

# **The 11th NATO Operations Research & Analysis Conference Proceedings**

## **Program Committee Forward**

It is our pleasure to publish the proceedings of the eleventh NATO Operations Research & Analysis (OR&A) Conference co-organized by Headquarters Supreme Allied Commander Transformation (HQ SACT) and the Science and Technology Organization (STO).

The 2017 event brought together approximately 120 OR&A experts from NATO commands and agencies, national defence analysis and research organisations, centres of excellence, academia and industry as part of the continuous development of a NATO OR&A Community of Interest building on the success of previous Operations Research and Analysis Conferences and Workshops.

The 2017 Conference offered an exceptional mix of senior military engagement, sharing of OR&A best practices and training opportunities for early career analysts. Dr Thomas Killion, the NATO Chief Scientist, opened the conference with some words about how OR&A has supported his decision making during his career. LGen Radford, Commander NATO Allied Rapid Reaction Corps, highlighted the critical role of OR&A in support of military decision making, while Dr David Alberts provided the community with the latest research into Agile Command and Control. Finally, Mr Alan Shaffer closed the conference with a call for the Community to stay militarily relevant.

This was also the first Conference where hands on training was offered by experts from the NATO OR&A Community. Practitioners from the NATO OR&A Community shared their expertise through practical Problem Structuring and Social Network Analysis training sessions. This new initiative aimed to promote professional development of the community and make the Conference more accessible to new members of the community and early career analysts.

As always, the Conference continued to prove its value as a centre of gravity for NATO's OR&A Community of Interest. Should you have any questions on the conference or its programme contents, please reach out to the program committee chairs:

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## 1.0 BACKGROUND

On the 2<sup>nd</sup> and 3<sup>rd</sup> of October 2017, the UK Defence Science and Technology Laboratory (Dstl) hosted the 11th NATO Operations Research and Analysis (OR&A) Conference in London, organized by the Headquarters Supreme Allied Commander Transformation (HQ SACT) and the Science and Technology Organization (STO).

As part of the continuous development of a NATO OR&A Community of Interest, this event built on previous OR&A conferences and workshops. The conference aimed to coordinate and improve the contributions of OR&A to NATO operations and capability development to finding solutions to NATO's challenges. It brought together the analysis community from NATO commands and agencies, national defence analysis and research organisations, centres of excellence, academia, and industry. Over the years, the themes of the conferences have spanned the domains of operations and capability development, and both looked back to lessons learned and forward to new technologies, techniques and emerging challenges for the Alliance. Each conference has offered opportunities for nations and NATO commands and agencies to present new work and new methodologies.

The central theme for 2017 conference was “**Enabling Accelerated Military Decision Making**” with the aim to encourage in depth consideration about how to deal with challenges, how to formulate the right questions, and what the future requirements of decision-makers in NATO will be. The conference was organized around three streams:

- Emerging technology: The impact of big data analytics, data visualization, cognitive computing, machine learning, Artificial Intelligence, open source, etc., on the speed and quality of military decision support.
- Multi-methodology: Reaching better answers by combining methods.
- Back of the envelope: Achievements and limitations of on-the-fly OR&A.

In addition, the conference offered the opportunity to attend hands-on training workshops on Social Network Analysis and collaborative problem structuring, and there were enlightenment sessions on offer where the community got an opportunity to speak face-to-face with experienced OR&A professionals.

The conference had a high level of attendance continuing the trend from the previous years and confirming that it provides the NATO OR&A community with an essential platform to discuss ideas and concepts to enable accelerated military decision making.

Short opening remarks to welcome the audience were given by Mr Rob Solly, Division Head Analysis in Dstl and by Brigadier General Henrik Sommer from HQ SACT who challenged the participants to be relevant in their study of current NATO issues of Defence and Deterrence.

For the first time this year, the conference was opened in plenary by the NATO Chief Scientist who encouraged the audience to remain grounded in the empirical evidence that makes analysis support so very valuable for the decision maker. Specialist topical key-notes were delivered by LGen Radford, Commander HQ Allied Rapid Reaction Corps (ARRC), who elaborated on the usefulness of OR&A in his experience in operations, and from Dr David Alberts who lectured the conference on Maturity and Agility requirements for Command and Control in future operations. In his end-note Mr Alan Shaffer, Director STO Collaboration Support Office (CSO), equated OR&A to intelligence underscoring that the primary task of OR&A is to provide the commander information and data to support decision making. His message was that OR&A should be marketed better by spreading the success stories of OR&A to reach operators and decision makers. Overall, the presentations and discussion served to confirm that the NATO OR&A community of interest is grappling with a multitude of challenges in its traditional approach to analysis and will have to embrace emerging technologies in analytics without losing approaches that allow it to provide on-the-fly advice.

## 2.0 DISCUSSION

The programme committee received many interesting and thought provoking submissions in response to the call for papers. The papers selected were those that best supported the conference theme of Enabling Accelerated Military Decision Making and three streams of Emerging Technology, Multi-Methodology and Back of the Envelope. To help participants identify the papers of most interest to them, the papers were grouped into the following topical streams for presentation: Defence Planning, Technology/Tools for OR&A, Scenarios/Futures, Modelling, Intelligence, Planning in Complex Environments, All Data, Maritime, and Supporting Decision Making.

Altogether the conference papers presented a mixed view of practical applications of OR&A in a defence context and novel methods and lessons learned for the advancement of OR&A. The papers also offered a strong opportunity for members of the OR&A community to stay abreast of the latest techniques and approaches in current use and see how OR&A is making a difference to decision making across a range of defence applications, from forecasting the future and scenario-based planning, to providing immediate advice to operational commanders in deployed HQs.

## 2.1 PLENARY: OR&A COMMUNITY UPDATE

In order to engage with the community at the conference and update them on developments on the OR&A capability within NATO, two sessions were held in plenary.

The first was a presentation prepared by Ms Dani Fenning, Ms Sue Collins and Ms Bianca Barbu from Allied Command Transformation (ACT) on “*Helping NATO to think differently: The successes and lessons identified of Alternative Analysis*”. Ms Fenning explained how ACT has been leading the creation of a new capability in NATO to inject independent, critical thinking and alternative views to enrich existing decision making processes. The capability is being called Alternative Analysis and centres on a set of structured thinking techniques and a process for applying those techniques in facilitated workshops in support of decision making.

