Technical Evaluation Report

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ABSTRACT

This technical evaluation report summarizes the main contributions of the presentations given during the 2017 NATO Modelling & Simulation Group (NMSG) Symposium on M&S Technologies and Standards for Enabling Alliance Interoperability and Pervasive M&S Applications. It augments the papers collected in the proceedings, addressed furthermore the main points of keynotes not accommodated by a paper, and presents a summary of discussion and identified key insights of these high calibre two-day convention of simulation experts working in support of the alliance. It recommends future activities based on the papers, presentations, and discussions summarized here.

1.0 INTRODUCTION

The Mission of the NATO Modelling and Simulation Group (NMSG) is to function as a management body in which the full range of Modelling and Simulation (M&S) interests can be represented; and to promote the coherent management and co-ordination of M&S across all alliance activities in the principal application areas of defence planning, technology development and armaments acquisition. In support of this mission, NMSG conducts annual symposia to present research conducted by NATO and the nations in key areas of M&S in support of defence applications. The focus of the 2017 symposium was *"M&S Technologies and Standards for Enabling Alliance Interoperability and Pervasive M&S Applications."*

The call for papers emphasises that M&S has become a critical technology in NATO and partner nations. M&S provides training opportunities where mission complexity or limited resources restrict live exercising possibilities. Analysis and mission planning tools use M&S to support operational decision making. Simulation technology is still rapidly evolving – the past years have shown significant progress, not in the least in the consumer and civilian market. These technological advancements create opportunities for new and innovative applications that can counteract the threats our military organisations face, as well as the fiscal realities. Simulation standards can improve interoperability within the Alliance and enable even more effective use and sharing of NATO and national assets. New technologies and standards nowadays allow easy access to simulation assets for a broader community than ever before; thus, making M&S a truly pervasive technology.

Alliance interoperability is a technical premise for pervasive M&S applications, but the best technical solution needs an educated workforce as well as managerial support to be successful. Therefore, the papers do not only address technical solutions, but do also provide recommendations to align processes to be followed in the alliance, make recommendations for improved governance, and address education. For the

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better organization of research as well as results, several contributions introduce reference architectures that have the potential to serve this purpose for future research and its applications.

This technical evaluation report has been compiled with the intention to summarize the main ideas of the papers, presentations and following discussions complementing the proceeding contributions as featured in this report as well. They reflect the interpretation of the evaluator and have been conducted with utmost scientific rigor. However, as the presented efforts are on the leading edge of science and research conducted in support of NATO, the reader is encouraged to carefully study the report itself and conduct additional research to ensure the maximal benefit.

2.0 KEYNOTE, INVITED PRESENTATION, AND YOUNG SCIENCE AWARD

The national keynote and the invited presentations did set the frame for the symposium at the beginning of the first day, as they provided complementary views on the role of M&S with focus on the pragmatics and practical challenges in the keynote on the one site, and by providing an overview of academic constraints currently being object of research in the invited presentation on the other site.

Furthermore, the NMSG recognized a young scientist for the contributions in the domain of M&S at the beginning of the second day. These three special presentations are summarized in this section.

2.1 Pragmatic Approach to Military Simulation & Virtual Training Industry, SMEs Dilemma: In House vs COTS Modelling & Simulation

The national presentation was delivered by Carlos Felix. The presentation focused on management challenges observed in industry over the last 25 years, mainly gained from supporting the military with advanced training systems on the global stage.

One of the decisions managers often are faced with is whether to build a solution in-house, or to acquire an commercial off-the-shelf (COTS) solution already developed that needs to be integrated. Three use cases from the company ETI were presented to exemplify decision parameters utilized by subject matter experts (SME) in supporting the decisions for or against off-the-shelf solutions.

General pros for the use of COTS solutions are leveraging the technology, in particular from gaming and visualization, keeping development costs low, enabling an easier entry to market, and the use of open standards and plug-in compatibility. It also reduces costs for own research, as generally accepted solutions are used. The cons are that the technology changes so quickly that mature technology, as required by the military, are rare. Also, the integration costs sometimes are significant and require well-understood, preferably in-house modifiable and adaptable middleware solutions. In addition, commercial tools are designed to provide vendor-specific support that usually is not satisfied by standardized solutions, so tools are optimized for this vendor advantage, not for standards. The focus on what is special, not on what is standardized. All this implies that a dependency to the vendor can be the result of integrating off-the-shelf solutions that can become a challenge by itself when the market changes.

The three use cases presented demonstrated that there may be trends, but no general solutions or recommendations for the use of COTS use. In all three use cases, a trade-of between own experience, development time and budget, and available solutions had to be conducted. The top ten key decision factors presented were acquisition cost, lowering the technology barrier, time-to-market/delivery, the market strategy, training system requirements, resource availability, company maturity level delivering the off-the-shelf solution, life cycle support (for upgrades, maintenance, etc.), technology maturity level, commonality of solutions, and interoperability.

The conclusion presented is that there is no general solution for COTS decision, but the ten key factors were applicable in all three use cases, and in particular user requirements and maturity of existing solutions will drive the project specific decisions.

The discussion supported the view of the national presentation, emphasising the need for interoperability standards that enable the easy integration of realistic representations based on the user requirements. The challenges of combat modelling are too big to be solved by just one company, so collaboration of various solutions is desirable. This requires transparency between the organizations and the solutions, facilitated by open standards and interoperable solutions. Longer living standards may be achieved by not focusing on solution- or domain-specific standards, but to use standards on the metadata level that are flexible and adaptable enough to survive short-term specific solutions.

2.2 Interoperability and Composability: A Journey through Mathematics, Computer Science, and Epistemology

This invited presentation was delivered by Andreas Tolk and is accompanied by a paper in these proceedings. It gives an overview of interoperability and composability related research in research organizations and academia, focusing on implication for NATO in general, and the NATO Modelling and Simulation Group (NMSG) in particular.

While interoperability is well understood in the community, the idea of composability still needs to be fully embraced, although first ideas into this direction are captured in other contributions featured in these proceedings, in particular when reference architectures guided by operational use cases are applied. Interoperability is generally understood as the ability to exchange data – and services – and make use of them in the receiving system. The standards captured in NATO architectures and profiles, such as the IEEE 1278 Distributed Interactive Simulation (DIS) and IEEE 1516 High Level Architecture (HLA) are interoperability standards. Composability goes beyond this definition and requires the logically consistent representation of truth in all participating system. It requires the conceptual alignment of all systems. If information is requested from the composition, the answer must be the same, no matter which component is delivering it. While *interoperability enables fair fight situations, composability ensures fair fight situations*. The mathematical foundations for this observation have been proven using model theory, which deals with formal languages and logic, requiring conceptual alignment of technically coupled models. Interoperability is necessary, but not sufficient to reach the objectives of NATO regarding M&S applications.

