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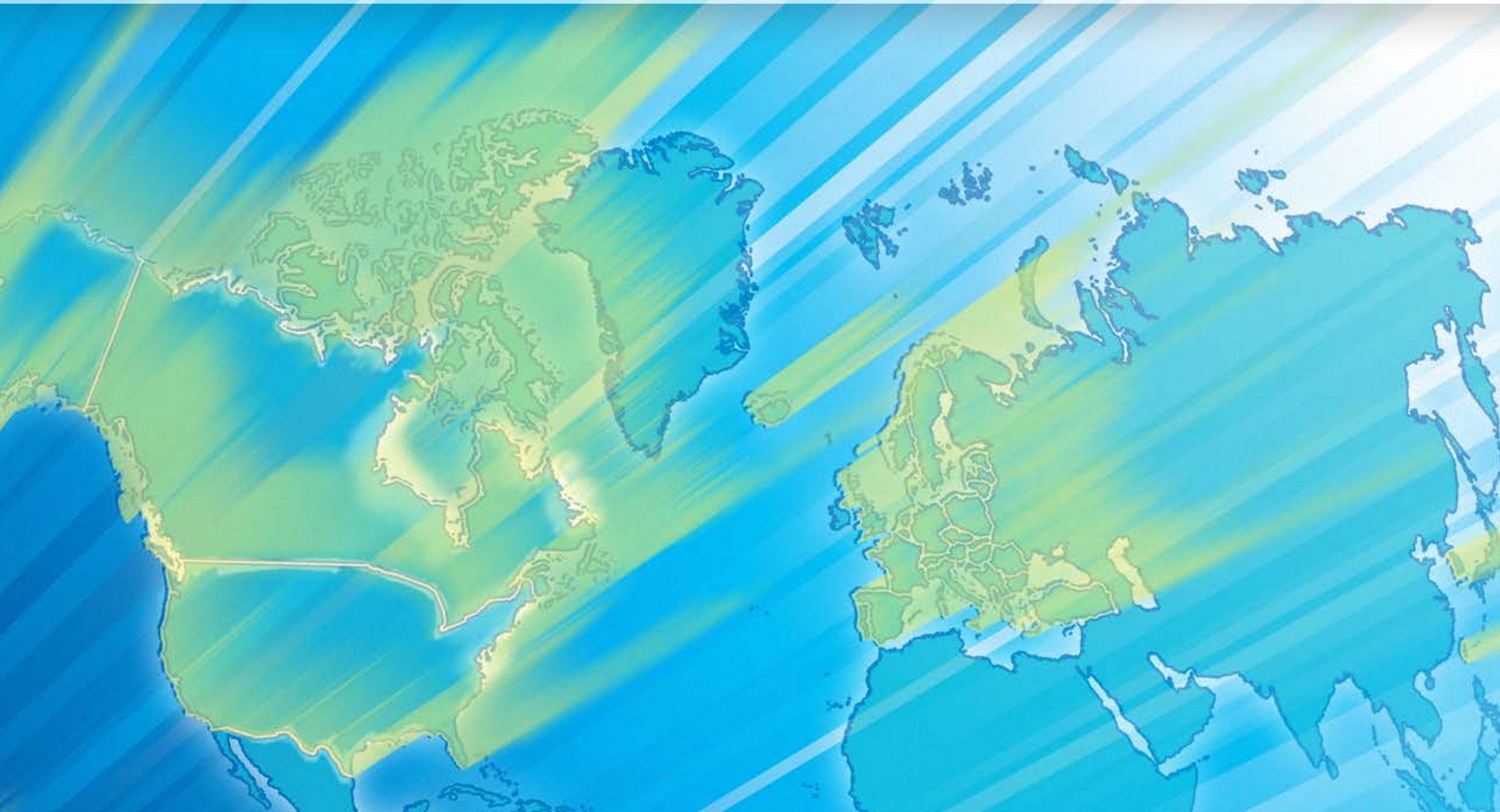

INTERNATIONAL

FROM THE EXECUTIVE EDITOR

IT IS WITH A GREAT DEAL OF SATISFACTION AND PRIDE that I commend this special "International" issue. With over 15 years of experience engaged in the realm of international science and technology cooperation with nations in Europe and along the Pacific Rim—there is a tremendous amount of effort with our coalition partners to share regarding ideas, standards, and solutions to the community's Modeling and Simulation (M&S) challenges. A great deal of this work goes unheralded, which is one reason why the editorial board recommended this international theme. The other reason is to provide an opportunity for U.S. readers to appreciate the kinds of efforts going on in other nations. We did our best to bring in articles from both our Atlantic and Pacific partners, as well as cover a broad spectrum of topics with the base theme of interoperability and all the complexities that term encompasses.

This issue begins with an article from Taiwan. "***BOM-Based Military Scenario for Synthetic Theater of War,***" describes research performed to integrate, exchange, and use data modules from different military simulation systems. In particular, the research pertains to the use of the Simulation Interoperability Standards Organization's (SISO) Base Object Model (BOM) standard and the Hadoop® technique for processing big data. Dr. Hsu and his colleagues' efforts demonstrate a dramatic decrease in the time needed for analyzing large quantities of military scenario data.

Next, the article, "***Meeting the NATO M&S Interoperability Challenge***," draws the reader in with an interesting discussion submitted by Mr. Huiskamp, Chairman of the NATO Modeling and Simulation Group. The paper describes the continuous effort to establish and maintain M&S interoperability across the many NATO members and the participating partner nations by establishing a documented standards profile. The key aspect being that common standards are essential enablers for simulation interoperability and re-use.

In terms of a real-world application of the NATO standardization effort, the article, "***Connected Training Initiative: The L-V-C World Cup***," describes the capability of the U.S. Army Combat Training Center (Hohenfels, Germany) to connect coalition partner training areas and forces to the Hohenfels Training Area (HTA) through the use of the Mobile Instrumentation System (MIS). The MIS is a transportable duplicate of the HTA fixed system; through the use of data links crossing international boundaries, it can connect to another training area through instrumentation and simulation. Colonels Norris and Patterson (U.S. Army) are strong advocates of multi-national training and using M&S technology to support that training.

The next article focuses on the topic of verification and validation of M&S tools. A multinational team of authors from Sweden, The Netherlands, and France describe in "***GM-VV — An International Recommended Practice for Verification and Validation of Models,***

Simulations, and Data," how another SISO product is being used in the international arena. The Generic Methodology for Verification and Validation (GM-VV) is a comprehensive methodology for setting-up, managing, and guiding the verification and validation (V&V) of M&S systems, simulations, underlying data, and results for specific intended uses. A key point of this work is that the GM-VV is the result of a long cooperation that started with a European effort (the Referent for VV&A (REVVA) project) evolving into a cooperative relationship between NATO and SISO.

Moving on to North America, our Canadian neighbors draw readers' attention to how they used M&S for major event security planning in support of the 2010 Winter Olympics. "***Major Event Security Planning: Secure by Design Through the Strategic Use of Integrated Modeling and Simulation***," illustrates the way in which M&S can strategically help design-in mitigating security strategies and protocols to deal with the uncertain threat and risk landscape inherent in major event planning. In light of tragic experiences at the 2013 Boston Marathon, the article by Drs. Masys and Vallerand could not be more relevent.

The final article of our international issue is "***An Introduction to the Indigenous ROK HLA Compliance Testing System and the Lessons Learned of Its First Use — A Case Study of the Advanced TaeGeuk JOS HLA Compliance Test***." Here, Dr. Lee presents an excellent example of adopting an M&S tool designed for High Level Architecture (HLA) compliance testing, training local technical staff in its use, and then modifying it to fit the needs of Republic of Korea military M&S confederates, not to mention some improvements that were made along the way. I have a personal interest in this work as I was the Foreign Military Sales (FMS) case officer that brought the software to Dr. Lee's organization, and witnessed all that they accomplished in just a few months.

All-in-all, this issue of the M&S Journal not only continues with our mission to educate through shared experiences, but does so on a global scale. The editorial board, staff, and I hope you will find this landmark issue of the M&S Journal enlightening.

GARY W. ALLEN, PH.D.
Deputy Director
Instrumentation Training Analysis Computer Simulations and Support (ITACSS)
Joint Multinational Readiness Center, Hohenfels, Germany

FROM THE DIRECTOR OF M&SCO

I WOULD LIKE TO TAKE THIS OPPORTUNITY TO THANK YOU, the loyal readers and contributors, for supporting our *M&S Journal* over the past several years. With your continuous and voluntary involvement, our success with the *M&S Journal* can only be attributed to you.

Despite its popularity and value to the M&S community, we have decided to discontinue the *M&S Journal*. Regrettably, due to recent budget cuts, this issue will serve as our final publication.

Since 1998, the *M&S Journal* has been a popular and well-regarded forum for describing new applications, sharing lessons learned, and as a platform for launching new concepts. It began after readers of our well-received newsletter recommended that we provide the M&S Community with an *M&S Journal* to highlight specific technical challenges as well as successful M&S programs. Over the years we've highlighted the development and enhancement of numerous warfighter-enabling technologies. Through hard copy and online publication, this journal has served as a bridge to connect M&S people for the purpose of creation, use, and reuse of models and simulations. It has brought readers the technical challenges, ingenious ideas, and personal perspectives of senior leaders with regard to M&S enabling technologies.

With that understanding, our global missions, and the appreciation for our international alliances, this final edition of the *M&S Journal* highlights several exciting and innovative efforts being worked on throughout the international community. These efforts include the integration of models, development of international standards, building security into models and interconnecting coalition partners within live, virtual, and constructive simulations.

It has been wonderful to observe and share the numerous contributions made by the dedicated people in the modeling and simulation community. These contributions have enlightened and challenged readers to broaden their technical lenses to see new, enabling, and more efficient approaches to M&S.

Once again, the success of the *M&S Journal* is a direct result of your unselfish volunteerism and commitment to excellence. Finally, I wish to express my hearty thanks to our Editorial Board, executive editors (past and present), publishing staff, over 2000 subscribers, and more importantly, the numerous authors that provided us with high quality articles over the past 15 years. We could not have produced it without your support and dedication to M&S. It has been a genuine pleasure and a privilege to produce the *M&S Journal*.

JESSE J. CITIZEN, JR.
Director
Modeling & Simulation Coordination Office

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A Guest Editorial: International Cooperation In Modelling & Simulation Within Nato

IT IS A REAL PLEASURE TO ADDRESS YOU IN THIS GUEST EDITORIAL IN MY CAPACITY AS THE NATO CHIEF SCIENTIST AND CHAIRMAN OF THE NATO SCIENCE AND TECHNOLOGY BOARD. THE BOARD GOVERNS THE NATO SCIENCE AND TECHNOLOGY ORGANISATION, WHICH IS THE LARGEST DEFENCE AND SECURITY NETWORK OF ITS KIND IN THE WORLD.

NATO HAS AN IMPRESSIVE PORTFOLIO OF VERY HIGH QUALITY SCIENCE AND TECHNOLOGY (S&T) PROGRAMMES AND ACTIVITIES, ESPECIALLY IN THE COMPLEX DOMAIN OF MODELLING AND SIMULATION (M&S). NATO, NATO NATIONS, AND PARTNERS CONSIDER M&S TO BE A VERY IMPORTANT STRATEGIC DOMAIN FOR CONTINUED CLOSE COOPERATION, M&S SUPPORTING THE VITAL INTEROPERABILITY AMONG THE NATO FORCES, DELIVERING ASSETS AND TOOLS OF MAJOR IMPORTANCE TO SAFELY PREPARE AND TRAIN THE ALLIED FORCES IN A COST-EFFECTIVE WAY. FURTHERMORE, INTERNATIONAL COOPERATION IN M&S WITHIN NATO ENABLES AFFORDABLE TECHNOLOGICAL PROGRESS AND SOLUTIONS, WHICH ARE FUNDAMENTAL IN THESE CHALLENGING TIMES OF PERSISTENT AUSTERITY.

NATO NATIONS, NATO BODIES, AND PARTNERS PARTICIPATE IN THE NATO S&T ACTIVITIES OF THE NATO MODELLING AND SIMULATION GROUP (NMSG). THE NMSG COMMUNITY OF INTEREST IS AN EXCELLENT AND TRUSTED NETWORK FOR IMPLEMENTING CONSTRUCTIVE DIALOGUES BETWEEN DEMAND FOR AND SUPPLY OF ADVANCED M&S S&T KNOWLEDGE TO THE BENEFIT OF THE MILITARY. ITS PROGRAMME OF WORK (POW) IS A PERFECT SHOWCASE OF THE ADDED VALUE OF NATO S&T IN M&S.

GUEST EDITOR

Major-General (BEL AF)
Albert Husniaux, MSc (Eng)
NATO Chief Scientist and Chairman of the NATO Science & Technology Board

NATO Science and Technology (S&T) is the S&T that Nations, NATO bodies and other participants elect to perform in a trusted NATO framework in order to serve Nation's and NATO's security and defence posture. Under the Science and Technology Organisation (STO) umbrella, Nations, governments, industries and academia cooperate through and with NATO bodies to provide NATO Nations with a knowledge and technology advantage, supporting the core tasks of the Alliance: collective defence, crisis management, and cooperative security.

NATO S&T covers a wide scope, encompassing S&T programmes and activities that contribute to the generation and exploitation of scientific knowledge and technological innovation in support of NATO core tasks. It includes programmes and activities in NATO and in Nations and spans the short-, medium-, and long-term horizon.

NATO S&T results in activities such as consultations, studies, standardization, experiments, demonstrations, and trials that can be used to develop capabilities and to deliver evidence-based advice to support decision-making. NATO S&T is based on multinational collaboration and on NATO (as the collective of Nations) investments in S&T programs and activities. In this way NATO S&T serves the Nations, both individually and as an Alliance, by generating added value and results that in most cases would be difficult to be obtained by them on their own.

NATO's STO is the main venue to deliver Defence and Security S&T, assisting NATO and Nations to gain a knowledge and technology advantage that they can use for their security and defence postures.

The STO is composed of a Board, Scientific and Technical Committees, and three Executive Bodies: the Office of the Chief Scientist (OCS) at NATO Headquarters in Brussels; the Collaboration Support Office (CSO), the former Research and Technology Agency (RTA) in Neuilly-sur-Seine near Paris; and the Centre for Maritime Research and Experimentation (CMRE), the former NATO Undersea Research Centre (NURC), in La Spezia, Italy.

Scientific and Technical Committees are composed of national defence S&T managers and Subject Matter Experts (SMEs). They are responsible to the Science and Technology Board (STB) for the planning and execution of the STO's collaborative PoW. They are supported by the aforementioned CSO.

There are seven Scientific and Technical Committees in the STO, one of those in the domain of Modelling and Simulation, the NATO Modelling and Simulation Group (NMSG). The NMSG community of interest is supported by the Modelling and Simulation Coordination Office (M&SCO), which is a part of the CSO.

The mission of the NMSG is to promote cooperation among Alliance bodies and NATO Nations and Partner Nations to maximize the efficiency with which modelling and simulation (M&S) is used. Primary mission areas include M&S standardisation, education, and associated science and technology. The activities of the Group are governed by a strategy and business plan derived from the NATO M&S Master Plan[1]. The Group provides M&S expertise in support of the tasks and projects within the STO and other NATO bodies.

The NATO M&S Master Plan outlines strategic objectives and addresses strategic linkages between NATO M&S customers, users, and suppliers, and amplifies those with specific stakeholder roles and responsibilities in fulfilling these objectives in a time-phased way.

The role of the NMSG is to function as a management body in which a full and balanced range of M&S interests can be represented, and to promote the coherent management and coordination of M&S across all Alliance activities in the principal application areas of defence planning, technology development, and armaments acquisition.

The NMSG PoW is divided into "Common Service" programmes that address training, standardisation and education under the lead of members of the M&SCO, and "Technical Activity" programmes managed by Task Groups. M&SCO works in conjunction with CSO's Information Management Systems Branch (IMSB) to provide the community with common services for the development, use and re-use of M&S by means of a NATO Simulation Resource Library (NSRL).

Out of the very long list of very high-quality successful NMSG activities, I will quote only a small number of recent S&T achievements, such as contributing to the development of the High Level Architecture (HLA) simulation interoperability standard, Exploiting Commercial Games for Military use or developing the Coalition Battle Management Language (C-BML).

A Battle Management Language (BML) is an unambiguous language used by Command & Control (C2) forces and systems conducting military operations. The objective of the NMSG C-BML activity was to develop a complete software language that permits the interaction of C2 systems and simulation systems, permitting them to work together in distributed simulations.

BML is particularly relevant in a network-centric environment for enabling mutual understanding. BML must also facilitate C2-simulation interoperability in an environment in which

[1]The Master Plan is freely downloadable from the MSG section of the NATO CSO Website www.cso.nato.int

multinational distributed and integrated capabilities are becoming increasingly common and gaining importance. BML is a means of representing doctrine, while not standardising it; the vocabulary must be well defined in the context of the respective application domain in order to unambiguously generate executable tasks at the end of the process.

A wider reference to the current NMSG activities can be found in other articles in this journal.

M&S is truly a revolutionary technology providing powerful tools that assist the search for improved operational effectiveness and yield value for money within NATO. The ability to represent and examine the behaviour of equipment and the military capability of armed forces continues to increase, particularly with the advent of simulations carried out over a distributed network that can include humans and live (real) equipment. M&S contributes to important savings in lives, time, and money, and to better prepare the warfighter both more quickly and less expensively.

I cannot finish without expressing that NATO's STO remains committed to promote excellence across its extended network, the needs of the Alliance and the NATO Nations continuously challenging our S&T capabilities. Therefore, we will continue to focus on ensuring that our stakeholders will have the S&T tools and assets they need to deal with future and emerging threats.

With this commitment and the support of our Nations and the M&S S&T communities, I am sure that we will continue to meet the challenges and that the results of our common work will permit all of our citizens to live in a safer world.

I cordially invite you to join us in this journey.

Guest Editor's Biography

Curriculum Vitae, Major General (Belgian Air Force) Albert Husniaux

Major General (Air Force) Albert Husniaux was born in Genk, Belgium on 7 July, 1957. He has an M.S. in Engineering, specialized in Mechanics, Ballistics, Aeronautics, and Astronautics.

Major General Husniaux is currently the NATO Chief Scientist. He chairs the Board of the Science and Technology Organisation, NATO's premier forum for Science and Technology co-operation among its Member Nations, comprising a network of more than 3000 Scientists and the Centre for Maritime Research and Experimentation. He is also the senior scientific advisor of NATO.

Major General Husniaux is an experienced executive manager of Science and Technology, having served his Nation from 1997 to 2009 and NATO since 2009. During his three-year tenure as the RTA Director, Major General Husniaux has been heavily involved in the NATO Agencies Reform, contributing significantly to the definition and the implementation of NATO's Science and Technology Reform. On 1 July, 2012, he started his tenure as the first Chief Scientist of NATO, having been appointed by the North Atlantic Council (NAC) on 9 January, 2012.

From September 2005 to July 2009, he was a member of the NATO Research & Technology Board (RTB) for Belgium; prior to that, from October 1997 to September 2005, he served as the Belgian National Coordinator to the Research & Technology Organization (RTO). He also represented Belgium in the R&T Board of the European Defence Agency (EDA). From December 2006 to July 2009, he managed the research activities of the Belgian Armed Forces in the fields of technology and security and defence, as the first Director General of the Royal High Institute for Defence, also a "think tank" within the Belgian Ministry of Defence.

Major General Husniaux is a Belgian flag officer with a career in a very wide array of domains: integrated logistic support (including acquisition) of aircraft, helicopters, rocket launchers (Ariane) and weaponry, teaching and education, strategic affairs, human resources, and research and technology.

Major General Husniaux was granted the honour to become a member of the Académie Royale de Belgique (Royal Academy for Sciences, Humanities and Arts), having been inducted to its Technology and Society Class on 12 May, 2012.

BOM-Based Military Scenario for Synthetic Theater of War

AUTHORS

Dr. I-Ching Hsu
Taiwan, Republic of China, Department of Computer Science and Information Engineering National Formosa University, hsuic@nfu.edu.tw

Dr. Yuan Kwei Tzeng
Taiwan, Republic of China, Chung-Shan Institute of Science & Technology, tzeng.yk@gmail.com

Mr. Jin-Cheng Jhang
Taiwan, Republic of China, Department of Computer Science and Information Engineering National Formosa University, d102752000@gmail.com

ABSTRACT

ONE OF THE LARGEST ISSUES FOR SYNTHETIC THEATER OF WAR (STOW) IS HOW TO INTEGRATE, EXCHANGE, AND USE DATA MODULES FROM DIFFERENT MILITARY SIMULATION SYSTEMS, AS DIFFERENT DATA MODULES AFFECT THE OUTPUT OF SIMULATION AND ULTIMATELY THE FINAL OUTCOME OF SIMULATION. ANOTHER ISSUE IS THAT THE LACK OF SUITABLE DATA MODULES FOR STOW LEADS TO DIFFERENT CHARACTERIZATIONS OF THE SAME MILITARY ACTIVITIES BY DIFFERENT MILITARY EXPERTS OR BRANCHES OF MILITARY SERVICE. THAT LEADS TO MISCOMMUNICATIONS AND OBSTRUCTS THE ACTIVITIES OF DIFFERENT UNITS OR BRANCHES OF SERVICE IN A STOW ENVIRONMENT. THE PURPOSE OF THIS STUDY WAS TO INVESTIGATE AND EVALUATE THE ESTABLISHMENT OF COMMON DATA MODULES FOR JOINT OPERATION TRAINING IN A STOW ENVIRONMENT USING BASE OBJECT MODEL (BOM). BOM WAS INTRODUCED TO ESTABLISH THE BASIC FRAMEWORK OF MILITARY RESOURCE, AND TO STUDY HOW TO INTEGRATE BOM-BASED DATA MODULES TO A MILITARY SCENARIO DATABASE IN ORDER TO ACHIEVE THE INTEGRATION OF HETEROGENEOUS LIVE EXERCISE SYSTEMS AND SIMULATION SYSTEMS. TO VERIFY THE FEASIBILITY OF THE INTEGRATION METHOD PROPOSED, A PROTOTYPICAL SYSTEM CALLED THE BOM-BASED "STOW SCENARIO EDITOR," OR BOMEDITOR, WAS DESIGNED TO PROVIDE THE EDITING OF BOM DATA MODULES FOR JOINT OPERATION TRAINING AND OUTPUT OF CORRESPONDING MILITARY SCENARIO DATA IN ORDER TO FACILITATE CROSS-PLATFORM DATA EXCHANGE AND REUSE. IN ADDITION, HADOOP TECHNIQUE WAS USED TO ANALYZE A LARGE QUANTITY OF MILITARY SCENARIO DATA. THE TEST SHOWS A DRAMATIC DECREASE IN THE TIME NEEDED FOR ANALYZING LARGE QUANTITY OF MILITARY SCENARIO DATA.

1. Introduction

The Synthetic Theater of War (STOW) environment is the next generation of military simulation systems [1]. Common data warehouse formats, specifications, and standards are required to integrate heterogeneous live exercise systems and simulation systems. These important specifications and standards are developed by the Simulation Interoperability Standards Organization (SISO), and include Military Scenario Definition Language (MSDL), Coalition Battle Management Language (C-BML), and Base Object Model (BOM). Extensible markup language (XML) was introduced to develop data formats for these specifications and standards, and BOM is the basic framework for the establishment of military resource and to study how to integrate BOM-based data modules to military scenario database in order to achieve the integration of heterogeneous live exercise systems and simulation systems. To verify the feasibility of the integration method proposed, a prototypical system called the BOM-based "STOW scenario editor," [2] or BOMEditor, is designed to provide the editing of BOM data modules for joint operation training and output of corresponding XML data in order to facilitate cross-platform data exchange and reuse.

The purpose of BOM [3] is to establish an abstract concept model that includes the types of objects and events, and the relationship between them. It is so named because of the focus on reusability and composability. Its functions range from concept model to information exchange model. BOM is a standard (SISO-STD-003-2006) established by SISO to help simulation system developers establish a basic object model with the purpose of interoperability, [4] even though the contents of the simulation system are not defined clearly. The concept of BOM is to provide the contents of objects and events for simulation and network-based training. The establishment is achieved by combining basic elements designed from abstract design and extraction. This application achieves the goal of object reuse easily; that is, it is possible to think and develop basic object models through abstract concepts using a method similar to object-oriented system design. They include their attributes and behavior contents as a basic type. For different applications of simulation, these basic objects can be used directly and specific new items can be added.

MSDL, C-BML, and BOM are specifications established based on XML, but are used in different fields of application. Even though MSDL, BOM, and other STOW scenario data modules may be combined through namespace, there is not an effective editor to generate data modules. Manual labor is required for data establishment, which is low in both efficiency and error tolerance, let alone validation of data formats. The above shows the importance of a STOW scenario editor. The study intended to improve the convenience, efficiency, and error tolerance of establishing military data modules for the personnel involved.

For the validation of data format, the Hadoop® [5] platform was introduced as the cloud foundation. Hadoop is developed by Apache Software Foundation and its source code is available for the public. It provides MapReduce and Hadoop Distributed File System (HDFS) for users' needs [6]. It features high error tolerance, data localization, simplified parallel programming, and ease to expand, making it suitable for execution with immense quantities of data. For the purpose of this study, HDFS was employed to store large military scenario data, and the parallel calculation of MapReduce was used to analyze this large military scenario data to identify whether the data format was correct and to improve the manpower cost and efficiency issue in the validation of data format [7], [8].

2. Technology

Section 2.1 describes where MSDL is applied in STOW and military scenario items; section 2.2 provides information of BOM development, use, and what advantages are provided from using BOM; and section 2.3 describes how Hadoop and its core technology work.

2.1 Military Scenario Definition Language (MSDL)

MSDL [9] is a descriptive language that defines military scenarios based primarily on XML formats. It combines military activity subjects, military missions, working units, and execution of equipment at various stages into a complete package of a military scenario. Thanks to the introduction of XML formats, MSDL serves as the data exchange standard in MSDL-based simulators. Established in 2001 by the U.S. Department of Defense (DoD), MSDL is a descriptive language defining military scenarios, and is used to develop contents of operations and exercises. MSDL uses the XML Schema format to specify the standard of military scenario information and the formats for document transmission, which helps unify military scenario document formats and facilitate data exchange across different platforms. A military scenario consists of 10 parts, the plan, environment, force structure, task organizations, installations, overlays, tactical graphics, Military Operations Other Than War (MOOTW) graphics, threats, and options.

2.2 Base Object Model (BOM)

BOM facilitates modeling objects and events in a STOW environment. Developed to solve the issues of Format Object Model (FOM), BOM works by breaking FOM modules down into smaller modules to facilitate the maintenance, customization, and reuse of object modules. For example, developers of simulated objects only have to make minor modifications of basic BOM object modules to satisfy the need of use. Also, developers may dynamically integrate multiple BOM object modules for the need of military simulation scenario.

BOM provides the following advantages [10]:

1. **Support for combination**: it allows combinations of several BOM object modules to show the relationship of joint operation or alliance.
2. **Expansion**: it allows the development of BOM object modules in addition to existing FOM for the expansion of FOM functions.
3. **Support for interchangeability**: conversion of different BOM object modules is permitted.
4. **Improved management**: in a process of group simulation scenario development, BOM object modules help simplify the management, maintenance and testing of military module establishment.
5. **Support for reconstruction**: FOM can be broken down into smaller BOM object modules, allowing the reconstruction of the broken-down BOM object modules into the original FOM.
6. **Support for conversion**: BOM allows conversions of object modules between different versions of Object Model Template (OMT). For example, an OMT 1.3 FOM object module can be broken down into several BOM object modules, which in turn are put together into an OMT 1516 FOM object module.

2.3 Hadoop

Hadoop is a cloud computing platform that is widely used for the establishment of cluster computer systems. It provides MapReduce and HDFS to satisfy users' needs. Featuring high error tolerance, data localization, simplified parallel programming, and ease to expand, it is suitable for execution with immense quantities of data. Many large corporations use Hadoop for cloud computing applications. For the purpose of this study, HDFS [11] was used to store large military scenario data, and the parallel computation of MapReduce was introduced to analyze this large military scenario data to validate the military scenario data formats.

HDFS is a Hadoop application of distributed file system mainly developed to deal with large data demands. Two types of nodes exist in the HDFS structure, the NameNode and the DataNode. The NameNode is in charge of the management of the execution schedule in the cluster, such as the management of namespace in the file system and the access user-end files, while DataNode is in charge of the distributed storage of data.

The MSDL military scenario data application is used to describe how HDFS works, as shown in figure 1. First, large quantity of MSDL military scenario data established for STOW needs are entered and NameNode will separate the data into blocks. In figure 1, NameNode separates the data into three blocks, Part1, Part2, and Part3. Then,

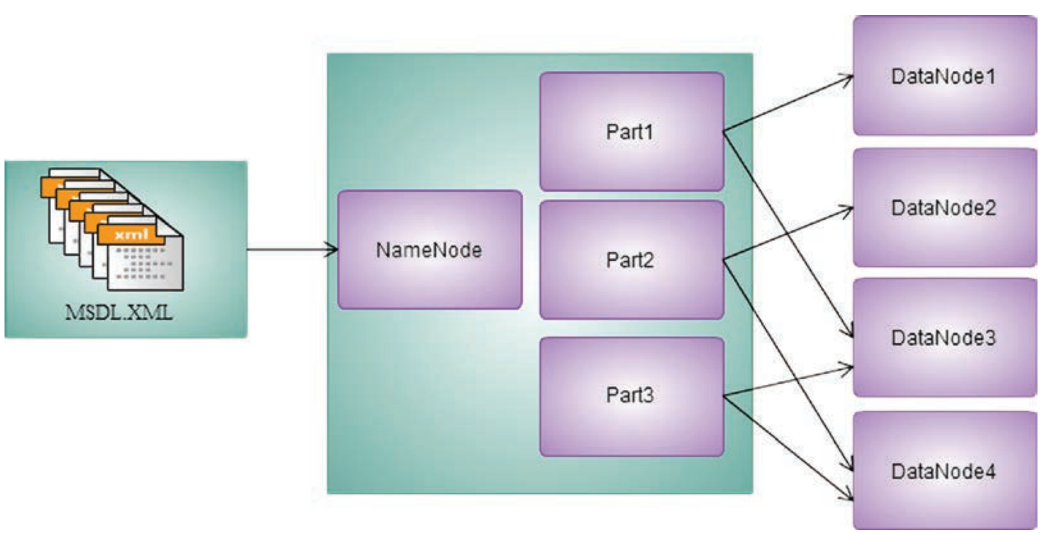

Figure 1: MSDL Military Scenario Documents Saved in HDFS

the blocks are saved to the DataNode depending on how many copies are set up. For example, in figure 1 blocks are saved with two copies. Block Part1 is saved to DataNode1 and DataNode2; Part2 saved to DataNode2 and DataNode3, and so on. If the number of copies is three, Part1 will be saved to DataNode1, DataNode2, and DataNode3.

The MapReduce consists of a JobTracker executed alone on the master node and TaskTrackers executed on each of the cluster nodes. The master node JobTracker is in charge of distributing tasks over different cluster nodes for TaskTrackers to execute while monitoring the execution of TaskTrackers. MapReduce has three models, one with multiple Maps and no Reduce, one with multiple Maps and one Reduce, and another with multiple Maps and Reduces, as shown in figure 2. The model with multiple Maps and one Reduce was selected for the study. Figure 2 shows how this model works. First, large quantities of MSDL military scenario data established for STOW needs are entered. In the process, each of the MSDL military scenario XML files are set to be a Map file and then validated for military scenario data format using the program written with XML Validation Application Programming interface (API) provided by Java™ and matching MSDL Schema. Finally, Reduce is used to summarize and output the results to show users whether the validation works. The efficiency is expected to be better than validation with stand-alone computers.

3. System Structure

The user establishes the required data modules with the BOMEditor based on the STOW needs. The editor is used to insert the modules in the MSDL military scenario data to achieve integration and exchange of various data modules in the STOW simulation system. Finally, the two core technologies of Hadoop HDFS and MapReduce allow the validation of the format of a large quantity of military scenario modules and data in the shortest time and best efficiency, thus enabling better efficiency and effectiveness of STOW in war gaming.

3.1 Structure Diagram

This section provides the description of the BOMEditor system structure (figure 3). Users may export BOM military data modules through BOMEditor and save these modules in MySQL database for access. In addition, BOMEditor is capable of inserting BOM military modules in MSDL. Finally, the core technology of Hadoop, the MapReduce, is used for the validation of military data modules.

