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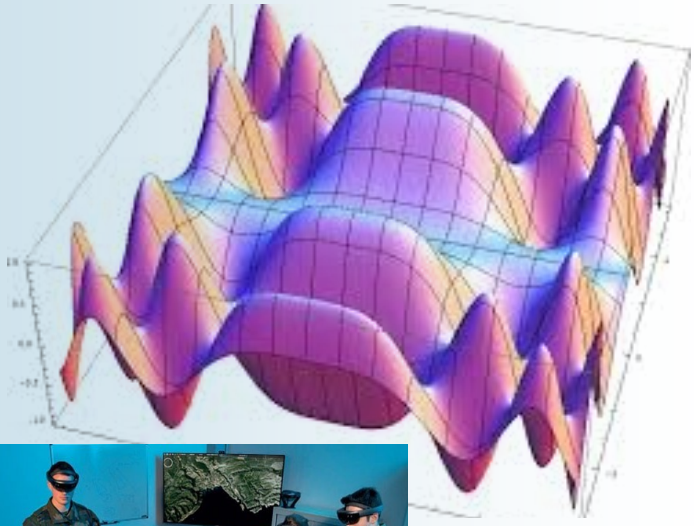
2019 Annual Review



NATO M&S COE

NATO
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Centre of Excellence

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Preface

Dear readers,

it is a constant great pleasure that NATO Modelling and Simulation Centre of Excellence is presenting our Annual Review. This year the challenge was to be able to select all the scientific productions that we receive during our M&S activities and events, considering that we were sure to publish them in the best way to give you the opportunity to use this articles and summaries of selected research, studies and events not only for reading but also to deepen in your daily job, eventually also a spark and enhancement for future studies and researches.

This year's review shows not only our continued work towards establishing M&S as a service architecture and efforts for Cyber and Autonomous System domains, but we provides details on the new portfolio courses that we will provide in the next future and an overview from our role leading the M&S Focus Area during different NATO exercises. We are expanding our field of experimentation activities towards the MDMP (military decision making process), Wargaming and analysis as the new step in the M&S applications considering that M&S is one of the most important "disruptive technologies" that NATO will develop from now to the next five years.

As a NATO Centre of Excellence our purpose is supporting NATO and Nations in their transformation efforts by providing subject matter expertise in all aspects of Modelling and Simulation. This journal is prepared in that spirit, to show our efforts to make our work more widely available and thus advance the capabilities of NATO, its Nations and partner nations. We are proud to publish it for you with all the support and devotion that our crew was dedicating to create this important and precious collection to support M&S research and experimentation activities.

Col. (ITA Army) Michele TURI

Rome, Italy

December, 2019

Acronyms

ACT	Allied Command for Transformation
AI	Artificial Intelligence
C2	Command & Control
CBRN	Chemical Biological Radiological and Nuclear
COE	Centre of Excellence
CP	Command Post
DIS	Distributed Interactive Simulation
GUI	Graphical User Interface
HLA	High Level Architecture
M&S	Modelling and Simulation
MSDL	Military Scenario Definition Language
NATO	North Atlantic Treaty Organization
NFFI	NATO Friendly Force Information
SACT	Supreme Allied Commander for Transormation
STO	Science and Technology Organization

Part I

PAPERS

1. NATO NEEDS FUTURE STRATEGIC ENGINEERS[1]

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Abstract

Contemporary dynamic world and security environments bring many changes and new challenges which were not significant or apparently visible before. One of the today's world significant trend, amplified by continuous pursue for the effectiveness improvement and lack of qualified personnel, is much wider penetration of advanced methods and technology (M&S, AI and so) into a "Strategic" decision making field, particularly in various non-technological areas. This trend leads to a need for additional research in management areas, revitalization of operational research principles implemented in "social-everyday" practice, integration of IoT (internet of things) and thus BigData and DataFarming concepts in decision support infrastructure, and mainly appropriate personnel development (education and training). Mentioned gap or needs, as it was indicated yet, is also apparent in the highly conservative resorts like defence, were the potential synergy in E&T with civilian education is highly possible and some serious research activities were already started within NATO (for instance STO/MSG-152 - NATO Modelling and Simulation Professional Corps Development). The article deals with the analyses of contemporary trends and future needs in various areas (including defence and security sector), and it evaluates the potential perspectives, solutions, architectures, providing a proposal for a convenient study programme and its design and implementation..

1.1 Introduction

Based on a long term experience, only the rational approaches in decision making give us the best chances to succeed in contemporary complex environment and, as a prove, we could consider the leading position we achieve thanks to the science and technology development.

Philosophically, if we think, as a human being, about our role in the universe,

[1] The article was published in the WAMS 2018 conference proceedings (ISBN 9788885741232)

from where are we coming and where are we going, we do not know the truth yet, but it seems that we are "genetically programmed" to search the answers and we do not know how much time we have for our "answer search" mission. So one rational outcome of this challenge is the decision to put our research and development effort to the limit, to do the maximum possible. As it was said, human beings are genetically programmed to search for right solutions in a smart way, what actually enabled us to survive and evolve on the earth, therefore this approach, step by step, is affected and modified by the routine life and/or many other constrains/boundary conditions.

1.2 Modern Contingencies on Strategies

In general the boundary conditions force the people to develop more and more sophisticated solutions as much as the environment turn to be complex, for instance by introducing large and strong interconnected social structures (Powerll 1992). In facts, along many areas we face the situation, that strategic government/management positions are "occupied" by "political" instead of "expert" personnel, searching usually the "comfortable", instead of "rational" solution. In particular in recent time the search for extreme short terms "consensus" as happen in Stock Exchange looking to next quarter or the political world focusing on continuous polls are very good example were the "strategy" is dictated by very short horizon and contingent elements; even international organizations are affected by this approach and if we step back and look to the effective progresses in humanitarian or military initiatives by major organizations, we could easily realize discontinuities in terms of objects, actions as well as lack of decision capability (Mintzberg 1994); these factors provide an high probability of failure in finalizing any strategic plan. Sometime we could accept the limited results achieved, justifying the results by the complexity of the problems, the different specific interests of the participants and by articulated constraints; however this is just a simplified view, considering that major problems with very articulated networks of participants and harsh limitation were solve in the past centuries (Macchiavelli 2009; Luttwak 2016; Dawson 2018) These aspects were always present along the ages, therefore today this situation is overstressed by the fact that the complexity of the problem we have to face is very high and often involve consideration on long terms (e.g. climate change, R&D investments, demographics) while our goals are very short terms (e.g. next quarter profits, next vote in Board of Director or local/national/federation elections). It could be possible to attribute these problems to lack of decision capability, divergent interests, search for consensus; indeed in case of accepting this theory, one solution could be found in the "single strongman command in charge" or in "dictatorial structures", but this is not the only way and not necessary the best one as history demonstrated many times. Vice versa sometimes it is necessary to get to the origins (rationalism) to succeed and this fact is surely more than

only important, but probably decisive for the 21 century in almost any domains. Indeed this corresponds to outline that education and training using new technologies to finalize rational decisions even in complex systems could be the way to create a common and effective capacity to face with strategies nowadays. Indeed, contemporary dynamic world and security environment brings many changes and new challenges which were not significant or visible before; in other cases in the past there were no appropriate methods and technologies available to deal with such problems considered "unsolvable". One of the today's world significant trend, coming from the time of economic crises and amplified by increasing automation and robotization is continuous pursue for the effectiveness in manufacturing or other areas, with reliance on lack of qualified personnel. This fact lead to a much wider penetration of advanced methods and technology (M&S, AI and so) not only in tactical areas and weapon arsenal, but also into a "strategic" decision making field (particularly in various non-technological areas), were you have very tiny space for a mistake (strategic mistakes usually lead to a complete failure of a system of a defeat).

1.3 Current Global Situation and Needs in Military

Current situation and complexity of interconnected operations domains (land, air, sea, space, cyber) in context of the world security environment and it's continuous deterioration trend lead us to the early threat identification and to the search for the possible solutions in advance. Based on the mentioned complexity and many "hybrid factors", changing the contemporary warfare into a tremendously complicated field, it results that an effective management of this issue could be hard to be effectively resolved relaying just on intuition and experience. This is especially true because, even very good experience of decision makers sometime arised in very different mission environments and could be hard to be applied successfully otherwise without properly understand the context and develop specific experiences (e.g. virtual experience, immersive environments) by using innovative technologies to quickly enhance the capabilities of a command; this concept was demonstrated by SIMCJOH as proposed in figure 1 (Di Bella 2015). In addition to the above mentioned consideration we have to be aware, that our potential opponents have similar access to the advanced military technology, like we have, they are thinking in a same way like we do and they will not give us a favor to behave like we wish to. From this point of view it is interesting to consider the modern concept of Hybrid Warfare, as evolution of previous not linear approach to war supported by new technologies (Bruzzone et al.2016); this concept is often attributed to Gen. Gerasimov, however if we read even just the title, and even better the whole article, we could easily realize the dimension of his view talking about the "value of Science in the foresight" (Gerasimov 2013). Even thought that armies are very conservative

systems, there exist many attempts to change the routine or usual way of thinking in a decision making domain and this could represent an opportunity for major advances. One of the well documented attept from 2008 is the DARPA's project – DEEP GEEN, which was focused on the Command and Control enhancement, especially MDMP (Military Decision Making Process) computer support and routine tasks automation. Contemporary, same as the past MDMP is usually executed in the way driven by the intuition and experience of individuals, thus this approach was significant breakthrough in C2 philosophy built on human intuitive judgment. The outcomes of the project did not significantly change the situation in the NATO C2 yet, but apparent improvement seems to be "shining on a horizon". Another interesting example, from this point of view, is proposed by SIMJOCH initiative devoted to immerse commanders in new mission environments combining different technologies such as MS2G (Modeling, interoperable Simulation and Serious Games), VR (Virtual Reality), IA (Intelligent Agents), HBM (Human Behavior Models) & Virtual Humans (Bruzzone et al.2015)

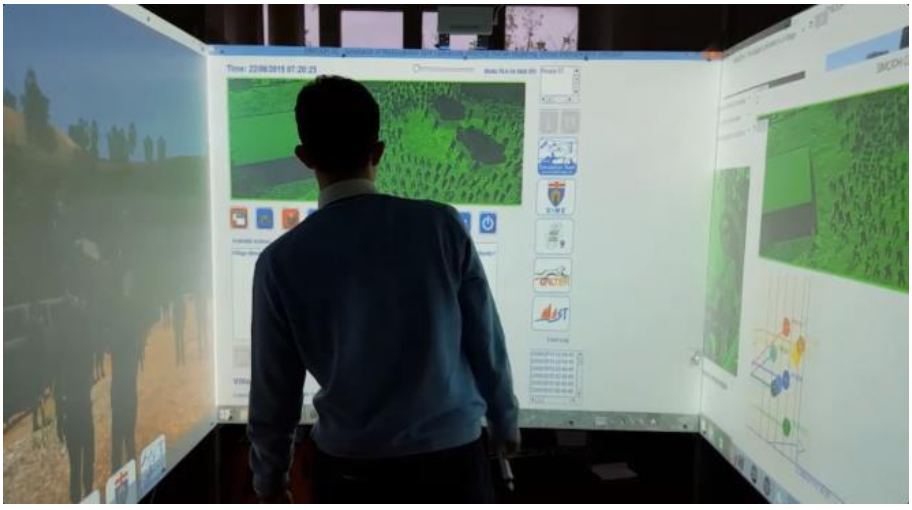

Fig. 1-1 –Commander evaluate COAs in SIMCJOH

1.4 The Military Decision Making Process

When we look at the MDMP (Military DecisionMaking Process) and its steps, which are usually similar in all NATO armies, even some details could vary, we could see a logical and highly "burocratically structured" process, fully employing a tens of individuals from the battalion (or higher echelon) staff. Contemporary structure of MDMP is visualized on following figure 2,

proposed by Battle Command Mission Program. One of the fundamental problem of contemporary MDMP is IPB (Intelligence Preparation of the Battlefield) an Operational Planning phase linked to a COA's(Course of Actions) Development (having a roots of its philosophical concepts in the Second World War), which is, due to the human personnel reliance only, limited to the counts of possible enemy and friendly COA's. Also the planning phase of friendly COA's goes to the depth, rather convenient for static, low dynamic or predictable conflicts.

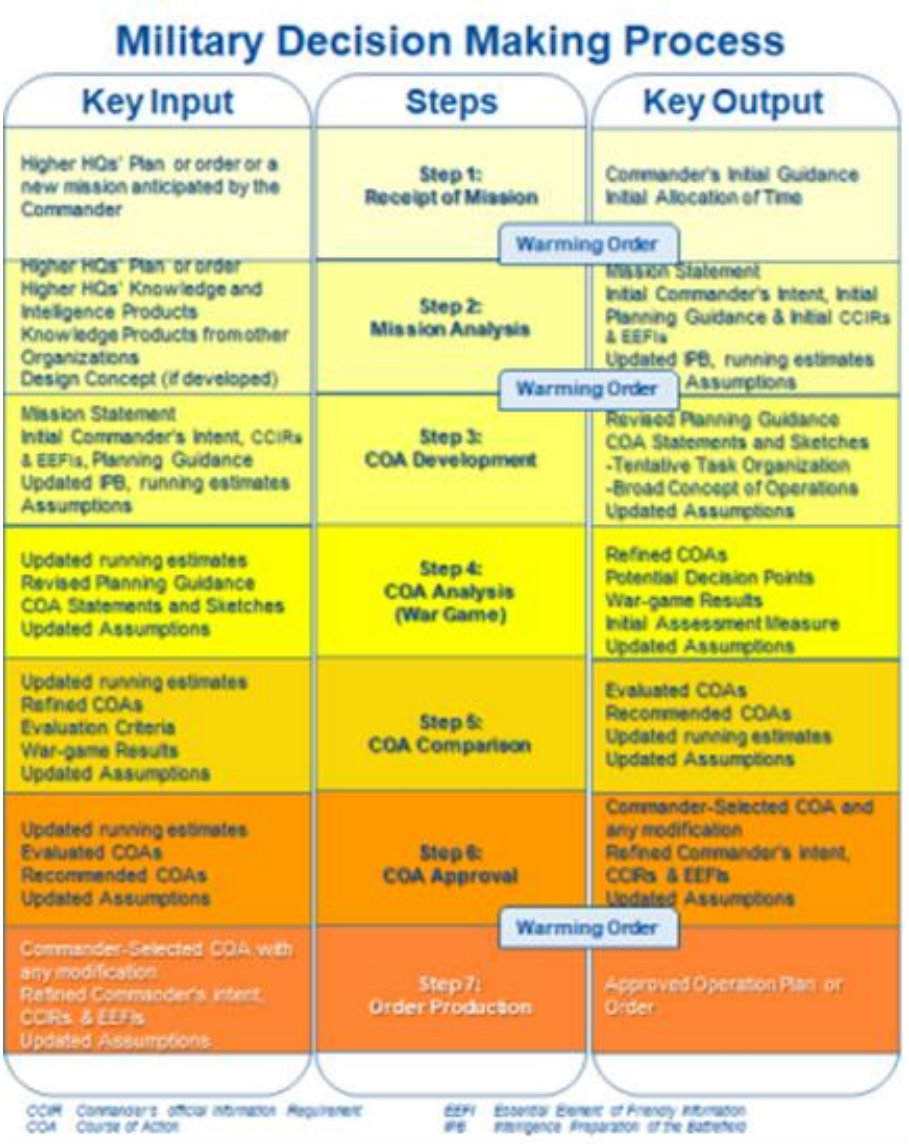

Fig. 1-2 - Military Decision Making Process.

1.5 Researches and Investigations

Nevertheless this concept for todays and future warfare seems to be obsolete and still, there is the continuous search for innovation on that field (Massei et al. 2014). In the following a couple of examples are proposed in terms of this

new approach.

Deep Green - As anticipated one of the significant attempt on this way, was the US ARMY project DEEP GREEN (as mentioned before), solved by DARPA in 2008. Deep Green concept was inspired by a Deep Blue supercomputer (1997) and is focused on development of a decision-making support system for US Army commanders.

The core of the system was based on the feature of advanced predictive capabilities to enable computers to efficiently and accurately predict possible future scenarios, based on an analysis of the current situation. Obviously a very critical aspect is related to the ability to create a reliable COP (Common Operational Picture), in order to give army commanders a better view of possible outcomes for their decisions. Deep Green concept is based on four major components, it's architectural and componentry scheme is proposed in the figure 3 inspired by DARPA research summarized in its technical report.

Figure 1-3 – Hi-Tech based Decision Process Scheme.

Obviously the idea relies on the capability to develop new High Tech Models and Decision Support Systems (DSS) to be developed based on enabling technologies: In the case of Deep Green the main innovative components were:

Blitzkrieg – analyse current situation and determines possible future outcomes for use in planning. When a plan is presented, Blitzkrieg analyse

the plan to point out possible results of that course of action to the commander. Blitzkrieg itself does not plane the action/operation, it merely determines the likely results of a plan formulated by a human commander.

Crystal Ball – Performs analysis of possible futures generated from the blitzkrieg, and determines the "best" choices by measuring flexibility, usefulness, and likelihood of each. It picks the best of these choices and presents them to the commander. Also updates model of battlefield situation with information pulled from the field. This might include reports from soldiers, through a program similar to the Communicator program that was developed under the Information Awareness Office or through automated RSTA systems such as HART. Commander's Associate – this is the user interface and visualization component. It consists of "Sketchto-decide" which presents the commander with a list of options, and "Sketch-to-plan" which is a screen on which the commander can draw up a plan, which Deep Green will interpret and put into action.

Indeed, this approach defines the philosophical fundaments of the new perception of the military management process architecture and redesign a traditional OODA (Observe-Orient- Decide-Act) Paradigm into parallel threads, which should be executed simultaneously. This approach could be more convenient for today’s highly dynamic operations and more effective in the computing and analyses effort distribution on the primary aspects of the possible near future (avoids planning to the depth, because long term prediction/estimation is usually useless on dynamic battlefield).Fundamental shift away from the traditional OODA Paradigm is summarized in the figure.

