Technical Evaluation Report

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ABSTRACT

The NATO Modelling and Simulation Group Annual Symposium was held in October of 2018, in Ottawa Canada. There were several different excellent papers and posters presented, all in support of the subject of the symposium which was focused on multinational interoperability, specifically including agility for military training and operational applications. Papers were presented in support of the topic, focusing on innovation and technology development in five broad areas. Those areas were (1) modelling and simulation to support operations, (2) artificial intelligence and behaviour modelling, (3) augmented reality and emerging technologies, (4) architecture and interoperability, and (5) sensor simulation. The symposium was a success in that several key research advances and findings from different research teams from across (and beyond) the NATO member nations were presented, and well received by the attendees of the symposium.

1.0 INTRODUCTION

The NATO Modelling and Simulation Action Plan highlights a requirement for modelling and simulation (M&S) education in NATO. Symposium 159 provided attendees a forum to advance M&S in the Alliance. The combination of M&S users and developers concentrated in this one forum served to educate attendees and provided fresh ideas for the furtherance and effective use of M&S in NATO.

The NATO Modelling and Simulation Group (NMSG) Annual Symposium was held in October of 2018, in Ottawa Canada. The title and topic of the symposium was defined as 'Multinational Interoperability: Agility for Military Training and Operational Applications, Innovation in Enterprise Level Consortiums and M&S Technology Development'. The symposium hosted several quite excellent topical papers and presentations, described in detail in this report, as well as a series of extra presentations which included two national presentations from the host nation of Canada, and one invited presentation. In addition, at the symposium there was a poster session where several ongoing research projects of interest to the subject matter of the symposium were presented.

The papers were presented over two full days at the event in Ottawa, and the attendees were highly engaged and approved of the findings and results presented by the authors of the various papers. The papers were presented in support of five research areas, listed below. These research areas provided for a sequence of six different sessions (one of the research areas included enough presentations for two different sessions). The various extra presentations (the national presentations, and the poster presentations) were integrated in the schedule (in the case of the national presentations) and presented concurrently to the sessions (in the case of the poster presentations).

The objective of the symposium was to provide a forum to identify and gain input on and resolution of issues associated with NATO M&S Policy and the NMSG Action Plan, provide overviews of current NATO M&S activities pertaining to both the development and effective employment of M&S, to highlight M&S impact assessments and lessons-learned. In this, the symposium was a success.

2.0 KEYNOTES, INVITED PRESENTATION AND YOUNG SCIENCE AWARD

There were two keynote presentations presented, by the host nation. The first set the tone for the symposium and came at the beginning of the first day. The second came at the beginning of the second day and gave further insight into the state of M&S work within Canada.

There was also an invited presentation that was part of the architectures and interoperability group, and it provided a view into the state of the art of interoperability thinking and practice within Great Britain. Findings from the presentation and paper, presented below, will be of interest to all Alliance nations and technical partners.

Finally, there was also a young science award that continued to reinforce the dedication of NMSG to supporting the development and research of the next generation of modelling and simulation researchers. The topic was of high interest to many of the attendees at the symposium, and will no doubt prove to be a useful addition, as well as an area of research for the future. Details on the contents and findings of the paper are presented below, in the section on Session III, where it was presented.

2.1 Keynote 1 – Innovation for Defence Excellence and Security.

Mr. Eric Fournier, the Director General for Strategic Decision Support, representing Defence Research Development Canada (DRDC-RDDC, Canada) presented the first national presentation for our host nation of Canada. The title of the presentation was IDEaS – Innovation for Defence Excellence and Security. The presentation was made on the first morning of the symposium, prior to the beginning of session 1.

The IDEaS program was the focus of the presentation and covered how innovation is a key component in Canada's Defence Policy. The focus is on innovative technology, problem solving, and generation of knowledge – and these are all seen as critical areas for Canada and her allies. The IDEaS program was set up to encourage and fund research and development supporting this goal. The investment from the Canadian government will be $1.6b over the next 20 years.

The science and technology focus areas were presented, as well as an overview of the structure of the program and the related efforts by Canada's allies. The types of efforts that the fund will be supporting were listed and described – these include competitive projects (innovators responding to published challenges), innovation networks (developing capability in research areas), sandboxes (the ability for researchers and innovators to receive feedback on research projects), and contests (where innovators are encouraged to present solutions to problems, and the best are selected). Finally, there will also be a future effort in innovation assessment, and support of innovation implementation. Those with further interest in exploring these programs were directed to a website at www.Canada.ca/defense-ideas.

2.2 Keynote 2 – In Silico

Mr. Dale F. Reding, the Director General for Science and Technology in the Air Force and Navy (DGSTAN), representing Defence Research and Development Canada (DRDC-RDDC, Canada) presented the second national presentation for our host nation of Canada. The title of the presentation was In Silico – an overview of the current (and future) state of the art of modelling and simulation was the focus of the presentation. The presentation was made on the morning of the second day of the symposium, prior to the beginning of session 4.

