military operations. The nature, extent, availability, and feasibility of these opportunities need to be determined.

Mild Traumatic Brain Injury: Post Concussive Symptoms in a Deployed Setting

Reference Number	Activity Type	Activity Start Date	Activity End Date
HFM-240	Lecture Series	01 Sep 2013	31 Dec 2018
Publication Reference https://www.sto.nato.int/publications/STO Educational Notes/STO-EN-HFM-240			

Abstract

Mild traumatic brain injury (mTBI), also known as concussion, is a significant military operational and civilian medical problem. This lecture series reviewed state of medical knowledge and discussed medical treatment in the deployed as well as post-deployment settings. Participants left with increased ability to accurately diagnose mTBI/concussion and to treat patients appropriately.

Technical Team Leader(s)

Capt (N) (Dr) Jack TSAO , United States , University of Tennessee Health Science Center

Background

Mild Traumatic Brain Injury (mTBI)/post concussiove symptoms (PCS) is a relevant military issue due to its incidence and prevalence both in deployed and non-deployed settings. Although explosive blast predominates as the primary mechanism of injury in current NATO conflicts, other mechanisms such as falls and motor vehicle crashes may contribute to the symptom manifestation and must be taken into account.

Acutely, symptoms from mTBI/PCS adversely may impact operational readiness of the individual or unit. In most cases, the acute effects are of short duration, but there is an small minority that has a prolonged course of recovery. This may impact both the health of the individual in the short term, their ability to remain in theatre, and may potentially affect their capability to deploy in the future if symptoms fail to remit.

Evidence-based public health policy is best served by the use of a rational evaluation framework such as Population Impact Analysis. Such organizing frameworks can be used to apply evidence from the literature to estimating the impact of implementing programs or policies for any given health issue on the local population.

Military Relevance

Failure to identify or recognize individuals who are impaired as a result of mTBI/PCS can have serious consequences for them, their comrades and the mission. Programs and policies that are implemented to manage mTBI/PCS have the potential to impact the military operation. Positive impact would include a appropriate early identification of injured personnel. Potential negative effects include unnecessary removal of personnel from operational duties and mis-attribution of symptoms. From a societal perspective, how the military leadership deals with mTBI/PCS has a potential impact on the public perception of their commitment to the care of their service members, which also ultimately can have an impact on public and individual resolve to remain in the fight.

Objectives

Cumulative research findings can help military leaders and nations understand existing clinical practice guidelines for the management of mTBI/PCS in a military operational setting that are currently employed by a number of NATO countries, summarize key research findings where relevant, and identify key principles for best practices in the management of mTBI/PCS in the deployed setting. Therefore, it is important to organize and carry out a RTO Lecture series (RLS) to disseminate the results among operational communities in NATO and Partner nations.

Synergies and Complementarities

There is considerable variability in how NATO and partner nations have chosen to approach this issue. To some extent this may be due to variability in factors such as the nature and duration of their deployments as well as the number of service members deployed. Ultimately, a sound approach should be guided by evidence collected and analyzed relative to each nation's forces. Decisions about the implementation of programs, policies and guidelines should be guided by these results and aided by the use of sound public health organizing frameworks.

Exploitation and Impact

Three Lecture Series (1 North America, 2 Europe) and Educational Notes

Conclusions

The RLS covered the following key topics and dimensions: a description of existing clinical practice for all participating NATO countries; current TBI research; identification of existing gaps in knowledge; and principles for best practices. Specific topics are addressed and includes: the potential Impact of mTBI/PCS on Military Operations; the significance of explosive blasts as a mechanism of injury; description of existing Clinical Practice Guidelines; and key features of mTBI/post-concussion syndrome and the co-occurrence and overlap with other physiologic and/or mental health problems, such as PTSD.

Aerospace Medicine - From the Ground Up

Reference Number	Activity Type	Activity Start Date	Activity End Date
HFM-264	Technical Course	01 Jul 2015	01 Dec 2016
Publication Reference (when published) https://www.sto.nato.int/publications/STO Educational Notes/STO-EN-HFM-264			

Technical Team Leader(s)

Col Gerald ROTS , Netherlands , Ministry of Defence

Background

Aerospace Medicine is a multidisciplinary specialty, focusing on health, safety, performance, and psychophysical stresses on the human. These operators are adapted for terrestrial life and suffering from natural disease and age related degeneration, but are exposed to the limits of human tolerance in austere environments. The specialty aims to prevent or to treat conditions to which aircrews are particularly susceptible, applying medical knowledge of human factors in aviation and is thus a critical component of flight safety. Aerospace Medicine is most effective when employed in a proactive manner, in the components of preventive, curative and supportive medicine. In anticipating, recognizing, and controlling factors, which could adversely impact human health, safety, sustainability and performance, including environmentally extreme conditions or NRBC threats, it is a force promoter ensuring that high-value trained assets are available to perform their roles. Aircrew is a critical resource.

Aircrew performance is a critical determinant of mission effectiveness. Modern technology has led to current air operations becoming increasingly challenging, which require aircrew to be physically, medically and psychologically fit. The development of dynamic fifth generation multi-role aircraft employs a single seat cockpit, which increase the pilots psycho-physical workload compared with previous generation aircraft. Costs of training Aircrew are rising, making each individual a significant financial investment, which gives an incentive to maintain Aircrew in flying status for longer, and therefore more likely to suffer from age related or natural disease. In this regard, Aerospace Medicine is becoming more personalized flight medicine focusing on the individuals capabilities and condition, which define the medical care required. In addition, adequate perception and situational awareness are key to the effectiveness of the human component of airborne military forces in the man/machine interface. In a network enabled air scenario (ISTAR) aircrew have to cope with multiple psycho-physical stresses. In this context, aircrew now include ground-based operators of Remotely Piloted Aerial Systems, and individuals working in cyberspace.

Maintenance and enhancement of aircrew performance and effectiveness include physical, medical and psychological monitoring, supervision and training. This requires the involvement of adequately trained Flight Surgeons from point of selection to retirement. It is critical that the Flight Surgeon understands the risks and benefits of the flight environment, aircraft and aircrew equipment assemblies for the Aircrew. It is important to consider and review the current aeromedical strategies and scientific results carefully. These include selection and training; clinical guidelines; waiver and downgrading policies; medical standards; Crew Resource Management; operational flight medicine; ergonomics and anthropometrics. With emphasis on performance, current scientific research programs can produce answers, understanding how individual health has an impact on performance, and how this affects the near- and long-term health (physical, psychological and emotional) of the individual.

Objectives

The objective of this Course is to provide state of the art knowledge and practices, share national practices and evaluate new and emerging technologies on the subject of Aerospace Medicine and Human Performance in its broadest context to NATO Flight Surgeons, by a group of expert lecturers from NATO, Partner & Other Nations. The course will cover the current and future challenges in Aerospace Medicine at home (selection, training, retention, career fields, aging) and in deployed area (exposure, threat, non-linear warfare) in more demanding and hostile missions, with exponentially growing technology, in a more volatile world.

Exploitation and Impact

AsMA, EAG, USAF 711 Human Performance Wing, USAFE

Workshop on Advanced Medical Technologies in Training

Reference Number	Activity Type	Activity Start Date	Activity End Date
HFM-267	Workshop	01 Jul 2015	01 Aug 2016
Publication Reference (when published) https://www.sto.nato.int/publications/STO Educational Notes/STO-EN-HFM-267			

Technical Team Leader(s)

Dr. Anja VAN DER HULST , Netherlands , TNO

Background

One of the greatest gains in reducing mortality on the battlefield results from improvements to prehospital care. Although the survival rate from battlefield injuries has increased to more than 90%, the majority of deaths still occur before reaching a medical treatment facility. As the most important timeline for survival is the time elapsing from injury to surgery, significant research efforts should aim at improving prehospital care. Three strategies are suggested:

1. Provide accurate diagnostics to identify the patients most at risk and make adequate triage for transport and treatment.

2. Delay deterioration of the patients vital functions by optimal emergency care given by every first responder including medical personnel.

3. Reduce the time between injury and damage control surgery (DCS) by logistic measures. This can be achieved by improving evacuation or moving damage control surgery forward.

As a main outcome of the HFM-249 Symposium on Emerging Technological Advances in Tactical Casualty Care, one common theme was captured in all three strategies. There is an urgent need for standardized training of all staff managing casualties, all the way from soldiers pre deployment, forward deployment, to the medical staff handling the damage control and/or resuscitation, to the surgeons. This encompasses the training of all actors as individual and as part of a team. In the Casualty Care chain, from the soldier as the first responder, up to the surgeon, extra training is needed for the interfaces within the chain.

Consequently, the aim of this workshop is to explore Advanced training Technology for the improvement of the training of all actors in the survival chain, with a focus on First responce. Soldiers, but often also medical personnel have very little relevant hands-on experience before providing first aid in the battlefield. The broad set of skills required for medical personnel are not learned in the civilian hospitals today. They may have had theoretical courses and limited live training with manikins. Such training evidently has its limits to prepare them for the severe trauma they may sometimes encounter under stressful battlefield conditions.

In the workshop we will explore the Advancements in Medical Training Technologies (AMTT) that may assist to better prepare soldiers and medical personnel for first response in battlefield conditions. The focus will be on simulation, serious gaming, augmented reality, and advanced skills labs. Such advanced training technology broadens the range of tasks as well as circumstances under which all staff managing casualties can be trained. It will also has great potential for the training of situation assessment and combat casualty care procedures. The application will target primary care skills and include training of mental resilience and specific technologies that can be used for simulation of extreme conditions (heat, humidity etc) occurring in the battlefield.

To be applied properly under stressful battlefield conditions, procedures must be automated to a large extent. . Automation can only be reached by repetitive training. AMTT has the potential of providing repetitive training of such procedures within a large variety of cases and environments. It also may facilitate a short-cyclic approach with gradual progression of complexity.

AMTT will also facilitate the training of Situational Awareness, Situational Analyses and Decision Making by allowing students to experiment in a safe environment and receive tactically valid feedback on their actions, and as such providing a host of relevant scenarios within limited time.

The workshop will have a highly interactive format. Besides a limited number of centralized sessions, three parallel working groups are anticipated with ample opportunities for demonstrations and hands-on. At the end of the final day the working groups will present their findings and conclusions to all members of the workshop.

Objectives

1) To create synergy and collaboration between research communities working on medical training, mental resilience training, and advancements in training technologies.

2) To investigate the potential and limitations of application of AMTT in first response training.

3) To provide an overview of advanced technologies suitable for training primary care skills and mental resilience, including specific technologies that can be used for simulation of extreme conditions occurring in the battlefield

4) To disseminate advances in technology and knowledge pertaining to first response training to NATO and associated organizations.

Exploitation and Impact
Roadmap (current, missing and the way to go)

Regenerative Medicine and advanced Rehabilitation - Today and in Future

Reference Number	Activity Type	Activity Start Date	Activity End Date
HFM-272	Symposium	01 Mar 2016	01 Dec 2016
Publication Reference (when published) https://www.sto.nato.int/publications/STO Meeting Proceedings/STO-MP-HFM-272			

Technical Team Leader(s)

Cdr (MC) Ass.-Prof. Dr. Stefan SAMMITO , Germany , Bundeswehr Joint Medical Service

Background

As seen in recent NATO military missions, the number of soldiers who survive severe and – in most cases - multiple injuries has significantly increased compared to previous operations predominantly as a result of progress in medical field care, first surgical treatment and advanced medical care along the rescue chain including (air)medevac and repatriation. As a consequence, quite a number of debilitating injuries is seen in wounded soldiers who expect recovery and rehabilitation outcomes that reach far beyond those achieved by traditional rehabilitation concepts. The best possible treatment has to be provided to the wounded warriors not only for ethical reasons but also to foster morals of those being deployed.

The STO HFM Symposium 228 “Force Sustainment: Rehabilitation, Regeneration, and Prosthetics for re-Integration to Duty” held in Milan (April 2103) and the STO HFM Workshop 243 “Regenerative Medicine” held in May 2014 in Berlin, Germany have demonstrated the rapid progress underway in the evolving field of regenerative medicine.

Thus, there is a need for gathering and expanding knowledge on the part of NATO as to what new medical treatment and rehabilitation options are on the horizon in order to be able to advise COMEDS as to further guidance of research and development efforts.

Objectives

The symposium will bring together international experts in the developing field of regenerative medicine, to provide a forum for them to present their most recent results and to envision possible ways to future treatment, rehabilitation and related technologies.

This activity is expected to create an overview about most relevant initiatives and efforts in the field of regenerative medicine, to highlight the most important needs (and opportunities) of scientific and clinical projects in this field and to expand the international network of experts aiming at new therapies to enhance the recovery of soldiers wounded in action.

Meeting Translation for NATO Operations (Speech and Language Processing, Project 8)

Reference Number	Activity Type	Activity Start Date	Activity End Date
IST-102	Task Group	01 Jan 2012	31 Dec 2016
Publication Reference (when published) https://www.sto.nato.int/publications/STO Technical Reports/STO-TR-IST-102			

Abstract

Language is a major obstacle to the communication among multinational personnel. Personnel must communicate in addition to their own language, in an official NATO language. For multi-national briefings, such as Operational Daily Briefings, this may cause a reduced efficiency. By integrating machine translation with other related communications technologies, such as speech recognition and synthesis, speaker and language identification, NATO personnel can work successfully in such operational settings.

Technical Team Leader(s)

Dr. Timothy ANDERSON , United States , Air Force Research Laboratory

Background

Language is a major obstacle to the communication among multinational personnel. Personnel must communicate in addition to their own language, in an official NATO language. For multi-national meetings, such as IST Panel meetings, this may cause a reduced efficiency. By integrating machine translation with other related communications technologies, such as speech recognition and synthesis, speaker and language identification, NATO personnel can work successfully in meetings. Standardized assessment methods using real meeting data and specifications for both commercial-off-the-shelf (COTS) and for development of **new** technology are required.

Objectives

To address these subjects a representative, multilingual, database of dialogues (both text and speech) is required. A relevant option is to collect these dialogues during NATO meetings, such as IST Panel meetings. One or more prototype systems would be developed and evaluated collaboratively within the Research Task Group. The prototypes could be standalone on a laptop or desktop computer or network based using multiple computers on a wide-area network. All specified applications could be assessed with such a methodology.

Synergies and Complementarities

For multi-national operations, the use of different languages may cause a reduced performance or even cause miscommunication of an action. Standardised assessment methods using real data and specifications for both commercial-of-the-shelf (COTS) and for development of new technology are required.

Cyber Defence Situational Awareness

Reference Number	Activity Type	Activity Start Date	Activity End Date
IST-108	Task Group	01 Jan 2013	01 Dec 2016
Publication Reference (when published) https://www.sto.nato.int/publications/STO Technical Reports/STO-TR-IST-108			

Abstract

The IST-081 Coalition Network Defence Common Operational Picture RTO Task Group (RTG) identified areas within the domain of Cyber Defence Situational Awareness (CDSA)that require further research including situational awareness metrics, visualization and mission assurance.

Technical Team Leader(s)

Mr. Douglas WIEMER , Canada , RHEA Group

Background

A Cyber Defence Situational Awareness (CDSA) capability is an emerging, urgent need across nations. NATO 20201 states that NATO must “accelerate efforts to respond the danger of cyber-attacks by protecting its own communications and command systems, helping Allies to improve their ability to prevent and recover from attacks, and developing an array of cyber defence capabilities aimed at effective detection deterrence.” Cyber defence situational awareness plays a vital part in this requirement. The IST-081 Coalition Network Defence Common Operational Picture RTO Task Group (RTG) identified areas within this domain that require further research including situational awareness metrics, visualization and mission assurance. In addition, several nations are developing CDSA tools, techniques and technologies, and are at the point where they could leverage each other’s efforts through international collaboration. These factors indicate a timely opportunity for international collaboration, thus it is recommended to create a new RTO Task Group (RTG) that addresses related research and technological issues in the area of CDSA.