Computational constraints are not only resulting from the use of different computers, languages, or compilers, but also because heuristics and numerical approximations and digitization adds slight misalignments that can have tremendous effects when computing the effects of non-linear activities. The computational constraints are theoretically well understood, and some principles go back to Alan Turing and Kurt Gödel, but they are often insufficiently considered in practical solutions that may lead to negative training or wrong decision support.

Epistemological constraints result from our different views of what is important. These views are not necessarily wrong, but they may be complementary, focusing on different facets, or competitive, showing real alternatives that may even be exclusive. *Models are purposeful abstractions and simplifications of a perception of reality.* Simulation implement these complementary or competitive models. Current standards, such as HLA and DIS, target the simulation implementation, not the model conceptualization, and that is where many misalignments occur. The use of standardized metadata allowing to check the conceptual alignment of composed solutions is a possibility worth evaluating.

In the era of MSaaS, this problem is magnified, as cloud based composition makes it technically easier to compose solutions that can exchange information, but that are not conceptually aligned.

Diversity of solutions can be beneficial when different facets are evaluated, but when conceptually contradicting solutions are composed, the resulting composition is meaningless. Consequently, the NMSG is encouraged to continue to support and evaluate core research on the mathematical foundations of interoperability and composability, which will allow for the generation of necessary metadata to accompany simulation solutions in repositories or presented as M&S as a Service (MSaaS). Furthermore, NMSG needs to provide the necessary governance to support interoperable and composable simulation solutions for NATO, as the underlying challenges are not purely solvable by technology methods, as the conceptual challenges cannot be fixed by technology solutions.

The discussion showed the need to address the idea of conceptual alignment in future activities, as the lower levels of interoperability are well addressed with various well understood solutions today. Operational use cases may help to create blueprints of missions that then can be instantiated with components that are aligned using the operational insight of the supported end users.

2.3 MSG Young Scientist Award Presentation: One World Terrain and Beyond – Photogrammetry, Mixed Reality and Simulation

On the start of the second day, Mr Ryan Spicer from the Institute for Creative Technology (ICT) at the University of Southern California received the *MSG Young Scientist Award.* His presentation described the "One World Terrain" project, which is creating virtual worlds for small team training using real world data, like photos or videos that can be collected by soldiers, drones, or other means.

Photogrammetry, the use of photography in surveying and mapping to ascertain measurements between objects, is a well-known technology used in several application domains. ICT is classifying the data resulting from these methods and makes them useable for simulations. This includes improvement of geometry and realism in representation, plus better classification of ground data, building and structures, and vegetation from the photogrammetric data. The resulting high-resolution, high-fidelity data allow for route planning, line-of-sight visualization, and other terrain- and environment specific calculations used by the simulated entities within the simulation. It is also used for building "virtual sand tables" that can be used for training, but also for operational support.

The process is low cost, geospecific, rapid, and is conducted in an established semi-automated pipeline. There are still challenges to overcome, such as noise in the data, longer time and more computational resources needed for high-resolution solutions, and the need to support better first-person visualization for soldier on the ground. Also, interior structures of photometrically captured buildings and material identification are not yet supported, but are the object of future work of the group.

In the discussion, the need for supporting additional data, such as multispectral and thermal imagery was raised, which is possible, but currently outside of the scope of the work. Also, the need to exchange and use other data, provided in open standards, was discussed.

3.0 SESSION 1 – EMERGING M&S TECHNOLOGIES AND CAPABILITIES

The first session comprised five presentations on emergent M&S technologies and capabilities, such as virtual and augmented reality and cloud computing. Special interest was given to the results, their implications, and prototypical implementations of the panel activity MSG-136, which focused in the recent years successfully on the concepts for MSaaS within the NATO domain.

3.1 Mixed Reality, the disruptive technology to increase exercise realism, improve live training efficiency and shorten exercise preparation (P1)

The first presentation was delivered by Lionel Khimeche. Virtual reality (VR) places human actors into a virtual environment, such as provided by simulators or VR googles. Augmented reality (AR) enriches real environments with virtual entities, such as displaying a building that is not yet there. Mixed reality (MR) uses inputs from both aspects, creating immersive environments comprising real and simulated entities alike. They provide a good opportunity to support better training, as it elevates Live-virtual-constructive (LVC) composition to a new level of interoperability and operational applicability.

The French Army requires very flexible and agile training tools in complex scenarios. AR seems to provide the technical capabilities to support collective and individual training, including training of dismounted soldiers. The presented approach extends the currently used VR solutions to evaluate the applicable of AR. This was done during the advanced study "SIMBA", which collected end-user requirements and conducted technology studies first, then conducted experiments, and now is ready to provide technology demonstrations for the end-user next year.

One of the lessons learned is that AR is not only about equipping soldiers with AR glasses. It also requires technology to scan the environment and build a 3D reconstruction, generating avatars and virtual artefacts, and deal with sensors. Accordingly, SIMBA has five governing functions: generate the environment, reproduce the senses, instrument legacy weapons to interact in the AR world, manage the AR exercise, and control the technical functioning. Main technical challenges were the development of efficient *Simultaneous Localization and Mapping* (SLAM) algorithms and the realistic display of real and virtual effects, such as augmented entities partly covered by real world objects (occlusion), or real-world objects exposed to augmented effects. Like the *Dead Reckoning* algorithms in DIS applications, agreeing on or even standardizing SLAM algorithms will improve the fair fight between such implementations.

In the first experimentation, a group of dismounted soldiers were equipped with SIMBA equipment and fought side-by-side with a tank-crew in a virtual simulator, both embedded into a DirectCGF constructive scenario. All elements were coupled using the DIS standard. The results overall were positive, although glasses only supported the representation of virtual targets within a 35^{o} cone, which was perceived as negative, as peripheral vision of soldiers was not supported. The second and third experimentation focused on dismounted combat in urban settings, as provided by the national training centre CENZUB. Improved AR technology overcame the original shortcomings and was well received by trainers and trainees. Virtual and real targets were successfully engaged using the legacy laser technology as well as digital bullets. The final experimentation supported a close air support exercise in which an observer successfully directed a real helicopter in the real environment to engage a virtual target.

