Technical Evaluation Report

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EXECUTIVE SUMMARY

The NATO Modelling and Simulation Group (NMSG) Conference (MSG-171), "Towards the Next Generation Synthetic Battlespace," was conducted in Vienna, Austria on 24 & 25 October 2019. All sessions of the Conference were unclassified. The Conference audience included participants from NATO countries, Partners-for-Peace (NP) nations, and invited nations. At the Conference, 18 papers were presented. A national presentation and an invited presentation were given at the beginning of the first day. Additionally, a panel session and two poster sessions were presented on the first day. The second day opened with the NMSG Young Scientist Award Presentation. Conference contributions were presented throughout in seven topic sessions. This Technical Evaluation Report summarizes the core ideas and results presented in this conference. This report also provides an overview of discussions conducted during the conference and concludes with a summary and recommendations section.

The theme for MSG-171 was the next generation synthetic battlespace. This theme reflects the need for M&S systems to modernize in order to better represent the complex and contested future operating environment and its effects. This scope covers a large spectrum of topics such as cyber, influence/information operations, space, autonomous systems, C4ISR & military-civil decision-making support, human behaviour, climate conditions, and simulation architectures.

Topics included future military and civilian challenges in the space, modelling the complexity of human behaviour, the challenging modelling domains of space and cyber, advances in the representation of chemical, biological, radiological and nuclear (CBRN) effects, applications of augmented reality / virtual reality (AR/VR), evolving architectures, and simulation of non-traditional warfare environments such as urban and subterranean terrain.

Summary recommendations include taking a more holistic approach to identifying future NMSG activities which is in keeping with the increasing complexity of integrated M&S and representation of systems of systems. Additionally, other presentation formats may increase knowledge acquisition benefits to participants, e.g. explicitly requesting shareable lessons learned and metrics in paper and panel sessions focused on applying new technologies. External to the symposium itself, value may be provided to participants through a virtual mechanism, e.g. a wiki or knowledge base, for sharing results of ongoing work. The summary recommendations also include suggestions for future topics.

1.0 INTRODUCTION

The theme for MSG-171 was the next generation synthetic battlespace. This theme reflects the need for M&S systems to modernize in order to better represent the complex and contested future operating environment and its effects. This scope covers a large spectrum of topics such as cyber, influence/information operations, space, autonomous systems, C4ISR & military-civil decision-making support, human behaviour, climate conditions, and simulation architectures.

This Technical Evaluation Report contains a synopsis of the plenary and paper presentations. Also included are significant technical and thematic aspects of the conference, concluding with recommendations for consideration by the organizers. While this Technical Evaluation Report serves as a record of the conference's activities, the best source of the information presented are the original papers and the related presentation materials.

2.0 DAY 1 (THURSDAY, 24 OCTOBER 2019)

2.1 National Presentation: Future Challenges for Austrian Armed Forces; Major-General Mag. Bruno HOFBAUER (Director Strategic Planning Directorate, Austria)

Major-General Mag. HOFBAUER began with an admonition against business as usual. Decades of peace have led to wishful thinking that military confrontation will not return. Contemporary war will happen in the "grey" zone, e.g. Ukraine and the South China Sea. Additionally, non-state actors are becoming increasingly sophisticated. He highlighted his areas of key concern:

- Hybrid warfare on the political, diplomatic, and economic levels including information operations, troop movements, cyber warfare, and disinformation. Artificial intelligence and the Internet of Things will accelerate hybrid warfare.
- Urbanization, both within and outside cities, will challenge us, e.g. high rises and subterranean dwellings. So, Realistic urban and subterranean training must become normal, not the exception. Sixty percent of the world's population currently lives in urban environments. Cities that grow the fastest will present the greatest challenge as non-governmental forces will fill gaps left by overextended governments. And those cities will be too large to cordon and control. The dense population will provide an abundance of human shields, and media relations (permanent media scrutiny) will be tools of non-state actors
- We must always be advancing our modern warfighting capabilities because the technological advantage of the military will be short-lived, e.g. drones. And we're already behind on communications equipment. We need to advance our use of autonomy and artificial intelligence (AI) while balancing ethical constraints our enemies don't have, e.g. support for fire control.
- Digitization will be the key driver for the next century, so we need more cyber warriors.
- Major-General Mag. HOFBAUER concluded by identifying areas where M&S can help with training:
    - Faster testing of tactics, techniques, and procedures (TTPs) and force structures
    - Expanding the size of the training space
    - Efficacy of integration of new technologies, e.g. autonomy
    - Threat representation
    - Urban environments

2.2 Invited Presentation: Security Challenges for Austrian Armed Forces; Dr. Ralph Hammer (Federal Ministry for Transport, Innovation and Technology, Austria)

Dr. Hammer's presentation focused on KIRAS, a critical infrastructure protection programme of the Austrian Federal Ministry for Transport, Innovation and Technology. This briefing was a valuable counterpoint to the preceding briefing because KIRAS has a civil focus, although it can be dual use. KIRAS selection maximized societal consent for projects, i.e. solutions that are socially acceptable. M&S-related projects include:

- Simulation of threat and damage potential of explosive devices at the urban level

- Evacuation scenarios
- Cyber security incidents tailored to Austrian companies
- Optimal first responder deployment during mass events
- Acoustic impact of stun grenades
- Police training for societal hot spots
- Interdependent critical infrastructure
- Risk analysis of energy grids
- Anomaly detection in industrial control / SCADA
- Preparedness in energy (blackout) and crisis situations

KIRAS is considering some "out of the box" new simulation proposals including an unsolvable situation similar to the "Kobayashi Maru" test, an exercise with no electricity or communications, and an exercise with a human or obstacle in the loop. The last of these is intended to get at the question of how effective / realistic the inclusion of a human decision-maker can be in the age of full, automatic engagement.

2.3 Session 1 – Modelling the Next Generation Synthetic Battlespace – Human Actors

Session 1 Chair – COL Wolfgang KRALICEK (MoD, Austria)

2.3.1 Paper #1 – Using Behaviour Trees to Model Battle Drills for Computer-Generated Forces; Per-Idar Evensen, Håvard Stien, Dan Helge Bentsen

Paper Abstract: *Modelling realistic human behaviour, including decision-making and creativity, is the hardest and most complex challenge in combat simulation. Behaviour trees (BTs) is a relatively new and increasingly popular approach for developing behaviour models for artificial intelligence (AI) and intelligent agents. The approach has become especially popular for creating behaviour models for non-player characters (NPCs) in computer games, robots, and autonomous vehicles.*

BTs are represented as directed trees with a hierarchy of control flow nodes and task nodes that control the behaviour of an agent. What makes BTs so powerful is their composability and modularity. Task nodes and control flow nodes are composed into subtrees which represent more complex actions, and these actions can be composed into higher level behaviours.