Objectives

The primary objective is to collaborate to advance research and technology in cyber defence situational awareness as a step towards developing and refining related metrics, standards, visualizations and mission assurance practices. Ultimately, the results would influence NATO and the supporting nation’s development of CDSA techniques, technologies and procedures. CDSA requires the integration and merging of topics including continuous monitoring, dynamic risk assessment, resiliency, metrics, and visualization. The task group will bring together subject matter experts in these areas to enhance collaboration, coordination and understanding of the factors, techniques, requirements and issues surrounding cyber defence situational awareness.

Synergies and Complementarities

A Cyber Defence Situational Awareness (CDSA) capability is an emerging, urgent need across nations. NATO 20201 states that NATO must accelerate efforts to respond the danger of cyber-attacks by protecting its own communications and command systems, helping Allies to improve their ability to prevent and recover from attacks, and developing an array of cyber defence capabilities aimed at effective detection deterrence. Cyber defence situational awareness plays a vital part in this requirement. In addition, several nations are developing CDSA tools, techniques and technologies, and are at the point where they could leverage each others efforts through international collaboration. These factors indicate a timely

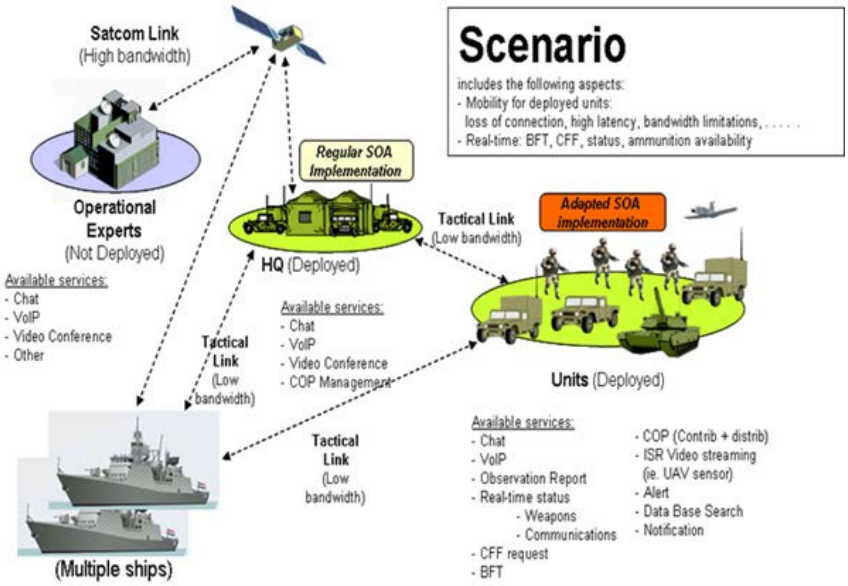
opportunity for international collaboration, thus it is recommended to create a new RTO Task Group (RTG) that addresses related research and technological issues in the area of CDSA.

SOA Recommendations for Disadvantaged Grids in the Tactical Domain

Reference Number	Activity Type	Activity Start Date	Activity End Date
IST-118	Task Group	01 Mar 2013	01 Dec 2016
Publication Reference (when published) https://www.sto.nato.int/publications/STO Technical Reports/STO-TR-IST-118			

Abstract

IST-118 provided concrete recommendations for the application at the tactical level of a subset of the Service Oriented Architecture (SOA) based HQ-level core services from the NATO C3 Taxonomy, based on systematic testing and evaluation. This can positively influence Training, Materiel and Interoperability



Technical Team Leader(s)

Mr. Peter-Paul MEILER , Netherlands , TNO-FEL

Author information

Barz, Christoph, M.Sc., DEU, Fraunhofer FKIE; Bloebaum, Trude, PhD., NOR, FFI; Alcaraz Calero, Jose-Maria, PhD, GBR, UWS; Chan, Kevin S., PhD, USA, ARL; Jansen, Norman, M.Sc., DEU, FKIE; Johnsen, Frank T., PhD, NOR, FFI; Manso, Marco, M.Sc., GBR, Rinicom Ltd; Meiler, Peter-Paul, M.Sc., NLD, TNO DSS; Owens, Ian, Lecturer, GBR, Cranfield University; Sliwa, Joanna, PhD, POL, MCI; Wang, Qi, PhD., GBR, UWS.

Background

The SOA paradigm is used by NATO to achieve interoperability at the (HQ) information infrastructure level. Currently applied technologies (e.g. Web services) were not designed for tactical networks. This frustrates interoperability and integration between tactical and HQ levels and is not cost-effective.

Objective(s)

IST-118 investigated the application of the core services to the tactical domain and provided recommendations for their deployment, based on experiences and experiments. These recommendations support the development of SOA at the tactical level, thus improving integration between tactical and HQ levels.

S&T Achievements

The recommendations enable application of existing SOA technology at the tactical level, which is a major advancement. IST-118 showed the advantage of cross-layer middleware, enabling adaptation of the services' communication behavior to the special needs of tactical networks and enabling parameterization of the network to fulfil the services' communication requirements. IST-118 also pursued video- and text-based services, contributing to their use on the battlefield. Technology demonstration events show that we reached TRL 4 (close to TRL 5). We produced 15 publications, 9 presentations and 4 workshops / demonstrations.

Synergies and Complementarities

By integrating knowledge and experience, IST-118 worked efficiently and effectively, creating synergy. Expertise, network emulator, radios, cross-layer middleware, communication services, et cetera were provided by different stakeholders. The work was done in synergy with other (national) ongoing projects and with NATO efforts such as NEC and FMN.

Exploitation and Impact

Making existing HQ-level SOA applicable at the tactical level improves integration between tactical and HQ levels. This increases defense capabilities and (**partly**) removes the need to develop and implement separate HQ and tactical versions of the same functionalities, thus reducing cost, both of required materiel, R&D and training.

Conclusion(s)

IST-118 generated NATO core services recommendations, enabling HQ- to tactical level integration and reducing costs. We achieved significant synergy for this quite large effort. Cooperation was achieved with other, (non-)NATO and (inter)national entities. We shared our gained knowledge and experience using demonstrations, workshops, publications and presentations.

Maturing and Validation of SILF Feasibility Study

Reference Number	Activity Type	Activity Start Date	Activity End Date
IST-119	Task Group	01 Jan 2013	01 Dec 2016
Publication Reference https://www.sto.nato.int/publications/STO Technical Reports/STO-TR-IST-119			

Technical Team Leader(s)

Prof. Mark LAST , Israel , Ben-Gurion University of the Negev

Abstract

Information exchange among coalition Command and Control (C2) systems in network-enabled environments requires ensuring that each recipient system understands and interprets messages exactly as the source system intended. Semantic Interoperability (SI) is defined as the ability of two or more computerized systems to exchange information for a specific task and have the meaning of that information accurately and automatically interpreted by the receiving system, in light of the task to be performed. The Semantic Interoperability Logical Framework (SILF) aims at meeting NATO's needs for semantically correct interoperability between C2 systems, as well as the need to adapt quickly to new missions and new combinations of coalition partners and systems. We have developed a detailed case study of applying the concept of SILF to a real-world military scenario, a Digital Close Air Support (DCAS) task, using semantic software tools. We have also explored the following key aspects of SILF vs. the legacy, ad-hoc approach to semantic interoperability: flexibility, quality, technical flexibility, technological maturity, extensibility, and cost. We show that the use of SILF is expected to provide an easier path for achieving semantic interoperability between C2 systems, and thus a more reliable, fast, and scalable support of a coalition mission

Background

Information superiority is one of the primary issues for NATO Network Enabled Capability (NNEC). It builds upon the idea of a common information space where all participating elements and organizations have the opportunity to supply and retrieve information according to their particular roles in the operation. Future C4I systems must be capable of accessing, 'understanding', and utilizing the information content within this space. Information must be conveyed in a secure and trusted way. This includes the idea that the meaning of the information as well as the purpose of the information exchange are understood and interpreted identically by all participating parties at all time. Unfortunately an identical understanding of exchanged information at human sender and receiver cannot be taken for granted.

Semantic Interoperability (SI) between information systems is not a goal that can be achieved through a one-shot action. Rather a process needs to be established and adaptively applied to each different situation. A harmonization of systems or a stable situation after a harmonization is an illusion due to technical innovations and system evolvements that cannot be synchronized globally and continuously.

The concept for a Logical Framework for Semantic Interoperability (SILF) has been developed and demonstrated in first implementations during the working phase of RTG IST-094 (2010-2012). SILF supports the mediation of information exchanged between heterogeneous C2 systems and guarantees that this information aligns to the semantic concepts of the target system and the context of the task. SILF covers NATO's needs for semantically correct interoperability among coalitions. Knowledge based mechanisms and policies are used to flexibly bridge semantic gaps.

Objectives

2.1. Maturing the concept

The prior RTG presented the architectural concepts of SILF, the mediation functionality as well as a concept for a centralized repository that provides the mediation resources. Two prototypes have been implemented and demonstrated by two organizations which provided the first proof of the SILF concept.

Now the concept of SILF must be further evolved, and the existing implementations have to be matured and extended to address a representative range of realistic use cases.

2.2. Evaluating the concept

The quality of the mediation functionality, the operational applicability and the cost efficiency must also be demonstrated and compared with other interoperability approaches (e.g. MIP, domain-based-approach, legacy way for interfaces, …).

The scientific evaluation will focus on systematic testing methods e.g. White box, Black box, Regression, Scalability, Security etc.

Also the application of standard knowledge representation languages (KRL) and referring tools and algorithms will be considered.

The operational evaluation will take under consideration time and resources needed for set-up of the SILF during design and runtime phases. Another relevant criteria is expected response time from SILF during runtime mediation phase.

Evaluation criteria are: acceptability, manageability, complexity, operating expenses, time needs, implementation and deployment effort, sustainability, maintainability, limitations etc.

Intelligence & Autonomy (Robotics)

Reference Number	Activity Type	Activity Start Date	Activity End Date
IST-127	Specialists Meeting	01 Oct 2014	01 Dec 2016
Publication Reference https://www.sto.nato.int/publications/STO Meeting Proceedings/STO-MP-IST-127			

Technical Team Leader(s)

Dr. Dirk SCHULZ , Germany , Fraunhofer FKIE

Abstract

The aim of this Specialists' Meeting on "Intelligence and Autonomy (Robotics)", held from 25-27 October 2016 in Wachtberg, Germany, was to bring together world-renowned researchers working on the different aspects of intelligent autonomous military robot systems, in order to discuss current trends and solutions with special emphasis on the military application domain. The main goal was to consolidate the NATO-wide knowledge in the field of intelligent and autonomous robots, identify the gap between civilian solutions and military needs and pursue the transfer of the most promising technologies and applications to the military domain. It was organized as a workshop consisting of several sessions with oral and poster presentations and plenty of time for discussions. Presentations covered areas such as: Environment perception; Robot motion planning; Task and mission planning; Autonomous navigation; Mobile manipulation; Knowledge representation; Multi-robot coordination; Soldier robot cooperation; Application scenarios; NEC aspects; C2 aspects; and Interoperability aspects.

Background

Over the last decade significant progress has been achieved in the autonomy of mobile robots and unmanned vehicles. Due to advances in 3D sensing, motion planning and navigation safe and reliable operation of autonomous military trucks will very soon be possible. Current research on semantic environment perception, mobile manipulation, and mission planning will enable mobile robots to perform task autonomously in the future that can only be carried out using tele-operation today, like e.g. EOD and reconnaissance missions with robots. It is also foreseeable that future autonomous systems will directly interact and cooperate with the soldiers in the field, e.g. for carrying equipment or during search and rescue missions. However, to achieve these goals the algorithms devised for the intelligence and autonomy of the systems have to address requirements specific to the military that are barely addressed by the main body of current research. Military robots have to operate in highly unstructured and hostile outdoor and off-road environments, raising the need to gain full situational awareness in 3D in real-time for autonomous navigation and task execution. They have to take military rules and tactics into account while performing their missions and they have to interact and cooperate with each other and the soldiers in the field. Therefore, specialized knowledge representations have to be developed that not only allow integrating the robots uncertain sensor information but also enable mission planning on a symbolic level. The representations also have to facilitate the direct interaction of robots and soldiers as well as the easy integration with modern command systems. To strengthen and speed-up the development of intelligent autonomous military robot systems a close collaboration between researchers of different NATO nations is necessary, especially in order to keep upcoming differing solutions compatible and interoperable.

Objectives

The aim of this specialist meeting is to bring together world-renowned researchers working on the different aspects of intelligent autonomous military robot systems, in order to discuss current trends and solutions with special emphasis on the military application domain.

Method for Architecture Definition and Evaluation in-line with NATO Architecture Framework

Reference Number	Activity Type	Activity Start Date	Activity End Date
IST-130	Specialist Team	01 Feb 2014	01 Jun 2016
Publication Reference (when published) https://www.sto.nato.int/publications/STO Meeting Proceedings/STO-MP-IST-130			

Abstract

The NATO Architecture Framework (NAF) is a mean to secure acquisition, engineering and usage of interoperable, dependable and reliable systems. The Science and Technology Organisation (STO) IST-130 study provides the version 4 of NAF (NAF V4) as a future STANAG, together with an architecture methodology.

Technical Team Leader(s)

Mr. Jean-Luc GARNIER , France , THALES

Author Information

Mr. Jean-Luc Garnier, Systems Engineering and Architecting Director, Thales, France.

Background

From the decision-maker and warfighter standpoint, there is a requirement to articulate operational needs; deliver affordable capabilities; and define smart defence scenarios and mission threads to meet current and future challenges in more complex and connected environments. Architectures are enablers to deliver alliance strategy that support operations, development, acquisition and delivery of capabilities, reuse, deployment and disposal. In particular, DOTMLPFI elements can be formalised through architectures and shared between organisations to achieve interoperability.

NAF is a coherent way to architect systems while taking account constraints such as budget, schedule, safety, security and human factors.

Military Relevance

Standard architecture methology will allow interconnection of the different networks used by NATO Nations, with faster communications and giving the Command and Control Centers broader situational awareness.

Objectives

The STO IST-130 has to provide the NAF V4 as a future STANAG, including a methodology.

This methodology extends traditional enterprise architecture approaches (i.e. more than just Information and Communication Technologies) to support and enhance capability that is potentially far more complex and costly for governments and Industry.

S&T Achievements

The methodology takes benefits of a strong new foundation including a complete ontology and a bi-dimensional structure of views.

It defines the main concepts for architecting, architecture principles and capabilities, a set of architecture activities at enterprise and project level including architecture landscape establishment, architecture vision, architecture description, architecture evaluation, migration planning, governance of architecture applications, architecture change decision and management of the architecture motivation.

Annexes include a complete example based on search and rescue, usage of NAF V4, definition of viewpoints and selection of views.

Synergies and Complementarities

NAF V4 is developed by IST-130, and coordinated by the Architecture Capability Team (ACaT). An experimentation phase involving NATO entities and National Ministries of Defence will provide feedbacks to improve this release.

From a scientific point of view, work of IST-130 is likely to be followed on by activities of Research Task Groups, namely on non-functional aspects of architectures. Feasibility of these activities needs to be analysed and discussed by participating members and NATO.

Exploitation and Impact

Under governance enforced by the NATO Enterprise Architecture Policy, NAF V4 aims to support the development of large complex programmes, like Future C2 and Federated Mission Networks (FMN) addressing concerns throughout their lifecycle.

This architecture framework is expected to be used by major domains which started engaging with NAF.

Conclusions

With the IST-130 work, the STO contributes significantly to the improvement of the architecture activities, coordinated by the ACaT.

A strong foundation and methodology embodied in NAF V4 makes it a credible candidate standard, in NATO and externally.

Experimentations and follow-on scientific studies can improve and reinforce NAF to be the indisputable architecture framework reference.