Next steps will be to find glasses with a larger field of view, improve the SLAM algorithms, and provide a modular architecture to better support distributed exercises. The vision presented targets the individual support by 2025, battalion level support by 2030, and full support of the CTC and mounted-dismounted engagements by 2035. The discussion brought up the questions to what degree this approach could benefit from MSaaS and vice versa. This question came up with different facets in the following presentations as well.

3.2 Enhancing Coalition M&S Responsiveness & Credibility by Understanding & Leveraging Proven Standards Ensembles (P2)

The second presentation was given by Kenneth Konwin, who represented the Simulation Interoperability Standards Organization (SISO) product development group (PDG) on "Acquisition M&S PDG - A Standards Profile for M&S Activities in Support of Acquisition Activities." The overall objective of the presented PDG activities is to apply proven standards and best practices to improve responsiveness and

increase credibility. Therefore, the SISO product aims to provide guidance on the selection and use of M&S standards and recommended practices to support the acquisition lifecycle and was recently extended to support the training community as well. The drafts of the documents are and future products will be accessible via the SISO website [1, 2]. NATO is following a similar route with their NATO Standards Profiles, providing not only description of the standard, but also on the context of their successful application, done in form of a vignette. Examples given in the presentation (and in the paper) include the simulation examples from training, procurement, and more.

The artefact-to-activity examples provide valuable lessons learned for project managers on which standards were successfully applied in which activities of comparable challenges. The PDG seeks additional input from practitioners, writing their experiences down in form of such tables, so that the experiences are shared regarding what works well, but also what did not work at all. The NMSG and the symposium audience was asked to play an active role in this process.

The following discussions emphasised that M&S as its own discipline needs to capture lessons learned in a professional way, and the presented approach is welcomed by practitioners. The continuation of the collaboration of NMSG with SISO is therefore encouraged.

3.3 The NATO MSG-136 Reference Architecture for M&S as a Service (P3)

Ole Martin Mevassvik presented the results of MSG-136 in the context of reference architecture applications. MSG-136 recommends a common approach for NATO and the nations to implement MSaaS. It published a technical reference architecture as a NATO report. It is supported by government and conceptual guidelines.

The paradigm and vision of MSaaS is to compose simulations from loosely coupled simulation services. The services are separated from their implementation and focus on implementation-independent descriptions of services and their access points, which can be brought into and discovered within a repository. These repositories may also comprise links to the implementation as well as successful compositions.

The simulation operator shall be supported in discovering, composing, and executing simulations and compositions. Discovery is the ability to find a simulation service that is capable to provide some needed functionality. The selected services are then composed into a loosely coupled solution that can be executed.

This new model places new constraints on validity and safety. It is well known that the composition of validated services not necessarily results in a valid composition [3]. It is therefore recommended to only store validated services and compositions in the repositories and in addition support the validation of new services by the users within the composition guidelines. It will also be pivotal to ensure the security of the provided services and data regarding unauthorized change or use. Several new requirements are likely to emerge on multi-level security in coalition scenarios that will require new solutions.

The technical reference architecture extends experiences from non-simulation domains that already provided solutions for more general challenges. The content is stored in the NATO C3 taxonomy. The structure is based on the Open Group SOA Reference Architecture. The multiarchitecture topology specifies what is included in a composed simulation service, extending the DSEEP DMAO [4] with a service oriented enclave. The next steps will be focusing on providing improved capabilities on M&S composition services, M&S repository service, and M&S security services, with the operational use targeted in 2025.

The discussions showed that the current focus on the technical reference architecture needs to be augmented by respective activities to support the business and conceptual challenges as well. Also, the experiences regarding DMAO need to be fed back to the community.

3.4 NATO Aligned UK Approach to Modelling & Simulation as a Service (P4)

Jon Lloyd delivered the presentation focusing on UK research outputs and how they can be used in support of the NATO vision of MSaaS. In the UK, moving simulations to the cloud was mainly driven by the need to deliver more agile simulation covering the full spectrum of operational needs. The enterprise level coherence is another pillar required by UK policy. MSaaS is generally perceived as an important concept to reach these objectives, so that UK supported MSG-136 as part of their research work.

The UK developed a UK Research MSaaS Portal that extends the three steps of discover, compose, and execute recommended by MSG-136 slightly, but consistently, by providing some additional details for the sub-phases (discover, events, compose, deploy, execute). The discovery is supported by repositories that feed into registries, which build the access point for search and queries. The repositories are configurable to allow privacy and filtering. Composition supports individual services as well as simple compositions that already have been validated and successfully used. Deployment and execution is supported by various new concepts, including cloud, virtualization, infrastructure as software, etc.

The UK portal was demonstrated by Keith Ford as part of the presentation. The discovery process is the most matured section, providing several ways to search for available services and compositions. Composition is currently in early stages, showing discovered services and compositions that know can be composed into the new, required functionality. Deployment and execution are limited to prototypes, but are based on extensible solutions.

In conclusion, MSaaS is a key enabler to maximising the effect of simulation. The technology is maturing to deliver an Initial Operational Capability (IOC) soon, but more investments are needed.

The discussion recognizes the applicability of the demonstrated idea for constructive simulation but recognizes potential shortcomings for the integration of live and virtual elements. New technologies, like the use of micro-services – a suite of independently deployable, small, modular services in which each service runs a unique process and communicates through a well-defined, lightweight mechanism to serve a business goal – may allow for new solutions that may not be achievable by virtualizing legacy solutions. Overall it was recognized that the virtualization of legacy solution is a good first step, but not sufficient to provide the flexibility envisioned by service-based concepts.

3.5 Proof of concept demonstrator of MSG-136 for using and providing simulation as a service within NATO environments (P5)

The final presentation of the first session was given by Danial Kallfass and Stefan Vrieler, featuring the contributions to develop a proof of concept demonstrator to show the feasibility of a service based environment defined in MSG-136. It took advantage of experiences made with the German systems demonstrator *VIntEL*, which has been featured in several NMSG conferences presentations in the past years. To show the international applicability, a Norwegian service was integrated into the demonstrator as well. The concept demonstrator comprises not only simulation components, but also command and control functionality.