The presentation was divided up into three sections – why is M&S important, how it is used in the Canadian Defence domain, and what are the future challenges and emerging technologies. Mr. Reding gave a thorough presentation of each of these three topics. In the first, he discussed the challenges that can be dealt

with (assisted, and in some cases solved) by the application of M&S. With that, he discusses some of the challenges that are present whenever M&S solutions and approaches are applied. Finally, there was a discussion of future application areas and initiatives where M&S will likely be useful.

The remainder of the presentation was a number of different example cases where M&S is currently being employed in the Canada Defence domain. These include several of the uses and experiments reported on in this symposium. The conclusion of the presentation, and the reported findings, are that there seem to be common themes and challenges where M&S is applicable, and also that pose challenges to the use of M&S. Additionally, there are some very promising science and technology areas where M&S will prove useful in the future.

2.3 Young Scientist Award Paper – Simulation-Driven Automatic Textual Report Generation for Staff Training

Peter Hammar, a new Ph.D. affiliated with the FOI Swedish Defence Research Agency, was the researcher receiving the NMSG Young Scientist Award for 2018. He presented on his research in the area of automatic textual report generation, which is driven by a simulation. His presentation was on the morning of the second day of the symposium, following the second keynote presentation.

Dr. Hammar's presentation was of the usefulness of his research, and explanation of the technique, and the experiences from developing and testing his system. The value of the research is in, for instance, generating information for trainees during command post exercises. The information should have as much facia validity as possible, so it is believable and the training that it supports will be successful. Generating such information, in the form of reports, is quite resource expensive, when done by hand. Having an automatic textual generation system will save much time, and if it is implemented well, will produce very believable textual reports to support training.

The prototype system is based on collecting the information about entities, position, and perceived activities from the information generated by a constructive (or other) simulation system. This data is then given context and placed in a textual mode that will appear as if the report were human generated. All of this requires a number of different (and interesting) computer-linguistic support methods including knowledge of data modelling, ontological representation, grammars and grammatical construction, and so forth. The research has led to a working system, proofing the viability of the approach. More research is needed, however, and new approaches to gaining and representing information, and building the final textual report are the presented requirements and challenges of moving forward. This promises to give good results, and be exciting to follow, for the next few years.

3.0 SESSION I – MODELLING AND SIMULATION TO SUPPORT OPERATIONS

This research area was host to four different research papers begin presented. The topic of using modelling and simulation to support operations was well represented, across several areas of operations, and several different applications of modelling and simulation. The areas of operations that were represented included planning activities, rotary wing aircraft operations in a nautical environment, decision support, and the evaluation of certain kinetic and non-kinetic effects in an urban environment. The topics of the papers, and their findings, are presented below.

3.1 Observations on the use of Modelling and Simulation for Advanced Planning in NATO (P1)

Dr's. Tremori, Sobrino, and Mansfield (all of CMRE) were joined by Mr. Wayne Buck (of NATO ACT) to

report on this effort from the Centre for Maritime Research and Experimentation, in La Spezia, Italy. The paper reported on a group that experimented in two different stages to explore the use of M&S for advance planning. The findings and lessons learned from the approaches are presented within the paper and reported on at the symposium.

The two stages that were the subject of the study reported on include (the first) the operation of a stochastic simulator to conduct experimentation at an operational level to understand the problem space of the exercise, and to select specific vignettes of interest. The second stage was to employ a simulator that is currently used for computer aided exercises, in order to better understand exercises, for optimisation.

The results were best practices grouped into five areas – those pertaining to stakeholders, those related to culture, those related to materiel, issues of data, and finally issues of process. These five areas produced a series of reported on observations and recommendations, and the authors, in order to present a ranking of the effort required to implement the findings for the various areas of the DOTMLPFI framework (Doctrine, Organization, Training, Material, Leadership, Personnel, Facilities, Interoperability), produced a ranking for each of the five observed areas of observed practices (ranking them as either low effort to implement, medium effort, or high effort). This gives some idea of where the best application of efforts would be, if the M&S approach were applied to specific areas of the DOTMLPFI framework. Future work should prove interesting, but these findings already can provide valuable insight into the use of M&S for planning and decision support.

3.2 Opportunities for expanding Shipboard-Helicopter Operational Envelopes using M&S tools (P2)

Researchers Wall, McTaggart, Thornhill, Comeau, Lee and McTavish presented their research and findings in this paper on using M&S to model helicopter interactions with ships (take off, landing, etc.), and the possibilities for future developments. The researchers were representing their work for the National Research Council of Canada (NRC-CNRC). The approach is to describe the shipboard helicopter operational limit (SHOL) concept, how this can be understood better with the use of simulation, and then to give some specific examples where M&S can be applied to improve either operations or training in this domain.

In understanding the elements that make up SHOL, the researchers present a nice model of the ship-aircraft interface, which combines information about the environment, the ship, and the aircraft together into a set of conditions (affected by, and affecting each), also the pilot response, and the capability of the aircraft. Together these will give a certain set of defining parameters for instance within the SHOL where pilot operations are feasible, and where they are not. Getting higher fidelity in modelling each of these, will allow for a more accurate understanding and representation of the SHOL operating space, and also the use of M&S to train pilots about operations (within the SHOL limits).