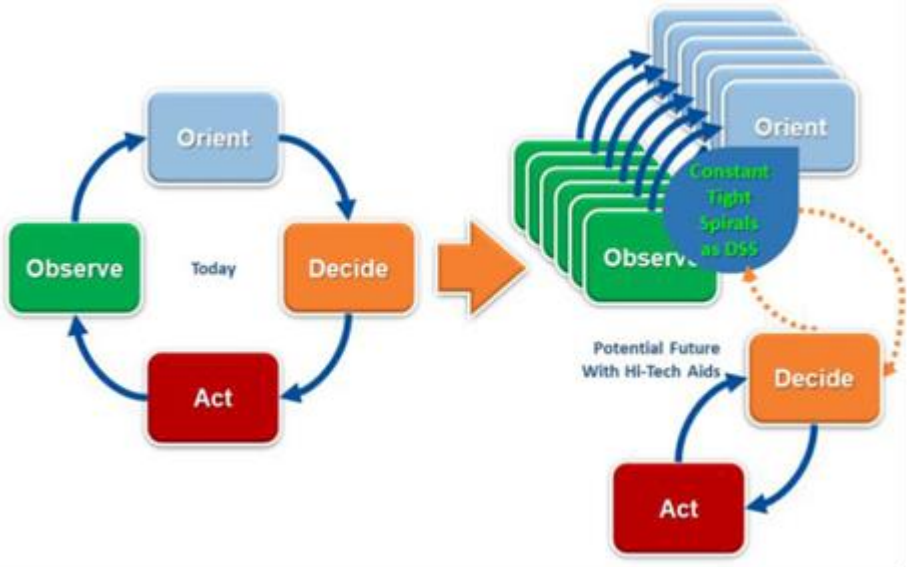

Fig. 1-4 - OODA Loop possible evolution.

1.6 SIMCJOH

The SIMCJOH (Simulation of Multi Coalition Joint Operations Involving Human Modeling) was activated as a major Military Project by Italian MoD in 2012 under leadership of Simulation Team Genoa University (Bruzzone et al.2015). The project was conducted in synergy with Military Organizations (e.g. NATO M&S Center of Excellence COE, CESIVA Italian Simulation and Validation Center, COI Joint Operational Command), Institutions (DIME University of Genoa, MSC-LES) and companies (i.e. CAE Gmbh, Leonardo spa, Mast srl, Cal-Tek). In facts the idea was to provide to Commanders a new generation solution adopting the new MS2G (Modeling & Interoperable Simulation and Serious Game) paradigm able to act as E&T (Education and Training) environment for Strategic Decision Making (Bruzzone 2018a). The concept was further developed in joint cooperation among Simulation Team Genoa University, VMASC Old Dominion University and Commanders with operational experience in different scenarios to identify the needs and opportunities to create such solution (Bruzzone et al. 2013). In facts SIMCJOH project allowed to create and demonstrate a new HLA interoperable immersive framework for the Commander and his staff within strategic decision making over a critical Joint MultiCoalitions scenario; the case study developed dedicated special attention to human factors and the Simulation Team Models on Population and Human Behavior Modeling represent in fact the core element of SIMCJOH Project (Bruzzone et al.2014,

2015). The experimentation faces issues related to strategic decision making over complex scenarios. It is evident that in the case of strategic decision there are many parameters and the human factors usually play a decisive role in the final success, so the use of innovative M&S (Modelling and Simulation) combined with AI (Artificial Techniques) is probably the most promising approach as demonstrated in this Project based on Simulation Team advances (Bruzzone 2013; Bruzzone et al.2011). In facts the combined use of SIMCJOH VIS & VIC, the virtual and constructive components of SIMCJOH project developed by Simulation Team allowed to reproduce by IA-CGF (Intelligent Agent Computer Generated Forces) the situation evolution and test multiple COAs over a complex scenario in an intuitive, immersive, interactive way as proposed in figure 1 (Bruzzone et al.2015). The SIMCJOH VIS & VIC have been created by Simulation Team (DIME, MSC-LES, Cal-Tek and MAST) and successfully tested and integrated in SIMCJOH Federation using Simulation Team IA-CGF. The SIMCJOH Federation includes different simulators such as Simulation Team VIS & VIC, Selex ES & SGA, CAE GESI. The interactive presentation and demonstration of SIMCJOH to Military Community was completed successfully in Rome since January 28, 2016 and replicated, with specific different focuses, several time in different Organizations and Nations (Di Bella 2015).

1.7 Modelling and Simulation in Strategic Decision Support Domain

Computer decision support in Strategic domain is one of the biggest challenge for Modelling and Simulation domain, because social-economic system on strategic level are characteristic by a high degree of stochasticity, so realistic outputs from the one simulation could be hardly achieved. The above mentioned cases represent a confirmation of the great potential of this approach, therefore a crucial key is the correct approach and level of understanding of the simulation results. From the logical and philosophical point of view, there is no theoretical boundary limiting a M&S implementation in strategic domains, only the human stereotypes and technology readiness (computationally intensive) could prevent that applications. From the technological point of view situation changed dramatically within a last decade, but human approaches and trust into the possible solutions do not. Therefore, from a mathematical point of view, the military strategy can be viewed as a selected sequence of the data configurations defined on the set of all possible variations of the system state. Depending on a level of approximation and detail level of the space model, there exist approaches how to implement promising solutions even in strategic domain if it is properly defined the influence of stochastic factors and the performance criteria. Generally, a strategy can be defined as a sequence of transformation vectors driving the transition of the System from state n to n + 1 within a multidimensional space. Following lines describing a procedural approach to

the Strategic Defence Capability Development, what is very common problem for the defence strategists. The aim of the optimal strategy search in the Defence Capability Development problem we could describe as an ideal defence budget distribution to the army specializations in context of readiness for future threat confrontation. The detailed description of the problem solution would exceed the scope of that article, but in generic steps, we could delineate following possible approach:

• Construction of the data model of capabilities (capability model) – aggregating the statuses of quantified coefficients of individual capabilities (vary from the Nations) within a operational spectra. Definition of statistical factors, stochastic variables and fidelity levels. This could be represented as mathematical vector with indexes representing each capability, quantification of each capability should be derived from the current status of organization structures, equipment and armament. Usually calculated from the ratio of current status divided by some "ideal" model of a corresponding basic tactical unit (platoon, company, battalion…).

• Construction of the status graph of the possible configuration of the capability model It is the set of possible capability configurations in time to be viewed from the mathematical point of view as the math graph (having a shape of traditional oriented tree) of possible combinations of the data models of the defense capabilities. Usually there are different discrete and limited improvements or degradation of capabilities (e.g. hardly achievable improvements of the capability from 0 to 10 within a one year); this actually drives and reduces the speed of tree expansion in time.

• Evaluation of overall cost and risks of transition between individual configurations of the status graph - Transitions between time steps and potential capability levels should be valued by the financial cost of a given capability improvement, stagnation or deterioration. Usually for simplifications only positive numbers - we do not expect any financial profit from the defence (for instance selling some asset).

• Evaluate operational level of efficiency/readiness for a given status of capability to face the future threats - Evaluate operational efficiency of the capability configuration (model) is one of the key parameters in the capability graph, with several methods being available for the calculation process. Since the one possible option copying an intuitive approach and logic can be characterized by the following steps:

1.Transformation capabilities into the model organizational structures

2.Create organization structures of the supposed opponent

3.Create/define scenarios

4.Place scenarios into expected/probable areas of the future operational deployment

5.Execute statistically representative counts of constructive war gaming within each scenario

6.Statistical evaluation of success ratio of given capability configuration and setting this value into the capability graph

• Calculate a possible solution - Calculation of a possible solution could be conducted in two phases, the first is to apply the Foyd-Warshall algorithm or its equivalent to the graph of financial part of capability development expenses, after that, it is necessary to apply a expected budgeting filter on each node in the graph within a time step/year and exclude all "over budget" nodes with its connections from the graph. Second step is the search for the optimal solution or a set of optimal solutions for the development of individual military capabilities in time (e.g. years) so that the total sum of the operational efficiencies of the individual capabilities configurations will be maximal or moves within a certain (max close) interval. This problem could be solved by the original or modified CPM method. In the case of situation where a defined budget capacity for the capability development prevent the effective capability status achievement, addressing forecasted threats and risks, so the military budget for capability development need to be reconsidered (increased).

Mentioned examples indicates, that this trend leads to a need for additional research in management areas, revitalization of operational research principles implemented in "social-everyday" practice, there is the time for a BigData and DataFarming concepts in decision support infrastructure, and mainly appropriate personnel development throughout proper education and training.

1.8 Education and Training Portfolio for Strategic Personnel

Mentioned gaps and/or needs, as it was indicated yet, is apparent in many resorts, not only in defence. We could hardly imagine the reliance only on a "single resort courses and training" and close synergy in E&T with civilian education is not only inevitable, but useful to improve final capabilities. In general this aspects are an open issue in many different sectors and require to be addressed effectively (Bruzzone et al.2009; Howell et al. 2003). Some serious research activities were already started within NATO (for instance STO/MSG-152 - NATO Modelling and Simulation Professional Corps Development), incorporating a civilian E&T programmers into a military certification of M&S professionals (Mazal 2018). Indeed this initiative aims to develop a professional M&S Education and Training portfolio and certification process to enhance current capabilities. As a one of the latest

reaction of University of Genoa to identified requirements and perspectives in mentioned field is the new master degree educational program named "STRATEGOS" that is focusing on this subject and it is proposed to International Community as an advance in this sector (Bruzzone 2018a).

1.9 Conclusion

The article deals with the analyses of contemporary trends and future needs in various areas (including defence and homeland security sectors). The discussion highlights that necessity as well as the opportunity to develop new approaches based on quantitative decision making processes and relying on innovative technologies. Indeed the paper proposes some case studies to demonstrate that this vision, as well as practical demonstration of the potential, is already available, but there is a fundamental need to prepare a new generation of decision makers and analysts able to work together on this subject. The potential perspectives, solutions, architectures are proposed and the authors are working, even more, to develop a more extended analysis of this situation. Furthermore, it is proposed the new Master in Strategic Engineering that represents a practical example of study program devoted to design and implement these concepts. It is evident the necessity by International Organizations involved in complex decision making to follow up on the proposed guidelines as recently pointed out, during last CAX Forum (Bruzzone 2018b). In general, it will be necessary to properly work together among Academia, Services, Governmental Institutions and Industries to properly develop future E&T programs devoted to decision making, including that one addressing Executives, Staff as well as Scientists; indeed the evolution of the relative culture is probably the most critical aspect to succeed.

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2. SYNTHETIC CYBER EFFECTS

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Abstract

Since 2016, NATO reaffirmed the defensive mandate and recognized the cyberspace as a complex and vast domain of operations in which NATO must defend itself as effectively as it does in the air, land, and sea.

To ensure cyber readiness, it is necessary to train cyber and non-cyber experts like war-fighters. . Training and exercise opportunities to improve cyber-expert operational readiness are growing faster and faster. However, there is a lack of tools and opportunities for the training of non-cyber-experts to face cyber effects and growing their cyber resilience. In order to train non-cyber experts to face cyber effects and growing their cyber resilience there is a lack of tools and opportunities.

The NATO Modelling and Simulation Centre of Excellence (M&S CoE), supported by the industry, is developing a research and study activity focusing on some of the aspects of Modelling & Simulation that can be used in support of Cyber Defense. This activity includes the contributions to the NATO M&S Group Specialist Team in top ten cyber effects for campaign and mission simulations providing a list of possible M&S cyber effects, and a proposed M&S architecture that could be suitable to be used in support of Headquarter-Staff training and exercise.

This paper focuses on a specific tool at the M&S state of the art that can be applied to build systems to support and train operators, war-fighters, and other actors that are not necessarily cyber experts, but who could have to deal with disruptive cyber effects during the execution of missions and critical operations.

The methodology proposed in this study allows to define a set of cyber-effects as the most desirable to be simulated in an exercise with the purpose of

training an audience of non-cyber-expert operators, within a military command post or an emergency operation center.

2.1 Introduction

In July 2016, the North Atlantic Treaty Organization (NATO) recognised cyberspace as a domain of operations in which NATO must defend itself as effectively as it does in air, land and sea (NATO, 2018). Building several strong layers of protection can be an effective approach but it still represents just an early starting point (Accenture, 2018). Infact, to keep the edge high and become effective in the long term it is important to work on resilience, that can be defined as the recovery of complex systems from potential adverse events, that means the recovery of complex systems from potential adverse events (Linkov & Trump, 2019). The Cyber resilience, in particular, refers to the ability of keep achieving the intended outcome despite adverse cyber events (Björck, Henkel, Stirna, & Zdravkovic, 2015), but this ability like any other, must be acquired developing an appropriate training programme. The first element of a cyber resilience programme involves being able to identify, assess and manage the risks associated with network and information systems, including those across the supply chain. It also requires the ability to protecting information and systems from cyber-attacks, system failures, and unauthorised access (IT Governance, 2019).

Nowadays everyone, not only the cyber experts, is exposed in the cyber domain, and this condition is going to become each day more relevant due to the growth of both connected devices (Ericsson, 2019) and malicious cyber activities (Marsh & McLennan Agency, 2018). Therefore, should cyber resilience be relied exclusively upon cyber warriors? The responsibility of cyber welfare is upon every one of us, independently of our expertise in the cyber domain, and this becomes even more relevant when moving from a general context to a highly critical scenario. Since one of the pillars of cyber resilience is training and awareness (U.S. Department of Homeland Security, 2018), the question shouldn't be who to train, as everybody can participate in cyber resilience, but how to train.The authors' study aims to investigate the role that the Modelling and Simulation (M&S) discipline can play for non-cyber experts training of. As the M&S works with a proper abstraction of reality, the focus moves from cyber threats (ISO, 2018) (potential cause of an unwanted incident, which may result in harm to a system or organization), to cyber-attacks (attempt to destroy, expose, alter, disable, steal or gain unauthorized access to or make unauthorized use of anything that has value to the organization), to cyber effects.

Due to the complexity and variety of possible actors and scenarios, it is not possible to take effectively into consideration all the spectrum of situations.

The scope of this activity is focused on the application of M&S for the training of operators and staff employed in a Command Post (i.e. a military Headquarter or potentially a civilian Emergency operation Centre) that are not cyber experts – i.e. via Computer Assisted Exercise (CAX) or Command Post Exercise (CPX).

In the light of the new strategic context, the Alliance has to assess and adapt its posture and capabilities to ensure its readiness to effectively face all the current and future security challenges. In the field of Cyber Warfare, the commitment of NATO has been recently reaffirmed in several major occasions (NATO, 2018).

In the military field, the application of M&S has always represented a critical factor, providing many benefits to all the conventional Domains. Furthermore, M&S' aptitude to evolve and keep the pace with the technological advances determined its dramatically growing importance, and it is expected to play an increasingly relevant role also in the newly recognized Cyber Domain.

The NATO M&S Centre of Excellence (M&S CoE) mission is to support NATO and the Partner Nations for all aspects of M&S activities. Since 2016, it has started to explore the boundaries and possible application areas of Communication, Networking and Cyber M&S (NATO M&S COE, 2018) through a research phase for a conceptual study to define how M&S could support Cyber Defence in NATO. This activity contributed to define awareness and interoperability gaps between the M&S and Cyber communities of interest and to define possible use-cases where to apply M&S capabilities in support of Cyber (Biagini, et al., 2018). The use cases selected use case about possible adaptation of C2 and C4ISTAR systems under a cyber domain perspective was developed in order to match the requirements for the collective training (NATO SACEUR/SACT, 2013) of multinational headquarters. As a result of the interest raised by the subject among professionals of training and exercise, this use case was taken in exam and tested to stress how the simulation of Cyber Effects in the C2 environment could effectively support the training and exercises of non-cyber expert operators working in deployed command posts.

According to this study and research activities the NATO M&S CoE provided to the NATO M&S Group Specialist Team (MSG-170), contributions regarding possible cyber effects considered relevant for training, and a proposed methodology to derivate and rank such effects.

2.2 Cyber Effects for Training

According to the world-wide cybersecurity community, a cyber threat can be defined as a malicious attempt to target and gain access to a computer system

or network".

The targets of cyber-threats are always people and/or organizations, and although the reasons for the cyber-attack attempts might vary, they most often aim at gaining a "competitive advantage" over the victims.

Cyber-attacks may differ in nature: attempt to damage or disrupt a network/computer, gain access to files, infiltrate and monitor, steal, alter data. Threats can also be identified and classified in several ways, and some examples include the identity of the target to be stolen or modified, the possible damage, or the Tactics, Techniques and Procedures (TTP) adopted.

Another crucial factor to describe a cyber-attack is to define "who is attacking who". From this point of view, in addition to hobbyist hackers, the most important sources of cyber-attacks are disgruntled insiders, business competitors, hacktivists, industrial spies, organized crime groups, terrorists, national states or governments. In some cases, it is not possible to define a clear separation between these categories. The identification of the motive behind the attack can then be used as an element of differentiation. After considering the previously described factors, it is possible to start defining "threat levels". Regarding how to measure a threat level there are several ways. A suggested approach is given by the Cyber Security Index that is a measure of the risk to the corporate, industrial, and governmental information infrastructure from a spectrum of cyber security threats. It takes in consideration the rapid change in cyber security threats and postures, the state of cyber security metrics as a practical art, and the degree of uncertainty in any risk-centred field (Cybersecurity Index, 2019). A number of public organisations are constantly working on the index (International Telecommunications Union, 2018) and threat level indicators (North Dakota State, 2017).

They based the outcomes of their indexing on several concurrent information, including shared global threat intelligence. These indexes are currently based on the threat world-wide activities according to the original "Counter Threat Unit (CTU) Cyber Security Index" (Secureworks, 2019) that is updated using information about a threat targeting software, networks, infrastructures or key assets. The ranking qualification are barely derived from a statistic/numeric analysis on the number of cyber incidents but often are fundamentally based on the CTU expert opinions. Thus, are mainly qualitative then quantitative.

This has been noted to imply that defining the "importance" of a specific Cyber Attack is strongly dependent by the context where the attack is performed and the opinions of the actors in that context.

Thus, to identify and classify the cyber effects, a clear understanding and definition of the threats has to be set up together with a specified context. In

particular related attacks have to be distinguished from other IT phenomena such as the hardware failures or software bugs.

This is crucial in training the aspiring cyber experts but it is also an opportunity to train "non-cyber" operators to behave in a way that eventually limits damages in case of a cyber-attack and thus even to be able to react to the effect of an attack regardless if it is triggered by a cyber-attack or not.

2.3 Methodology for the Derivation of Cyber Effects

The list of the threats and related possible attacks must be associated with some of the many possible contexts in order to focus on those of greatest interest for training in this specific field. It is important to bear in mind that this list won't ever be complete, considering the continuous evolution in the technologies and attack TTPs involved in this field.

Therefore, a continuous updating based on a solid methodology must always be considered. This activity allows to upgrade the type of training according to the evolution of the technology and the capabilities of the aggressor.