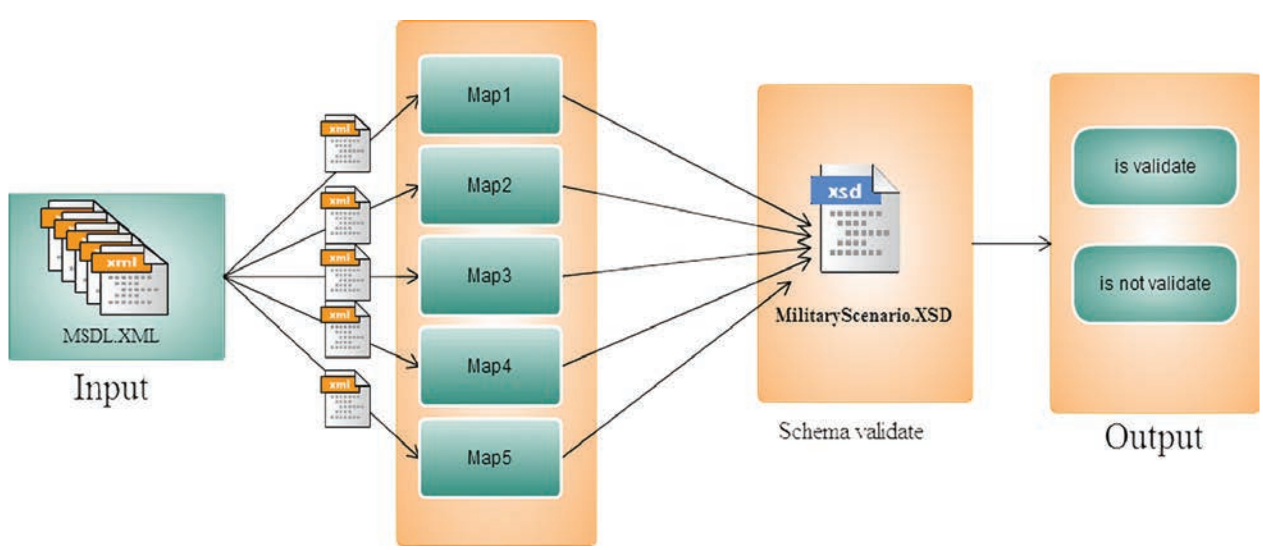

Figure 2: Scheme of Military Scenario Application in Parallel Analysis of MapReduce

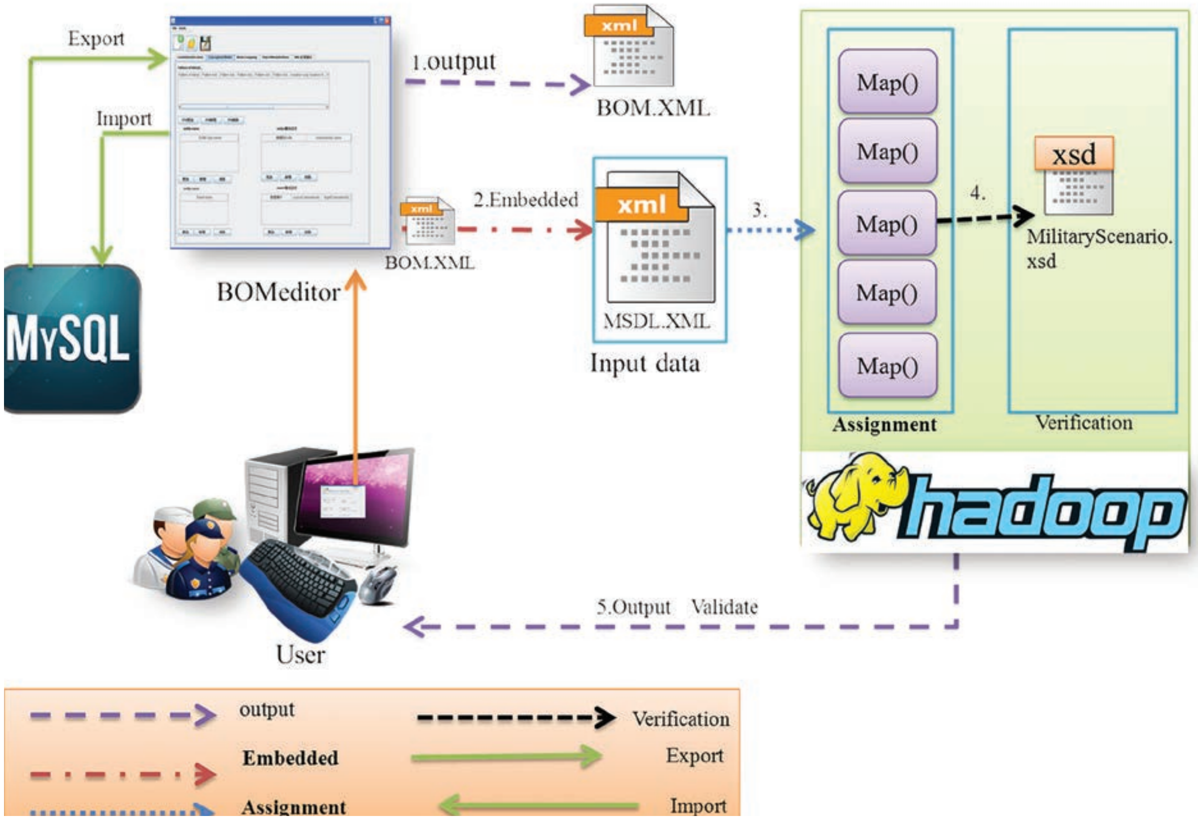

Figure 3: Data Stream-Based BOMEditor Structure

The data stream-based steps are described as follows:

Step 1.

A user uses the BOMEditor to edit STOW military scenario data based on the STOW simulation scenario needs. A copy of the BOM XML file is the output once the editing is completed, and imported to the Import MySQL database depending on the STOW warehouse needs. Alternatively, the existing BOM data is exported from the MySQL database to BOMeditor.

Step 2.

As the BOM data is edited in Step 1, a copy of the XML file is the output and technically integrated in the BOMEditor through the namespace of XML. A User may use the BOMEditor to insert BOM data in MSDL.

Step 3.

The types of military scenarios and modules generated by inserting BOM in MSDL as needed vary due to the diversity of STOW needs. Hadoop MapReduce is introduced to assign a Map to every military scenario or module.

Step 4.

Maps assigned to military scenarios or modules are validated in a distributed manner using Java Validate API [12].

Step 5.

As Hadoop validation is completed, the Map validation results are integrated using single Reduce and then sent back to the user.

3.2 System Establishment

Eclipse was introduced as the programming environment for the BOMEditor developed for this study and Java was selected as the programming language. The items in the data editing pages of BOMEditor are developed by referencing BOM and MSDL specifications. XML namespace [13] is used to insert BOM entities or events into MSDL. Table 1 shows the programming environment of BOMEditor and figure 4 provides an example of BOMEditor use.

Item	Programming environment/technology/ standard
OS	Windows 7
System analysis	UML
Integrated programming program	Eclipse
Language	Java
Java Development Kit	Java SE Development Kit 7
Database	MySQL
Scenario data exchange standard	XML, MSDL
Basic object module	BOM

Table 1: BOMEditor Programming Environment

Description of sequence diagram (figure 5):

1. Data Editor:

- **When to execute:** user uses BOMEditor.
- **What to execute:** to edit BOM data based on scenario needs.

2. Export:

- When to execute: BOM data editing is completed.
- What to execute: BOMEditor exports the data edited by user and saves it in XML format.

3. Importing:

- When to execute: it is necessary to edit and modify external BOM files.
- What to execute: external BOM data is exported to allow user to modify.

4. Imported Successfully:

- When to execute: external BOM data is imported successfully to BOMEditor.
- What to execute: a message of successful importing is sent to user.

5. Embed:

- When to execute: different data modules are provided depending on military scenarios.

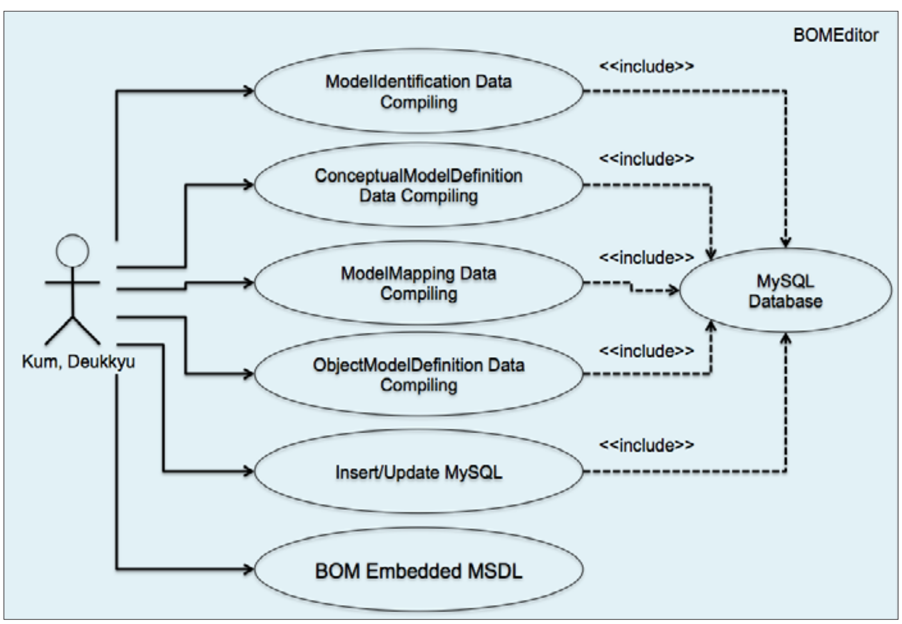

Figure 4: Example of BOMEditor Use

- What to execute: BOM entities or events are quoted by MSDL.

6. BOM Insert/Update MySQL:

- When to execute: a database is provided to store BOM data or allow user's access to BOM data for editing and modification later depending on STOW warehouse needs.
- What to execute: database access.

7. Return Database Message:

- When to execute: BOMEditor saves BOM data in database or retrieves data from database.
- What to execute: a message is sent to user after saving or accessing to inform if it is success or not.

8. MSDL MapReduce:

- When to execute: BOM is inserted in MSDL before exported to Hadoop.
- What to execute: Map is separated into several data sets.

9. Validate:

- When to execute: MSDL separation into data sets is completed.
- What to execute: MSDL data sets are validated using Schema.

10. Return Validate Message:

- When to execute: data set validation is completed.
- What to execute: the validation results are sent to user who is informed of the success after the results are integrated by Reduce.

4. STOW Military Module Example

An Air Force highway strip was taken as an example of a military scenario to establish basic military modules and scenarios of BOM, and to demonstrate how to insert the BOM's basic military modules into MSDL military scenarios through XML namespace.

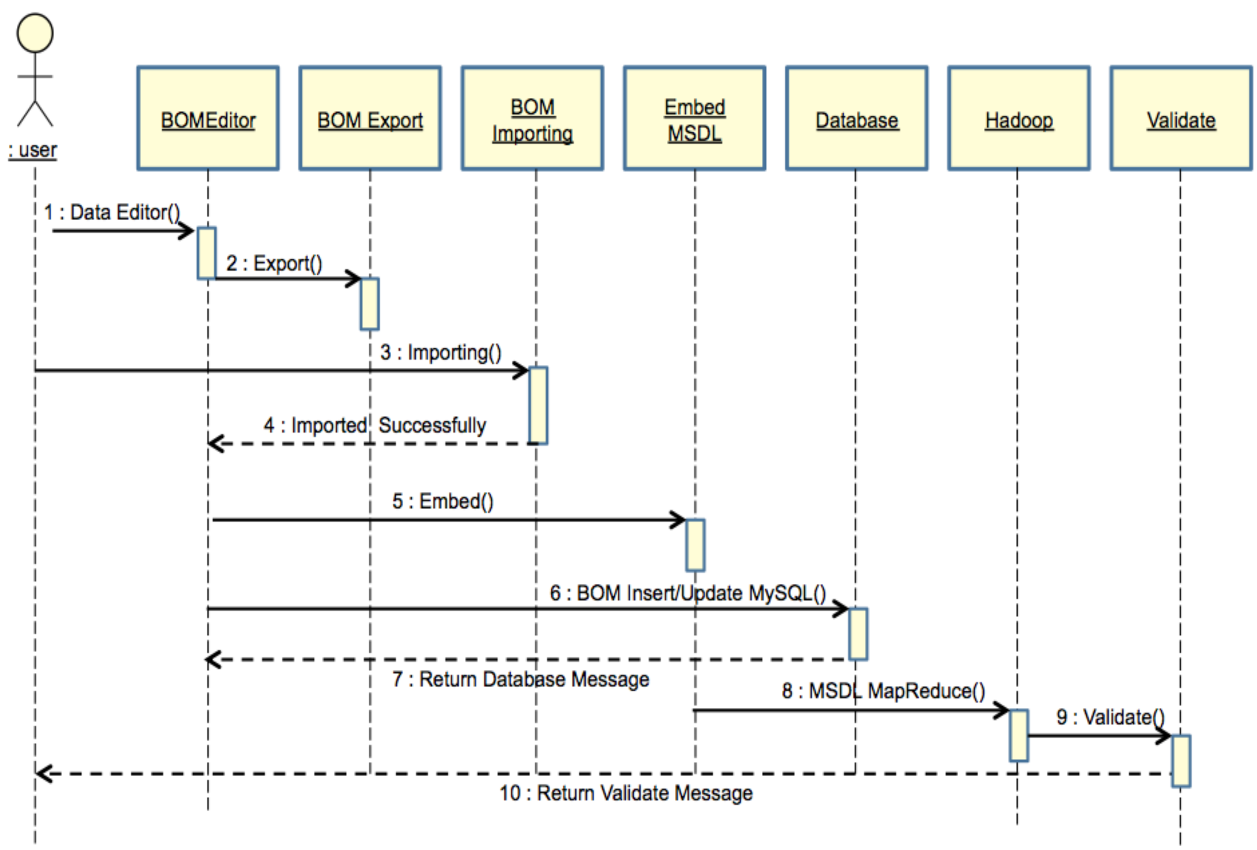

Figure 5: System Establishment Sequence Diagram

4.1 BOM Example – Air Force Highway Strip

The Air Force highway strip scenario started with fighter planes landing on the highway strip at Madou for supplies and preparation after most of the major airports along west coast of Taiwan were attacked and damaged by enemy missiles. Two of each of the F16, Mirage 2000, and IDF planes land on the strip at two minute intervals. Ah-1W Super Cobras, armed with Sidewinder missiles, circle over the strip for air cover to allow the fighters to taxi to the south preparation zone. OH-58D reconnaissance helicopters stay below 50 feet for battlefield intelligence. Later on, units are dispatched for security inspections, supplies and loading weapons, and then the planes start to line up and take off. The BOM modules established for the scenario include fighter types, helicopter types, security personnel, maintenance crew, and weaponry crew. Figure 6 below provides the XML codes written for some of the BOM modules and includes the XML code for IDF fighter entity, which is an entityType in the Air Force highway strip BOM. The entityType defines the name of the Air Force fighter plane, IDFEntity, and the characteristics are described of the IDF plane. This part is established by referencing the EntityTypes specifications in the SISO document of BOM Specification_v2006_FINAL. An entity type may correspond to several characteristics, thus the characteristics item of IDF are developed based on real traits, such as the fighter's ID, maximum speed, combat radius, and combat pattern of air to air, or air to surface, etc.

```
<entityTypes>
  <entityType>
      <name>IDFEntity</name>
      <characteristic>
          <name>ID</name>
      </characteristic>
      <characteristic>
          <name> Maximum_speed_1.8Mach</name>
      </characteristic>
      <characteristic>
          <name> Combat_radius_1100km</name>
      </characteristic>
      <characteristic>
          <name> Thrust_to_weight_ratio_0.94</
          name>
      </characteristic>
      <characteristic>
          <name>Air_to_air</name>
      </characteristic>
      <characteristic>
          <name>Air_to_surface</name>
      </characteristic>
  </entityType>
<entityTypes>
```

Figure 6. XML code of BOM IDF Entity

4.2 BOM Insertion into MSDL

This section explains how to insert the IDF Entity BOM object module established in the previous section into the MSDL military scenario data. Figure 7 shows the MSDL developed for this study based on scenario needs. It consists of necessary items such as Options, and non-necessary items established for the scenario that include Plan, ForceStructure, and TaskOrganizations. Table 2 describes these items and their applications. The red rectangle in Figure 7 signifies that XML namespace is used to quote this BOM resource. In this MSDL example, the BOM resource of the Air Force highway strip is quoted. For example, the MSDL Equipment quotes the IDF of the Air Force highway strip BOM. In this MSDL example, the Air Force highway strip BOM is named afb.

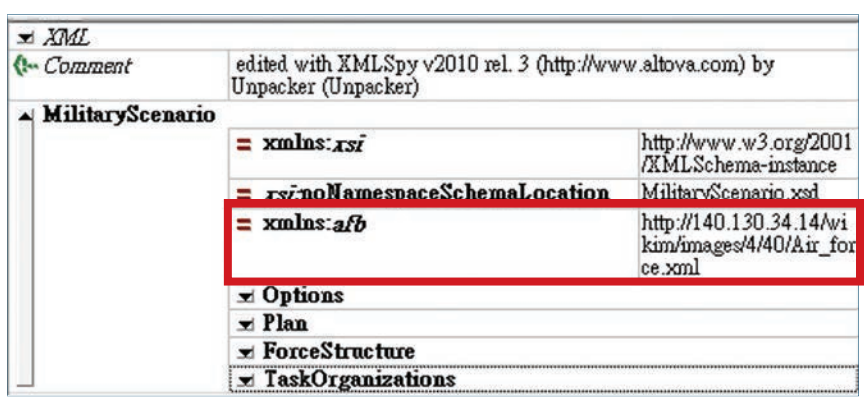

Figure 7: Main Items of MSDL Example

Options	Description of information such as MSDL version, date, and so on.
Plan & COA	Courses of action (COAs) to be executed in a military plan
Force Structure	Description of force structure, troops and the country's position
Task Organizations	Description of COA units and devices and equipment used in actions

Table 2. Main Tags of MSDL

4.2.1 Items to be inserted

Figure 8 is an item in the MSDLTaskOrganizations. EquipmentItem is under Equipment. The red rectangle is the Air Force highway strip BOM IDFEntityentityTypes quoted by MSDL. Figure 9 displays the XML code of Air Force highway strip BOM quoted by MSDL. It is clear in this figure that the beginning of the MSDL's XML code declares the namespace as the afb and points at the URL at the address of http://140.130.34.14/wikim/images/5/56/Air_force_english.xml, meaning that the resource of this URL is quoted and represents the location where the Air Force highway strip BOM is saved. This BOM module is quoted through namespace. In Figure 9, afb is added in front of the entityTypes, meaning that the Air Force highway strip is quoted. For example, the name of entityType is IDFEntity and the content of the characteristic's name is Air to surface. Corresponding items can be found through the URL of the namespace above.

```
<?xml version="1.0"?>
<MilitaryScenario         xmlns:xsi="http://
www.w3.org/2001/XMLSchema-instance"
xsi:noNamespaceSchemaLocation="MilitaryScenario.xsd"
xmlns:afb="http://140.130.34.14/wikim/images/4/40/Air_force.
xml">
<EquipmentItem>
<ObjectHandle>6c84332e-0bfa-4a26-875f-2dcc852b6cda</
ObjectHandle>
<SymbolId>SFG*EVATM-*****</SymbolId>
<Name>IDF</Name>
                ……
<afb:entityTypes>
        <afb:entityType>
        <afb:name>IDFEntity</afb:name>
        <afb:characteristic>
        <afb:name>Air_to_surface</afb:name>
        <afb:semantics/>
        </afb:characteristic>
        </afb:entityType>
</afb:entityTypes>
</EquipmentItem>
                ……
</MilitaryScenario>
```

Figure 9: Air_forceEquipmentItem XML Code

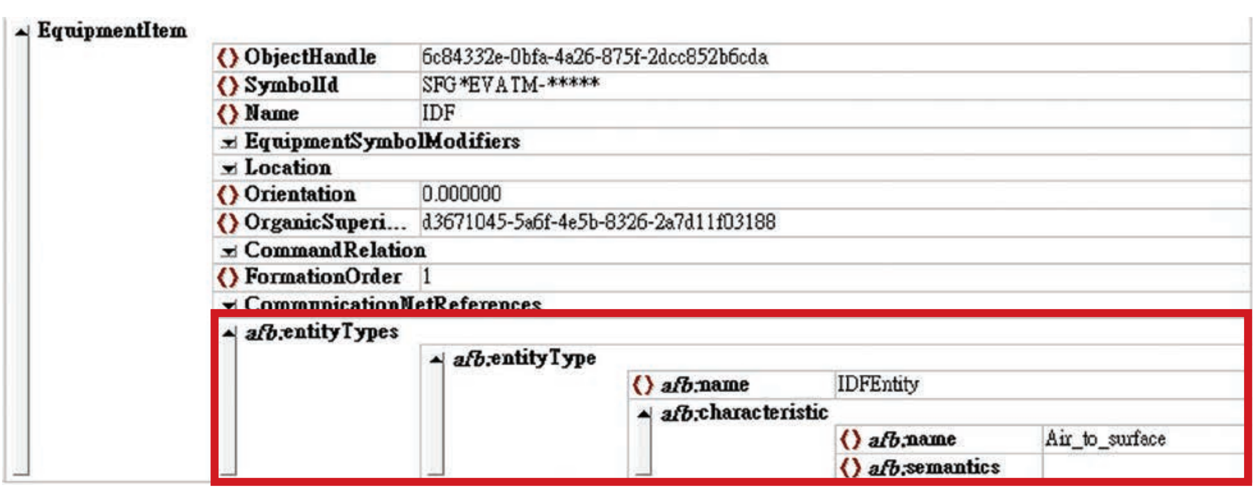

Figure 8: MSDL EquipmentItem

4.2.2 Advantages that MSDL Quotes BOM

The specifications of BOM and MSDL provide the glimpse of the difference between BOM and MSDL. BOM is designed to establish an abstract conceptual model that includes the types of objects and events, and the relationship between them. MSDL is developed to characterize the initial military simulation scenario. Therefore, a military scenario with a smaller scope is required for MSDL. Data has to be developed for multiple military scenario items in MSDL, but the contents of these items do not necessarily meet military scenario needs. Thus, it may not achieve effective applications on a STOW simulation system. On the other hand, the BOM enables the use of a conceptual model definition for fast establishment of physical types and event types for the scenario, and characterizes how physical types achieve the changes in an interactive relationship and status through event types. BOM allows the modules established to be defined in a military scenario with a small scope and provides expandability, composability and reusability. Therefore, the main advantage of MSDL quoting BOM is reducing the time establishing data modules, and the existing BOM data modules can be used as the source of data establishment. Furthermore, there seems to be insufficient needs and applications for the heterogeneous platforms of STOW since MSDL is used primarily to characterize the initial simulation scenarios. For example, a house is being built in real life. The MSDL is considered as the main structure of the house and BOM is the building blocks of the house. The constructor of the house uses the building blocks of BOM to customize the structure of the house for different clients and satisfies their needs. Therefore, in the characterization of military scenarios of STOW, MSDL is used to describe the grand structure of a military scenario, while various BOM modules developed are used for details, thus satisfying the fast development of STOWs for different military scenarios.

5. Performance Assessment

For the performance assessment of this study, Ubuntu 12.04 was used to establish the Hadoop cloud computing platform as the test environment. Table 3 shows the test environment for performance assessment, including the stand-alone PC environment and cluster Hadoop environment. The stand-alone PC is equipped with a dual-core CPU, 2GB of memory, and a 250GB hard drive. Single verification programs are used to validate the data format for a military scenario. The cluster Hadoop consists of 7 computers, one being the Namenode and the other 6 being Datanode. The performance tests are preformed using MapReduce, the core technique of Hadoop. The differences between the execution times in validation with the stand-alone PC and cluster Hadoop were compared.

Platform	CPU	Memory	HD
Stand-alone PC	2.4GHz*2	2G	250GB
Cluster Hadoop	3.4GHz*7	16G	250GB

Table 3: Hardware Specifications for Test Environments

Table 4 provides the test modules for performance assessment with test time in seconds. The tests were performed with 1,000 files, 5,000 files, and 10,000 files. Table 4 shows it takes 948 seconds, or approximately 15 minutes, for the stand-alone PC to validate 1,000 files, while the cluster Hadoop validated the same number of files in just over three minutes. Figure 10 shows the difference is increased by slightly over 500% between the two methods for this test. When validating 5,000 files, it takes 4,740 seconds, or 1 hour and 19 minutes for the stand-alone PC, and 15 minutes for the cluster Hadoop. Finally, with the validation of 10,000 files, the cluster Hadoop takes approximately 31 minutes as opposed to more than 2 hours for the stand-alone PC. This assessment shed some light on the enormous saving that the distributed computing of the cluster Hadoop can provide in both manpower and validation time. Figure 10 shows clearly that for the validation of 5,000 files, the cluster Hadoop is pulling away from the stand-alone PC in terms of time, proving that the distributed computing of cluster Hadoop is much faster than individual PCs in terms of computation of large quantity of data.

Test environment	1,000 files	5,000 files	10,000 files
Stand-alone PC	948(s)	4740(s)	9480(s)
Cluster Hadoop	194(s)	940(s)	1863(s)

Table 4: Validation Test Results

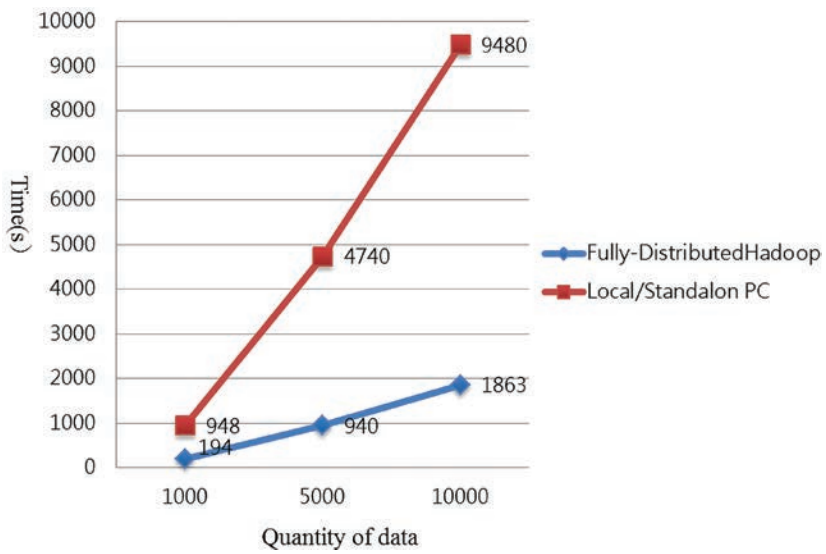

Figure 10: Broken Line Graph of Performance Assessment

6. Conclusions

It is not necessary to invest a large quantity of manpower for exercises and military operations for military development because of the advanced technology we enjoy today. For example, a much larger supporting staff was required for war gaming in the past. With the establishment of specifications proposed by SISO, such as the MSDL, C-BML, and BOM, the number of countries that have adopted the STOW military simulation for military exercises is growing significantly. Countries are now given the opportunity to choose the specifications that meet their demands from those established by SISO.

Java was selected for the development of the editor used for BOM-based STOW scenarios called BOMEditor, which allows the editing of BOM data modules and exporting the modules into XML files. In addition, BOM data can be inserted into MSDL through this editor according to STOW needs. For the technique of insertion, the namespace technique is introduced for the insertion since the SISO specifications are established mostly XML. For validation, the demands of STOW are huge. For validation purely in the old-fashioned way, it requires large manpower to validate the military data modules, and the time spent on such validation or the cost on accuracy is large as well. Therefore, the cluster Hadoop environment was selected for this study and its core technique, MapReduce, for validation in order to achieve reduction in manpower costs and improvement of execution efficiency or time.

A suggestion for future studies is to incorporate SISO specifications, (MSDL, C-BML, and BOM), and Internet of Things [14], and wireless sensor network [15] in one package for applications outside of military domain, (i.e., the joint disaster relief effort of government). Another topic worth looking into is the insertion of sematic web [16]-[18] in BOM data modules for the improvement of sematic description capability of these modules. The BOMEditor proposed in this study is developed using MySQL database. The HBase [19] of Hadoop may be used to improve the overall performance of cloud computing.

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Authors' Biographies

Dr. I-Ching Hsu

Dr. I-Ching Hsu received a Ph.D. degree in the computer science department at the National Chung-Hsing University of Taiwan in 2007. Dr. Hsu has worked at Chung-Shan Institute of Science & Technology in the area of information engineering since 1991. He is currently an associate professor of Computer Science and Information Engineering at National Formosa University, Taiwan. He has participated and directed projects in the area of Cloud Computing, MSDL, UML modeling, and Military's LVC Environment. His current research interests are in Cloud Computing, Social Web, Semantic Web, and Synthetic Theater of War.

Dr. Yuan Kwei Tzeng

Dr. Yuan Kwei Tzeng is project manager for the Republic of China (R.O.C.) Military's LVC Environment research project. Dr. Tzeng has been working at Chung-Shan Institute of Science & Technology in the area of intelligent data integration technologies since 1985. His current research aims at the creation and study of Semantic Web for modeling and simulation network security mining applications and information modeling. He holds a Ph.D. in computer science and engineering from the National Chung-Hsing University of Taiwan.

Mr. Jin-Cheng Jhang

Mr. Jin-Cheng Jhang is a graduate student in National Formosa University, Taiwan. Mr. Jhang has worked with associate professor I-Ching Hsu in the Department of Computer Science and Engineering at the National Formosa University of Taiwan. His research interests include BOM and cloud computing.

Meeting the NATO M&S Interoperability Challenge

AUTHORS

Mr. Wim Huiskamp	*TNO, NMSG Chairman, M&S Standards Subgroup(MS3), MSG-068 NETN, The Netherlands*	wim.huiskamp@tno.nl
Mr. Adrian Voiculet	*NATO CSO, MSCO, MS3 secretary, France*	adrian.voiculet@cso.nato.int
Dr. Erdal Cayirci	*JWC, MSG-068 NETN Chairman, Norway*	erdal.cayirci@jwc.nato.int
Mr. Björn Löfstrand	*Pitch Technologies AB, MSG-068 NETN, MSG-106 SPHINX, Sweden*	bjorn.lofstrand@pitch.se
Mr. Bharat Patel	*Dstl, MSG-068/MSG-106 NETN/SPHINX, MSG-048/085 C-BML, United Kingdom*	bmpatel@mail.dstl.gov.uk
Mr. Lionel Khimeche	*DGA, MSG-048/MSG-085 C-BML Chairman, France*	lionel.khimeche@dga.defense.gouv.fr
Dr. Kevin Heffner	*Pegasus Research & Technologies, MSG-048, MSG-085, Canada*	k.heffner@pegasim.com
Mr. Nico de Reus	*TNO, MSG-048/MSG-085 C-BML, The Netherlands*	nico.dereus@tno.nl
Mr. Jean-Louis Igarza	*Antycip Simulation, MSG-073 GM-VV Secretary, MS3, France*	igarzaj@voila.fr
Dr. Jeroen Voogd	*TNO, MSG-073 GM-VV, The Netherlands*	jeroen.voogd@tno.nl
Dr. Manfred Roza	*NLR, MSG-073 GM-VV, The Netherlands*	Manfred.Roza@nlr.nl
Mr. Niels Krarup-Hansen	*DALO, MSG-084 NMSMP, Denmark*	nkh@mil.dk

ABSTRACT

THE NORTH ATLANTIC TREATY ORGANIZATION (NATO) MODELLING & SIMULATION MASTER PLAN (NMSMP) CALLS FOR THE APPLICATION OF MODELLING AND SIMULATION (M&S) IN AREAS THAT INCLUDE, BUT ARE NOT LIMITED TO: SUPPORT TO OPERATIONS, CAPABILITY DEVELOPMENT, MISSION REHEARSAL, TRAINING AND EDUCATION, AND PROCUREMENT.

COMMON STANDARDS ARE ESSENTIAL ENABLERS FOR SIMULATION INTEROPERABILITY AND RE-USE. THIS INCLUDES TECHNICAL ARCHITECTURE STANDARDS (E.G., HLA - THE HIGH LEVEL ARCHITECTURE), DATA INTERCHANGE STANDARDS (E.G., SEDRIS - SYNTHETIC ENVIRONMENT DATA REPRESENTATION AND INTERCHANGE SPECIFICATION) AND BEST PRACTICES (E.G., DISTRIBUTED SIMULATION ENGINEERING AND EXPLOITATION PROCESS - DSEEP).

THE NATO MODELLING AND SIMULATION GROUP (NMSG) WAS OFFICIALLY NOMINATED AS THE DELEGATED TASKING AUTHORITY FOR M&S STANDARDISATION IN 2003. NMSG HAS DEVELOPED NATO STANDARD AGREEMENTS (STANAG) (E.G., HLA AND SEDRIS). HOWEVER, THE NEED WAS IDENTIFIED TO PROVIDE AND MAINTAIN A “STANDARDS PROFILE” OF EXISTING OR EMERGING STANDARDS FOR M&S. IN COOPERATION WITH THE NATO STANDARDIZATION AGENCY

(NSA), THE NMSG DETERMINED THAT AN ALLIED PUBLICATION (AP) IS THE MOST APPROPRIATE DOCUMENT FORM FOR A "STANDARDS PROFILE." IN MAY 2007, THE NMSG APPROVED THE ESTABLISHMENT OF THE M&S STANDARDS SUBGROUP (MS3), WHICH IS TASKED TO CREATE AND MAINTAIN THE NATO M&S STANDARDS PROFILE UNDER THE REFERENCE "AMSP-01 (ALLIED M&S PUBLICATION)." THE AMSP-01 DOCUMENT INTENDS TO ESTABLISH A COMMON UNDERSTANDING OF THE TERMINOLOGY ASSOCIATED WITH M&S STANDARDISATION, PRODUCE, AND MAINTAIN THE LIST OF EXISTING STANDARDS (AND PROMISING EMERGING STANDARDS) APPLICABLE TO THE M&S DOMAIN. AMSP-01 ALSO PROVIDES RECOMMENDATIONS TO NMSG AND STANDARDS DEVELOPING ORGANIZATIONS (SDOS) FOR NEW STANDARDISATION PRIORITIES BASED ON THE IDENTIFIED AREAS WHERE ADDITIONAL STANDARDS ARE NEEDED.

THE MS3 CO-ORDINATES ITS ACTIVITIES WITH SDOS, WHICH INCLUDE SIMULATION INTEROPERABILITY STANDARDS ORGANIZATION (SISO), INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE), AND INTERNATIONAL STANDARD ORGANIZATION (ISO), ALONG WITH CORPORATE ASSOCIATIONS (E.G., NATIONAL TRAINING AND SIMULATION ASSOCIATION (NTSA) AND EUROPEAN TRAINING AND SIMULATION ASSOCIATION (ETSA)).