In this paper we will give an introduction to BTs based on available literature and discuss the possibilities and limitations of employing this modelling technique for creating behaviour models for computer-generated forces (CGF) in combat simulations. Furthermore, we will give a concrete example of how to create a BT from a textual description of a battle drill, and provide tips and tricks on how to create BTs in general. Finally, we will summarize our experiences from working with BTs.

Discussion: This paper focused on the application of BTs to increasing combat effectiveness in land force operations. BTs are directed, rooted trees that represent all the possible courses of action an agent can take. The author asserted that BTs are powerful because of composability and modularity. It is not currently feasible to use AI to build very complex BTs. Capturing behaviour of real units in exercises might be a farther future experiment to generate models more easily. The following questions are derived from the paper, but there was insufficient time to answer them during the presentation:

1. *We found that hands-on experimentation with different control flow patterns was very useful to better understand how BTs work, and how to create good BTs.* What specific lessons were learned through experimentation with different control flow patterns?

2. *It is good practice, at the start of a subtree, to always make sure things are configured correctly before continuing and not assume anything was correctly configured before.* This sounds like you want to check that the environment hasn't changed. But wouldn't the process of executing the BT from the root node check the status of the environment? And wouldn't control flow nodes with memory exacerbate this problem because they would retain "stale" state?

3. *The behaviour models also need to be validated, and this will typically be done by face validation by military SMEs and officers from the Norwegian Army.* Have you considered more rigorous validation methods?

4. *To make this possible we need to ensure that the models also exist as conceptual models that can be implemented in other simulation systems.* Discuss BTs as a form of conceptual model. How do they compare to other forms, e.g. sequence diagrams?

Recommendation: See summary recommendations 2 and 3. Answers to the above questions could be provided virtually.

2.3.2 Paper #2 – Computer Modelling of Human Populations in Support of Military and Civil Command and Control (C2) Exercises; David Robson

Paper Abstract: *This paper discusses the design of a computer modelling framework for a UK military training and education requirement, lessons learned during its construction and implications for representing the complex and contested future operating environment.*

The "Influence and Infrastructure Combat Model" (IICM) is a computer simulation that models the flow of information and resources through a Human Terrain and the supporting critical national infrastructure networks (CNI). This project began as a study on methods of modelling the effects of Cyber activities on a local population and was extended to include wider military actions including Hybrid, Military Operations in Urban Areas (MOUT) and Informational Manoeuvre activities.

IICM treats the population as an unstable equilibrium destabilised by external actors. Drawing upon group dynamics theory and epidemiological compartment modelling techniques, information is modelled as mimetic packets which are passed between software agents representing population groups, changing the level of support for different factions. These act as a quantifiable 'target' for influence operations within an exercise.

Drawing on our experience in military exercising, IICM is designed to operate as an independent model or federated with a kinetic warfare simulation. It presents effects as seen by the military decision maker, rather than the low-level analyst or system operator.

Discussion: The speaker provided an overview of shortcomings of current kinetic simulations, e.g. very low-resolution representations of urban environments. There is a need to represent cyber and civil populations and deal with resistance to the impacts of those on traditional kinetic training. They're looking for indicative rather than predictive outputs for non-kinetic representations. Contemporary manual wargames are making faster progress on the mathematics in this domain than the military. Getting social interaction results back into kinetic simulations is a challenge because the kinetic simulations aren't designed to take those results as inputs. The bulk of the presentation focused on the underlying models of population behaviour.

The paper lists the following as elements of the simulation: Cyber and CNI disruption change electronic communications; a "Capacity based Comms model" models electronic information flow; information flows through a population; an "Agent based Social Interaction model" models the transmission of influence between people. The introduction of two nascent modelling domains, human and autonomous systems behaviour (HASB) modelling, and responses to electronic communication disruptions might confound understanding of underlying impacts and make it hard to validate the federated simulation. The speaker concurs that doing so could be almost impossible, particularly because of second and third order effects. Messages representing social interactions are handled by a handful of SMEs because the task is so challenging, e.g. breaking down an input like a newspaper article and figuring numeric changes in sentiment.

Recommendation: HASB is a broad, deep, significantly-challenging modelling domain that needs more persistent attention. See summary recommendations 4.a and 4.b.

2.3.3 Poster Session

Data Farming

This poster provided an overview of the architecture to realize the recommendations of MSG-155 for data farming core services. These services are intended to enable a simulation-based methodology to support defence planning, operations planning, warfare development, and concept development and experimentation via multiple simulations runs. This poster was unstaffed, so the following questions were not answered:

- What techniques and tools are being used?
- What data from each of the use cases will be examined?
- What types of outcomes might be expected?

C2SIM

C2SIM integrates C2 systems with simulations via interceding software, eliminating the need to modify C2 systems which is infeasible. It's implementation as a service realizes NATO's M&S as a service (MSaaS) vision. The C2SIM project also participates actively in standards including the Simulation Interoperability Standards Organizaton's (SISO's) C2SIM and Cyber Data Exchange Model (DEM).

Navantia's Digital Twin Implementation Perspective in Military Naval Platform Life Cycle; Juan Ignacio Silvera, Juan Luis Muñoz, José María Luquero, Angelina Cajade, Manuel Bustelo

This paper describes Navantia's proprietary Digital Twin architecture and integrated NAVANTIS training suite. The approach to developing this architecture is intended to meet current best practices including developing a conceptual architecture that is modular, scalable, data-oriented, and data-driven via agile methods. These observations are based on reading the paper because no poster was provided, and the poster briefer was not familiar with the work.

Recommendation: The poster sessions would have been more effective with printed posters at each station and briefers present to answer questions.

2.4 Session 2 – Modelling the Next Generation Synthetic Battlespace – Systems and Sensors

Session 2 Chair – Wim HUISKAMP (TNO, The Netherlands)

2.4.1 Paper #3 - Simulating the Future Operating Environment for Training and Education; Matthew Smith, Neil Smith

Paper Abstract: *Military operations are performed in an increasingly complex world where the behaviour of force elements is affected by the state of the natural environment, political effects and social effects, in addition to physical (kinetic) warfare effects.*

Modelling and Simulation (M&S) systems have a limited representation of these aspects, and mainly provide static representations of the natural environment and physical warfare effects. The effects of electronic and information warfare such as offensive and defensive cyber and the use of social media as an influence tool are of increasing importance to military users. Current synthetic based training systems employ a component known as Computer Generated Forces (CGFs) to represent the majority of human and systems behaviour as an integral element of the simulation and/or Synthetic Environment (SE) used to deliver the training. However, no single CGF adequately represents the breadth of system, human, organisational and social behaviours that occur in operational environments, and often more than one CGF needs to be employed which were not designed to be interoperable which impacts the ability to provide consistent representation of effects across dissimilar simulation systems. This is a capability gap identified by previous research carried out by the UK Defence Science and Technology Laboratory (Dstl) in partnership with supplier organisations. Related to this issue, "Simulating Future Battlespace Complexity" is one of five UK Defence Innovation Priorities published by the UK MOD.