On the other side also the organizational, methodological and technological characteristics of the target have to be assessed. A number of significant scenarios for training purpose will help in defining the most important effects.

To summarise, the following Figure 1 shows the proposed flow at a glance.

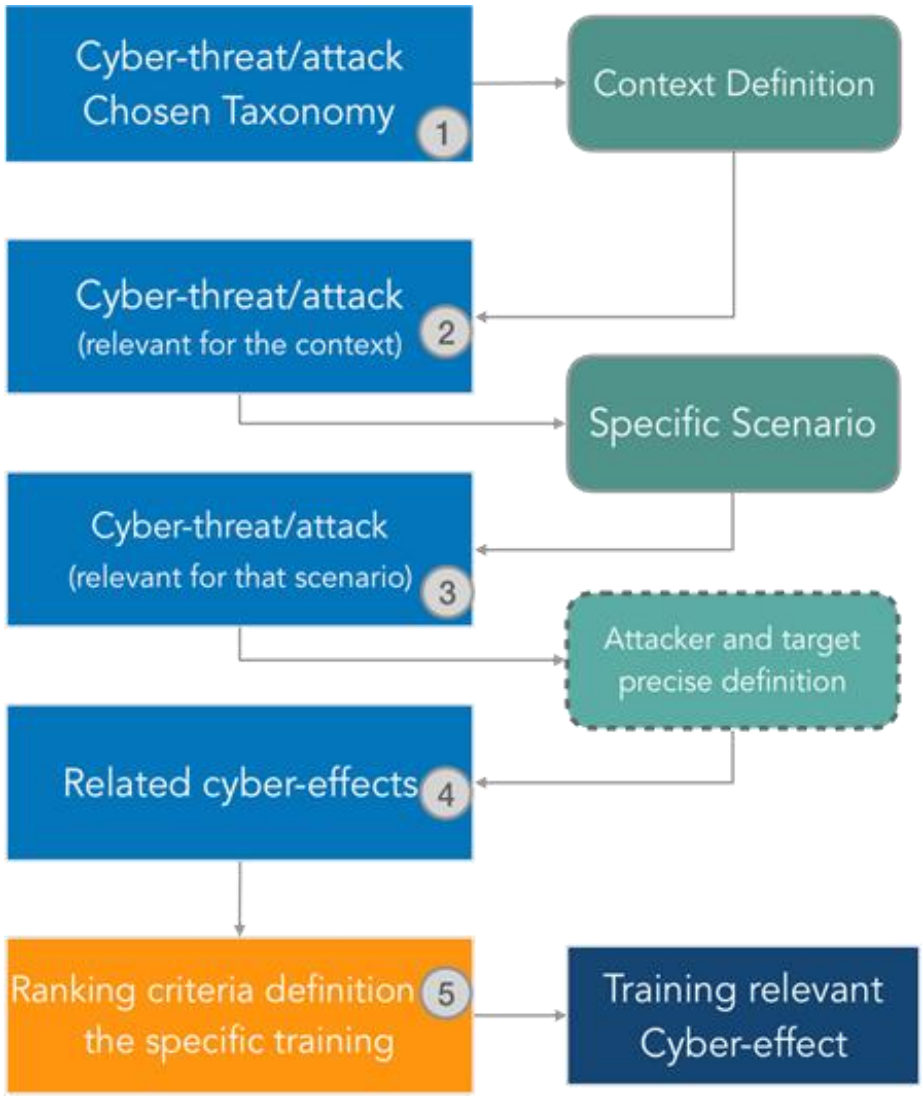

Figure 2-1: Methodology flow.

The proposed method has been developed starting from the most updated and comprehensive list of cyber threats-attacks, sorted according to the chosen taxonomy (MITRE, 2018) (block 1) but it is independent from any specific taxonomy.

This is done because the cyber domain is in constant and rapid evolution and

also because in literature (Agrafiotis, Nurse, Goldsmith, Creese, & Upton, 2018) (Mavroeidis & Bromander, 2017) (European Union Agency for Network and Information Security, 2016) (Defence R&D Canada, 2013) it is possible to find a number of different taxonomies according to several approaches and considered parameters.

Thereby, a more extensive or precise taxonomy couldbe adopted in the future without changing the methodology but just refining the results in terms of classification and the ranking will be amended accordingly.

The chosen taxonomy has to be filtered (green rounded blocks) firstly by considering a specific context. In our case a "military context" has been chosen. Armed forces are involved in wartime conditions (including operations such as Peace-Enforcing and Peace-Keeping) and, in this context, some of the collected threats-attacks will be excluded, because not applicable, or better focused taking also into consideration the experience of the military training staff in a particular exercise environment (specifically in a CAX). This will allow to obtain an appropriate subset of relevant possible incidents (block 2).

In the proposed methodology, the second step to be done is to choose a specific scenario. The single threat-attack can cause different effects for each scenario and the same activity in different situations can range from non-significant to disruptive, up to causing irreparable disasters.

In our example a Command Post scenario is considered defining a new sub-set of incidents (block 3).

Depending on the scenario complexity an optional test can be performed. Because of the nature of the attacker and the target in a very complex and differentiated environment like the Command Post, this filter can be applied to consider a specific function among all the possible. The effects (block 4) could be then ranked according to proper criteria (block 5) chosen by an opportunistic approach and training considerations (e.g. the frequency of that particular attack, the ease of its simulation, the importance of the final consequences, the experience and ability of the trainee and so on). This will result in a number of focused exercises.

2.4 Cyber Headquarter Effects Simulations Services

All the operators of the HQs are potentially exposed to the effects of a cyber-attack, so they should be trained to properly react even if they are not cyber experts, but during the exercises, the training audience is often stimulated just with communications, without really including a cyber component in the simulation.

The NATO M&S COE supported by the industry is developing, customizing

and integrating off-the-shelf solutions to make available a cyber effects simulator capability. Currently, the prototype is ready for being connected to a Federated Mission Networking (FMN)-alike architecture (NATO Allied Command Trasformation, 2015) to inject simulated cyber effects able to simulate a corruption in data integrity affecting NATO C2 systems and operators' workstations without compromising the exercise networks and systems.

During a NATO Exercise Process, the Exercise Controller (EXCON) has both direction and control functions which allow it to establish the conditions needed by the Training Audience (TA) to achieve the Training Objectives (TOs) (NATO SACEUR/SACT, 2013). The EXCON manages several systems, some of them are the simulators that run the models which provide the tracks of the simulated units to stimulate the TA's Command and Control Systems. In facts, the TA operators manage some C2 systems and Common Operational Picture viewers, in order to be aware of the ongoing situation retrieving the tracks from the track store in which converge all the systems managed by the EXCON.

According to the collected requirements, the Cyber Headquarter Effects Simulation Services (CHESS) platform should allow a modular approach for introducing a new training and exercise layer, engineered in order to avoid (or minimize) the impact on the training and exercise infrastructure, introducing several ad-hoc effects in order to make achievable the related TOs.

The CHESS project focuses on the development of an M&S solution to inject synthetic cyber effects in a military command post under exercise, for example to support training at Commander and Staff level during CPXs-CAXs. The Command Post (CP) training audience could be at multinational Brigade and above level. The solution, however, is also suitable to be used at Battalion/Regiment level. In the case of the training of CP personnel, the possible effects implemented allow the injection of several kind of effects in a simulation.

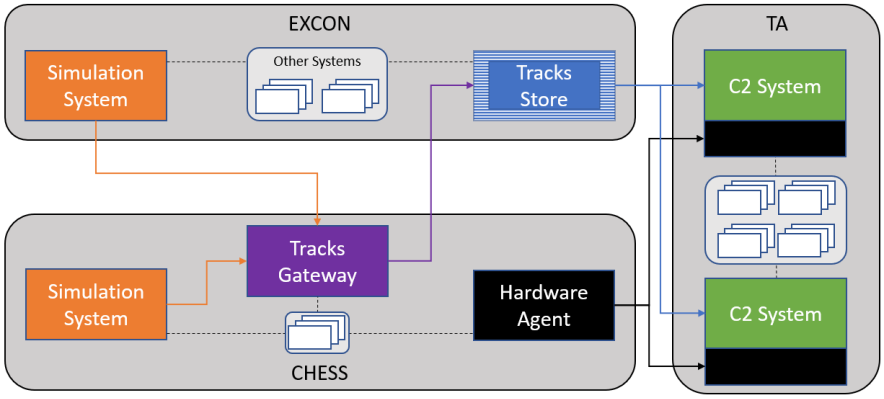

Fig. 2-2: CHESS configuration for the introduction of C2 and hardware cyber effects.

The architecture in Figure 2-2 represents an example of exercise with CHESS plugged in to stimulate the TA with C2 data integrity issues and hardware malfunctions simulated with cyber effects. The nodes that play a key role are highlighted:

- the EXCON, who represents the exercise control;
- the CHESS Simulator who provides Cyber Effects injections to the TA;
- the TA who operates on C2 systems

Adopting the methodology described above to select the most suitable cyber effects for the TO, a particular configuration of CHESS has been tested in a scenario with four players: one directing the EXCON, two playing as TA operators interested by the cyber effects training, and one as the CHESS controller. In this configuration, the EXCON-side simulator and the CHESS-side simulator were computers both connected in DIS protocol (IEEE, 2012) to a track gateway (Sim/Real Gateway) that fed the track store (NIRIS) using the NFFI protocol. The track store provided the common operational pictures with the tracks generated by a constructive simulator (JCATS) translated by the track gateway and injected via the track store to a cop viewer (iGeoSit) and to a NATO C2 system (ICC) on the TA-side. In parallel, an agent was installed and configured both on CHESS-side and on the interested TA's computers.

The EXCON operator set a scenario and ran a simulation. The TA players were operating on the assigned C2 systems, which were stimulated in different moments with two families of effects (derived with the methodology described above) by the CHESS operator.

Operating with the CHESS constructive simulator (STAGE) and the Sim/Real Gateway, the CHESS player could introduce in the flow new (fake) tracks, or interfere with the existing ones by hiding them or corrupting them (i.e. changing their coordinates).

Operating with the hardware agent, the CHESS player was able to: interfere with the monitor of a desired TA operator (turning it off or making it flickering), send him an audio message (would it be a fake order, a fake audio alert or an audio noise to limit his operative capability) and to stuck his mouse pointer.

Receiving those effects, the TA players had to deal with unexpected effects that were sometimes evident and sometimes latent.

The proper application of CHESS makes possible to exercise the TA on existing procedures (i.e. part of a doctrine), to perform a what-if analysis on new procedures that are meant to be explored, and to exercise the TA to react in a new situation, where eventually none of the procedures they dispose of are applicable.

2.5 Conclusions and Way Ahead

Warfighter's Cyber resilience cannot be fully achieved if Cyber Defence remains confined to the cyber experts' community. In a highly networked world, where the number of connected objects hugely overwhelms the number of connected people, Cyber is an aspect that must be considered by everyone in every field at any moment.

The study presented focuses on the training of non-cyber experts to properly react to a cyber issue by executing the right procedures. Although the scope is limited to a very specific training audience, the operators of a deployed military command post, the findings of the study are an important step in the direction of demonstrating that a proper use of Modelling & Simulations can be a game changer when, in an effort to harden cyber resilience, initiatives are taken in areas outside the cyber experts' enclave.

Capability design and development, analysis of alternative solutions and course of actions, training and exercise, situation awareness production, defense planning, are some of the activities that can take enormous benefit from using the modelling and simulation of cyber effects to embed the component of cyber resilience that is under their jurisdiction, thus contributing, synergistically, to the cyber resilience of the whole.

The M&S CoE is strongly committed in providing and experimenting solutionsthat can support a holistic approach to cyber defense and cyber resilience in general. Future works and experimentation activities in exercises like CETATEA will aim to proof the concept and to exploiting and

broadening the scope of the initiatives put in place to support Cyber with Modelling and Simulation.

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2.7 About the Authors

Claudio Zamponi is a Lieutenant Colonel of the Italian Army Aviation, with a Bachelor and Master degree in Electronics Engineering, and a military licensure for helicopter and light aircraft maintenance. He managed for more than twelve years the logistics and maintenance of Italian Army Aviation helicopters and related ground support equipment. After a tour of duty at the NATO HQ SACT in Norfolk (VA) USA, as a Staff Officer in the Concept Development Branch, from 2014-2018, currently he is Concept Development Section Head at the NATO Modelling & Simulation Centre of Excellence, where he is focussing on M&S in support of Cyber.

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Marco Biagini is the Concept Development and Experimentation Branch Chief at NATO Modelling & Simulation Centre of Excellence. He has a Ph.D. in Mathematics Engineering, and Simulation. He has master degrees in strategic studies, peace keeping and security studies and, new media and communication. He was Battalion Commander at the Italian Army Unit for Digitization Experimentation and Section Chief in Computer Assisted Exercise and M&S Branches at the Italian Army Simulation and Validation Centre. He is visiting professor and Lecturer also at the NATO School, member of the Board of Directors of the Italian Movement for Modelling & Simulation and Chairman of the M&S supporting NATO CD&E Research Task Group (MSG-150).

Alessandro Mura has been involved for more than a decade in processes and intelligent systems for the training and distribution of technical information. He has been a member of a number of groups for the standardization of technical documentation at NATO level and has assumed responsibility at national and European level for several research projects on training supported by simulations. For over three years he was the transnational head of Simulation and Training at the Simulation and Training Unit of the Integrated Systems Division of AMS Ltd. He currently works in Rome at the Chief Strategy and Innovation Office of Leonardo SpA for Innovation and Technology Governance, specifically dealing in the area of simulation, supporting the business throughout the product life cycle. In the last three

years he has been involved in projects that make intensive use of operational simulation for the study of the insertion of RPAS in ATM with particular attention to cyber security aspects.

3. STRATEGIC ENGINEERING AND INNOVATIVE MODELLING PARADIGMS[2]

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Abstract

Modelling and Simulation (M&S) is an important approach which could be used to find possible solutions of many actual problems in various fields, starting from training of personnel and up to strategic planning of company development. In this paper, it is presented an analysis of typical constraints and limitations imposed by both M&S developers and final users as well as proposed solutions of these issues, such as utilization of MS2G (Modeling, interoperable Simulation and Serious Games) paradigm during development. Furthermore, it is proposed a multidisciplinary training course in Strategic Engineering aimed to create a new generation of M&S developers and users, capable to utilize new approaches of problem solving and strategic planning.

Keywords: Modelling & Simulation, Interoperability, Decision Support,

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Strategic Engineering, Serious Games

3.1 Introduction

Nowadays, the world faces numerous problems caused by Geo-political situations and fast evolution of society, which affect humanity in different ways (Bruzzone 2018). For instance, changing the economic and political situation is otherwise causing alternation of approaches to public safety and security. Many of these changes are caused by recent technological advances, which could be observed in virtually all fields, starting from communication and interconnectivity and up to IoT (Internet of Things), Big Data and AI (Artificial Intelligence). Obviously, new technologies and approaches create new challenges, however, in case of proper understanding of their potential they could be seen also as opportunities, which would allow analyzing, foreseeing and solving critical strategic issues of the modern world. Strategy is an ancient term which comes from Greek and means army leading (stratos and agein). In fact, the necessity of proper military Strategy in order to succeed was known from millennia, however, the understanding of its indispensability in management and control in other fields was realized much later. For instance, according to Jomini, "Strategy is the art of good direction" ("La Stratégie est l'art de bien diriger", Jomini, Prècis de l'Art de la Guerre, 1838). At the same time, Von Clausewitz stated: “we need a philosophy of strategy that contains the seeds of its constant rejuvenation, a way to chart strategy in an unstable environment” (Vom Kriege, 1832). For these reasons, in order to succeed today, it is critically important to rely on strategic planning, which in its turn requires new simulators and models capable to deal with the current level of complexity of the world. Obviously, in order to create and utilize properly such technologies it is necessary to apply proper approaches and engineering methodologies. In this context, it is important to highlight a MS2G paradigm, which allows to partially solve the mentioned issues by improving interactivity of simulation and involving more regular users. In fact, this paper proposes an overview of how to create and use new simulation models, highlighting importance of preparation of personnel responsible for strategic decision making.

3.2 Challenges

As mentioned, new technologies coupled with smart algorithms are able to provide and elaborate big amounts of data, to predict sophisticated behavior of complex systems by analyzing numerous alternatives, as well as to be easily adapted to utilize new information, tasks and boundary conditions (Bruzzone 2018). Considering this, it is easy to imagine the impact of these technologies that could have on the field of decision making at different levels, from small company management to a country budgeting. The first

researches, aimed to utilize simulation as decision support tool, were performed in the 60's, however, in that period, they were quite rare and available mostly for big governmental and industrial entities (Longo 2011), due to technological and methodological limitations of such solutions. Despite such limitations, the necessity of M&S solutions were clear, in fact, some of early works, such as Mission Earth initiative and GENI (Global Energy Network Institute) global simulation, were inspired by Club of Rome, established in 1968 at Accademia dei Lincei in Italy (Meadows et al., 1972). John McLeod, founder of Society for Computer Simulation International (McLeod 1968, 1986; McLeod John & Suzette, 1974; Clymer 1969, 1980, 1994; House & McLeod 1977), established another important example of such initiatives, named "Mission Earth". The initiative was focused on development of new simulators capable to address in the innovative way concepts used in World Simulation Game and support development of new strategies (Fuller 1969). As mentioned, notable example of a project development in this framework is GENI, which was related to solve the problem of power distribution in a global scale in order to support world development (McLeod 1999; Clymer A. 1993; Clymer M. & Mechoso 1997). Hence, it is clear that understanding of M&S as well as some of supporting technologies were known for many years, however, for many reasons, from limited understanding and up to difficulty in data acquisition, their development and utilization was mostly performed by volunteers with scientific background. In contrary, nowadays, big amount of available data, possibility of cooperation between scientists and interoperability of various models allowed to develop new generation of solutions as well as to distribute them between many users, providing "Service to the Society" by means of M&S.

These considerations open a new question: "so why we don't do all this marvelous use of simulation if it is possible?". To understand this issue it is important to consider mentioned characteristics of technological enablers, for instance, the technical possibility to combine different models is indispensable in context of complex strategic problems (Bruzzone et al. 2014). In fact, if we analyze the mentioned case of worldwide power distribution, it is clear the necessity to combine models, which address different aspects of civilization and society, from quality of life and up to politics.