Following services were used:

- Synthetic environment services (which are presented in more detail section 6.2 of this report and P16 in the proceedings) to provide common terrain;
- Route planning service as an additional service used by the simulation;
- Computer Generated Forces Service (provided by PAXSEM) to execute the simulation;
- Web Application *WebLage* as a generic web-based exercise visualization and control tool;

- German Army C2 system *FüInfoSysH* to display the situation and give new orders.

The demonstrator had clear rules for responsibilities and order of execution, supporting fair fight consistency by its design. The integration took advantage of mature technical solutions, like OGC Web Map Services (WMS) or RESTful (Representational State Transfer) services, and used NATO standards as well, in particular the NATO Friendly Force Information (NFFI) standard and the Coalition Battle Management Language (C-BML).

The demonstrator showed the feasibility and possible reuse of existing services. Standardized interfaces and lightweight services simplified the use and integration.

Editorial remark: A sixth paper originally planned for this session unfortunately had to be withdrawn. The paper presented another successful prototype of simulation service applications.

4.0 SESSION 2 – M&S TO SUPPORT OPERATIONS

While training and education remains a dominant application domain of M&S in NATO, the number of operational use cases benefiting from M&S functionality during operations increases. The papers comprised in this session exemplified the supporting role of M&S for influence operations, information warfare, protection against terroristic attacks in ports and harbours, and the use of unmanned systems. A common factor is the integrated use of artificial intelligence (AI) within or coupled with M&S, and the need to extend current reference architectures by cognitive components to support this new application field.

4.1 M&S for Influence Operations (P7)

Antony Hubervic presented recently gained insights on the support of information operations, in particular the training of information operation officers. Focus of the presented work was the information exchange and collaboration of information operations with other entities on the military level, such as key leader engagement, psychological operations, etc. These operations shall support friendly and allied forces and oppose adversaries, opponents, and detractors. To do so, first the perception of the targeted entity is effected, then the attitude, and finally the behaviour in the battle sphere, which includes space and cyber. To support these objectives, the IO model leverages motivations and targets vulnerabilities of these entities.

Information officer training is currently insufficiently supported by simulations. The goal of the presented efforts was to close this gap. The first activity was development of an environmental model that allowed to represent the entities with characteristics of interest for information operations. Once this was accomplished, a message model could be implemented to capture possible messages between and their effects on the enties. The action model uses these messages, but adds injection vectors to it. The propagation model was used to represent if messages are perceived, get attention, and may change the attitude or even the behaviour of the receiving entity.

The implementation used a legacy combat arms simulation used for training that was modified by the information operations simulations. If the behaviour of own or opposing forces was changed based on the information operations, this effected the efficiency of the combat arms simulations. In addition, new visualizations were used to contribute to the overall situational awareness, by displaying the landscape and effect of information operations.

In conclusion, the current model is mainly focused on short term effects. In the future, long term effects of key-leader engagements, civic engagement, etc. need to be modelled as well. Overall, the propagation model can be improved as well. Despite these shortcomings, the new model and its innovative user interface was accepted within the community by trainers and trainees. The new forms of visualization for information

operation maps may even influence future command and control efforts, as information operations need to become part of the situational awareness displayed in the common operational pictures.

The discussion pointed to the need and difficulties of validating information operation effects. It may be useful to bring new disciplines from psychology and social sciences, as they are already engaged with NATO in Human Factors and Medicine (HFM) panel efforts. The recommendation for and enhanced collaboration between MSG and HFM has been made several times in earlier technical evaluation reports and is today more important than ever before, as the human component is gaining more and more interest.

4.2 Use Case Analysis of the Information Warfare Engagement Model Architecture (P8)

The second presentation of this section follows the presentation of the information engagement warfare model given at the 2016 NMSG symposium. The update was given by Mark Hazen.

Current M&S solution fall short in support of information operations and information warfare. This will add complexity to the simulation, but there is a clear need to model information content that will affect decision-making and unit behaviour. How this can be reached by conduit, content influence, and cognition is object of the current studies. Taxonomies of information warfare operations have been built, but how to consistently bring them into a simulation supporting framework is still to be solved. The resulting model as presented has four layers, that were slightly modified from the model presented in 2016: the cognition/decision making layer, the content layer, the conduit layer, and the physical/kinetic effects layer. The functionality that had to be provided by each layer was developed by use cases for the information warfare engagement model. Weapons, e.g., have primary effects on the physical layer, secondary on the conduit layer, and tertiary effects above. Similarly, objects of interest can be broken down using this layered model. These research results allowed for coloured interaction models that show clearly what activities happen on which of the cognition, content, conduit, and physical layer.

These results were applied to the standard solution for messaging, such as HLA, DIS, but also the MIM/JC3IEDM or latest C-BML and MSDL efforts. All of them fall short of supporting the cognition layers, and mostly also the content layer.

In conclusion, the project is now ready to build software in support of these ideas. It already has been recognized that perception and truth needs to be separated for CGF, as this is the basis for information operations' effects. Main goal, however, is to provide a common architecture for future developments.

The discussion showed that the architecture adds an additional dimension to think about when defining services. Most of the other services are addressing ideas of how to modularize the entities and effects on the physical layer. Here, we see that every such physical layer services may have to be accompanied by conduit, content, and most likely cognitive services that hopefully become as composable as their physical counterparts. Each service on the physical layer requiring decision making would have to be accompanied by a service on the cognitive layer, adding complexity, but also flexibility and agility.

4.3 SAFEPORT – Smart Planning of Worldwide Harbour Protection (P9)

This presentation was given by Pedro Baia. Topic was the implementation of harbour protection simulation in support of analysis of possible threats. The objective was to provide a simulation-based tool set that is configurable and adaptable to support a wide variety of threats in diverse harbour settings. The focus was on the physical/kinetic elements.

The workflow starts with the selection of sensors and their location optimization. Those are then used in a simulation that implements different threats against various defence configurations. The result was that the product shows potential to be a decision support tool for planning operations in the context of harbour

protection. Simulation-based optimization helps to find optimal allocation and configuration of the available resources against an assumed set of threats. In the future, the integrated use in parallel to operations is possible, such as in a scenario where the threat vector significantly changes during the time in the harbour.

The implemented solution allows to optimize solutions regarding several criteria, such as overall coverage, successful defence operations, but also number of sensors or workload of patrol boats. The possible integration of improved optimization heuristics will furthermore increase the usefulness of the tool. As in the design phase the model was decided to be a stand-alone situation, it currently doesn't support a great variety of standards, but has a flexible enough architecture to support them in the future.