This paper describes research conducted by the UK Defence Science and Technology Laboratory (Dstl) into the representation of Future Operational Environments (FOE) in Simulation (FOESim). This is aimed at investigating methods and technologies relevant to representing the increasing complexities of operational environments in simulation in a more coherent and effective manner. The scope of this research includes,

• assessing opportunities for M&S to provide more efficient and effective training in Future Operating Environments (FOE);

• new approaches for the composition of more coherent and improved representation of human and systems behaviour across simulation systems;

• the representation of warfare effects on current and emerging operating domains such as space and cyber, including non-physical force behaviours such as electronic and information warfare effects;

• consistent representation of dynamic natural effects such as weather and terrain on operational environments;

Discussion: The presenters provided an overview of several existing modelling challenges, e.g. composability, cyber, human behaviour, autonomous system behaviour, social media. Interaction with various MSGs is key to achieving their research aims:

- Modelling and Simulation as a Service (MSaaS) (MSG-136, -164)
- Environmental effects (MSG-156, -163)
- Simulation open standards (MSG-145)
- Representation of human and autonomous behaviours (MSG-127)
- Representation of non-physical effects (MSG-151, -170, -181)
- Representation of autonomous systems (MSG-154, -183)

This overview led to a discussion about preventing various NMSG activities from becoming stove-pipes. A top level down, more structured approach was discussed. With respect to MSG-127 and the previous discussion of HASB modelling challenges, it was observed that a lack of available behavioural data sets to serve as a basis for building or validating HASB models remains a challenge. The briefer reported that Dstl is just about to let contracts to collect such data, but there are ethical and legal issues with collecting and using this data.

Recommendation: Research overview briefings such as this one are most valuable to attendees if they can apply the results to their own efforts. See summary recommendation 2. This project and the one described in paper #4 should coordinate as they both face the challenge of validating HASB models. See summary recommendation See summary recommendation **Error! Reference source not found.**.

2.4.2 Paper #4 - The Representation of Information Warfare Effects in the Synthetic Battlespace; Keith Ford, Deryck Arnold

Paper Abstract: *The current generation of Simulations and Synthetic Environments (SEs) focus on physical warfare effects and do not adequately represent the wider spectrum of activities in the operational environment. In order to provide a more realistic environment, the next generation synthetic battlespace must include a better representation of other aspects of operations including information warfare, infrastructure, logistics, human interactions and the general populace.*

Thales has led a project on behalf of the Defence Science and Technology Laboratory (Dstl) in the UK to research the provision of Information Warfare effects in the synthetic battlespace. This includes the ability to deny, degrade, corrupt or destroy the enemy's sources of information whilst preserving its own. The future synthetic battlespace must also get synthetic entities to change their behaviour as a result of the information they receive through sources such as web sites, social media, television and radio.

To promote the reuse of Modelling and Simulation (M&S) across the defence community, the UK MOD has a desire to move away from monolithic simulations to more component architectures when representing the synthetic battlespace. In keeping with this approach, Thales has developed a 5 layer communications model in which the information can be manipulated at different stages of the communications chain.

Discussion: The speaker led with a humorous simulated information warfare attack followed by an overview of information warfare effects. He related this to his 3-axis battlespace model: environment (LVC), cognitive, and 5-layer communications model. With respect to V&V of such simulations, the briefer acknowledged that he had no methodology for cyber simulations, and that V&V for behaviour models is particularly challenging.

Recommendation: Given that they project using SISO's C2SIM in the future, the project should get engaged with the SISO Cyber M&S effort, especially the Cyber DEM. This project and the one described in paper #3 should coordinate as they both face the challenge of validating HASB models.

2.4.3 Paper #5 - Introduction of Unmanned Airborne Combat Systems into Future Threat Scenarios: Opportunities and Challenges; Marco Weiß, Johannes Haindl, Florian Gräßel

Paper Abstract: *In future air combat, the integration of unmanned cooperative systems will be a potentially huge force multiplicator. Key factors for its success will be teaming intelligence, coordinated mission planning and cross-platform mission management. Therefore, the task of conceptualizing the next generation airborne weapon system requires a holistic system-of-systems approach that considers the different air vehicles itself, their avionics mission systems and the overall concept of operation against future threats. For early validation of possible solution concepts and assessment of their operational performance, a dynamic multi-agent combat simulation has been developed over the last years within Airbus Defence & Space Future Projects. In addition to its faster-than-real-time engineering functionality, the simulation allows real-time human-in-the-loop experiments to foster collaboration between engineers, operators and customers. This paper presents our approach to dynamic mission simulation and insights from the application of our tool during the Future Combat Air System (FCAS) studies, during which it became clear what will be a key challenge for future applications: Implementing a robust high-level planning algorithm that generates ad-hoc mission plans for complex air operations while considering reactive low-level agent behaviour, human operators and online user input.*

Discussion: The abstract indicates this paper focuses on significant advances in simulation to support evaluation of unmanned cooperative systems, but the bulk of the paper is about a federated, constructive simulation of the type that has been in use for decades. The presenter provided an overview and history of the Future Combat Air System (FCAS) followed by well-known modelling and simulation issues. Their approach to dealing with disruptive technologies appearing in the future is to use a stochastic, Monte Carlo tool to investigate parameter sensitivity. But the brief acknowledged that they can only simulate what they know. They are currently engaged in concept design, only representing current air warfare tactics, not experimenting with new tactic representation.

Recommendation: The authors should get engaged with the SISO Cyber DEM effort. Also see summary recommendation 4.b.