One of open technological issues is related to the fact that even in case of utilization of consolidated, since many years, interoperable simulation standards, such as HLA (High Level Architecture), it is still difficult to integrate simulators (Kuhl et al.2000; Bruzzone & Massei 2017). Indeed, the standards are mostly related to the technological aspects of interoperability while missing the conceptual ones (Bruzzone et al. 2017a), at the same time,

some programming aspects, especially the ones which affecting reliability, need to be improved (Bruzzone 2017). Another important aspect is related to the human factor, which is quite difficult to model considering its stochastic nature (Bruzzone et al. 2015). As mentioned, another major issue is quantity and quality of available information: while in the past it was difficult to obtain it due to limited data sources, now it possible to collect and transmit it in quasi-real time. Hence, it is possible to elaborate, check, validate and filter as well as to extrapolate information, which in practice, was not possible in the past (McAfee et al., 2012, Sanchez, 2014).

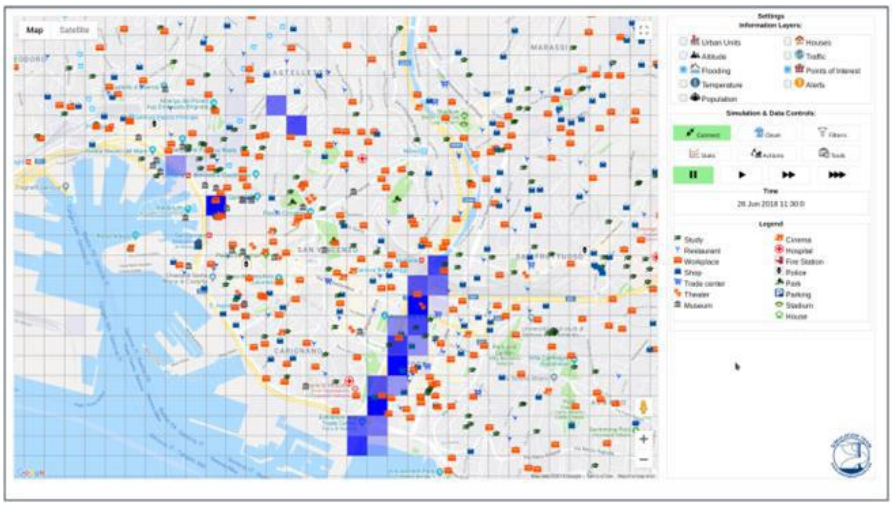

Fig. 3-1 - Decision Theater GUI

Considering all mentioned factors, it is important not to underestimate recent advances in AI (Artificial Intelligence) based algorithms, which significantly changed approach to data elaboration (Wu et al., 2014; Najafabadi et al., 2015). Furthermore, it is important to take into account new ways to utilize technologies as well as their perceptions by new generation of users. In fact, new mobile solutions are widely operated by people without specific preparation or knowledge, hence, in order to benefit from such equipment and provide MSaaS (Modeling and Simulation as a Service) or cloud services (Li et al.,2010; Cayirci 2013) it is necessary to improve their reliability, immersive capability and interactivity.

Considering the analyzed issues it is clear that despite huge capabilities of simulation, the community as well as scientists and developers have to work

hard in order to make M&S more usable and reliable. In the last years to address such issue, it was proposed an MS2G paradigm, which highlights necessity of immersive solutions rather than technically perfect representation of the reality, allowing to regular users to understand and utilize M&S solutions. At the same time, it is fundamental to consider the importance of preparation of final users and creation of multidisciplinary teams (Elfrey 2006; Bruzzone et al.2014b, 2017b). For instance, such goal could be achieved by introduction of new educational programs to support evolution of potential users. While considering actual opportunities it is important to forecast future challenges. In fact, complex scenarios created by MS2G combined with modern technologies (e.g. Data Science, AI & Machine Learning, Internet of Everything) allow to create an innovative context, creating in the same time new challenges. In fact, technological evolution must never be underestimated. For example, some technologies, such as GPS and autonomous driving systems were operational since 90's, however, available data was very limited and algorithms much simpler, allowing to vehicles only to plan routes without considering many important aspects such as traffic (Varaiya 1993; Bart et al. 1996). In contrary, nowadays it is common to see compact and light smartphones capable to identify with high precision optimal path, providing in the same time tips to the user, for instance, information about points of interest (Kim 2017; Wan et al., 2016).

For example, nowadays it is expected from the simulation not only to analyze several important world level scenarios, but also to support decision makers at all levels, optimizing costs and improving efficiency. At the same time, application of MS2G paradigm could improve trustiness between institutions and population by providing easy to understand and utilize models while proposing various solutions of everyday problems (Bruzzone et al.2014b). For instance, it could be possible to utilize M&S to compare, check and validate solutions proposed by different leaders, allowing to citizens to make their own proposals and improving reactions of decision makers at changing conditions and situations. In order to provide an example of this kind of M&S solution it is possible to mention an ongoing project the authors are working on, which is related to crisis management support and currently utilized by different authorities involved in traffic management in Genoa after the collapse of "Morandi Bridge" (Harding 2018). In this case, the initial model, which was developed as part of Decision Theater project with the aim to support strategic urban planning and to address typical for Genoa issues related to flooding, was adopted to extend its capability to simulate road traffic (Bruzzone et al.2017b). The project was finalized in the end of 2017, which means that at the day of the tragedy the public administration had already available model of the city (fig. 1). At the same time, it is necessary to understand possible consequences of improper use of simulation, making it necessary to address not only technical but also ethical issues (Oren et al.,

2002; Balci, 1997). In fact, not validated or deliberately corrupted models could lead to wrong decisions. Furthermore, in case if the end user does not have understanding of subject, the misused simulation could provide invalid results. For instance, in case of garbage collection optimization without considering necessities of the population, it could cause even reducing of efficiency. This because the solution should be related not only to optimization of garbage truck route, but to more sensitive factors; for instance in some countries it is common to pay back for empty bottles (Huang et al., 2005; Duma & Nemeslaki 2013).

3.3 Solutions

As mentioned, one of new enabling concepts in M&S is MS2G, which allows to develop new solutions capable to benefit from synergy of these methodologies, namely interoperable simulation and immersive capabilities, typical for serious games. Furthermore, MS2G allows the users to become decision makers with corresponding time and resource constraints (Bruzzone 2018). In this case, it could be useful to provide interoperability between different models, at the same time, maintaining controls on fidelity of single components. To address issues related to improper use of the simulation, it is necessary to train and educate people in strategic view. Obviously, a special strategic 'forma mentis' and properly balanced multidisciplinary preparation are required to fully take advantages provided by modeling and simulation.

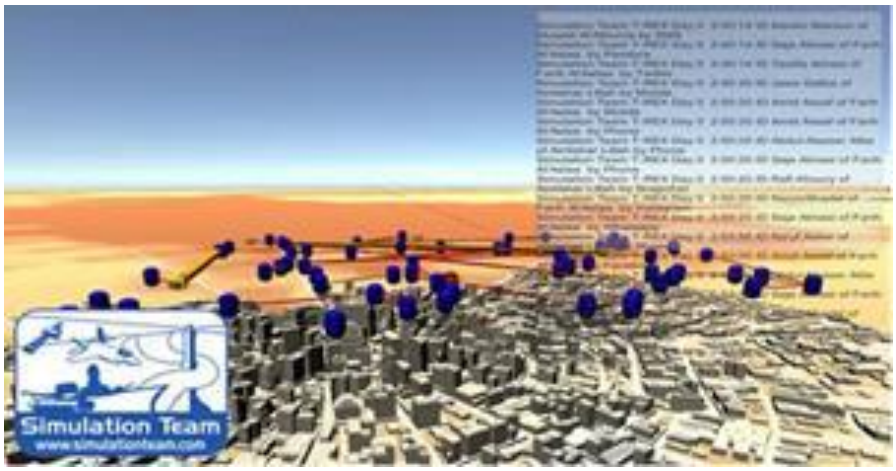

Fig. 3-2 - Hybrid Warfare Simulation for Strategies

Furthermore, it is clear that one of the key issues in this case is related to availability of personnel with required skills and experience. For this reason, new initiatives such as STRATEGOS, master program in strategic

engineering recently activated at the Genoa University (www.itim.unige.it/strategos), are aimed to address such issue. Indeed, STRATEGOS is devoted to prepare a new generation of engineers capable to support decision makers. One of important problems of the M&S, which to be addressed, is related to mentioned ethics of the simulation. For example, new solutions are capable to predict behavior, analyze communications and biodata. However, as said Mahatma Gandhi, "freedom is not worth having if it does not include the freedom to make mistakes"; obviously, improper utilization of such technologies could give possibility to control single individuals or groups, cause mass computational intelligence, otherwise to predict and influence evolution of entire society as it happen with psychohistory (Asimov 1951); it is clear that such scenarios are not so good for the humanity. These issues are already analyzed in scientific literature, highlighting the importance of proper utilization of technologies maintaining in the same time pragmatic approach (Duderstadt 2005; Blackmore 2006, Barrat 2013).

It is difficult to find the final solution, however, it is clear importance of identification of such problems as early as possible. In fact, human being is able to be responsible and to act ethically, to lead for equality and freedom and to make right decisions despite consequences.

3.4 Strategic Engineering

As analyzed, strategic engineering could be one of many potential solutions of actual and expected problems in the field of Decision Support. In fact, the main goal of the course is to create multidisciplinary framework with strong scientific foundations, that could allow to prepare experts and create new interoperable and interconnected models, hence, it is evident the necessity of synergy with such paradigms as MS2G (Bruzzone 2018). In fact, such engineering approaches allow to develop strategies in various fields, such as Industry, Business, National and International Activities, Defense and Homeland Security.

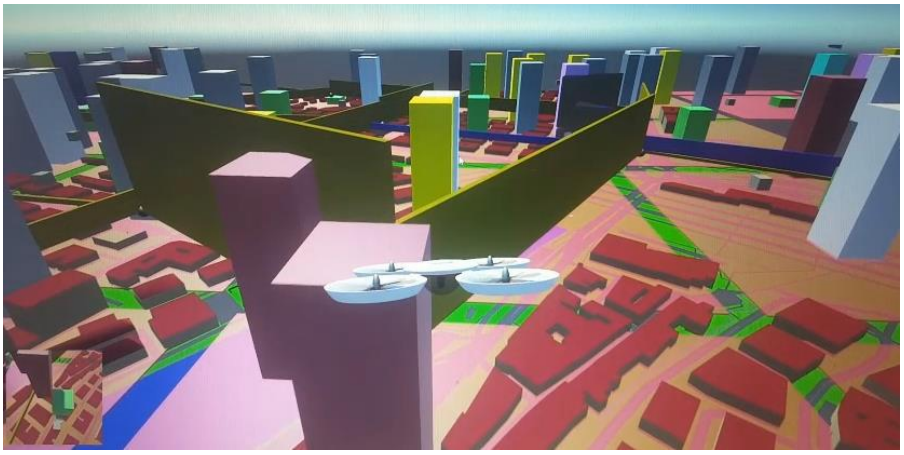

Fig. 3-3 - ARPIA

Obviously, if used by a strategic engineer, such technologies as M&S, Data Analytics, AI, IoT and cloud based solutions allow to solve numerous complex problems in these fields. For these reasons, in order to improve efficiency of problem solving, it is necessary to consider not a single technologies and concepts, but their effective synergy, such as the one which could be achieved between MS2G and Strategic Engineering, reaching another level of decision making and complex problem solving. In fact, well prepared personnel with best available tools is capable to develop new strategies in numerous sectors, especially if multidisciplinary elements are indispensable to succeed (Elfrey 2006). Hence, it is necessary to define and develop capabilities and skills required for strategic engineering, create educational programs which would benefit from collaboration between scientific institutions, industry and public administration in order to train new specialists to develop and utilize new methodologies and instruments (Bruzzone 2018). In order to provide examples of solutions, which benefit from synergy of MS2G concepts and multidisciplinary approach, it is possible to consider following applications:

ARPIA: MS2G in Urban Strategic Planning

ARPIA (Augmented & virtual Reality for Population modeling based on Intelligent Agents) is an interoperable Simulation Environment which utilizes different Simulation Models and IA-CGF to reproduce City Dynamic Evolution as well as People Consensus and Population Behaviors in different boundary conditions, for instance, during normal everyday life otherwise in case of crisis, figure 3. (www.itim.unige.it/projects/arpias.html).

T-REX: MS2G in Homeland Security

T-REX (Threat network simulation for REactive eXperience) is an example of MS2G dedicated to analyze different types of mission environments, such as Homeland Security and Hybrid Warfare; indeed, T-REX supports HLA interoperability standard and capable to be federated with other elements to evaluate different aspects and their interactions (e.g. economics, finance, politics) even through interoperability among models, figure 2 (www.liophant.org/projects/t-rex.html).

SO2UCI: MS2G for Defense & Cyber Warfare

SO2UCI (Simulation for Off-Shore, On-Shore & Underwater Critical Infrastructure) is a Simulation for Vulnerability Reduction in Critical Infrastructures considering direct/indirect impacts & multiple domains (www.itim.unige.it/projects/so2uci.html)

These examples highlight advantages of combining multidisciplinary approach and MS2G paradigm; a possible way to achieve it could be by means STRATEGOS educational programs. In fact, considering complexity of the world, today strategic thinking and strategy development are key competitive factors. In this context, strategy means ability to handle numerous variable factors, take into account their uncertain nature, consider scalability, extensibility and dependability. Good statement which confirms these considerations was done by Ma Yun (also known as Jack Ma) co-founder and executive chairman of Alibaba: "If you want to grow, find a good opportunity. Today, if you want to be a great company, think about what Social Problem you could solve". In fact, following of these strategies allowed Alibaba to grow in net revenues in one month by 56%, achieving 23.8 GUSD revenues and 6.2 GUSD profits. Hence, it is clear impact of proper strategy and quantitative analysis of various data in the field of complex systems.

Despite these considerations, nowadays there are only several Master Programs in the world, dedicated to strategy development, multidisciplinary preparation and utilization of M&S and innovative enabling technologies. Indeed, in the world of today, engineering is more than designing of new systems, technologies and products, now it requires to identify and develop new strategies, processes, solutions and organizations. These considerations are especially important considering that due to quite long life cycle of innovative systems, to forecast their behavior it is necessary to consider many variables, different scenarios and uncertainties. At the same time, proper M&S approach and quantitative analysis are fundamental for the final success. However, nowadays these strategic aspects are addressed by traditional approaches, performing qualitative static analysis of the problem, omitting opportunities provided by modern M&S, AI and data acquisition solutions, capable to address same problems in more effective dynamic way.

Indeed, the aim of this initiative is to setup an innovative international engineering master program, which would benefit from synergy of mentioned technologies and approaches, address in the new way decision support. These results could be achieved by strategic engineering, with deep scientific knowledge and technical skills, capable to develop, tailor, assess and utilize innovative strategic methodologies.

The outcome profile of this master is expected to operate in various domains, from manufacturing and engineering and up to military sector and society development, being capable to design new methodologies, apply strategies and utilize appropriate models (Bruzzone 2018). 18

3.5 Conclusions

In this paper it is presented an innovative approach to combine new simulation paradigms such as MS2G with the Strategic Engineering, a new discipline arising from the necessity to combine enabling technologies in decision support; it is evident that this potential could allow to prepare a new generation of engineers to address the future challenges by using simulation as strategic science to model and investigate complex systems. In addition, it is also outlined the opportunity for Government, Institutions and Companies to enroll these new engineers into their staffs and also to support the development of new educational initiatives in this sense. Indeed, it is proposed a new master program, which would benefit from this approach and will use simulation as main support tool to sustain education in this field. Furthermore, critical issues, opportunities and requirements relate to this combination are proposed in relation to real case studies, where the approach was successfully applied in a wide spectrum of sectors from defense to homeland security and industry.

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4. *TEMPUS FUGIT*: TIME AS THE MAIN PARAMETER FOR THE STRATEGIC ENGINEERING OF MOOTW[3]

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Abstract

This paper reviews, based on current operations, some of the critical issues to be addressed in order to develop a strategic capability based on innovative technologies. Indeed the aspect of time and timing is outlined as one of the main factors that lead to success as it is well known not only in military operations, but even in common life.

It is evident that the approach proposed based on introducing science and models into this context emerges as one of the crucial elements to succeed, as well as the necessity to let decision makers and experts to interact within common immersive and intuitive interactive simulation frameworks. These considerations suggest the need to develop strategic engineering as a new discipline addressing these issues and preparing new generations of decision makers and scientists.

4.1 Introduction

Observing the world and history is a great teacher and could help into identify gaps and opportunities; indeed today technologies sound as great enablers, however it is very important to decide how to use and to shape new solutions. From this point of view this paper goes into evaluating up-to-date situations as well as consolidated knowledge to identify a need for developing new capabilities based quantitative approaches. One of most popular books on strategy, dating back to 500 BC, states:

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夫未戰而廟算勝者，得算多也；
未戰而廟算不勝者，得算少也；
多算勝，少算不勝，而況於無算乎？
吾以此觀之，勝負見矣。

Indeed Sun Tzu define the importance of completing proper quantitative analysis by saying that "*the general who wins a battle makes many calculations in his temple ere the battle is fought.*

The general who loses a battle makes, but few calculations beforehand. Thus do many calculations lead to victory, and few calculations to defeat: how much more no calculation at all! It is by attention to this point that I can foresee who is likely to win or lose".

It is evident that today, the calculation capability mentioned by Sun Tzu relies on advanced modelling and simulation used to support decisions as well as on data science and smart techniques to support decisions. These aspects are obviously fundamental in war, but even in other mission environments as well as in industrial business and it is fundamental to guarantee access to this capability by preparing the "calculation" systems, the people that have to operate and feed them as well as the decision makers that should be able to get benefits from their usage.

Indeed this paper presents the related considerations and propose an approach to develop new capabilities in strategic management in operations other than war.

In facts one of the most scares resource in developing strategies is often the Time and this paper consider it in its wide definition including physical and human phenomena that affect execution of plants; it is evident that Time could often make difference between success and failure respect strategy development.

4.2 Models for Supporting Strategies

In facts the main goal of this paper is to consider the issues related to Time within different kinds of operations with special attention to Military Operations Other Than War (MOOTW) and to consider it respect other Measures of Merits (MoM). From this point of view, it is interesting to consider the potential of a new emerging discipline such as Strategic Engineering in supporting achievements of strategic goals respect existing risks and stochastic factors, especially into unusual mission environments such international mission, asymmetric or hybrid warfare. It is important to outline that these context have been already investigate by the authors in terms of creating simulation solutions able to support analysis as well as new doctrine development respect complex mission environments (Bruzzone et

al.2016); these results have been presented both to Nations and NATO and resulted a successful example of models that could be effectively used for creating a Strategic Engineering Capability; in figure 1 is proposed the T-REX Simulator operating from a an immersive interactive interoperable solution developed by Simulation Team is proposed to allow analyst to investigate a complex scenario involving threat networks population behavior, cyber warfare, critical infrastructures (i.e. power grid, oil resources, water resources), autonomous systems on both side.