The second was an open discussion led by Ms Jacqueline Eaton from the STO Office of the Chief Scientist (OCS). Ms Eaton encouraged the audience to share their ideas for how to invigorate the NATO OR&A community going forward. A key concern of the community was a feeling of being under-valued and under-utilized when it came to the provision of analytical input to important decisions. It seemed that in some areas analytic input is routinely sought whereas in others, where analysis could really provide significant benefit, it is rarely sought. The key-note speech of LGen Tim Radford was exactly what the community needed to hear coming from a senior officer with a track record of asking for OR&A support and feeling the benefits throughout his career. The session was quite short and so there was not time to look into solutions for this issue. However, it should be something that the community devotes some time and energy to address in the future.

## 2.2 STREAM SUMMARIES

### 2.2.1 Stream 1 - Defence Planning I (Chaired by Ms Sylvie Martel)

This stream had two presentations. The first presentation “*Collaboration between Operational Analysts and Military Staff in the NATO Defence Planning Process (NDPP)*” by Mr. Glenn Richards and Cdr Sokratis Karamoutas was prepared jointly by ACT – NATO Communications and Information (NCI) Agency. It was presented by Mr Glenn Richards from NCI Agency. Mr Richards introduced a range of OR&A techniques and methods developed to support the identification of capability requirements in the NDPP, and highlighted the essential collaboration between analysts and military staff throughout the application of these methods. Some of the challenges associated with such collaboration were also discussed. This presentation led to engaging

discussions with the audience on the understanding of “minimum” in the Minimum Capability Requirements produced within the NDPP, the challenges faced when defining a hierarchy of capabilities (joint vs. service-specific capabilities), and the suitability of current OR&A techniques and tools to address the current security environment.

The second presentation “*Operational Analysis Support to Alliance Future Surveillance and Control (AFSC) Programme*” was also a joint ACT-NCI Agency brief on work by Dave Allen and Andrew Wind, both from NCI Agency and Mr. Simon Purton, Operational Analysis Branch from ACT. Mr Allen discussed the complications of providing OR&A support to the AFSC Programme which involves long term decisions, and how a broad range of methodologies are being applied to address these complications. The methods introduced included the development of scenarios and vignettes set in the 2035 timeframe, the use of a mission-to-task decomposition to identify AFSC potential use and required interfaces, and the use of influence diagrams to validate capability architectures. Some of the topics raised during the Q&A session included the challenges of identifying potential tasks for the AFSC as it is very difficult to get a sound appreciation of what the operational environment might be in 20+ years’ time; it was highlighted that this work is anchored on ongoing strategic-level assessment of the future security environment including the Strategic Foresight Analysis work. Some questions also addressed the type of supporting tools / software used to conduct the analysis of capability requirements.

### **2.2.2 Stream 2 - Technology and Tools for OR&A (Chaired by Mr Andy Bell)**

The technology and tools for OR&A stream had two presentations. The first presentation “*The Application of Artificial Intelligence in Operational and Strategic Level Planning*” was presented by Major Kathleen McKendrick, Course Director, NATO Centre of Excellence (CoE) Defence Against Terrorism (NATO). Major McKendrick described her analysis of where and how Artificial Intelligence (AI) could potentially be best employed to support the operations planning process as described in the Comprehensive Operations Planning Directive (COPD). Limitations and risks of the use of AI to support complex decision making were also discussed. Major McKendrick concluded by calling for a redesign of the Operational Planning Process, better education in automated analysis tools and increased partnership with industry for safe AI.

The second presentation “*Big Analytics and Active Learning Applied to Cyber Security*” was offered by Mr Christophe Meyer and Ms Martine Lapierre from Thales Communications & Security. Ms Lapierre introduced the audience to the use of big data and machine learning to reduce the risk of missing a cyber threat at a Cyber Security Operation Center. Several machine learning approaches were introduced to the audience and their application for cyber threat detection was discussed. The importance of explainable AI was also highlighted and the presentation concluded by suggesting that a combination of active learning and explainable AI was where R&D investment should focus to achieve positive interaction between AI and cyber experts.

### **2.2.3 Stream 3 - Scenarios/Futures (Chaired by Mr Phil Sparrow)**

The scenarios/futures stream had 3 presentations. The first presentation was “*Speeding Up Scenario Development for Games and Exercises*” which was prepared by Mr Håvard Fridheim and Mr. Stein Malerud from the Norwegian Defence Research Organisation (FFI). Mr Feidheim gave the presentation on FFI’s revised approach to scenario development based upon a problem structuring approach. The discussion on the presentation raised the topic of whether the process could deal with competing demands for levels of detail from the various stakeholders and Mr Fridheim confirmed that this was possible and usually addressed in the initial stage using the questionnaire – the questionnaire form is freely available but unfortunately only in Norwegian. He also confirmed that while the process is most often used to create new scenarios from scratch, it can also be useful for updating old ones. In these instances the same steps (i.e. using questionnaire, identifying factors) are used to see if the assumptions, requirements and contents of the old scenarios are still valid. If they are not, it helps to concentrate the required update efforts.

The second presentation was “*Visions of Warfare 2036: a futurist prototyping methodology to support long term decision making*” by Mr Mark Tocher from NATO ACT. Mr Tocher presented the futurist prototyping approach adopted to produce the Vision of Warfare 2036 document provided to the conference participants. Mr Tocher explained that the intention is to see whether the work could be incorporated into the NDPP and this would be discussed in the near future. It was observed that during the workshop associated with the work there was a need to achieve a mix in the audience of ‘believers and non-believers’. For some the approach was seen as ignoring the reality that some platforms, e.g. aircraft, will not change that fast. But it was counter argued that while the platforms may be unchanging, in a lot of cases, the technology within the platforms will change significantly.

In the third presentation of this section “*Use of Morphological Analysis in Decision Support*” by Dr Bianca Barbu and Mr. Simon Purton, from NATO ACT. Dr Barbu briefed ACT’s approach to Morphological Analysis and highlighted how it had been utilised to look into the AFSC Requirements. The audience asked whether a software program to support the approach had been developed and it was confirmed that a third party company had produced a programme for ACT tailored to their needs. Clarification was also sought with respect to how much had the process been influenced by the assumed platform (i.e. an aircraft) and Dr Barbu confirmed that the process was used to capture the requirements and was essentially platform agnostic. In addition the question was raised as to how consensus on output was agreed. The speaker here reiterated that it was important to have the right people involved from the start to reach assessments and that the most interesting output areas are, in her experience, those that are assessed as ‘yellow’ and these tend to be the focus of most of discussions.