Security Challenges for Multi-domain Autonomous and Unmanned C4ISR Systems (e.g., UxVs, Robotic Systems Security)

Reference Number	Activity Type	Activity Start Date	Activity End Date
IST-136	Specialists Meeting	01 Jan 2015	01 Dec 2016
Publication Reference (when published) https://www.sto.nato.int/publications/STO Meeting Proceedings/STO-MP-IST-136			

Technical Team Leader(s)

Ir. Robert BEEN , Netherlands , CMRE

Background

A number of factors will influence unmanned program development in the future [US DoD Unmanned Systems Integrated Roadmap 2013-2038] and the number of UxVs will likely significantly increase due to the value gained with unmanned (vs. manned) vehicles and obvious costs savings of these smaller platforms. Current UxVs were mostly developed with C2 and sensor feeds as the primary objectives, and not necessarily considering (cyber) security implications of the vehicle/platform. In these kinds of embedded systems, the compromise (e.g., corrupted/compromised software, component reliability) has already happened and will pre-deterministically affect the mission. In addition, jamming communications can result in mission compromise, and the provable integrity of trusted components from supply sources is unknown and can subsequently cause undesirable secondary effects (e.g., fail-safe measures).

A cross-domain and multi-national perspective is emerging to detail mission capabilities unique to unmanned systems and to improve efficiency, effectiveness and survivability, and to reduce the burden on manpower at lower costs, while still meeting future operational requirements. For example, ACT is supporting a multi-year CMRE project entitled Persistent Autonomous Reconfigurable Capability (PARC) that will 1) scope aspects of this problem space, 2) focus on design and architectural aspects (in close collaboration with NIAG-157 and STANAG 4586 V3), and 3) will begin work on assessing critical component capabilities and capability gaps of 'system-of-systems' (SoS) architectures, with emphasis on aerial and maritime unmanned autonomous intelligence, surveillance and reconnaissance (ISR).

This activity aims at combining the strengths of the CMRE and the NATO STO Information Security and Technology (IST) panel, in order to start addressing the security requirements regarding unmanned multi-domain systems.

Objectives

The objective of this RSM is to utilize existing/emerging methods and techniques to evaluate the communication and cyber security risks, and ways to mitigate those risks associated with missions conducted by unmanned autonomous vehicles in all military domains. Of interest is the balance of resources used for security and cyber defence vs. mission realities such as communications constraints (e.g., bandwidth, processing, communication types and pathways) and the impact on C2 and sensor feeds back to the operator (e.g., flying UAVs and sensing targets).

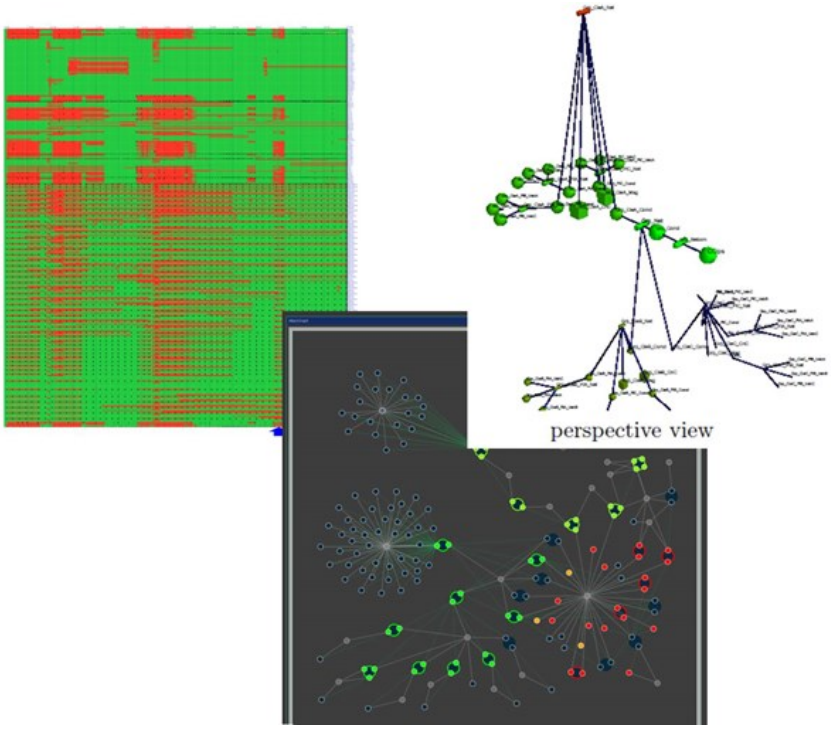
This 3-day RSM will bring together experts and practitioners from NATO member military agencies, along with industry leaders and academic visionaries to present and discuss the state-of-the-art developments and security challenges for multi-domain autonomous and unmanned C4ISR systems.

Exploitation and Impact

The report will contain recommendations regarding eventual follow-up activities such as an RTG, a technology demonstration, a symposium and or a standardization effort

Cyber Defence Situation Awareness

Reference Number	Activity Type	Activity Start Date	Activity End Date
IST-148	Symposium	01 Jan 2016	01 Dec 2016
Publication Reference https://www.sto.nato.int/publications/STO Meeting Proceedings/STO-MP-IST-148			



Cyber defense Situational awareness is mandatory for modern warfare

Technical Team Leader(s)

Mr. Douglas WIEMER , Canada , RHEA Group

Background

The aim of the Symposium on “Cyber Defence Situation Awareness” held from 3-4 October 2016 in Sofia, Bulgaria, was to bring together experts and practitioners from NATO member military agencies along with industry leaders and academic visionaries to present and discuss the state-of-the-art developments and hard challenges in cyber defence situational awareness, cyber security and the application and exploration of cyber security metrics, dynamic risk assessment, visualization and visual analytics in cyber defence. The meeting resulted in a raised awareness of our common efforts and the development of collaborative opportunities. The following theoretical and empirical topics were covered: Cyber defence; Cyber resiliency; Current challenges in cyber security; Cyber situational awareness; Security metrics; Dynamic risk assessment; Mission assurance; Continuous monitoring; Network analysis and monitoring; Visual analytics; Case studies, best practices and lessons learned; Evaluation of situation awareness effectiveness in CD; Cyber security models and architectures; and Security verification, evaluations and measurements

Background

NATO 2020 states - Responding to the rising danger of cyber-attacks: NATO must accelerate efforts to respond to the danger of cyber-attacks by protecting its own communications and command systems, helping Allies to improve their ability to prevent and recover from attacks, and developing an array of cyber defence capabilities aimed at effective detection and deterrence.

An important requirement for cyber defence is improved Cyber Defence Situation Awareness (CDSA) of the cyber environment. The IST-108 CDSA research task group (RTG) was established to investigate requirements and capabilities in this emerging and urgent need across nations. The CDSA Symposium is proposed as an opportunity to present current state-of-the-art projects and research activities in the domain of CDSA, including presentation of outcomes from the IST-108 CDSA RTG.

Military Relevance

Cyber as an Operational Domain not Mature, SA necessarily coupled to all disciplines. Understanding SA in cyber context needs addressing. Knowledge presentation in dynamic environment demands succinct representation

Objectives

Bring together experts and practitioners from NATO member military agencies along with industry leaders and academic visionaries to present and discuss the state-of-the-art developments and hard challenges in cyber defence situational awareness, cyber security and the application and exploration of cyber security metrics, dynamic risk assessment, visualization and visual analytics in cyber defence.

S&T Achievements

Issues Arising :

Legal framework, Impact on society, Uncertainty or missing data/knowledge, Detail to be presented to decision makers, Automated decision support, Leverage of extant software, Interface with commercial bodies, coalition partners etc.

Exploitation and Impact

The meeting will result in a raised awareness of our common efforts and the development of collaborative opportunities.

Conclusions

The Symposium dealt with Timely Appropriate Topics, General views were presented as well as Models based on Graph Theory and Examples derived from Visual Analytics, although no definitive solutions exist more topics have to be addressed : Information sharing, Cognitive aspects of SA, Active features and Automation.

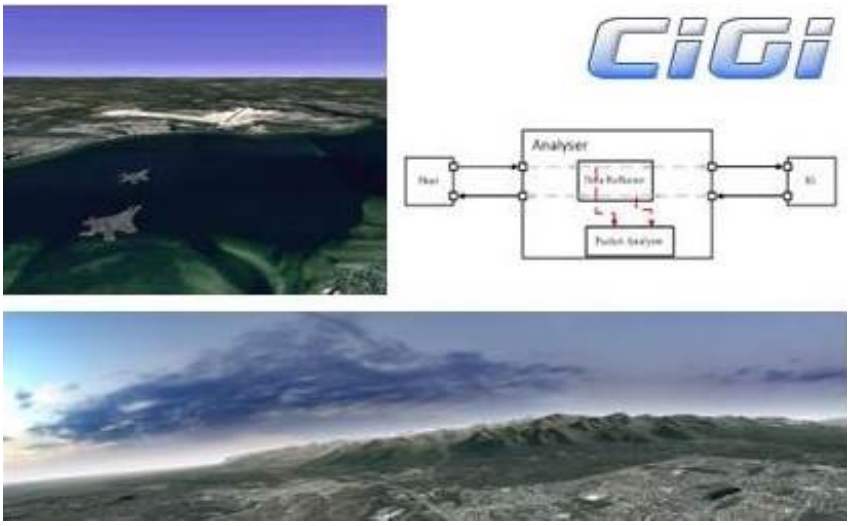
Development of Common Image Generator Interface (CIGI) v.4 Compliancy Testing Tools

Reference Number	Activity Type	Activity Start Date	Activity End Date
MSG-118	Task Group	01 Oct 2012	01 Oct 2016
Publication Reference https://www.sto.nato.int/publications/STO Technical Reports/STO-TR-MSG-118			

Hitting a Moving Target – CIGI Compliance

Abstract

Working to define tools and tests to determine the compliance of Image Generators (IG's) to CIGI open standard (v4) helping to reduce integration complexity and costs and ensure that IG's and host computers behave as expected.



Hitting a Moving Target – CIGI Compliance

Technical Team Leader(s)
Mr Grant BAILEY , United Kingdom , UK MoD

Background

Although versions of the Common Image Generator Interface (CIGI) standard have been around for some time, its construct and management allowed Image Generator (IG) manufacturers to tailor and adjust the standard in a bespoke manner. The result was often high integration costs when introducing an IG to a simulator's host computer either as part of a new build or an upgrade replacement.

In order to address and prevent such local modification of the standard, a first open version of CIGI (v4) was created and released under the auspices of SISO in Q4 2014. However, a gap now existed for the testing of compliance against CIGI v4 to reduce the risk of poor implementation, errors in the design of host software and lengthened integration times.

Objective(s)

Develop a suite of tools and tests that prove if an IG performs as expected across a declared scope.

Make the CIGI v4 Compliancy Tools freely available for all to use including IG manufacturers.

S&T Achievements

Compliance testing of IG's is not a simple task, not only is much of the CIGI specification optional but the visual output can be interpreted differently (e.g. a tank could be a high fidelity 3d model or an icon on a map).

The IG compliance testing tools are therefore being developed to allow vendors to create a testing subset that covers all the available CIGI features of that IG, this gives not only the compliance but also the (functional) feature set of an IG. It is also designed to protect the Intellectual Property Rights for the IG.

The host tool constantly analyses the host->IG CIGI traffic maintaining a mock system state and reports any detected anomalies immediately providing a useful debugging aid and saves time on reported IG bugs where the fault is 'erroneous data from the host'.

By using Python to develop tests it is also possible for vendors to develop tests for their own extensions to CIGI which will provide greater test coverage and therefore reliability.

Synergies and Complementarities

The CIGI v4 standard is maintained by SISO via its CIGI PSG (product support group).

MSG-118 reports specification issues directly to the PSG using the PCR (problem / change request) forms. Some members of MSG-118 are also members of the SISO CIGI PSG.

Exploitation and Impact

The Common Image Generator Interface (CIGI) is an interface designed to promote a standard way for a host device to communicate with an image generator (IG) in the simulation industry. A co-operative approach is justified by the fact that the selected CIGI compliance process will be distributed as part of national capabilities. The tools are also intended to be used by end users to ensure that features work as expected.

These tools not only will further IG compliance but also be a valuable debugging aid when developing systems based on CIGI. The compliance methods used could also be applied to other interfaces where the supported functionality and results are not easily testable.

Conclusion

The CIGI v4 compliance tools will provide a greater degree of stability in IG implementations of CIGI and therefore users can have greater confidence that a CIGI v4 based IG will act as expected.

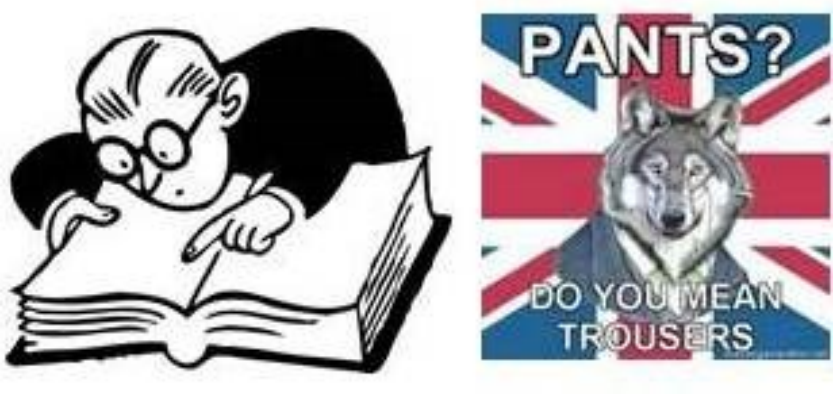
NATO M&S Glossary of Terms

Reference Number	Activity Type	Activity Start Date	Activity End Date
MSG-120	Task Group	15 Jan 2013	15 Jan 2016
Publication Reference (when published) https://www.sto.nato.int/publications/STO Technical Reports/STO-TR-MSG-120			

Clearing the Fog around variations in M&S Terminology

Abstract

Continuing work on the maintenance of the NATO M&S Standards Profile and other work in the M&S domain reveals that there is a clear lack of coherence and co-ordination with regards to the terminology used across NATO M&S, which in turn hampers interoperability and drives the need for a NATO M&S Glossary.



Do we really know what each other means when we converse regarding M&S Terminology?

Author information

Mr Grant Bailey, Defence Equipment & Support, UK MoD

BACKGROUND

NATO has long recognised the need for its Members and Partners to be able to communicate clearly and unambiguously, as misunderstandings in NATO's political and military activities can lead to inefficiency or more serious consequences. The NATO Terminology Programme (NTP) provides the framework for the terminology activities of all NATO's senior committees. The terminology approved through the NTP sets the standard for terminology used in NATO documents and communications of all kinds.

OBJECTIVE(S)

The initial intention of MSG-120 was that the NATO M&S Glossary of Terms would become a NATO Allied Standard product covered by a NATO Standardisation Agreement (STANAG). In 2015, two years after the group started their work, the NATO Standardisation Office (NSO) merged all unclassified NATO glossaries

from all specialist domains into a single database called “NATOTerm” – consequently, the M&S Glossary terms were fed into NATOTerm.

S&T ACHIEVEMENTS

The M&S terminology developed by MSG-120 has been incorporated into the NATOTerm database, which currently contains more than 10,000 definitions. NATOTerm is helping to promote a common understanding, and is available on the NSO website (https://nso.nato.int/nso/).

SYNERGIES AND COMPLEMENTARITIES

There are many other NATO non-M&S glossaries – it is important for the MSG-120 Glossary to adopt a similar ‘look and feel’, and it is beneficial to learn from the experience of others. Care must be taken to ensure that terms are not duplicated in other glossaries to avoid confusion, therefore content was restricted to fundamental M&S-specific terms only. Where necessary and appropriate, reference is made to definitions listed elsewhere, such as those held by recognized organisations
that develop standards.

EXPLOITATION AND IMPACT

The Glossary is expected to be used when any collaborative or joint M&S-related work is conducted, allowing each participant to understand the other. The M&S Standards Sub- Group (MS3) of the NMSG is the custodian of the M&S Terminology developed by MSG-120, and a process for adding new terms, proposing amendments, etc., has also been established.

CONCLUSIONS

The M&S terminology will provide a valuable aid to interoperability. It will allow individual Nations to communicate using a common language in the M&S domain through the use of specific technical terms and will be a living document that continues to evolve as technology develops and progresses.