A case is made for the standardization of representation (and then, of models) for various elements of the environment (wind, anemometer readings, air wake, shop motion, etc.). With higher fidelity models representing these, there can be a great fidelity in the simulation of helicopter/shipboard operations. The authors present that expansion and application of modern M&S tools and methods are crucial to advances that can be made in this area, and that the NATO community represents the ideal place for discussions about how this can best be accomplished.

3.3 Neuro-Symbolic Modelling for Operational Decision Support (P3)

Authors Vogd, Hanckmann, de Heer, and van Lith (all from TNO in The Netherlands) present a paper providing the symposium with very interesting findings in the area of neuro-symbolic modelling. The intent here is to incorporate neuro-symbolic modelling, to assist with semi-automated processing of information and input, so as to more rapidly produce situational understanding during operations, and thereby assisting with operational decision support. The methods presented are very interesting, and the results are promising.

The paper as presented, gives the symposium information about the proposed system, of using a neuro-symbolic system to associate concepts (symbols of information) with each other in the correct way to generate information to present to the decision maker. The proposed idea is described, within the paper, as having connections to other NATO study areas, including big data, M&S as a service, and data farming – all of these will impact the proposed solution and research described here.

An example application is given in the paper, of using the neuro-symbolic modelling technique to provide insight into patterns of life within a populated area. The typical data elements that could be gathered themselves are (or perhaps in combination) representative of information, rather than just data. These are therefore symbols. If a neuro-symbolic system could be trained (as a neural network is training – associating input to a field of sensors, to certain identified outputs), then those symbols of the elements of patterns of life could be recognized, and some output to a decision maker could be generated.

The conclusions of the authors give a good overview of the current state of the research. They give some examples of the benefits of the research if pursued to more solid results, and they also give a second overview of how this work would be complimentary with other NATO research areas.

4.0 SESSION II – ARTIFICIAL INTELLIGENCE AND BEHAVIOUR MODELLING

Findings and progress reported on supported the ongoing work in a number of different M&S areas dedicated to either the application of artificial intelligence techniques, or the modelling of human behaviour. Subject areas included the use of artificial intelligence and cognitive modelling to support learning, ongoing work in the development of a reference architecture for human behaviour representation, and a web based graphical user interface for controlling entities in a constructive simulator.

4.1 Supporting Technology Enabled Learning with Artificial Intelligence and Cognitive Modelling (P5)

Dr's. Emond and Jarmasz, with backing from the National Research Council of Canada (NRC-CNRC) present to the symposium findings on their work regarding research into technology enabled learning, augmented by artificial intelligence methods and cognitive modelling. The results of the exploration of artificial intelligence methods is manifest in this research by providing synthetic teammates (avatars) in a simulated training environment, that have behaviours and characteristics that assist with learning. The findings presented address the development of such synthetic teammates, how they are interacted with, what the essential characteristic are, and a review of projects where they have already been experimented with. Conclusions follow, in what is a good report on ongoing research, although a field that is already producing results.

The goals given for simulation-based training are the ones many research teams are familiar with – it increases the availability of training by reducing the reliance on live training events, and it increases readiness of individuals to participate in larger team training exercises. The use of synthetic teammates will facilitate that readiness. In order to realize these goals, the development of synthetic teammates must have an improved, more agile process. The appropriate characteristics of synthetic teammates (in effect, defining

the cases where they might be most effective) include very structural operational context where well defined behaviour and communication is expected (from either a human teammate, or accepted from a synthetic teammate). The second characteristic is defined as use cases where such teammates can be "shallow entities" – appearing to be human-like, but not being required to exhibit much general intelligence.

Results from several experiments where such teammates either have been, or are planned to be, employed are presented as part of the findings. Following these, the conclusions of the research are presented – including points on how the use of such synthetic teammates will allow individuals to "over train" in their own tasks and communication skills, in order to better be prepared for their job, and other more complex training involving mission critical tasks. Future application is almost assured, as this represents both a cost savings and a capability multiplier, but further research will be useful in determining more finely the use cases and characteristics that are appropriate for synthetic teammates.

4.2 A Reference Architecture for Human Behaviour Representations (P6)

A multination team consisting of Lewis (GBR), Alexander (DEU), Huiskamp (NLD) and Blais (USA) present to the symposium the results of their effort to develop a reference architecture for human behaviour models. These are designed to support needs where the development or employment of a human behaviour model (HBM) is a critical element in a training simulation, or where understanding of such a model is necessary integration or interoperability; to increase model reuse; to reduce initial model development costs; and to increase the flexibility of using alternative modelling formalisms.

The authors present a definition of HBM from RTO TR-47, and also a list of factors involved in decision making – suggesting a framework for the affecting characteristics to be represented by factors in an human behaviour representation reference architecture. This is then constructed, and presented in the paper, showing how it (originally) was divided up into several different aspects of the human (perception, cognition, physiology, etc.). This has been advanced to the current state, where a more unified view of the human is presented, and the relational aspects between the different perspectives are also addressed.