#### **2.2.4 Stream 4 - Modelling (Chaired by Mr John Redmayne)**

Two presentations were given in the modelling stream. The first presentation “*The Mission Command Model*” was presented by Mr Nick Bell from the UK’s Dstl. The Mission Command model is a highly innovative tool which uses a mathematical optimisation based Mission Planner to provide greater automation of campaign level simulation modelling. A question was posed as to whether the approach could work at the battlegroup/brigade level as opposed to the campaign level. Mr Bell responded that it depends upon the level of detail required, but the answer is probably yes, but it may require nested planners i.e. one for the theatre commander and one for the battlegroup commander. Dstl have not tried this to date and it would require careful balancing of complexity and computational load.

The second presentation was “*M&S in Support of the Operations Process: Challenges and a novel implementation*” by Ir. Bas Keijser, Mr. Guido Veldhuis and Mr. Nico de Reus who are all researchers from the Military Operations section of the Dutch Defence Research Agency (TNO). Mr Keijser described eight challenges for effective use of M&S as part of the operations planning process, and then offered a novel M&S-based decision support environment in which knowledge of the operational environment and mission accumulates within simulation models to assist decision-making. He explained that the great advantage of the model was its inherent flexibility: the analyst can change the parameters, so for example it could account for interdependencies between the non-military actors. But the underlying dynamics of the situation are an important aspect that needs to be understood. Ir Keijser indicated that TNO had done limited verification to date: the intent was to demonstrate the potential contribution to decision-making of a flexible simulation model rather than provide an exact output.

During this stream a more general discussion arose regarding M&S within NATO Commands to support course of action analysis as part of the operations planning process. Challenges noted were: models being too situation/scenario specific, and Commanders often requiring answers in such short time that using M&S was not feasible. Subsequent discussion concluded that effective support to NATO’s operations planning process would depend on the types of tool available. Going forward, AI and machine learning approaches may be able to support the Commander’s decision making at the ‘speed of relevance’.

### **2.2.5 Stream 5 - Defence Planning II (Chaired by Ms Jackie Eaton)**

Three presentations were given in this second stream on analysis support to defence planning. The first presentation “*Military-Analytic Method to Support Refinement of Force Packages in the NATO Defense Planning Process (NDPP)*” was offered by Mr Alan Campbell from the Operational Analysis Service Line at the NCI Agency. Mr Campbell explained the structured military-analytic method he developed and how he applied the method to revise Force Packages developed within NDPP Step 2 Phase 1 to align with the final Minimum Capability Requirement (MCR) 2016. He concluded that it is possible to optimize the structural elements to align with the MCR 2016 while retaining military validity and that all domains can be consistently represented under the structural framework. However, he warned that it was important to understand the strengths, weaknesses and limits of the analytic techniques and so it was vital to maintain flexibility and evolve the approach. Furthermore, in some cases, brute force computation, modern computers and weekends had delivered a faster, better solution than the optimization model.

The second presentation was “*Utility Assessment of Maritime Unmanned Systems in Anti-Submarine Warfare*” delivered by Mr Alex Bourque from the Centre for Maritime Research and Experimentation (CMRE), which is part of NATO STO. Mr Bourque explored the question of how to assess the value of Maritime Unmanned Systems (MUS) in Anti-Submarine Warfare (ASW) missions. He first summarized other work that had been done in this area and then explained how he developed a mixed methodology that enabled ‘on-the-fly’ assessments of the utility of the MUS based on national priorities. Through the use of his method it was clear that, compared to the manned baseline, existing MUS were not as capable or as flexible, but excelled in some functional areas.

“*A Steady-State Analytical Model to Assess the Impact of Warship Characteristics and Fleet Size on ‘Naval Presence’*” was the third presentation in this stream. This presentation was prepared by Dr Bart van Oers, Mr Richard Logtmeijer and Mr Siebe Otten of the Defense Material Organization (The Netherlands). Mr Logtmeijer delivered the presentation. Mr Logtmeijer explained that the Dutch authorities are in the process of renewing their navy and at this early stage in the procurement, decisions need to be made about the fleet composition so it is helpful for decision makers to have access to visualizations that help them to understand how the various fleet composition decisions will affect the time on station of the maritime force. Mr Logtmeijer presented the deterministic analytic model and visualization tool that was developed to assist decision makers with this complex issue.

### **2.2.6 Stream 6 - Intelligence (Chaired by Dr Ana Barros)**

The importance of sound intelligence analysis for operations was highlighted by all three presentations in the intelligence stream. The presentations also showed the added-value of OR&A methodologies to support intelligence analysis at different levels and to evaluate current analysis methodologies.

The first presentation was “*Assessment and Communication of Uncertainty in Intelligence to Support Decision-Making*” by Dr David R. Mandel who is a Defence Scientist in the Socio Cognitive Systems Section of Defence Research and Development Canada. In particular, Dr Mandel’s presentation addressed some of the research of SAS-114, such as the exploration of the information credibility on intelligence analysts’ judgments as well as the effectiveness of meta-information on analysts’ judgments. Also the results of the investigation of the communication fidelity of standards for communicating uncertainty in intelligence products were presented. These cases clearly showed how a scientific OR&A approach can be used to create new insights on how to effectively conduct intelligence analysis.

“*A Multi-Methodology Framework for Modelling Opponent Organizations in the Operational Context*” was the second presentation by Dr Bob van der Vecht, Dr Ana Barros, Dr Bert Boltjes, Dr Bart Keijser and Mr. Nico de Reus who are all Research Scientists in Military Operations at TNO. Dr Van de Vecht’s presentation introduced some exploratory research aimed at creating a modelling framework to model the dynamics of

opponent organisations and their potential reactions to interventions. The preliminary results showed the potential of this approach for understanding opponent organisation resilience and there was some discussion on their applicability for military decision making and in particular for the intelligence community.