4.4 Improved Situation Awareness on the Operation of Unmanned Systems through Simulation (P10)

Paulo Sousa Dias presented the work conducted at the Portuguese underwater systems and technology laboratory. The focus of the work is the emphasis on system of systems solutions, including the required communication and net structures. The simulation has been developed in support of a real light unmanned systems, and is part of a tool chain: *Neptus*, the command and control system, IMC, the message protocol; and DUNE, that on-board control software.

Neptus supports all phases of the mission life cycle: planning, execution, review, and analysis. It provides a situation display for all phases. For the planning, environmental data on the current situation of the water or depth sounding data are accessible. S57 charts –a standard for the exchange of digital hydrographic data between hydrographic offices and others and for its distribution to users – and other standards are evaluated regarding reading in various obstacles.

Another piece of data is the foreseeable battery usage needed for a planned course, so that the unmanned vehicle doesn't run out of power during the operations, or has not enough power to make it back to the rescue point after an operation. The simulation is part of this planning support as well, as the vehicle path can be simulated, taking obstacles and pay load capabilities into account. This also helps during execution, as it can be visualized if the vehicle follows the predicted path with assumed progress. Updates from the vehicle can be used to reset the simulated stage and continue anew from the new situation. Furthermore, external other web sources are used to increase external situational awareness, ensuring higher survivability of the system that now is aware of dangers, threats, and obstacles.

The discussion looked a deliberative planning on the unmanned systems themselves, using on board simulation capabilities that are possible next steps in the research.

4.5 Developments in Artificial Intelligence and Opportunities and Challenges for Military Modelling and Simulation (P11)

Andrew Fawkes provided an overview of opportunities and challenges of artificial intelligence (AI) for military M&S. One of the underlying ideas that triggered several of the presented opportunities was to train intelligent agents in the same way as we train soldiers today: using simulation. The developments in AI are entwined with those in M&S and gaming.

AI has been recognized by NATO to be important, such as its application in the domain of big data. AI also has become an omnipresent concept in daily life, as it is used in cell phones, automobile technology, etc., and recently got new life with deep learning success stories, like IBM's Watson [5]. However, AI has a diverse set success stories. Early successes were soon followed by "AI winters." In simulation, AI is usually found in SAF modules: semi-autonomous forces. Current approaches within NATO standardization efforts, in particular C2Sim, provide a common language that can serve humans and AI entities.

AI was successfully applied in many games, most famously in Chess and Go, where AI based solutions could beat human masters and champions of the game. To succeed in the Go championship, AI trained itself just based on playing the game against itself, learning from each mistake. Currently, robots already get trained using simulation. In the military, AI is increasingly used in support of autonomous vehicles. There are ethical dimensions of AI that must be addressed, but nonetheless: what is morally wrong in our culture may be use by adversaries anyhow, so we should know about it, and be ready to encounter it. Despite these advantages, the lack of validation methods for new methods, like neural networks, is a significant obstacle.

In summary, AI is not new, but gains new popularity with new computational advances. It is used for the increasing use of autonomous systems. It should be on NATO's radar screen as well. In particular the idea to train the brain of autonomous systems using military training simulation is be appealing.

In the discussion, the annual NATO conference on Modelling and Simulation for Autonomous Systems (MESAS) as well as a recent NATO effort on autonomous systems [6] was mentioned, emphasizing the need for a broad community outreach. Mutual support and research exchanges between NMSG and MESAS could benefit both groups.

5.0 SESSION 3 – M&S TO SUPPORT CAPABILITY PLANNING

One of the promises of M&S has been to allow the evaluation of the performance of systems as well as their operational effectiveness within the system of systems of the portfolio long before first metal is cut. Necessary and innovative methods supporting this vision for future capability planning are presented in this section.

5.1 Role and Place of Modelling and Simulation in Wargaming (P12)

Jan Hodicky presented the case for the increased use of M&S in the analytical domain. Many decisions are still supported by wargaming, which is mainly driven by human players representing the opposing sides. The term *wargaming* is not consistently defined or used, even not among NATO and the nations. Some users integrate simulation in its definition, other focus only on scenarios and rules.

In support of analysis, wargaming usually comprises scenarios, the order of battle, objectives to be reached, maps and charts, timing devices, and rules enriched with data (such as expected effects based on actions, rulebooks, etc.). Players are supported by facilitators and umpires, so that analysts can observe and obtain data during the wargame to support their task. As such, wargaming is an objective driven activity that in its current form can be very work and personnel intensive.

A case study identified M&S constraints for the various elements of a wargame as described above. Overall, there is a need to support operational and strategic views, but the study showed that many readily available M&S solutions remain on the tactical level. Scenarios and their descriptions are one example, measures of merit needed for the evaluation is another one.

Wargaming should produce explainable and reproducible results. As humans play an important role as players, umpires, and facilitators, the danger of introducing human bias is always given in all of these roles. An automation of some decisions is therefore beneficial, not only to cut costs, but also to support the scientific principles of reproducibly better. How wargaming is currently used in the capability planning process in the Czech Ministry of Defence was presented in an overview to support these case study findings.

To support better alignment of terms, a computer assisted wargaming (CAWG) ontology is currently developed in collaboration of the Centre for Security and Military Strategic Studies at Czech University of Defence and the U.S. Naval Postgraduate School. Such a rigorous classification will help to better

understand the overlap between M&S based and wargaming based research. This ontology is in the final stages of initial development and will soon be released.

The discussion mentioned that in recent years the need for M&S support was focused on the tactical level, and often not even on combat intensive operations. The developments of the recent months may lead to a new emphasis on strategic and operational levels, which would be aligned with the requirements identified in the presented study.

5.2 The Disruptive Role of M&S in Capability Acquisition (P13)

Douglas Stapleton presented insights from current challenges to be addressed within the Australian DoD, which are summarized as follows: Battlespace communications is too complex a network to test in its entirety, which drives the need to support their operational test and evaluation (OT&E) increasingly through simulation. This implies that the capability acquisition must be responsible for acquiring the synthetic test models to allow for the joint simulation of that platform in war gaming exercises. This does not only include own forces, but for effective OT&E it is also necessary that disruptive future simulation of potential adversaries at IOC must be included for consideration during Gate Zero acquisition processes.