2.5 Panel Session – The NMSG and The Next Generation Synthetic Battlefield

Panel Chair – Dr. Robert SIEGFRIED, Vice-Chair NMSG (Aditerna GmbH, DEU)

Panel Members:

- Agatino MURSIA, Chairman NMSG (Leonardo Company, Italy)
- Dr. Andreas TOLK (The MITRE Corporation, USA)
- Dr. Keith FORD (Thales UK, United Kingdom)
- Dr. J. Mark PULLEN (George Mason University, USA)
- Lesley JACOBS (TNO Defence Research, The Netherlands)

Discussion: Dr. Siegfried opened the panel by putting the following questions to the panel members:

1. What are the real drivers / challenges for future work?
2. What is the role of the NMSG in this future work?

Panelist	Drivers	NMSG's Role
Agatino Mursia	• Combination of technology and political issues, e.g. ○ AI, "Whoever rules AI will rule the world." – *Putin* ○ The potential power of quantum computing, especially with respect to AI	• Attract early career engineers and scientists and pair them up with operational warfighters • Champion migration of technologies, e.g. MSaaS, from concept to implementation
Andreas Tolk	• Operational agility • Autonomous systems	• Education • Contribute to technical solution
Keith Ford	• Outside phase 3, dominate, of warfare • Non-lethal effects, e.g. dazzle lasers, stun grenades, acoustic hailer, tasers • Information warfare	• Weather (including terrain impacts) • Human behaviour • Information warfare • Infrastructure logistics, e.g. traffic • Populace
Mark Pullen	• Geopolitics • Breadth of information, threats, and countermeasures • Cyber	• Support alliance cohesion systems and technologies • Spot and encourage scalable innovation

Lesley Jacobs	• Multi-domain battlespace: information, physical, human	• Integrated analysis of M&S, Data science, operational analysis • Persistent synthetic battlespace capabilities

Discussion: After answering the initial questions, the subsequent discussion included the following observations. Information warfare simulation is challenging because it gets highly classified almost immediately. As a community, we don't know about social sciences simulations while we need to understand both the cyber and HASB aspects. We still don't know how to model influence. Progress is hindered by a lack of trust among the NATO nations with respect to sharing existing data "owned" by the nations. Even so, SMEs agree that, in most cases, the data available is insufficient to validate simulations.

How can simulation support the requirement to reduce military fuel use to meet the 2030 requirement in the Paris Accords? Higher resolution representations of logistics, i.e. fuel, are required. "The Uninhabitable Planet Earth" identifies 12 individual effects, but doesn't analyse the interacting effects which could be done via simulation.

Recommendation: The panel itself provided recommendations for paths forward. STO should create policies to support data sharing including output data and validated system representations. A new task group on information warfare should be started; it should result in a persistent international simulation capability with data storage and sharing.

2.6 Session 3 – M&S in Support of Operations

Session 3 Chair – Prof. Andrzej NAJGEBAUER (Military University of Technology (MUT), Poland)

2.6.1 Paper #6 - Optimizing Flight Paths Through Anti-Aircraft Gun Fire with Machine Learning; Esben Lund, Bernt Almklov, Runhild A. Klausen

Paper Abstract: *We present a methodology intended to optimize the flight path through a flight corridor occupied by enemy anti-aircraft guns. This is relevant for all kinds of aircraft, missiles, and drones moving through air space that is fully or partially controlled by such guns. To this end we use Q-learning - a type of reinforcement (machine) learning - which tries to find the optimal strategy to avoiding the anti-aircraft guns through repeated semi-random flight path trials. Q-learning can produce an optimal flight path through the enemy fire without modeling the anti-aircraft guns directly. An adversary response is still needed, but this can come from a black box simulation, user input, real data, or any other source. Here, we use an in-house tool for generating the anti-aircraft fire. This tool simulates a close-in weapons system (CIWS) guided by a fire control radar and Kalman flight path prediction filters. Q-learning can also be supplemented with neural networks - so-called deep Q-learning (DQN) - to handle even more complex problems. In this work, we present results for a subsonic flight corridor pass of one anti-aircraft gun position using classic Q-learning (no neural networks.*

Discussion: The presenter described the specifics of the operational environment represented, i.e. anti-aircraft fire. He proceeded with an overview of machine learning approaches including unsupervised learning, supervised learning, and reinforcement learning. From there he walked through the calculations of Q-values for the optimized flight path problem and showed results for large numbers of episodes. It might be possible to use this method to represent the anti-aircraft gun. There is a plan for incorporating this into a larger simulation involving UAVs. The following questions are derived from the paper, but there was insufficient time to answer them during the presentation:

1. What other applications might this have?

2. Might this learn the wrong lesson by not representing all aspects, e.g. radar? Should it not look at more parameters?

Recommendation: See summary recommendations 2 and 3. Answers to the above questions could be provided virtually.

2.6.2 Paper #7 - Intelligence Tools for Environmental Threats: Integrated Technologies for Chemical Hazards; Jodi L. Ryder, Victor F. Medina, Manoj K. Shukla, Josh J. Lemonte, Christa M. Woodley

Paper Abstract: *Accounting for environmental hazards in mission planning requires the most up-to-date observations and forecasting of the dynamic battlefield environment. In addition, some hazards, such as the exposure to toxic industrial chemicals and materials (TIC/Ms) in complex urban environments, cannot be predicted in time and space without significant a priori knowledge of TIC/Ms presence in the battlefield, potential release scenarios, and the dynamic ongoing natural environmental processes that result in hazardous soil, water, and air exposures. Teams at the US Army Engineer Research and Development Center (ERDC) are engaged in the development of tools to improve the timeliness and reduce the uncertainty of TIC/Ms risk identification through the integration of spatial and database tools including probable TIC/M locations and quantities, toxicological hazards, fate and transport properties, and soil properties. Furthermore, ongoing efforts to expand the reach of operational hydro-meteorological prediction allow these tools to be applied in rapid fate and transport modelling with greater certainty over a larger swath of the globe than is presently possible. The end result will enable more accurate and dynamic understanding of the chemical hazard potentials that can be encountered during battlefield operations, allowing for better informed routing and equipment selection.*

Discussion: This work is to be commended for the effort to improve multiple dimensions of the representation in this challenging domain by integrating existing, authoritative, disparate sources and tools including US Environmental Protection Agency (EPA) Toxic Release Inventory (TRI), Joint Warning and Reporting Network (JWARN), Incident Command for Drinking Water Protection (ICWater), Specialized Hazard Assessment Response Capability (SHARC), and Hazard Prediction and Assessment Capability (HPAC). Potential future applications could include integrating offline best- and worst-case scenarios as input to more complex constructive simulation environments for the purpose of improving mission effectiveness analysis.

Recommendation: When the research and engineering activities are complete, the results of this effort could be very interesting. See summary recommendations 2 and 3.