The third presentation was “*Terror Pattern Analysis*” by Mr Levent Berke Çaplı and Dr Altan Özkil from the Defence Research Applications and Research Center at Atılım University Turkey. Dr Özkil’s presentation addressed how OR&A techniques can be used to analyse and detect patterns of terror events between 2010 and 2015 in the South-Eastern Anatolia region. The presentation also addressed how open sources can be utilized to compensate for a lack of data and how the data should be collected in order to create a terror data repository to support knowledge retention. The conducted analysis identified (less obvious) patterns in the terror attacks and unveiled some of the tactics used which provided valuable insights for the military organisation and support for counter terrorism.

### **2.2.7 Stream 7 - Planning in Complex Environments (Chaired by Mr Han De Nijs)**

This stream on planning in complex environments contained two presentations. The first presentation “*A Framework for Risk Analysis to Support Operations planning*” was prepared by Mr Stein Malerud and Dr Håvard Fridheim who are both Principal Scientists at the Norwegian Defence Research Establishment (FFI). Mr Malerud explained that a recurring issue in military planning is how to cope with uncertainties associated with the future situation and operational environment and presented a risk analysis approach intended to support operations planning. The method combines scenario and capability analysis with risk analysis to identify vulnerabilities and provide a basis for risk management. It can be used to support development of more robust and adaptable plans and provide input to revision of plans.

The second presentation was “*Data Farming Decision Support for Operation Planning*” by Dr Johan Schubert, LtC Stephan Seichter, Mr Alexander Zimmermann, Dr Daniel Huber, Mr Daniel Kallfass and Dr Guro K. Svendsen. Dr Schubert briefed and identified that there is a possibility in Phase 3b of the NATO COPD, which is to develop, analyse, compare and refine Courses of Action (COA), to benefit from data farming. He presented the Data Farming Decision Support Tool for Operation Planning (DFTOP) which was developed by MSG-124 as a potential solution and was successfully demonstrated at Coalition Warfare Interoperability Experiment (CWIX) 2016 and 2017. The tool offers three ways of interacting: data can be analysed, results can be visualized, or the analysis can be influenced by the user. The tool automates statistical analysis and allows the military commander to focus on the big picture of how to win in a military context and when we will win in different specific situations.

### **2.2.8 Stream 8 - All Data (Chaired by Mr Andy Bell)**

The all data stream contained three presentations. The first presentation was “*The Importance of Multiple Perspectives and Methods to Enable Military Decision Making*” by Ms Laurie Fenstermacher from the US Air Force Research Laboratory. Ms Fenstermacher explained how it is important to understand both the first person and third person perspectives of observed behaviour if we are to identify the difference between behaviour with mischievous intent versus disruptive intent. Ms Fenstermacher showed how an aggregated model that takes into account events, sentiment and discourse is the best predictor of future behaviour, and that using past events to predict future events was the worst predictor there is, but is still the most frequently applied.

The second presentation was on “*Exploiting Data from Sensors of Opportunity from Across the Battlespace*”, which was delivered by Mr Dave Steer a Senior Principal Consultant at QinetiQ. Mr Steer’s presentation introduced the idea of a Single Intelligence Environment Corpus which would process data collected automatically by all platforms within a battlespace. Essentially the idea was that Intelligence Surveillance and Reconnaissance data could be collected as a background activity without operator involvement and automatically produce textual reports explaining what was found. Two approaches to collection and processing

were tried: Return to base disk transfer and on the platform processing. It was found that with minor changes to Tactics Techniques and Procedures disk transfer could work easily, but that a fully integrated capability with real time alerting would need integration into the mission system.

*“Finite to Fail but Infinite to Venture: Data Collection and Analysis in Complex Environments”* was the third presentation in the stream. It was presented by Mr. Robert Grossman-Vermaas, Vice President, Technical Services, Crisis, Conflict and Governance, IBTCI. Mr Grossman-Vermaas focussed on the data collection challenges inherent in understanding complex environments with whole-of-government interventions. He recommended multiple data collection methods and triangulation of data to get good quality data. Mr Grossman-Vermaas stated the case for monitoring and verification of data collection in complex environments as a necessary component of quality data collection and offered a five tier scale to describe different levels of effort with respect to monitoring and verification. He concluded with the remarks that as NATO embarks on increasingly various and unpredictable missions, the challenges will increase and the need for monitoring and verification will be even more important.

### **2.2.9 Stream 9 - Maritime (Chaired by John Redmayne)**

The maritime stream addressed new challenges in maritime mine counter warfare relating to the introduction of new technology like autonomous mine hunting systems. It contained two presentations. The first presentation was *“Autonomous Mine Hunting Systems”* by Mr. Christopher Strode a researcher at the CMRE. Mr Strode’s presentation addressed how OR&A modelling is used for evaluation of mine hunting performance. This modelling provides operators and planners insight into the effectiveness of the use of the new autonomous systems and can also be used on board of the autonomous vehicle to increase their autonomy (by providing the vehicle itself with the capability to monitor its performance and make appropriate adjustments to increase its effectiveness.

The second presentation was on *“Rapid Operational Effectiveness Modelling and Analysis to Support Ship Design and Procurement”* by a team from TNO consisting of: Mr. Guido Veldhuis, Dr. Robbert van Vossen, Ms. Anna van Velzen, Mr. Rinze Bruining, Dr. Ir. Guus Beckers and Dr. Ir. Bart van Oers. Mr Veldhuis delivered the presentation and focused on the use of a flexible simulation tool Holon to support and evaluate the feasibility and implications of different ship concepts for mine countermeasures operations and the required mix of unmanned systems needed to conduct such an operation. This study showed how the results of these analyses were used as one of the key inputs for the fundamental design choice that will shape the future mine countermeasure fleet of The Netherlands and other European Defence Agency partners and their concept of operations.

### **2.2.10 Stream 10 - Supporting Decision Making (Chaired by Mr Han De Nijs)**

The final stream focussed on how to support decision making with an OR&A capability. The stream contained three presentations. The first presentation was on *“Supporting Strategic Decision-Making in the UK Government: Realizing Benefits from the Use of Multi-Methodology”* by Ms Jane Christie, an ESRC CASE researcher at Kent Business School, University of Kent. Ms Christie revealed how surveys show how most practitioners use multi-methodology in at least some of their studies these days. Her survey also showed how combining methods gives better research results for decision makers and has the potential to reduce the time it takes to conduct studies. However, some of the key challenges with using multi-methods is how to integrate findings and stakeholder views and how to choose and link methods.