THE NMSG IS ALSO COORDINATING RESEARCH AND DEVELOPMENT OF NEW M&S STANDARDS THROUGH ITS MSG TASK GROUPS. PROMINENT EXAMPLES OF RECENT YEARS ARE THE WORK DONE IN MSG-068 (NATO EDUCATION AND TRAINING NETWORK), MSG-048/MSG-085 COALITION BATTLE MANAGEMENT LANGUAGE (C-BML) AND THE MSG-073 GENERIC METHODOLOGY FOR VERIFICATION AND VALIDATION (GM-VV).

THIS PAPER ELABORATES ON THE CHALLENGES TO MEET THE ALLIANCE'S AND THE NATION'S M&S INTEROPERABILITY NEEDS. THE AUTHORS PROVIDE A COMPREHENSIVE OVERVIEW OF THE ACHIEVED RESULTS AND CURRENT ACTIVITIES IN WHICH NATIONS AND NATO ORGANISATIONS COOPERATE UNDER THE LEADERSHIP OF THE NMSG. THE GUIDELINES AND STANDARDS DEVELOPED WITHIN NMSG AND SISO ARE BASED ON CONTRIBUTIONS FROM NATIONAL EXPERTS AND SHOULD BE LEVERAGED NATIONALLY WHENEVER POSSIBLE TO BENEFIT FROM SHARED KNOWLEDGE AND IMPROVE INTEROPERABILITY.

1. Introduction

Modelling and simulation (M&S) is a revolutionary technology that enables nations and North Atlantic Treaty Organization (NATO) to provide support to operations, capability development, mission rehearsal, training and education, and procurement. Some particular benefits on the training side include saving time, money, and even lives, when training unsafe scenarios. Economic considerations at the national and NATO level demand a more cost-effective balance between live training and simulation-based training. In addition, M&S facilitates joint and coalition training.

Development of distributed simulations is a complex process requiring extensive experience, knowledge, and skill in order to design, develop, and integrate systems into a federation that meets operational, functional, security, and technical requirements. Interoperability among distributed systems is a multifaceted problem. It ranges from technical exchange of data through semantic issues dealing with a common understanding and use of information to mutually accepted security measures.

Interoperability is increasingly important, as distributed simulation is rapidly becoming a necessity for mission training. With current-day joint and coalition based missions, we will never fight alone. Thus, we need to train together, within and between nations. Standards allow people working with different systems to cooperate, and allow collective training or experimentation. Standards reduce costs and they are a natural way to share investments avoiding duplication of efforts on new technologies, while reducing risk linked to their use.

Interoperability is especially important to smaller nations. Using international standards makes it possible to acquire systems from different vendors in a competitive market, and thereby acquire systems affordable to smaller nations. In other words, it is possible for smaller nations to find solutions that are interoperable and within smaller budgets.

Standards protect investment; scenario descriptions, models, and databases may be reused in a variety of applications. They also allow upgrades to newer systems or changes to systems from another vendor. Finally, standards can reduce complexity and produce more modular and reconfigurable implementations, thus reducing development risk.

This paper elaborates on the challenges to meet the Alliance's and the Nation's M&S interoperability needs. The authors will provide a comprehensive overview of the achieved results and of current activities, in which Nations and NATO organisations cooperate under the leadership of the NATO Modelling and Simulation Group (NMSG).

2. NMSG

The NMSG is part of the NATO Science and Technology Organisation (STO)[1] [1].

The NMSG is responsible for coordinating and providing technical guidance for NATO M&S activities undertaken by 28 NATO and partner nations, and various NATO Bodies [2]. The administration of M&S activities is the responsibility of the NATO Modelling and Simulation Coordination Office (MSCO).

2.1 NMSG Mission and Objectives

The mission of NMSG *is to promote cooperation among Alliance bodies, NATO, and partner nations to maximise the effective utilisation of M&S. Primary mission areas include: M&S standardisation, education, and associated science and technology.* The activities of the Group are governed by the NATO M&S Master Plan (NMSMP) [3]. The group provides M&S expertise in support of the tasks and projects within the STO and from other NATO bodies.

The NMSG was officially named as the Delegated Tasking Authority for NATO M&S standardisation.

The organisational structure (figure 1) of the NMSG consists of four main elements:

- The Programmes and Planning Committee (PPC). In charge of coordinating proposals for new research activities and monitoring progress;
- The Military Operational Requirements Subgroup (MORS). In charge of identifying M&S gaps based on short-term and long-term operational needs;
- The M&S Standards Subgroup (MS3). In charge of standards agreements and standards recommendations;
- The M&S research is carried out by multi-national task-groups (TGs), typically running for three years. These activities are identified as MSG-XXX.

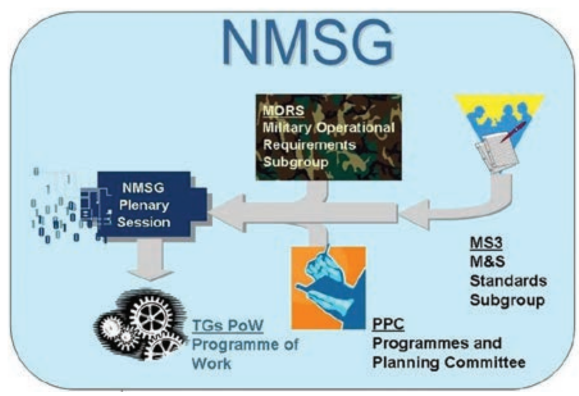

Figure 1: NMSG Structure

The NMSG plenary meets twice yearly to discuss and decide on NMSG activities. Nations have one vote in the NMSG.

The lessons-learned within NATO are also very applicable within each nation. The challenge to achieve interoperability between different branches of the armed forces and all its organisational entities can be daunting. The guidelines and standards that have been developed within NMSG and SISO should be applied nationally whenever possible. Cooperation within international teams usually results in

[1]The STO was known as the Research and Technology Organization (RTO) before July 2012.

better solutions and a more effective use of resources than proprietary solutions. The benefits of improved quality and increased interoperability outweigh the possible additional time needed to achieve consensus.

Concerns regarding security need to be considered. However, these concerns are in most cases related to the actual information exchange during an exercise or event. Standards like the High Level Architecture (HLA), Coalition Battle Management Language (C-BML) or Generic Methodology for Verification and Validation (GM-VV) are basically meta-standards that define how information is structured and exchanged, rather than what the information content is during run-time. Security concerns do not prevent achieving consensus on these types of standards.

2.2 NATO M&S Master Plan

The first NMSMP was approved by the North Atlantic Council (NAC) and signed in 1998 by the NATO Secretary General. It has served as the implementing document for M&S in NATO since that date. Significant results have been achieved in meeting its objectives. However, many of its provisions are as relevant today as they were when written. The NMSMP has recently been revised under coordination of the NMSG to reflect changes in NATO structures and organisations, and to position NATO M&S for the future.

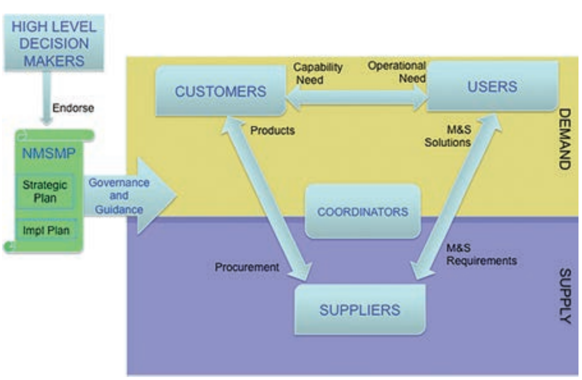

Figure 2: NATO M&S Stakeholder Relations

The NMSMP articulates the NATO vision and guiding principles regarding the use of M&S in support of the NATO mission, discusses the impact that achieving this vision will have on NATO M&S application areas, and identifies the governance mechanisms and bodies, and the primary NATO M&S stakeholders (figure 2).

The document presents the M&S main objectives and actions required to achieve the vision. One of the main objectives is to *establish a common, open standard technical framework to promote the development of a capability for interoperability and reuse of models, data and simulations across the Alliance* [3]. This objective is the driver for NMSGs standardisation efforts.

2.3 MS3

In May 2007, the NMSG approved the establishment of the M&S Standards Subgroup (MS3) as its permanent custodian and coordinating body for M&S standards. The MS3 has a close working relationship with other Standards Developing Organizations (SDO), which include Simulation Interoperability Standards Organization (SISO) [4], Institute of Electrical and Electronics Engineers (IEEE), and International Standard Organization (ISO), along with corporate associations (e.g., National Training and Simulation Association (NTSA) and European Training and Simulation Association (ETSA)).

3. STANDARDS

NATO recognises the ISO/IEC concept of a standard as follows: "A standard is a document, established by consensus and approved by a recognized Body that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context." It is noted that, "a standard should be based on the consolidated results of science, technology, experience, and lessons learned" [5].

A NATO standard is a standard developed by NATO and promulgated in the framework of the NATO standardisation process. The NATO standardisation process involves proposing, developing, agreeing, ratifying, promulgating, implementing, and updating NATO standardisation documents. The primary products of this process are covering documents (Standardisation Agreement (STANAG) or Standardisation Recommendation (STANREC)) and Allied Standards (Allied Publication (AP) or Multinational Publication (MP)).

The production of NATO standardisation documents is the direct responsibility of the so-called Tasking Authorities (TA) (i.e., a senior committee that makes all its decisions by consensus). Member nations are responsible for the ratification or approval, implementation of the NATO standardisation documents, and may identify standardisation requirements.

> The general standardisation policy of NATO is to use civil standards whenever possible and cooperate with SDOs in developing standards that meet its needs via Technical Cooperation Agreements.

This is the rationale for the close relationship between NMSG and SISO, which was formalised in a Technical Cooperation Agreement (TCA) signed in July 2007.

3.1 Characteristics of Good Standards

M&S technology is becoming a mature industry but is still too diverse in general approaches and technical solutions. A mature M&S community should not depend on unique/proprietary solutions, but should adopt generally accepted standards. Historically, the need for establishing M&S standards became apparent with the emergence of the distributed simulation concept and the associated technology (late 1980s, early 1990s). Reuse of different simulators/simulation applications developed under different technological approaches and implemented on different platforms became possible: a requirement for developing interoperability protocols and/or architecture standards emerged. While simulation interoperability spurred the development of many standards, there are other types of M&S and M&S-related standards, e.g., engineering practices.

The main qualities that make good standards are:

- Relevance: a standard shall be relevant to the targeted user/developer community;
- Substantive content: a standard shall provide meaningful information and/or results;
- Timely production, in an efficient manner, to ensure that the product is useful to the community;
- Reviewed by the technical community to which the product applies & large acceptance;
- Generality: standards should be as general as possible, while still maintaining usefulness, to support the broadest community of current and future users;
- Stability: standards should be established and changed only as necessary. They should be prototyped and tested before being proposed for adoption to demonstrate their maturity;
- Supportability: Standards should maintain the integrity of the existing product suite and the needs of the user.

After some years of standards development, it appeared that existing standards were only partial solutions to the overall interoperability problem. The current situation is improving, but a lot still has to be done. Standards development and maintenance is an evolutionary process. Existing standards must mature to meet changing requirements. When new requirements emerge or technical innovations become possible, new standards will likely be needed.

4. M&S Standards

The NMSG is the Delegated Tasking Authority in the NATO M&S standardisation domain. In cooperation with the NATO Standardization Agency (NSA), the MS3 has determined that an Allied Publication (AP) is the most appropriate document form for a "Standards Profile." The MS3 was tasked to create and maintain the NATO M&S Standards Profile under the title "AMSP-01 (Allied M&S Publication)" [6].

4.1 AMSP-01

AMSP-01 maintains information on M&S standards and recommended practices relevant to achieving interoperability and re-use of components, data, models, or best practices. The AMSP-01 provides recommendations that can be used as guidance in the selection and use of M&S standards for NATO and national activities, e.g., coalition training and experimentation.

Standards are classified in the following categories:

- M&S methodology, architecture and processes with sub-categories: Architecture Frameworks, Systems Engineering processes, and Verification and Validation;
- Conceptual Modelling and Scenarios;
- M&S Interoperability;
- Information Exchange Data Model;

- Software Engineering;
- Representation of natural and human-made environment with sub-categories General, Data sources and formats, Imagery, 3D Models, Interchange of environmental data, Production processes, and Visualization;
- Simulation Analysis and Evaluation;
- M&S Miscellaneous.

There are many standards in existence that have, or may have, an indirect impact on M&S activities e.g., system engineering standards. However, only those standards directly applicable to M&S development, integration, and employment are considered for inclusion in AMSP-01. This document is not intended to be an encyclopaedia of standards.

In terms of maturity, standards and guidance documents are characterised as either "obsolete," "aging," "current," or "emerging."

4.2 Approach to M&S Categories, link DSEEP

The identified M&S Standards categories of the AMSP-01 was influenced by Distributed Simulation Engineering and Exploitation Process (DSEEP) [9], which is an approved IEEE standard developed by SISO that supports the overall M&S lifecycle. Although DSEEP is rather new, it is based on the widely accepted HLA Federation Development and Execution Process (FEDEP) [7], [8], thus DSEEP is a very suitable reference.

Figure 3 indicates the relationships between the standards categories and the seven main DSEEP steps. The eight rectangles above and below the centre row of the DSEEP steps represent the standards categories, and five are linked to the DSEEP steps where the standards are most applicable. Rectangles representing more general standards, such as "Architecture Framework Standards" in the top-left corner, are not tied to any particular step.

The MS3 issued the first release of the AMSP-01 in October 2008 and provides a regular update of this document. The current release is AMSP-01 (B) (January 2012) and includes more than 40 M&S related standards. The standards and products included in AMSP-01 are not formally mandated by NATO unless they are supported by a specific STANAG.

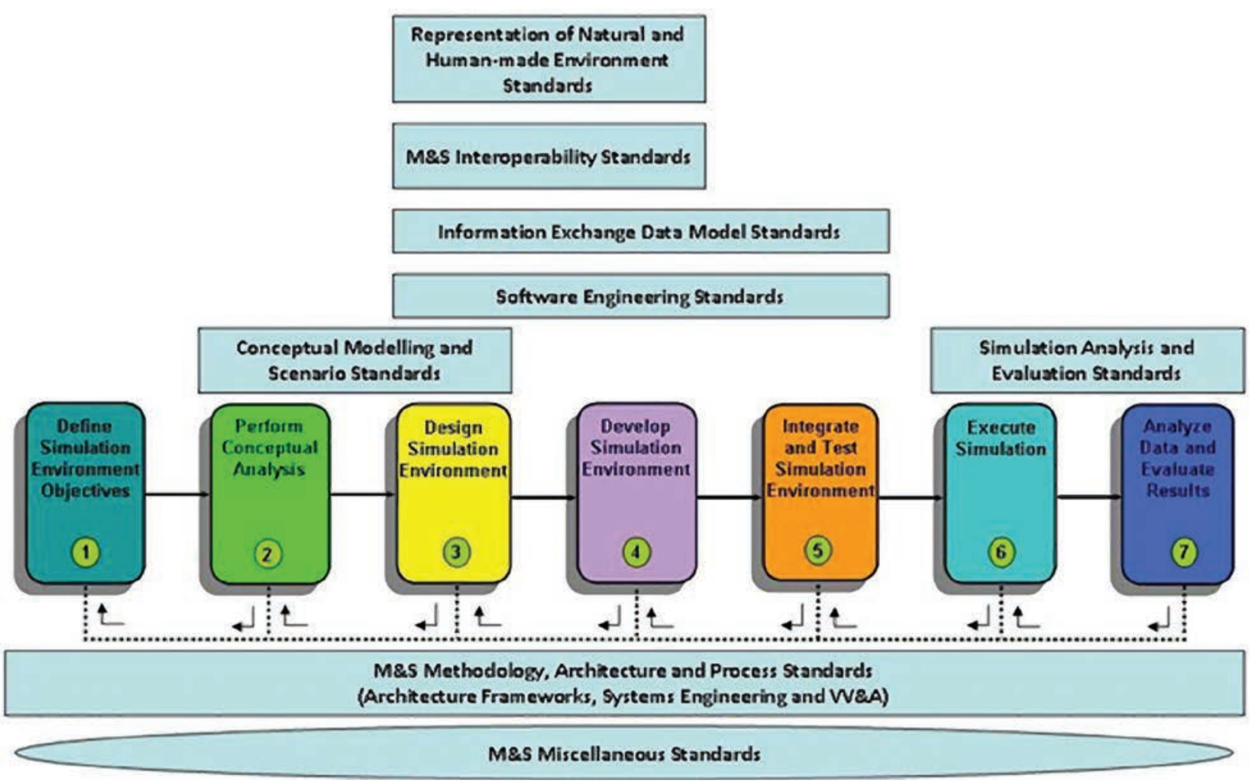

Figure 3: The 7-step DSEEP Simulation Engineering Process and the Standards Categories

However, all identified standards/products were included in AMSP-01 following a formal selection and classification process by the MS3 experts and therefore, should be considered as relevant for the M&S domain.

4.3 Emerging Standards

The AMSP-01 obviously includes well-known standards, like the High Level Architecture (HLA IEEE1516-2010), which are also covered by NATO STANAGs (STANAG 4603). The following paragraphs will not discuss these established M&S standards, but rather present some of the key new standards that have been included in the AMSP-01 as 'emerging'. They are currently nearing completion by their respective NMSG Task Groups, often in close cooperation with SISO.

These prominent examples of recent years resulted from work done in MSG-068 NATO Education and Training Network (NETN), MSG-048 C-BML and the MSG-073 GM-VV. The objective of this paper is to provide an overview of these standards development activities. Detailed technical explanations would exceed the scope of the paper, but may be found in the extensive reference list of publications and reports.

5. Education and Training Network

Training of the combined headquarters is the responsibility of NATO, while nations are responsible for the tactical training of the assigned forces. Although NATO and nations conducted geographically distributed training simulations in the past, these simulations were one-off infrastructures that had to be re-established for every exercise. That is neither the most cost effective, nor responsive to current and future training requirements. A Persistent Infrastructure is seen as a key-enabler to achieve NATO's vision of timely and cost-effective distributed simulation based exercises (figure 4). A NETN that consists of a persistent architecture, distributed training and education tools, and standard operating procedures can not only support the training of NATO headquarters, but also enables the nations to cost-effectively collaborate with the other nations to train their tactical forces and headquarters. Moreover, it also introduces an opportunity to integrate the training of NATO headquarters (i.e., both technically and procedurally) with the tactical forces when needed for short notice mobile mission rehearsal trainings and other integrated exercising requirements.

Figure 4: NATO Vision of Distributed Exercises

To meet this operational demand, Allied Command Transformation (ACT) requested NMSG to start a technical activity in 2006. The MSG-068 NETN was chaired by the NATO Joint Warfare Centre and had participants from ACT, Joint Forces Training Centre (JFTC), NATO Consultancy, Command and Control Agency (NC3A), and 13 nations (Australia, Bulgaria, France, Germany, Hungary, Netherlands, Romania, Slovenia, Spain, Sweden, Turkey, U.K., and the U.S.). MSG-068 assessed the distributed simulation and learning capabilities that could contribute to the development of an NETN capability. The Task Group (TG) recommended and demonstrated a way forward for interoperability, technical standards and architectures to link these training and education centres to provide a persistent capability, and also identified and recommended roles and responsibilities of NATO and nations within the scope of NETN.

5.1 NETN Reference Architecture

The NETN Reference Federation Architecture comprises the fundamental deliverable of MSG-068 because it is a key contributor to integrating national systems. This reference federation architecture is intentionally generic in order that it might be used for live virtual constructive and multi resolution federations at any level. MSG-068 developed, tested, and made recommendations regarding an HLA based Reference Federation Agreements and Federation Design document (FAFD), and Federation Object Model (FOM).

These documents were delivered as part of the final report of MSG-068 [10] and will be placed under custodianship of MS3. The extensions to the HLA data model will be submitted to SISO for general standardisation as part of a new modular reference FOM. These extensions are an example of a new basic design pattern for modelling request, negotiation, and delivery of services (figure 5). The Service Consumer-Provider Pattern defines two types of entities: Service Consumer Entities and Service Provider Entities. Federates that model these entities are called Service Consumer Federates and Service Provider Federates, respectively. If these entities are modelled in different federates, the interactions will be published and subscribed using HLA services.

MSG-068 also defined an NETN Logistics FOM Module, which is based on the Service Consumer-Provider Pattern with extensions to support specific logistics services for Supplies, Repair, Deposit, and Transport.

5.2 NETN Experimentation

MSG-068 recommendations were tested and validated in a standalone distributed experimentation event between October 25 and November 5, 2010, and at I/ITSEC 2010 (figure 6).

A large number of nations (Bulgaria, France, Germany, Hungary, the Netherlands, Spain, Sweden, Turkey, the U.K., and the U.S.) and five NATO Headquarters (HQ)/organisations (HQ-Supreme Allied Commander Transformation (SACT), Joint Warfare Centre (JWC), Joint Force Training Centre (JFTC), NATO Consultation, Command, and Control Agengy (NC3A), and M&S Center of Excellence (CoE)) joined the experiment from one of 5 different locations (Bydgoszcz, Paris, Ottobrunn, Porton Down, and The Hague).

Figure 6: Demonstration of NETN at I/ITSEC 2010

The network infrastructure was based on the Combined Federated Battle Laboratories Network (CFBLNet). This backbone provides a secure and managed intranet over a bearer network, such as, NATO General Purpose Segment Communication System (NGCS), the Internet, leased lines, etc. CFBLNet architecture allows creating enclaves (a virtual private network within CFBLNet) with various classification levels up to NATO Secret. An enclave can have only a single level of security classification at a time. However, the security classification of an enclave can be changed from one event to the other. The CFBLNet was recommended by MSG-068 as the backbone for the persistent infrastructure.

5.3 NETN Future Work

The MSG-068 group identified additional IEEE 1516-2010 features that the team was unable to implement

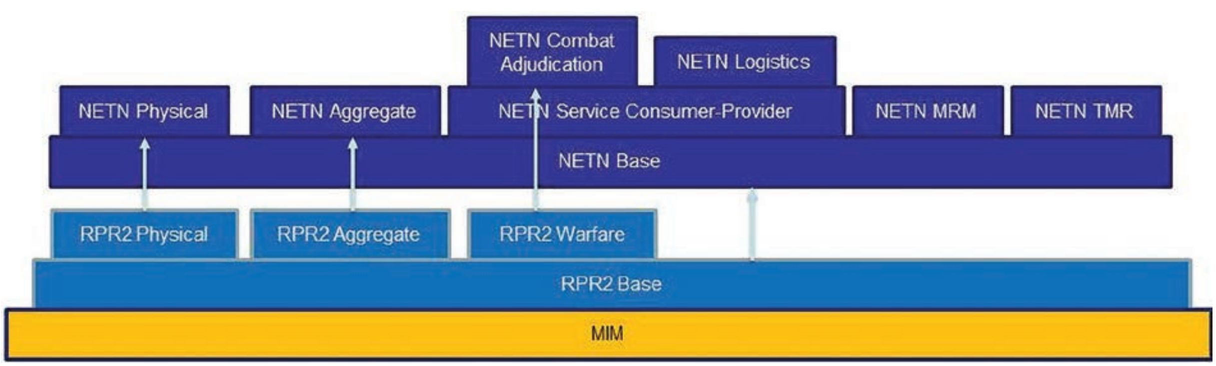

Figure 5: NETN Modular FOM

and test due to time constraints. The recommendations include future development and testing of smart update rate reduction, fault tolerance, Data Distribution Services as an enabler of scalability, web services, and modularization of the RPR2 FOM Module itself to increase efficiency and flexibility. Several proposals for further improvement were made in the area of combat adjudication services and research related to transfer of control and Federation Execution Control and Monitoring. These activities will be addressed by a new Task Group - MSG-106 (Enhanced CAX Architecture, Design, and Methodology (nicknamed SPHINX)). The MSG-106 will focus not only on the technical aspects and development of further FOM modules, including a C-BML module, but also address the procedural and governance issues in using the reference architecture for computer assisted exercises (CAX). This will result in a "Handbook" for organizing and conducting multinational distributed CAX.

MSG-106 is organized in three subgroups OPS (Operational), TEK (Technical), and GOV (Governance) with the following objectives:

1. Provide guidelines for exercise control and simulation control (EXCON and SIMCON) in performing CAX.
2. Update the MSG-068 reference federation architecture and HLA FOM design document (FAFD) to improve and extend it based on tested technical solutions.
3. Governance of the MSG-106 products for:
   a. Recommendations for the governance and maintenance of products;
   b. Standardisation, dissemination, quality assurance, risk management;
   c. Coordination and collaboration with external bodies.

The MSG-106 Task Group started in 2012 and will complete its work in 2015. The HLA data model (FOM) will be submitted to SISO through the NMSG for formal standardisation.

6. CBML and MSDL

During the last decade, considerable progress has been made in establishing interoperability-enabling standards in both the Command and Control (C2) domain through the work of the Multilateral Interoperability Programme (MIP), and within the M&S community through the efforts of SISO.

The interoperation between command & control information systems (C2IS) and simulation systems is a common theme in the transformation of modern military forces. This is required to support the military enterprise in the execution of business activities and mission threads, such as operational training, information sharing, and decision support. This implies the ability to seamlessly integrate C2IS and simulation systems and to provide the means for a meaningful and unambiguous information exchange. This applies to systems of systems functioning toward a common goal at different levels: (1) within services, (2) across services (i.e., joint), and (3) across nations in a multinational or coalition context.

Enabling such information exchange in a timely, efficient, and cost-effective manner requires standardized language and interfaces that allow C2 and simulation systems to interoperate. C-BML is being developed by SISO for this purpose [11]-[14], [17].

C-BML defines a digitized form of C2 information such as orders, plans, reports, and requests. In a digitized format, C2 information can be processed readily by C2 systems, simulation systems, or interfaces to automated forces (i.e., robotic systems) – as depicted in figure 7.

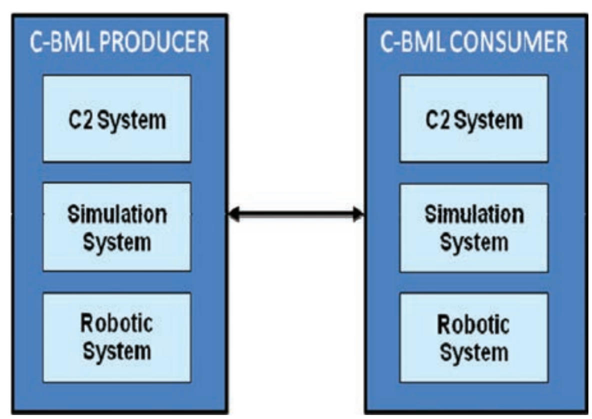

Figure 7: C-BML Producers/Consumers

Based on the set of possible C-BML producer/consumer relationships, figure 8 presents a view of the various areas of interoperability that were considered during C-BML development.

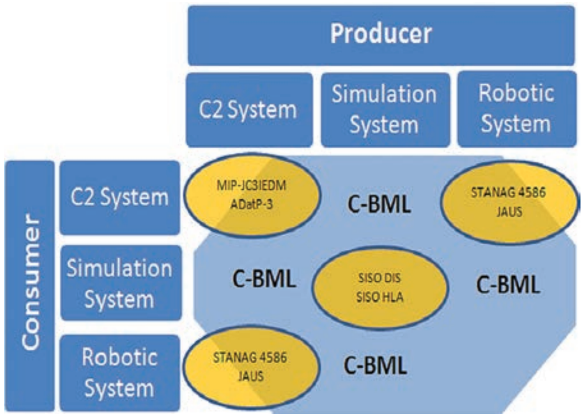

Figure 8: C-BML Producers/Consumers Matrix

The fundamental building blocks of C-BML are often referred to as the five W's (*Who, What, When, Where,* and *Why*). They are relatively well represented in the Joint Consultation Command and Control Information Exchange Data Model (JC3IEDM).

Use-case scenarios involving information exchange across C2IS and simulation systems often require a pre-requisite initialization of all systems that is consistent with existing operational and/or simulation databases. This currently represents a significant obstacle to C2-simulation interoperation. The Military Scenario Definition Language (MSDL) has been developed as a standard by SISO for the initialization of simulation systems to enable C2IS-simulation interoperation. It was approved by SISO in 2008 [15], [16], [18].

The NMSG focuses on the operational use of C-BML and MSDL in support of military enterprise activities. It facilitates the standardisation of C-BML by providing recommendations to the standardisation bodies and the guidelines for MSDL/C-BML alignment for simulation initialization.

6.1 C-BML and MSDL Convergence

C-BML is an unambiguous standardized representation of military information such as orders, plans, reports, and requests based on an operations-centric common reference model JC3IEDM, developed by MIP. C-BML expressions are a digitized form of C2 information that readily can be disseminated to C2IS, simulation or autonomous system interfaces where it can be processed. C-BML is particularly relevant in a network-centric approach for enabling mutual understanding, to allow for preparing, rehearsing, and executing missions—as well as commander & staff training—in a multinational and collaborative environment.

MSDL provides a set of XML-based scenario information at one instance in time. It is intended to provide a standard mechanism for processing military scenarios primarily for the purposes of simulation initialization. MSDL also may be utilized as a means to capture a snapshot of a situation at a given time during scenario execution for subsequent analysis, review, and debrief activities. The friendly and enemy tasking or Course of Action (COA) is also part of the scenario definition. However, tasking is within the scope of the C-BML standard. Conversely, using C-BML to execute tasking requires references to initial task organisation and unit/material status that can be specified using MSDL. Therefore, C-BML and MSDL are two mutually dependent standards.

Within SISO, the MSDL and C-BML Product Development Groups are collaborating on defining common elements and applying a consistent structure and style to these two standards to ensure they can be applied in concert with one another.

The main idea is not to merge both standards into one, but rather to define a common core such that each standard can include and reference core elements and subsequently, benefit from each other. Therefore, the main work in progress is to express operational requirements in a common shared manner.

6.2 The MSG-085 Technical Activity

The MSG-085 Technical Activity started in June 2010 and has over thirty participants representing thirteen nations. It has been formed to assess the operational relevance of C-BML while contributing to C2-Simulation standardisation, and assist in increasing the Technical Readiness Level of C-BML technology to a level consistent with operational employment by stakeholders. MSG-085 follows on from a previous task group MSG-048, which initiated the C-BML implementation and exploitation within NATO nations, as well as informed the development of the emerging standard.

6.3 MSG-085 Objectives

The principal high-level objectives of the MSG-085 (represented graphically in figure 9) are as follows:

- Define the scope, operational, and technical requirements for C-BML;
- Establish a set of reference expressions based on NATO operational procedures;
- Assess and leverage available C-BML implementations;
- Address C2IS and Simulation Initialization Requirements;
- Demonstrate and communicate the Operational Relevance and Benefits of C-BML for improving the efficiency of military operations.

The primary objective of MSG-085 is to clarify the C-BML scope and requirements. The scope of C-BML is defined and prioritized in the form of a set of operational use-cases that are based on the relevant operations procedures, such as the NATO Allied Procedural Publication (APP) 11 (NATO Message Catalogue) or NATO Standardisation Agreement (STANAG) 2014. From these use-cases, technical requirements are derived, analysed, and captured in a formal specification that can serve as the basis for standards development and system development, while ensuring that relevant identified use-cases are satisfied.

The second objective is to reach a consensus regarding the way to produce a set of digitized expressions, such as the operations order (OPORD) and plan (OPLAN). In addition to the NATO OPORD, other orders such as the Fragmentary Order (FRAGO), the Warning Order (WARNO), the Air Tasking Order (ATO), and Air Coordination Order (ACO) form a common reference set of expressions that includes reports such as Intelligence summary reports (INTSUMREP), Enemy Situation Reports (ENSITREP), Battle Damage Assessment (BDA), Task Status Report (TASKSTAT), etc. This set of expressions represents a minimum, but does not preclude the construction of other expressions to fulfil requirements specific to national systems and procedures.

The third objective is to assess and leverage available SISO C-BML implementations. A C-BML implementation is a software infrastructure consisting of communication services allowing for the manipulation of C-BML expressions packaged in C-BML messages, or payloads, and exchanged across a given network. These services include: message validation, dissemination, acknowledgement, storage, search, and notification. The assessment considers a range of criteria consistent with given coalition application domains. The assessment requires the establishment of a set of evaluation criteria and test-cases.

The fourth objective is to address C2 and simulation system initialization requirements, including the complementary use of SISO MSDL with C-BML for simulation initialization. When initiating an exercise involving C2IS and simulation systems, it is necessary for these systems to operate in a consistent and coherent manner. In addition to force structures and initial position and status, the synthetic environment and operational databases often need to reflect other elements comprising the military scenario that is shared across the operational and simulated domains. In some instances, a shared, common data format such as the one proposed by MSDL may be sufficient. In other situations, additional elements may be required to ensure that the requisite pre-conditions are satisfied before proceeding with the exchange of messages. Currently, there is no generalized procedure for initializing C2IS with the equivalent of those information elements found in an MSDL document.

The fifth objective deals with the operational aspects related to the utilization of C-BML for military applications, such as decision support, mission planning, mission rehearsal, commander and staff training, after-action review, etc. In this context, C2-to-C2 interoperation is generally based on the operational use of C2 protocols. Therefore, the MSG-085 has to demonstrate how C-BML complements the current C2 standards and improves the military efficiency as related to the use of these applications. This includes revisiting and establishing relevant procedures for each application domain in order to assist the military community in adopting C-BML and MSDL. This objective entails demonstrating the operational benefits to the stakeholders through several experiments leading up to a final operational experimentation event with operational users in the loop.