Analytical Support to the Development and Experimentation of NLW Concepts of Operation and Employment

Reference Number	Activity Type	Activity Start Date	Activity End Date
SAS-094	Task Group	01 Jan 2012	01 Dec 2016
Publication Reference https://www.sto.nato.int/publications/STO Technical Reports/STO-TR-SAS-094			

'Deep Dive' to Identify Non-Lethal Options to Enhance Mission Accomplishment and Reduce Civilian Casualties (CIVCAS) and Collateral Damage

Abstract

ISAF recommended "a 'deep dive' to identify non-lethal capabilities and options", as initial data showed 80-90% reductions in undesired outcomes (own force casualties or CIVCAS) when NLW were available. SAS-094 answered effectively with analysis of the future security environment to identify challenges across likely missions, development of 15 case studies, integration of subject matter expert input through a Land-focused Concept Development Assessment Game, and a Maritime-focused tabletop wargame and assessment of two NATO Non-Lethal Technology Exercises.

Author Information

Colonel Rey Masinsin, USA Marine Corps, Director Joint Non-Lethal Weapons Directorate and Chairman, SAS-094

Radio Frequency (RF) Vehicle stopper being used in NNTEX-16L.

Background

NATO has had interest in non-lethal weapons (NLW) for over a decade. In 1999, the North Atlantic Council signed the NATO NLW policy, defining NLW as "weapons which are explicitly designed and developed to incapacitate or repel personnel, with a low probability of fatality or permanent injury, or to disable equipment, with minimal undesired damage or impact on the environment."

It also identified NLW as a "critical, additional capability needed in order to meet the demands of future operations." Recent and ongoing operations have confirmed this need and further increased NATO interest as indicated by the report for COMISAF[1] calling for a 'deep dive'.

[1] Joint and Coalition Operational Analysis (JCOA) Civilian Casualty Study Update for ISAF: Quick Impact Recommendations, Dec 2010.

Objective(s)

SAS-094's objectives were to support the development and experimentation of NATO and national NLW concepts of operations, employment and use.

S&T Achievements

SAS-094 organized and undertook the following activities:

- Future security environment assessment, resulting in the development and analysis of a set of representative scenarios;
- Examination of past operational experience, lessons learned, and existing concepts and doctrine, leading to 15 case studies;
- A Concept Development Assessment Game and a tabletop wargame to gain operational and technical subject matter expert judgments;
- Integration of quantitative and qualitative results from national utility exercises and assessments;

Assessment and analysis support for two NATO Non-lethal Technology Exercises (NNTEX): one Maritime and one Land.

Synergies and Complementarities

SAS-094 integrated national efforts with numerous NATO and non-NATO efforts to achieve their objectives: the two NNTEX exercises sponsored by NATO's Defence Against Terrorism Programme; NATO Army Armaments Group; European Defence Agency and European Union projects; and several NLW symposia.

Exploitation and Impact

SAS-094's research provides the Alliance with data-based analysis to support national NLW concept development and experimentation and allows for leveraging opportunities for NLW usage in many other areas (e.g., with Ground Based Air Defence on Counter-small Unmanned Aerial Systems opportunities). Their analysis identified six areas where NLW contributions need to be integrated into NATO and national concepts.

Conclusion(s)

SAS-094's innovative analysis allows for effective implementation of NLW within National operational concepts and doctrine which will increase the overall operational effectiveness of NATO.

Robots Underpinning Future NATO Operations

Reference Number	Activity Type	Activity Start Date	Activity End Date
SAS-097	Task Group	01 Apr 2012	07 Mar 2017
Publication Reference https://www.sto.nato.int/publications/STO Technical Reports/STO-TR-SAS-097			

Abstract

Due to rapid proliferation of robotic technologies and artificial intelligence into almost all fields of our lives, SAS-097 works to bridge the existing gap between the cutting edge of technology and military operational needs. Due to experience with deploying human-robot teams to real Urban Search & Rescue missions, the research provides experimental support for robotic concept development and testing.

Author Information

By Michal Reinštein, Ph.D., Czech Republic, Czech Technical University in Prague, co-chair of SAS-097

Urban Search & Rescue robots deployed to earthquake-hit area of Mirandola, Italy, 2012 as part of EU FP-7 project NIFTi and TRADR (top-left, bottom); Multipurpose UGV platform TAROS (top-right).

Background

In the very near future, robotic systems will redefine the way modern warfare will be conducted and may render existing capabilities obsolete. Due to experience with deploying real human-robot teams, the task group addresses this critical issue in SAS-097.

Objective(s)

The main objectives of SAS-097 were as follows: to analyse the gap between operational requirements and technical possibilities; to bridge the gap between the cutting edge of technology and military operational needs; to provide experimental support for robotics concept development and testing; to organize NATO supported events – workshops or symposia; to create and supervise bidirectional working links to the European Commission R&D activities in dual-use of robotics; to open possibilities for the new robotics research motivated by military needs and funded by third parties.

S&T Achievements

SAS-097 helped to integrate several CZE universities to work collaboratively on robotic systems and with the CZE industry. Due to SAS-097, the *Centre for Advanced Field Robotics* was established to cooperate both nationally and internationally with CMRE, TARDEC (Tank Automotive Research and Development Centre), and several NATO Centers of Excellence (CoE), especially JAPCC, EOD, C-IED, M&S, and CMRE. In cooperation with NATO Modeling & Simulation CoE, two international workshops MESAS'14 and MESAS'15 were held in Rome, ITA and Prague, CZE, respectively. Robotic prototypes were developed - one of them, the TAROS (Tactical Robotic System), was presented during several international events.

Synergies and Complementarities

SAS-097 consolidated links with the NATO ACT Concept Development and Experimentation program. The experiment of *Tactical Autonomous Reconnaissance* was incorporated into the ACT CD&E POW 2016 and approved to help test the NATO future concept associated with the development of operational (counter) autonomous weapon systems in the next years. The task group supported the Multinational Capability Development Campaign (MCDC) 2013-14 lead by USA and aimed at autonomous systems, and within a new campaign, MCDC 2015-16 SAS-097 helps to elaborate Counter Unmanned Autonomous Systems effort.

Exploitation and Impact

Beside exploitation through the MCDC campaign and the NATO ACT CD&E program, the group focused efforts on bringing together academia, military, and industry aiming for dual use of robotics under the umbrella of Centre for Advanced Field Robotics and also by being an active member of the euRobotics AISBL. They applied the results of the research in the field of *human-robot teaming*, where they aimed to achieve the *accepted autonomy of robots*.

Conclusions

The final report addresses the future direction of robotics with respect to four themes of the 2014 NATO STB Symposium on Autonomous Systems: control, sensors, platforms, and systems. For each theme we analysed the conceptual, technological, and operational aspects. In the final, SAS-097 was active not only in the field of technology, but also addressed the legal, human, ethical, and operational issues in robotics.

"*Beside exploitation through the MCDC campaign and the NATO ACT CD&E program, the group focused their efforts on bringing together academia, military, and industry aiming for dual use of robotics*."

Methods to Support Decision Making for Joint Fires

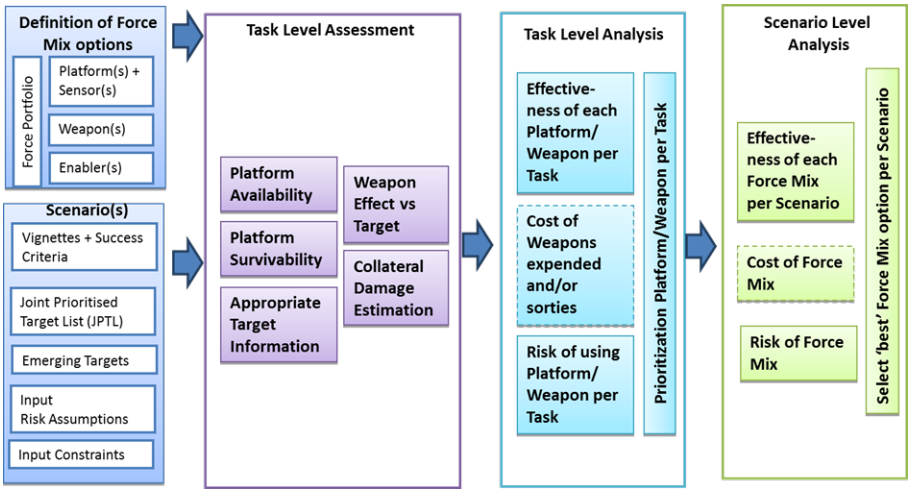
Reference Number	Activity Type	Activity Start Date	Activity End Date
SAS-108	Task Group	01 May 2014	27 Sep 2016
Publication Reference https://www.sto.nato.int/publications/STO Technical Reports/STO-TR-SAS-108			

Abstract

Informed decisions for Joint Fires must be made during force planning, system procurement, pre-deployment planning and in-theatre-operations. To do this requires both a trade-off between effectiveness and operational risks and a trade-off between effectiveness and cost. SAS-108's results provide a framework and common set of definitions to help nations support decision making and develop strategies regarding Joint Fires.

Author information

Marcel Smit, The Netherlands, TNO, Strategic Business Analysis



Framework developed by SAS-108 to weigh risks, cost and effects of Joint Fires

Background

Due to increasing relevance of Joint Fires, there is a need to identify the most cost and risk effective combination of weapons, munitions and platforms available (Joint Fires) in a variety of scenarios. Many nations are interested in Joint Fires and are developing initiatives in these areas.

Objective(s)

SAS-108 sought to develop methods to quantify and balance the operational risks, effectiveness and costs of Joint Fires for given scenarios.

S&T Achievements

To help find the most cost-effective force mix while at the same time minimizing risk, the activity developed a new framework which includes definitions, scope and boundaries, investigated current methods and models and determined requirements for this analytical tool. This new framework utilizes a common set of definitions, methods and models on effectiveness, costs and risk quantification drawn from the participating nations. Gaps in these models related to the framework have been identified.

Using a number of case studies, the framework proved to be appropriate for different types of Joint Fires decision making. It can also be used with a range of analytical techniques from judgmental methods to simulation.

Synergies and Complementarities

SAS-108 united members from other NATO agencies and the five participating Nations. They surveyed current NCIA models (mainly on strategic defence planning). The group also contained members from the NAAG Indirect Capability Group Indirect Fire Subgroup 2 which has a program to develop software focusing on weapon system effectiveness, the SG/2 Shareable Software Suite (S4). The software part of S4 was also considered by SAS-108.

Exploitation and Impact

This framework could be used to support national force mix planning and acquisition, pre-deployment and in-theatre planning, and elements of the Joint Targeting Cycle the NATO Defence Planning Process. Joint Force and Component Commands may also wish to consider how the framework can be used to support decision making for joint fires. The framework should be tested for 'fitness of purpose' before application to provide familiarity with the approach and determine appropriateness.

Conclusions

The framework developed by SAS-108 will enable informed decision making for Joint Fires during force planning, procurement programs, pre-deployment planning and in-theatre-operations. It will also provide input for the NATO Defence Planning Process. Moreover, it provides common definitions related to Joint Fires to enable a better understanding of the Joint Fires context.

"There is a need to identify the most cost and risk effective joint combination of weapons, munitions and platforms available."

Future Defence Budget Constraints: Challenges and Opportunities

Reference Number	Activity Type	Activity Start Date	Activity End Date
SAS-113	Specialist Team	01 Jan 2015	01 Feb 2016
Publication Reference https://www.sto.nato.int/publications/STO Technical Reports/STO-TR-SAS-113			

Abstract

SAS-113 identified and evaluated defence resource management practices implemented by member nations facing financial stress and developed a common analytical framework to promote better use of defence resources. The study found that most practices focused on reactive resourcing strategies versus proactive planning and also discovered that there is no generally accepted NATO-wide analytical framework to assist nations with identifying, organizing, and sharing defence resource management practices.

Author Information

Dr. Todd Calhoun, USA, Director, Program Analysis and Evaluation, Programs and Resources Department, Headquarters, USA Marine Corps.

"… this is not just about how much money we spend on defence. It's also about what we spend that money on. And how we spend it." Secretary Jens Stoltenberg (Keynote address at the 60th Plenary Session of the NATO Parliamentary – 2014).

Background

In the years following the Great Recession, average defence spending by NATO countries, as a percentage of GDP, declined from 1.72% in 2009 to 1.46% in 2013. This decline and the likelihood of continued fiscal austerity increases the need for NATO to respond, including the widespread application of effective and efficient defence resource management practices.

Objectives

1) Identify and evaluate resource management strategies implemented by member countries to mitigate the negative impacts of reduced defence spending.

2) Identify valuable practices in defence resource management when responding to budget constraints which have broad applicability within the Alliance.

S&T Achievements

SAS-113 developed an analytical framework which organized "exemplar" country defence resource management practices. The framework is based on four key components: 1) Rationalize Capabilities and Programs; 2) Improve Transparency and Accountability of the Resource Management Process; 3) Generate Operating Efficiencies, and 4) Promote Assessment Mechanisms. These components closely correspond to the logic of Planning, Programming, Budgeting, Execution, and Assessment reflected in financial management systems used within the Alliance. The framework provided a common foundation to organize country practices and allowed SAS-113 to assess where countries focus their efforts when responding to defence resource management challenges.

Synergies and Complementarities

SAS-113's recommendation to develop a collaborative process to identify and share defence resource management practices aligns with other NATO initiatives, such as Smart Defence, Connected Forces Initiative and Framework Nations Concept, designed to mitigate budgetary risks. These efforts encourage multinational cooperation; interoperability; and the development of defence capabilities through prioritization, specialization, and cooperation.

Exploitation and Impact

Study results will be presented to NATO boards and committees, such as: the Defence Policy and Planning Committee, the Conference of National Armaments Directors and the Resource Policy and Planning Board, for review and future action. Target audiences are budgeting authorities within member country defence ministries that are challenged with maximizing the value of scarce resources.

Conclusion(s)

Currently, there is no generally accepted NATO-wide analytical framework to assist member nations with identifying, organizing, and sharing defence resource management practices. The adoption of SAS-113's proposed analytical framework will provide a common foundation to help improve defence resource management.

*SAS-113's framework provides a common foundation to help improve defense resource management***.**

SMART Cooperation on Operation Analysis Simulation Models

Reference Number	Activity Type	Activity Start Date	Activity End Date
SAS-115	Workshop	01 Jan 2015	01 Jan 2016
Publication Reference https://www.sto.nato.int/publications/STO Meeting Proceedings/STO-MP-SAS-115			

Abstract

The intent of this workshop was to identify how to increase cooperation in OA simulation models with the benefit of cost reduction, improved efficiency and leveraging good practice on sharing models.

Author Information

By Peter Rindstål, Senior Analyst, Sweden, FOI, Div. of Defence Analysis

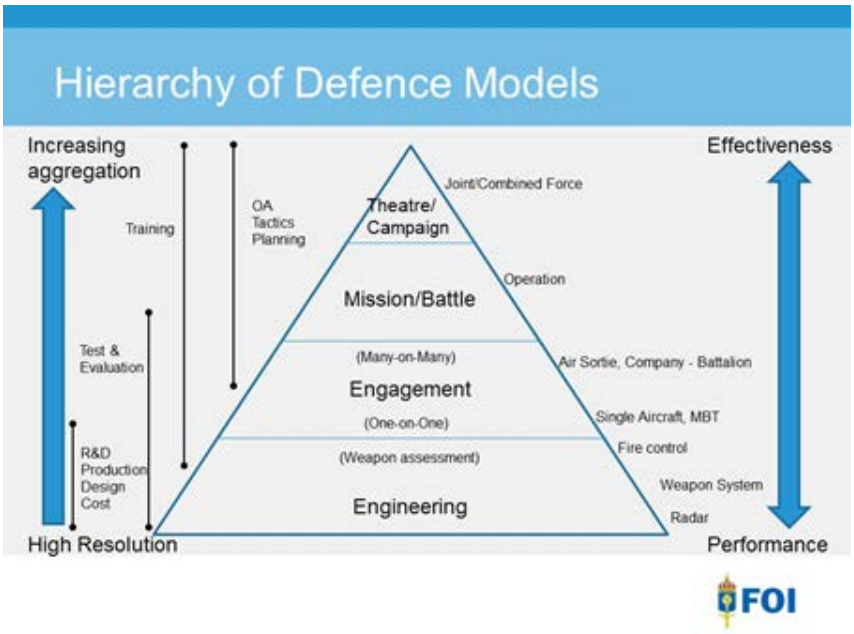


Illustration of the scope of OA simulation models that could be shared with smart cooperation.