The second presentation covered the Estonian experience of *“How to Build Up OR&A Capability in Support of Military Decision Making. Experiences and Challenges.”* The presentation was delivered by Lieutenant Colonel Sten Allik, the Chief of the Estonian Center for Applied Research. LtC Allik described how since 2014, the Estonian Defence Forces have been building their OR&A capability from one analyst to the current situation with more than nine analysts. The effort had to start at the military academy to include OR&A training



in the curriculum and include students at all levels. The idea of starting from the ground up was to influence the mindset and military culture towards a more evidence based decision making culture rather than a decision based evidence culture. LtC Allik explained how decision makers had been convinced one project at a time that there was value in building the capability.

The third presentation “*Enabling the 1st Step and the Final Mile: The Power of MOD’s Science Gateway Network*” was by Ms Louise Hoehl and Mr Thomas Scales from the Senior Science Gateway Head Office of Defence Science and Technology Customer Engagement at the UK MOD. Ms Hoehl introduced how the UK Dstl has placed scientists, analysts and engineers throughout the staff of the UK MOD to work alongside decision makers and provide essential assistance to those decision makers in formulating their questions in a way that science and technology research can provide added value and in helping the decision makers make sense of the results they receive, and make effective use of the products of the science and technology research community to support their decision making. Ms Hoehl emphasized the need to find the right people to take positions within the network, that is, those people who have a strong background in science and technology but are also able to communicate effectively with decision makers to put the work in context.

## **2.2 OR&A TRAINING SESSIONS AND WORKSHOPS**

For the first time, this year training sessions were held at the conference with the intent of educating and developing the attending analysts in different OR&A techniques. Also, one of the Systems Analysis and Studies collaborative research studies hosted a workshop to seek feedback on their developing method for assessing technologies in various future contexts.

### **2.2.1 Problem Structuring Training**

This training on problem solving was offered by Mr Guido Veldhuis from the TNO, The Netherlands. It focused on collaborative problem structuring using the group model building approach and helped participants experience its potential in a hands-on workshop. It looked at using causal loop models for problem structuring, discussing both the methodological background of the approach and sharing best-practices for applying the method in group sessions. Following the instruction, a “hands-on” problem structuring session was run in which the participants tackled a given topic together.

### **2.2.2 Social Network Analysis Training**

Mr Clovis Autin, a Senior Operational Research Analysts with the Joint Analysis Lessons Learned Centre, ran training focused on the importance of understanding network structure using Social Network Analysis (SNA) and demonstrated the potential of SNA in a practical exercise session. The SNA session got participants acquainted with using SNA for understanding network structure. After a short introduction on the different aspects of SNA, participants learned how to use the software NetDraw and how to import a dataset into the software. A practical exercise followed in which participants analysed a specific dataset and identified the key players by using different algorithms integrated within NetDraw.

### **2.2.3 Futures Assessed Alongside socio-Technical Evolutions (FATE) Workshop**

Dr Gitanjali Adlakha-Hutcheon, Defence Scientist, Department of National Defence (Canada) ran a workshop introducing the analytical method (FATE) developed by her group to examine futures. As a defence/strategic planner in the year 2035 – the method is meant to provide insights into which technologies will thrive (and therefore to plan for) in which type of projected future scenarios. Participants contributed to the SAS-123 study by providing feedback on the method, and sharing with the study team what they are looking for in a method to assess future technologies and how the method could be made more relevant to them.

## 2.3 VIEWPOINTS FROM SENIORS LEADERS

Four Senior Leaders from the NATO OR&A Community were invited to share their experiences of OR&A with the audience:

- Dr Thomas Killion, NATO Chief Scientist
- LGen Timothy Radford, Commander HQ ARRC
- Dr David Alberts, Senior Fellow at the Institute for Defense Analyses
- Mr Alan Shaffer, NATO Collaboration Support Office Director

While Dr Killion and Mr Shaffer set the scene and closed the conference, the speeches by LGen Radford and Dr Alberts were more topical. Dr Alberts' paper associated with his talk is included later in these proceedings. We are also grateful to LGen Radford's staff for providing the following redacted version of LGen Radford's speaking notes for these proceedings.

### 2.3.1 Speaking Notes from LGen Tim Radford, Commander ARRC

Thank you Dr Killion for your kind introduction and for the opportunity to speak to you this morning. Currently I'm serving as COMARRC<sup>1</sup> (the UK's Corps HQ) and have done so for a year on the back of being Deputy Commander of Op RESOLUTE SUPPORT in Afghanistan.

My own background – COMARRC – 33/11 – I have been very fortunate to have commanded at every rank and have had a blended career of 11 years on ops. So I suppose I have a little operational experience against which to offer some thoughts on Operational Research and Operational Analysis.

As I'm sure many of you will be only too familiar, perhaps one of the most famous recorded examples of military operational analysis was in the late 19<sup>th</sup> century, when in 1869 Joseph Minard designed the first pictograph – illustrating statistical information in pictorial form. His chosen subject was Napoleon's great invasion of Russia in 1812. By gathering and checking information from many sources, he was able to show very clearly the correlation between the size of the Army, the distance marched on the retreat from Moscow set against the temperature.

Minard's pictograph presents in a clear and immediately understandable way the erosion of the Grand Armée from 422,000 to 100,000 on its entry into Moscow and then the terrible impact of cold and distance on the Army during the retreat. Just 10,000 men were left to re-cross the Neiman River on 12 December at the end of the campaign. Minard's pictograph thus showed how statistics could be brought to life and understood pictorially. Useful in hindsight but of course much more valuable as a predictive tool. Today we are very familiar with this approach but Minard's work remains one of the most impressive by virtue of its simplicity and clarity.

Last week I took the HQ and a number of Divisional Commanders and senior Corps enabling Brigade Commanders on a terrain walk to Poland, Latvia and Lithuania as part of our Corps Training. We took 32 stars altogether and a smattering of Colonels and, guided by our academic Professor Niall Barr, we spent an hour or so on the Neman during which we dwelt, albeit briefly, on the brilliance of Minard's pictograph and by extension the value of OA<sup>2</sup>. It had real impact for what I suspect may be an influential cohort in the medium to long term.