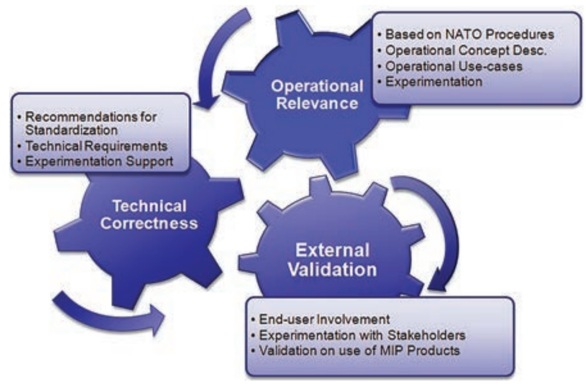

Figure 9: C-BML Relevance, Correctness, and Validation

6.4 MSG-085 Experimentation

The MSG-085 Experimentation Programme is a key component to the Technical Activity. The goal is to establish a capability that can be deployed in the medium-term that will improve NATO Forces effectiveness. In order to be more efficient, MSG-085 is divided into Common Interest Groups (CIGs) that provide dedicated work in different C2-simulation interoperation technical and operational areas. The CIGs include participation from both the Operational Sub-Group (OSG) and the Technical Sub-Group (TSG), as shown in figure 10.

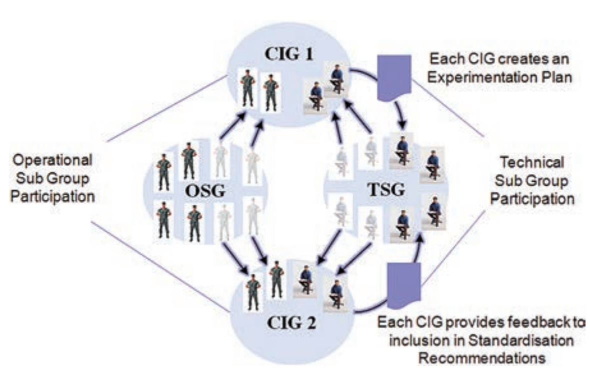

Figure 10: MSG-085 CIG Approach

CIG themes being addressed by MSG-085 include the use of C-BML simulated command agents (NLD, NOR), the development of a formal expression for exchanging military information (DEU, USA), autonomous air OPS (CAN, GBR, USA) for capability development, Maritime OPS (CAN, DEU, NOR, TUR), Land OPS (DEN, DEU, ESP, FRA, NLD), Joint Mission Planning (GBR, USA) for support to operations and MSDL/C-BML infrastructure (GBR, SWE, USA) for C2, and simulation systems initialization (see figure 11).

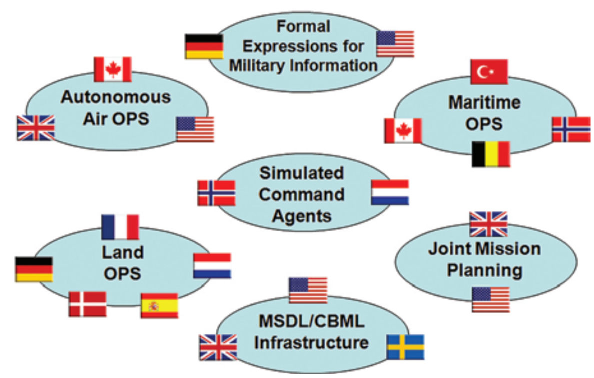

Figure 11: MSG-085 Common Interest Groups

Figure 12 shows a view on the German (Fraunhofer-FKIE) surrogate C2 system C2LGGUI, as used in the CIG Land OPS. On the left hand side part of the C-BML unambiguous machine interpretable expression is shown, and on the right hand side the corresponding C2 overlay.

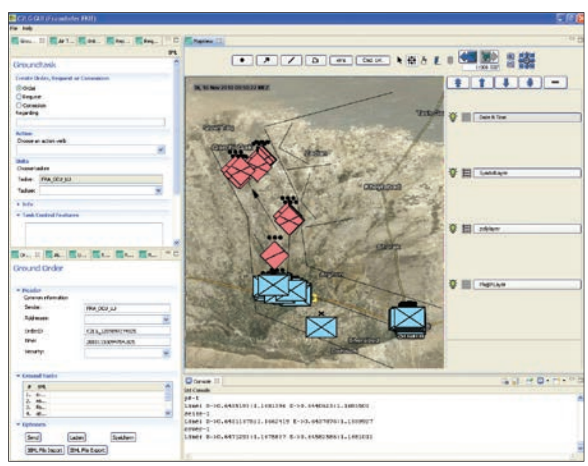

Figure 12: View of Example C-BML Editor

As a result of the CIG efforts, an Initial Operational Prototype (IOP) will be developed for 2013. It will consist of participating nations' contributions that will be federated leveraging C-BML and MSDL, standard-based implementations, infrastructure, and supporting tools. The experimentation will assess IOP robustness for the benefit of NATO stakeholders such as the NATO Joint

Warfare Centre (JWC), the NATO Joint Forces Training Centre (JFTC), NETN, and related projects such as the Multi-sensor Aerospace-ground Joint ISR Interoperability Coalition (MAJIIC) project. The NATO MSG-106 Task Group will directly benefit from the IOP by using the knowledge, standards, and tools becoming available within MSG-085, including the development of the C-BML HLA FOM module.

Furthermore, part or all of the IOP may endure beyond the MSG-085 Technical Activity, and thus forms the basis for further experimentation and development by the nations.

7. GM-VV

GM-VV provides a generic framework to efficiently develop verification and validation (V&V) solutions for models and simulations, to assess whether they are acceptable for a specific context of use. The GM-VV is currently following the SISO standardisation process through the GM-VV product development group (PDG) [19], [20]. NATO initiated the MSG-073 Task Group to support the standardisation process of GM-VV. One of the main objectives of this activity is to include the balloted SISO standard within the NATO M&S Standards Profile.

Which V&V solution works best in a given situation depends on the individual needs and constraints of an M&S organisation, project, application domain, or technology. However, common principles and best practices are clearly recognizable between existing V&V solutions, and this was the key driver behind the development of the GM-VV. The GM-VV provides a general baseline and guidance for V&V of M&S that is tailorable towards individual needs of a wide variety of M&S organisations, projects, technologies, and application domains.

7.1 GM-VV Framework

The GM-VV comprises an abstract framework that consists of three parts (the Conceptual Framework, the Implementation Framework, and the Tailoring Framework) that build upon existing V&V methods and practices.

The GM-VV *conceptual framework* provides essential V&V terminology, semantics, concepts, and principles. This framework facilitates communication, understanding, and implementation of V&V across and between different M&S contexts. The GM-VV implementation framework translates these concepts and principles into a set of generic building blocks to develop consistent V&V solutions.

The *implementation framework* consists of the interrelated products, processes, and organisation. The product dimension contains information-based V&V products that can have multiple instances, representational, and documentation formats. These V&V products are produced by the processes, activities, and tasks defined by the process dimension. They can be executed recursively, concurrently, and iteratively. The roles defined in the organisation dimension are involved in the execution in one or more of the V&V processes, activities, and tasks.

The GM-VV *tailoring framework* provides ways to tailor the aforementioned implementation framework for each individual M&S organisation, project, or application domain. The tailoring framework supports modification of the building blocks in the GM-VV product, process, and organisation dimensions to satisfy the specific V&V needs and constraints in the M&S environment in which the GM-VV is applied. Risk-based tailoring is applied during the execution of the V&V work. This form of tailoring identifies and analyses the M&S use risks, and aims to address these risks by guiding the V&V work towards the level of risk of each identified risk item. As such, risk based tailoring is used to find optimum cost-benefit-ratio (e.g., distributing project resources based on M&S use-risk) of the V&V work itself.

7.2 GM-VV Argumentation Approach

The objective of V&V is to develop a body of evidence upon which an acceptance recommendation can be based. This objective is articulated by GM-VV as an acceptance goal. This high-level goal should be translated into a set of concrete and assessable acceptability criteria for the M&S system or result(s). This part is called the Goal Network. Relevant and convincing evidence should then be collected or generated to assess the satisfaction of these criteria.

When it is convincingly demonstrated to what extent the M&S system or result(s) does or does not satisfy all of these acceptability criteria, a claim can be made on whether or not the M&S system or result(s) is acceptable for its intended use (i.e., acceptance claim). This is the Claim Network. The acceptance claim with the underlying evidence is used to construct the acceptance recommendation for the M&S system or result(s).

Developing an acceptance recommendation usually involves the identification of many interdependent acceptability criteria. Collecting the appropriate evidence is not always straight-forward, or even possible due to various practical constraints (e.g., budget, time, and availability). Therefore, the acceptability criteria and evidence underlying an acceptance recommendation should be developed in a structured manner using a format where the reasoning is traceable, reproducible, and auditable. The GM-VV argumentation structure approach provides a systematic approach to deriving such relevant acceptability criteria and evidence (figure 13).

8. Conclusion And Road Ahead

NATO is an alliance of many nations and organisations each bringing their own legacy systems, procedures, etc. Successful cooperation depends on achieving and continuously improving interoperability at all levels. Standards for interoperability are a crucial step towards this goal. Considering the large number of M&S standards and guidance documents identified in AMSP-01 it is tempting to declare that the situation is rather satisfactory for the simulation domain. Unfortunately, there are some observations that temper this conclusion. A quick assessment shows that there are overlapping standards in some specific areas and some obvious gaps in other areas. Where there are too many "standards" in support of a particular domain it means there is "no real standard." but sometimes many competing technologies or methodologies. Where gaps or unnecessary overlaps are identified, there is a need for NMSG to cooperate with the M&S community and, in particular with SISO, to fill the major gaps and align overlapping standards.

A second observation is that even where standards do exist, they must be maintained and endorsed by NATO and national organisations. The AMSP-01 is a suitable guideline document for the relevant M&S standards that should be used in development projects and procurement projects. The profile needs to be widely disseminated by NMSG and accepted by the nations.

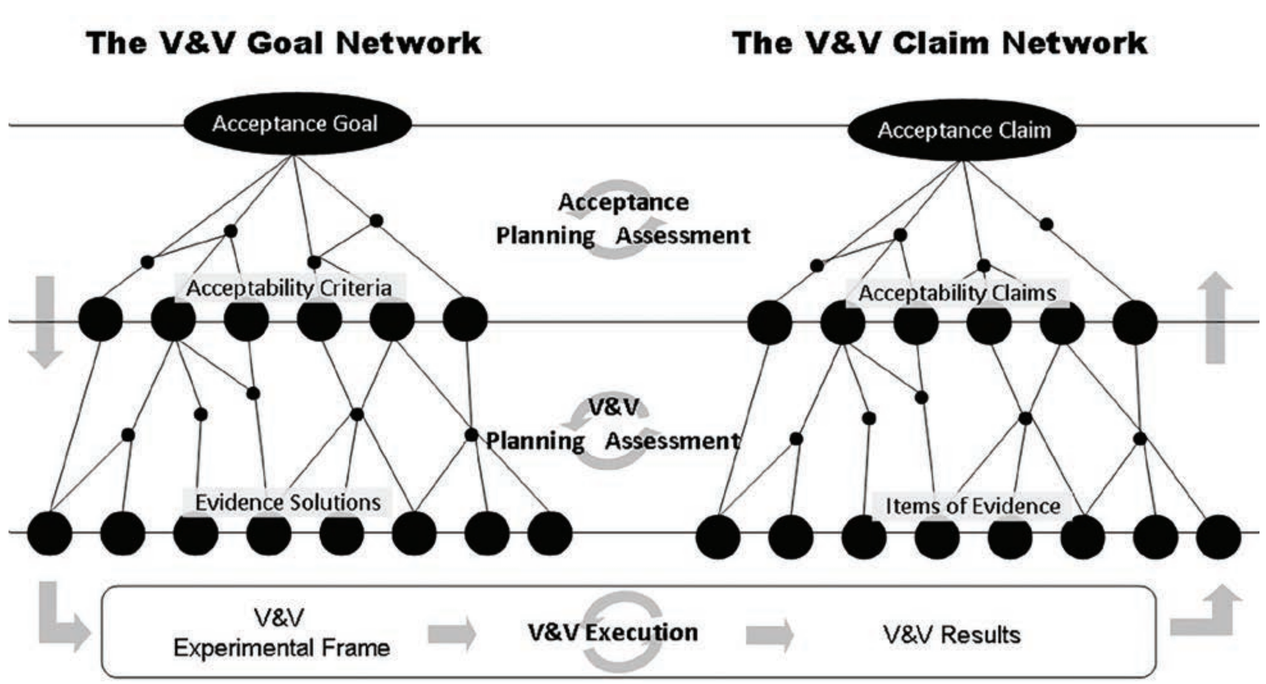

Figure 13: Argumentation Structure Consisting of a Goal (Left) and a Claim (Right) Network

8.1 Conclusion

Given the continuously evolving nature of M&S standards and processes, timely updates and review of the standards and of the AMSP-01 as a guidance document is required.

> There are accepted benefits to identifying and using common open standards, recognizing that due to breadth of application of M&S there is no "one size fits all."

The guidelines and standards that have been developed and tested within an international context of NMSG and SISO should be applied nationally whenever possible. The improved quality and increased interoperability of international standards outweigh the possibly added time needed to reach consensus.

> Nations and Organizations should actively contribute to developing open standards.

Profile documents (e.g., AMSP-01) maintained by M&S experts, rather than formal STANAGS, meet the need to be more responsive with regard to guidelines and best-practices. A profile can include emerging standards and encourage their use before the standards have been fully completed. This acknowledges the fact that technology is evolving. Gaps still exist within current standards development regarding certain functional areas of M&S, and some gaps exist within current standards regarding breadth of application in a functional area. International experts groups like NMSG and SISO are crucial in identifying these gaps and initiating activities to address them.

8.2 Road ahead

NATO organisations, member and partner nations, are encouraged to contribute additional standards for consideration, and consider active participation in the MS3 subgroup. The NMSG actively solicits support of standards development organisations to address gap issues.

Requirements are sometimes specific to a particular community of interest, such as Tactical Data Link domain or the Virtual Ship effort; those communities are encouraged to draft their own standards as required and publish them to contribute to the M&S body of knowledge. These domain specific solutions should strive to use or build on existing solutions as much as possible. HLA and DSEEP for example, are explicitly intended to tailor to a particular domain.

The NMSG is very active in investigating the need for new or improved standards, evaluating proposals, and in some cases, developing new standards for M&S interoperability. The examples discussed in this article (NETN, C-BML, and GM-VV) represent those activities. Specific efforts will be made by the NMSG and nations to encourage focus on identified gap areas like, human behaviour modelling and scenario definition languages.

M&S interoperability is a primary concern of NATO, and efforts have to be maintained to improve the current situation of overlapping standards and to make progress towards meeting the challenge of substantive interoperability. The formal relationship between NMSG and SISO is very beneficial in maintaining a close cooperation with the international M&S community and will continue and increase where possible.

Acknowledgments

The authors would like to acknowledge the contributions of the NMSG members. Special thanks are due to the MS3 group and the members of Task Groups MSG-048, MSG-068, MSG-073, MSG-084, MSG-085, and MSG-106 for the ideas and results that are presented in this paper.

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Authors' Biographies

Mr. Wim Huiskamp

Mr. Wim Huiskamp is chief scientist modelling, simulation, and gaming in the M&S department at TNO Defence, Security, and Safety in the Netherlands. He received an M.Sc. degree in electrical engineering from Twente University of Technology, The Netherlands. His research areas include system architecture, distributed real-time simulation, and C2-Simulation interoperability problems. Wim acted as project lead for several national and international simulation (interoperability) projects and he leads TNO's research programme on Live, Virtual, and Constructive Simulation, which is carried out on behalf of the Dutch MoD. Wim is a member of the NATO Modelling and Simulation Group (NMSG) and acted as member and chairman in several NMSG Technical Working groups. He is currently Chairman of the NMSG, former Chairman of the NMSG M&S Standards Subgroup (MS3) and he is the liaison of the NMSG to the Simulation Interoperability Standards Organization (SISO).

Mr. Adrian Voiculet

Mr. Adrian Voiculet is a technical officer in the Modelling and Simulation Coordination Office (MSCO) at NATO Science and Technology Collaboration Support Office (CSO), Neuilly-sur-Seine, France. He received a M.Sc. degree in Electronics and Antiaircraft Missile Systems from the Military Technical Academy, Bucharest, Romania. He served in staff appointments in ROU Air Force and Military Technologies Research Centre; and as ROU Voluntary National Contribution, Help Desk Officer at the MSCO. Upon retiring from the Armed Forces (2009) he joined the NATO MSCO - in charge of standardisation in NATO M&S domain, reuse of simulation resources, and support to the NMSG. Adrian is currently the secretary of the MS3, admin of the NATO Simulation Resource Library (NSRL), and liaison officer with NATO Standardization Agency (NSA).

Dr. Erdal Cayirci

Dr. Erdal Cayirci graduated from Army Academy in 1986 and from Royal Military Academy, Sandhurst in 1989. He received his M.S. degree from Middle East Technical University, and a Ph.D. from Bogazici University both in computer engineering in 1995 and 2000, respectively. He retired from the Army when he was a colonel in 2005. He was an associate professor at Istanbul Technical University, Yeditepe University and Naval Sciences and Engineering Institute between 2001 and 2005. Also in 2001, he was a visiting researcher for the Broadband and Wireless Networking Laboratory and a visiting lecturer at the School of Electrical and Computer Engineering, Georgia Institute of Technology. He is currently Head, CAX Support Branch in NATO's Joint Warfare Center in Stavanger, Norway, and also a professor in the Electrical and Computer Engineering Department of University of Stavanger. His research interests include modelling and simulation, cloud computing, wireless sensor networks, and mobile communications.

Mr. Björn Löfstrand

Mr. Björn Löfstrand is the services and training manager at Pitch Technologies. He holds an M.Sc. in computer science from Linköping Institute of Technology (Sweden) and has been working with HLA federation development and tool support since 1996. He was the technical lead for the MSG-068 FOM and Federation Design (FAFD) work and is co-leading the technical subgroup of MSG-106.

Mr. Bharat Patel

Mr. Bharat Patel is a senior capability advisor and international research leader in the Defence Science and Technology Laboratory (Dstl), part of the UK MoD. He provides strategic direction to MOD's simulation, training and evaluation, programmes, and impartial scientific and technical advice to NATO, MOD, DE&S, and the UK Forces. He holds a B.Sc. (Eng) from University of London and an M.Sc. from Royal Military College of Science. He has been working in modelling simulation and distributed synthetic environments for approximately 20 years. He has been the UK lead for the US/UK Synthetic Theatre of War programme (a key programme for HLA and CGF development), and the DERA Assistant Director Simulation and Synthetic Environments. He also has several years experience in Defence Procurement and MODHQ as well as industry and academic research background in aerospace engineering and aerodynamics/CFD.

Authors' Biographies (Continued)

Mr. Lionel Khimeche

Mr. Lionel Khimeche is an R&T program manager in the field of M&S for planning and forces readiness at the DGA (Direction Générale pour l'Armement)/Center for Defense Analysis. His main topic of research deals with C4I-Simulation Interoperability, mission training via distributed simulation and embedded training. He co-chairs the NATO Technical Activity on C-BML and he leads several international projects for cooperation.

Dr. Kevin Heffner

Dr. Kevin Heffner holds a B.S. in engineering from the State University of NY at Buffalo and a Ph.D. from University of Paris VI. He has worked in the field of modelling and simulation for over 20 years. His work includes applying model-centric concepts to flight simulator architectures and interoperability among C2, simulation, and automated forces, including Unmanned Aircraft Systems.

Mr. Nico de Reus

Mr. Nico de Reus is a member of the scientific staff in the M&S department in the Defence, Security, and Safety Division in the Netherland's TNO. His work focuses on the application of Modelling & Simulation in mainly the military domain, and on mathematical modelling for other domains. He has a background in applied mathematics and received a M.Sc. degree in applied mathematics at Delft University of Technology, the Netherlands.

Mr. Jean-Louis Igarza

Mr. Jean-Louis Igarza retired from the French MoD in 2010, after 41 years of activity, mainly for DGA (General Directorate for Armament). He is now supporting the "Antycip Simulation" company as a consultant. Formerly chief scientist of the NATO MSCO for three years, he has been an NMSG member since 2003 and chaired it from May 2006 to May 2008. He is now one of the few Members at Large of the NMSG representing France. The main part of his career in DGA was in the Operational Analysis (air domain) then in M&S. He taught M&S at the University of Versailles as an associate professor for ten years.

He is presently an elected member of the SISO Executive Committee (the unique non-US member) and chairs the GM-VV Product Development Group of SISO. He is a founding member of ETSA (the European Training and Simulation Association) and the vice-chairman of the ETSA Board of Directors.

Dr. Jeroen Voogd

Dr. Jeroen Voogd is a member of the scientific staff in the Defence, Security, and Safety Division at TNO. He holds a Ph.D. (1998) in computational physics from the University of Amsterdam in the field of modelling and simulating of biophysical systems on parallel and distributed computing platforms. A recurring theme in his work of the last years is the quality of simulations. This includes V&V of simulator assets, as well as quality assurance within TNO.

Dr. Manfred Roza

Dr. Manfred Roza is a senior R&D engineer in the Training, Simulation, and Human Factors department of the National Aerospace Laboratory - NLR. He holds a Ph.D. (2005) in aerospace engineering from the Delft University of Technology in the field of simulation fidelity, verification and validation. Currently, he is the SISO drafting group editor for the GM-VV and technical lead for the Dutch V&V expertise centre - Q-tility.

Mr. Niels Krarup-Hansen

Mr. Niels Krarup-Hansen is senior advisor working for the Danish Defence. He has a M.Sc. in operations research from Denmarks Technical University and attended Senior Course at NATO Defense College. His work included high level defence planning, membership of many NATO and WEAG groups, ex-chairman of NMSG, and acquisition of M&S systems.

Connected Training Initiative: The L-V-C World Cup

AUTHORS

Colonel (U.S. Army) John G. Norris
Hohenfels, Germany,
Commander Operations Group,
Joint Multinational Readiness Center

Colonel (U.S. Army) Joseph G. Patterson
Hohenfels, Germany,
Senior Intelligence Officer,
Joint Multinational Readiness Center

ABSTRACT

THIS ARTICLE COVERS VARIOUS ASPECTS OF THE U.S. ARMY EUROPE EFFORT TO EXTEND LIVE, VIRTUAL, AND CONSTRUCTIVE (L-V-C) TRAINING CAPABILITIES TO REMOTE LOCATIONS. THE EFFORT IS KNOWN AS THE CONNECTED TRAINING INITIATIVE (CTI). THE ARTICLE CONTAINS BACKGROUND MATERIAL ON THE DEVELOPMENT OF DISTRIBUTED TRAINING, THE RATIONALE FOR THE CTI EFFORT, AND A DESCRIPTION OF AVAILABLE SYSTEMS. THE ARTICLE CONCLUDES WITH A DISCUSSION OF CURRENT SHORTFALLS AND CHALLENGES IN THE LVC SIMULATION ENVIRONMENT.

Introduction

Whether you start with the Prussian's development of Kriegsspiel war gaming or Defense Advanced Research Projects Agency's (DARPA) early efforts with Simulation Network (SIMNET) distributed interactive simulations, there has long been a desire by military organizations to provide capabilities for the use of theater level strategy and training. The purpose of this article is not to present a history of distributed simulations, but rather to use some historical references to introduce a current concept that provides multi-national simultaneous training by connecting various Combat Training Centers (CTC) through a strategic vision called the Connected Training Initiative (CTI). The baseline capabilities that enable the CTI are provided by the Joint Multinational Readiness Center (JMRC) in Hohenfels, Germany. The article's focus then shifts to the essential components of JMRC's Mobile Instrumentation System (MIS) that enables the CTI Live, Virtual, and Constructive (L-V-C) training environment. These components include the instrumentation system, distributed simulation network, cloud infrastructure, virtual systems, battle command networks, and command and control interoperability. The article will close with a discussion of some of the significant challenges that bears on the CTI.

Readers with long experience in the development of L-V-C will see that today's JMRC technologies and techniques were originally developed by a couple of key events led by the DARPA. In 1990, DARPA employed The MITRE Corporation to study the application of distributed interactive simulation principles employed in the SIMNET to aggregate-level constructive training simulations. Based on prototype efforts, a community-based experiment was conducted in 1991 to extend SIMNET to link the U.S. Army's Corps Battle Simulation (CBS) and the U.S. Air Force's Air Warfare Simulation (AWSIM). The success of the prototype and users' recognition of the value of this technology to the training community led to development of production software. The first Aggregate Level Simulation Protocol (ALSP) confederation, providing air-ground interactions between CBS and AWSIM, supported three major exercises in 1992 [1].

On the heels of SIMNET came The Synthetic Theater of War - Europe (STOW-E) project. STOW-E was co-sponsored by DARPA, the Defense Modeling and Simulation Office (DMSO), and the U.S. Army Europe, 7th Army Training Command, Grafenwoehr, Germany, with supporting U.S. Navy and Air Force participation. The focus of STOW-E was the integration of L-V-C simulations, and culminated with ATLANTIC RESOLVE 94, a joint service training exercise [2].

The specific goal of STOW-E, from the U.S. Army perspective, was to provide an interim capability to support training by using existing virtual world simulators, constructive model simulations, and instrumented vehicles. The use of Distributed Interactive Simulation (DIS) protocols, interface capabilities, and the Defense Simulation Internet (DSI) provided operational commanders an opportunity to train with fewer "work-a-rounds" normally associated with previous efforts to manually link such systems [2].

Over the following 20 years significant strides in instrumentation and simulation interoperability have resulted in an ability to provide the L-V-C training that is found at today's U.S. Army CTC's. This capability has, in turn, been emulated by many coalition partners. While the focus for JMRC and CTI are the current North Atlantic Treaty Organization (NATO) member nations and partners, the concept could be promulgated in other theaters.

Connected Forces Initiative

In the near future, NATO will shift its emphasis from operational engagement to operational preparedness. This requires NATO participants to remain capable of performing core tasks – described in the Strategic Concept. Numerous programs are in place to help achieve this, with the goals set out in the plan for "NATO Forces 2020." The Connected Forces Initiative (CFI) presented by NATO Secretary General Anders Fogh Rasmussen at the 2012 Munich Security Conference, will help maintain NATO's readiness and combat effectiveness through expanded education and training, increased exercises, and improved use of technology.

After the end of current obligations like Afghanistan, the CFI will guide the sustainment of NATO forces and build on the Alliance's experience to ensure that Allies can work together effectively and with coalition partners.

The main requirements of CFI are to ensure that Allies are interoperable and can communicate, train and operate together effectively. The NATO Response Force (NRF) also plays an important role in this context by providing a vehicle both to demonstrate operational readiness, and serve as a "test bed" for Alliance transformation [3].

Connected Training Initiative: USAREUR's support to NATO and the CFI

"Combat training center capacity provides a platform to conduct multinational exercises that improve understanding, interoperability, and trust between the U.S. and regional partners" [4].

U.S. Army Europe (USAREUR) trains U.S. and partner (allied) forces at its CTC, the Joint Multinational Training Command (JMTC). Currently, JMTC trains individual Soldiers and units to brigade level in exercises that blend live, virtual, and constructive events. At the division level and 3-Star headquarters, JMTC events focus on using the virtual and constructive realms. Current technology enables JMTC, in the constructive realm, to conduct exercises that integrate allied forces based in various nations around the world. This has already been demonstrated in numerous named regional exercises like Saber Strike, Saber Guardian, and Saber Junction. To date, USAREUR has never attempted to conduct a simultaneous, live exercise that is distributed across partner CTC's throughout Europe. The capability exists and now is the time to explore this connected training opportunity as we pursue efforts to sustain multinational partnerships, interoperability, and fulfill the intent defined in the CFI.

A majority of U.S. European Command's (EUCOM) and USAREUR's partner nations have developed their own Combat Training Centers over the years and are now fully operational and capable (FOC) with live, virtual, and constructive capabilities. Although limited in size and capability, they are modeled and equipped similar to JMTC. Figure 1 depicts a generic example of how the training centers that USAREUR routinely supports would be connected. These FOC CTCs are also an excellent example of regional cost savings for any future training event where many nations can now train in their home nation or a neighboring country; limiting the cost associated with travel and shipment of large pieces of military equipment. Partnered nations can train in their home country while still being connected simultaneously in an L-V-C environment.

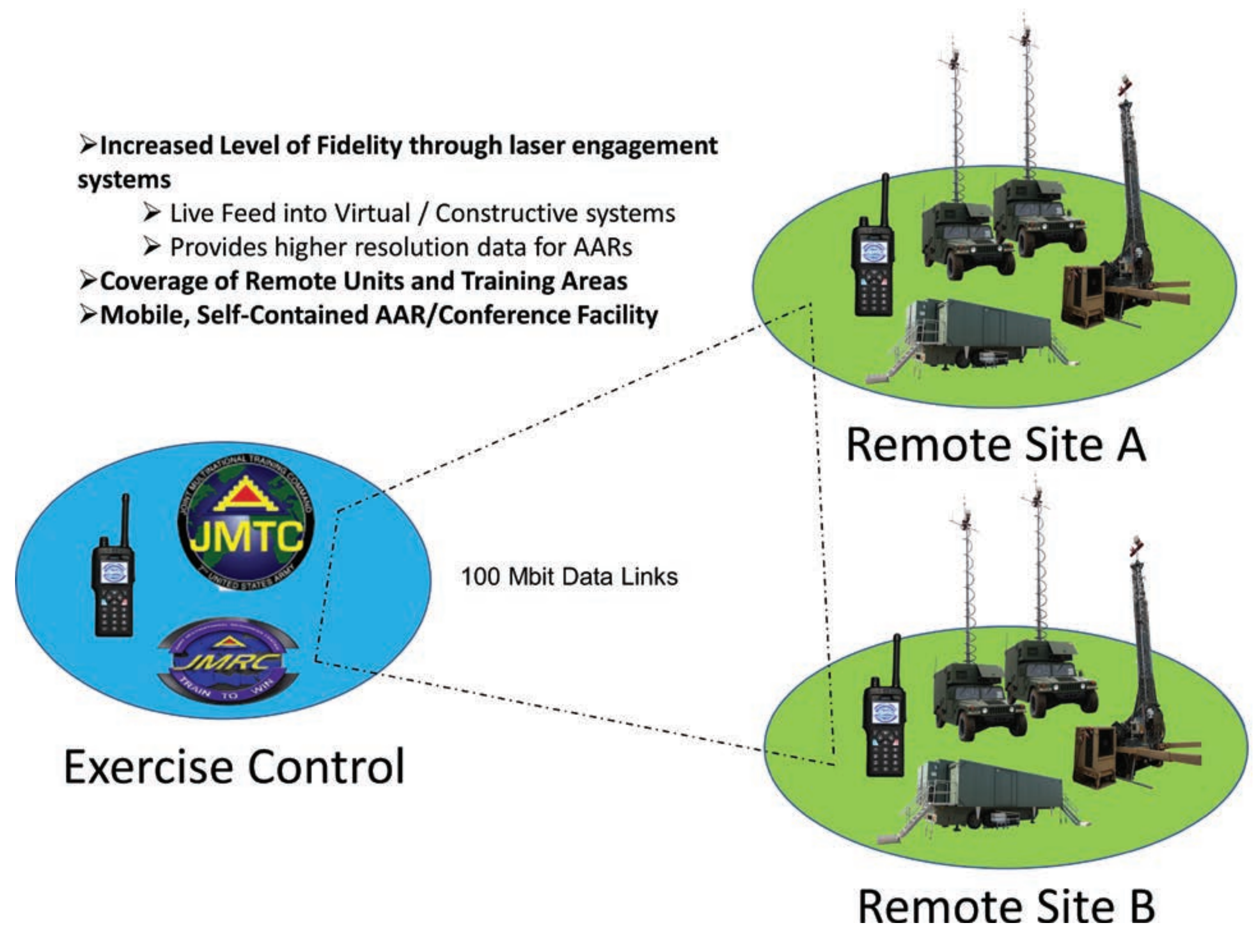

Figure 1: Connected Training Initiative Extended JMRC Instrumentation System

To support the CFI, and thanks to years of security cooperation and numerous military partnership training events, USAREUR and EUCOM now have the opportunity to integrate, "connect" a larger number of our allied forces into its training exercises. The CTI is that opportunity to integrate and leverage existing technologies to create L-V-C training events that are distributed regionally across a number of CTC's with our partner nations.

The opportunity to connect regionally in a distributed environment is no longer limited to the tactical level. For instance, JMRC has the capability to connect tactical to operational level commands with a Corps Headquarters establishing a Joint Operations Center at the Joint Multinational Simulations Center in Grafenwoehr to control and "fight" the distributed exercise. At the JMRC in Hohenfels, a multinational Brigade Headquarters conducts a live exercise with subordinate battalions, companies, or adjacent Brigade Headquarters located at JMTC's partner CTC's throughout Europe.

The post International Security Assistance Force (ISAF) 2014 environment and shift of emphasis from operational engagement to operational preparedness initiates an opportunity for CTI and is an ideal training model for NATO and Allied Land Command (LANDCOM) as it is intended to train its nine NATO Rapid Deployment Corps and the NATO Response Forces.

Mobile Instrumentation System (MIS) Capabilities

The MIS is the basis of technology that provides the interoperability that makes the CTI possible. This system is an integrated set of L-V-C technologies that are installed in platforms that are transportable and can be deployed globally. The major components of the MIS are the Remote Base Stations (figure 2), the After Action Review (AAR) Theaters (figure 3), Data Link Transmission Towers (figure 4), and the Hard-sided Expandable Light Air Mobile Shelters (HELAMS), which provide work areas for the Training Analysis Feedback (TAF) Teams (figure 5).

Figure 2: Remote Base Stations

Figure 5: HELAMS

Figure 3: AAR Theater

Figure 4: Data Links

With equipment already on hand, it is possible for the JMRC to link three remote sites to the Instrumentation System at Hohenfels, which has installed fiber data links to the US Army Grafenwoehr Training Area. Fully deployed, it is possible to link five CTCs in a theater level exercise. The live portion of the architecture is provided through the use of a personnel/vehicle laser engagement system and compatible location radios that, in turn transmits player data to the virtual and constructive simulations employed during the exercise.