Use cases for the military domain, of interest to NATO, are presented. Several challenges for the approach, and also an enumeration of particular deficiencies in current HBM approaches are listed. These are then supplanted with areas of more development, including such techniques (in a recommended approach presented in the findings of the paper) that includes looking at training application cases for requirements, development of reference architecture building blocks to address the different elements of representation, finally development of solution building blocks, and then experimentation and assessment of these elements of an approach to the problem. A very fine contribution from this group, and the ongoing work will be of interest to follow for NMSG for the next few years.

4.3 Easy-to-use, Web-based Graphical User Interface for Controlling Entities in Constructive Simulations (P7)

Authors Evensen, Selvaag, Bentsen, Holhjem and Stien, of the Norwegian Defence Research Establishment, present to the symposium a paper and presentation on their research which has resulted in a web-based GUI developed for controlling entities in constructive simulation events. With this research they are addressing a common problem with the employment of constructive simulators – that is, they are often complex and require special training to use. The authors are addressing, with their research, an approach to make the simulators more accessible, and therefore easier to use and to incorporate in analysis, studies and training.

The approach they are taking, with the development of their webSAF, is a web-based GUI (easy to access, easy to use) system for controlling entities in constructive simulations, specifically those powered by the simulators VBS (Virtual Battle Space, from Bohemia Interactive) and VR Forces (from MAK Technologies). Benefits include (1) minimal hardware requirements, no simulation software required on

operator client stations, tailored to a specific use case, independent of the simulator that is controlling the ordered entities, many libraries and tools exist that can enhance and enable the development of web-based GUIs and their applications. This all results, per the findings of the paper, in the goal of increased accessibility by users to the constructive simulation.

Future work is identified and includes further work with the simulation systems accessed (i.e. VBS). Also, more calibration, validation and testing (for acceptance into the event and analysis communities). Finally, there is a goal to leverage other NMSG research groups, such as Coalition Battle Management Language, and WebLVC, in order to improve the possibility for further interoperation with other systems. Another good report of useful research that will be of interest to NMSG for years to come.

5.0 SESSION III – AUGMENTED REALITY AND EMERGING TECHNOLOGY

Findings and updates in this area included results in two different areas of advanced visualization, these included a paper on holographic displays and use cases for defence, as well as a paper on using augmented reality for understanding human performance within imperfect systems. In addition to these two sets of findings, there was a report from the SISO Standing Study Group on Next Generation Technology Application for Modelling and Simulation.

5.1 Holographic Displays: Emerging Technologies and Use Cases in Defence Applications (P8)

Authors Hamilton, Butyn and Baker, of Avalon Holographics (Canada) present their paper that discusses emerging holographic visualization technology, and the potential use cases for defence. The paper presents, initially a description of the different types of holographic display technology, and present some of the different techniques and strategies of making 3d display possible. One of the problems discussed is the problem of combining focus, convergence, motion parallax, and binocular disparity into a view intended to convey 3d representation to more than one user (i.e. more than one set of eyeballs, or different perspective sets of the parameters listed above).

In addressing some of the problems of doing believable 3d representation, there have been several different strategies and solutions developed, and the paper presents several of these in some detail. Many of these will be of interest to NMSG researchers interested in this area, as they are strategies used by different manufacturers and equipment integrators. Finally, a next generation effort is described, that is based on light field rendering and transmission. This is the area of research that Avalon Holographics is involved in, and results already look very promising.

After presenting the limits and promises of different technical solutions, and also including the research (promising) that Avalon is putting into their solution, the paper presents a number of different defence related use cases and gives some examples of how 3d and/or holographic views could benefit those use cases. Those covered (in detail in the paper) include battlespace visualization, medical imaging, air traffic control, enhanced detection navigation and ranging, training and simulation (i.e. 3d simulated world view), and finally computer aided design and analysis. The summary of the paper reiterates the current situation, the promise of the next generation solutions, and a dedication by Avalon to further research, and interest in pursuing the listed use cases as the starting point for future applications in this area.

5.2 Augmented Reality: Understanding Human Performance with Imperfect Systems by using Virtual Simulations (P9)

Dr's. Graybeal and Bosq, representing Kinex, Inc, and working for the US Army Research Development and Engineering Command (US Army RDECOM), present their findings in the area of understanding, and

potentially exploiting the imperfections present in virtual and augmented representation of simulated worlds. The paper presents the basic problem of imperfects in virtual environments, a possible case of exploiting that situation, and then an experiment and results of that experiment.

The problem, as presented in the paper and presentation that the authors brought to the symposium, is that there are inaccuracies and inconsistencies in the representation of augmented reality (AR) systems. This leads to a question, how good (i.e., lacking in those inaccuracies and inconsistencies) does AR information have to be, in order to have a positive impact on human behaviour in situations where AR systems are used?

The experiment developed was to measure the reaction time, for aiming, when either no AR is used, or when there is "perfect" AR (i.e. an augmented reality aim point system that helps the user determine their target quicker). Also included in the study, were several cases where there was not perfect AR, but some variance off perfect. The findings suggest that even when there was not perfect AR, there was still an improvement over the situation of using no AR, so that even employing AR that is not perfect (i.e. with some inconsistencies and inaccuracies) will lead to benefits in performance. While this represents only one battery of experimental examination of the situation, it is a promising result, and provides data where before there was only supposition. This is extremely useful work for those considering the employment of augmented reality in a number of situations, and further work in this area by this group, supported by RDECOM, will be welcome.