Fig. 4-1 – T-REX as support for Hybrid Warfare

In this sense the authors participated in experimentation of innovative solutions based on new paradigm MS2G (Modeling, interoperable Simulation and Serious Games) devoted to support Commander and his staff in Strategic Decision Making respect SIMCJOH Project (Di Bella 2015).

Fig. 4-2 – Cooperative Decision Making in SIMCJOH

Figure 2 propose the example on how cooperative decision making is carried out immersed in the Time of Scenario Dynamics by interacting with the simulator and population behavior as well as with the virtual humans representing Commander's staff (Bruzzone et al. 2015)

4.3 Common Sense, Quotes & Proverbs from the Past

In many cases, people think that *common sense* can solve most of the problems; in facts this assumption could be true in several contexts, but we have to consider that *common sense* is a very rare gift and that, usually, we should rely on techniques and methodologies to find solutions considering most people don't have a speak of *common sense*.
As starting point it could be interesting to remind the definition of *Strategy*; the word derives etymologically from Greek and results from combining στρατός (army) and ἄγω (leading); indeed based on classic definitions the *Strategy* relies on capability to develop effective plans able to achieve success in challenging situations such as business, politics, war, etc. Looking back to quotes from the past a very good definition is provided by General Jomini in his "Prècis de l'Art de la Guerre" (1838AD): ""La Stratégie est l'art de bien diriger" (Strategy is the art of well leading"). Therefore modern experts of strategy since over two centuries point out very actual problems in this context; indeed it is really shocking to read the following statement by Carl Von Clausewitz, as written in the book edited by his wife Marie (1832AD): "*We need a philosophy of Strategy that contains the seeds of its constant rejuvenation, a way to chart strategy in an unstable environment*".
Now the necessity to develop a conceptual approach and methodologies to continuously control strategy evolution respect a very dynamic and unstable environment, makes it evident the actuality of this consideration.

If we look to the words of one of the major text in strategic planning, Militarische Werke (Von Moltke, 1871) it is clearly outlined the challenge to keep plan up dated respect evolving situation and the need to proper develop this capability:

"*Strategy is a system of expedients*"

"*No plan of operations extends with any certainty beyond the first contact with the main hostile force*"

In addition to hostile force dynamics, it should be even consider the difference on mission environments requiring specific approaches and avoiding possibility generalize single case.

Indeed, in 1926, the Russian Commander and Professor, Aleksandr Svechin,

wrote in his book on Strategy that "*it is extraordinarily hard to predict the conditions of war. For each war it is necessary to work out a particular line for its strategic conduct. Each war is a unique case, demanding the establishment of a particular logic and not the application of some template*". So the knowledge of these aspects was known since millennia and the theory was formalized centuries ago; however it seems even today we have problems in real operations; for instance many modern results into a mess based on external view, such happen in the past in Korea, Vietnam, Gulf Wars (Betts 1978, Mueller & Mueller 1993; Summers 2009; Pauly 2017). From this point of view even humanitarian operations and large plan often fail in many contexts even related to small regions when resource applied appear to be huge (Muchemi 2017; Bruzzone et al., 2017); sometime it seems we are very focused on short terms objectives or detailed aspects missing the real strategic perspective, or vice versa, we look to satisfy so many inter-related factors generating not satisfactory results. From this point of view it is interesting to remind a very well know proverb "*cannot see the forest for the tree*"; indeed this sentence evolved from an old statement "*I see, ye can not see the wood for tree*", dating back almost 5 centuries as reported by John Heywood. Indeed if we look at recent operations based on very sophisticated equipment and infrastructures and well trained resources we are usually so focused on detailed planning that we miss the whole picture and the limited success achieved. From an opposite point of view, a common objection to people stating that the apparent failures and difficulties into achieving strategic goals is related to the real complexity of the problems. This topic is even more popular nowadays, in a period where political and cultural movements, currently defined as "populist", apply severe simplifications often without strong foundations, in some way emotionally reacting to partial/total failure of strategic management carried out over years by Institutions and qualified Experts. Currently as reaction against this attitude, it is becoming very popular among experts the sentence "complex problems have simple, easy to understand wrong answers"; this is usually known as Grossman's Law and results from misquoting Mencken's phrase "*for every complex problem, there is a solution that is simple, neat, and wrong*". Now, this absolutist statements are currently promoted by opponents of populism reacting exactly on the same mood, in facts such assumption sounds questionable as "*involution*" of a much more acceptable sentence "*we should be careful about simple solutions to complex problems*" (Statell 2014). Despite author's personal point of view and the evidence that we need good capabilities and skills to solve problems, it is important to consider that thinking back to history we can find many cases where simple solutions solved pretty complex problems; the most well know case, still mentioned today as example, date back to the Gordian Node, a problem pretty complex solved by Alexander with a single slash of his sword as reported by Arrian of Nicomeda, 2'300 years ago.

This considerations is willing to allow readers to reject all polarized approaches such as Black/White, or Simple/Compex, but to apply lateral thinking realizing that things need to be analyzed considering their specifc nature and characteristics; from this point of view the example of Alexander the Great, not just Gordian node, but his whole life, propose us a man born into a court where assassinations and intrigues were so common and complex that the capabilities required to survive were gigantic; so despite the simplification of Alexander as a "great general" and "gifted horseman warrior" it is an evident simplification, considering that his capabilities were much more articulated just to allow him to survive in early years; without to mention that when he obtained the power on his kingdom he resulted capable of transforming "phalanxes" into an army able to travel the world and conquer gigantic empires, usually located at a distance that today could require over 2 months by forced march on roads that at his time don't even exist. This consideration leads to point out that the complexity on past time was not at all so little respect our modern world, so we should not complain on this argument as an excuse for failing in strategic plans nowadays. Another aspect to be mentioned is the problem in taking decisions due to the necessity to satisfy a too wide community of heterogeneous stakeholders;, even in this case another contestable sentence is that we have "too much democracy" and that dictatorship systems are more efficient; indeed the importance to have a common plan and single mind in charge is well know, anectodes about Sun Tsu role assignment by Emperor Ho-Lv of Wu or even more the Dictator role that Roman Republic was assigning pro tempore at a very high qualified person to serve as magistrate entrusted with the full authority of the Republic and to face a military emergency or a crisis (Livy 2012, Jones 2015). Therefore the success of strategies does not rely on just dictatorship approach and there are many historical cases that confirm this aspect. The current main problem related common decision making is related to the short terms goals versus long terms achievement and the necessity to satisfy a too wide audience of supporters without capability to lead them.

Indeed this is exactly a lack of leadership and strategy that, as we said before, lays on leading capability. In facts the western organizations that evolved along the last two centuries have been based on democratic principles obtain great strategic success in many applications; along the years their public opinion as well as general feeling reinforced the concept of fairness, however recently for many reasons, including media manipulation and social network capabilities, we observed a polarization of public opinion on few superficial positions.

This obviously was caused also due to the restriction of "*ideals*" that currently it is strongly concentrated just on individual success and profit with quick and dirt approach based on short time and superficial view missing most of

traditional ethical considerations; indeed this attitude is pretty common in declining societies where there is not need to be active and to fight for resources (Gibbon 2017; Gordon 2017). These boundary conditions lead to create a framework where people don't have too much interest in common enterprises, education and training, so they focus on their specific activities loosing trustiness in Institutions and result even more easy than in the past to be manipulated and divided. From some point of view we capsized the original meaning of the Latin sentence "divide et impera" into a new one "divide et from a way to create fractions in opponents to a way to block any decision "divide et cunctare"; this means that we shifted from creating division in opponents to rule over them to a reality where we subdivide in multiple petulant group that just hesitate to finalize any decision.

4.4 Strategic Engineering & Strategies

Currently is emerging a new discipline defined as Strategic Engineering that represent comprehensive approach to design, develop and use new solutions in order to achieve strategic results against risks, uncertainty, competitors, threats and within critical environments (Bruzzone 2018). Indeed Strategic Engineering is based on the integrated use of innovative technologies such as M&S (Modeling and Simulation), AI & IA (Artificial Intelligence and Intelligent Agents) and Machine Learning as well as Data Science to face Challenges & Uncertainty in Complex Systems and have a wide spectrum of application fields from Defense to Homeland Security, from Government to Industrial Applications; obviously these capabilities are based on enabling technologies and advances that make possible to collect, analyse and process data in models as it was impossible in past years. Therefore strategic engineering addresses also the crucial issue to create transdisciplinary teams where scientists and decision makers could work together, so it requires an evolution on the skill and methods in use within these categories (Elfrey 2006;). Obviously new Education and Training (E&T) programs in this area will be necessary to prepare new generations to get benefit of this integrated approach.

4.5 Time as Crucial Element in Strategies

Among all challenges in Strategy Development, it is evident that one of most crucial element is represented by Time as well as in the capability achieving specific results quickly and in correspondence to the planning; these elements represent probably one of most crucial element for the final success. Indeed, despite the impossibility to generalize cases, already mentioned, it is evident that examples are very useful to improve general understanding if the above mentioned considerations are kept in mind; so in the following some of these considerations are proposed. Today, a disgruntled Public Opinion in the

Western Countries is witnessing the 17th year of the US and NATO intervention in Afghanistan. In such contest, Time, considered both in its physical and human perception dimensions, looks like a neglected factor in the political and military analysis in the Western Countries. This is witnessed by the current statements of US and NATO officials, which are putting the emphasis on "conditions based" end of both Resolute Support (NATO) and Enduring Sentinel (US) operations in Afghanistan rather than time lapse. Sometime it could seems necessary to adopt this approach for the achievement of the missions objectives, therefore it is evident that it could potentially introduce big risk of wasting a scarce resource in conflicts such as Time, marking a turn down in its comprehension and management.

However Time, intended as physical and human phenomena, it is ineludible and its eventual mismanagement poses serious hindrances in strategy development.

As anticipated, the purpose of this paper is to propose a time management in military operations vs other measurable indexes of effectiveness, by the contribution of the surging discipline of Strategic Engineering, which has the potential to achieve strategic results against risks, uncertainty in the management of Military Operations Other Than War (MOOTW) and other types of Asymmetric confrontation.

4.6 Challenging Scenario Exist

There are examples of regions, along centuries, that resulted in very challenging scenarios for military operations. Classical cases could be found from Russia (e.g. Russian Campaigns from Napoleon to World War II) to Vietnam (e.g. Vietnam War, Sino-Vietnamese War) and it is quite possible to observe that the geographical region in terms of terrain and population spirit result to have a fundamental role against opponents even when they belong to a major well trained force (James & Davies 2018, Fuller 2018; Goscha 2017; Sardesai 2018).

Afghanistan is another good example of a region able to provide many troubles to several strong players such as British Empire, Soviet Union and even NATO; this was going along many different conflicts in different times, such as Anglo Afghan War, Afghan Civil Wars, War in Afghanistan (Jalali 2017), Therefore it is interesting to note that in previous centuries, when satellite and drones were not even a dream, Alexander the Great, Genghis Khan and Timur achieved success in the same region by applying each one quite different approaches; as anticipate we don't want to over simplify, but it is evident that strategy could be successfully applied even in challenging scenarios.

4.7 Modern Example: Afghanistan

Let consider a brief exposition of the current situation in Afghanistan in these day (from Press and OSINT).

Nowadays, US Government feels indeed the necessity to bring to a close a 17-year-old war, even though its efforts seems to be jeopardized by the political upheaval in Kabul and the stalemate in the confrontation between Insurgents (Taliban, ISIS K etc.) and the International Community - backed Government of the Islamic Republic of Afghanistan (GIROA). "*Throughout the ups and downs of this conflict, it's become evident that the United States is not going to defeat the Taliban insurgency, even though it can prevent a Taliban victory*" (The Washington Post, 1st September 2018).

The use of local forces to fight the opponent reducing friction for NATO force is effective from some point of view, but strongly affect capabilities on the terrain and affect the trustiness of the different players in a way that could lead to future crisis.

From another perspective, the purely *Train, Assist and Advice* mission carried out by NATO in favor of Afghan Security Forces, named "*Resolute Support*", it is showing instead signals of stability for what concern the presence of NATO troops, even though such cannot be reasonably assessed as timeless.

This case so it is a good example of how quantitative analysis based on reliable models should be applied to consider human factors and timing in strategy development. Indeed the authors were involved, respectively as Project Leader and Military Expert, in the development of innovative M&S solutions applied to Kapisa region in Afghanistan to support operational planning for CIMIC and PSYOPS in strong connection with the general plan. The simulator CAPRICORN was a stochastic simulator, federated with other HLA models and able to reproduce CIMIC and PSYOPS operations as well as their interactions with the human factors of the whole population in the region as well as military units, paramilitary entities and insurgents as proposed in figure 3 (Bruzzone 2013).

Fig. 4-3 – CIMIC PSYOPS Interoperable Simulation

4.8 Time Management in MOOTW

It was already clearly stated that Time is the major aspect in strategy development; now we have to consider the specific concepts of Time Management in War (Warfare) and MOOTW.

In the Modern era, Napoleon should be credited as the first modern Strategist that derived from the management of the forces on the battlefield an insight about "….the vital significance of time and its accurate calculation in relation to space. The loss of time in war is irreparable, in war; Space you can recover…time never, he once asserted" (Chandler 1966). In the contemporary age, the credit to have re-introduced meaningful considerations about time and its impact in the military operations have to be given to Robert R. Leonhard, which elaborated the concepts in his opera "Fighting by minutes: Time and the Art of War", (Leonhard, 1994)

Indeed based on this considerations, Time could be considered as the leading factor in the Strategic Engineering analysis of MOOTW, with a clear distinction between time required vs time available. This is especially true in conditions where the asymmetric threats could obtain support from local population and get reinforced while regular forces are worn down; obviously this situation could be capsized by getting support of the population, condition that is hard to achieve in case of time delay in operations and long term warfare as happen in other scenarios (Galula 2002, 2006).

As such condition happen, as in the case of Afghanistan, the Time turns to be a decreasing resource for the Western Powers (WP), which are affected by internal public opinion, current alliances framework and neighboring country attitude, and last but not least, economic sustainability.

The consideration about Time drives the desired END State. For instance while to Short Time correspond the military classic confrontation- symmetric

warfare; on Long time the Nation evolve into a MOOTW or Civil Wars frame. Both of them as a certain point could potentially crash against the available Time resource. Obviously this resource is not known in advance, and it is continuously decreasing. Indeed currently the authors are considering to develop a model that hazards a correlation among the time necessary to reach the END STATE and the most critical parameters; among these it is considered for sure the human development index of the Country to be stabilized, the GDP of the intervening country, the intervention limit threshold, identified in terms of power (e.g. task force, battlegroup, etc.) beyond which the level of commitment of the intervening nation is subject to the scrutiny of public opinion. All these elements are strong affecting the time scale and to delay specific achievements could result in losing support of public opinion, decision makers or even of your own troops.

In any case, usually the weakest among the competitors try to get more time, in order to overcome the disparity, especially if he could count on some external support (e.g. environmental conditions, local population, domestic public opinion of the opponent, financial sustainability, etc.).

In the proposed asymmetric confrontation ongoing in Asia, the time works against the Western Forces (WF), while it is almost a bottomless resource for the Insurgents. From the other hand, Time in Symmetric Confrontations among Global Military Powers (US, Cina, Russia, etc.) it is non-influent variable, since the power unleashed from the arsenals (in their conventional, nuclear and cyber dimension), could rapidly determine the war exhaustion of one or both sides.

4.9 Strategic Engineering & MOOTW

As anticipated, the Strategic Engineering is the process of using engineering approaches and technologies in the designing and analyzing new solutions in order to achieve Strategic Results against time constraints, risks, uncertainty, and multi faced threats in critical environments. Obviously MOOTW/Country Reconstruction Operations are very good examples of this complex scenarios and it is necessary to develop Strategic Engineering in order to guarantee its capability to offers an effective body of knowledge (Discipline) for this purpose. Indeed Strategic Engineering should be structured in order to able to be effective into planning, execution, evaluation, assessment and drive of MOOTW and Country Building Operations at Political and Military Strategic levels. In a future it could be expected to have Strategic Engineering as a resources for MOOTW, in this hypothetical future (for now) the Strategic Engineering Cell could be located inside a Provisional or Transitional Civil-Military Authority with the mission to build and address the civilian parameters for the Stabilization Requirements, which in turns affects the Security and Military Parameters. So, the optic of a Country

Stabilization in the contest of a MOOTW driven by Strategic Engineering, it is about economy and infrastructure development at the same pace of security, with an eye to the hourglass. As example, in the stabilization of Afghanistan, the Western Powers have so far followed the traditional approach, which is the one adopted at the end of WWIIs: win militarily, then initiate the dissemination of western style democracy together with an aided economic development. This was indeed right for a symmetric confrontation, where the challenge it was winning the military confrontation in its geometric domain, but has proven so far unsuccessfully in asymmetric conflicts, where instead the time, in its physical and human dimension, it is the dictating size. So far then, the security has been the primary concern to address before all the others, with a constant difficulty by the military establishment to comprehend that even overwhelming victories of the WP are turned into political gains for the Insurgents, because of the media. In any case, the paradigm of any military operation has always been the defeat of the opposing forces. This prove to be the truth in many conflicts, however it is just to mention the case of the French occupation of Spain (1808-1814), where a conventional military force perfected trained to fight against a similar force failed to control the internal insurgence. The focus it has always been the defeat of the military component of the enemy, with little or to late efforts to cope with the country and the time constraints.