The virtual and constructive components are the individual parts of the U.S. Army Joint Land Component Constructive Training Capability-Entity Resolution Federation (JLCCTC-ERF). This is a federation of constructive DIS and other state-of-the-art-technologies that, collectively, simulate military operations. JLCCTC-ERF includes an entity-based ground maneuver model (JCATS 6.0), a fire support model (FIRESIM XXI), and an air defense model (EADSIM) that provides ground and airborne air defense, tactical ballistic missile defense, ground and airborne target acquisition and intelligence gathering, and fixed and rotary wing aviation models. JLCCTC-ERF also enables the capability to link the virtual, constructive, and live domains of training at the Army`s CTCs through the use of software and hardware that allows data to be exchanged between the CTC's Instrumentation System (IS) and the JLCCTC-ERF simulated environment [5].

Virtual environments are provided by the internationally used Virtual Battle Space 2 (VBS2), which is a configurable game-based virtual environment that can simulate real-world systems. The simulation confederation also has the ability to portray virtual Unmanned Aerial Vehicle System (UAS) products and virtual Close Air Support through a partnership with the U.S. Air Force at the Warrior Preparation Center (WPC) in Einsiedlerhof, Germany. The virtual UAS replicates platforms like Hunter, Shadow, and Predator to include the same communication chat program and networks, as well as, air tracks for Mission Command systems. The current JMRC simulation architecture is shown in figure 6.

Another significant capability that provides for the training effectiveness of the MIS is the Battle Command Network used by the players, and a separate/secure communication system for the Observer/Controller Teams. That current system is the Observer Controller Communication Subsystem (OCCS). The OCCS provides two-way, non-tactical voice and data communications between Observer Coach Trainers (OCTs), TAF analysts, senior leadership, and various support personnel. The system provides the necessary privacy to command and control the battle's course of instruction without the exercise players intercepting OC communications.

Ultimately, the purpose for the fusion these capabilities are twofold. First, the data generated provides the training analysts the information needed to provide extensive feedback to both the trainers and training audience. The fidelity and quantity of available data is the basis for the highest quality AARs available today. Second, and of high value to all involved, is the Common Operating Picture (COP). The continuous influx of data gives controllers the ability to see that the training flow is meeting established objectives; better provide for command centers to effectively conduct battle management; and last, establishes an added margin of safety for the participants.

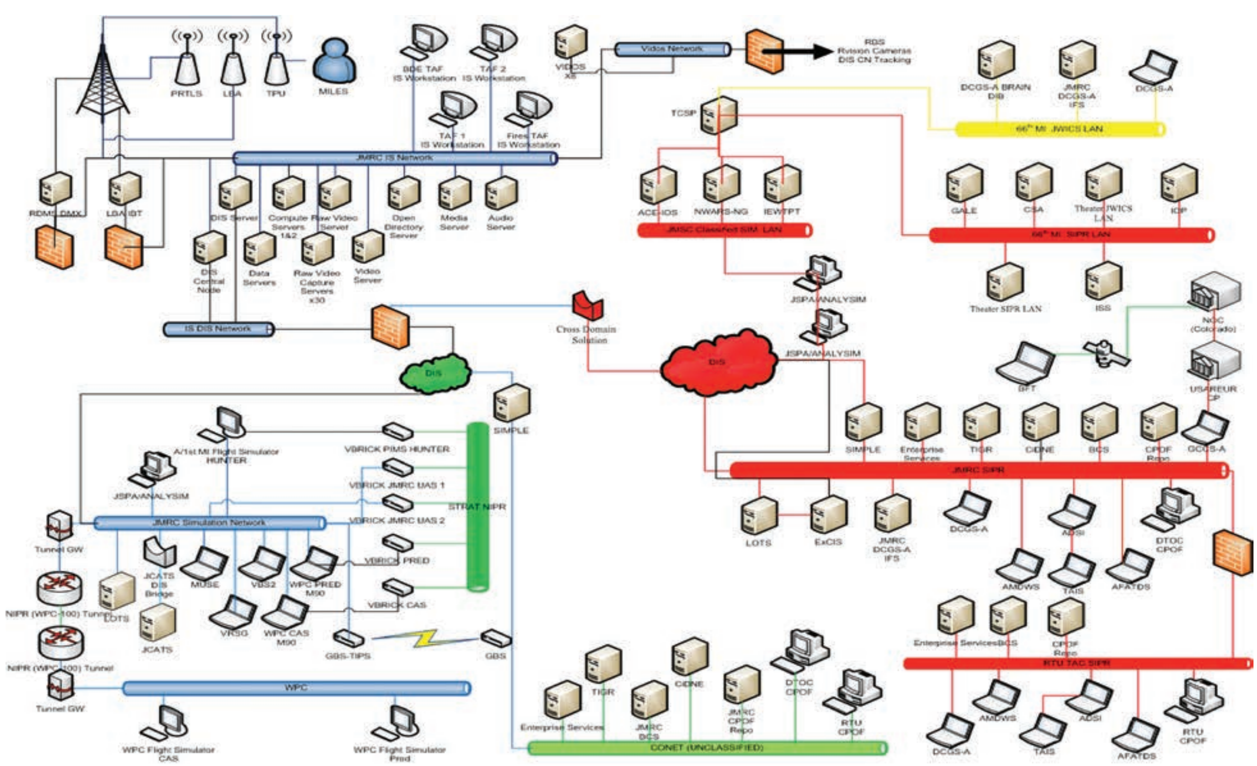

Figure 6: JMRC Overall Architecture

Challenges

The concept of the CTI is certainly within the realm of technical reality, and is accomplished today on a smaller scale at remote training sites used in the vicinity of Hohenfels and Grafenwoehr. On the other hand, interconnecting remote locations in other countries provide additional challenges. Chief among these are the establishment of broadband data links, various interoperability issues, and in the simulation arena, limitations of the current set of approved DIS Protocol Data Units (PDU).

Data Links (Point A to B to…)

Those with experience in setting up large scale distributed L-V-C training environments know that one key to success is a reliable ability to transmit large amounts of data in real time. In the U.S. there is the Joint Training and Experimentation Network (JTEN), and theater areas like Korea have established their own persistent training networks. The European theater does not have that capability so every exercise involving an "away game" at a coalition partner CTC will necessitate the need for dedicated broad band data links running across international boundaries.

Interoperability

Interoperability is a perennial problem with distributed training. While great strides have been made in this area over the past 20 years, the majority of these advances have been made for a U.S. joint environment where working within a coalition provides a broader set of issues.

One challenge that is not part of the MIS is interoperability of coalition Command and Control Information Systems (C2IS). In order to accomplish this, it requires both system and semantic interoperability. While it is beyond the scope of this article to cover system issues, it is important to mention that NATO has made progress in the area of semantic interoperability through the Multilateral Interoperability Program (MIP). The purpose of the *MIP* is to "achieve international interoperability of C2IS at all levels from corps to battalion, or lowest appropriate level, in order to support multinational combined and joint operations" [6]. Therefore, the MIP is a functioning specification that would be the focus of providing the command net communication in a CTI supported exercise. Another interoperability area of concern is the interface between the MIS and various laser engagement systems. Suffice it to say that not all laser engagement systems are horizontally compatible or will interface with the MIS. The ability to solve this will depend on each exercise and the participants.

Don't Shoot that T-72 He's a Good Guy!

Bringing in to exercises Partners for Peace (PfP) also brought in military equipment and systems that were previously only accounted for in DIS PDUs as opposing force systems. There are also situations in coalition exercises where there are civilians that may not be aligned with "blue" or "red" forces, are armed, and need to be accounted for in the simulations. Addressing this situation currently requires some creative "work-a-rounds" by the simulation staffs, and is unique to each training event.

Conclusion The use of L-V-C technology and the initiative of command leadership from the U.S. and our coalition partners' CTCs have become an invaluable component of military readiness. This article provided an outline for the next step in making even greater use of available training capabilities. While the technology to support the CTI exists, there are challenges that must be met in order to make this scale of training as readily available in the future as multinational training is available at the JMRC today. The way is clear and with the support of leadership, along with the excellent technical personnel at JMRC, that future will soon become a reality.

Acknowledgment

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Authors' Biographies

Colonel John G. Norris

Colonel John G. Norris hails from Louisville, Kentucky. He enlisted in the United States Marine Corps and graduated from the University of Louisville in 1987, where he was a Distinguished Military Graduate and a George C. Marshall award winner. Commissioned in the Infantry, he attended the Infantry Officer Basic Course, Airborne, and Ranger Course at Fort Benning, Georgia. His first assignment was with the 101st Airborne, Ft. Campbell, Kentucky where he served as a rifle platoon leader, anti-armor platoon leader, company executive officer during Operations Desert Shield and Desert Storm, and Battalion S3 Air.

Following the Armor Officer Advanced Course at Fort Knox in 1992, he was stationed in Mannheim, Germany with the 3rd Brigade 1st Armored Division and served as the Brigade assistant S4, and later as the Brigade S4 during the 3rd Brigade relocation from Europe to Ft. Lewis, Washington. COL Norris then commanded B Company 1- 23rd Infantry at Ft. Lewis.

In 1996, COL Norris was assigned to Fort Benning, Georgia, and served as a small group instructor and tactics team chief for the Infantry Officer Advance Course. After graduation from the US Army Command and General Staff College in 1999, he was assigned to the 24th Infantry Division, Fort Riley, Kansas, and initially served as the G3 chief of operations for 24ID. COL Norris subsequently served as the battalion operations officer and executive officer for 1- 41st Infantry and deploy in support Operation Desert Spring. Following this assignment, he was the secretary of the General Staff for the 24th Infantry Division.

In 2003, COL Norris activated the 4th Battalion 23rd Infantry Regiment of the 172d SBCT (STRYKER) located at Ft Richardson, Alaska. He commanded this unit for 41 months, to include 16 months of combat duty in Mosul, Tal Afar, and Baghdad during Operation Iraqi Freedom II-III. Following command, he was assigned as an instructor at the School of Command Preparation prior to beginning the Advanced Operational Arts Studies Fellowship at Ft. Leavenworth, Kansas.

August 2008, COL Norris assumed command of 4-2 SBCT at Ft Lewis, Washington and led the brigade through a 10 month accelerated deployment to Iraq as the last combat brigade in Operation Iraqi Freedom IX-X.

Following brigade command he served as the executive officer for the I Corps Commanding General and deployed to Afghanistan to serve in the ISAF Joint Command Headquarters.

COL Norris has a masters of military arts and science degree from the Command and General Staff College and a masters from the Advanced Operational Arts Studies Fellowship. His awards and decorations include the Bronze Star (2nd Oak Leaf Cluster), the Legion of Merit, Meritorious Service Medal (3rd Oak Leaf Cluster), Joint Meritorious Service Medal, the Army Commendation Medal (3rd Oak Leaf Cluster), the Army Achievement Medal (2nd Oak Leaf Cluster), and the Armed Forces Expeditionary Medal and the Valorous, Meritorious and Joint Meritorious Unit Awards. His badges include the Combat Infantryman Badge with second award, Expert Infantryman Badge, Parachutist Badge, Air Assault Badge, and Ranger Tab.

COL Norris is married to the former Sandra Stevens of Louisville Kentucky. They have two sons Nathan and Matthew.

Colonel Joseph G. Patterson

Colonel Joseph G. Patterson currently serves as the senior intelligence officer and OIC of the Instrumentation Training Analysis Computer Simulations and Support Directorate, Joint Multinational Readiness Center (JMRC), Hohenfels, Germany. He has over 24 years of operational experience that includes strategic assignments in U.S. Forces Korea, Ft. Meade, Special Operations Command Europe (SOCEUR), U.S. Army Africa Command/Southern European Task Force, Commander - 24th Military Intelligence Battalion, 66th MI Brigade in Wiesbaden, Germany, and deployment to Afghanistan as the Afghanistan Remote Operations Cryptologic Center OIC.

His awards and decorations include the Bronze Star Medal, Defense Meritorious Service Medal with oak leaf cluster, the Meritorious Service Medal with three oak leaf clusters, the Joint Service Commendation Medal, the Army Commendation Medal with oak leaf cluster, Joint Service Achievement Medal, the Army Achievement Medal with oak leaf cluster, and the Parachutist Badge.

GM-VV — An International Recommended Practice for Verification and Validation of Models, Simulations, and Data

AUTHORS

Mr. Fredrik Jonsson
Swedish Defense Material Administration (FMV)
Banérgatan 62
SE-115 88 Stockholm, Sweden
fredrik.jonsson@smart-lab.se

Mr. Constantinos Giannoulis
Stockholm University, Dept. of Computer and Systems Sciences (DSV)
Forum 100
SE-164 40 Kista, Sweden
constantinos@dsv.su.se

Dr. Manfred Roza
National Aerospace Laboratory NLR, Q-tility V&V expertise center
Anthony Fokkerweg 2
1059 CM Amsterdam, The Netherlands
manfred.roza@nlr.nl

Dr. Martin Adelantado
ONERA-MiP DTIM/MAGS
2, Av. Edouard Belin
FR-31055 Toulouse, France
Martin.Adelantado@onera.fr

Dr. Jean-Louis Igarza
Antycip Simulation
9, Av. du Marais Parc des Algorithmes –
Bât Platon BP 30172
FR-95105 Argenteuil, France
igarzaj@voila.fr

ABSTRACT

THE GENERIC METHODOLOGY FOR VERIFICATION AND VALIDATION (GM-VV) IS A GENERIC AND COMPREHENSIVE METHODOLOGY FOR SETTING-UP, MANAGING, AND GUIDING THE VERIFICATION AND VALIDATION (V&V) OF MODELING AND SIMULATION (M&S) SYSTEMS, SIMULATIONS, UNDERLYING DATA, AND RESULTS FOR SPECIFIC INTENDED USES. THE GM-VV IS NEITHER PRESCRIPTIVE NOR DIRECTLY TIED TO ANY SPECIFIC M&S APPLICATION DOMAIN, STANDARD, TECHNOLOGY, ORGANIZATION, OR OTHER DISTINCTIVE M&S CONTEXT-RELATED IMPLEMENTATION DETAILS FOR V&V. THE GM-VV IS AN OFFICIAL-APPROVED GUIDANCE PRODUCT OF THE SIMULATION INTEROPERABILITY STANDARDS ORGANIZATION (SISO) FOR DEVELOPING ARGUMENTS TO JUSTIFY WHY M&S ASSETS ARE ACCEPTABLE OR NOT FOR A SPECIFIC INTENDED USE IN A TRACEABLE, REPRODUCIBLE, TRANSPARENT, AND WELL-DOCUMENTED MANNER.

SUCH ARGUMENTATION SUPPORTS M&S STAKEHOLDERS IN THEIR ACCEPTANCE DECISION-MAKING PROCESS REGARDING THE DEVELOPMENT, APPLICATION, AND REUSE OF SUCH M&S ASSETS. THE GM-VV COMPRISES A COMPLETE TAILORABLE TECHNICAL FRAMEWORK THAT FACILITATES COMMUNICATION, UNDERSTANDING, AND IMPLEMENTATION OF V&V ACROSS AND BETWEEN DIFFERENT M&S CONTEXTS.

FROM THE INTERNATIONAL POINT OF VIEW, THE GM-VV IS THE RESULT OF A LONG COOPERATION EFFORT THAT STARTED WITH A EUROPEAN EFFORT (THE REVVA PROJECT) EVOLVING TO A COOPERATIVE EFFORT OF THE NORTH

ATLANTIC TREATY ORGANIZATION (NATO) AND SISO. THIS IS THE FIRST COMPLETED JOINT DEVELOPMENT OF SISO AND NATO SINCE THE SIGNATURE OF A TECHNICAL COOPERATION AGREEMENT IN 2007.

THIS ARTICLE PRESENTS AN OVERVIEW OF THE GM-VV ACCOMPANIED WITH EXAMPLE APPLICATIONS CARRIED OUT IN SWEDEN, GERMANY, AND THE NETHERLANDS.

1 Introduction

Nowadays, simulation systems are utilized more and more across every domain within the defense; from analysis and engineering, to acquisition, to testing and evaluation, and from training to exploration.

This constitutes the verification and validation (V&V) of simulation systems as an essential prerequisite to assure that their development and deployment provide confidence of use to their stakeholders and users for the anticipated results. For simulation systems in safety-critical areas, where associated risks typically may have more severe consequences, the need for V&V is greater. Moreover, the need for thorough and robust V&V evidence supporting acceptance or non-acceptance of simulation systems is imperative. Such V&V evidence is required to ensure that both development and utilization of modeling and simulation (M&S) technology provides credible results that do not pose unacceptable risks for decision making.

The selection of V&V methods and techniques suitable for a given M&S effort depends on the individual needs, constraints, and capabilities of an M&S organization, project, application domain, or technology. As a result, there exist many varying approaches, techniques, and methods for V&V that rely on a wide variety of V&V terms, concepts, products, processes, tools, and techniques.

The increased usage and reliance on M&S has been the driver for the development of new techniques and methods for the V&V of M&S technologies [1], [2] as well as the update of old ones [3].

Often, a particular selection of approaches limits or hinders the transition of V&V results and relevant information from one M&S organization, project and technology, or application domain to another. This practical issue has been the motivation and key driver behind the development of a generic approach for conducting V&V, namely the Generic Methodology for Verification and Validation (GM-VV), which has been recently established as a recommended practice guide within the Simulation Interoperability Standards Organization (SISO) [4]. The GM-VV consists of three documents: Volume 1: Introduction and Overview [2], Volume 2: Implementation Guide [5], and Volume 3: Reference Manual [6].

The aim of this article is twofold; the first objective is focused on introducing the M&S community to the GM-VV and its related SISO products. The second objective is focused on sharing experiences of exercising this newly developed V&V approach.

The article is structured as follows; Section 2 presents an overview of the GM-VV, section 3 presents the GM-VV as a SISO Recommended Practice Guide, section 4 presents the exercises carried out, and section 5 concludes the article by discussing preliminary experiences of applying the GM-VV.

2 GM-VV

The GM-VV provides guidance for any V&V effort regardless of particular specificities that may be entailed by an M&S application context. The methodology is goal-driven and suited to support M&S stakeholders' acceptance decision in each phase of the M&S life cycle. It guides V&V practitioners to build traceable, reproducible, and transparent evidence-based acceptance arguments [1].

The GM-VV facilitates common understanding and communication of V&V of M&S by providing common semantics and components for V&V that can be used unambiguously across and between different M&S organizations, projects, and technology, or application domains. Moreover, the methodology also facilitates the reusability and interoperability of V&V results, as well as tools implemented and techniques practiced.

The GM-VV comprises a reference model and architecture for V&V that consists of three parts (the Conceptual Framework, the Implementation Framework, and the Tailoring Framework) that build upon existing V&V methods and practices. For a full presentation of the GM-VV please refer to [2], [5]-[7].

2.1 GM-VV Conceptual Framework

The GM-VV conceptual framework describes fundamental elements in terms of V&V terminology, semantics, concepts, and principles. This framework is rooted in the premise that models and simulations are developed and employed to fulfill specific stakeholder needs (e.g., trainers, decision makers, or developers). The GM-VV uses a four-world view to structure the context in which these stakeholders' needs have to be fulfilled.

The four worlds (real world, problem world, M&S world, and product world) define a generic M&S life cycle view to which V&V is applied. V&V is considered as a specific domain of M&S, the "V&V World" (bottom of figure 1), which groups the products, processes, and organizational aspects required for the development of an *acceptance recommendation* with respect to an M&S system and its intended use. This effort is driven by stakeholders' V&V needs (e.g., budget, schedule, risks, and liabilities).

From a technical perspective, the GM-VV recognizes five conceptual activities in this effort:

1. Define a set of concrete and assessable *acceptability criteria* for the M&S system
2. Build *evidence* to demonstrate the satisfaction of the acceptability criteria
3. Assess the *evidential quality* of this demonstration using V&V Quality criteria
4. Develop arguments that underlie the claim whether or not the M&S asset is acceptable for an intended use (i.e., *acceptance claim*)
5. Compile the information from the prior four activities into an acceptance recommendation.

Acceptability criteria, items of evidence, and arguments underlying an acceptance recommendation should be developed in a structured manner with transparent, traceable, and reproducible reasoning.

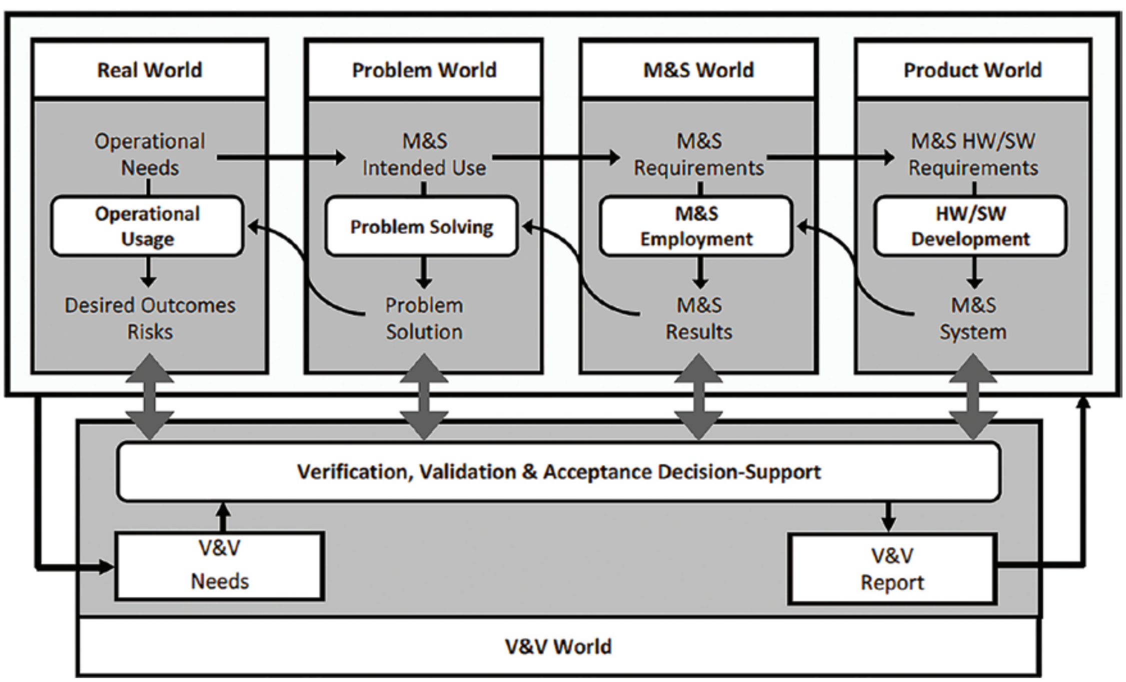

Figure 1: GM-VV Worlds View (Adopted from [2])

For the GM-VV, this entails establishing and assessing acceptability criteria with respect to three M&S properties (see figure 2):

- Utility refers to the extent to which the M&S system is useful to the M&S user/sponsor needs;
- Validity refers to the extent to which the M&S system representation corresponds to the simuland from the perspective of the intended use;
- Correctness refers to the extent to which the M&S system implementation conforms to its specifications and is free of design and development defects.

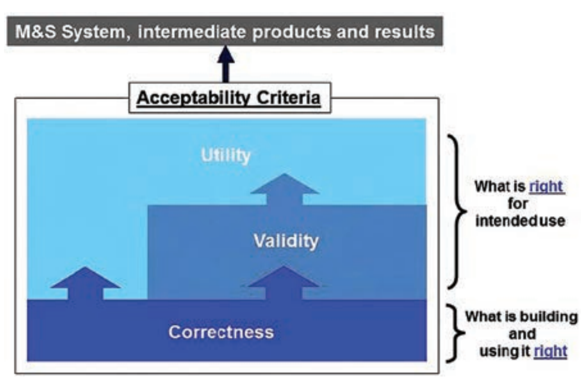

Figure 2: M&S Properties for V&V (Adopted from [7])

This is accomplished by the GM-VV *V&V argumentation structure* concept that encapsulates, manages, and consolidates all underlying evidence and argumentation necessary for developing a defensible acceptance recommendation. Possible implementations of such an argumentation structure comprise a V&V goal-claim network (figure 3) or an M&S requirements traceability matrix.

Compliant to general systems engineering principles, the GM-VV describes three organizational levels for V&V efforts to be considered; technical level, project level, and enterprise level:

- The technical level concerns all technical aspects of a V&V effort necessary to develop and deliver an acceptance recommendation for an M&S system;
- The project level concerns all aspects relevant to the management of the project to the technical work execution;
- The enterprise level establishes, directs, and enables the execution of VV&A projects.

The GM-VV provides the concepts of *V&V project* and *enterprise memory,* which, respectively, retain information from current and past V&V efforts to support quality assessment and cost-effective execution of V&V. These

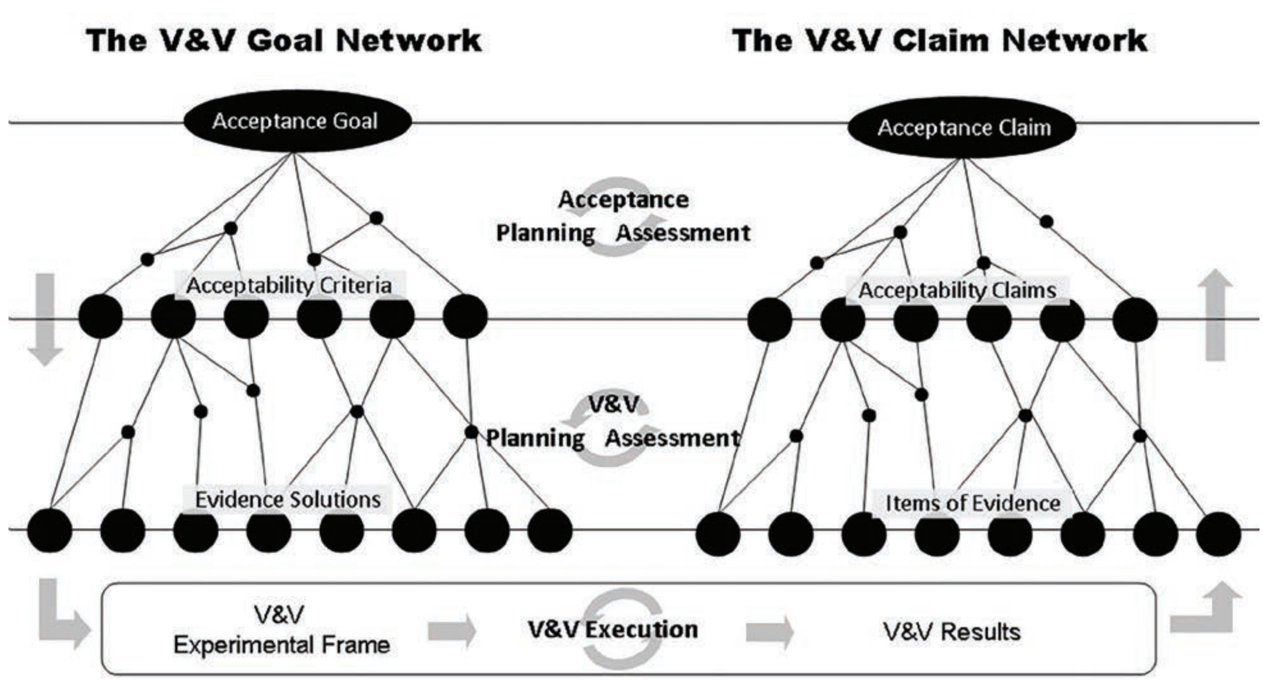

Figure 3: The V&V Goal-Claim Network (Adopted from [2])

memories consist of an information and knowledge repository and a community of practice.

2.2 GM-VV Implementation Framework

The GM-VV implementation framework operationalizes the methodology's basic concepts into a set of generic V&V components. These components are classified and designed with respect to three interrelated dimensions (see figure 4). All components are meant to be combined for the implementation of tailored V&V solutions that fit any particular M&S organization, application, and technology or problem domain. Each dimension contains building blocks that cover technical, project, and enterprise level aspects of V&V.

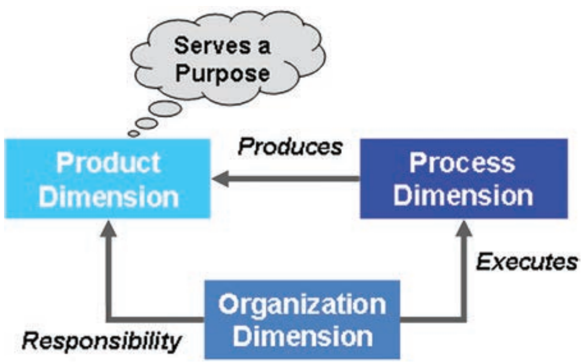

Figure 4: GM-VV Implementation Framework Dimensions (Adopted from [2])

The product dimension describes information-based V&V artifacts that can have multiple instances, representational, and documentation formats.

Processes, activities and tasks for their provision are undertaken as defined by the process dimension. They can be executed recursively, concurrently, and iteratively.

The roles defined for the organization dimension are involved in the execution of one or more of the V&V processes, activities, and tasks. Roles are specified in terms of responsibilities of either people or organizations involved in a V&V effort. These roles can be played by separate organizations, teams of people in one organization, or by a single person.

2.3 GM-VV Tailoring Framework

The GM-VV implementation framework provides a set of generic V&V components that should be tailored for each individual M&S organization, project, or application domain. The GM-VV tailoring framework supports the modification of the building blocks for each dimension to satisfy the specific V&V needs of the M&S system for which the GM-VV is used.

The set of generic V&V components should first be cast into a V&V method instantiation suited for the organization or application domain and then be optimized for the VV&A project at hand. Four tailoring approaches are defined for optimization:

- **Extension**: adding elements not specified in the GM-V&V (e.g., additional information artifacts);
- **Reduction**: cutting out GM-VV elements (e.g., activities and tasks that are not meant to be executed);
- **Specialization**: adaptation of GM-VV elements (e.g., using domain specific V&V methods);
- **Balancing**: adaptation to find optimum cost-benefit-ratio (e.g., distributing project resources based on M&S use-risk).

Tailoring through these approaches should be performed across the three dimensions of the GM-VV implementation framework for a consistent and coherent GM-VV instance of the V&V effort to be obtained.

3 GM-VV as a SISO Recommended Practice Guide

The GM-VV has been established as an official recommended practice guide within SISO [4]. It has undergone through the standardization process of SISO leveraging the support of NATO Modeling and Simulation Task Group 073 (MSG-073) to carry out all the necessary activities. The methodology consists of three documents:

- **GM-VV Volume 1**: Introduction and Overview [2];
- **GM-VV Volume 2**: Implementation Guide [5];
- **GM-VV Volume 3**: Reference Manual [6].

Volume 1 is intended for all M&S professionals, managers, and M&S users/sponsors seeking to incorporate V&V in their organization and projects in a general applicable and standardized manner. It provides a high-level description of the GM-VV conceptual, implementation, and tailoring frameworks.

Volume 2 is intended for all M&S professionals and managers aiming to apply the GM-VV on technical, project, and enterprise levels. It provides a detailed description of the GM-VV implementation framework components, as well as guidance on how to apply these components to develop tailored and concrete V&V solutions.

Volume 3 is intended for all M&S professionals and M&S users/sponsors aiming to apply the GM-VV on technical, project, and enterprise levels. It provides the foundations of the GM-VV concepts, their dependencies and rationale, and includes example applications of the methodology.

4 Example Cases

Several case studies have been conducted for the development and evaluation of the GM-VV and to illustrate its tailor-ability and applicability towards specific M&S applications, both in an international context within the MSG-073 Task Group, as well as within national efforts. The results of these case studies are presented here on a high level. The detailed outcomes and findings can be found in referenced papers where applicable.

4.1 Case Study "Flashing Lights"

The "Flashing Lights" case was historically the first case to test the GM-VV methodology. This case comprised a recently executed test and evaluation study for Dutch Ministry of Transport, Public Works, and Water Management. For this study the TNO research-driving simulator was used. This full-motion simulator is used for human driver behavior studies. This simulator was upgraded with a new visual model that simulated the flashing lights of emergency service vehicles. The case comprised the V&V of the upgrade of the simulator and the simulator was used as a test-bed for the investigation of the effects of a new traffic accident signaling strategy.

As this experiment was the first real attempt to apply the GM-VV methodology, the findings, while applying theory in practice, were meticulously recorded and used for later evaluation. As a result of this exercise, the then present set of GM-VV documents went through a major restructuring process. This process also led to a reduced document set as duplications between documents were removed. It was also found that more case studies were necessary to fully fine tune the methodology for practical application in a wider community, and that support by automated tools is a mandatory pre-requisite.

The findings of this case study were published and presented in a paper and presentation of the SISO Simulation Interoperability Workshop held in Spring 2010 [8].

4.2 Case Study "Heavy Weather Ship Handling"

The "Heavy Weather Ship Handling" case study was designed around a mutual understanding of the value of a V&V effort for the design and outcomes of an M&S based experiment for the Royal Dutch Navy. The team that designed the experiment covered specialists from the human factors domain to simulation engineers from various organizations involved, and the V&V experts. For the experiment, a full motion research simulator was equipped and prepared to facilitate the conditions required.

The proposition of the acceptance goal, the GM-VV wording of the actual answer to the main question, was formulated as:

> *"The results of the experiment are useful in the determination of the significance of physical motion in simulation of high sea state for training and doctrine evaluation."*

This proposition ultimately needs to be demonstrated with evidence collected while preparing for the experiment (V&V of the model used) and running the experiment itself (V&V of the experiment).

Based on the case study as executed, the conclusion was that the GM-VV contains all necessary high level ingredients for a rigorous approach to V&V. The methodology, however, needs to be instantiated and the instantiated V&V method needs tailoring in order to fit to the needs of the V&V project at hand. Tailoring has been applied in several ways: during instantiation, elements are added or removed from the default GM-VV and during the execution of the processes specialization has been applied. One of the main technical products, the V&V Goal-Claim Network, is built with a continuous tailoring by balancing results, risks, costs, and time. Defining the V&V Experimental Frame also required extensive balancing. The GM-VV tailoring principles worked well, which resulted in a practical application of the GM-VV.