2.7 Session 4 – Synthetic Environment

Session 4 Chair – Niels KRARUP-HANSEN (DALO, Denmark)

2.7.1 Paper #8 - Modelling & Simulation for Underground Operations; Major Christian RESCH

Paper Abstract: *Due to the increasing volume of traffic and the resulting efforts of the society to reduce traffic in urban areas and settlements, to build bypasses or due to the topography to move this partially underground. Resulting in an increasing number of complex traffic and safety concepts, which include underground infrastructure. From a fire safety perspective, hazards are manageable and risks are largely calculable. The scenario of a dangerous goods accident in a road tunnels or the release of chemical agents into underground facilities is treated very sparingly (if at all), neither are military concepts for underground operation. However, the attack with Sarin on Tokyo's subway in 1995 shows that underground facilities in particular have a particular vulnerability here.*

Discussion: The presenter began with a description of potential underground vulnerabilities in Vienna, illustrating the types of hybrid threats in his paper: railways, metro, tunnels, canals, parking, shopping malls, and event halls. Most recent R&D has focused on mining, less so on underground infrastructure representation for military or first responder applications. He highlighted specific challenges: geology and construction; water and chemicals; limitations in effects of actions; operations under extreme conditions - movement, TTPs, darkness, obstacles, logistics, communication. The MoD is building 3D models of read underground structures using LIDAR while universities are building models of materials. Applications of this work include: hazard, risk and vulnerability assessment; intelligence preparation of the environment (IPE); protection technologies; TTPs; infrastructure protection / enhancement; emergency planning; and VR/AR training. Visualization is challenging because usual 3D projection systems don't work well with tunnels. The project is working more with assessing team effectiveness within enclosed environments, especially in training first responders.

Recommendation: A demonstration or video of the resulting training capability could be very informative. See summary recommendation 3.

2.7.2 Paper #9 - Representation of Dynamic Synthetic Environments in Distributed Simulation; Arno Gerretsen, Neil Smith, Ruben Smelik, Ralf Stueber

Paper Abstract: *Current practices, standards and technologies are aimed at achieving correlated static synthetic representations of Defence operational environments across distributed simulation systems. However, real world operational environments are dynamic in nature. Weather varies with time and place, and the terrain is affected by both natural effects (e.g. heavy rainfall, snow, flooding) as well as the effects of force behavior, such as munitions damage to buildings and infrastructure. Where multiple simulation systems are federated, both the static and dynamic representation of the operational environment needs to be consistent.*

This paper describes work being carried out by the MSG-156 Task Group (TG) to investigate simulation architectures, processes and standards aimed at achieving improved and consistent representations of dynamic environments across simulation systems. This includes the representation of weather data in simulation, processes to dynamically modify the terrain and protocols for simulation systems to retrieve the current state of the simulated operational environment. Modelling and Simulation as a Service (MSaaS) is assessed as being a key enabler required to achieve this.

This paper describes a set of Use Cases and the Conceptual Models that has been derived from these Use Cases. A proposed architecture for achieving a consistent dynamic synthetic environment is also included, together with a description of planned experiments to evaluate the proposed solution.

Discussion: The speaker began by identifying the MSG-156 focus areas: dynamic terrain and variable weather. He proceeded by describing the program of work and reporting MSG-156's progress against the program. Latency has been identified has been identified as a performance requirement, but the actual metrics haven't been worked out. At this point, the project is mostly focusing on concepts and worrying less about performance requirements because technology will continue to improve. MSG-164 may be providing draft interface specifications for MSaaS next year. Although they don't yet have any preliminary concepts of needed standards, they would consider pursuing those through SISO in the future. They are currently looking at SEDRIS as a source of representations. Although all the use cases are military, this technology also has civilian application.

Recommendation: See summary recommendation 3.

3.0 DAY 2 (FRIDAY, 25 OCTOBER 2019)

3.1 NMSG Young Scientist Award Presentation - Reliability Requirements for Augmented Reality in Visual Search Tasks; Samuel S. Monfort, John J. Graybeal

Paper Abstract: *In military operations, quick and accurate target detection and identification is critical for mission success. Augmented reality (AR) technologies can aid target detection and identification by layering digital imagery atop a Soldier's field of view to increase situational awareness. These systems are rarely perfect, however, and in some cases unreliable AR may actually interfere with performance. This investigation focused on the capacity for unreliable AR to impair performance. We showed participants a series of simulated two-dimensional scenes where highly-visible AR cues were superimposed over tanks placed randomly in a grassland environment. The reliability of these cues varied (from 25% to 100%) throughout the experimental session, as some valid targets were erroneously un-marked (false negatives) while some invalid targets were erroneously marked (false positives). Participants were asked to search for the vehicles while being assisted by the AR; search accuracy and response time were analyzed, and participants provided feedback regarding their mental workload and trust in the AR. We found the expected negative relationship between unreliability and performance, but also found that AR false positives were more damaging to performance than AR false negatives. Unreliable AR also hurt performance more when marking vehicles at greater distances. Further, although error type and target distance had powerful effects on participant performance, they had less of an impact on subjective trust and workload, suggesting that Soldiers using AR might not be consciously aware of how their own performance changes as a function of AR properties. In summary, unreliable AR hurt performance differently depending on the type of errors produced by the system, and impaired some aspects of performance but not others. These results carry important implications for how AR is designed to improve performance on the battlefield.*

Discussion: Testing engineers' hypotheses about the value of cool new tech. How accurate does AR have to be to improve human performance? Contribute to general AR usage guidelines; adapt our existing simulation capabilities to be able to answer sensor- and task-specific questions. False alarms are more damaging than misses. Distance magnifies the undesirable effects of unreliable AR. Although false alarms are more damaging, misses cause more resource drain because those participants increase effort to compensate. Overwhelmingly people with stimuli causes them to withdraw. Future AR systems may allow users to adjust detection thresholds, i.e sensitivity. There is a tangible cost to automating a task that cannot be automated well, e.g. target detection at distance. This study has led to others at NVESD:

- Visual search in a. high clutter environment
- Target acquisition with varying target density, clutter, field of view, and field of regard
- Vehicle identification with algorithm biased towards threats and imagery degradation
- Land navigation with imperfect waypoints

This paper clearly deserved to win the NMSG Young Scientist Award.

Recommendation: Use this work as a template for future presentations on design of experiments. See summary recommendation 4.b.