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<sup>1</sup> Commander HQ ARRC

<sup>2</sup> Operational Analysis (the UK use the term Operational Analysis as synonymous with Operational/Operations Research)

Today, the HQ, HQ ARRC (450 strong 65% UK and 35% 23 other nations), sits as one of 9 NATO Corps-level HQ that are categorised as High Readiness Forces (Land). However we were the first to be set up in 1992, and, since then, the ARRC has deployed to Bosnia in 1995, Kosovo in 2000 and Afghanistan twice in 2006 and 2011.

It was built on the nucleus of the old 1(BR) Corps so it's history as a Corps HQ dates way back to 1815 when it fought at Waterloo as 1<sup>st</sup> Corps – even then as a multi-national HQ under the first commander – the Prince of Orange who, interestingly, entered the British Army in 1811 at the age of 19 and promoted to full General 3 years later, spending only 17 days in the rank of Lt Gen – I'm pleased to say a little different to today's promotion regime! Since then the HQ has commanded and led with distinction in South Africa in 1876 under Redvers Buller, during WW1 under Haig, in WW2 under Croker at Normandy and then in Germany for 40 years as 1BR Corps, transitioning to the ARRC before returning to Gloucester in 2010.

And my sense is that we've had a long relationship with Operational Analysis and Operational Research. Our OA Branch, currently 8-strong (5 x mil of which 2 are analysts and 3 civilian) which increases to 10 on deployment, can trace its lineage back to 21<sup>st</sup> Army Group in 1943, when it was styled as No2 Operational Research Section. Perhaps typically, when Montgomery was asked by the Chief Scientific Officer of the time if he would accept a small band of scientists to observe his operations, he replied 'I observe my own battles'.

Later, he recognised and acknowledged the need for 2 Operational Researchers who were invited, quietly, to join his staff for the duration of the war, with an analyst even landing on D Day.

Those 2 ORs<sup>3</sup> subsequently became the OAB<sup>4</sup> in 1 BR Corps and then latterly in HQ ARRC. I'm pleased to say that we have moved on considerably since 1943.

As I mentioned, I've had the huge privilege of serving on operations for 11 years of my 33 years in the Army – in Northern Ireland, the Balkans, Iraq, Sierra Leone and 3 years in Afghanistan.

During that time I've seen the enormous value that OA can bring to an operation, and its ability, crucially, to help shape commander's decision-making. As you can imagine making decisions, with humility, of sometimes national significance, whether that be in Northern Ireland during periods of heightened security, during highly sensitive covert operations, during times of increased political tension or, more recently, on point as Task Force Helmand Commander in the brutal summer of 2009, carries with it considerable responsibility and required as much accurately analysed information as I could lay my hands on.

In both cases OA played a central role in shaping my decisions, and those of my staff and my subordinate commanders. Now, at the ARRC, I continue to place considerable store on the products from Angus Main and his OA team and recognise that OAB is just as valuable at the higher tactical, lower operational Corps HQ level as it proved to at the sub tactical level in a Bde or even in my Battlegroups in Southern Afghanistan.

### **Northern Ireland (NI)**

I suppose though my first contact with OA and OR was in NI where I served for 7 years in various guises. As many of you will be well aware Scientists and Analysts were deployed in the Province since 1969, with a small section in HQ Northern Ireland Scientific Advisor (SCIAD) undertaking research and analysis.

For 'Green' Army framework operations this hugely productive team provided, among other products, crucial analysis on POL, route clearance, incident and patrol statistics (200K reports in a 2 year period). Invaluable in

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<sup>3</sup> Operational Researchers

<sup>4</sup> Operational Analysis Branch

its own right but arguably the real value of which was when it was considered and contextualised in conjunction with wider military judgement.

At one stage, by way of illustration, following some broad campaign analysis in relation to Permanent Vehicle Check Points (PVCs) it was recommended that because there had been no significant finds made around PVCs they should be closed down. A sensible and logical deduction which played into the arguments of those who wished to save or redeploy manpower and resources until their real value was seen in terms of reassurance to the population predominantly on and around the Border with the South; a simple example perhaps but one which emphasises the importance of collaboration at all levels.

Gaining a technical advantage over the Republican and Loyalist terrorists was key and SCIAD NI was central to this particularly in terms of trials and threat analysis. SCIAD also provided a key link to the UK research community and allowed rapid prototyping and field testing. In the 1980s, for example, following the capture of a PIRA device a bespoke technical solution was introduced within a month, rendering the device obsolete within 3 months.

This, as with many other pieces of research, undoubtedly saved lives. On the covert side the scientists and analysts were particularly active in the fields of both electronics and surveillance; a key weapon in the GOC and Chief Constable's arsenals and the brilliance of which played a major part in sowing doubt in the mind of the terrorist and ultimately bringing them to the political negotiating table.

I'm reliably informed that the SCIAD NI team also became involved in some of the more bizarre ideas to be tested such as the foam gun – a device for covering rioters with thick foam, and 'instant banana peel' a liquid capable of making road surfaces slippery, making rioting almost impossible. Some novel solutions with a wonderful mind-set of finding solutions to tactical challenges.

### **Balkans**

In the Balkans, we drew on some of our hard-won knowledge from NI and adapted it to our first true experience of Coalition operations. During the ARRC deployment the OAB was at the forefront of campaign monitoring, gauging the performance of the former warring factions' against the requirements laid down in the Dayton Peace Agreement. In addition it was tasked with monitoring the return to normality across Bosnia and Herzegovina; still considered to be an exemplar of campaign monitoring. It included obvious data sampling such as outbreaks of violence and casualty numbers but, of note, also included normality indicators such as sales of underwear, lipstick and the presence of flowers in front gardens. Confirmation, if ever there needed to be one, that warfare is indeed a very human endeavour; an unsurprising comment perhaps from an infantry officer.

The OAB deployed again with HQ ARRC as part of the Kosovo Force (KFOR) during which it undertook the compliance monitoring as the Kosovo Liberation Army demilitarized. The resulting analysis, spread across a spectrum of 148 compliance tasks, harvested from across the HQ and its deployed formations, was presented weekly to Gen Mike Jackson to allow him to gauge progress and inform his Key Leader Engagement with the Kosovo Liberation Army. Of note both IFOR and KFOR had clear political aims linked to fixed military objectives which were conducive to campaign analysis and assessment. This was less clear in Iraq and Afghanistan.