Australia provides architecture models in support of battlespace communication systems development. The systems are used for real world testing across different terrain with varying parameters. The results are conceptualized using mathematical interpolations which then can be utilized in simulations. These results should be embedded into the simulation capability for OT&E. However, the question of who should develop these capabilities remains without a clear answer. The preferred option would be the capability acquisition group, but alternatives like the Joint Command – running the joint simulations – or individual, independent developers providing commercial off-the-shelf solutions, are options as well. In any case, the use of open standards to ensure that the simulation calibration results from the initial OT&E tests in resulting solutions is preferable, but not yet implemented.

The disruptive feedback from simulations of requirements is another important factor. As the time between definition of defence system solutions and their introduction to the forces can be several years long, OT&E should not only test against current threat, but increasingly against threat vectors that may be present at the time of its IOC. *Only simulation can support such disruptive future testing!* Historical examples show that catastrophic effects can be explained using simulation after the fact, but it should be done in anticipation of such effects before the system is build. To ensure comparability of results, capability acquisition projects must have a strong say in the development and application of such simulation exercises.

The discussion showed that on the one hand side a standardized threat vector would facilitate standardized OT&E, but that may become counterproductive, as potential opponents could use such threat standards as well to optimize their actions. Instead, metadata standards that can be used to unambiguously describing the threats without giving away what these threats are may be the better solution.

5.3 The Synergistic Coexistence of Distributed Integrated Testbeds and Data Farming (P14)

The final presentation of the session given by Tobias Schlaak described how the German System Demonstrator VIntEL supports data farming to support a comprehensive system understanding. To support this vision, the VIntEL testbed connects live systems and data with CGF simulations provided by PAXSEM. This simulator plays a double role in the testbed, as it injects stimulus to other systems as well as providing a vehicle to drive data farming experiments itself.

The testbed was successfully applied in support of data farming experiments supporting operational challenges of the German helicopter TIGER in preparation of operations in Afghanistan. At the time an

operational analysis was needed, there were not yet any previous operational experiences, as the system TIGER was new and has never been deployed before. Instead, the simulation system was used to execute runs including the AIRBUS Helicopter's SimCo TIGER simulator embedded as the virtual component of the VIntEL testbed. The results were data helping to shape decisions on optimal engagement distance and best approximation routes. This was only possible due to the very close collaboration with the soldiers, who help to set up the implemented use cases. In other words, the operational data was performed on data completely derived from operationally defined simulation runs using virtual simulation for the system to be evaluated, and CGF for the opposing and neutral forces in a common virtual environment that reflected the circumstances expected to be experienced in the future operational battle sphere. The results were fully supported by the end user.

The discussion reemphasized the need to root this kind of experiments in operational use cases, with the soldiers driving not only the requirements, but also the scenarios and the metrics for their evaluation.

6.0 SESSION 4 – MODELLING SENSORS AND ENVIRONMENTS

One challenge for realistic training is to provide soldiers with situational awareness information as close as they will experience it in operations as well. To meet this challenge, a realistic representation of the synthetic environment providing immersive training is needed. Furthermore, sensors must be able to collect information on simulated entities with the same accuracy as they do for real world objects. The papers of this session provide examples of current efforts and recent research results.

6.1 Enterprise Terrain Data Standards for Joint Collective Training (P15)

Thomas Walrond presented US work on enterprise terrain data standards that are of interest to NATO as well. Ultimately, a common approach will be needed. The Joint Staff J7 Environment Architecture Division designs the architecture, defines the technical standards, approaches and specifications, integrates the current simulation capability and builds the next generation joint training enablers, to improve the operational effectiveness of the current and future joint force.

Despite earlier standardization efforts, producing simulation terrain data remains a time and cost intensive effort. Poorly correlated source data and the lack of web-based authoritative data sources are among the main reasons. Following the recommendations of the Technical Standards for Terrain Data (TSTD) Working Group, the foundational attributes for selecting a common standard should allow open, evolving, publicly-available, published standards that are platform independent, support runtime applications and source data storage, allow simulation clients to modify the terrain data store during an exercise/training event, and support dynamic terrain and revision history.

Within the presented study, the following solutions were evaluated: Master Database (MDB) – developed and used by the U.S. Army; NAVAIR Portable Source Initiative (NPSI) – developed and used by the U.S. Navy; Air Force Common Dataset (AFCD) – derived from the NPSI specification and used by the U.S. Air Force; and the Common Database (CDB) – used by USSOCOM, NGA, U.S. Marine Corps, Joint Staff J7, and 13 foreign partners. The evaluation identified CDB as a strong candidate. Details of metrics and evaluations are given in the paper.

The future plan is to set up a Geospatial Repository and Data (GRiD) on the midterm, and to migrate the enterprise toward adoption of a common database standard/specification, including a management framework. The envisioned end sate is adopting a common enterprise standard for future capability development, including providing runtime solutions of enterprise terrain.

The discussions highlighted that M&S requirements may add new challenges that are different from the

geospatial requirements, as supported by international standard bodies, such as the OGC (Open Geospatial Consortium). The currently yet NATO recommended approach using SEDRIS was not evaluated further, as it did not fulfil the requirement of providing runtime support, and a revalidation of the STANAG is not certain, as discussed in the next section as well.

6.2 SEDRIS on the Test Bench – The Future of Exchanging Environmental Data to become Part of M&S as a Service (P16)

A different approach was presented by Ralph Stueber, who presented research conducted on how to use SEDRIS as a service. SEDRIS is an ISO standard and has been adopted as STANAG 4664. It represents environmental data, a spatial reference model, a dictionary, and a data interchange mechanism, supporting a wide range of applications that span ocean, terrain, atmosphere and space.

The SEDRIS Data Representation Model (DRM) support 2D views as well as 3D models and contains the Environmental Data Coding Specifications (EDCS), a glossary of terms used in synthetic data tagging. Originally, SEDRIS defined a binary interchange format (STF) and was platform, programming language, and version dependent, as it was distributed in form of a software development kit. There was only limited support of ideas as underlying the MSG-136: to provide reusable services, which can be combined and integrated to be used in different M&S tasks. The presented German study addressed these challenges and showed a possible way to use SEDRIS in this context. The main challenge was that the STF is outdated and not ready for a service infrastructure, so it was replaced by a more service oriented approach.