4.10 Conclusions and Way Ahead

Nowadays, as the long and costly US and NATO commitment to Afghanistan drags itself on rather than with a clear ending, but as condition based, spanning over a temporal dimension which encompass a generation, this brings further evidence that pretending to extinguish a complex conflict which it is a jigsaw of ethnic and tribal rivalry, civil war, criminal panels, country/institution building framed by (relatively) unfriendly powerful neighbors, just with a strong accent on the military means, it is has been proven not successful. Strategic Engineering in such contests has the potential to introduce a new dimension in the military operations, by integrating in the conflict management the capacities deriving from Quantitative Modeling for to Decision Making Support, paired with Strategic Thinking and Scenario Analysis competencies. Indeed it makes sense to think back to Sun Tzu quote "*….the general who wins a battle makes many calculations….. the general who loses a battle makes few calculations*"; so what we need now is a modern calculator, people able to feed and use it, as well people able to adopt the output of the calculator to define and develop their strategies. By the way the authors are further developing these concepts by working on new MS2G solutions combining their different skills & backgrounds. Indeed one of the authors is a scientist that investigated over several years the Afghan Scenario related to NATO Intervention to apply M&S in different cases and that also

served as Project Leader for some years in NATO; while the other author is an Officer with operational experience in several oversee scenarios, including service in Afghanistan right now and in NATO M&S Center of Excellence, currently he is finalizing his PhD defense on use of M&S in this kinds of applications.

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5. NEW EDUCATIONAL PROGRAMS BASED ON M&S FOR STRATEGIC ENGINEERING[4]

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Abstract

This paper proposes a new initiative, named STRATEGOS, devoted to promote Strategic Engineering as a new discipline to be taught in University and to prepare a new generations of engineers able to use new technologies for supporting decision makers on strategic issues.

This initiative is strongly based on the capability to combine different methodologies in real applications; the pillars of this discipline are represented by Modeling and simulation, data science, machine learning and smart optimization solutions. Also, the paper proposes applications and program as example for further developments.

Key Words: Strategic Engineering, Simulation

5.1 Introduction

In modern world we face many challenges that usually require efficient

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strategic decision making; therefore we assist, not rarely, to failures due to decreasing of trustiness in Institutions and Politics among the population. It happens similarly in military operations as well sometime in industry and business. These kinds of issues in supporting strategies have been addressed since centuries by classical writers, including Livy and Machiavelli, therefore, recently some pretty interesting reading about these subjects with special attention to complex scenarios and systems have published (Powell 1992 Mintzberg 1994; Galula 2002; Gordon 2017). Obviously, many books related to decision making and strategies are available, but a crucial element emerging as critical is the decision making capability (Summers 2009; Luttwak 2016; Payly 2017). This problem has two evident sides: decision makers along with their staff should acquire new capabilities. Nowadays we are experiencing the revolution of information age and many new data sources and resources are available; indeed also computational capabilities are much higher than before and AI (Artificial Intelligence) is demonstrating major advances (e.g. intelligent search, human profiling, communications, transportations, etc.) in complex scenarios (Massei et al.2014). So it is evident that today it turns possible to use enabling technologies and new methods into an integrated way to support decision makers, but, at the same time, it emerges the necessity to prepare a new generation of scientists, engineers and decision makers able to work using this new tools and related innovative approaches.

A promising solution to this challenge is provided by Strategic Engineering, a new discipline focusing exactly on these issues. The authors developed an new educational program, named STRATEGOS that is an example of new deal in this direction and could represent a way toward the necessary achievement in Strategic decision making (Bruzzone 2018b).

5.2 Models for Strategic Engineering: Some Examples Introduction

Despite the highly innovative nature of Strategic Engineering, ideas about this capabilities have been considered since several years (DARPA 2007); furthermore it is evident that today multiple models are already available to be used; in the following few examples based on Simulation Team achievement are listed (Bruzzone 2013; Bruzzone et al. 2009, 2011, 2014, 2015, 2016):

• ARPIAS: Augmented & virtual Reality for Population modeling based on Intelligent Agents

• BACCUS: Behavioral Advanced Characters & Complex Systems Unified Simulator

• CRIPEM: CRitical Infrastructure Protection in Extended Maritime framework

• Decision Theatre: SMARTCITY, Strategic Decision Making in Urban Environment

• DIES-IRAE: Disasters, Incidents & Emergencies Simulation & Interoperable Relief Advanced Evaluator

• MALICIA: Model of Advanced pLanner for Interoperable Computer Interactive Simulation

• MEGACITY Simulator

• MOSES: Modeling Sustainable Environments through Simulation

• SIMCJOH: Simulation of Multi Coalition Joint Operations involving Human Modeling - Virtual Interoperable Simulation & Virtual Interoperable Commander

• SO2UCI: Simulation for Off-Shore, On-Shore & Underwater Critical Infrastructure

• ST_CRISOM: Simulation Team Crisis Simulation, Organization and Management

• S4PT: Safety, Security Simulation System for Port Terminals

• T-REX:Threat network simulation for REactive eXperience

In these solutions apply Intelligent Agents and interoperable simulators, able to create a virtual framework where is possible to test strategies (Bruzzone & Massei 2017); indeed these simulators and virtual environments have to be even considered as major resources for E&T programs (Education and Training) in Strategic Engineering to organize classes, interactive experiences, exercises and role play games in realistic scenarios with experts (Di Bella 2015).

5.3 Strategic Engineering Initiatives

Strategic Engineering is an emerging new discipline that was already promoted in different Initiatives by authors including Workshops, R&D Projects, Seminars, Webinars, etc. For instance recently several workshop, presentations or tracks were included in conferences such as :

• Future Forces Forum, Praha, October

• 11th Workshop in Applied Modeling and Simulation, Praha, October

• Strategic Engineering & Simulation Session

• Serious Games for Strategy Session

• 15th International Multidisciplinary Modeling & Simulation Multiconference, Budapest, September

• 8th International Workshop in Defense and Homeland Security Simulation, Budapest, September

• Track on Simulation for Strategic Engineering, Budapest, September

• Logistics Enhanced by Simulation Nowadays: Strategies and Guidelines for addressing New Opportunities & Challenges, Invited Speech at TIDE, Think-Tank for Information, Decision and Execution Superiority, Spring 2018, organized by NATO ACT (Allied Command for Transformation)

• Presentations on the 3rd NASP International Workshop on Conflicts and Institutions

In addition there are active calls for Journals on this subject:

• *Special Issue on M&S and SG for Strategic Engineering*

5.4 Strategos Initiative

As anticipated, STRATEGOS represent a new initiative devoted to promote quantitative analysis and modeling for strategic decision making process (Bruzzone 2018a). Indeed along the years several qualitative approaches are emerged addressing management issues for companies and even qualitative engineering turned to be popular. The good performance of qualitative engineering in supporting professionals playing key roles, is strongly related to the necessity to take decision in presence of highly degree of uncertainty while facing complex systems that result not predictable and it could still have application for those who are confident with these approaches. Therefore many realized a strong change due to technological enablers: indeed, it results evident that new technologies allow to access, process and model huge amount of data, often obtained in quasi-real-time. It makes possible to perform quite effective quantitative analysis. The point is create engineers mastering these technologies in order to combine them together and obtain

reliable and punctual quantitative results. In facts, STRATEGOS aims to create a new generation of engineers dealing with Strategic Thinking based on quantitative models and methodologies so that they might support Decision Makers. It is evident that these achievements strongly rely on specific techniques such as advanced Modeling & Simulation (M&S) and Mathematical Modeling (Cianci et al. 2016). Obviously several enabling technological and scientific areas supporting this approach are to be covered by STRATEGOS Program.

Fig. 5-1 – STRATEGOS Programs, courses, workshops and project work

In facts, the term Strategy define the ability to deal with a variety of variables, considering uncertainty, extensibility, scalability, dependability as well as opponent reactions.

Also, it make sense to remind a major Strategist, Von Moltke, who defined "Strategy as a system of expedients; it is more than a mere scholarly discipline". He was used to add that "no plan of operations extends with any certainty beyond the first contact with the main hostile force" (Militarische Werke, 1871). These considerations are still valid today, however the Preußischer Generalfeldmarschall did not state “Strategic Planning is

useless" but the opposite: the necessity to adopt a Dynamic and Fluid Strategic Approach that is exactly what we have to face nowadays. In facts, STRATEGOS does not deal with creating Strategists, but people mastering the techniques and technologies to create Dynamic and Fluid Aids to Strategic Decision Making based on current advances. So the main aim of STRATEGOS, Master in Engineering, is to prepare people to develop these new models and architectural solutions able to win the present and future competition within a wide spectrum of applications. From this point of view, it is possible to find a validation of this approach in many current initiatives; for instance, it makes sense to consider just one statement, among millions, that confirms the importance of Strategic Engineering: "If you want to grow, find a good opportunity. Today, if you want to be a great company, think about what Social Problem you could solve." (Ma Yun, alias Jack Ma, co-founder and executive chairman of Alibaba, in 2018: Personal Net Worth 42.2 GUSD; Alibaba 462th World Raking, 23.8GUSD Revenues, 6.2GUSD Profits, 56% Growth in Net Revenues, Stocks +15% within a single month). Indeed if we analyze major success in business (e.g. Facebook, Alibaba, Amazon, Booking, etc.) they are strongly addressing social issues and turning them into a business opportunity.

In facts, social factors play a major role in development of Strategies and the access to computational capabilities based on new quantitative models reproducing the dynamics of Complex Systems an using big data. It is interesting to outline that STRATEGOS initiative is among first ones worldwide and it specifically focuses on applications for industry, business and governmental agencies. A special attention will be devoted to Defense as well as other applications: organizational changes, finance, marketing, services, operations. The Master addresses the requirements for developing capabilities for support to Strategy Planning and Development and the major pillars are Simulation, Artificial Intelligence, Mathematical Modeling Machine Learning, Innovative Operational Research & Data Analysis (Sciomachen et al. 2005; Bruzzone 2013). The STRATEGOS students are expected to learn how to design architecture for supporting decision process and how to combine the different methodologies in algorithms to be supported by Information and Communication Technologies (ICT). It is important to state that engineers are not just about to design new Systems and Products, but also to support Definition and Development of New Strategies. Obviously these aspects deal with the ability to define and implement New Processes, new Solutions and change Organizations able to guarantee the achievement of Strategic Goals. In facts new Systems have a quite long and risky Operational Lifecycle, strongly affected by many variables as well as by changing boundary conditions and general scenarios. STRATEGOS aims to provide the students with proper understanding of all these issues. As

anticipated, up to now they are often roughly addressed by educational practices: for instance, by applying basic qualitative approaches or simplified static analysis methodologies to provide insights of complex systems.

5.5 The Educational Program

The abovementioned new Engineering Master Program, MSc, deals with enabling technologies while combining different domains to address Strategic Decision Making.

STRATEGOS is a Joint Venture among different Engineering Departments, Faculty of Economics and Political Science as a new educational path providing deep Scientific Knowledge as well as Technical Engineering Skills combined with Strategic Planning and Decision Making Approaches in use for Business and International Affairs.

The final goal is to give a proper scientific background to those expected to work closely with decision makers with different backgrounds. The graduates will be capable to develop, tailor, propose and update strategies both on planning and development phase. The new Strategic Engineers will be able to use advanced quantitative methodologies and Models directly together with decision makers and executives for Strategy Definition, Innovative Solution Development and Capability Assessment. The details of the focus are under definition within the steering committee (international experts in different domains e.g. power, communications, defense, consultancy). Indeed the scope is to create a strong synergy between Academia and Industries as well as Governmental Institutions, Military Services and International Organizations. In this way the professionals generated as outcome of STRATEGOS will experience leading Institutions and Companies while their internship & project works to reinforce their capability to operate in a variety of application domains ranging from Manufacturing to Engineering, from Military Sector to Business, from Politics to Personal and Societal Development. They should be able to apply Strategies using the most appropriate Models, but also to finalize system requirements and to design new Methodologies, Techniques and Instruments for Strategic Planning and Management (Amico et al. 2000). Topics addressed in STRATEGOS include:

- Computational Methods
- Computer Programming
- Continuous Modeling and Simulation

• Crisis Management

• Cyber Physical Systems

• Cyber Warfare

• Decision Making

• Decision Support Methods

• Discrete Modeling and Simulation

• Game Theory

• Graphics Modeling and Simulation

• Human Behavior Modeling

• Hybrid Warfare

• International Relationships & Geopolitical Models

• Mining and Analyzing Big Data

• Modeling and Design of Complex System

• Modeling and Simulation of Maritime Systems

• Modeling for Monitoring and Diagnostics

• Models and Principles of Economy

• Operational Research

• Probabilistic System Design

• Social Network Modeling

• Software Systems Design Techniques

STRATEGOS program includes seminars and workshops open to selected audience addressing hot spots (e.g. Social Network Modeling, Demand Forecast, Modeling for B2C, Hybrid Warfare, Human Behavior Modeling, Cyber Warfare, Crisis Management, Anti-Access Area Denial A2AD, Agile

C4I, CBRN, etc.). Indeed these subjects are pretty relevant and require use of modern scientific approach to be effective (Gerasimov, 2013) it worth to mention that current operational scenarios propose very interesting cases where strategies, despite big efforts, resulted in failures due to multiple causes that a Modeling approach could face (Jalali 2017; Di Bella 2015). The students will perform team working on simulators (figure 2) as MIPET students do (MIPET is the 1st International Master Program of Genoa University in Industrial Plant Engineering and Technologies). Topics such as project management, construction, sustainability issues are addressed by experts from Industry using computer simulation to investigate alternatives and finalize virtual experience: innovative simulators such as SIMCJOH will be in use for this purpose (Bruzzone et al.2015). Moreover, STRATEGOS is an International Master open to student from worldwide, lectures are delivered in English language and optional courses will be offered also in other Languages to improve cultural background in soft skills (e.g. Project Management, Team Building) as well as in Language (e.g. Italian, English, Spanish, Chinese, Portuguese). The STRATEGOS program is currently organized over 2 years, where 3 semesters are focused on lectures, exercise, simulations, role play games and laboratory activities, while the latest is devoted to a project work within a Company or Institution; indeed it is possible also to spend some weeks in international initiatives to enhance the capabilities of the students.

Fig. 5-2 - Interactive Class on PM in MIPET

5.6 Roles for Strategic Engineers

The STRATEGOS Engineers could serve in multiple roles in Industry, Business, International Activities, Defense and Homeland Security; some examples are listed hereafter:

• Scenario Identification, Definition and Analysis

• Support Decision Makers by Quantitative Methodologies, Models and Analytical Approaches

• Strategic Analysis and Decision Support in Defense

• Development of Models, Processes and Analysis to support Governmental and International Institutions, Policy Makers and Public Authorities

• Support to Industry in Strategic Decision Making, Planning and Scenario Definition

• Development of Models of Complex Systems

• Data Farming by Simulation to extend, integrate and fuse Big Data for Data Analytics

• Development of New Algorithms, Models and Architecture devoted to model, simulate, anylize and support decisions in complex Systems

• Modeling, also through the capture of data and information conditioning, of the scenario in which the organization moves

• Supporting the management of an Organization, civil or military, in defining the objectives and planning the actions necessary to achieve them

• Simulation, through the implementation of self-built systems, of the evolution of events on the

basis of planned actions to verify whether the objectives of the organization are likely to be achieved.

• Development of plans to defend and restore to normal operating conditions following attacks or major emergencies.

5.7 Placement Opportunities

Modeling, analysis and strategy planning are some of the competences and skills expected to be usable for several applications. The expected target include large companies, but also Small Medium Size Enterprises (SMEs) given the typical current uncertainty in Industry and Business.

Specific competences, that are expected to be useful particularly for advanced business dealing with complex systems and closer to the world of the research, include discrete and continuous modeling, statistical techniques, scenario simulations, enabling ICT technologies.

Position in public/private research and management/administration centers is targeted as well as in Industries and Companies. Hereafter some examples:

• Support to the Board of Directors: Oil & Gas, Industrial Process Plants & Industries, Major Manufacturing Companies, Strategies for B2B, Strategies for Business to Consumers, Strategies for Communications Services, Strategies in Energy, Strategies in Resilience & Sustainability, Strategies in Investments, Retail, etc.

• Support to the Directors: Strategies on Operations for Major Industries, Strategies in Multi-Project Management in Companies, Operational Level and Grand Tactics devoted to implement Strategies, etc.

• Strategies for Specific Domains: Power, Constructions, Services, Logistics, Marine Sector, Airport Networks and new Air Traffic Control Solutions; New developments enabled by Autonomous Systems; Space & Aerospace (e.g.Micro Satellites and Enabling Technologies in Aerospace); Underwater Resources (e.g.Impact of advances in Underwater Robotic Systems), etc.

• Support to Defense & Homeland Security: Commander Decision Support in Operational Planning -Course of Action Definition, Quantitative Support to Negotiation and Consensus, Strategies for Homeland Security & Defense, New Programs and Simulation Based Acquisition, etc.

• Support to Agencies & Governmental Institutions (e.g. EDA, ONU, NATO): Strategies on International Affairs, Consensus, Strategies in Service to Society, Health Care & Strategies, etc.

• Models for Companies specialized in complex Systems and Plants, etc.

• Design, service and management companies (including Banks and Insurances) requiring scenario simulation and data processing and

interpretation, etc.

• Companies (e.g., software houses, mechanical electrical and electronic components and systems, etc.) interested in Decision Making and Engineering, especially considering product/system/service strategy. This should concern also SMEs.

5.8 Strategic Engineering Skills

STRATEGOS Engineers are expected to address models and algorithms development and carry out Scenario and System Analysis. In addition the Strategic Engineers are trained to identify the Target Functions in a Complex Systems, that is why Strategic Engineer Skills include among the others:

• Engineering and Mathematics applied for modeling complex systems

• Modeling and Simulation

• Data Farming and Data Analytics

• Artificial Intelligence, Intelligent Agents and Machine Learning

• Robotic Process Automation and Autonomous Systems and Heterogeneous Networks

• Mathematics, Information Technology and Engineering for the implementation of Simulators and for the Critical Analysis and Decision Making

• Economic and Political Analysis of Scenario and Operational Context and Feasibility Analysis of the Alternative Solutions

• Context Engineering for the Technical Sustainability of the Strategies developed and the Plans to implement Them

• AR, VR, Graphics and Visualization, to move results into an easily accessible and understandable, interactive, immersive and interoperable framework

STRATEGOS Degree is multidisciplinary, it aims to providing skills for addressing and coordinating complex systems such as that ones in Defense, Homeland Security and Industry. Simulation Team and Elios Lab provide a major support to promote the education activities of the Master making available their resources.

5.9 Steering Committee

STRATEGOS Steering Committee involves Top Quality Experts and Scientists from Academia, Industry, Services and International Agencies in order to keep updated its contents and to guarantee continuous improvements. In addition, the engagement of Excellence Centers guarantee to enhance the opportunities for the STRATEGOS Students. Currently Agostino G. Bruzzone and Alessandro De Gloria serve as coordinators, however new organizations and institutions are expected to be involved into the process. Indeed Memorandum of Understanding, Patronage and Collaboration with many entities are foreseen, even considering Education & Training emerging needs (Mazal 2018).