Background

Due to budget cuts in NATO (nations) S&T it would be worthwhile to examine the possibilities of SMART cooperation in operation analysis (OA) simulation models. We know that now and in the past, good examples of co-development, sharing and exchanging of OA simulation models do exist. Nevertheless, a lot of potential interesting opportunities to exploit cooperation in OA simulation models have been failed, due to all kinds of reasons.

Objectives

The workshop aimed at identifying current barriers that restrict sharing, best practices and lessons learned from past experience in sharing models, and provide recommendations on how to create and manage a NATO model portfolio.

S&T Achievements

The workshop covered the following topics:

- Identification of barriers that restrict model sharing.
- Identification of solutions that can minimize or remove these barriers.
- Revision of the TTCP "Guidance on good practice for sharing models", identify content that should be changed or added to address the NATO perspective.
- Identify recommendations on how to create and manage a NATO model portfolio.

Synergies and Complementarities

For this study, the scope was limited to cooperation in the field of OA simulation models. Those could be defined as computer models that can perform constructive simulation (many runs, no human-in-the-loop) for analysis of joint, maritime, air and/or land operations. This focus was chosen since these models normally have high development and maintenance costs and therefore need to be used for a long time to be cost-effective.

A base for this work was The Technical Cooperation Program "Guidance on good practice for sharing models". TR-JSA-TP3-7-2000. Version 3, Oct 2002 and its revised version from 2014.

Exploitation and Impact

The workshop has provided a list of challenges for developing and sharing OA-simulations models (tools, databases, models within tools, procedures …) and ideas on actions on how to overcome those challenges.

The revision of TTCP document proved that it was a solid base with sound guidance for cooperation in OA simulation models and with a few minor additions would also satisfy the SAS-115 objectives.

The workshop also proposed a Model Catalogue Database Structure in order to create and manage a NATO model portfolio. This structure includes requirements on the amount and type of information needed.

Conclusions

The workshop identified current barriers that restrict the sharing of models and provided a range of solutions to minimize or remove those barriers. The participants also presented lessons learned from past experience with respect to model exchange and/or collaborative development and use. Finally the workshop discussed and came up with recommendations on how to create and manage a NATO model portfolio containing up-to-date information on potentially sharable OA simulation models.

Hybrid Warfare: Ukraine Case Study

Reference Number	Activity Type	Activity Start Date	Activity End Date
SAS-121	Specialist Team	20 Nov 2015	26 Aug 2016
Publication Reference https://www.sto.nato.int/publications/STO Technical Reports/STO-TR-SAS-121			

Hybrid warfare methods have created challenges for Ukraine and NATO.

Abstract

Analysis of hybrid warfare (HW) and Russia's actions in Ukraine has led to a significant body of material, almost none of which accounts for the first-hand experiences and expertise of Ukrainian military and government personnel. SAS-121 examines the war in Ukraine as a case study, and specifically focuses on the capture and analysis of relevant strategic, operational, and tactical level events as experienced by Ukrainian personnel, to build upon the existing definition of HW.

Author information

Neil Chuka (Chair), Defence Research and Development Canada – Centre for Operational Research and Analysis, Ottawa, Canada.

The annexation of Crimea and the war in Eastern Ukraine has seen Russia apply a mix of traditional and novel means to further its policy goals.

Background

Russia has applied a mix of traditional and novel means to further its policy goals in its border regions, particularly in Ukraine, as evidenced by the annexation of Crimea and the war in Eastern Ukraine.

Colloquially known as hybrid warfare (HW), these methods created specific challenges for Ukraine and, more broadly, for NATO. Over the past several years, analysis of HW and Russia's actions in Ukraine has led to a significant body of material, most of which does not account for the first-hand experiences and expertise of the Ukrainians.

Objective(s)

The objective of SAS-121 was to build on the existing definition of hybrid warfare by examining the war in Ukraine as a case study to provide a greater understanding of HW to further inform Ukrainian and NATO decision makers.

S&T Achievements

SAS-121 enhanced existing definitions of HW by examining the war in Ukraine as a case study, specifically focusing on the capture and analysis of relevant strategic, operational, and tactical level events as experienced by Ukrainian personnel. Additionally, this is the first strategic analysis partnership between Ukraine and NATO, which introduced additional leadership challenges in generating trust and participative and consultative engagement with Ukrainian partners.

Synergies and Complementarities

SAS-121 provided the venue for NATO and partner nations to work directly with Ukraine in a joint effort to learn about hybrid warfare through the lens of those that experienced it first-hand. This work would not have been possible without the strong support and participation of Ukraine.

Exploitation and Impact

The results provide valuable insights and have informed the Ukraine-NATO Defence Investment Group to draft the "The NATO-Ukranian Platform for Identifying Key Lessons-Learned from Hybrid Warfare" under the NATO-Ukraine Joint Working Group on Defence Reform at the NATO Warsaw Summit. SAS-121 also increased the practical ties between NATO and Ukraine.

Conclusion(s)

SAS-121 provided a unique contribution to the hybrid warfare literature, and when cautiously employed in concert with other analysis, generates a greater understanding of hybrid warfare in support of Ukrainian and NATO decision makers. It has also increased the practical ties between NATO and Ukraine.

EO and IR-Countermeasures against Anti-ship Missiles

Reference Number	Activity Type	Activity Start Date	Activity End Date
SCI-224	Task Group	01 Apr 2012	01 Apr 2016
Publication Reference (when published) https://www.sto.nato.int/publications/STO Technical Reports/STO-TR-SCI-224			

Technical Team Leader(s)

Mr Carlos MARAVIGLIA , United States , Naval Reseach Laboratory

Background

The defense against anti-ship missiles is difficult. In general a layered defense is used after the missile is detected at long distance. The outer layer will typically use interception missiles while the final active defense is taken care of by a close-in-weapon-system (CIWS). The layer in between involves the use of soft-kill, either active ECM or passive decoys (chaff and decoys against respectively RF and IR guidance systems). In some cases soft-kill is the preferred option for ship self-defense. For optimum deployment of these decoys, timing and positioning is critical. With the advent of IR and visible band imaging seekers this has become even worse because the fact that these type of seekers can distinguish between the target ship and potential countermeasure decoys. Therefore, tools for the evaluation of the effectiveness of decoy deployment strategies are required.

Anti-ship seeker simulators for the evaluation of RF decoy countermeasures already exist, facilities for the evaluation of infrared countermeasure deployment strategies for ships, however, are lacking. At their Fall 2008 meeting, AC/141 MCG8 on Electronic Warfare recommended the RTA/SCI Panel to set up a Task Group to investigate the development of countermeasure evaluation tools for future use in MCG/8 Trials. In the long term this can also provide inputs for future updates of the NASMDEF package with an IR capability.

Objectives

The main purpose of the proposed Task Group will be to analyze the effectiveness of different IR and visible imaging and non-imaging anti-ship missile seeker algorithms against existing and future passive and active countermeasures. Symmetric and asymmetric threats will be analyzed. Deficits in countermeasure possibilities against such threats will be studied and reported. This group's results should identify common simulation and analytical methods.

The activities of the Task Group will result in a final report on the options for countermeasures and countermeasure concepts against IR and visible band Anti-Ship Missiles. This will include:

-A listing of national simulation tools and their availability to participating Nations

-Summary of the results of the simulation studies

-Recommendations of future toolsets for countermeasure evaluation based on available sets.

-Results of conducted surveys

Deliver technical recommendations on visible band and infrared guided ASMD issues to NATO groups in particular MCG/8.

Present proposals for contributions to yearly MCG/8 trials including resources.

Directed Infrared Countermeasure (DIRCM) State of the Art and Flight Testing Methodology

Reference Number	Activity Type	Activity Start Date	Activity End Date
SCI-237	Task Group	01 Apr 2012	01 Apr 2016
Publication Reference (when published) https://www.sto.nato.int/publications/STO Technical Reports/STO-TR-SCI-237			

Abstract

IR guided missiles and particularly Man-Portable Air Defense Systems (MANPADS) represent a significant threat for NATO aircraft. Moreover, MANPAD seekers are using more and more sophisticated infrared countermeasures (IRCM) which require the self-protection systems, currently based on flare dispensers, to be improved and or to be replaced by new technologies. The laser-based Directed Infrared Counter Measure (DIRCM) system is seen as offering a potential solution. The adjunction of these new DIRCM systems on NATO aircraft asks many questions including the effectiveness of DIRCM equipment against current and future generations of IR missile seekers (i.e. rosette scan and imaging seekers). In the past, the DIRCM technology has been limited to systems developed by companies in the United States. These U.S. built systems were initially limited to transport aircraft, but more recently have been adapted to rotary winged aircraft. Knowledge of these systems has been limited due to restrictions placed on nations when leasing aircraft with DIRCM systems installed. These aircraft, leased by Canada, Great Britain and Australia, are being used daily to transport U.S. troops in Afghanistan. DIRCM equipped aircraft have also been purchased for use by NATO in the AWACS and transport roles. The obvious question is how adequate is the protection the current DIRCM systems provide to coalition troops as they are transported in hostile environments? On 10-11 February 2011, the SCI-237 ET on DIRCM State of the Art and Flight Testing Methodology had its first meeting in Paris (France) with participants from CA, FR, IT, NO, NL, SP, TU, US and the NATO International Staff. A second meeting was held at NATO Headquarters in Brussels, BE on 23-24 June 2011 where representatives from Denmark and the NATO Force Command were also in attendance. At each meeting, participants highlighted the need to have a better understanding of the fielded DIRCM systems including their reliability, maintenance requirements and effectiveness. They also expressed interest in finding other alternatives to those systems currently being built within the United States. Team members held a strong desire to identify other potential DIRCM technologies currently in the infancy stage and develop a standardized test methodology which could be used to conduct side by side comparisons of multiple systems. The nations that intend to participate in this follow-on Technical Group study after the SCI-237 ET are Canada, Denmark, France, Italy, Netherlands, Norway, Spain, Sweden, and the United States. All NATO nations, as well as Australia, and New Zealand were invited to be involved in the effort. The study would benefit greatly if subject matter experts from Great Britain and Germany were allowed to bring their knowledge of the DIRCM technologies into the group.

Technical Team Leader(s)

Mr Tommy SANDERS , United States , Naval Surface Warfare Center, Crane Division

Background

IR guided missiles and particularly Man-Portable Air Defense Systems (MANPADS) represent a significant threat for NATO aircraft. Moreover, MANPAD seekers are using more and more sophisticated infrared countermeasures (IRCM) which require the self-protection systems, currently based on flare dispensers, to be improved and or to be replaced by new technologies. The laser-based Directed Infrared Counter Measure (DIRCM) system is seen as offering a potential solution. The adjunction of these new DIRCM

systems on NATO aircraft asks many questions including the effectiveness of DIRCM equipment against current and future generations of IR missile seeker (i.e. rosette scan and imaging seekers). In line with NAFAG action 92/8, the NAFAG Aerospace Capability Group 3/Sub-group 2 on EW Self Protection Measures for Joint Services Airborne Assets at its Spring 2009 meeting approved sending a request to study DIRCM technologies to the RTO. On 15 October 2009 the RTO received a formal study request on State of the art of DIRCM and methodology for testing a DIRCM system on NATO military aircraft. A standard method for assessing such systems on aircraft is also critical for NATO. This study supports DAT Item 1 on Reducing the Vulnerability of Large-body Aircraft to MANPADS.

Objectives

The objectives of the study are as follows:

1)Conduct a World Market survey on DIRCM

2)Summarize Operational Experience of the DIRCM systems

3)Identify future DIRCM requirements for NATO aircraft

4)Develop a common assessment methodology for testing a DIRCM system in flight

The deliverables are expected to be:

1) A technical report which includes a world market survey on DIRCM activities, operational experience with U.S. systems and recommended future DIRCM requirements on NATO aircraft. The report is expected to be classified as NATO Secret due to the technical content and recommendations for NATO future requirements section which will be the basis for updating the NATO Staff Requirements (NSR) document.

Synergies and Complementarities

The laser-based DIRCM technologies are now being advanced by other NATO nations. Indra in Spain and Elettronica in Italy have done extensive work in this area and have successfully conducted lab and ground field tests with their systems. While still not operational, current plans are to conduct a flight demonstration of the Spanish system at Trial EMBOW in September 2011, a biennial test event coordinated by Sub Group 2 on Aircraft Survivability of the NATO Air Capabilities Group 3. Efforts of the study will be used to update the NATO Staff Requirements (NSR) document on DIRCM. This document serves as a guideline for identifying future DIRCM requirements for NATO aircraft.

Exploitation and Impact

1) A technical report which includes a world market survey on DIRCM activities, operational experience with U.S. systems and recommended future DIRCM requirements on NATO aircraft. The report is expected to be classified as NATO Secret due to the technical content and recommendations for NATO future requirements section which will be the basis for updating the NATO Staff Requirements (NSR) document.

AG-300 V.30 High Altitude Rotary Wing Flight Testing

Reference Number	Activity Type	Activity Start Date	Activity End Date
SCI-255	Agardograph	01 Apr 2012	01 Apr 2016
Publication Reference https://www.sto.nato.int/publications/STO Technical Reports/STO-AG-300-V30			

Technical Team Leader(s)

Dr John O´CONNOR , United States , US Naval Test Pilot School

Background

Much of rotary wing (RW) flight testing takes place at test centers located at or near sea level with limited high altitude evaluation. What high altitude testing is performed is largely done on small detachments and within a limited time frame. Helicopter performance has continually improved and NATO commitments expanded to increase operational use of RW assets in high altitude environments such as found in Afghanistan.

Objectives

This AgardOgraph will document various aspects of high altitude RW flight testing and highlight test considerations and hazards associated with RW operations above 10,000 feet.

Route Threat Detection and Clearance Technologies

Reference Number	Activity Type	Activity Start Date	Activity End Date
SCI-256	Task Group	01 Apr 2012	01 Apr 2016
Publication Reference https://www.sto.nato.int/publications/STO Technical Reports/STO-TR-SCI-256-Part-III			

Abstract

The activity assessed the potential and limitations of new and emerging technologies for detecting route threats, such as landmines and Improvised Explosive Devices (IEDs). The Task Group investigations were based on setting up, conducting, analysing and reporting demonstrations, tests and trials of systems based on these technologies.

Author information

Dr. Arnold Schoolderman, The Netherlands, TNO

Background

The use of IEDs and other on- and off-route threats have become so wide spread that they have become a global and enduring issue. In order to counter these threats, government laboratories, universities and companies worldwide are developing new countermeasures. These countermeasures explore different aspects of defeating the threat, such as detection, conformation and neutralization, and are based on many different technologies. For nations participating in NATO operations and encountering route threats, it is important to obtain information on the expected performance of the countermeasures and their suitability for deployment in military operations.

Objective(s)

The objective of the Task Group was to investigate the potential and limitations of new and emerging techniques for countering on- and off-route threats (landmines, IEDs, emplaced explosive hazards).

S&T Achievements

SCI-256 conducted three tests to evaluate current and future system capabilities. The first test in the Netherlands evaluated the use of experimental (stereo) camera and LIDAR systems on ground vehicle-based changed detection technology. The second test in the Czech Republic examined both COTS hand-held detectors and developmental vehicle-mounted systems on non-linear junction detection. Finally, SCI-256 demonstrated methods and technologies for inspecting culverts in the presence of IEDs at a test site in Sweden.

Synergies and Complementarities

This task group represented defence R&D from 12 NATO and Partner nations. It developed an active network and contributed to several bi- and trilateral cooperative agreements. In addition, both the NATO Counter-IED Centre of Excellence and the Military Engineering Centre of Excellence have shown interest in the work.