The solution implemented as a prototype and integrated into the VIntEL framework uses the Geography Markup Language (GML), which is an XML grammar defined by the Open Geospatial Consortium (OGC). The Synthetic Environment Service (SCS) does not only provide terrain information, it also supports versioning and history. It further contains web feature services, web map services, and SES texture services. All services were implemented and supported several technology demonstrations, such as using EPIC as a flight simulation service, SES as a terrain service, and composing them under the roof of MSG-136.

The discussions showed the need to feed ideas back to the SEDRIS. However, the STANAG is currently up for re-evaluation, and it is unclear if the standard will be ratified again. The discussion furthermore showed that SEDRIS is conceptually still valid and can technically be transformed into new paradigms, such as MSaaS.

6.3 Simulation of LIDAR Systems for Aerial Intelligence, Surveillance, and Reconnaissance (P17)

Steven Webster presented his work on supporting multiple intelligence simulations with sensor simulations for various platforms. LIDAR simulates laser detection and range effects. The usually airborne carrying platforms flight predefined patterns, using active LIDAR and passive RGB and MWR cameras to acquire 3D images. They are mapped with Geo-registration and processing, which is communicated via downlink and data transfers to be utilized by the intelligence cells. The resulting point cloud is mapped to various intelligence products of interest, using the Night Vision Image Generator (NVIG), which is a mature solution working over the full spectrum from UV to long IR.

The LIDAR sensor sends a series of laser light pulses out. The LIDAR sensor measures the time it takes the photons to return and calculates the distance from sensor to target. Multiple returned photons allow a 3D rendering of the target. The more photons returns are measured, the more accurate will be the rendering of the target. Using this physics, the 3D point cloud generation with intensity values with 32-bit precision is possible, plus noise and other important physical factors that can be considered. The resulting point clouds in their various frames can now be used apply the usual method to generate the Intelligence products.

In conclusion, LIDAR simulation is sufficient for training collection and exploitation, but currently only used for a small set of Intelligence focused simulations. No connection to C2 systems has been established due to the lack of customer requirements.

6.4 Environmental cues in thermal images impair vehicle identification training: Simulated thermal imagery as a potential solution (P18)

A use case in a related domain was presented by John Graybeal. The case study looks at training soldiers in their fighting vehicles, using simulated thermal images instead of real thermal images. The objective is therefore to discuss vehicle identification training problems caused by limitations in available thermal imagery and how thermal modelling can help.

To create real thermal images is time and cost intensive, which results in images for a given vehicle that are typically collected from the same sensor at the same location. Therefore, the pictures often include additional cues, like tracks, environmental details, etc. While training focuses on consciously directing attention to different visual elements of the vehicle, unconsciously other cues may become dominant, such as the tracks. Perceptual Learning is the process of becoming more sensitive to subtle differences in visual "categories," such as the vehicle type, but tests have shown that soldiers trained with real thermal images often scored lower on this test than expected. It turned out that soldiers were passing the tests by using background cues to pass the training assessment. Soldiers became sensitive to differences in vehicles, but also to differences in image background. Attentional learning explains that when a unique background is tied to a single vehicle, attention will necessarily shift towards the background if it is more informative than other visual cues.

Simulated imagery did not have these shortcomings. Distraction from the important features by more dominant cues in the background can be avoided. Also, field collection of data requires that desired weather and environmental condition are met, while simulated images can be produced under all desired conditions, from all angles, etc. All this results in more flexibility and an easier way to calibrate the images when simulation is used. Various equipment, weather, and terrain can be used to produce pictures, that are very close to images soldiers will experience in an upcoming operation.

First results in the laboratory have shown improvements in the recognition using simulated imagery, but no operational validation of these results has been conducted yet. These results, however, are encouraging that the use of simulated thermal imagery can significantly improve the learning.

7.0 SESSION 5 – M&S INTEROPERABILITY IMPROVEMENTS

The final session provides information on two NATO collaborative efforts to improve interoperability, namely the new and improved HLA certification process, that allows to evaluate the compliance of federates with the most recent HLA standard requirements, and the Urban Combat Advanced Training Technology (UCATT), which provides training to NATO troops.

7.1 The New HLA Certification Process in NATO (P19)

The first presentation was introduced by Horst Behner, describing the new HLA Certification process, the result of MSG-134. It was initiated by the NMSG observation that the formerly used process for HLA certification was no longer appropriate, as it was technically too limited and did no longer supported conceptually the right breadth of tests to ensure the NATO vision of interoperability.

Björn Löfstrand presented the technical details. The MSG-134 utilized the NATO Standards Profile for Modelling and Simulation (AMSP-01), NATO Education and Training Federation Architecture and FOM Design (NETN FAFD), and IEEE 1516-2010 High Level Architecture (STANAG 4603), also known as

HLA Evolved, as the guidance for what is needed to be tested. One of the insights of recent NMSG research presented at various NMSG symposiums is that HLA compliance is necessary, but not sufficient.

MSG-134 objective was to develop CONOPS for a NATO Simulation Interoperability Test and Certification Service and establish initial operating capability (IOC), design and implement tool to support Integration, Verification and Certification (IVCT) of federate interoperability capability, develop set of IVCT tests to support test, verification and certification of interoperability capabilities related to AMSP-04/NETN FAFD, and – on behalf of NATO NMSG/MS3 – maintain AMSP-04/NETN FAFD and support its publication as STANREC 4800. All documents are now ready for publication.

The ultimate objective, beside reducing cost of integration, risk and time of integration, and increased level of interoperability in distributed simulations, was to enable composition of synthetic environments based on pre-tested and verified simulation components with certified interoperability capabilities. The NATO Simulation Interoperability Test and Certification Services provide processes and test procedures to conduct certifications that are more specific than the formerly used general certificates. It uses NATO interoperability compatibility badges that clearly describe the test requirements and test cases. An Integration Verification and Certification Tool is used to conduct the test.

The status of the activities is that a first use supported the NATO CWIX 2017. The new certification process in NATO is set up, identifying the Accreditation Authority (AA) to be the NATO Modelling and Simulation Standards Subgroup (MS3), the Certification Entity (CE) to be the NATO Modelling and Simulation Centre of Excellence (M&S CoE), and the Accredited Test Laboratory (ATL) must be decided on. A proposal developed for continued support by NMSG for moving IOC to Final Operating Capability (FOC) has been decided in favour immediately before this NMSG conference.