The outcomes of this case study were published as a paper [9] and several presentations that appeared in SISO's Simulation Interoperability Workshops (2011 Euro SIW, 2011 Fall SIW) and conferences like I/ITSEC 2011 and ITEC 2012.

4.3 Case Study "Air-to-Air Missile"

The "Air-to-Air Missile" case study is based on the report [10] on a case where the GM-VV had been tested within the Swedish Defence Research Agency (FOI) on an unclassified model of a generic air-to-air missile. The intended use of this missile model was to train fighter pilots in beyond-visual-range (BVR) scenarios, thus aimed at being *Suitable for Air Combat Training* (figure 5).

The exercise involved a team of M&S developers using requirements specifications on this generic model coming from project sponsor organizations, such as the Swedish Armed Forces and industrial partners. The GM-VV was used to refine and elaborate on these requirements specifications to derive an acceptance recommendation for the intended use of the model.

Three top requirements on the model were selected to test and apply the GM-VV:

- Sufficient realism: choices of physical modeling in terms of structure and sub-models reflecting the vital components of a BVR missile;
- Sufficient transparency: information regarding the interaction between the missile and all surrounding objects (target, environment, etc.) to be displayed to the pilot during flight but also for post mission review;
- Be executable in a simulator: use of MERLIN, a component based simulation framework for soft real time simulations of weapon platforms, to run the missile model.

Objectives of the exercise regarding the GM-VV:

- Test the applicability of the methodology;
- Coach the application of the GM-VV process;
- Support the development of the V&V Goal-Claim Networks;
- Support tailoring the M&S process and documentation activities;
- Gather feedback from M&S developers regarding utility and benefits of using the GM-VV, highlighting particular aspects of the methodology being more relevant/useful, as well as ones that are less relevant/useful that need be improved.

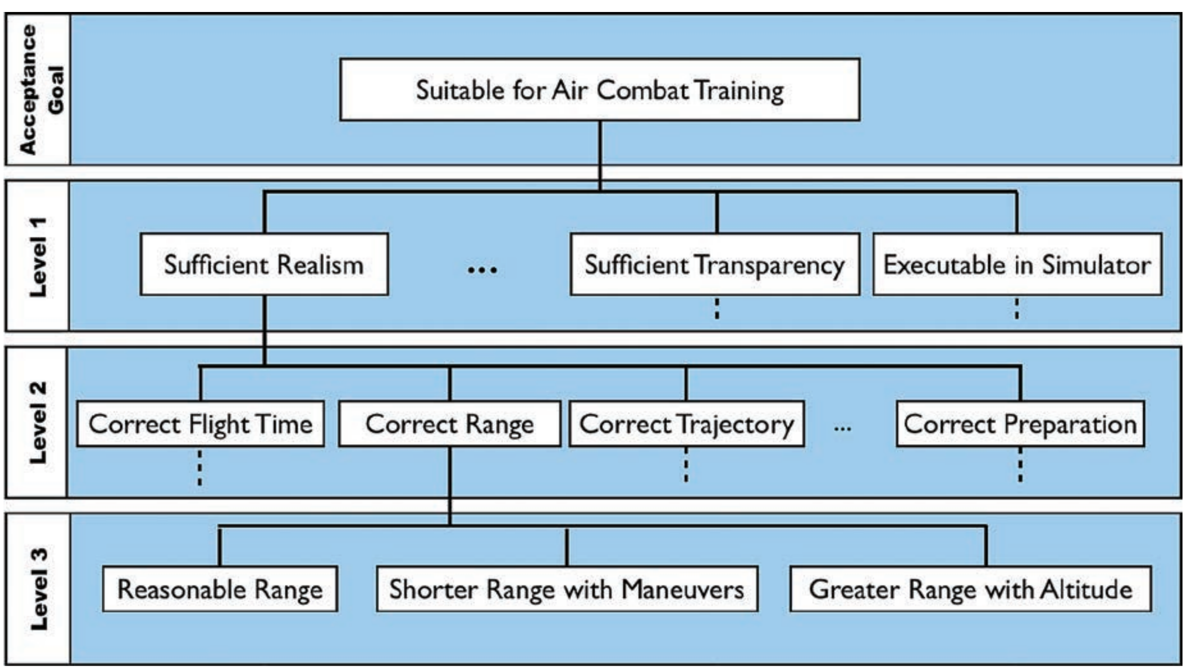

Figure 5: Illustration of a Requirements Breakdown from Acceptance Goal to Testable Statements (Adopted from [10]).

Major findings and lessons learned:

- GM-VV is a promising method for the validation of missile models, and should also be suitable for other applications. A strength of the method is the clear link to the application and targets with the model;
- With a structured V&V methodology created, a documented and transparent chain of evidence between the declared objective of the model and the assertion that the model lives up to the goal;
- The importance of a thorough requirements definition and formulation of the intended use of the model has been clarified in the work. In the reported example, it has been found that a simpler model of the missile could have had fulfilled the use area so as described herein;
- The work carried out has also further demonstrated the utility of a close dialogue between V&V implementers, M&S developers, and users.

4.4 Case study "Pioneers Ribbon/Floating Bridge"

In context of the development of a team training simulator (as visually represented in figure 6) for coordinating actions that have to be taken to assemble different parts of a ribbon/floating bridge for crossing a river, major experiences have been gained from the application of a project, and the model documentation process according to German national guidelines adapted to GM-VV requirements. The aim of the exercise was to examine the usability and efficiency of the proposed documentation and tailoring concepts for the training simulator. According to general process, product, role, and tailoring guidelines, the project was processed cooperatively by a team including representatives of the project sponsor (BWB), M&S developers (szenaris GmbH), and an independent V&V-agent (ITIS). This entailed coaching the application of the GM-VV, as well as documenting according to national guidelines, supporting tailoring activities for the M&S process, indicative application of V&V techniques for quality control and cost estimation of V&V activities, and feedback gathering.

Major findings and lessons learned:

- The proposed documentation structures and guidelines were perceived as time-consuming, but beneficial by the M&S developer. After this case study, the company decided to apply the guidelines in other projects on its own initiative;

Figure 6: Visual Representation of the Floating Bridge Case

- Standardized formalization languages, methods, and tools are indispensable for model documentation;
- IPR and know-how protection has been seen as a critical issue related to model documentation and (independent) model V&V;
- Costs and efforts for model documentation and model V&V should be calculated as early as possible along with tailoring decisions. As total project budget, as well as quality assurance, will significantly depend on tailoring decisions, these should be accepted and well documented by all contributing parties.

4.5 Case Study "Robot Movement Simulator"

The goal of the German "Robot Movement Simulator" case study (as visually represented in figure 7) was to investigate acceptance, feasibility, and involved efforts/costs for development and application of a V&V plan in the context of a robot simulator project. For budgetary reasons, the scope of this case study was limited, or tailored to a subset of the model development phases, and to 3 of 13 predefined application scenarios.

The scope limitations resulted in supporting the required model documentation, developing a V&V plan tailored based on project requirements, budget, and cooperative decisions together with the sponsor and the developers, as well as sampling the application of V&V techniques to investigate their effectiveness.

Major findings and lessons learned:

- Time and effort required for the initial application of the documentation guideline is extremely high (especially for the M&S developer who rarely documents his work).

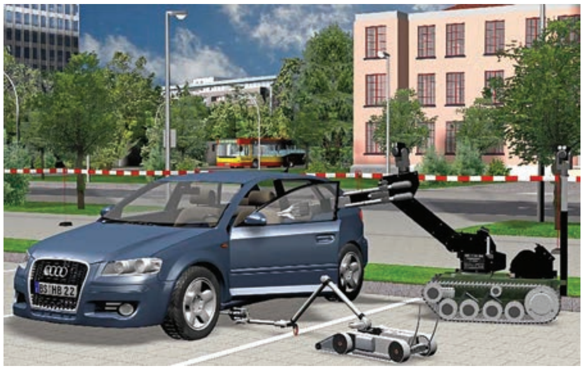

Figure 7: Visual Representation of the Robot Movement Simulation

However, once such a guideline is properly introduced to the M&S development team, documentation time/ costs for further projects can be significantly reduced;

- A documentation guideline and structures in the form of flexible, "living" guidelines and documents would increase efficiency. Consequently, two studies for development of electronic guidelines were initiated and conducted;
- The "V&V Triangle" concept can be applied for process management tasks (such as planning, organizing, and monitoring the V&V effort), as well as for technical tasks (like analyzing, evaluating, reviewing, and testing model elements);
- Tailoring at the beginning of an M&S project and tailoring through adaptation during the M&S development process are indispensable;
- Regarding IPR and know-how protection, the following concept was proposed:
  - —The independent V&V agent specifies detailed V&V requirements, examination criteria and measures, and contents of V&V reports for model work products subject of V&V;
  - —An internal inspector on the M&S developer side (e.g., from the quality assurance department) performs the specified examination according to the V&V requirements, and documents the V&V process and its results;
  - —The V&V agent evaluates correctness and validity of the model, simulation, and data based on the created examination protocol of the internal inspector.

4.6 Case Study "Guidelines for Platoon Commanders": V&V

The aim of the German "Guidelines for Platoon Commanders" exercise (as visually represented in figure 8) was an examination of V&V for a safety-critical constructive simulation system. The goal of the simulation project was to be able to analyze different guideline options for platoon commanders to lead his or her platoon in different and safety-critical scenarios. One of the project requirements defined a limited time frame for simulation system development and availability of the requested simulation results. Beside this time limitation, the quality of the modeling process and its results should be evaluated through V&V. Therefore, as a case study, ITIS as an independent V&V agent was assigned to guide or support some V&V activities concurrently with simulation system development.

This entailed the V&V agent to support the preparation of model documents (check completeness and consistency), tailor the M&S activities in collaboration with the project sponsor and the M&S developers, prepare the V&V plan, select and conduct V&V techniques with respect to the V&V plan, and document and demonstrate the V&V results.

Figure 8: Visual Representation of the Terrain for the "Guidelines for Platoon Commanders" Case

Major findings and lessons learned:

- The generic tailoring concept of GM-VV was applied and has confirmed its usability as a general framework;
- A combination of different V&V techniques (e.g., combination of Inspections, Face Validation, and Visualization/Animation in this case study) was very useful and demonstrated to be very effective;
- Time and efforts required for execution of V&V techniques and interpretation of V&V results has to be calculated at

the beginning of a project based on project constraints and requirements. Experience showed that just time scheduling requirements and availabilities of team members (roles) has to be considered as a limiting factor for processing certain V&V activities. This experience indicated the need for tailoring actions during development.

4.7 Case Study "Distributed Air Operation Mission Training Environment"

The "Distributed Air Operation Mission Training Environment" (figure 9) case study is based on references [11] and [12]. In order to be able to operate effectively and safely, the Royal Netherlands Air-Force (RNLAF) Air Operation Control Station (AOCS) needs fighter controllers that are familiarized with F-16 cockpit operations. Until recently, fighter controllers were trained for this purpose by several familiarization flights in the RNAF F-16B dual seat aircraft. For economic reasons the RNLAF has phased out all its F-16B aircraft. Therefore, AOCS had to find alternatives to continue this type of fighter controller training. A simulation-based training system could provide the fighter controller a cost-effective and safe learning environment in which fighter controllers can experience F-16 flight operations in realistic mission scenarios. To support the concept development and specification phase of such a future simulation training environment, a prototype was developed by the Dutch National Aerospace Laboratory (NLR). This prototype integrates NLR's four existing fixed-based F16 flight simulators, a constructive simulation that provides computer generated air threats, and two real-life and NATO classified fighter controller working stations (MASE) into a single distributed air operation mission training environment. Interoperability between all simulation assets was accomplished through DIS.

A V&V study was requested to assess the utility and validity of this training simulation concept and its underlying technology for intended use of AOCS. Based on the acceptance recommendations of this V&V study, AOCS would take decisions regarding the acquisition process of a new alternative training environment (e.g., go-no-go decision for an M&S system or M&S requirements refinements). The GM-VV is currently the recommended guidance for V&V within the Dutch MoD. The Dutch V&V service supplier organization Q-tility performed the V&V activities. As a V&V User/Sponsor, AOCS was actively involved in the V&V work (e.g., review of the V&V argumentation structure, V&V plan approval, and SME provision in the V&V execution phase) and was kept up to date on the V&V progress by Q-tility though regular V&V progress reports.

Figure 9: Distributed Air Operation Mission Training Environment Architecture (Adopted from [11])

Objectives of the exercise regarding the GM-VV:

- Evaluate the utility of the GM-VV project and technical level components for the V&V of (LVC) distributed simulation applications;
- Establish a tailored instance of GM-VV in the form of a reusable V&V life cycle model by applying the GM-VV tailoring framework Phase 1: instantiation [5];
- Evaluate and refine the freeware yEd tool for developing V&V argumentation structures and standard office tools (e.g., MS-Word, MS-Excel, MS-Project, and MS-Share-point) to support the GM-VV process activities, document, and manage the GM-VV information artifacts;
- Develop an initial basis for a M&S risk-analysis and reporting approach that could be applied as a future concrete technique for "tailoring by balancing" in the GM-VV tailoring framework Phase 2: optimization [5].

Major findings and lessons learned:

- The GM-VV project and technical level components showed sufficient utility for a satisfactory V&V of this (LVC) distributed simulation application;
- The yEd tool and the standard office application based GM-VV support tools showed to be effective and efficient for this V&V study;
- The V&V of the classified simulation application MASE required additional V&V planning, time, and resources to complete the V&V study compared to the non-classified simulation applications. Furthermore, V&V configuration and information management process required more attention, effort, and more formal implementation.

4.8 Case Study "Public Order Management Serious Game"

The "Public Order Management Serious Game" (as visually depicted in figure 10) case study is based on reference [13]. TNO examined how commanders can learn to maintain public order in their area of operations. Serious gaming proves to be an effective and efficient learning tool. Q-tility has performed an explorative V&V study to the added value of a demonstrator Public Order Management (POM) serious game. The study results show its added value as well as extensions to the current game.

One of the POM game users is the Royal Netherlands Marechaussee (KMar). The game can potentially be used for a number of training objectives. With V&V, the KMar instructors wanted to find what objectives the game is already suited for and what needs to be adapted in order for the game to have utility for the full set of training objectives.

Figure 10: Public Order Management Serious Game (Adopted from [13])

Objectives of the exercise regarding the GM-VV:

- The KMar trainers and various subject matter experts hired by Q-tility derived the acceptance criteria from the main goal: the game must ensure that training objectives are achieved more efficiently and effectively;
- Further define templates for GM-VV documents;
- The V&V tests consisted of two full training sessions, 4 days in total, in which KMar personnel used the POM game as they intend to use;
- V&V techniques included interviews, observations, 360° assessment, and hardware/software inspections.

Major findings and lessons learned:

- The V&V results confirmed many of the strengths and weaknesses of the game;
- The added value of V&V is that now sufficient— and independently obtained—data is available to back up these claims;
- The POM game developers also appreciated the inde-pendent view on the usefulness of the game to prevent tunnel vision in the development team;
- Immediately after the V&V tests, the KMar had started implementing changes to allow for efficient and effective use of the POM game.

5 Concluding Remarks

This article has presented an overview of the GM-VV to support the acceptance of simulations, models, and data.

GM-VV is the outcome of a long international collaboration which has been driven by the need to share V&V results and relevant information from one M&S organization, project and technology or application domain to another, without limitations due to V&V methods practices and techniques chosen.

Moreover, this article has also presented a number of cases, where GM-VV has been applied across different countries. The outcomes of the cases presented have been well received by stakeholders and practitioners paving the way for a wider adoption of GM-VV in more M&S organizations and domains. According to stakeholders and practitioners involved in these cases, GM-VV has demonstrated utility for their V&V efforts by providing:

- A clear path between M&S application/use, M&S goals/intentions, and the rigor required to verify and validate this path. Especially the goal orientation of the GM-VV has been acknowledged as an important practical advantage, especially in terms of validation, which aims at whether the M&S goal is achieved
- Structure in the V&V effort based on a documented and transparent chain of evidence produced between the declared intended use of M&S and the assertion whether the intended use is met or not, thus concluding acceptance
- A rigid requirements definition and formulation process for M&S intended use based on existing standards and practices (e.g., [3]), which makes the V&V of such requirements clear with respect to the intended M&S use.

Furthermore, GM-VV is an approved SISO recommended practice guide. A product support group has been setup within SISO [14], to monitor and collect experiences from applications of GM-VV to amend future improvements of the methodology.

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Authors´ Biographies

Mr. Fredrik Jonsson

Mr. Fredrik Jonsson is working as a product and project manager for M&S infrastructure at the Swedish Defence Materiel Administration (FMV). He holds an M.Sc. degree in mechanical engineering from Linköping Institute of Technology (LiTH), Sweden. Over the last 10 years he has been working with different M&S projects focused on M&S infrastructure and design guidelines for the Swedish Armed Forces. He is the Swedish PoC in the MSG-073 task group and has been part of the SISO GM-VV product development group.

Mr. Constantinos Giannoulis

Mr. Constantinos Giannoulis is a Ph.D. candidate at the Department of Computer and Systems Sciences (DSV) at Stockholm University. He holds a M.Sc. in information technology from the Royal Institute of Technology (KTH). His research interests include Goal & Strategy Modeling, Enterprise Modeling, Requirements Engineering, and Systems V&V. Mr. Giannoulis has been assistant draft editor for the SISO GM-VV product development group.

Dr. Manfred Roza

Dr. Manfred Roza is a senior R&D engineer at the Training, Simulation, and Operator Performance department of the NLR. He holds a M.Sc. and Ph.D. in aerospace M&S technology from the Delft University of Technology. He specializes in requirements, quality assurance, and verification and validation of models and simulation, as such he is one of the technical principles of the Dutch V&V expertise center Q-tility. He was the drafting group editor for the SISO GM-VV product development group and technical lead within the MSG-073 task group.

Dr. Martin Adelantado

Dr. Martin Adelantado graduated from the French Graduate School for Engineers in Computer Science (ENSEEIHT) in 1979. He received his doctorate in 1981 and his HdR (Accreditation to Supervise Researches in Computer Sciences) in 2004. He is working at ONERA (The French Aerospace Laboratory) in Toulouse, France as senior researcher engineer in M&S of complex systems. Since April 2011, Dr. Adelantado has chaired the MSG-073 task group and has been member of the SISO GM-VV product development group.

Dr. Jean-Louis Igarza

Dr. Jean-Louis Igarza retired from the French MoD in 2010 after 41 years of activity, mainly for DGA (General Directorate for Armament). He is now supporting the "Antycip Simulation" company as a consultant. Formerly chief scientist of the NATO MSCO for 3 years, he has been an NMSG member since 2003 and, chaired it from May 2006 to May 2008. He is now one of the few Members at Large of the NMSG representing France. The main part of his career in DGA was in Operational Analysis (air domain) and then moved into M&S. He taught M&S at the University of Versailles as an associate professor for ten years. He is presently an elected member of the SISO Executive Committee (the unique non-US member) and he chaired the GM-VV product development group of SISO. He is a founding member of the European Training and Simulation Association (ETSA) and the vice-chairman of the ETSA Board of Directors.

Major Event Security Planning: Secure by Design Through the Strategic Use of Integrated Modeling and Simulation

AUTHORS

Dr. Anthony J. Masys Dr. Andrew Vallerand

Centre for Security Science
Defence Research and Defence Canada

ABSTRACT

SHOCKS IMPINGING ON MAJOR EVENTS STEMMING FROM NATURAL HAZARDS, ACTS OF ARMED VIOLENCE, TERRORISM, AND TRANSNATIONAL CRIME CAN HAVE SIGNIFICANT SECURITY IMPLICATIONS. TODAY, NATIONS HOSTING A MAJOR EVENT FACE AN UNCERTAIN AND COMPLEX SECURITY LANDSCAPE, IN WHICH THREATS IMPACT/TARGET THE PHYSICAL, SOCIAL, ECONOMIC, AND CYBER DOMAINS. WITH CONSIDERATION OF THIS THREAT LANDSCAPE, SUCH EVENTS AS VANCOUVER 2010 WINTER OLYMPICS, LONDON 2012 SUMMER OLYMPICS, SUPER BOWL XLVIII OF 2014, AND SOCHI 2014 WINTER OLYMPICS EPITOMIZE THE INHERENT COMPLEXITIES ASSOCIATED WITH SECURITY PLANNING. FOR EXAMPLE, THE VANCOUVER 2010 OLYMPICS THEATRE OF OPERATIONS INCLUDED OVER 30 SECURE VENUE LOCATIONS SPANNING 150 KILOMETERS AND COVERED APPROXIMATELY 15,000 SQUARE KILOMETERS, THEREBY SURPASSING ALL PREVIOUS MAJOR EVENTS WITHIN CANADA IN SCOPE, SCALE, AND COMPLEXITY. FIVE OVERARCHING DIMENSIONS CAPTURE THE COMPLEXITY INHERENT IN SECURITY PLANNING AND OPERATIONS:

- THEY ARE MULTIDIMENSIONAL AND MULTIDISCIPLINARY;
- THERE ARE DIFFERENT POSSIBLE WAYS OF LOOKING AT THEM;
- THERE EXISTS A RESIDENT UNCERTAINTY AND OFTEN LACK OF INFORMATION REGARDING MATTERS PERTAINING TO SECURITY PLANNING AND OPERATIONS;
- THERE IS A NECESSITY FOR GROUP INTERACTION TO FACILITATE DECISION MAKING;
- SOLUTIONS ARE OFTEN CHARACTERIZED AS HAVING COMPETING AGENDAS.

MODELING AND SIMULATION IN SUPPORT OF MAJOR EVENT SECURITY PLANNING CAN STRATEGICALLY HELP DESIGN MITIGATING SECURITY STRATEGIES AND PROTOCOLS TO DEAL WITH THE UNCERTAIN THREAT AND RISK LANDSCAPE. DRAWING UPON VANCOUVER 2010 WINTER OLYMPICS, G8/G20 SUMMIT, AND ASIA-PACIFIC ECONOMIC COOPERATION (APEC) COUNTER-TERRORISM TASK FORCE MAJOR EVENT SECURITY FRAMEWORK PROJECT, THIS PAPER DESCRIBES HOW MODELING AND SIMULATION (M&S), AS PART OF A "DESIGN THINKING" APPROACH, CAN ADD VALUE AND CAN BE, AND HAS BEEN, INTEGRATED INTO THE FIVE PHASE MAJOR EVENT SECURITY PLANNING PROCESS: INITIATION, ORIENTATION, CONCEPT OF OPERATIONS, PLAN DEVELOPMENT, AND PLAN REVIEW.

Introduction

Events such as the Vancouver 2010 Olympics, London 2012 Olympics, FIFA World Cup, G8/G20 Summits, and APEC Summits are considered major events by virtue of their international context, importance, and complexity. These characteristics coupled with the dynamic and complex security landscape challenge the organizers along three pillars: event program, security, and safety. These three seemingly independent elements are in fact interconnected and thereby require an integrated approach to major event planning and management. Security design in particular is a problem-solving task that requires the exploration of the "possibility space" associated with the complex threat landscape.

The complexity of the security design for major events cannot be underestimated. The London 2012 Olympic and Paralympics Games successfully ended on 9 September 2012 without any significant disruption. The threat landscape for the major event was, however, significant. "The day after the bid had been won, suicide-terrorist bombs exploded on the London transport system, killing 52 and injuring more than 700 people. Only 355 days before the start of the Olympics, rioting, looting, and destruction had rocked London and other UK cities for four days, resulting in five deaths, injuries to more than 180 police officers, and damage estimated at more than £200 million" [1].

Complex security design requirements confront decision makers, particularly during early phases of the event planning with varyingly over-determined or under-determined system structures. An integrated design approach to support major event security planning is thereby required; one that provides the requisite fidelity and insights to support decision making. Modeling and Simulation (M&S) emerges as a key element to support security planning [2]. Bringing M&S to the act of designing influences the way we see, think about, and approach security design outcomes. From a high-level perspective, M&S supports security design:

- Describe the holistic human-environment system considering all interacting factors;
- Coordinate different areas of security design that are usually objects of separate consideration;
- Shape the security "system behavior" (facilitating foresight through design).

In this sense, M&S cannot be considered as a feature that is just added to the design or the engineering specification. It interacts profoundly with many design aspects "on the surface," as well as with the implementation and operationalization of the security design. Therefore, M&S should not be managed as an additional discipline separate from the security design, but must be integrated into the planning and design process.

This paper describes an integrated approach to major event security planning through the strategic integration of M&S within the Major Event Security Framework (MESF) [2]. It also describes some elements of the MESF that add value to other nations and how it will be used by the Asia-Pacific Economic Cooperation (APEC) economies that are transitioning it to their environment.

Major Event Security Framework

The MESF was designed stemming from the lessons learned from the Vancouver 2010 Olympics and the 2010 G8/G20 Summits. The strategic vision of the "Whole of Government" MESF is to further enhance the preparedness of the Canadian government through its security and safety stakeholders by formally establishing a standard and comprehensive approach to major event security and safety planning. With this in mind, the framework is defined by its purpose in:

- Facilitating an overarching guide for Major Events Security Outcome Management;
- Providing standardized planning process;
- Ensuring control of strategic and operational planning;
- Enabling strategic goals to be translated to operational level security objectives;
- Enabling stakeholders to guide development of the plan, and to synchronize and integrate joint; operational security functions;
- Maximizing effective and efficient use of resources [2].

The corner stone of the framework realizes that a sound planning process should be orderly, analytical, and consist of logical steps to identify a mission or requirement; develop, analyze, and compare alternative courses of action; select the best course of action (COA); and produce a plan.

The MESF itself underwent a robust Verification, Validation, and Acceptance (VV&A) process that involved process and content validation through iterative prototyping, conceptual modeling, numerous table-top exercises, and feedback derived from operational deployment. The MESF facilitates unprecedented levels of collaboration, a standardized (scalable) planning process, Tools and Techniques (What to do and How to do it), draws upon best practices, links to knowledge repository of templates, examples and reference material, provides a knowledge sharing mechanisms within and across economies, enabling effective and efficient use of resources, and embraces a Whole of Government posture to major event security planning.

The kernel of the MESF is the security planning process. It is comprised of five phases: initiation, orientation, concept of operations, plan development, and plan review (figure 1).

The success of the MESF is derived from the design thinking approach that shaped the development, which includes the M&S strategies integrated into the process.

Design Thinking

"Design thinking" as a concept captures a problem structuring/designing approach popularized by Rowe [3]. Across the application domains of design, design thinking can be seen as a grounding framework for multidisciplinary teams to communicate and to coordinate activity [4]. Design represents a process that embraces innovation, creativity, opportunity analysis, and problem framing and solving. Historically, design has been treated as a downstream step in the development process [5], however it is argued in this paper that design (integrating M&S) is an essential element of security planning.

Design Thinking is characterized as an iterative (not linear) five step process (figure 2). Within the context of M&S integration, the five steps are:

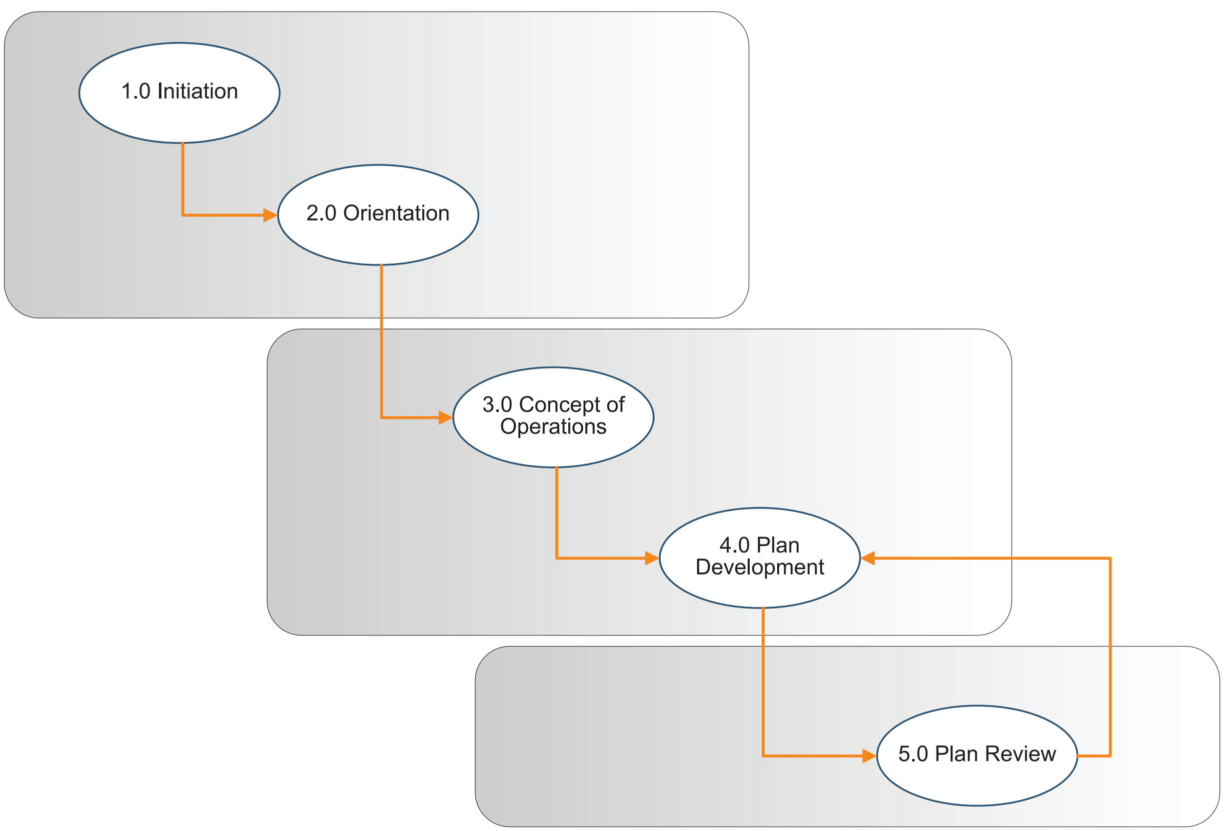


Figure 1: Major Event Security Planning Process

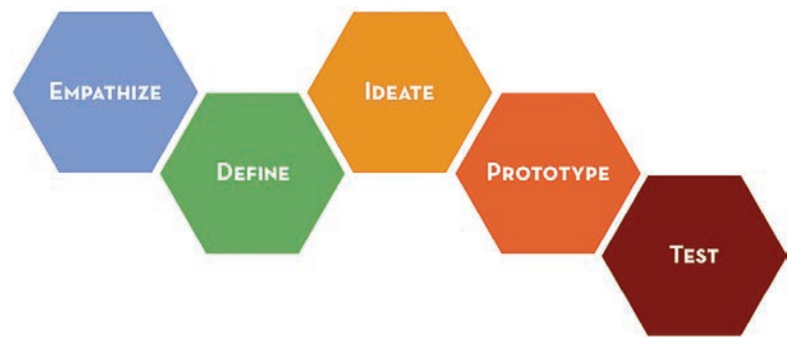


Figure 2: Design Thinking Process

- **Empathize**: Empathy is a key element. It is about understanding the problem space from the stakeholders perspective: in effect walking in the shoes of the stakeholder. It is about understanding the stakeholders needs (empathy) and their challenges;
- **Define**: Define is about making concrete the actionable problems. This is essentially Problem Framing supported by M&S;
- **Ideate**: Ideate is to come up with many solutions, exploring the problem space through M&S. Examining creative solutions (holistically);
- **Prototype**: Prototyping is about iterative development informed through M&S. Developing some rapid prototypes that help refine the problem understanding;
- **Test**: Testing is about validating the security design. M&S and VV&A figure prominently in this phase.

The design thinking approach integrates M&S to support the major event security planning.

Results and Discussion

Lessons learned from deployed application of the MESF have emphasized the requirement for the application of M&S during each one of the five phases. As an integrated element of security planning, M&S provides the requisite vehicle to facilitate the security design. Figure 3 presents the five phases of the security planning process linked to a "smorgasbord" of M&S instruments: tools, techniques, and methodologies that support the security design. Given that building security capability to support major events requires facing a variety of tradeoffs, M&S helps to support decision making by providing verified and validated "evidence-based" models that are transparent, rigorous, and insightful. A security design cannot be deduced directly from specification; M&S is required to support specification development, to test options, and to iteratively approach the final design. As such, M&S informs each phase of the planning process.

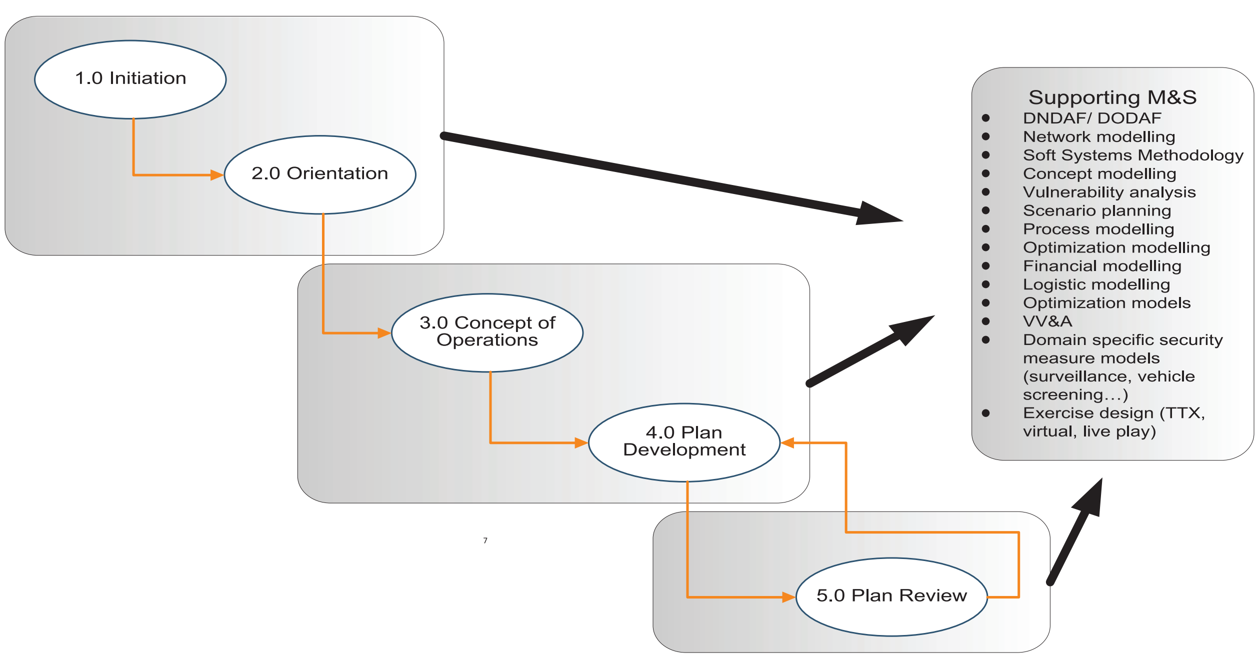


Figure 3: Canadian Examples of Where M&S was Mapped to Major Event Planning Process

An integrated M&S approach improves the transparency regarding security decision making and thereby enhances the security design by identifying organizational threats, opportunities, and capabilities required to support the management of risks.