Exploitation and Impact

The final product of the Task Group includes information on the benefits and limitations of several new and emerging technologies for the detection of route threats. It also provides recommendations on their suitability as detection tools in mounted and dismounted route clearance operations. Ultimately, this work

can be used by defence research establishments to further enhance their R&D research planning and decision-making process.

Conclusion(s)

The collaborative efforts of 12 nations in 3 cooperative tests expanded the understanding of current and future route threat identification technologies. As a result, essential information is now available to national R&D planners developing technology to counter on and off route threats to NATO forces.

Pull Quote

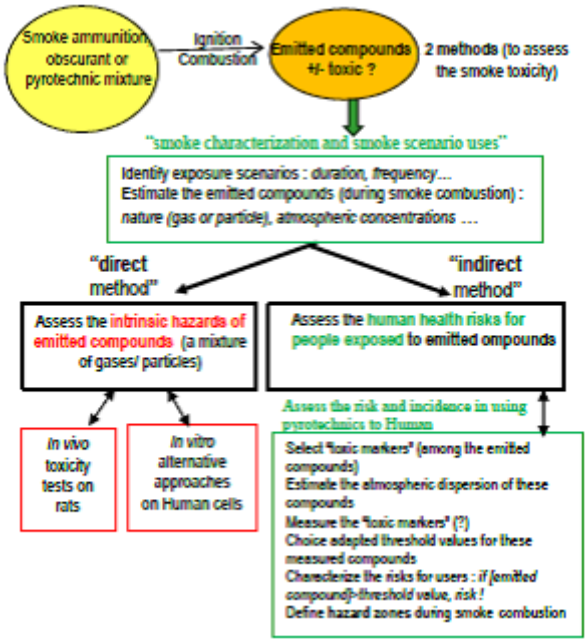
The use of improvised explosive devices has become so wide spread that they have become a global and enduring threat.

Caption

Experimental ground vehicle-based change detection systems (top) and non-linear junction detectors (lower left). A culvert (lower right) on the test site for the culvert inspection methods and technologies demonstration in Sweden.

Guidelines for Toxicity Testing of Smokes, Obscurants, and Pyrotechnic Mixtures

Reference Number	Activity Type	Activity Start Date	Activity End Date
SCI-273	Task Group	01 Dec 2013	01 Dec 2016
Publication Reference https://www.sto.nato.int/publications/STO Technical Reports/STO-TR-SCI-273			



SCI-273 proposition to assess the smoke toxicity

Abstract

The NATO task group SCI-RTG-273 was tasked to evaluate the potential interest of incorporating new toxicological testing methodologies into a set of guidelines to assess the effects on human health of military smoke and obscurant materials with the aim of minimizing or eliminating the use of animal models in the research. The adoption of a "tiered approach" to the toxicological evaluation of new smokes and obscurants has been recommended. The proposed approach consists of three tiers: Tier I is a non-experimental approach towards risk assessment through computer modelling and analysis, Tier II is a testing approach utilizing cell culture assays and chemical characterization, and Tier III involves traditional toxicology testing in animal models. Put together, these studies will provide a toxicological database that will be sufficient to assess the Health Impact Assessment of exposure to new smokes and obscurant materials. In addition, it is recommended that the exposed personnel are monitored for potential adverse health effects associated with exposure to the materials. An epidemiological questionnaire has been proposed to fill by military personnel, trainers and veterans.

Background

At the forefront of new detectors, one of the counter-surveillance means is the decoy by use of multispectral smokes or obscurants. This constitutes an important element of protection for human and materials. But, in the current context of protection of the Human and the Environment, it is actually

necessary to better know products emitted by these pyrotechnic compositions and obscurants during their use, and to define a methodology of evaluation of risks, to be able to classify them and determine precautions of use of these multiphase miscellaneous according to the context (operational, evaluation and expertise).

Objective(s)

The objectives of the SCI-273 Specialists' Meeting "NATO are to investigate the feasibility to develop new guidelines to measure pyrotechnic hazards, to assess the risk and incidence to humans when using pyrotechnics and on a larger scale, on the environment. The SCI -273 will work to provide advice and guidance on pyrotechnic inhalation hazards during military activities in both training and operational use.

S&T Achievements

The group proposes two methods "direct "and "indirect" to assess the risk for Humans. These propositions include a solid understanding of the emitted products in smokes which are mainly composed of gas and particles and a state of art of the technologies to assess human health risk in particular technologies with predictive codes or an "in silico" method and a "in vitro alternative model" to replace in vivo tests. Main exposure smoke are obtained with the reaction products of various protection grenades, colored signaling hand grenades.... Obscurant exposure scenarios have been analyzed to define recommendations and the technical scheme (see figure 1) would benefit from the focused NATO attention via the STO activities.

Synergies and Complementarities

One of the important components of the meetings will be the opportunity for cross domain and cross Panel collaboration. Panel representatives from Applied Vehicle Technology (AVT) presented on-going characterization emission activities and Camouflage, Concealment, Deception & Obscurant (AC 224/…/ CCDO) a link with operational opinion. The SCI 273 group mixes the most appropriate technical participation to write or complete his program of work.

Exploitations and Impact

The SCI-273 proposition to assess the smoke toxicity by the "indirect method" is mainly accepted by proving ground operational or industrial to preserve a safe zone for Human. The 'direct method" requires the development of methods and particular means that are not available in all the countries.

Conclusions

SCI-273 effectively brought to generate fresh and innovative ideas to enhance resiliency in the products generated by smokes in operational for Humans and Environment and to establish an "*in-vitro*" protocol to screen the toxicity of novel smoke and obscurant formulations.

Considerations for Space and Space-Enabled Capabilities in NATO Coalition Operations

Reference Number	Activity Type	Activity Start Date	Activity End Date
SCI-283	Symposium	01 Jan 2015	31 Dec 2016
Publication Reference https://www.sto.nato.int/publications/STO Meeting Proceedings/STO-MP-SCI-283			

Abstract

This two-day Symposium on the "Considerations for Space and Space-Enabled Capabilities in NATO Coalition Operations", held in Loughborough, England, saw 91 participants from 20 Nations attend 77 technical presentations and one keynote speech delivered by the Italian Defence General Staff's Chief of Intelligence and Security, MGen Giovanni Fungo

Phased-array radars like this one in the United States provide space surveillance capabilities to the Alliance.

Author Info

Dr. Donald Lewis, USA, The Aerospace Corporation

Technical Team Leader(s)

Mr MPhil CPhys Harjinder Singh JOLLY , United Kingdom , DSTL (Defence Science Technology Laboratory)

Background

NATO is significantly dependent upon services in and from the space domain to address its operational missions and related responsibilities. While NATO does not specifically own or operate any space-based assets, it has an increasing requirement for space domain awareness. This Symposium set out to identify areas for enhancement of the resilience of NATO's use of

space to ensure comprehensive mission success.

Objective(s)

The Symposium's objective was to share and disseminate information on efforts related to increasing NATO awareness and preparedness in employing space-enabled capabilities in coalition operations. This informed and continued to bridge
NATO's operational and S&T communities to ensure a coherent approach for the development and exploitation of space capabilities.

S&T ACHIEVEMENTS

Several core themes emerged from the Symposium. The development of space domain awareness capability was the most discussed theme and participants acknowledged the need and desire for a community approach to this issue. Other themes identified included the role of commercial systems in enhancing planning and execution of NATO missions, S&T support
to retaining capabilities in denied or degraded environments, and the challenge of addressing resilience.

SYNERGIES AND COMPLEMENTARITIES

This Symposium made it possible for 20 Nations to share scientific perspectives on space-enabled capabilities in NATO coalition operations. The presentations enabled information sharing among the Nations and the participants left the event
with an understanding and agreement on the way ahead.

EXPLOITATION AND IMPACT

As a result of the Symposium, several topics were identified for future activities. Exploratory Teams have already been established on "Resiliency Concepts to Enhance Preservation of NATO Space Capabilities" and "Collaborative Space
Domain Awareness Data Collection and Fusion Experiment". The SCI Panel is also considering additional studies on "Maturity of Concepts for Space-Based Tracking of Moving Objects" and "Opportunities/Implications of Large-Scale
Commercial Small Satellite Constellations to NATO Ops". In addition, the SCI space community is now providing scientific support to the NATO Bi-Strategic Command Space Working Group as it plans the next TRIDENT JUNCTURE exercise.

CONCLUSIONS

This Symposium proved very successful in developing new S&T activities within the STO. Four separate activities are anticipated over the next year that will begin to address several of the concerns identified.

Space Domain Effects on NATO Operations

Reference Number	Activity Type	Activity Start Date	Activity End Date
SCI-285	Lecture Series	01 Jan 2015	01 May 2016
Publication Reference https://www.sto.nato.int/publications/STO Educational Notes/STO-EN-SCI-285			

Technical Team Leader(s)

Prof. Mauro MESSEROTTI , Italy , National Institute for Astrophysics

Background

Space domain plays a key role in space-supported NATO operations, as the perturbations it is subject to can be mission-critical via their possible impacts onto any space system. Hence, awareness and preparedness are fundamental requirements to cope with the relevant phenomena in order to minimize its effects on operations. Due to the complexity of the phenomenological scenario and the operational needs, the required level of knowledge has to be adequately identified based on the operational personnel, ranging from quite basic for the soldiers in the theatre to advanced for the space planners (see e.g. the SCI-229 RTG study). This can be achieved by a targeted training based on multi-level use cases and is definitely a key tile in creating the operational conditions suitable for guaranteeing the NATO military long term capability preservation based on space.

Objectives

The objectives of the proposed RLS are manifold, as they span from the basic-to-advanced awareness raising on space domain perturbations and impacts on space-supported NATO operations to the risk evaluation for missions and the provision of the basics on mitigation techniques (when existent).

Distributed RF Operations in Congested Electromagnetic Environment

Reference Number	Activity Type	Activity Start Date	Activity End Date
SCI-289	Workshop	01 Sep 2015	01 Sep 2016
Publication Reference https://www.sto.nato.int/publications/STO Meeting Proceedings/STO-MP-SCI-289			

Technical Team Leader(s)

Dr. Wei SU , United States , US ARMY RDECOM

Abstract

The SCI-289 Workshop was held on 25-26 May 2016 at Dstl Porton Down in the United Kingdom. This 2-day Workshop provided a forum for information exchange on the use of distributed RF operations, typically Electronic Warfare (EW) against communications signals. The Workshop identified potential opportunities to operate distributed RF sensors and effectors as well as the different techniques which could be applied to these systems to gain improved situational awareness, intelligence gathering, and delivery of non-kinetic fires.

Background

Wireless personal communications and device-to-device (D2D) communications will soon be extended to everywhere using high accessibility, high connectivity, and high speed networks [1]-[2]. Phones are no longer used for the voice communications alone and Cyber space is no longer constrained to the internet. Massive deployment of low-cost sensors or communication devices in 5G communications has been expected in 2020 to provide connectivity for 300,000 devices within one cell with long battery life over decades. This new technology has led to revolutions in the way mobile and wireless systems are used for voice communications and the electromagnetic spectrum becomes congested and contested. Furthermore, Cyber-based services such as e-banding and e-health monitoring will share the infrastructure of the high data-rate, high data volume, and low latency communication networks. Capabilities that have recently been identified as priorities for NATO Electronic Warfare (EW) operations are Electronic Warfare Planning and Management Tools (EWPMT) and distributed EW architectures that can support joint and coalition operations [3]. With a limited EW budget among NATO nations, leveraging and reusing the existing EW assets distributed globally for high quality coalition Electromagnetic Spectrum Operations (EMSO) or cyber space is the best solution for the EW community, and a common interest to all NATO nations.

Many modern and future signals of interest are difficult for Electronic Support (ES) operations, this can be overcome through real time data sharing and cross-cueing between collection assets [3]. Research experiments performed by US Army and a NATO SCI-222 field trial have demonstrated the impressive performance improvement and processing gain in ES applications by extracting high-fidelity EW information from the low-quality RF collections from distributed software-defined radios (SDRs) [3] [5]. This inspired the interest in the EW community to exploring new technologies for processing distributed RF signals in congested and contested EMSO and developing low-power distributed Radars. Attention has also been paid to evaluate the possibility of leveraging the existing or future commercial or military communication network-sharing service in the cyber space for EW operations in order to reduce the development and maintenance expenses. Therefore, new concept for future EW operations should be addressed immediately.

Objectives

Most NATO and allied nations are facing shrinking defense budgets. Combining resources and efforts will enable NATO nations and their allies to maintain the same level of capability at a reduced cost [3]. The objective of this Task Group is to discuss the scenarios and architecture of coalition operation using distributed EW assets, find technical solutions and limitations for leveraging distributed EW assets to perform the joint EW tasks, exploit the concept in leveraging the existing and future communication networks for enhancing EW operations, and investigate the challenges and opportunities in performing EW operations in the congested and contested EMSO. The following subjects will also be addressed: (in two years)

(1) Evaluate the performance of network-enabled ES including signal detection, classification, and geolocation using distributed sensors or radios through cyber space.

(2) Assess the effectiveness of EA including the jamming, interference mitigation, and noise cancellation by leveraging distributed emitters in cyber space.

(3) Analyze the scenarios of EP including active and passive EA detection, jamming and interference mitigation, and data traffic optimization in the network-enabled EW environment.

(4) Investigate the data fusion and decision fusion methods to improve the EW capabilities and performance.

(5) Assess the challenges and opportunities in using distributed and Cyber based EW operations.

Research deliverables form US Army and the previous NATO programs will be leveraged. Tutorials/classes will be given at the workshop to review the state-of-the-art and future challenge in the distributed RF operations. Workshop/conferences will be considered to investigate the scenarios of distributed EW, and the technical solutions, recommendations, and reports will be provided to NATO nations.

Fifth Generation (5G) COMMS and MIMO Challenges in Electronics Warfare

Reference Number	Activity Type	Activity Start Date	Activity End Date
SCI-290	Workshop	01 Sep 2015	01 Sep 2016
Publication Reference https://www.sto.nato.int/publications/STO Meeting Proceedings/STO-MP-SCI-290			

Technical Team Leader(s)

Dr. Wei SU , United States , US ARMY RDECOM

Abstract

The SCI-290 Workshop was held on 20-21 April 2016 at the TNO facilities in The Hague, Netherlands. This 2-day Workshop provided a forum for information exchange on the 5G and MIMO (Multiple Input Multiple Output) challenges and issues/concerns to EW (Electronic Warfare) from each participating Nation. The exchanged information was discovered through open-sources which may be used by commercial network providers/developers to advance future 5G networks. The Workshop identified potential requirements to operate EW systems in the projected 5G/MIMO environment (projected 5G deployment date is 2020).

Background

The 5G (5th generation) wireless communications systems will be fully operational by 2020 [1] – [3]. The technical objective of METIS (Mobile and Wireless Communications Enablers for the Twenty-Twenty Information Society) supports:

1. Data rate: 10x - 100x higher user data rate

2. Data volume: 1000x higher mobile data volume per area

3. Latency: 5x reduced end-to-end latency

4. Connectivity: 10x – 100x higher number of connected devices

5. Reliability: 99.999%

6. Battery life: 10x longer battery life for low-power massive machine-machine communications (MMC)

This revolutionary approach will be achieved through a flexible combination of evolved existing technologies (e.g. 3G, 4G, Wi-Fi, etc.) and many new radio concepts. NATO experience demonstrated that a capable civilian telecommunications infrastructure has a high probability of being leveraged by adversaries for Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance (C4ISR) operations. Therefore, extensive investigation is essential to assess the impact of 5G to current and future military operations, and analyze the challenges and opportunities of 5G technology to both the military communications and electronic warfare (EW) in various scenarios. Since the 5G technology will be a worldwide EW issue to all NATO nations in a few years, it should be addressed by NATO Task Group (TG) immediately and seriously.