### **Iraq**

In Iraq in 2003, commanding a small group of soldiers on the edge of Basra, I had less call for OA but dual-hatted as an Liaison Officer (LNO) for 1 UK Armoured Division, I know that the Divisional HQ was supported extremely well by its OA team throughout the initial combat operations. That team successfully conducted combat resolution modelling and force ratio analysis. Latterly, analysts played a major part in the stabilization

effort monitoring reconstruction efforts in Multinational Division South East (MND (SE)). I think Iraq serves to highlight a number of issues, in particular, in a challenging security environment how best to use the Force Elements to gather data.

I would argue that this is initially dependent on convincing particularly those less enlightened military commanders of the value of OA to support decision-making.

### **Afghanistan**

Over the past 15 years there have been myriad examples, at every level, of how OA has helped, indeed shaped, the campaign. Some commanders used it more than others. Gen John Allen, as COM International Security Assistance Force (ISAF) in 2011 and 2012, was a statistician by background and his daily briefs were banded full of detail. He was forensic in his analysis and to great effect; a brilliant and decisive leader. Others were less inclined to lean on OA favouring a more intuitive approach in terms of decision-making.

Encouragingly, during my last tour as DCOM RS, the Afghan National Defence and Security Forces began to get more involved in the analysis of data, with polling and manpower flow perhaps the most obvious illustrations. This was, in no small part, driven by the National Security Advisor (NSA) Atmar and President Ghani himself who during my regular interactions with him was very keen to understand detail, trends to support his own decision-making.

At the tactical level, during Op HERRICK 10, in Helmand Province, as the Brigade Commander, I relied heavily on my wonderful OA team, during what was a very busy tour. In Lashkar Gah I had 2 analysts Floss House and Amy de Vries and a Deputy SCIAD Kim Simpson.

This very impressive, all-female team sat right on the frontline in equal danger to the remainder of the HQ and undertook some vital work as we planned to counter the Taliban threat. We arrived in Apr 2009 and left 6 months later at the apogee of fighting. To give you a feel for the context of your tour, Mullah Omar has declared to the Quetta Shura that Helmand was to be his ME that summer, resulting in an influx of foreign fighters. In addition we shaped the arrival of 10,000 US Marines into our AO and, alongside our Afghan brothers, we fought a major offensive operation to link up the Provincial Capital Lashkar Gah to the economic capital Gereshk and created the conditions for Elections. In a battle of wills in this totemic Taliban heartland we made a collective statement and regained the upper hand.

In so doing we conducted over 500 patrols a week across the respective Areas of Operations, we faced 1780 Improvised Explosive Devices (IEDs) (1209) and tragically I had 76 soldiers in my TF of 10,000 killed with over 300 wounded. So I was asking all my people to operate in a large, unfamiliar, complex, congested and highly dangerous battlespace. For each Operational Analyst, as for all of us, these were challenging times both professionally and personally.

My OAB's time was spent, among other things, analyzing IED plots, IED events, patrol statistics, vehicle tracks, weapons effects, logistic calculations, performance of armour, capturing tactical lessons, vehicle performance and cultural understanding, as well as some more sensitive projects.

Prior to offensive operations much work was done to calculate population density where no information was available, to calculate force ratios for operations and assessing traffic into and out of Babaji to assess whether our shaping operation was having an impact. More widely the SCIAD facilities in Bastion and Kandahar allowed successful trials of Urgent Operational Requirement (UOR) Counter-IED (C-IED) equipment to take place.

A flavour only of some of the tactical successes and benefits of close cooperation between a hugely capable, forward-leaning OA team and a HQ that embraced it.

The ability to identify trends, understand data in relation to the ongoing operation or series of operations, to conduct field trials in theatre, to offer impartial objective advice in a highly-charged atmosphere and establish reach-back to National or NATO Science and Technology organizations was invaluable to me as a commander.

### **Challenges**

So in relation to OA and OR, commanders and those responsible for decision-making at all levels face a number of practical challenges prior to, during and after any operational deployment. I'll highlight 5 to illustrate.

First, there is the danger of incomplete or an inaccurate data set, data that has been inherited from a team on a previous rotation (perhaps from a different Nation) which then requires an understanding of a Commander and the HQs approach to tactical risk.

Second, there is an obvious requirement to send physically and particularly mentally robust, courageous personnel into theatre with a desire to add value and, ideally, with strong emotional intelligence. With Amy and Flis during the hard yards of HERRICK 10, I was blessed.

Third, explaining to the military personnel in the HQ the roles and value of the OAB and having a military champion (ordinarily the Head of Ops or Plans) was essential.

Fourth is the requirement to have regular access to the Commander and to have a clear understanding of his intent. This means building in routine meetings into what we call our battle rhythm, getting a seat at the wider Command Board to ensure currency and maintain situational awareness and also building up.

Fifth, and now reflecting my current role, I would argue that we could do a lot more to improve coherence across NATO. I may be wrong but it strikes us that there is currently no clear owner of OA within NATO, rather it's spread across a number of Centres of Excellence, with perhaps the closest being the Modelling and Simulation Centre of Excellence (CoE) in Rome.

OA staff can be found in, amongst others, HQ SACT, Joint Analysis and Lessons Learned Centre, Joint Force Command (JFC) Brunssum, JFC Naples, Land Command, Air and Maritime Commands and NATO Communications Information Agency but, candidly, our sense is that this is a loose federation of interest. We are therefore delighted that the Dr Killion has an aspiration to bring the community together.

Interestingly we think that the ARRC is the only Corps HQ with dedicated OAB manned and led by professional scientists; so we're delighted to help where we can and include it within our burgeoning Concept Development and Experimentation (CD&E) programme.

### **Concept Development, Experimentation and Recalibration**

At HQ ARRC since 2106 we have begun a 3-year rolling CD&E Plan looking at a series of wide-ranging issues such as Command and Control (C2) data flow, modelling of non-lethal effects in the information domain flow and the development of a Corps-level war-game. It's a plan that has been endorsed by the UK CGS and CDS<sup>5</sup>, and SACEUR and one which has nested within it a program that we are styling as Corps Recalibration.

On arrival at HQ ARRC in Jul 16 it was evident that over the past decade while we have been conducting Counter Insurgency (COIN) in Iraq and Afghanistan we had forgotten many of the lessons of war-fighting;

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<sup>5</sup> Chief of the General Staff, Chief of the Defence Staff

how to move, how to conceal ourselves, how to fight against a near-peer enemy and indeed how to communicate with each other.