3.2 Session 5 – xR Technologies & Applications

Session 5 Chair – Leigh YU (DMSCO, USA)

3.2.1 Paper #10 - Exploiting Virtual Reality Technology in Support of Collective Training for the British Army; David 'Rusty' Orwin, Andrew John Fawkes, Peter Harvey

Paper Abstract: *The British Army's Collective Training Transformation Programme (CTTP) is seeking collective training that is conducted in more dynamic and complex environments (physical, virtual and cognitive). It is developing a Future Collective Training System (FCTS) which includes the aim by 2023 to deploy high fidelity simulation across all Army locations. Pilot studies have been initiated, including an investigation of Virtual Reality (VR) technology. Supported by the UK MoD's Defence Innovation Fund, Bohemia Interactive Simulations (BISim) were selected in December 2018 to conduct an FCTS pilot study into the use of Virtual Reality (VR) in Collective Training to explore the strengths, weaknesses, opportunities, and threats of VR technology and its employment. Over a 3-month period, the pilot considered the effectiveness, fidelity, practicality, architecture, scale, interoperability, infrastructure and mobility of VR. The pilot increased in scale and complexity culminating in 37 players in VR conducting training in a combined arms battle. It also investigated Mixed Reality (MR), cloud technology and training measurement and evaluation. The VR technology showed significant potential in support of collective training and conclusions and recommendations from the pilot are presented including those from the spiral development process.*

Discussion: The presentation began with an overview of a typical training demonstration and an overview of well-known personality aspects of the current warfighter demographic, followed by programmatics. Although they asked for soldier feedback, there was no experimental design or data collection. A suggestion was made to customize avatars' body shapes and movement rather than faces because those are the cues used in field situations. The setup was not well designed, leading to damage to the demonstration environment equipment. NATO has a task looking at advocating for standards that might consider new simulation interoperability standards to support CT VR set up. The presentation erroneously identified HLA as not having an open API while suggesting that commercial solutions do.

Recommendation: Virtual reality has been available, at least experimentally, for at least a decade, and there has been considerable hype about its potential applications. More experimental design and data collection should be performed to measure effectiveness objectively. See summary recommendation 4.b.

3.2.2 Paper #11 - Project Hyper Real Immersion (HRI) - A Partnership Approach to the Development of a Mixed Reality (MR) Capability; Sean Bell

Paper Abstract: *Technology used to provide military forces with their asymmetric advantage; however, the increasing pace of technological advances - particularly in adjacent markets in response to huge investments – is creating new challenges for global military forces. Procurement processes that have matured over decades are well suited to large complex equipment programmes, but are less well suited to exploiting technology, where the pace of change outpaces defence's ability to set requirements, go to competition, down-select, contract award, take delivery and finally get technology into service – by which time the technology is already outdated. In addition, training is a vital ingredient in converting equipment into relevant, credible capability. However, defence is not the market leader in simulation technology, and its procurement processes tend to drive industry to the cheapest compliant solution, rather than incentivising industry to capitalise on adjacent market advances to create a vibrant and evolving training eco-system.*

The UK MOD is pioneering a fresh approach. Through the Defence and Security Accelerator initiative, it has down-selected Close Air Solutions (Project Hyper Real Immersion) and its Mixed Reality capability to be a vanguard project in a co-investment partnership approach to capability development. MOD believes that Project Hyper Real Immersion has the potential to transform the operational training landscape and provide our armed forces the ability to fight as we train– quite the opposite of what our peacetime training model provides today. Rather than waiting for a mature product to be available and then start a lengthy *procurement process, leading to early obsolescence, MOD is exploring the benefits of a partnership approach, through rapid iterative development activity, to inform MOD's future requirements.*

Project Hyper Real Immersion is thus exploring not only the potential technological benefits that MR might offer defence in the near future, but also whether a very different relationship with industry is required to capitalise on the technological revolution. This exciting Team UK approach to addressing future Modelling and Simulation requirements could have profound implications for the way modern military forces procure and develop capability; the UK MOD is very keen to collaborate with other nations facing the same challenge.

Discussion: The presentation began with a review of well-known training and procurement challenges and proceeded to a marketing pitch for the presenter's commercial product. NATO and US partners will be invited to participate in the pilot project. The UK MoD is working on changing Joint Terminal Attack Controller (JTAC) Memorandum of Agreement (MOA) accreditation to allow use of VR.

Recommendation: Marketing pitches are probably more appropriate for the show floor at ITEC than for the NMSG annual symposium, especially as this one was labelled as proprietary.

3.2.3 Paper #12 - Immersive Simulation, Prototyping, and Evaluation of Infrared Sensor and Augmented Reality Technologies; John Graybeal, Jacob Quartuccio, Todd Du Bosq

Paper Abstract: *The U.S. Army CCDC C5ISR Center's Night Vision and Electronic Sensors Directorate (NVESD) is tasked with the development of low-light and infrared sensor technologies, which can range in form from air/vehicle mounted sensors, to infantry weapon sensors, and to head-mounted sensors and displays. In this paper, we discuss an immersive testing environment recently acquired by NVESD that is capable of virtual prototyping exercises for different sensor systems, and is likewise capable of serving as an immersive environment examining variations of AR displays and methods of presenting AR information to human operators. The immersive environment consists of a "green room," consisting of plexiglass panels that emit green light via controllable, electroluminescent tape. A pair of cameras, paired with a Vive virtual reality headset (HTC Corporation), are used to form a composite view of real objects and virtual overlays; any object observed in the immersive testing environment is visible to the user, but open green space is replaced by the virtual environment. We describe the new system and simulation use cases for both sensors and AR technologies, describing how such simulation technologies can allow for strict control of empirical scenarios, providing a vigorous evaluation of device characteristics. Ultimately, such simulations will allow Soldiers to experience sensor characteristics and AR displays before the first physical prototype is ever constructed, soliciting valuable user feedback early in the design phase of the acquisition lifecycle.*

Discussion: The presenter began by identifying the shortfalls of non-immersive technologies for prototyping technologies that will be used in a full, live environment. NVESD's "holodeck" is image generator and display agnostic. He illustrated integration of the "holodeck" with a 3D-printed prototype of a proposed sensor. NVESD is working on an experiment of eye-tracking of AR elements vs field of regard because AR elements are expected to be distracting initially. Warfighters haven't reported adverse symptoms after short usage, nor do they see evidence of AR / VR impacting warfighter performance immediately following use, e.g. in flight simulators. The project is researching causes of simulator sickness including gender variance, some of which is device specific. Collectively, the results of the AR Red Team simulations demonstrated that the accuracy thresholds required for AR systems to improve human performance vary as a function of both the specific task itself, and the difficulty of various perceptual judgements within the same task, i.e. distant versus close targets. This is true for any visual task, e.g. detection of people in ghillie suits vs out in the open.

Recommendation: Invite this presenter / project back to discuss the results of these efforts, focusing on experimental design and objective outcomes, as well as lessons learned integrating different technologies into the "holodeck." See summary recommendations 3 and 4.b.