5.3 An Update from the SISO Exploration of Next Generation Technology Application to Modelling and Simulation Standing Study Group (P10)

Author Chris McGroarty (US ARMY RDECOM) prepared the paper and the update on progress and activities of the Exploration of Next Generation Technology Application to M&S (ENGTAM) standing study group (SSG), supported by SISO. The presentation at the symposium was made by Ms. Lana McGlynn, who is supporting the SSG. The update describes that activities that the SSG has made in the past year – developing a problem statement, the formation of the group, the literature search, and approaches to technology adoption.

Following their formation, development of a problem statement and literature search, the SSG found the typical models of technology adoption – the Gartner Hype cycle, Roger's Bell Curve, Moore's Law, and others. The goal of the SSG is reported as looking for perhaps better adoption standards for M&S technology. As this will be an ongoing effort to help the M&S community, and potential user communities, the transition of the group from study group to standing study group was approved. Some of the work they have produced is a technological adoption model specifically suited to M&S. This includes the steps of understanding the current state of the technology; exploration of possible new technology and capability; evaluation of those new developments; adoption of those developments, where promising; and finally, the management, maintenance, and adjustment to the new developments.

The five-step technology adoption model for M&S was then used as the language to describe where the community is in regard to several technology areas examined by first the study group, and later by the SSG. These include such areas as artificial intelligence, big data, gaming, internet of things, and others. The SSG activity is an ongoing one and welcomes new membership. The adoption model will prove a useful metric to consider where the efforts are in new M&S technical capabilities, and the examination of technologies, and the reports on the same, will benefit host nations and supporting research organizations.

6.0 SESSION IV – ARCHITECTURES AND INTEROPERABILITY PART I

This session and the next represent together the largest track of papers for this symposium. The efforts reported on here, to include an invited paper from the UK, represent a wide variety of different

interoperability research and application efforts from across the nations. Several of these are the result of ongoing (long term) research programs, but others are new, indicating that while the interoperability and architecture areas of research have been with us for a while, that there is fresh interest, and new ideas, being researched in these areas, which present promise to NATO of new solutions.

6.1 Moving towards internal and external M&S distributed simulation interoperability – the UK approach (Invited Paper)

Grant Bailey (UK) presented to the symposium results from a paper authored by himself and Mr. Michael Lewis. The focus of the paper is a report on what the UK is doing in the M&S domain regarding simulation interoperability – both the challenges faced, and the organizational and strategic efforts to address those challenges. The presentation focused on both the challenges, enumerated initially, and then the efforts of the Defence Modelling and Simulation Coherence (DMaSC) organizational response to those challenges.

The solutions that DMaSC are providing have to do with internal M&S competencies, and interoperability, as well as external interoperability. Some of the organizational improvements, since the new Defence M&S policy of August 2018, are that M&S coherence will flow down from DMaSC, that there will be a M&S catalogue, that DMaSC compliance for all M&S systems will be required (and defined by the DMaSC), that there be a Defence Simulation Centre and other issues. These were presented as all positive improvements for the state of M&S inside UK Defence. New capabilities and services, especially from the Defence Simulation Centre were described, to include new capabilities like centralized terrain & 3d modelling capability, as well as new capability for distributed simulator management.

Further organizational improvements include the establishment of a DMaSC M&S catalogue, and an examination of the ability to build qualified personnel in the M&S domain. The summary comments addressed how the better coordination and improved simulation accessibility will all be positives for UK Defence, and for UK M&S interoperability with NATO. Reasons for expectations of success are that this was developed with an appropriate governance structure in place, that it is a mature and unified approach taking advantage of years of observation of the community, and also that the approach is built to not stifle innovation (still a developing field). The presentation and the findings all agree on positive effects coming out of the new policy.

6.2 Naval Platform Simulation using the NATO Virtual Ships Standard (P11)

Authors McTaggart, Oakey, and Spengen of the Defense Research and Development organization of Canada (DRDC) are joined by Gary Henry (Systems Engineering & Assessment Limited) of the UK. Together they present findings reporting on the simulation of naval platforms, and the ongoing use of the NATO Virtual Ship standard.

The NATO Virtual Ship standard was presented as part of the report from the authors, giving the history of the standard, its current state, and the effects and usefulness of the standard. This was followed up by several example simulations where application of the standard has proven useful. Those listed include the simulation of international replenishment at sea, where the modelling of the sea itself, as well as ship motions, and multiple ship platforms operating in proximity are all required, and the standard is an extremely useful tool to ensure fidelity amongst the various models. Another effort, requiring the modelling of several platforms, is the simulation of launching and recovering rigid hulled inflatable boats.