Initiation Phase

The initiation phase is characterized by identifying the context, vision and mandate of the major event, the key stakeholders, and how security is envisioned. Conceptual modeling and network modeling figure prominently in the initiation phase (figure 4). It is used to describe, understand, and manage the complex relationships regarding major event security. As such, it supports the creation of a roadmap to achieve security objectives by providing a common approach to systematically and completely define the operational view [6].

Both Vancouver 2010 Olympics and G8/G20 Summits highlighted the importance and value of employing M&S at this early stage through the application of architectural frameworks and network modeling.

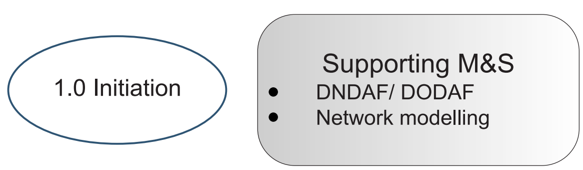


Figure 4: Initiation Phase and Supporting M&S

Employing major event security architecture through modeling supported by Department of Defense Architecture Framework (DODAF)/Canadian Department of Defence Architecture Framework (DNDAF) facilitates decision making to support alignment with the strategic vision of the major event. As described in Dixson and Genik [7], "…an architecture framework (AF) is a mechanism for articulating and describing all the components that comprise a business5 enterprise as well as their connections to one another. The framework is based upon the idea of looking at the enterprise structure from different 'views'." Some of the benefits of employing a major event security architecture include:

- **Information Management**: Improved quality, availability, and communication of information supporting security operations;
- **Decision Support**: Improved analysis for decision making to reduce risk;
- **Event/Security/Safety Alignment**: Alignment of solutions with organizational vision and strategy and operational requirements;
- **Managed Complexity**: Provision of simplified views that help communicate the complexity of security processes and systems;
- **Managed Mental Model**: Alignment or realignment of the deep understanding of people's thought processes associated with security processes and systems;
- **Managed Situational Awareness**: Improved quality, availability and communication of real time geo-located information, alerts, and warning;
- **Interoperability**: Specification of interfaces between major event security systems and organizations (both internal and external) to improve security system quality and flexibility;
- **Economies of Scale**: Identification of opportunities for reuse, shared services, and information;
- **Standardized Vocabulary**: Enables analysis with a reference architecture.

Modeling supported by major event security architecture is represented through graphics, models, and narratives that describe the security design. To provide consistency across the resulting complex design, the representations are developed according to a unifying architectural framework. The purpose of the framework is to communicate various perspectives of the major event (program/security/safety), such that analysis and decisions are co-created through informed participative analysis, thereby supporting rigorous, explicit, repeatable, and defensible arguments. In this way, the modeling approach provides a structure for organizing information and for describing and managing change within the major event security.

Such conceptual modeling as realized by the Operational View (OV) (figure 5) provides an operation level description of the tasks, activities, business processes, and information exchange requirements to accomplish security objectives. This is achieved through a collection of graphical and textual operation sub-view products. The Operational

View comprises seven main areas:

- Operational Concepts;
- Operational Nodes;
- Information Exchange Requirements (IER);
- Organizational Relationships;
- Operational Activity;
- Operational Rules and Dynamics;
- Logical Data Models of OV data requirements and rules.

Network modeling (figure 6) figures prominently in the initiation phase and the orientation phase. It provides insights into security organizational matters pertaining to command, control, and information sharing. Research has shown that information sharing is one of the critical elements of security planning and operations. As such, its prominence as a design tool is essential. It is important to realize that one consequence of a highly complex environment is that our internal mental modeling ability quickly

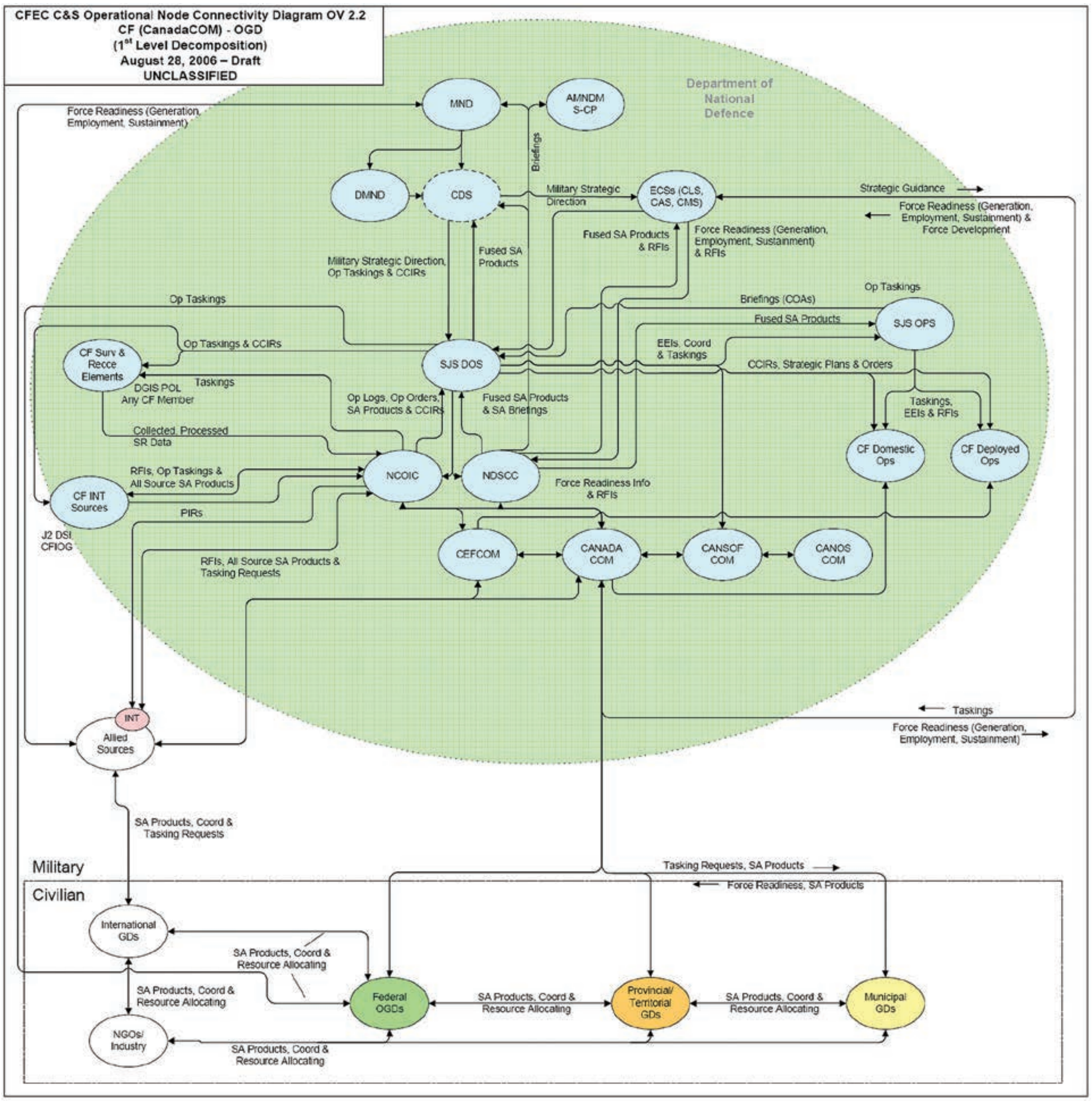


Figure 5: Operational View Interagency Connectivity

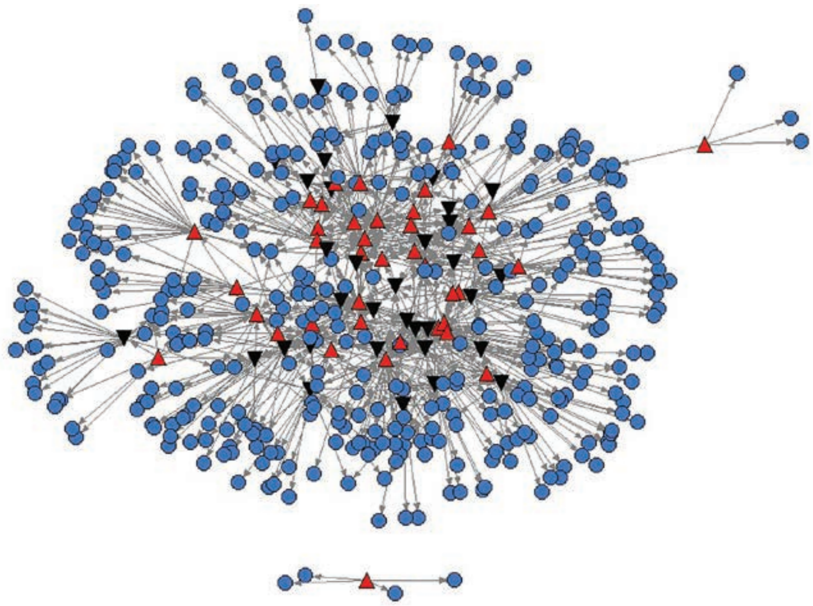


Figure 6: V2010 Olympic Security Planning and Operations Complete Affiliation Network Based on Key Information Sharing Relationships [9]

becomes overwhelmed. While this situation can occur within complex military Operations, it is equally, if not more, likely to occur within complex multi-agency domestic security or Counter-Terrorism Operations [8]. Architecture framework modeling such as in figure 5 normally helps achieve alignment of mental models amongst multi agency units.

Orientation

The orientation phase is characterized by further developing strategic relationships as well as articulating the threat and vulnerability landscape. Vulnerability analysis/modeling and scenario planning figure prominently in the orientation phase (figure 7).

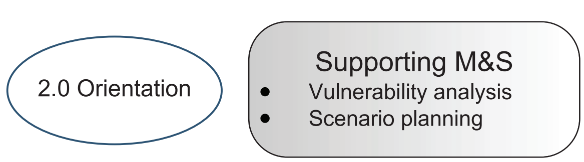


Figure 7: Orientation Phase and Supporting M&S

Managing and communicating risks have become crucial tasks in security planning. Visualization—through its numerous cognitive and communictive advantages—can play an important role in comprehending and conveying risks [10]. Risk models, such as that depicted in figure 8, help to support risk-related communication through risk maps showing impact/likelihood. This model is further supported through network vulnerability analysis depicted in figure 9. Modeling critical infrastructures within the security environment of the major event helps to identify security resource and capability requirements.

Overall, supporting decision making through risk visualization, M&S

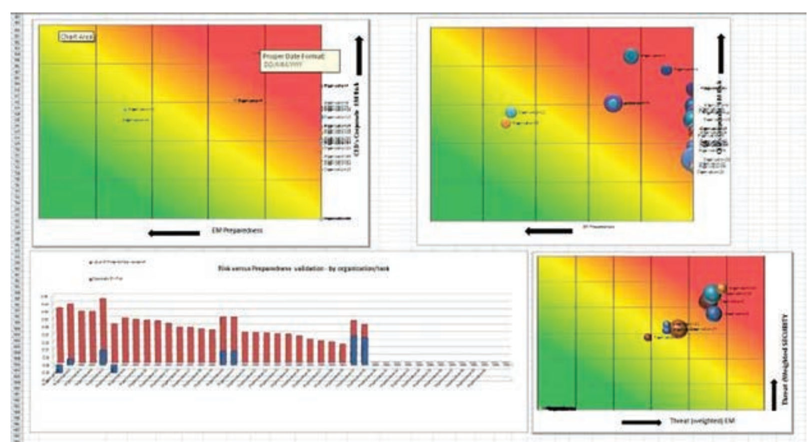


Figure 8: Risk Mapping

outputs through charts, conceptual diagrams, visual metaphors, and mapping techniques improve the understanding and subsequent management of risks [10]. One such mapping technique for common situational awareness in Canada is Multi Agency Situational Awareness System (MASAS) [11]. Currently operationalized by about 475 Agencies in the government of Canada, MASA visually Geo-locates Alerts, Warnings, and Hazards for common situational awareness to all involved in the Event. Being

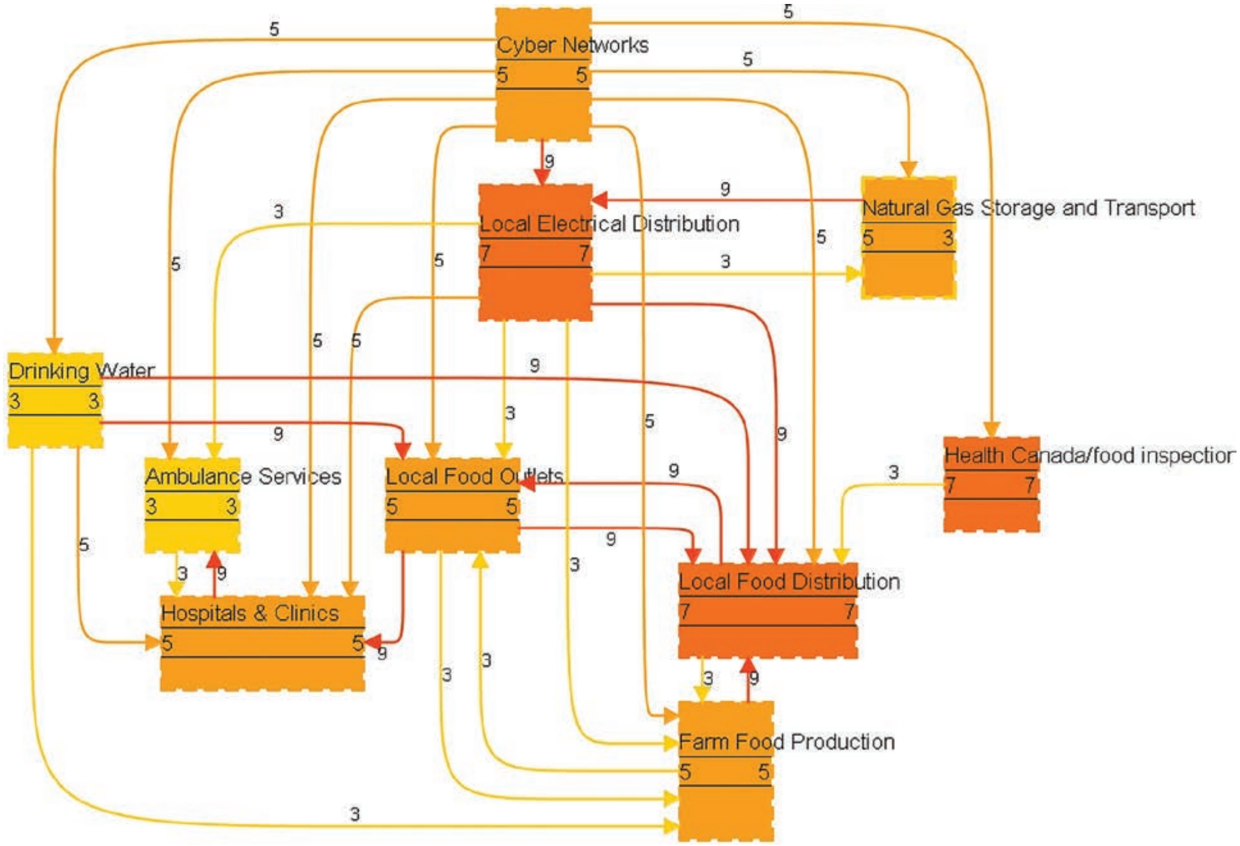


Figure 9: Infrastructure Model-Vulnerability and Interdependency Model [12]

an open architecture with International Standards system, the MASAS derived Canadian situational awareness was rapidly and persistently extended to the Americans by an easy plug in to the USA systems from Department of Homeland Security (DHS) Science and Technology (S&T) (Virtual USA) and Federal Emergency Management Agency (FEMA) (IPAWS) in the "CAUSE 2" simulated scenarios of that "Beyond the Border" Experiment [11] requiring the right input, the right visualization for the right transborder decision making in Homeland Security scenarios.

As described in Masys [13], scenario planning represents a set of tools and methodology for foresight facilitating discourse with the purpose not to predict, but to facilitate a change in the mindset of the people who use them: in short, to think the unthinkable [14]. Supporting major event security planning, the use of scenarios stretch and refocus thinking, thereby challenging the assumptions that characterize foresight and planning. Informed narratives or stories about possible or plausible futures informed through validated M&S are essential tools of the scenario planning process supporting major event security planning. To be effective, these stories must represent a combination of analysis and imagination, and be challenging, credible, and convincing [15].

Masys and Vallerand [2] argue that the development of security and safety scenarios, and the establishment of a threat-based view of a major event, steers the focus of major events security toward a capability-based planning approach. Since the problem space of security and safety involve an inherent uncertainty, it is important to explore and build capabilities that can be applied to a wide variety of incidents. Capability-based planning is all-hazards planning that identify a baseline assessment of safety and security efforts and emerges as a key deliverable from the orientation phase and subsequent phases.

Concept of Operations (CONOPS)

The CONOPS phase captures the models and insights derived from the initiation and orientation phases, and begins to develop a conceptual model of the major event security. Soft Operations Research (OR) and conceptual modeling figure prominently in this phase (figure 10).

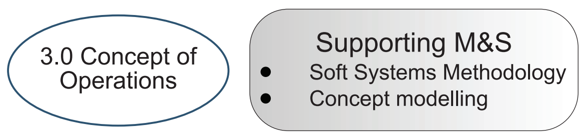


Figure 10- Concept of Operations Phase

Soft OR methods have become widely accepted as a significant new direction for operational research and systems movement. They mainly help define where the problems actually lie and attempt to provide a clear view of how to overcome them; a key factor in security planning [16]. Soft Systems Methodology (SSM) (figure 11) is one of the most widely used soft OR methods. Comparing real world and abstract "model" world facilitates insights and debate focused on the differences, disconnects, and uncertainties. In this way, SSM acts as a learning system, a system of enquiry, and helps the user to pay attention to the activities within the problem situation and take a systematic view to understand it [16].

Checkland [18] proposes the "rich picture" as a representation to be used at the beginning of the SSM process. It is a diagrammatic way of sharing one's own experiences and perceptions regarding a given problem situation through the identification and linking of a series of concepts. The creation of a rich picture thereby provides a forum in which to think about a given situation in a collaborative manner.

A rich picture (figure 12) is a graphical representation of a problem, concept, situation, or work domain. It can include any kind of figure or text and has no prescribed rules or constraints. Its primary purpose is to describe a system in such a way that is useful to both individuals external to, and actors within that system; it serves to organize and structure the body of information provided by the experts.

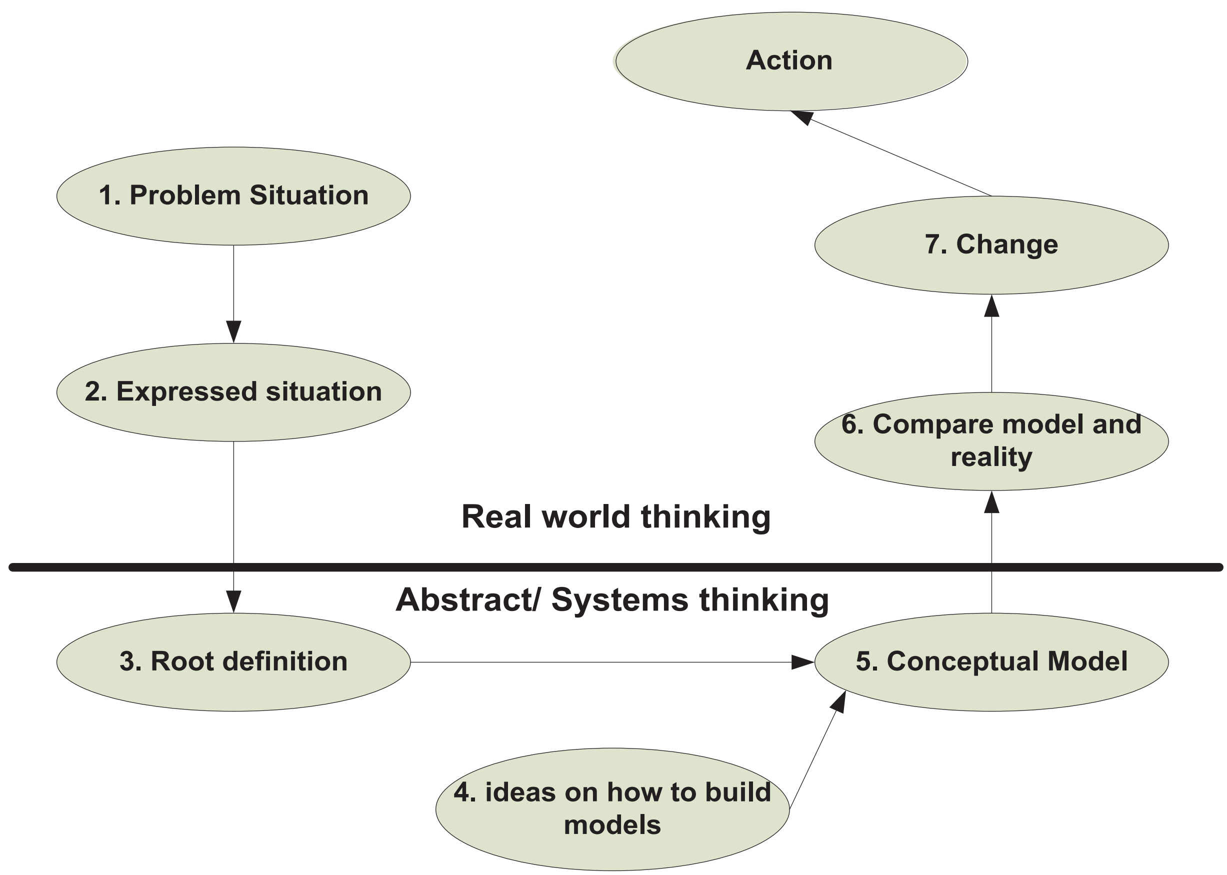


Figure 11: Soft Systems Methodology (SSM) [17]

These rich pictures serve as models produced in facilitated interventions and used by managers to share and increase their individual understandings of the problem situation of interest, help them articulate their preferences, and thus enable them to appreciate the potential impact of different options, and facilitate the negotiation of courses of action [19]. The qualities of transparency (easy to understand), accessibility (easy to make), and collaboratively developed, make this visual method highly successful in framing the problem space. By having everybody collaboratively contribute to a rich picture, a shared understanding of a given situation emerges.

The rich picture in figure 12 depicts the operational planning derived from a security planning workshop held in support of the APEC Counter-Terrorism Task Force Santiago, Chile, October 2013 [20]. It shows a high level view of the MESF planning process and the key considerations in each phase.

The rich picture helped structure and facilitate the conversation regarding security planning process and was instrumental as a communication tool during the security planning workshop [20].

Plan development

The plan development phase builds upon the outputs from the previous phases to identify and build the "integrated" security plans. Domain specific security M&S figure prominently in this phase as we begin to provide an operational and tactical design and direction (figure 13).

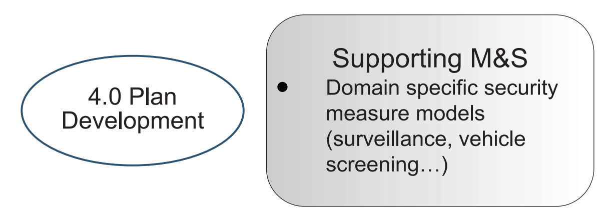


Figure 13: Plan Development Phase

Uncertainty is a strategic concern for many organizations concerned with security planning. The application of scenarios supports the identification of key factors that will have serious implications in the future. By taking actions and informed decisions based upon the scenarios, future risks can be avoided and possible opportunities anticipated [21].

The power of visualization lies in its potential to surface implicit assumptions, capture different perspectives, and reveal key insights. Recognizing Chemical, Biological, Radiological, Nuclear, and Explosives (CBRNE) as part of the threat landscape associated with Vancouver 2010 Olympics and G8/G20 Summits, M&S in the guise of windfield dispersion models figured prominently in the design of security measures, protocols, and resource allocation (figure 14).

Similarly, M&S was employed to support Vehicle Screening and Personnel Screening protocols supporting both Vancouver 2010 Olympics and G8/G20 Summits [2], [25].

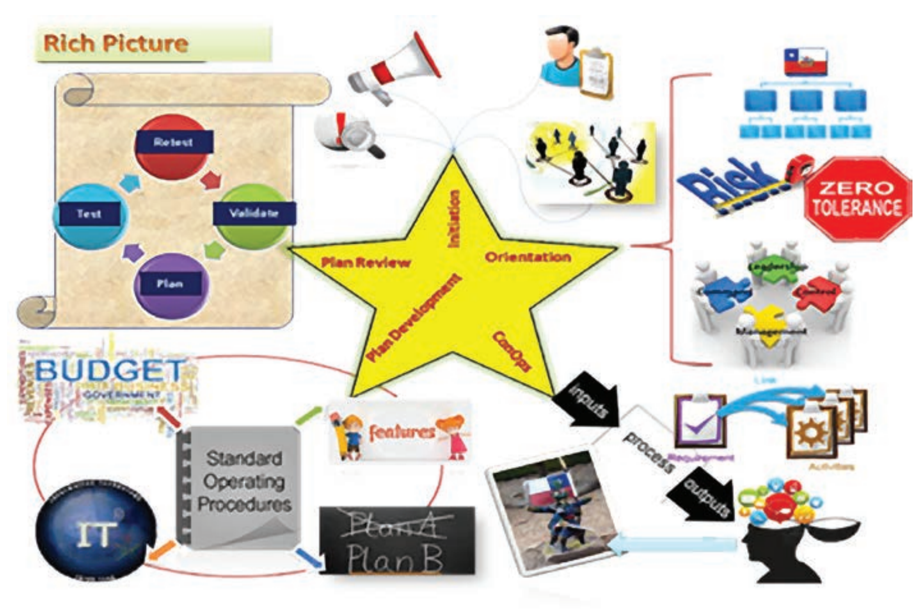
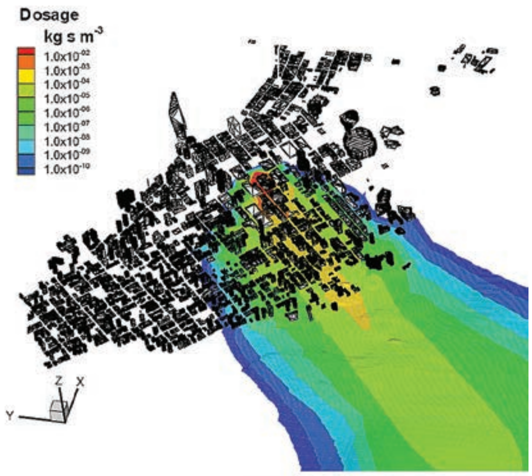
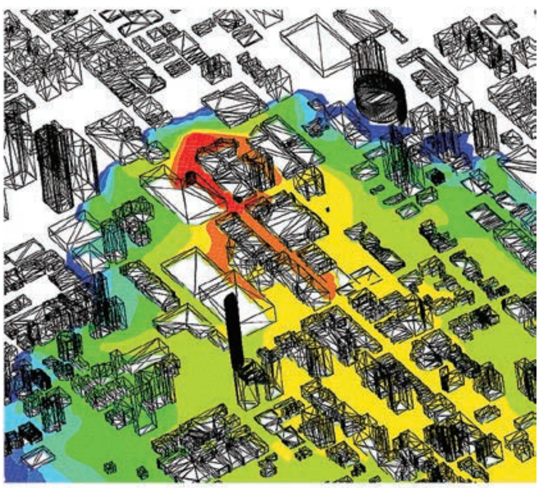


Figure 12: Rich Picture of MESF Planning Process



(a) Large area



(b) Small area

Figure 14: Dispersions Models Used to Support Planning for Vancouver 2010 Olympics [2]

Plan review

The plan review phase is characterized by establishing a confidence and preparedness assessment of the security measures in place for the major event. This essentially is a verification and validation process. Exercise design using table-top, virtual, and live play methodologies figure prominently in this phase (figure 15).

While most conventional exercise design focuses on what analysts believe is the most likely outcome, contingency "what if" analysis focuses on the possible causes and consequences of an unlikely event [26]. During Vancouver 2010 Olympics, these were explored through various

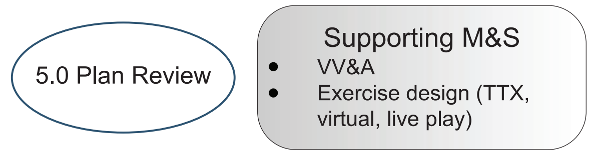


Figure 15- Plan Review Phase

exercises Bronze, Silver, and Gold [2]. The objectives of the GOLD exercise were designed specifically to *confirm* various existing Vancouver 2010 CBRNE response plans and ConOps, as well as the joint command, control, and communications processes within both the urban and Olympic domains (figure 16). Over the course of five days, organizations at every level (municipal, provincial, federal, and international) participated in a series of command post exercises (CPX), and two live-play events resulting in the largest exercise of its kind in Canadian history.

Figure 16- Support to the Major Events was Realized in Part Through the Deployment of Science Town [2]

In many ways, all phases of the MESF (i.e., Initiation, Orientation, CONOPS, Plan Development, and Plan Review) and the broad strategic use of M&S have been used by Canadian authorities, but they are also being exploited (i.e., transitioned and operationalized to support security partners such as the APEC economies through the APEC Counter-Terrorism Task Force [20], [22-24], and in support of the "Sommet de la Francophonie," 2014 in Dakar, Senegal).

Conclusion

The evidence from this manuscript has suggested that M&S in support of major event security planning can strategically "design-in" mitigating security strategies and protocols to deal with the uncertain threat and risk landscape of any Major Homeland Security Event. Drawing upon Vancouver 2010 Winter Olympics, G8/G20 Summit, and APEC Counter-Terrorism Task Force Major Event Security Framework exploitation, this paper described how M&S, as part of a "design thinking" approach, adds value to authorities' mental models, decision making, situational awareness, etc., and has been integrated into the five phase major event security planning process: Initiation, Orientation, Concept of Operations, Plan Development, and Plan Review.

Linked to a suite of M&S tools, techniques, and methodologies, the security design process effectively enables the development of the five phases of the security planning in either a complex military operations or a similarly complex, or even more complex, multi-agency ecosystem. Given that building security capability in support of major events requires facing a variety of tradeoffs, M&S helps to support decision-making by providing verified and validated "evidence-based" models that are transparent, rigorous, and insightful. M&S is also known to facilitate the alignment of different mental models of various individuals from different environments supporting the effort. Though M&S for Major Event Security Planning emerge as extremely powerful instruments, tools, and solutions to the multi-agency decision makers, significant gaps remain, particularly in what we don't know. Owners and custodians of very critical national infrastructure, physical and digital, have repeated that one of the elements that they fear the most is what they don't know but can affect them the most, for instance "Black Swan" events. The Black Swan Events are low probability and high consequence events that seem to follow a power-law distribution in line with a major catastrophe that just started small and did not stop growing to develop into extreme sizes. Modeling, or better modeling of such new and emerging events would enable from an All Hazards perspective, related emergency management planning and business continuity planning, when there is none. Further, and more recently, another significant M&S gap has surfaced: the modeling of the "Dragon-King" event. This is another category of event that seems to be difficult to predict, as it can be seen as a disastrous outlier event [27]. A Dragon-King event would appear as a result of amplifying mechanisms that are not necessarily fully active for the rest of the population: i.e., sustained drift whose duration time is much longer than that of any other event, or an abrupt shock whose amplitude velocity is much larger than other event [27]. Regardless of their mechanism of action, the ability to detect and to mitigate such All Hazards events (terrorism and man-made events to natural hazards) certainly appear as two key gaps and challenges for the M&S Community in support of Homeland Security events.

In conclusion, though there are many ways to formulate the Planning of Major Event Security, it is suggested that the Strategic use of Integrated Modeling and Simulation instruments offers a superb opportunity to generate (with data and visualizations) in a complex multi-agency environment, "Security by Design."

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Authors' Biographies

Dr. Andrew Vallerand

Dr. Andrew Vallerand is the Director of the Directorate of Science & Technology (S&T) Public Security of the Center of Security Science, the Defence Research and Development Canada (DRDC) Centre that invests in Homeland Security S&T for impact. As a physiologist and a simulationist, Andrew specializes in the research, design, and transition of innovative S&T in support of Defence & Security Capabilities. At various Centers in Canada and overseas, he has established investment guidance and directions for S&T in Applied Physiology, Modelling & Simulation, eSecurity (cyber), Critical Infrastructure Protection, CBRNE, and Border Security domains. He has led major S&T initiatives, mentored staffs, supervised graduate students, and spearheaded several major S&T programs nationally, as well as Internationally (5-Eyes TTCP; 5-Eyes TSWG; MOUs with US DHS S&T and UK CPNI; NATO RTA Panels). He is now leading Programs in support of "Whole-of-Government"/National efforts to address National Security Capability gaps, with engagement with Government, Industry, Academia, and Allies. He is a passionate S&T author who is recognized by his peers by more than 125 scientific papers and 250 scientific presentations. He has remained engaged with Academia, by retaining responsibilities as adjunct or associate professor at various universities.