5.10 Designing Flexible Selection Process

The Selection process in this innovative program need to consider that different people could apply: new graduates with a BSc in Engineering, but also professional people such as officers or scientists working in this field and interested to develop strategic engineering skills; due to these reason STRATEGOS created a special Committee for selection including as observers representative of the Institutions and Companies involved in the Steering Committee. In addition STRATEGOS is designed as proposed in the general scheme, to develop and include specific workshops, seminars and preliminary classes devoted to provide credits to people applying for this MSc Program that don't have the titles to finalize the procedure; in this way the applicants will attend these initiatives and acquire missing credits.

In facts the admission to STRATEGOS is subject to the possession of specific curricular requirements and adequacy of personal preparation.

The verification of the preparation will be carried out as described in the academic regulations of the M.Sc.

Indeed for professional people with experience it will be possible to send applications to be evaluated by the selection Committee. The validation of such credits will be obtained as result of the recognition of Professional knowledge, expertise and skills certified individually in accordance with current legislation.

Other knowledge and skills gained through educational activities at university level is possible; obviously, considering the lectures and the educational material will be all in English, it is required to have adequate knowledge of the English language, with reference to disciplinary vocabularies, equivalent

to B.2 or higher.

5.11 Conclusions

STRATEGOS focuses on developing an innovative framework for new generation engineers dealing with Strategic Engineering. The students will attend classes and labs to use modern M&S, MS2G (Modeling, interoperable Simulation, Serious Games) Machine Learning, Big Data, innovative ICT solutions (Bruzzone et a. 2009, 2018a; De Gloria et al. 2014). These "tools" have a great potential to support effectively strategic analysis for dynamic complex systems affected by emergent behaviors. In addition, STRATEGOS considers as a major atout the partnership with Institutions and Companies: this is a stronghold able to support this Master by means of valuable Internships and Excellent Placements.

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6. DRAWEVA: A SERIOUS GAME FOR STRATEGIC COLLABORATION[5]

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Abstract

Leadership and collaboration are key factors for decision making, particularly at strategy level. However, sharing goals, tasks and knowledge is difficult, in current organizations, and it is the subject of careful and expensive training programs. One tool that is being explored to support such training activities is given by serious games (SG). This paper presents Draweva, a multi-player 3D SG designed to coach decision makers to focus more on synergies with others and collaborate also beyond their own area of responsibility. The Draweva plot, set in a fantasy environment, requires players with different roles to communicate and collaborate in various tasks in order to achieve the final target of their adventure. In a preliminary qualitative tests, experts have positively assessed in terms of development flexibility and efficiency the technological solutions we have implemented to support Draweva.

Keywords: Serious Games; strategy; collaboration; decision making

6.1 Introduction

The Serious Game (SG) term is used to define games which provide a mental contest and are played with a computer in accordance with specific rules for government or corporate training, education, health, public policy, and strategic communication (Noghani, 2010). Serious games are not meant to replace traditional learning methods, they rather aim at integrating them and allowing users to learn and have fun at the same time (Arnab, 2012) and to contribute to the player's level of motivation (Bellotti, 2010).

Games are intrinsically related with strategy, as they typically require and spur a player to think of and implement a strategy in order to achieve the goal.

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SGs add to this the fact that they purposely target a goal which is not pure entertainment. For instance, describing the Wuzzit Trouble game, (Pope, 2015) write: "the game engaged learners in an iterative process of decision-making by calling for students to try, check, and revise their strategy as they played".

This paper presents Draweva, a SG stemmed from the observation that, today, people in organizations tend to work in what are called "invisible silos": they are only aware of their own targets. At the same time, they are often not aware of others and miss the opportunity to make relevant (strategic) decisions based on a general view of the entire organization. Draweva was developed with a view to help decision makers in organizations to focus more on synergies with others and collaborate beyond their own area of responsibility.

The primary audience of the game are leaders who want to lead high-performance team. The leaders can be from global, regional or local organizations, and can be from different leadership levels. Many multinational corporations and also small-to-medium enterprises set the focus on collaboration and teamwork, and these aspects will become even more important in the next years.

The game is embedded in a bigger frame, called Q Coaching Camp, which is an online platform for measuring, developing and sustaining behavior change. It is designed to be played in a specific time-frame by a set of people from an organization which is coached by the Q Challenge company specialists. The game is in its final stage of development and will be used in real Coaching Camps starting from Q1 2019.

This paper is organized as follows. Section 2 describe the related works in the context of SGs about knowledge and skills for business. Section 3 describes the relevant requirements and the relative design of the Draweva game. Finally, Section 4 reports some of the preliminary experimental results obtained.

6.2 Related Works

(Earp, 2014) argue that SGs can be considered suitable means to contribute to develop knowledge and skills for business. They highlight that SGs impact should consider both cognitive and affective/behavioral aspects and that SGs should allow appropriate personalization of learning paths.

Regular training of social skills in organizational settings is being ever more supported for an effective communication among members, which is important particularly in emergency situations. (Haferkanmp, 2011) proposes a disaster communication methodology providing a SG which enables its users to train soft skills, also including group decision, in a virtual

environment simulating under safe conditions. In a terror attack simulation, (Chittaro, 2015) shows that a SG for emergency preparedness is able to improve knowledge, self-efficacy and risk and severity perception. The authors explore psychological models, particularly the Protection Motivation Theory, that explain how people are motivated to protect themselves from danger. Testing a SG for environmental management, (Jean, 2018) argue its aid in crossing knowledge boundaries and supporting stakeholder collaboration. After surveying water-related SGs, (Aubert, 2018) propose many research opportunities for behavioral operational research as no SG exist that support preference elicitation compatible with multi-criteria decision analysis, which is used . An overview of SGs for decision making and strategy development for environmental and disaster management is provided in (Solinska-Nowak, 2018).

SGs have also been utilized to facilitate distributed requirements elicitation, by enhancing communication and collaboration between project members (Hadi-Ghanbari, 2015). Observing three SGs from L'Oréal, IBM, and Thales, (Oihab, 2017) propose a theoretical model with five distinct influence domains of serious games useful for collaborative open training: relations, culture, knowledge, innovation, and desire.

(Bellotti, 2014) presents a table template for the scouting of SGs for university-level entrepreneurship education and defining the most appropriate mix for their use in the courses, keeping into account targeted competences and skills, usability and pedagogical effectiveness. In the corporate training area, (Bacharova, 2012) discuss metrics for effectiveness, that is key to assess the impact of a SG.

In the defense area, systems to support Situational Awareness take increasingly advantage of data and information fusion techniques. (DeRosa, 2018) describe the Reliability Game, that was developed to characterize information source factors impact on human belief assessment.

(Westera, 2017) argues that Cognitive flow in serious games can be effectively modelled in computational models, that explain how different user strategies in serious games produce different learning curves. Generalizing the concept, we argue that these models might be used for identifying unexpected strategies that may arise in a gameplay. Concerning uses of M&S addressing Human Factors and Human Behaviors for Defense against Terrorism, it worth mentioning that researches successfully used SG in Education and Training even by web games (Bruzzone et al. 2009).

It is important to finally highlight that different research studies claim that

specific design features should be carefully investigated since they may compromise the success of a collaborative-competitive SGs in terms of usage and learning (Buchinger, 2018). (Carvalho, 2015) have proposed a SG analysis and design support methodology that builds on the Activity theory to so support an in-depth analysis of how the combination of a SG's elements support its target pedagogical goals.

6.3 Requirements and Game Design

Requirements for the game design are provided by the Q Challenge experts in leadership coaching. In particular, the most important requirements are:

• Observation and Search for Trends: the decision maker needs a complete understanding of the industry/military context, trends, and business drivers. He has to routinely explore and synthesize the internal trends in his day-by-day work (e.g. pay attention to the issues that frequently arise in the organization).

• Ask the right question: questions are fundamental for strategy planning. By becoming curious, and looking at information from different points of view, the decision maker should be able to reduce the uncertainty and see different possibilities, approaches, and potential outcomes.

• Collaboration: the decision maker has to be proactive about connecting with colleagues and peers both in his organization and business context, in order to understand what happens and then share findings.

• Non-realistic settings: the decisions have to be taken in an abstract context, different from the one in which the user performs his activity. This is important in order to allow the training to be effective for various industrial/military contexts and to focus on the skills needed to strategic decision making instead of the details of a specific context.

• Dilemmas and Pitfalls: success is not a matter of absolute performance, but depends on how well the decision maker does relative to others (collogues and competitors). The best decisions must anticipate the moves of others. Some guidance comes from the game theory, with situations like the "prisoner's dilemma" or the "rock-paper-scissors" game, in which the winner is determined by the interaction of all players' decisions.

• Planning: people should be rewarded for evidence of thinking, not just for reaction. The organizational culture has to encourage the anticipation of opportunities and the avoidance of problems (e.g. managers have to be rewarded when they quickly propose solutions to problems with long-term

benefits for the overall organization).

6.3.1 Technological architecture

Based on the stated requirements, we have implemented a first version of the Draweva game, developing a set of technical functionalities on top of the Unity Game Engine (Petridis, 2012). The main components are:

• A 3D fantasy scenario implemented through the 3D graphics rendering of the Draweva 3D virtual world and where the player interaction is managed. The scenario consists of different naturalistic and fantasy places (e.g. rivers, mountains, caves, etc.) with a medieval castle in the center, in order to adhere to the "non-realistic landscape" requirement. The 3D world module leverages all the features already available in the Unity Game Engine (rendering, event management, scripting, etc.).

• A multiplayer support responsible for collecting events and information from game clients (used by the players) during the different game phases. The modules provides players with data about the internal state of the game to allow them maintain a complete version of the game world (e.g. current position and action of other players). This is important to allow collaboration between player.

• An assessment component which interprets the action performed by players during the game (e.g. make a right decision, collaborate or compete with others, etc.) and decides on the current evaluation of the user based on the Item Response Theory (IRT) (Bellotti, 2009). Based on information about performance, the game can provide feedback to the players using scores and badges.

• A dialog manager module responsible for allowing the user to interact in natural language with Non-Player Characters (NPCs). This gives the perception of a deeper involvement compared to traditional communication systems. The module allows the user to freely express his questions in textual form and provides the user with an adequate answer. This is developed to meet the "Ask the right question" requirements.

• A set of points-of-decision responsible to present the user with dilemmas and pitfalls during the game. For example, the player has to decide to use a tool alone or waiting for others, or he has to collect items in collaboration or in competition with other players. Actions performed

by the players in all points-of-decision will have an impact on the final game outcome.

• An online chat room to allow players to communicate among each other in real-time during the game sessions. This can facilitate collaboration among peers. It is possible to set up different rooms in order to send messages to everyone or to a specific group of players.

Finally, we have implemented also a dashboard to allow the Q Challenge specialists to get data and metrics about the user progression during the game (e.g. how players are completing phases, how difficult levels are to complete, what score players receive upon completion, and how quickly they are completing the tasks). This is important to allow players and instructors to have an informed debriefing session after the gameplay.

6.3.2 Game Plot

The Draweva game is played contemporaneously by three teams of seven players each, that go through the 3D fantasy scenario (Figure 1) with the major goal to kill a monster (Draweva), which lives in a castle in the center of the game map. This requires killing it in a special way and before a certain time. Each team is led to believe that it is fighting its own individual creature, so the strategic decisions during the game are related only to a part of the whole problem. There are a Vampire, a Werewolf and a Dragon. But, actually, the three monsters are just one creature composed of the three different personas. This represents the real big problem to overcome, which needs a complete strategic view.

Fig. 6-1 - Draweva Screenshots

6.3.3 Game Roles

There are seven routes to the castle. Each team puts one member on each road, so that three members from each team are faced with the same task

on each road. Every team member has his own task according to his road:

- the “Weapon Specialist” has to find in the virtual world the right weapon to kill the monster;

- the “Sourcing Specialist” has to support the Weapon Specialist by developing a special additive for the weapon, to make it lethal;

- the “Logistical Specialist” has to find the best way to move towards the castle bringing the weapon;

- the “Safety Specialist” has to find ways to protect the entire team from the monster;

- the “Creature Specialist” has to find a way to organize the team to have a good collaboration while fighting with the monster;

- the “Bodyguard” has to find the best attack methods to weaken the monster;

- the “Team Leader” has to lead the team in terms of decision making about overall strategy.

6.3.4 Game Phases

The game is divided into five phases, in which the players are faced with different tasks that simulate regular decision-making situations in an international company. The task completion is evaluated using an ad-hoc designed assessment method (which assesses player learning, engagement and satisfaction from patterns of usage based on quantitative data collected during the game play) in order to provide feedback to the players about their achievements. The positions of players are shared between clients leveraging a multiplayer server, apart from the team leader, who has to overlook the actions of his team and make strategic decisions based on the information he gets from his team members. His main task is to manage the limited budget and the time.

The phases for the other six players are the following.

- Phase 1 (Collecting information). The player has to collect information according to his specialty by posing questions to different Non-Player Characters (NPCs). The player has to take decisions in order to collect relevant information, focusing on the overall team objective. Information to make a right decision frequently comes from several different stakeholders, and it is underestimated how important this aspect is for the success of the organization.

- Phase 2 (Empowerment). The player has to ask for help from other team members for information he cannot get himself. Since he will get also requests from others, he has to collect information in order to help others in the right way as well. In this phase, players chat together using an instant messaging feature embedded in the game. Breaking down silos also means reaching out others and asking for help.

- Phase 3 (Challenge with rivals). The players will get to a point in the virtual world which is only passable once, independent of how many players actually pass. If a player arrives before the others and passes, he later finds out that he has to go back to help the others cross. In daily business life, workers are constantly benchmarked and should also rely on others to ensure goal achievement .

- Phase 4 (Synergies). The players arrive in front of a castle. But, to get in, they have to pay guardians with diamonds that can be found nearby. There is the possibility for the teams to share diamonds and pay only one guardian, in order to save a lot of time. This is a crucial point to show that strategic decisions should consider an exploitation of synergies.

- Phase 5 (Killing). The players confront with the monster while realizing that it is one creature. They have to use all information and items collected earlier to kill Draweva. In this phase it is critical to achieve the goal in the right time.

6.4 Preliminary Results

Draweva is currently in the testing phase and will be used with real users in real contexts of use starting from 2019 Q1. We are planning extensive user test in order to access its impact on decision-making skills.

By now, we have evaluated the technical architecture consisting of the previously described modules (the fantasy 3D scenario, the multiplayer support, the assessment component, the dialog manager module, the points-of-decision and the online chat room), that were designed to support versatility, maintainability and extensibility.

In order to have a qualitative assessment of the benefits of such technological support, in terms of development efficiency and usability, we piloted an advanced-development Draweva prototype. The pilot took place in a time frame of six months, from September 2017 to February 2018.

Three game developers from Wondertech SRL (the company who developed Draweva) participated in the pilot. The participants were asked to develop one phase of the game, using the available components, and then report on advantages and disadvantages of the technological solution provided as the

basis for the development.

The responses highlight that all the programmers correctly understood the meaning of the components and the rules for leveraging them for the implementation of the game phase.

In the future, more tests are necessary for a clearer assessment. However, this first session allowed us to confirm the validity of the approach, that we argue could be extended to other games as well.

6.5 Conclusions

The Draweva game was designed to help leaders in organizations develop leadership and collaboration skills, that are key factors for decision making, particularly at strategy level.

In order to implement the game, we have designed a set of game modules to meet the main requirements coming from experts in strategic thinking teaching.

Based on this experience, we argue that our technological solution is able to provide SG developers with significant benefits, particularly in terms of development flexibility and efficiency. Preliminary tests showed that the proposed architecture can be fruitfully adopted for designing SGs. The next step of our research will involve the test of Draweva in its real context of use.

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He works since long time in innovative technologies such as M&S, IA, AI, VR, AR, directly applied in Industries, International Organizations, Agencies, Services, Defense and Homeland Security.

Part II

CA2X2 FORUM 2019
Extended Abstracts

7. IMMERSIVE VIRTUAL REALITY MEDICAL SIMULATION: AUTONOMOUS TRAUMA TRAINING SIMULATOR

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7.1 Background

Immersive virtual reality (IVR) can be highly effective as a medical simulation training platform.1-7 Given recent advancements this technology has become increasingly portable and visually realistic. While IVR technology appears to hold promise, there is a great deal to learn about the best way to functionally develop, implement, and share these training resources. Several groups have created models that recreate current simulation lab environments with instructor input. While these systems increase training opportunities, decrease equipment needs, and offer broad potential, they still require a skilled trainer to 'prompt the system.' Removing this limitation seems like a potential way to increase scalability. We are currently in the process of creating, to our knowledge, the only simulator that would offer immediate autonomous feedback to users through both real-time patient physiologic responses and overall grading. This is a multi-phase project, we will present phase one (simulation creation) and preliminary data from phase two (initial user testing).

7.2 Methods

We created a working group of 10 active duty or former military emergency medicine physicians and 2 technical experts. We hosted 15 meetings to facilitate the development process (results). The program was developed with financial support from the Telemedicine and Advanced Technology Research Center (TATRC), through the primary vendor Exonicus, Inc, with support from Anatomy Next Inc, and Kitware, Inc. Development was completed using an agile project management style, which allowed our team to review

progress and provide immediate feedback on previous milestones throughout its completion. The working group completed the resulting 4 simulation scenarios to evaluate perceived realism and training potential. Finally, while one member of the team was deployed, testing of the technology platform off the network in a deployed role 3/tent environment was conducted.

7.3 Results

Upon completion of phase one we have created four IVR scenarios based on the highest mortality battlefield injuries: hemorrhage, tension pneumothorax, and airway obstruction. Throughout this process there have been a number of lessons learned and we present those here to show what we have created as well as provide guidance to others creating IVR training solutions.

Virtual Reality Platform. We reviewed the technical specifications of the current IVR platforms (Mobile, Microsoft Mixed Reality, HTC Vive), and augmented reality platforms (Hololens). A smaller focus group tried each platform and reviewed computing, graphics limitations, network connectivity, and space requirements. Given its portability, graphics capabilities, and computing potential we opted for primary development using Microsoft Mixed Reality.