The results presented find that the Virtual Ship standard has served NATO very well and proven extremely useful. The application of HLA to naval platform simulation is extremely useful in many situations, however because of the high degree of complexity of a full HLA implementation, and because the example use cases (and others) only benefit from some of the aspects of HLA implementation, it may be that a reduced subset of HLA capability proves to be the most useful for modelling naval platforms. Finally, in

light of this, and with the Virtual Ship standard in mind, the development of an HLA prototype federation may prove extremely useful. The report specifically names Dr. John Duncan, and issues gratitude for his efforts in Chairing the NATO Subgroup 61 efforts on the Virtual Ship standard.

6.3 STANREC 4800 – AMSP-04 NATO Education and Training Network Federation Agreement and FOM Design (P12)

Björn Löfstrand, of Pitch Technologies (Sweden) presented the findings of a culmination of work from several NATO MSG groups, that has come together in the form of the NATO Education and Training Network (NETN) Federation Agreement and FOM Design (FAFD) document. This is covered by NATO Standard Recommendation (STANREC) 4800. The presentation covered very well the nature of the contents of the STANREC, the purpose and background of NETN FAFD, and also findings included a report of its use in exercises such as Viking. Finally, a report of ongoing activities within MSG-163 are presented, along with expected future developments.

The report on the history of NETN FAFD began with a timeline showing overlapping NATO MSG groups (068, 106, ET-35, 134, and now 163), and details as to the features and experimentation done within each. This was followed up with a description of the current state of NETN FAFD, and the included FOM modules. Some of the capabilities now feasible, with reliance on NETN FAFD (transfer of modelling responsibilities, multi-resolution modelling, federation initialization, increased fidelity and capability in modelling logistics, chemical/biological/radiological/nuclear (CBRN) modelling, and simulation to C2 interoperability were all reported on). The last new capability reported on – simulation to C2 interoperability – included mention of some other efforts reported on at the symposium, notably C-BML and Low-Level BML.

Finally, the use of NETN FAFD in Viking was reported on, giving details on the use of several FOM modules (including LLBML HCBML, MSDL and others), as well as the NETN capabilities. Status on reported feedback from Viking stated that findings were fed back to NATO MS3, through MSG-163. Future promised features of NETN FAFD are related to several issues – first is handling the ongoing list of problem and change requests (PCRs), some of which were enumerated in the report, and a hit of future support for developers, integrators, federation architects and M&S event decision makers concerning existing and new M&S capabilities that NETN FAFD could support. The report was very well received by the symposium, and useful questions and discussion followed the presentation. Future developments will no doubt be followed, and the final reports from MSG-163 should prove to be very useful, once available.

6.4 C2SIM in CWIX: Distributed Development and Testing for Multinational Interoperability (P13)

Dr. Mark Pullen (US) presented the findings from this paper, co-authored with Mr. Lionel Khimeche (France), and Mr. Kevin Galvin (UK). The findings are focused on results of ongoing with with C2SIM, which will culminate with the successful combination of C-BML and MSDL. In order to be evaluated properly for elevation to a STANAG, the findings report first on the need for experimentation and results evaluation of C2SIM, and second on a series of such experimentation within CWIX 2018 and plans for CWIX 2019.

The contents of the presentation started with a history of how C2SIM came to where it is, with the history of both Coalition Battle Management Language (C-BML) and the Military Scenario Definition Language (MSDL), and their history in both NATO MSG groups, as well as within SISO as the subject of standardization efforts. This was followed on by reporting on NATO MSG-085, which saw the development of C2SIM, combining the early efforts, and resulting in a number of different useful products, such as the C2SIM Core Ontology (containing a logical data model of all the data classes making up the elements addressable by C2SIM), and also several extensions to C-BML and MSDL, specifically in the area of

manoeuvre warfare. Methods of C2SIM development and experimentation were detailed, and details on the C2SIM Reference Implementation Server were presented.

Reports on the 2017 and 2019 CWIX (Coalition Warrior Interoperability Exploration, Experimentation, Examination Exercise) were presented, as well as plans for the 2019 CWIX. Final concluding statements cover that continued development, and maturation of the appropriate standards is required, and moving towards a STANAG is the expected path for the next few years. Plans for 2019 CWIX and plans for continued with MSG-145 were also discussed. This has been a long-term body of work for NATO MSG and seeing results will no doubt provide useful solutions for many interoperability and simulation to C2 modelling problems. Although progress towards a STANAG and future exercise-based experimentation are all required and will prove useful, the impacts that CBML and MSDL (and now C2SIM) have made on other NATO MSG groups (several reported at this symposium) have proven the worth of this ongoing research program.

7.0 SESSION V – ARCHITECTURES AND INTEROPERABILITY PART II

7.1 Simulation-Supported Wargaming using M&S as a Service (P14)

Martin Asprusten presented the findings of this research effort, co-authored with Jo Erskine Hannay, both of the Norwegian Defence Research Establishment (FFI Norway). The paper is addressing the Allied Framework for M&S as a Service, and how it can be used with Docker containerization technology as a service enabler. Technical issues on adopting and implementing the technology are presented, as well as issues in general related to M&S as a service. Finally, promising findings are presented as to the potential future world, of M&S as a service, leading to compositions of simulated solutions, available "on the fly" – or in demand, as the user requirements present themselves.