3.3 Session 6 – Architectures

Session 6 Chair – Horst BEHNER (MoD, Germany)

3.3.1 Paper #13 - M&S as a Service (MSaaS): Proof of Concept Development and Integration of a Sensor-as-Service for a Virtual Flight Training Eurofighter Simulation; Daniel Kallfass, Martin Sommer, Stefan Vrieler, Marius Dickebohm

Paper Abstract: *The NATO Modelling and Simulation Group MSG-136 "Modelling and Simulation as a Service (MSaaS)" as well as the follow-on MSG-164 "M&S as a Service (MSaaS) Phase 2" targets to develop a service architecture providing rapid deployment of interoperable and credible simulation environments.*

This paper presents the results of a proof of concept implementation of an optical and infrared sensor which is realized as a Sensor-as-a-Service. This Sensor-as-a-Service can be provided to other simulators or real operational systems as a lightweight service which can easily be deployed and hosted e.g. on a NATO cloud. As a use case the sensor-as-a-service was integrated into a flight training Eurofighter simulator of Airbus.

Through this proof of concept implementation it was investigated, how a sensor-as-a-service can be designed and hosted on a cloud system and be interconnected with a virtual flight training Eurofighter simulation.

A key issue in infrared image generation is to provide a virtual 3D terrain including multispectral information such as terrain surface types. In this proof of concept demonstration the OGC standard Common Data Base (CDB) was selected. Moving objects are received either through DIS/HLA distributed simulation networks or optionally passed through a service request to the sensor as a service. The sensor parameters like the spectrum, orientation or zoom level can be steered by the virtual Eurofighter cockpit through the service interface.

Discussion: This effort extends the German system demonstrator VIntEL based on the recommendations of MSG-136 and MSG-164, integrating a German Eurofighter virtual cockpit, Common Data Base (CDB)-based synthetic environment service, common operating picture (COP) service, PAXSEM CGF service, virtual sensor service, and a weapon service. The architecture makes extensive use of open, international standards identified in NATO Allied M&S Publication 01 (AMSP-01). They have not yet verified whether containerization improves simulation setup and deployment or reuse, nor do they have a clear recommendation on appropriate granularity of services. Lessons learned for adopting MSaaS include:

- Containers are a mature technology and M&S standards are easy to integrate. But, standards for modularizing functionality are still lacking.
- A business model is needed that works for businesses, users, and developers.
- Decomposing legacy systems is probably not a good idea.

Recommendation: Encourage more sharing of reusable lessons learned such as those above. See summary recommendation 2.

3.3.2 Paper #14 - Development of an Air Operation eXtension with the (Future) C2SIM Standard; Magdalena Dechand, Lukas Sikorski, Irmtrud Trautwein, Bruno Gautreau, Eric Bouvier, Lionel Khimeche

Paper Abstract: *The MSG 145 group is working on the Operationalization of Standardized C2-Simulation*

Interoperability, side-by-side with the Simulation Interoperability Standards Organization (SISO) Product Development Group (PDG) which is developing the C2 System to Simulation System Interoperation (C2SIM) *standard. The C2SIM standard will improve upon and replace the currently existing combination of Military Scenario Definition Language (MSDL) and Coalition Battle Management Language (C-BML) SISO standards, with a modular approach enabling users of different domains to define their needs in extensions. The main elements of the C2SIM standard are a core logical data model (created as ontology), an extension mechanism, and several extension ontologies (e.g., Land Operation eXtension). The C2SIM standard also supports the transformation of the exchanges (tasking/reporting messages, initialization of C2 and simulation systems) into Extensible Markup Language (XML) schemata.*

This paper describes the work done by a French-German subgroup of the MSG-145 to implement a new C2SIM extension for an Air operation domain. The work includes the operational analysis of an Air operation scenario, the design of the logical model with ontologies, the generation of the XML schemata, and their implementation in the systems. This paper concludes with lessons learned, and contributes to the evaluation of the operationalization and the extension of the C2SIM standard.

Discussion: Commission Electronique (COMELEC) is an ongoing French-German project. The presenter provided a brief overview of the relationship between ontologies and schemata. The project illustrates how to add air operations entities to the existing C2SIM core ontology including replacements for both MSDL and C-BML. There are challenges with generating schemata from ontologies, so the PDG agreed to some constraints to achieve a workable standard, e.g. relying on users to use the standard sensibly rather than implementing restrictions. In the future, once the C2SIM PDG has focused on modelling ontologies, they may pursue solutions to the issues identified concerning OWL reasoning features.

Recommendation: See summary recommendation 3.

3.3.2 Paper #15 – A New Simulation Infrastructure Supporting the Next Generation of Simulation-Based Testing and Training Applications; Andreas Tolk, Omar Valverde, Joe Clapis

Paper Abstract: *The next generation of simulation systems contains new requirements for simulation infrastructures significantly different from current solutions. Current simulation interoperability standards, such as IEEE 1278 Distributed Interactive Simulation (DIS) and IEEE 1516 High Level Architecture (HLA), are updated on a regular basis by standardisation bodies. Nonetheless, their conceptual frameworks and technical structures are rooted in the last decades' technology and often reach their capability limits when applied to support the most recent system engineering challenges. NATO continues to support and apply these standards, despite them being no longer sufficient to support training, education, and testing of next generation defence systems. We present concepts needed to implement a novel simulation infrastructure, centred around an Information Exchange Services Matrix (IESM) and accompanied by supporting services. This allows the application of new technologies and accommodates the evolution of these technologies in support of composable solutions that provide both "fair fight" training and analysis. These general concepts are applicable to the development of a Joint Simulation Environment (JSE) for the next generation of simulation systems. This paper describes the concepts behind the IESM and their supporting services.*

Discussion: The presenter asserted the need for new standards without knowledge of progress being made in existing standards, identification of actual issues, or evidence that their proposal would solve these unknown issues. The proposed schedule to prototype an entirely new infrastructure in two years and have it fully functional in four years is unrealistic given substantial data available on the development time required for existing simulation interoperability solutions. When asked about tackling conceptual modelling and composition, known unsolved problems in M&S, rather than building a new infrastructure that substantially reproduces the functionality of HLA, the briefer asserted a new interoperability solution was required because their problem was constrained to a smaller one than the one solved by HLA.

Recommendation: A more complete, detailed vetting process would eliminate technically inaccurate papers such as this one. Additionally, this is effectively a marketing pitch for a proprietary architecture that competes with NATO's policy of using open standards.