Canada, Germany, France, Sweden, Italy, Spain, UK, US, Belarus, Bulgaria, Romania, NATO M&S COE, and NATO CMDR COE participated in these activities, resulting in a tools framework available as open source on GitHub, including executable test cases for common interoperability requirements. In addition, the NETN FAFD will be released as STANREC 4800. This new certification process is a significant step forward for the NATO HLA community.

The discussion showed that future developments may be the inclusion of DIS based simulation systems as well. The discussion addressed furthermore the need for support of the general guidelines as given in the DMAO [4] as well, but this requires additional commitments by NATO and the nations. The presentation and discussion showed that the framework as documented supports to test arbitrary interfaces with HLA as a starting point, but can be extended to other specifications captured in DMAO as well.

7.2 The Increasing Importance of Alliance Interoperability in the Live Simulation Domain and how UCATT delivers on its Promise (P20)

Mark Chamberlain gave an update on the UCATT (Urban Combat Advanced Training Technology) activities of NATO, in particular MSG-140 Live Simulation Systems (LSS) activities.

The overall UCATT mission is to identify and standardise the interfaces that allow interoperability of different systems for live training focusing on the urban environment and to maintain our delivered products. Over the lifetime of UCATT, the mission remained, although the focus changed from technical questions on how to provide urban training to standardizing and maintaining solutions.

UCATT has Norway, United States, Switzerland, Germany, Sweden, Netherlands, United Kingdom, France, Canada, Austria, New Zealand, Slovenia, and Denmark as active members. As an activity, UCATT predates the NMSG and started with the identification of common training requirements for urban warfare, which resulted in demonstrators and use cases showing the supporting role of M&S and instrumentation, with focus

on the needs of soldiers, resulting in a UCATT functional architecture, which defines the interfaces to be supported.

The results for the standard structure of UCATT are published under the umbrella of SISO and are often downloaded. Multi-national instrumented exercises have been executed based on the UCATT principals and concepts have been successfully conducted. Industry is responding, and defence procurements are calling for UCATT standard in their requirements.

In summary, UCATT has become a focal point and go-to advisory group in respect of live simulation with increasing interest in participation from Nations and Organisations.

8.0 SUMMARY AND RECOMMENDATIONS

The objective of this symposium was to provide a forum to identify and gain input on and resolution of issues associated with NATO M&S Policy, 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. By bringing researcher, managers, and users together, the discussions following the presentations could deliver insights beyond the scope of the papers.

The discussions showed potential for many new research challenges, as captured in the detailed contributions of the former sections. Some points that came up after several presentations are the following.

- MsaaS is more than virtualizing legacy simulation systems. New technologies, like microservices or edge computing [7], will provide better and more efficient solutions. The current use is a good start, but the paradigm switch has just begun. One open question is how MSaaS can better support the important tenets of live and virtual simulation. MSaaS has demonstrated its usability and support of constructive simulation well, but how it can support the benefits of LVC approaches is an open research questions.

- Validation and Security are not new topics, but they get a new meaning in the context of MSaaS.
    - The ease of building compositions on the technical level must be accompanied by better methods to ensure the validity of such compositions as well. It may be reasonable to establish a research group to address this challenge. This is particularly necessary for information warfare modelling and its effects.
    - Comparably, multi-level security in MSaaS environments will need to be supported. The same service may deliver different results depending on the level of trust or the need to know of the participating partners to protect national or industry interests. The simulation of a new sensor may produce highly accurate data in the context of internal reuse, or aggregated detection probabilities within a multinational collaboration. Obfuscation, filtering, and modification are known to support such ideas, but NATO has no common solution to approach this challenge.

- The work on information warfare engagement showed that services should not only by provided in support of various physical/kinetic effects in the battle sphere, but that in addition conduit, content, and cognition services will be needed. An architecture working group looking at the resulting matrix of services would benefit to prepare the ground for reusable and shareable components not only in the kinetic space, but also on their effects in the cognitive layers. The AI approaches presented can help with first cognitive services. Like other simulation projects, it will be pivotal to establish a set of operationally accepted use case that can be used as a blueprint for the information operations to be modelled and evaluated.

- The enterprise perspective of system of systems gains increasingly interest, in particular in the light of user requests for more operational agility. Complex operational scenarios require a degree of adaption and flexibility as it has not been seen so far. The interconnectedness of decisions is higher than ever before. Simulation is the most promising tool to address this high degree of agility need in complex environments [8].

- The support of new weapon systems of the 5th generation in agile operations will provide new challenges regarding the sheer amount of data that must be provided to the weapon systems and therefore to their virtual and constructive representations. New M&S methods capable to cope with these data in a timely manner may be required. At least, a study on the degree to which current solution provide a solution should be conducted.

- An increasing number of federations support more than one simulation interoperability standard. This did lead to the development of the international IEEE 1730.1 Recommended Practice for Distributed Simulation Engineering and Execution Process Multi-Architecture Overlay [4]. If NATO solutions continue focusing on HLA solution, many potentially beneficial simulation solutions may be excluded. Research to what degree DMAO can be exploited is needed.

- The strategic alliance with SISO has been proven to be beneficial for NMSG and should be continued, in particular to reach a broader audience and gain their input for research activities as described here. Mutual supported events, such as NMSG/SISO events during ITEC and IITSEC, maybe making increasing use of distributed collaboration, could support this alliance.

- To engage more academic contributions, it may be necessary to rethink the publication strategy of NMSG. The current form does not reach all potential contributors to future solutions, as our proceedings are not featured in the usual search engines or supported by any academic index. Possible solutions are submissions of best papers to journals, such as the *Journal for Defense Modeling and Simulation (JDMS),* or the collection of best papers for a special volume within a publisher series, such as the *Springer Series on Simulation Foundations, Methods, and Applications*. This may also increase the number of papers that focus on the core challenges of M&S, which will require new solutions with the new requirements regarding the amount of data that need to be handled in new scenarios, such as supporting 5th Generation Air Force Operations.

As possible themes for future NMSG symposia, the following topics emerged.

- ***Emerging Challenges for LVC in the Era of MSaaS***

- ***Defining Reference Architectures supporting Research, Development, and Governance for M&S***

- ***Managing Complexity to allow Operational Agility using M&S***

This list is neither complete nor exclusive and only reflects the view of the technical evaluator.

In summary, it can be observed that the maturity of the presented ideas and professionalism of the prepared papers encourages the continuation of the NMSG symposium as a flagship of NATO science and research conferences.

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