The use case for the experimentation with the docker containerization approach was described, and belonged to a simulation supported wargame, done by Norway FFI, for the Norwegian Army, and focused on simulation supported wargaming for the analysis of plans. Within this experiment the simulation capabilities were referred to as architecture building blocks, consisting of both an M&S capability, and an implementation independent description of the capability. The latter is what is relied on for the composition. Technical details on system requirements, and operational concerns for employing Docker were presented, giving key details for those wishing to follow this experiment with Docker.

Results and future work presented by the authors include a description of what it means to have a system such as Docker running remotely ("in the cloud") and having what it means to enact the composition decisions of the different service architectural blocks. A model-based approach to describing the capability of each block may be necessary, and a suitable modelling candidate to do this might very well be the BOM modelling standard (Base Object Models), another modelling standard from SISO. Seeing real progress, and promising results, in the simulation as a service research area is rewarding, and further work from FFI in this area will be welcome by NMSG.

7.2 'Mind the Gap' – Avoiding pitfalls in taking the MSaaS concept from research into everday use (P15)

Researchers Skinner, Stuart, Ford and Lloyd, all from the UK, present this paper on caution and also promised benefits from making the transition between research and operations in the area of modelling & simulation as a service (MSaaS). The work is based on efforts performed within MSG 136 and 164, both of which focused on MSaaS. The work also reports out on the results of the UK's Architectures Interoperability and Management of Simulation (AIMS) project. The findings presented, and the recommendations made are a composite of the work produced inside the MSG groups and also findings from

the AIMS project.

The MSaaS process, and the necessary supporting architecture are described. The researchers refer to the architecture, and supporting contextual environment, together as the MSaaS ecosystem, and in addition to containing the enabling technology as well as all the services, supporting infrastructure, data tools, portal, etc. that makes the M&S service oriented architecture work, the ecosystem also includes the administration of the system, the simulation developers, the resource providers (where external resources are relied on), and also the simulation user. A timeline for a typical M&S event, being run while employing MSaaS, is given and it includes the typical required functional SOA steps – discovery of the resources, composing the resources, deployment of the resulting composition, execution of the overall composition, and then analysis of the results. The AIMS project showed that this SOA based approach is compatible with the DSEEP distributed simulation process.

A series of complexity issues and technical challenges, many of which have to do with key problems of composing service together to make a whole simulator, as well as the typical challenges with distributed and composed systems, are presented and discussed within the paper. Potential solutions are given, many of which will be applied through further experimentation and iterative attempts at MSaaS implementation. The use of standards is recommended, as well as the application of a minimum viable product approach to the design of composable service items. These findings are endorsed in the conclusions, and if followed within NMSG, should continue to show benefits, as this paper itself has.

7.3 Distributed Simulation for Training: Promises, Barriers, and Pathways (P16)

Dr's. Jarmasz and Martin, of the Defence Research and Development organization of Canada (DRDC) presented their findings and observations about using distributed simulation, and the observations and recommendations based on the experience in Canada. The presentation describes distributed simulation, as understood within DRDC, and also an approach to discussing technology adoption and barriers (making this a nice partner paper to that described in section 5.3, above). Finally, conclusions and recommendations are presented, including pathways to better adoption of distributed simulation for training.

In the description of distributed simulation for training, one of the interesting features enumerated is that distributed simulation can use centralized, or de-centralized architectures. Also notice of the many different potentially contributing standards (DIS, HLA, etc.). Benefits of using distributed simulation for training are given, as are general benefits from using simulation at all (distributed, or not). The Canadian experience with distributed simulation is briefly described, as is an interesting presentation on the Gartner Hype cycle. In enumerating barriers to distributed simulation, many of the common challenges reported by many organizations are reiterated here, with some details specific to the Canada experience. These include problems with distributed after-action reporting, LVC integration, network security, lack of expertise with sims and simulation distribution, and other areas.

In attempting to quantify and parameterize the barriers to simulation, a technique is borrowed to divide up barrier originated exceptions into the areas of technology, process, administration, environment (organization), and training stakeholders. This was borrowed from the literature on educational technology, so originally instead of training stakeholders, it included "faculty" as an area. Dividing up and categorizing the barriers to distributed M&S in this way provides a way to specifically focus solutions appropriate to the barrier. The conclusions report on this as a means of moving forward, and also describe the benefits of developing solutions in a single category (perhaps the solutions can be reused to other problems, with other events, in the same category; perhaps some solutions will have benefits to barriers in multiple categories; etc.). The authors recommend a more systematic study of barriers and the pathways to move past them. From the results and findings in this paper, the technical reviewer agrees that this may be a good way ahead, and should be of interest to NMSG.

8.0 SESSION VI – SENSOR SIMULATION

This, the final session of the symposium, covered two different presentations, dealing with the modelling and simulation of sensors and signature management. The modelling of sensors and signatures is an important part of Defence M&S but is often viewed as separate from other pursuits of M&S, treated as something special that happens by itself. The papers and findings presented here give promise to the idea of combining such M&S with other operational and studies-based M&S.