3.4 Session 7 – M&S Applications

Session 7 Chair – Julie TREMBLAY-LUTTER (DRDC, Canada)

3.4.1 Paper #16 – Virtual Reality CBRN Defence; Johannes Göllner, Andreas Peer, Christian Meurers, Gernot Wurzer, Christian Schönauer, Hannes Kaufmann, Chris Bösch

Paper Abstract: *Over the past decade, training in virtual reality for military and disaster preparedness has been increasingly recognized as an important adjunct to traditional modalities of real-life drills. However, there are only a few existing solutions that provide immersive virtual reality training and improve learning through an increased amount of presence. In this paper, we present a novel and flexible Virtual Reality (VR) training system for military and first responders that enables realistic multi-user training in large environments. We show how the requirements of peer stakeholders for disaster relief with an explicit focus on CBRN disaster preparedness transfer to the concept, current implementation and future features of our system. The development and integration of multiple technologies allows a wide variety of interaction and collaboration within our immersive system. In addition, we demonstrate the training capabilities of our proposed system with a multi-user training scenario, simulating a CBRN crisis. Results from our technical and user evaluation with 13 experts in CBRN response from the Austrian Armed Forces (National Defence Academy & Competence Center NBC Defence) indicate strong applicability and user acceptance. Over 80% of the participants agreed "much" or "very much" that the presented system can be used to support training for CBRN-crisis preparedness.*

Discussion: The paper provided a good survey of previous work in the field which is to be commended. One of the focuses of this effort is cost effectiveness. Automated after action review (AAR) is planned for the prototype. Training was well received by users and trainers, but objective measures of training effectiveness do not appear to have been captured. Experts are needed from the military, commercial industry, and academia to understand the training problem(s) and technologies.

Recommendation: See summary recommendation 3.

3.4.2 Paper #17 – Joint Simulation Environment for United States Air Force Test Support; Timothy Menke

Paper Abstract: *Advances in integrated, multi-domain warfighting capabilities are challenging the ability of militaries to rapidly design, develop, field, support, test, and train next generation war fighting capabilities. Today's physical test ranges, in their present form, are inadequate to meet the testing and training needs of these future integrated weapon systems. Future test capabilities must be augmented with state-of-the-art modelling and simulation technologies to form a virtual range capable of meeting development, test, and training needs in a rapid and cost-effective manner. The United States Air Force, in concert with our Service partners, intends to develop an integrated modelling and simulation based virtual test range to address these challenges. The Joint Simulation Environment (JSE) leverages lessons learned from recent modelling and simulation activities in support of Joint Air Force and Navy testing. JSE seeks to advance the state of the art in modelling and simulation technologies applied to test, training, and experimentation. This paper will discuss JSE use in supporting Air Force objectives, challenges, way-forward, and potential NATO Partnership opportunities.*

Discussion: Standards, interoperability, reuse, and partnering are critical. Live ranges no longer meet testing needs for the Joint Strike Fighter (JSF) due to: geographical constraints, technology limitations, electronic warfare, frequency spectrum, operational limitations, and safety. Live asset integration has not been levied as a test requirement, but it might be as part of training.

Recommendation: This topic represents an opportunity as a use case for tackling emerging M&S challenges across NATO. See summary recommendation 4.c.

3.4.3 Paper #18 – Integrated Analysis in a Synthetic Battle Space - Lessons from JPOW 2019; Linda van der Ham, Lesley Jacobs, Hester Vermeiden, Maj. Alexander Mac Lennan, Lt.Col. Dirk Reinartz

Paper Abstract: *This paper describes the collaborative R&D effort that has been conducted to develop and implement, for the first time in its history, an integrated analysis concept in the Joint Project Optic Windmill (JPOW) exercise series. Since the first edition in 1996, JPOW provides an extensive synthetic battle space - suitable for live-virtual-constructive participation - in which NATO and its coalition partners focus on enhancing interoperability in the Integrated Air & Missile Defence (IAMD) domain by exploring, testing and training future IAMD concepts and solutions.*

The work presented is a joint effort of TNO Defence, Safety & Security, the Royal Netherlands Armed Forces, the German Air Force, and JPOW participants. This paper elaborates on the iterative and multi-disciplinary development and use of several state-of-the art data collection, monitoring, analysis, and visualisation tools enabling both in-situ/real-time data and performance analysis, as well as 'deep analysis' in a post-exercise analysis environment such as the Dutch IAMD Battle Lab. In addition, the organisational innovation that is required to successfully implement an integrated analysis concept will be highlighted. Based on lessons which were identified from JPOW19, this paper concludes by depicting the way ahead on how integrated analysis can enhance the effectiveness of synthetic battle spaces for both current and future military operations.

Discussion: The presenter provided an overview of the history and participants in the yearly JPOW exercises. Legacy live systems can still only be stimulated via DIS, not HLA. The 2019 JPOW lessons learned identified the need for deep analysis, e.g. evaluating the effectiveness of design defence on a daily basis. The presenter illustrated the analysis approach and architecture.

Recommendation: See summary recommendation 4.c.

4.0 SUMMARY AND RECOMMENDATIONS

The following is a summary of the presentation by the TER at the end of MSG-171. The items contained here are solely the opinions of the technical evaluator and are not intended to reflect any form of official position.

The opening, invited presentations provided excellent complementary military and civilian perspectives on future challenges for M&S. The organizers are to be commended for selecting papers encompassing all aspects of the theme, Next Generation Synthetic Battlespace.

Recommendations:

1. Several suggestions were made to take a more holistic approach to identifying future NMSG activities which is in keeping with the increasing complexity of integrated M&S and representation of systems of systems. This approach should be encouraged and reflected in a future symposium.

2. One of the key benefits to participants is knowledge acquisition they can apply to their own efforts. In future calls for paper, explicitly request shareable lessons learned and metrics that may help other

participants improve their own efforts. Consider sessions with shorter briefings (15 min.) followed by a panel session where presenters share lessons learned and answer questions from attendees on applying new technologies.

3. Because the topic of the symposium changes every year and presentations are often on work in progress, attendees may not receive the full benefit of the final outcomes of the projects presented. Additionally, the symposium's focus on new and emerging technologies guarantees the topic field is moving very fast, making continuous engagement by attendees highly beneficial. Establish a virtual mechanism to maintain momentum on the topic including follow up detailed questions to presenters where all attendees can view answers, e.g. a wiki or knowledge base. It could also be a mechanism for sharing results of ongoing work.

4. Consider the following for future topics:

   a. V&V of nascent modelling domains, e.g cyber and HASB, to get out in front of potential problems before there are implementations whose results may not be trustworthy.

   b. Experimental design for emerging technologies

   c. Cross-NATO use case challenges, i.e. addressing individual M&S challenges unified by a single use case; this ties in with summary recommendation 1.