Objectives

NATO nations need to maintain pace with the evolution of new technology in order to ensure dominance of the electromagnetic spectrum. The objective of this TG is to assess impacts, investigate threats, and search for opportunities of 5G technologies to current and future EW operations based on the recommendations in NATO SCI-267 Specialists' Meeting Report [2]. The recommendations addressed fast evolving threats in the areas of Electromagnetic Environment (EME), Interoperability and Spectrum Management, Next Generation EW Technology, and Cyber and EW. The working group will provide knowledge, recommendations, and solutions to NATO nations for solving the emerging 5G issues. The following activities are described based on the technologies proposed to fulfil the requirements of 5G scenarios:

1. Assess the impact of 5G to the congested and contested EME of the future associated to the following technology areas:

- Dynamic spectrum access (DSA) communications
- Millimetre wave frequency communications
- Direct device to device (D2D) communication (50 billion connected devices by 2020)
- Massive machine communications (MMC)

2. Understand new waveforms and evaluate their impact to Electronic Support (ES) especially for the spectrum survey and signal exploitation of:

- Massive distributed MIMO (Multiple-Input Multiple Output) wireless RF communications
- Li-Fi (light and Wi-Fi) wireless communications
- Vandermonde-subspace frequency division multiplexing (VFDM) modulation format

3. Examine the effectiveness of Electronic Attack (EA) and Electronic Protection (EP) with:

- Advanced interference and mobility management systems
- High bitrate, low latency, and ultra-reliable communication architectures

4. Discuss the problems in geolocating and mapping mobile communication systems in:

- Dense small cells networks
- Multi-hop networks
- Moving networks (MNs)
- Virtualized wireless network
- Pervasive/ubiquitous networks

5. Investigate issues in monitoring and managing signals in the dynamic and agile environment such as:

- Dynamic spectrum access (DSA) scheme
- Dynamic Ad-Hoc wireless networks (SAWN)

It has been acknowledged in the NATO recommendations [2] that current and future EME are significantly different than that which existed when our current EW systems and CONOPS were developed. The emerging of 5G makes our job more challenging. Many other techniques in 5G will also affect the current

and future EW capabilities such as the use of directional antennas for mobile communications, cloud services, and human-centric networks. The TG may investigate the impacts of all technologies proposed for 5G depending on the working load and time schedule.

Since 5G covers a very large technical field including both legacy and modern electronic devices, it is essential to consolidate the limited resource from multiple nations and establish the teamwork under NATO platform to investigate all big issues. 5G is an ongoing research and growing business, technology watch, progressive learning, and continuing assessment will be needed as a long-term effort for NATO TG. Workshops and NATO conferences on 5G may be considered and tutorials/lectures will be conducted to exploit the new technologies developed by 5G community. The TG has two working sessions to investigate threats and opportunities accordingly. Field trials may be conducted if possible, survey papers will be published, and NATO reports will be delivered.

Scenarios for Assessment Methods for Camouflage in Operational Contexts

Reference Number	Activity Type	Activity Start Date	Activity End Date
SCI-291	Workshop	01 Jan 2016	01 Dec 2016
Publication Reference (when published) https://www.sto.nato.int/publications/STO Meeting Proceedings/STO-MP-SCI-291			

Technical Team Leader(s)

Dr Karin STEIN , Germany , Fraunhofer

Background

In the evaluation and design of camouflage systems the military operational context currently plays a small role, whereas it is crucial to assess the performance of these systems in military practice. For instance, most evaluations are performed in a controlled and static setting while dynamic environmental aspects are largely ignored. In some circumstances the added value of camouflage will be marginal (e.g. in dense forest) while in other situations camouflage can make an important contribution to survivability. It would be prudent to opt for camouflage that is adapted to enhancing survivability. Such aspects should be part of the evaluation procedure and incorporated into models that seek to predict performance in a military context. Also, it is not clear how improved performance measured during evaluation translate to the added benefit when used in military operations.

A first step towards good understanding of camouflage effectiveness in operational scenarios has been made by SCI-212 that identified the military requirements for camouflage systems. Their study showed that the evaluation of camouflaged targets in a tactical operational setting proves to be difficult. The task group SCI-287 intend to investigate new assessment methods that take military strategies and context into account.

A crucial aspect is the use of realistic operational scenarios, so a set of critical scenarios and contexts will be established in interaction with military experts, on which the evaluation will be based (such as ambush, patrol and hasty defence).

The main objective of the TG SCI-287 is to investigate and verify recommended techniques for incorporating the operational context in camouflage assessment and requirement analysis. Interfaces between different existing software packages will be incorporated into a framework for assessing camouflage utility at different levels. This study should lead to evaluation methods that are able of capturing the operational context including time dependent factors and aspects such as variation in weather conditions, seasonal variations, movement, tactical use of equipment, adaptive camouflage, operating theatre, spectrally designed materials and lighting conditions. The focus will lie on personal camouflage and camouflage systems for vehicles in visual, near infrared and thermal infrared spectral regions. Radar signatures might also be taken into consideration.

Here we will focus on the application of these new methods (e.g. wargaming, physics based models, photo-realistic simulation, and models of operational effectiveness, morphological analysis) to the assessment of existing camouflage techniques also in time depending conditions. We expect these techniques to be highly useful for the investigation and development of future camouflage concepts (e.g. adaptive camouflage, see SCI-230). Results and methods from SCI-230, SCI-212 and SCI-219 will be utilized in SCI-287.

Objectives

The proposed workshop will bring together military and scientific expert to exchange information and experience of different scenarios. The military can assess which scenarios are relevant for present and future NATO operations while the scientist assess which scenarios are useful as input to the modelling tools. The outcome of the workshop is supposed to be a catalogue of scenarios that are both relevant and useful.

Space Domain Awareness Concepts and Approaches to Support NATO Operations

Reference Number	Activity Type	Activity Start Date	Activity End Date
SCI-292	Lecture Series	01 Jan 2016	01 Dec 2016
Publication Reference https://www.sto.nato.int/publications/STO Educational Notes/STO-EN-SCI-292			

Technical Team Leader(s)

Dr Moriba K. JAH , United States , The University of Texas Austin

Background

Increasingly NATO is dependent upon the space domain and space capabilities to conduct its mission responsibilities as an Alliance. Comprehensive awareness of the space domain is similarly becoming increasingly important to effective deployment of the space capabilities and services provided to it from the member nations as well as enabling those nations to protect their assets. Some of the more important aspects of space domain awareness (SDA) to NATO operations include exploitation of space object locational information to avoid (and when necessary attribute) collisions between space objects, geolocate and characterize RF interference with satellite communications, and predict and assess the impact of the space environment on space system performance. The sole purpose of SDA is to provide decision-making processes with a body of timely and quantifiable evidence of behaviour(s) attributable to specific threats and hazards. Education of NATO space operators, space planners, and those responsible for NATO space capability requirements should become familiar with the growing capabilities throughout the Alliance to conduct and sustain space domain awareness. Similarly, education of those NATO communities on the techniques and processes necessary for SDA will help with the achievement of a NATO-Common Space Domain Awareness picture. This activity is focused on those elements of SDA that are concerned with the locational and orbital flight characterization of space objects and associated collision avoidance.

Objectives

• To provide an organized educational forum on the technical basis and techniques of selected space domain awareness elements.

• To increase the awareness of practical space-related considerations for NATO planners and space coordinators.

Ship radar signature management system accuracy, sensitivity and confidence level

Reference Number	Activity Type	Activity Start Date	Activity End Date
SET-203	Task Group	21 Jan 2014	01 Dec 2016
Publication Reference (when published) https://www.sto.nato.int/publications/STO Technical Reports/STO-TR-SET-203			

Abstract

The signature of a ship is a crucial factor in determining the range at which a ship is detected and whether or not soft-kill, in the form of jammers or decoys, is effective. The signature of a ship is not a fixed value, the signature level seen by a threat will depend on a number of parameters: threat sensor characteristics, the environment and the state of the ship. If a ships signature and the threat are known to the ships command then informed operational decisions can be made with knowledge of the likely resultant susceptibility of the ship. Currently signature requirements are important in the development of a new ship, but there is no real-time awareness of the signature and hence of the ships susceptibility during operations. NATO SET154 has started the work within NATO towards a ship signature management system. The group has used nationally available data in addition to that gathered at the SQUIRREL trial organized by SET144 and SET154.

Technical Team Leader(s)

Dr. Frances M. TALBOT , United Kingdom , Defence Science and Technology Laboratory

Background

The signature of a ship is a crucial factor in determining the range at which a ship is detected and whether or not soft-kill is effective. The signature seen by a threat will depend on a number of parameters. If a ship's signature and the threat are known to the ship's command then informed operational decisions can be made with knowledge of the likely resultant susceptibility of the ship. Currently there is no real-time awareness of a ship's signature and susceptibility during operations. NATO SET154 has started the work within NATO towards a ship signature management system (SMS). The group has used nationally available data in addition to that gathered at the SQUIRREL trial organized by SET144 and SET154. The SQUIRREL trial was part of the RIMPASSE trial organized by the Centre for Ship Signature Management in Kiel. The proposed new group will investigate the accuracy, sensitivity and confidence level for a SMS, in particular for the supporting modeling. It will concentrate on radar signatures, but will take compatibility with the other signatures into account, drawing on the work of SET144 and follow-on group for infra-red and SET166 for underwater signatures.

Objectives

The objective was to provide improved tactical advice to ship operators and national tacticians to improve ship survivability and provide advice to the procurement and materiel organisations on procedures for the optimisation of ship signatures during the design phase.

S&T ACHIEVEMENTS

Traditional propagation codes were written to match data, primarily at frequencies up to 18 GHz. At higher frequencies, for example 35 GHz, there has been much less validation of the codes; the Task Group provided suggested changes to the

codes, where required. The RTG's work has raised the awareness of the significance of ship signatures. Knowledge of
the signature data currently available onboard ships will be used to suggest how the ship best estimates the propagation conditions to improve its situational awareness and vulnerability assessments.

Synergies and Complementarities

The sharing of data from trials and predictions is a valuable exercise that increases confidence in the models. Through participation in the NEMO 2016 trial, SET-203 participants gathered a more comprehensive set of data than would have been
possible by a single Nation. In addition, during the analysis phase, the Nations were able to share different analysis echniques

EXPLOITATION AND IMPACT

The work conducted here will be exploited through delivery of improved tactical advice for surface ships. The propagation knowledge gained will be included in susceptibility modelling, and the studies and trials reported by SET-203 will lead to greater confidence in the modelling. The work conducted by this RTG has led to advice being given to the organisers of the NEMO trials to allow them to better interpret anti-ship missile defence activities. A common approach has been followed
for analysing and presenting the data.

CONCLUSIONS

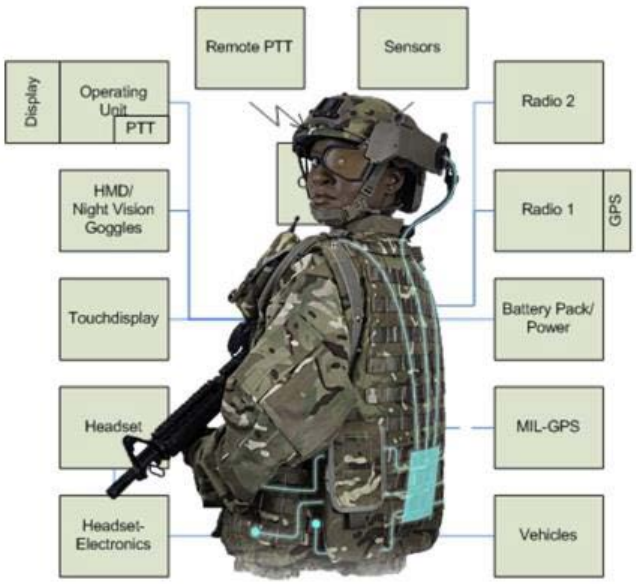
The RTG demonstrated excellent co-operation in sharing modelling and trial information, which has led to improvements in understanding to how to improve surface ship survivability. Ideally, these results will be further developed in future NATO and national work.

Energy Generation for Manwearable/Manportable Applications and Remote Sensors

Reference Number	Activity Type	Activity Start Date	Activity End Date
SET-206	Task Group	05 Mar 2014	01 Dec 2016
Publication Reference https://www.sto.nato.int/publications/STO Technical Reports/STO-TR-SET-206-Part-II			

Abstract

Future Dismounted Soldier Systems (DSS) are developing into integrated solutions. A major issue at present is the weight of batteries (energy) which contributes a significant part of the soldier's burden and is expected to increase. The reports generated by SET 206 (1) defined the current portable power requirements, (2) assessed available power sources, (3) demonstrated a mission planning tool for power consumption and (4) conducted an analysis of trends and tradeoffs of soldier systems currently fielded and in development.



Technical Team Leader(s)

Mr Marc David GIETTER , United States ,

Authors

Mr Christopher Ford C Eng MIMMM, UK, QinetiQ, Batteries, Cables and Connectors.
Mr. Jasper Groenewegen, NL, DNV GL – Energy, Specialist Energy Storage

Background

Many nations currently have or are replacing discreet DSS operational equipment with an integrated approach. This has required the development of centralized power and data architectures. These efforts are being developed on a national basis which presents problems for meeting the interoperability goals of the NATO community.

Objectives

The objectives were (1) to identify current trends and to develop a methodology for selecting the optimized power source for a given application and (2) to conduct a study of soldier systems in an effort to collect information for identifying areas of commonality and “lessons learned”.

S&T Achievements

The analysis showed the majority of power sources to be at a relatively high TRL. The integrated soldier systems are not requiring significant technology breakthroughs. The work has been presented at the Joint Services Power Expo (Aug 2015) and will be presented at the 47th Power Sources Conference in June 2016

Synergies and Complementarities

Many nations contributed power source data and information on integrated soldier systems fielded and being developed. SET 206 also collaborated closely with the Land Capabilities Group Power Team of Experts.

Exploitation and Impact

The information collected on power sources has a wide range of applicability to NATO members. The study on soldier systems highlighted those areas where future collaborative efforts (system architecture standard, cable less power and data transfer) would provide most benefit.

Conclusion(s)

Having an integrated soldier system that is powered by an optimized central power source allows for the most efficient use of the available energy while reducing the overall weight of the system. This results in longer mission times and reduced fatigue on the soldier..

Signal processing for implementationin hand-held multi sensor ground penetrating system

Reference Number	Activity Type	Activity Start Date	Activity End Date
SET-208	Task Group	28 Apr 2014	01 Dec 2016
Publication Reference https://www.sto.nato.int/publications/STO Technical Reports/STO-TR-SET-208			

Abstract

The work undertaken by the group was focused on an attainment of knowledge on present state of the art in ground penetration technology and an assessment of the possibility of its application for hand-held system. To this end the members of the group were organizing meetings during which the discussions were run on current trends in research and technological applications and achievements of the partner institutions in the field were presented. Plans of possible joint research and experimentations were analysed. The effects of the computer simulation experiments of the GPR signal (data) processing done on the simulated as well as the real registered signal data were validated. The perspectives of exchange the signal data (simulated and registered) were studied. In this context the feasibility of multisensor hand-held ground penetrating system with radar as the main sensor aided by auxiliary sensor(s) was analysed. The data fusion was considered as extremely important aspect of possible implementation of a system. The result of the group activity was a realistic assessment of the hand-held system feasibility with emphasis on all the difficulties and constraints. There is no decision on the possible continuation of the joint research but the question could find a positive answer in the nearest future.

Technical Team Leader(s)

Dr. Witold CZARNECKI , Poland , Military University of Technology

Background

Detection of objects hidden in the soil by means of ground penetration is very important for NATO. The technology based on the use of microwaves known as ground penetrating radar (GPR) technology has been under continuous development for over 20 years. It has found applications in numerous areas and in particular in military sector where its usefulness for detection of landmines and improvised explosive devices (IED) buried under the soil surface as well as explosive remnants of war (ERW) is extremely important. There are numerous companies furnishing GPR systems mounted on trolley-cart and heavy armoured vehicles. However, in many situations when the access to the area is difficult the use of a wheeled vehicle even a small one is not acceptable. That is why a hand-held system should be taken into consideration. In order to boost the reliability of detection such a hand-held system ought to be multisensor carrying out a fusion of data obtained from different sensors. In addition to the GPR the following auxiliary sensors could be taken into consideration:

- advanced metal detector,

- chemical explosive vapour detector,

- CCD camera,

- positioning sensors set.