8.1 SigMa Lab – Concept and Development (P18)

Layton Gilroy (DRDC, Canada) presents findings to the symposium on the signature management M&S advances performed at the SigMa Lab. The case is made for why signature management is such an important factor in many different training and development programs related to naval platforms. This includes both above and below water signatures. The SigMa Lab worked with the Centre for Ship Signature Management, a multinational effort including Norway, German and the Netherlands, and the DRDC was instrumental in developing a prototype signature management system. Findings on the development, related activities of the lab, and recommendations for a way ahead were presented.

The method involves operating, within SigMa, a Signature Control Room Simulator (SCORSim) which simulates the many, many different factors on a naval platform that can affect the generation of signatures coming from that vessel. This has to do with factors such as the physical configuration (including such elements as open or closed hatches, for example), which electronic systems are currently active, the state of the machinery and engine room, and many other factors. These are then coordinated with a Signature Acquisition Sensor Server (SASS) and a Sensor Error Notification System (SENS) in order to provide a complete simulated suite of appropriate data outside the SigMa Lab. That suite of data is then fed to a Signature Management System, in order to stimulate the system and simulate a realistic generation of signature data coming from the platform.

SCORSim works via HLA, so can be included (in future) in federations to provide valuable signature simulation to a number of different NATO simulators. This allows for a broad range of training and evaluation events to be conducted, with near-real data, all possible without taking the naval platform to sea. The simulator can be adapted to a broad range of different conditions and naval platforms (potential future applications include the RCN frigate, or a future naval combatant). The system, as it exists, and as it can be configured, appears to give a very useful suite of data, and provides more complete platform information than exists in a number of other current platform simulations. Further development will not doubt improve the depth of data and data-fidelity, while applying the system to additional platforms will increase its breadth of applicability. This was a very good report to the symposium and highlighted (as an exemplar) very good use of M&S for a broad range of applications.

8.2 Electro-Optical Sensors Performances estimation/study using Synthetic 3D Environments (P19)

Researchers Gagné and Dion (DRDC, Canada), with Bernier and Ross (AEREX Avionic, Canada) prepared and presented findings to the symposium on the use of synthetic 3d environments, and improvements from M&S to producing simulated wartime scenes, but with corrections made to reflect the current state of the art for electro optical sensors. Guillaume Gagné presented the findings to the symposium, which included a description of the technology, the problems faced, and the results from a developed improvement.

The use of generated 3d scenes and imagery is a powerful capability multiplier in the area of simulation for training. Also, having the ability to rely on M&S to assist with the evaluation of sensor performances and effectiveness is equally powerful. However, in recent years the capability of the sensors may have outpaced the ability to faithfully reflect them in a simulated environment. The 3d scene generator used by Canada is

Karma. The findings of the paper report on a method in which the fidelity of the scenes, where an electro-optical sensor view is being simulated, have been improved through new visualization capabilities being incorporated into the M&S tool of Karma, called the FPAImager. Results prove to the solution to be very efficacious in presenting better fidelity imagery than previously.

The development of the module, and the method in which it was subjected to test and experimentation and reported out to the NATO MSG symposium is a perfect example of a national defence organization working with an industry component in order to solve problems. NMSG will no doubt welcome more, future reports on how Karma is being improved, and the findings should be of interest to other simulated view efforts that face similar problems in representing modern sensor-based imagery.

9.0 CONCLUSIONS – RECOMMENDATIONS

The papers presented at the symposium represent a slice of the many M&S efforts, and interoperability efforts that could be reported out to NATO at any one time. What arises out of this selection of papers, however, is that while interoperability remains a challenge, in many ways it is being broadened out, and affected by other research areas within NATO. These include cloud operations (simulation as a service, for example), big data and data analytics (simulated generation of text, contextual simulation and pattern of life simulation), the use of high-performance computing (high fidelity platform and physics modelling) and artificial intelligence (AI informed learning assistance and of course the human behaviour reference model).

Standards and standards-based interoperability remain a high level of interest (C-BML, C2SIM, Virtual Ship Standard), as well as further improvements in the basic technologies enabling distributed simulation (NETN FAFD). Continued interest and investment in these areas will continue to provide improvements to the capabilities of NATO to perform high value simulation.

Finally, the investment and interest in emerging technologies (augmented reality, virtual reality, sensor simulation) show that there is not yet a horizon in where M&S can go, and how it can bring benefits. Additionally, new use cases for M&S (wargaming, operational planning, assisted learning) show that where M&S can be effective is growing equally fast. The interest shown by the nations (as seen in the Host Nation presentation of the innovation promotion program IDEaS) is extremely reinforcing that these two different areas need to be addressed (expanding the capabilities of M&S, and expanding the application areas of M&S), and finally the ongoing interest in new developments and emerging technology from within the community (as seen in the report from the ENGTAM study group) show that there is no slowdown in the ability of organizations (government, industry, academia) in support these two different areas of expansion.

As a glimpse in the state of the art, no symposium can be complete, but the cross section of papers and research highlighted in this 2018 event was of universal high quality and speaks to the good work being done within NATO and across the nations in many different areas. As this work continues, it will be exciting to watch, and to participate.