Dr. Anthony Masys

Dr. Anthony Masys is a defence scientist for the Department of National Defence, DRDC Centre for Security Science. Assigned as scientific advisor to the Royal Canadian Mounted Police (RCMP) Major Events and Protective Policing Division, Dr. Masys supported both the Vancouver 2010 Olympics and G8/G20 Summits, and through this has influenced the development of the "whole of government" Major Events Security Framework (MESF).

In addition to his duties as a defence scientist supporting the safety and security domains, Dr. Masys is also an associate tutor for the Distance M.Sc. Program on Risk Crisis and Disaster Management at the University of Leicester (UK) and has also been appointed as adjunct professor at York University (Toronto) within the Disaster Management Graduate Program, an adjunct professor at the University of Ottawa (Telfer School of Management), and an associate researcher for the Waterloo Institute for Complexity and Innovation.

A former senior Air Force Officer, Dr. Masys has a B.Sc. in physics, an M.Sc. in underwater acoustics and oceanography from the Royal Military College of Canada, and a Ph.D. from University of Leicester (UK).

He has published extensively in the domains of physics and the social sciences. His research interests focus on terrorism/counter-terrorism studies, human security, complex socio-technical systems, human error, systems thinking, risk, crisis and disaster management, knowledge management, and organizational learning.

An Introduction to the Indigenous ROK HLA Compliance Testing System and the Lessons Learned of Its First Use –

A Case Study of the Advanced TaeGeuk JOS HLA Compliance Test

AUTHOR

Dr. ChongHo Lee

Technology Analysis Team, Defense Agency for Technology & Quality
Korea Economic Daily News Bldg. 4F, Jungnim-dong, Jung-gu, Seoul, Republic of Korea
lchongho@lycos.co.kr

ABSTRACT

SINCE THE EARLY 1990s, THE ROK MILITARY HAS HEAVILY USED SIMULATIONS TO PROVIDE A REALISTIC TRAINING ENVIRONMENT. SOME OF THE TRAINING WAS CONDUCTED SOLELY BY THE ROK MILITARY, WHILE OTHER TRAINING WAS CARRIED OUT BY THE ROK AND U.S. MILITARY COMBINED. SINCE THE HLA WAS DESIGNED AND DECLARED AN IEEE STANDARD, THE ROK MILITARY HAS PUT MORE EFFORTS INTO DEVELOPING ROK SIMULATION MODELS BASED ON THE HLA WHILE THE U.S. MODELING AND SIMULATION COORDINATION OFFICE (M&SCO) PROVIDED COMPLIANCE TESTS FOR THE ROK MODELS. WITH THE U.S. M&SCO ANNOUNCEMENT STATING THAT NO MORE FREE HLA COMPLIANCE TEST WILL BE PROVIDED TO ALLIANCE NATIONS AFTER 2012, THE ROK MILITARY HAS TRIED TO BUILD AN HLA COMPLIANCE TESTING SYSTEM UTILIZING THE KSIMS INFRASTRUCTURE OWNED BY THE ROK. INTRODUCED HERE IS THE ROK HLA COMPLIANCE TESTING SYSTEM AND THE LESSONS LEARNED FROM ITS FIRST USE EVENT FOR THE ADVANCED TAEGEUK JOINT OPERATIONS SIMULATION (JOS).

1. Introduction

Considering the Korean military operational requirements and security environments in the Korean peninsula, the combined operations between Republic of Korea (ROK) and United States (U.S.) military, and the joint operations within ROK military services are very important. Since the early 1990s, especially after the High Level Architecture (HLA) was designed and declared as an IEEE 1516, the ROK military has put more efforts into developing various ROK simulation models based on the HLA to ensure interoperability and reusability not only among ROK models, but also with U.S. models to fulfill the operational requirements.

In 1999, the Korea Simulation Systems (KSIMS), an infrastructure designed to build a federation including all ROK and U.S. models, was proposed [1], [2] and successfully developed by 2004. Also, each service of the ROK military has developed its own ground, naval, air, and amphibious models by the mid 2000s. Initially, the ROK military had built a single federation including all ROK and U.S. models with U.S. consensus. Later on, the ROK military developed a hierarchical architecture including ROK and U.S. federations to control effectively, providing autonomy to the U.S. federation [3].

Up to 2011, all ROK models got the HLA compliance tests from Johns Hopkins University (JHU) Applied Physics Laboratory (APL), sponsored by the Modeling and Simulation Coordination Office (M&SCO). One interesting fact found in connecting ROK models to U.S. models for the ROK-U.S. combined exercises was that even though all ROK models received the HLA compliance certificates, ROK models needed to correct or modify a great part of the data structures before building a federation with U.S. models.

In 2009, M&SCO announced a new HLA compliance test policy and emphasized that the HLA compliance test would no longer be free to alliance nations beginning in 2012, which was a significant change. In consideration of M&SCO policy changes and the ROK military operational requirements, the ROK Defense Acquisition Program Agency (DAPA) finally decided to build a ROK HLA compliance testing system.

2. Major Milestones for Building an ROK HLA Compliance Testing System

2.1 ROK Military Efforts

In 2010, right after the ROK DAPA decided to develop a ROK HLA compliance testing system, they assigned a mission of building an HLA compliance testing system and delegated formal authority as an agent conducting the HLA compliance test to Defense Agency for Technology and Quality (DTaQ). DTaQ, The technology analysis team, formed a small research group and started to build capabilities. At the very beginning of the research, the group studied HLA using manuals and papers, and also participated in the HLA compliance test events as observers for the ROK Army Korean Army Aviation Reconfigurable Tactical Trainer (KARTT) and the ROK Navy Operation and Resource Analysis Model (NORAM) held in 2011.

During that period, the team also tried to establish a formal process and a legal background including rules and regulations for conducting the mission as an agent. In 2011, DTaQ got the fully endorsed authority from the ROK military M&S Coordination Committee chaired by the ROK Joint Chief of Staffs (JCS). In November 2013, the Defense Acquisition Program Management Regulations was finally revised, which states a legal authority of DTaQ for conducting HLA compliance tests.

With all these efforts, DTaQ tried to get the KSIMS infrastructure from the ROK JCS to build an indigenous ROK HLA compliance testing system. Based on the concepts from Government Off The Self (GOTS) products, and with roughly a yearlong administration effort, DTaQ got one copy of KSIMS infrastructure software. Also, to prevent problems that can arise due to lack of experience during the HLA compliance test, DTaQ outsourced to a couple of experts who were KSIMS developers and currently work as system operators.

2.2 ROK & U.S. Military Coordination and Cooperation

In addition to the ROK's own efforts, DTaQ absolutely needed U.S. M&SCO support to build a ROK HLA compliance testing capability. Therefore, DTaQ raised an agenda requesting U.S. M&SCO support at the 42nd ROK-U.S. Defense Technological and Industrial Coordination Committee (DTICC). The ROK and the U.S. reached an agreement that the U.S. would support ROK in building its own capabilities [4]. They also discussed that after the ROK DTaQ built its own HLA compliance test capability, the ROK DTaQ may provide HLA compliance test services on the request of any U.S. alliances in the Pacific and Southeast Asia.

Based on these agreements and consensus, the ROK and the U.S. opened a Foreign Military Sales (FMS) case for purchasing HLA capability [5]. In general, the U.S. M&SCO HLA compliance testing tools consist of two specific tools including the Federate Test Management System (FTMS) and Federate Compliance Testing Tool (FCTT). As aforementioned, because DTaQ had intended to use the KSIMS infrastructure, DTaQ purchased only the FCTT, excluding the FTMS. The FMS process took about a year and a half to reach an agreement in October 2012.

In June 2013, a copy of the revised FCTT was delivered, and DTaQ successfully built an indigenous ROK HLA compliance testing system consisting of the FCTT and the KSIMS infrastructure. The U.S. M&SCO instruction team with one active duty and three civilian experts visited DTaQ, Korea, and conducted FCTT operator's training using the ROK HLA compliance testing system from the last week of July to the second week of August, 2013. The training was successful. After finishing the training, the U.S. M&SCO issued an FMS training certificate on the FCTT and partially endorsed the ROK capability to implement HLA Compliance test [6].

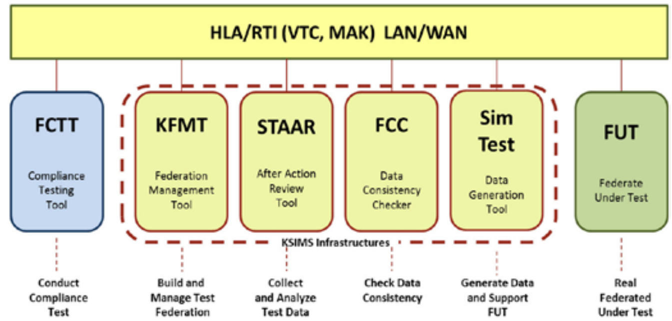

Figure 1: The ROK HLA Compliance Testing System

3. An Indigenous ROK HLA Compliance Testing System

3.1 System Architectural Concepts

The first consideration to build an ROK HLA compliance testing system was to concentrate on the systems themselves rather than personal issues because of DTaQ's shortage of manpower. DTaQ purchased a copy of the revised FCTT as a primary testing tool from the U.S. M&SCO through the FMS case, and acquired a copy of KSIMS infrastructure from the ROK JCS through the GOTS instead of purchasing FTMS. Then, DTaQ built a federation connecting the FCTT and the KSIMS infrastructure and aimed to minimize the human resource requirements for conducting compliance tests.

In the first stage, DTaQ built the Initial Operation Capability (IOC) with operational capabilities on the Local Area Network (LAN) environments, running only on the Virtual Technology Corporation (VTC) Runtime Infrastructures (RTIs). In the next stage, DTaQ will gradually build the Full Operational Capability (FOC) which will include capabilities such as conducting operations on the Wide Area Network (WAN) environments, running on both VTC and MAK RTIs, providing an auxiliary test federate, and data crosschecking, etc.

3.2 ROK HLA Compliance Testing System's Architecture

DTaQ designed and built an indigenous ROK HLA compliance testing system connecting the FCTT with the KSIMS infrastructure as shown in figure 1. Even though the primary tool for the indigenous ROK HLA compliance testing system is obviously the FCTT purchased from the U.S. M&SCO, the ROK HLA compliance testing system is still very efficient and effective. The advantages and disadvantages of the ROK HLA compliance testing system compared to the U.S. counterpart are as follows. First, it is more efficient and powerful in forming and managing a test federation including the Federate Under Test (FUT), with a comparable capability of conducting compliance tests as using the U.S. testing tool. Also, during the test, it can monitor all FUT status and data such as objects and interactions published and subscribed on near-real time. Further more, if anything goes wrong during the test, not only can it provide detailed information on the issue that caused the problem, but it can also help to solve the issue. Unfortunately, it does not have the online capability of handling HLA test applications requested through the internet from overseas. The differences between the ROK's and the U.S.'s HLA compliance testing systems are shown in Table 1.

U.S. HLA CTS	Application Areas	ROK HLA CTS
FTMS	Manage Test Request/Test Federation/Test procedure	
FCTT	Conduct Compliance Test	FCTT
	Create/Manage Test Federation	KFMT
	Log Test Data, Process and Analyze Logged Data	FCC
	Conduct Data Consistency Test	FCC
	Support FUT as Auxiliary Federate	SimTest

Table 1: The Comparison of the U.S. and ROK HLA Compliance Testing Systems

3.3 Descriptions for the Each Component of the ROK HLA Compliance Testing System

As shown in Figure 1, the ROK HLA compliance testing system consists of five components such as the FCTT and the KSIMS infrastructure including KSIMS Federation

Management Tool (KFMT), Systems of Theater After Action Reviews (STAAR), Federation Cross Checker (FCC), and Simulation Tester (SimTest). A brief description for each component of the ROK HLA compliance testing system is shown below.

- **Federation Compliance Testing Tool (FCTT)** - Has been used to directly conduct a HLA compliance test. The test consists of a static test and a dynamic test. The static tests are conducted in two paths, first on the Conformance Statement (CS) and Simulation Object Model (SOM), and secondly on the SOM and Federation Object Model (FOM). The dynamic test, which is the primary test using FCTT, is conducted as the Runtime Compliance Test (RCT) in running condition [7].
- **KSIMS Federation Management Tool (KFMT)** - Has been used to build and manage a test federation including FUT, as well as the FCTT and KSIMS infrastructure. It monitors all activities such as joining and resigning for each component of test federation, and also provides various status reports on the test federation in near-real time.
- **System of Theater After Action Review (STAAR)** - Usually has been used to collect, analyze, and replay all data on the federation. It also monitors the whole transmitted data and closely scrutinizes some of the data if required, and monitors if anything goes wrong during the test.
- **Federation Cross Checker (FCC)** - Originally was designed to cross check all data on the federation before starting exercises to ensure data consistency. It is applied to the HLA compliance test federation because of the abnormalities often found in ROK models while preparing for the ROK and U.S. combined exercises, even though the ROK models passed the HLA compliance test. Eventually, the ROK military has intended to reinforce the HLA compliance test to check and ensure the consistency of all data on the FUT.
- **Simulation Test (SimTest)** – Has been designed and developed to emulate some of the federates, since those federates did not exist when the KSIMS was first developed early in the 2000s. It emulates any kind of federate with some RTI service capabilities. It can act as an auxiliary tool for the FUT by providing interoperable capabilities and checking some of the RTI services.

4. Lessons Learned from the First Use for Advanced TaeGuek JOS HLA Compliance Test

4.1 The first Use Event: Advanced TaeGuek JOS HLA Compliance Test

After DTaQ built an indigenous ROK HLA compliance testing system as described above, DTaQ conducted an HLA compliance test for the advanced TaeGuek Joint Operation Simulation (JOS), as the first use event. The advanced TaeGuek JOS was initially developed for the ROK JCS as a stand alone model in 2004, and modified to become interoperable to other models based on the HLA in 2012. Because of the change in the U.S. M&SCO HLA certification policy, the advanced TaeGuek JOS could not apply an HLA compliance test until DTaQ built ROK HLA compliance testing capabilities. The final objective federation with the advanced TaeGuek JOS in the future is shown in figure 2.

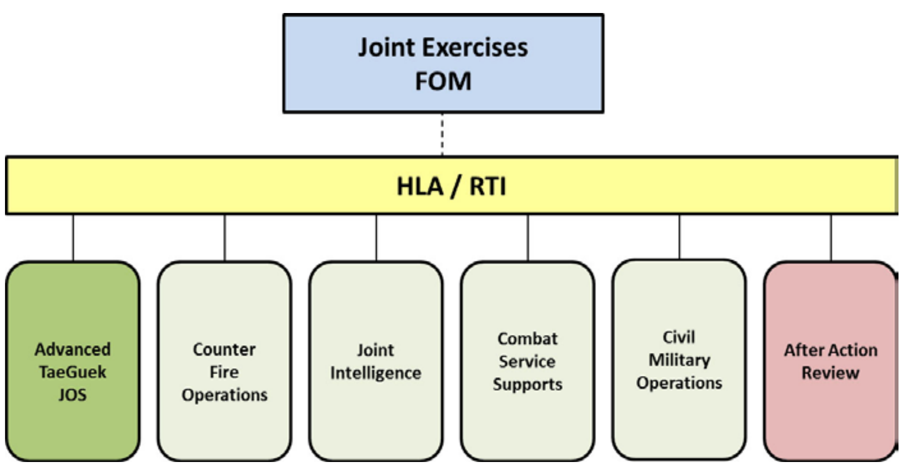

Figure 2: The Objective Federation with the Advanced TaeGuek JOS [8]

The HLA compliance test environment and test system architecture for the advanced TaeGuek JOS is shown in figure 3. Since this first use event is the first HLA compliance test conducted by DTaQ solely, DTaQ decided to conduct the test on the LAN environment conservatively. DTaQ established a test plan and set up the test environments with two separate rooms, one for the test federation, and the other for the FUT.

The test procedure used for the advanced TaeGuek JOS compliance test is in fact the same as the U.S. M&SCO procedure, but has been slightly modified by DTaQ as shown in table 2 [9].

The HLA compliance test for the advanced TaeGuek JOS was conducted from the last week of October until the first week of November, 2013. In the first week of

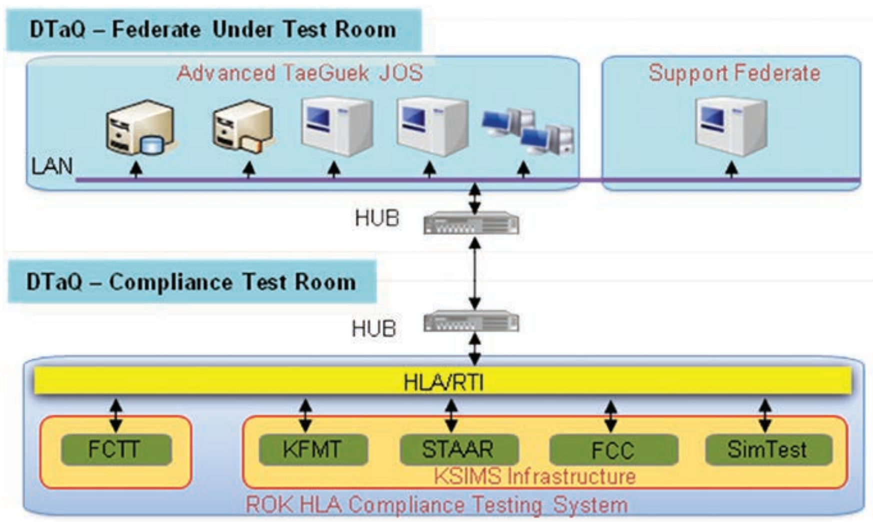

Figure 3: The Test Environment and Test System Architecture

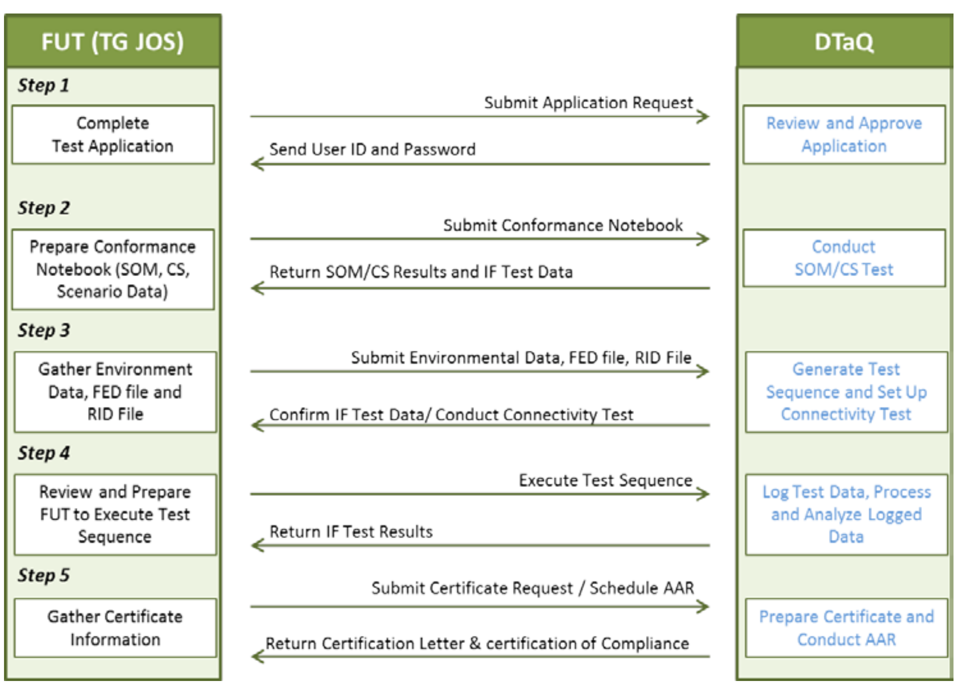

Table 2: The Procedure for the Advanced TaeGuek JOS HLA Compliance Test

the test the primary focus was on the static test, and in the following week on the dynamic test. Both tests were successfully accomplished in a timely manner. The test lists and results of the RTI services applied for the advanced TaeGuek JOS are shown in table 3. The final results of the test are as shown in table 4. Also, some screen captures of the components of the ROK HLA compliance testing system are shown in figure 4 and figure 5.

As initially planned, the HLA compliance test for the advanced TaeGuek JOS was successfully accomplished within two weeks, and finally evaluated as "Pass" by DTaQ. After that, a review session was held for a week with the U.S. M&SCO experts. In actuality, the JHU APL members double-checked the whole procedures in detail and made the same evaluation on the federate.

RTI Services	Detail Service Descriptions	Plan	Test Result		Success
			Pass	Fail	
Federation Management	Create/destroy federation execution	○	○	–	○
	Join/resign federation	○	○	–	○
	Save/restore federation	○	○	–	○
	Use synchronization point service	X		N/A	
Time Management	Set time policy	○	○	–	○
	Time-stepped time advance requests	○	○	–	○
	Event-based time advance requests	X		N/A	
Declaration Management	Publishing objects	○	○	–	○
	Subscribing objects	○	○	–	○
Object Management	Registering/deleting object instances	○	○	–	○
	Updating/reflecting object attributes	○	○	–	○
	Exchanging interactions	○	○	–	○
Ownership Management	Ownership pull	X		N/A	
	Ownership push (Negotiated Push)	X			
	Ownership push (Unconditioned Push)	○	○	–	○
Data Distribution	Create regions, binding object/interaction	X			

Table 3: The Test Lists and Results of the RTI Services

Test Events		Detail Descriptions	Results
Static Test	Preview	– Review and Check Compliance Database	– Check 22 Object Classes and 574 Attributes Within SOM
	CS	– Syntax/Semantic of CS – Consistency with SOM	– 2 Deficiencies in CS → Errors Corrected
	SOM	– Syntax/Semantic of SOM – Consistency with FOM	– 4 Deficiencies in SOM → Errors Corrected
	FOM	– Syntax/Semantic of FOM – Consistency with SOM	– 1 Deficiency in FOM → Error Corrected
Dynamic Test	IF Test	– Create Federation – Conduct Connectivity Test	– 1 Publish and 1 Handle Errors → Errors Corrected
Final Result		Success (Pass)	

Table 4: The Results of the Advanced TaeGuek JOS HLA Compliance Test

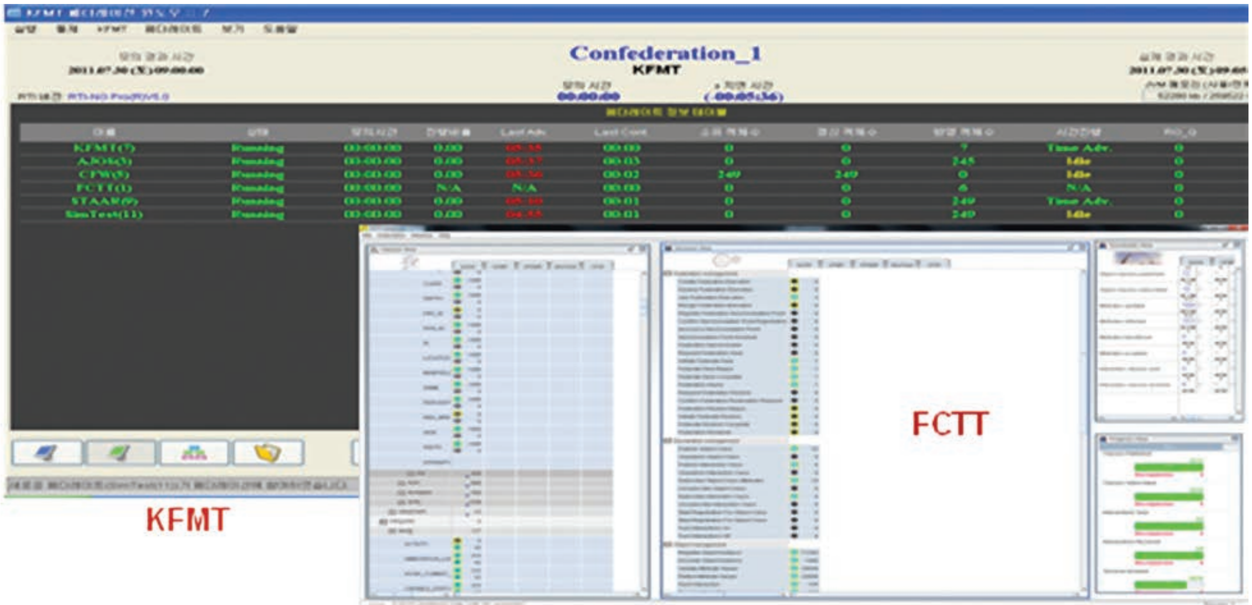

Figure 4: Snap-Shots of the Advanced TaeGuek JOS HLA Compliance Test (KFMT, FCTT)

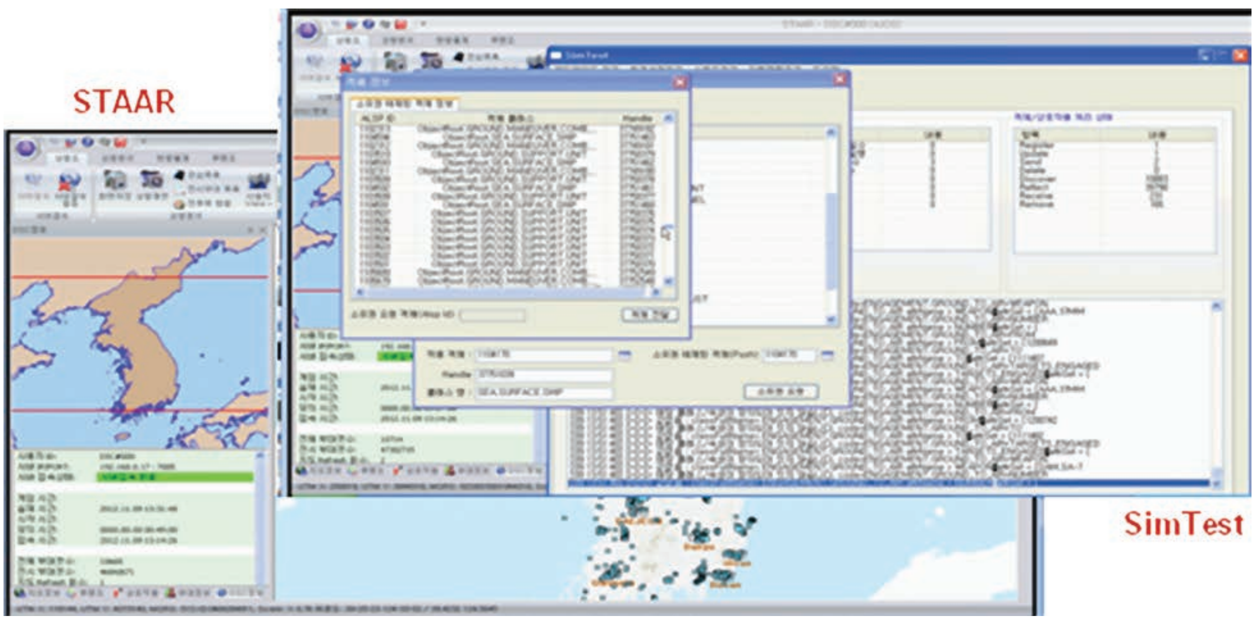

Figure 5: Snap-Shots of the Advanced TaeGuek JOS HLA Compliance Test (STAAR, SimTest)

4.2 Lessons Learned from the First Use Event

Throughout the first use event of conducting the advanced TaeGuek JOS HLA compliance test using the indigenous ROK HLA compliance testing system, several lessons learned and interesting aspects were observed.

The first lesson learned was during the test preparation phase. Just after the FUT test application was requested and before the test was conducted, DTaQ had a pre-test session with an applicant and explained the test procedure and the data preparation process in detail. This activity provided the applicant a better chance to understand the test procedures and to prepare data such as the CS, SOM, and FOM. This presumably resulted in less time conducting the test and a greater chance of passing the test. The lesson learned during the test preparation phase is that the better coordination and collaboration between the test agent and test applicants before conducting the test, the better chance there is to pass the test.

Second, during the test phase, throughout the static test and the dynamic test, whenever the FCTT detected any abnormal or error on the CS, SOM, and FOM, the KSIMS infrastructure was very useful in figuring out the problems and their causes. In most cases, the FCTT by itself detected and indicated problems and abnormalities such as mismatches among the CS, SOM, and FOM. In some cases, however, even after the FCTT had captured a problem or an abnormal situation, it couldn't identify its cause or reason. Unfortunately, one of the most frequently encountered fundamental problems is that it happened even before utilizing the FCTT, due to the failure of building the test federation. In this case, KFMT of the KSIMS infrastructure turned out to be very useful and valuable, since the FCTT itself does not provide any guidance or assistance to address the issue. Also, if the FCTT detected any problem or error whose cause was difficult to figure out, STAAR of the KSIMS infrastructure could find the cause by enhancing the chance to scrutinize every single detail of the entire data. Whenever it is impossible to conduct a whole test due to the lack of completeness in the FUT and the auxiliary federate submitted to the test, SimTest of the KSIMS infrastructure provided a better test environment. The lesson learned during the test phase was that the better preparation for the KSIMS infrastructures with the FCTT on the compliance test federation, the better chance to pass the test by reducing testing time and manning requirements.

Finally, through the overall test period, several miscellaneous lessons learned and interesting aspects were found as presented below. First, conducting a compliance test using the fully developed FUT such as the advance TaeGuek JOS and setting high test standards, provided a great opportunity to test and examine the entire federate in detail. The lesson learned from this is that conducting two tests for each FUT should be considered; the first test at the beginning part of the development, and the second test right before the operational test or the fielding test. Second, conducting a compliance test using the ROK HLA compliance testing system with better prepared KSIMS infrastructure, may be possible in reducing the test duration to 2~3 weeks, which is significantly shorter than the commonly required 2~3 month duration. Third, by using KFMT of the KSIMS infrastructure, two minor abnormalities on the FCTT were observed such as "Join" service reports counting error and "Request Federation Restore" not successfully restored error. One presumed bug was detected such as incorrectly reporting the "Restore" services as their "Save" counterparts on the VTC RTI-NG Pro® v5.0 [10]. Even though abnormalities of the FCTT were fixed on site during the review session with the JHU APL experts, rewriting the FCTT completely is now seriously taken into consideration for the ROK DTaQ's own long-term purposes.

4.3 The Future Improvement Plans for the Indigenous ROK HLA Compliance Testing System

As introduced in this paper, during the past three years, the ROK DTaQ has aimed to build an indigenous ROK HLA compliance testing system, and now has finally built and successfully conducted the test for the advanced TaeGuek JOS. The test system consists of the FCTT and the KSIMS infrastructure based on the VTC RTI-NG Pro v5.0, and the test was conducted on the LAN environments.

To improve the test system in the future, various perspectives are considered as follows:

1. Build a capability to operate on different vendor's RTIs such as MAK by developing an adaptor for the KSIMS infrastructure.
2. Build a capability to conduct test on the WAN environments, especially for any U.S. alliances in the Pacific and the Southeast Asia, if needed.
3. Add FCC to the test federation and actively use it to facilitate and enhance interoperability in checking and maintaining consistency of the whole data on the FUT.
4. Rewrite the entire FCTT code to customize or tailor to the ROK operational requirements.
5. Seriously consider building a brand new compliance testing system by modifying the ROK HLA compliance testing system to facilitate the live-virtual-con-

structive (LVC) simulations [11] based on the DSEEP, IEEE 1730-2011 [12] and the FEAT developed by the SISO [13].

5. Conclusions

During the past three years, the ROK DTaQ has tried to build an indigenous ROK HLA compliance testing system by purchasing the FCTT and acquiring the KSIMS infrastructure in accordance with the U.S. M&SCO policy change. The ROK DTaQ built its own test capability by self-study and FMS training from the U.S. M&SCO. The first use event using the ROK test system for the advanced TaeGuek JOS was successfully conducted from the last week of October to the second week of November 2013. Several lessons learned and interesting aspects were found during the test, and a future improvement plan is considered crucial to fulfilling the operational requirements as discussed above. The ROK DTaQ will continuously pursue to build and improve the indigenous ROK HLA compliance testing system, while closely working together with the U.S. M&SCO.

Acknowledgments

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Author's Biography

Dr. ChongHo Lee

Dr. ChongHo Lee (Retired ROK Army COL) is the Chief of the Technology Analysis Team, Defense Agency for Technology and Quality, Seoul, Korea.

In 1978, he graduated from the Korea Military Academy, Seoul, Korea, and was commissioned as Second Lieutenant in the ROK Army. He graduated from the U.S. Naval Postgraduate School, Monterey, California, in 1988 earning an M.S. degree in operations research. In 1994, he earned his Ph.D. degree in industrial engineering from Texas A&M University, College Station, Texas.

While employed at the CBSC/KBSC, ROK-U.S. Combined Forces Command, in 1999, he proposed a simulation architecture (single federation) that allowed the ROK and U.S. models to interoperate for combined exercises and accomplished it in 2004. In 2009, he proposed an enhanced hierarchical architecture (federation community) for the ROK-U.S. combined exercises.

Additionally, he has 18 years of teaching experience in graduate schools at Korea University, Kwangwoon University, and the National Defense University, Seoul, Korea. He wrote several papers in the area of defense modeling and simulation and the book, "The Theory and Practices for Defense Modeling and Simulation" in March 2008.

His special interests are interoperability of simulation systems and various applications of modeling and simulation in the military.

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