Such an approach to the detection of buried objects could be seen as ground penetration by GPR sensor aided by auxiliary sensors. It can be judged by available literature that nowadays there are a few

commercial devices combining GPR and metal detector making use of data fusion and equipped with imaging facility. Signal processing mentioned in the title of the proposed activity concerns mainly the processing of the GPR signal that would be complemented by the fusion of data provided by auxiliary sensors. Appropriate imaging of these data would support detection and recognition as well as make possible correct positioning of the detected object. However, a very serious problem arises that concerns the size, weight and power consumption of the system and it means in practice that the system should be sufficiently simple. In spite of this simplicity a multisensor system could be a reasonable alternative to even an advanced wheeled GPR system that do not always satisfactorily meets the requirements as far as the probability of detection and resolution achieved are concerned. An assumption that effective ground penetration with the aid of a compact multisensor system seems to be justified provided that advanced signal and data processing procedures used will be appropriately simplified.

It should be emphasized that the detection of buried objects is assured by the GPR sensor and the signal processing affects the reflected radar signal. The simple hand-held ground penetrating sensor system should cope with processing of extremely compound signal and the background on which it appears. It is due to the complex nature of the microwave sensor signal penetration into the ground and the propagation, reflection, dissipation inside of it. The ground medium inside of which the mentioned processes run is usually nonhomogeneous, often of layered structure producing a multipath strong clutter signal. A reliable detection of the useful echo signal component needs advanced signal processing that ought to be implemented in and comply with the proposed hand-held system weight and size constraints. The feasibility of such an implementation could be made possible provided that substantial simplifications will be introduced to the processing algorithms. In particular they could concern the organization of the algorithms themselves as well as the organization of the appropriate processing procedures. The following processing algorithms could be mentioned:

- homomorphic deconvolution of the received signal components for an effective separation of the useful signal component better detection of hidden objects,

- matched filtering based on the time reversal concept better depth resolution,

- coherent synthesis of the antenna aperture better position (cross range) resolution,

Objectives

The objective of the activities proposed is to research comprehensively the current state of the art in signal processing applied in the ground penetration technology and to analyse possibilities of new signal and data processing algorithm applications in a multisensor hand-held system. The homomorphic deconvolution, inverse filtering, matched filtering by time reversal, coherent processing could be considered. The planned research should be focused on an analysis of the probability of correct detection, positioning and recognition. The principal challenge of the proposed action would be to design appropriate advanced signal processing and data fusion procedures suitable for the implementation in the hand-held ground penetration system working with the given probing signal.

The proposed activity would be complementary to the activities of the former and existing already task groups working on GPR technology application in military sector. In particular the Detection and Neutralisation of Route Threats (SCI-193) group specifies in the description of the group objectives that “The sensor technologies should be complemented with the appropriate signal and data processing techniques”

Synergies and Complementarities

NATO has been currently involved in an investigation of countermeasure of threats caused by landmines and IEDs. Numerous efforts are focused on route threat detection and clearance. They are often oriented to stand-off detection of changes on or near routes that may be the result of the explosives emplacement. The detection of command wires or other components to arm or set off explosive devices remotely are also the objectives of the actions undertaken. The proposed activity would be complementary to the activities

of the groups that were or are working actually on GPR technology application in military sector. The following groups could be mentioned: Route Threat Detection and Clearance Technologies (SCI-256) end 2015 Ways and Means for Attacking the IED Network (SCI-243) end 2014 Route Clearance Concepts (SCI-233) end 2013 Countering Improvised Explosive Devices in a Long-Term Perspective (SET-175) end 2011 Detection and Neutralisation of Route Threats (SCI-193) end 2011 Sensor Support for Defense Against Terrorism and Asymmetric Warfare (SET-149) end 2008 Sensors and Technology for Defence Against Terrorism (SET-125) end 2008 The activities mentioned above are related to the: CNAD DAT Priority #4 Countering Improvised Explosive Devices (IEDs) LTCR Priority #9 Counter Improvised Explosive Device (C-IED) The countermeasure cannot be limited only to stand-off detection but often should also be complemented by in-situ inspection of an area of action in order to eliminate the threat of explosion. In complex surroundings a hand-held multisensor GP system seems to be very useful, often inevitable.

Exploitation of Human Signatures for Threat Determination

Reference Number	Activity Type	Activity Start Date	Activity End Date
SET-209	Task Group	30 Apr 2014	01 Dec 2016
Publication Reference (when published)			
https://www.sto.nato.int/publications/STO Technical Reports/STO-TR-SET-209			

Abstract

In today's urban environment, threats often come from individuals or small groups who blend in with the civilian population. It is increasingly difficult to differentiate and identify the non-combatant civilian from individuals that pose a threat to NATO forces. As such, Soldiers are required to identify targets and threats in more complex environments and situations. Before acting, Soldiers must assess the situation, acquire and identify the threat, and execute the proper course of action. Night vision and thermal sensor technology has greatly helped Soldiers accomplish this task, whether it is used by a dismounted Soldier on foot, or by a crew of Soldiers in an armored vehicle. Soldiers utilize a variety of different tools to aid in the ability to acquire and engage targets on the battlefield. These tools range from helmet- and rifle-mounted visible, low-light, and thermal sights to vehicle-mounted visible, low-light, and thermal sensors. Many agencies have conducted various target acquisition experiments involving human targets. Experiments in the 1990s, focused on human target detection consisting of humans standing, moving, and kneeling. In these experiments, biological motion cues were determined to be the primary source of image information. In many cases the presence of a weapon or object could be accurately inferred based on biological motion alone, even when the weapon or object itself was not resolvable or detectable. Further experimentation, in the early 2000s, focused on the recognition of hand held objects such as weapons, tools and electronic devices. These experiments focused on the recognition of the objects alone, without additional information from biological motion. Current experiments focus on determining whether a person is holding a weapon or a non-weapon. This human threat research is currently on-going and would benefit greatly from joint NATO cooperation.

Technical Team Leader(s)

Mr. Jonathan Giles HIXSON , United States , US Army RDECOM CERDEC NVESD

Background

In today's urban environment, threats often come from individuals or small groups who blend in with the civilian population. It is increasingly becoming more difficult to differentiate and identify the non-combatant civilian from individuals that pose a threat to NATO forces. Many different imaging sensors have been developed to aid Soldiers in distinguishing various threats and a need exists for common practices to be developed to asses an imaging sensors effectiveness at distinguishing various human signatures.

Objectives

The primary objective is research to evaluate ultraviolet through millimeter wave active and passive imaging sensor performance for the following tasks: human activity and behaviors, dismount tracking, human gait, facial identification, and weapon non-weapon discrimination. In addition to sharing ideas and research the group will work towards establishing standard techniques for assessing imaging sensors, including laboratory, field, and performance modeling methodology. Anticipated outcomes are a consistent methodology for sensor performance comparison against a standard hierarchy of human threat definitions for sensor evaluation relevant for current conflicts, and a summary of lessons learned.

Synergies and Complementarities

Performance assessment of imaging systems with respect to human signatures and threat determination is critical in determining whether sensors can accomplish the tasks needed to meet demanding operational requirements. Methods need to be developed that allow proper assessment of a sensors ability to accomplish these requirements. Adequate field-performance prediction and sensor characterization capabilities for such techniques contribute in obtaining optimum performance at minimum costs. The proposed RTG will jointly develop and apply common tools and methods for assessing advanced sensor technologies specifically focused on collection of human signatures and threat determination.

Swarm Centric Solution for Intelligent Sensor Networks

Reference Number	Activity Type	Activity Start Date	Activity End Date
SET-222	Specialists Meeting	07 Jun 2016	08 Jun 2016
Publication Reference https://www.sto.nato.int/publications/STO Meeting Proceedings/STO-MP-SET-222			

Technical Team Leader(s)

Dr. Francesco FEDI , Italy , Leonardo Company

Abstract

Swarms are space-distributed dynamically self-organized systems and may be considered as an evolution of sensors networks in the dimensions of space, time and operational capabilities as cooperation and autonomous decision making. State-of-the-art is represented by research in Swarm Robotics (SR), a robot swarm being a collection of autonomous nodes designed to coordinate and cooperate to carry out tasks addressing common goals. From an engineering perspective a Swarm-centric system is a system based on net-centric architecture and cooperating agents, i.e. heterogeneous specialized entities (people, robots, sensors, software agents, intelligent devices), able to self-organize, share the same mission and adapt even to possible asymmetric threads. Main operational advantages offered by swarms are: autonomy (little or no human control is needed), adaptability (the swarm adapts its configuration and workload to current operative status), and robustness (a limited number of single failures may only impact on mission performance, e.g., the completion time, not on the mission success; execution errors of single robots may be fixed by other robots). The main relevance to NATO is that, from the human operator viewpoint, swarm-centric intelligent sensor networks improve human awareness acting as a ubiquitous sensory system which may act as an extension of human perception in the field.

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The main relevance to NATO is that, from the human operator viewpoint, swarm-centric intelligent sensor networks improve human awareness acting as a ubiquitous sensory system which may acts as an extension of human perception in the field.

Objectives

The proposed research aims at answering to the following question: "What specific features new sensing and actuating platforms should exhibit to comply with new swarm-centric paradigm requirements? "

The proposed activity aims at organizing a Specialist Meeting (SM) with experts of different topics to clarifying the issues concerning swarm-centric intelligent sensor networks, defined as sensory systems based on network-centric architectures of cooperating nodes, which are able to dynamically (self-) organize to fulfill the common mission goals and adapt to react to the same threats (e.g. the ones posed by asymmetrical warfare or by natural calamities). Chapter III provides a set of possible topics to be addressed in the workshop.

Lecture Series Radar and SAR Systems for Airborne and Space-Base Surveillance and Reconnaissance

Reference Number	Activity Type	Activity Start Date	Activity End Date
SET-235	Lecture Series	01 Jan 2016	22 September 2017
Publication Reference https://www.sto.nato.int/publications/STO Educational Notes/STO-EN-SET-235			

Technical Team Leader(s)

Dr. Matthias WEISS , Germany ,

Background

For NATO's military and peace-keeping operations radar and SAR systems for airborne and space-based surveillance, reconnaissance, and target acquisition (RSTA) are essential tools for a large number of missions. Its ability to function during day and night, relative immunity to weather, capability of localizing targets in range, long range operation, to generate highly accurate interferometric 3D-maps, detection and tracking of mobile targets, and classification of objects, make it the sensor of choice in many situations. New emerging concepts employ high-resolution multi-channel imaging radars, for instance, and/or multiply radar/SAR sensors distributed over the area of interest in a Network-centric environment to enhance the information quality gained by a single sensor. They offer multiply benefits, for instance boosting the potentialities to characterise the target by exploiting the multiple observation angles or using already available signals of opportunity.

Objectives

The objective of this Lecture Series is to present the cutting edge of SAR/MTI systems for airborne and space-based surveillance and reconnaissance applications and sophisticated modern data fusion and tracking techniques for these systems and thereby increases the awareness of their value to the NATO scientific and engineering communities. Lectures are given by leading experts in this area and discuss their pros & cons. These discourses will based on advanced applications in various fields relevant to NATO's mission, such as covert surveillance by airborne and space-based SAR/MTI systems, or security assistance systems for NATO DAT and their fusion products for producing better situation pictures in NATO's ISTAR systems, for instance. Moreover, the LS will review current developments in this area.

Maritime Radar Surveillance from Medium and High Grazing Angle Platforms

Reference Number	Activity Type	Activity Start Date	Activity End Date
SET-239	Specialists Meeting	25 Oct 2016	26 Oct 2016
Publication Reference https://www.sto.nato.int/publications/STO Meeting Proceedings/STO-MP-SET-239			

Technical Team Leader(s)

Dr. Michael Kenneth MCDONALD , Canada , Defence Research and Development Canda

Background

The NATO SET-239 Specialists' Meeting on "Maritime Radar Surveillance from Medium and High Grazing Angle Platforms" was held 25-26 October 2016 in Edinburgh, UK, under the chairmanship of Dr. Mike K. McDonald from Canada. This Specialists' Meeting brought together experts in Maritime Surveillance Radar and Sea Clutter. The meeting comprised of 19 papers on sea clutter modelling and target detection techniques and two panel discussions. Results were presented from collaborative activities within SET-185 and from other work in the subject area. The results triggered discussions and collaboration among the participants concerning future developments of the modelling and detection techniques, and the application of results to future procurements

Background

Airborne wide area, maritime surveillance has traditionally been accomplished using non-coherent high bandwidth radar systems operating on low altitude aircraft at low grazing angles. At low grazing angles the signal to clutter ratios of typical maritime targets of interest are usually sufficiently large to allow the use of non-coherent approaches which can be implemented using simple lightweight radar designs with relatively low computational demands. The intention by many nations to transition their airborne surveillance capabilities to high altitude platforms such as jet aircraft, UAVs (MALE and HALE) and aerostats will lead to much steeper look down or grazing angles during surveillance missions. Grazing angles of 25o will lead to increases in clutter cross sections of 10-15dB with respect to typical low grazing angle geometries of less than 3o with correspondingly large decreases in detection performance.

Over the past four years the NATO SET 185 technical group has examined a number of technical issues surrounding the characterization of these high grazing angle environments and investigated the development of appropriate detection strategies which will help mitigate the detection performance degradation expected with legacy radar systems. A successful migration to higher grazing angle geometries will require a holistic approach in which the role and effect of different platforms, radar designs and signal processing approaches is considered.

Objectives

The general goal of the symposium is to bring together parties with a vested interest in developing the medium to high grazing angle maritime surveillance capability. This will include industrial, government and academic participants involved in areas such as platform design, radar design and signal processing development as well as any operational implications defined by the solutions developed. Specific goals of the workshop are as follows:

a) Provide for information exchange between members of the broad technical community and foster on-going and future collaborative opportunities.

b) Provide detailed information on current and future technical capabilities for medium to high grazing angle maritime surveillance.

c) Educate and inform military contingent on the deleterious effects of migration to high altitude platforms for maritime surveillance and identify outstanding challenges.

d) Allow industrial participants to highlight their technical capabilities and product base.

e) Publicize the result of the NATO SET 185 technical group.

Reconfigurable and Scalable Multi-Function RF Systems in a Congested EM Spectrum

Reference Number	Activity Type	Activity Start Date	Activity End Date
SET-SCI-230	Specialists Meeting	18 Apr 2016	19 Apr 2016
Publication Reference Upon request			

Technical Team Leader(s)

Dr Ric SCHLEIJPEN , Netherlands , TNO

Background

Future NATO operations will be conducted using a wide variety of Radio Frequency (RF) devices within a congested RF spectrum. As a result, the management of the spectrum and the optimum use of the spectrum will be critical for future NATO success. Both the SET and SCI panel cover several activities covering several sub-areas addressing this issue, ranging from hardware solutions in RF front end, via studies on cognitive radar and advanced waveforms to spectrum management tools and the final effect on the common operating picture. These are just examples of the activities involving a wide range of different expertise needed.

Scalable and Software Defined system designs offer the potential to support multiple RF functions, including communications and Electronic Warfare (EW) from within a single, resource-shared system as a part of the solution of the EM spectrum issues. The effectiveness of these types of solutions needs to be investigated from various points of view, requiring a wide range of expertise.

Objectives

This special session aims at bringing together specialists in the fields of EW and radar/communications from SET and SCI and potentially also from IST to trigger cross panel discussions and identify future NATO Panel activities. A two-day specialist meeting is proposed to:

- Assess the state of the art of the relevant research activities among the NATO nations.

This will be followed by subcommittee sessions to:

- Identify potential gaps in the research portfolio of SET and SCI panels;

- Harmonise the activity portfolios of SET and SCI (and potentially IST) panels.