Perhaps most worrying was our inability to command in a war-fighting scenario. I arrived at our major Exercise in Oct into a tented camp of 750 personnel. Not to my mind an act of War.....

So Recalibration this year looks at C2, next year at the Deep Battle and in 2019 at the Rear Battle. This will be conducted alongside our current routine NATO requirements to be certified periodically as a JTF HQ and LCC HQ<sup>6</sup>.

As we develop into a HQ that is fit for purpose for the 21<sup>st</sup> Century against a near-peer enemy we will need considerable OA support in work that I sense will be of interest to you. I think it's fair to say that in today's conflicts, timelines will be compressed so any analysis that can be garnered before conflict begins will be vital. As such we must re-design a scalable HQ that, when deployed in a war-fighting or potential war-fighting scenario, is: able to survive, with a painfully small forward Command Post (CP), is technically superior, Joint aware, low profile and one that can operate forward with minimal Emissions Control (EMCON).

We aim for a HQ which is mobile, protected, agile, distributed and potentially dispersed, with maximum reach-back and whose procedures empowers a staff that can cue decisions for the commander. A HQ which draws on the strengths of its multinational staff and one which understands, is connected to, and is coherent with the other High Readiness Forces (HRFs) that it will potentially fight alongside. A credible HQ with a revised doctrine, one that can analyse risk, find solutions and, where appropriate, tactfully speak 'truth to power' in NATO to drive concepts forward.

An HQ that can plan, command, synchronise, allocate resources to, and manage the battle-space for up to 5 Divisions as well as shape and command the deep battle in support of manoeuvre Divisions and Special Forces – all delivered through Integrated Action. It's also got to be a construct that allows the commander to make decisions forward, to conduct KLE<sup>7</sup> with a Host Nation as well as the myriad actors on the modern battlefield. Finally, interoperability will be fundamental in any future operation.

This needs early investment and, as a Corps HQ in this era of coalition warfare, requires us to act as a higher tactical and, on occasions, operational-level gearing between Alliance partners. So, much to interest our OAB branch and much to gain from having their input.

## Summary

The current definition of Military Operational Analysis remains apposite, namely:

'The application of scientific methods to **assist executive decision-makers** and as such is the analytical study of military problems undertaken to provide responsible commanders and staff agencies with **scientific based reasoning for decisions** and actions to improve military operations'.

In sum, as with many other areas I think there is much more that could be done to cohere and standardize OA across NATO.

I would contend that the speed of the next conflict will mean that we need to work hard now, collectively, to develop modern yardsticks against which to plan, based on empirical data and detailed analysis. As such I see OR and OA as a growth industry. Developing a Centre of Excellence or indeed a lead nation would perhaps

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<sup>6</sup> Joint Task Force HQ and Land Component Command HQ

<sup>7</sup> Key Leader Engagement

be a prudent, initial move. As our experiences in NI, the Balkans, Afghanistan and Iraq fade I believe that we must continue to recognize what Operational Research and Operational Analysis can offer, at every level (from military strategic to sub-tactical) and incorporate it into every aspect of our training and planning.

### 3.0 CONCLUDING REMARKS

The 11th NATO OR&A Conference attracted a record attendance and provided the community with a platform to discuss ideas and concepts at the cutting edge of OR&A. Collectively, the presentations and discussion served to confirm that there is a wide variety of high quality and highly relevant OR&A occurring within NATO, in collaboration among NATO Nations and partners, and in industry and academia.

In his closing remarks Mr Alan Shaffer, Director STO CSO provided his perspective on the two-day event. He equated OR&A to another form of Intelligence for the Commander in that the Operational Analyst's primary task is to provide Commanders with information and data that support their ability to make informed decisions. He went on to identify some of the important ideas that he observed during the conference:

- Everything Starts with Data
- OR&A Analysts need to Learn to Talk in “Operator Speak”
- Outputs Vary—Analysis Depends on Output
- Combat Effectiveness
- Total Life Cycle Costs
- Correlation of Forces
- Funding For Analysis is in Decline
- How Do We Deal With Unknown – Unknowns?
- Can We Even Achieve Surprise?
- It appears that the idea of automated Force Generation Analysis is being looked at again

He also indicated there were a number of topics he did not see throughout the conference that should be addressed in the future:

- Risk Management
- Probability of Occurrence / Consequence of Occurrence
- Little on Cyber / Electronic Warfare and other emerging warfighting modes
- Discussion on Challenging Assumptions
- Interoperability and System of System Analysis (except LGen Radford)
- Kill Chain Analysis (except Anti-Submarine Warfare)
- Capability verses Cost Analysis
- The need to sell the value of OR&A

He ended by saying there were many challenges left for the OR&A scientist: in modelling Electronic Warfare, in provision of analysis for Anti-Access/Area Denial, in understanding Cyber Operations, and in conducting simulations for Logistics. He expressed a need to bring in the uniformed force to the conference to help demonstrate the need for OR&A and to highlight current problems in the operational force.





**LIST OF ACROYMNS**

<b>Acronym</b>	<b>Expansion</b>
ACT	NATO Allied Command Transformation
AFSC	Alliance Future Surveillance and Control
ARRC	UK Allied Rapid Reaction Corps
C2	Command and Control
CD&E	Concept Development & Experimentation
CoE	Centre of Excellence
COPD	NATO Comprehensive Operations planning Directive
CSO	NATO STO Collaboration Support Office
Dstl	UK Defence Science and Technology Laboratory
FATE	Futures Assessed Alongside socio-Technical Evolutions
FFI	Norwegian Defence Research Organization
FOI	Swedish Defence Research Agency
IED	Improvised Explosive Device
M&S	Modelling and Simulation
MCR	Minimum Capability Requirement
MOD	UK Ministry of Defence
MUS	Maritime Unmanned Systems
NCI Agency	NATO Communications & Information Agency
NDPP	NATO Defence Planning Process
NI	Northern Ireland
OA	Operational/Operations Analysis
OR	Operational/Operations Researcher or Operational/Operations Research
OR&A	Operational/Operations Research and Analysis
R&D	Research & Development
HQ SACT	NATO Headquarters Supreme Allied Commander Transformation
SCIAD	Scientific Advisor
SNA	Social Network Analysis
STO	NATO Science and Technology Organization
TNO	Dutch Defence Research Agency
UOR	Urgent Operational Requirement