Select a training goal/simulation plan. We initially sought to create a visually realistic training environment around one case. However, this seemed to profoundly limit immediate training benefit. Furthermore – the environment may be visually real, but most IVR platforms lack easy and scalable methods to change ambient temperature, moisture, or produce complex haptics. As we learned how to incorporate the physiology engine, we shifted towards a complex medical decision trainer, which could be placed in an endless number of environments and internally scaled to multiple patients in future iterations. The user is presented with an unstable trauma patient with a random injury. The physiology engine settings were selected to result in the patient's death in 2-2.5 minutes, if the player does not identify the injury and complete appropriate intervention. The player must keep the patient alive for a minimum of 5 minutes. This is our primary endpoint for the user. To keep the patient alive. Additional factors such as hand washing, complete assessments are tracked/graded, but do not affect the patient's immediate survival. Standard trauma care actions are also available and tracked.

Selecting the case. Several individual cases, procedures, and environments were considered. However, selecting a single case or procedure seemed to drastically limit the scalability. We selected a generalizable trauma scenario for a few reasons. First, it allows multiple branch points to individual procedures (mini simulations) in future iterations. Second, several open

source physiology engines existto run the physiology in these scenarios. The individual scenarios were further built to allow 3 progressive levels of consciousness if an injury is not addressed in time, and a failure state (death) that can be reversed if an injury is identified and treated.

The room and 3D objects. We sought to include every 3D object that could be required in caring for a trauma patient, which totaled 36 items. The room was based on a 3D rendition of a standard military trauma bay.

Visual, audio, and exam cues. The selected injury scenario dictated visual/audio/exam cues (as in a traditional simulation).

Physiology engine. The incorporation of the physiology engine (Pulse) allowed us to develop a dynamic and more realistic simulation. Tying the simulation timeline to the physiology engine, allows a player to see realistic vital sign changes, and complete the course of care as they would in a real patient scenario. It also allows for rapid case variations and randomization.

Team member interaction. Trauma management is a team sport. While a multiplayer/multi-disciplinary approach is optimal – this again requires multiple skilled professionals to participate simultaneously. We sought to automate this process through 2 computer characters, a Nurse and a Medic. Commands are given vocally or through gaze activated menus.

Master action list/grading scheme/feedback system. A list of all the potential actions a player couldmake was developed (132), and each was tied to a specific outcome (injury treatment, lab availability, medication administration). These outcomes are injury and level of consciousness specific. Furthermore, each action was tied to a grade based on useful actions, neutral actions, and harmful actions. The Joint Trauma Committee Clinical Practice Guidelines and Advanced Trauma Life Support content were incorporated into the grading schematic.

User interface. The working group members have been end-users of several computer training solutions, and sought to minimize technical frustration. The primary mode of interaction is using 3D objects to trigger animations. There are also multiple duplicate pathways, for example, starting intravenous access via a 3D object, voice command, or a menu selection.

User tutorial. It was readily apparent a thorough self-guided user tutorial would be necessary. We included key interventions and steps that would allow the user to ‘interact’ in the virtual environment.

Gaze/location tracking system. Given the user is completing actions in a digital world it is quite easy to track multiple data points that may further relate to performance. We incorporated a gaze/location tracking system to allow for further analytics. At completion of the trauma scenario creation, the

working group unanimously indicated a high level of realism and potential training usefulness. The technology platform selected worked in a deployed/tent environment, without internet connectivity further highlighting the capabilities of this autonomous IVR system for military training.

7.4 Conclusion

Overall the authors feel this pilot project helps reveal the broad potential IVR has for medical training. Our team developed four trauma scenarios that, to our knowledge, are the only IVR trauma scenarios to run autonomously without instructor input. Furthermore, we provide a potential template for the creation of future autonomous IVR training programs. This framework may offer a dynamic starting point as more teams seek to leverage the capabilities IVR offers.

7.5 Learning Objectives

Describe the Trauma Simulator project: an autonomous immersive virtual reality medical training simulation

Discuss methods to develop immersive virtual reality training solutions

Discuss potential ways to incorporate physiology engines into immersive virtual reality simulations to increase individual and global scalability

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8. VR/MR SUPPORTING THE FUTURE OF DEFENSIVE CYBER OPERATIONS

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Abstract

US Army C5ISR Center Cyber Security Service Provider (CSSP) is a 24/7 defensive cyber operations (DCO) organization that defends US DoD and US Army networks from hostile cyber activity, as well as develops technologies and capabilities for use by DCO operators within the DoD. In recent years, C5ISR Center CSSP has been researching various advanced data visualization concepts and strategies to achieve higher cyber analysis speed and efficiency, and investigating 3D visualizations, virtual reality, and mixed reality as a means of reducing the dimensionality and complexity of the data presented to an inexperienced cyber analyst. Visualizations can enhance the efficiency of analysts' workflow by providing contextual information to various sets of cybersecurity related data, information regarding alerts, among others, however, textual displays and 2D visualizations have limited capabilities in displaying complex, dynamic and multidimensional information. There have been many attempts to visualize data in 3D, while being displayed on 2D displays, albeit with limited success. We propose that customized, stereoscopically perceivable 3D visualizations aligned with seasoned analysts' internal representations of a dataset may enhance their and other analysts' capability to have actionable situational awareness of that dataset in ways that visualizations on 2D displays cannot afford. In addition to providing advanced visualizations via 3D representations, we also seek to provide a more flexible training and operational working environment for analysts. Security Operations Centres (or equivalent) provide limited visualization capabilities both in the physical and logical sense. Our briefing will encompass an overview of the capabilities being developed as aligned to our research and operational requirements, our expected outcomes as the result of VR/XR usage in training and operational cyber environments, and our planned path to accomplish these goals.

8.1 Introduction

To provide cybersecurity analysts working at C5ISR CSSP with useful tools that would allow them to harness the potential of stereoscopically perceivable Virtual and Mixed Reality environments and visualizations, Army Research Laboratory (ARL) is building the Virtual Reality Data Analysis Environment (VRDAE), which will present analysts with a collaborative environment and a variety of 3D data visualization tools, including one that can provide a representation of the network, complete with the computers, routers, switches and communication lines between them all [1]. VRDAE is in its early stages of being tested by ARL cybersecurity analysts and researchers. The project has been underway since early 2017 and a fully functioning prototype is just starting to come out of the lab [2].

VRDAE environment will enable analysts to use various data visualization tools collaboratively; for example two of such tools that that are currently being developed by C5ISR and US ARL are Visual Intrusion Detection System (VIDS) [3] and Virtual Data Explorer (VDE) [4].

8.2 Approach

Cybersecurity analysts ingest and process significant amounts of data from diverse sources to acquire situational awareness of the environment they must protect. Visualizations provide analysts with visual representation of alphanumeric data that would otherwise be difficult to comprehend due to its large volume. Such visualizations aim to effectively support analyst's tasks including detecting, monitoring and mitigating cyber-attacks in a timely and efficient manner [5]. Cybersecurity specific visualizations can be broadly classified into three main categories: 1) network analysis, 2) malware analysis, 3) threat analysis and situational awareness [5]. Timely and efficient execution of tasks in each of these categories may require different types of visualizations.

Herein we focus on visualizations that would benefit analysts in 1st and 3rd category. Also, while most of the analytical work is done independently, analysts often need to share their findings and consult with their colleagues or superiors. Hence the necessity to have a standardized VR environment (VRDAE) for (data) visualization, where collaboration would be possible, no matter the physical location of the participants of a session.

The development and testing of 3D data visualization methods can be done in parallel, as their development doesn't depend on the specifics of that environment. Hence the VIDS and VDE project, that are being developed using the Unity 3D game engine.

8.3 Results and Discussion

A recent study by one of the authors [6] captured cybersecurity analysts'

impressions of a network topology presented as a stereoscopically-perceivable 3D structure.

Fig.8-1 - Virtual Data Explorer's 3D display of a Blue Team's network topology and behavior, rendered from NATO CCDCOE Locked Shields 2018 Partner Run dataset. Videos and previous papers: https://coda.ee/CA2X2

Overall, the impressions towards stereoscopically-perceivable 3D data visualizations were highly favorable. Multiple participants acknowledged that such 3D visualizations of network topology could assist in their understanding of the networks they use daily. Participants expressed a wish to integrate such visualization capabilities in their workflow. Prior experience with 3D displays had no influence on user preferences, while participants with prior gaming experience adjusted quickly to the Oculus Touch motion controllers used during the study, suggesting that the relevant dexterity and muscle memory for gaming console controller usage helps users adjusting

from those controllers to handling input devices for VR experiences.

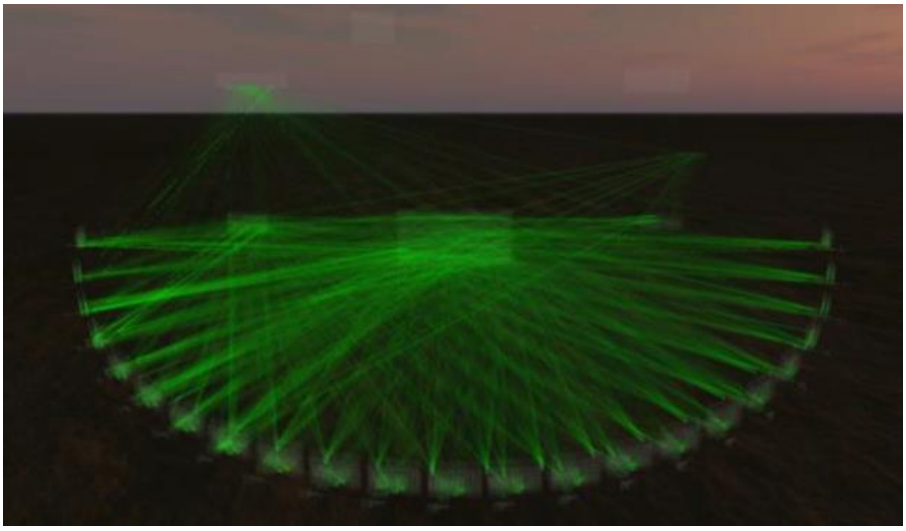

Fig. 8-2 - 3D display of LS18PR network topology and network traffic using VDE, displaying an overall view of the meta-shape – a datashape consisting of multiple datashapes.

8.4 Conclusions

C5ISR CSSP Analysts' feedback for and their impression of the VRDAE collaborative environment and data visualization tools VIDS and VDE have been very positive. Wider deployment is needed to evaluate VRDAE and 3D data visualizations' advantages in operational environment.

Further research is also needed to understand what specific 3D data shapes would be useful and for which datasets (e.g. computer network topology, application logs, etc.) to create additional 3D visualization suitable for analysts' preferences and test the usefulness of those visualizations. Follow-up studies are also needed to evaluate operators' performance (including discomfort, length of a session etc.) in VRDAE environment, once it's tentatively fielded in an operational environment.

8.5 Author/Speaker Biographies

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Lee Trossbach is a Technical Director at ICF, supporting C5ISR Center CSSP as a contractor within the United States Army. He has worked in defensive cyber operations since 2004 as an intrusion detection analyst, staff officer, and technical architect engineer. His current focus areas include analytics, visualization, and data fidelity as a supporting element to cybersecurity analysts performing their day to day mission.

Kaur Kullman is researching at U.S. ARL whether stereoscopically perceivable 3D data visualizations would be helpful for cybersecurity analysts, incident responders and other operational roles. This aligns with his PhD studies at TalTech University. He's been in IT since '90s, focusing on cybersecurity since late '00s. His interests are hands-on technical (OS-hardening, malware analysis, pentests), while his duties at RIA were more various

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9. A STUDY ON ASSESSING WEAPON EFFECTIVENESS USING HIGH-RESOLUTION ENGAGEMENT SIMULATION

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Abstract

Using accurate weapon effectiveness data is important in understanding the outcome of the engagement. To assess weapon effectiveness, following models and techniques are required: (1) simulation models of threat and target systems, (2) synthetic natural environments, and (3) damage assessment techniques. Usually, researchers follow JMEM (Joint Munition Effectiveness Manual) process to produce Pk (Probability of kill). During the process, it is needed to generate vulnerability data(Pk/h) of a target hit by a shooter with specific azimuth and elevation angle of impact. The current Low-Resolution M&S systems calculate Pk by accumulating the vulnerability data and CEP (Circular Error Probable). With this approach, it is not able to consider the effects of environmental factors such as terrain, weather, and obstacles and operational factors such as the formation of combat units. This paper suggests four steps to assess the weapon effectiveness. The first step is setting a scenario. The MSDL (Military Scenario Definition Language) enumeration is extended to consider the environmental and operational factors in the engagement scenario. Here, experimental design method is used to generate the possible engagement cases. The second step is calculating Pk of single shot, which is calculated using the high-resolution simulation environment named AddSIM (Advanced distribution SIMulation environment). With high-resolution models of weapon system in AddSIM, we can calculate the specific damaged part of a target based on the trajectory and detonation position of individual munitions. The vulnerability data or lethal area data is applied to estimate the damage of the simulation objects. The third step is calculating final Pk values, which is the result of a statistical analysis on Pks of the single shots. In the last step, the format of Pk values is transformed to suit current M&S systems. As a result of this project, we expect AddSIM to produce the Pk values considering environmental and operational factors of an engagement.

9.1 Introduction

In Defense M&S, it is important to measure accurate weapon effectiveness in

understanding the outcome of the engagement. Existing studies on weapon effectiveness have focused on developing engineering-level models which elaborately simulates vulnerability and lethality of single-shot at the end state(Conditional Probability of Kill given a hit, Pk/h) [1]. Meanwhile, engagement-level simulation tools determine the outcome (Probability of Kill, Pk) by simply accumulating vulnerability data and CEP [2, 3]. With this approach, it is not able to consider the effects of specific parameters of a weapon, or the effects of environmental factors such as terrain, weather, and obstacles. This paper suggests a method to evaluate weapon effectiveness for high-resolution engagement simulation environment AddSIM, which describe event interactions between multiple players based on detailed engineering models [4].

9.2 Analysis Procedure

Generally, Pk values are produced by Joint Munition Effectiveness Manuals(JMEM) process. Since End-Game model uses constant Ph(Probability of hit) values instead of simulating delivery process, it cannot consider the environmental factors such as terrain and wind speed. As such, considering different factors should be considered for high-resolution engagement simulation, this paper suggests four steps to assess the weapon effectiveness as presented in Fig.1.

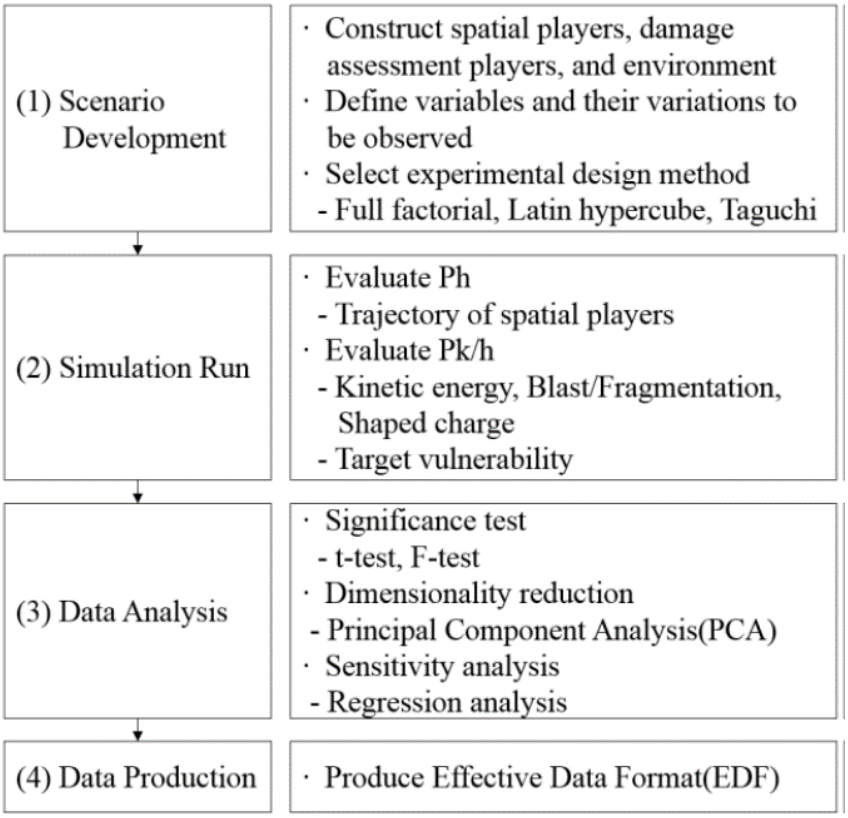

Fig. 9-1 - Weapon effectiveness analysis procedure

- **9.2.1 Scenario Development**

The items of AddSIM scenario are defined referring MSDL(The Military Scenario Definition Language) enumeration. This scenario can be presented as extended MSDL, which contains more detailed information on equipment. Equipments in MSDL are defined as spatial players in AddSIM. The players are designated to be friend, enemy, or neutral to interact each other based on discrete event models.

To measure weapon effectiveness in AddSIM, a basic set of players are a launcher, a munition, a target, and a damage assessment player. In damage assessment player, we can define a corresponding damage mechanisms as listed in Table 1.

Target Munition	Human	Armored Vehicle
Direct Fire	-	KE*, Shaped charge
High-angle Fire	Blast/ Fragmentation	Shaped charge
Guided Missile	-	Shaped charge
*KE : Kinetic Energy		

Table 1. Damage mechanism of munition and target.

After setting players, AddSIM users can apply synthetic natural environment to calculate more realistic Ph, or infinite plane space to eliminate external factors.

At the last step of scenario development, users can design an experiment by arranging variations of parameters. In case of full factorial design produces too many scenarios, Latin Hypercube or Taguchi sampling method can be applied.

- **9.2.2 Simulation run**

During simulation, trajectory and attitude of spatial players are calculated and visualized for each time step. When a munition hits a target, damage assessment players execute appropriate damage mechanisms and explore vulnerability of targets to evaluate Pk/h.

The effectiveness of KE and shaped charge is measured based on velocity, weight, and angle of attack. These two mechanisms are applied to different vulnerability data of targets, which is provided as cell-by-cell data format. Meanwhile, blast/fragmentation causes damage to targets within certain distance. This area is divided into smaller parts, and presented as a table format.

- **9.2.3 Data Analysis**

The simulation result is provided as a structured table composed of input (parameters and attributes of players) and output variables (Pk). Users can identify influential variables on Pk through t-test or F-test, reduce dimensionality through PCA, and analyse sensitivity analysis by regression analysis. In order to fully support Joint Vignettes, which is run almost all over the CWIX, it is better to duplicate if possible the involved M&S capabilities. If ignored, the risk could jeopardize M&S testing.

- **9.2.4 Data Production**

The last step is producing EDF, which is a structured data that presents input variables of scenario and Pk. The format of EDF is

defined based on existing M&S models such as AWAM and COSAGE to apply to the other engagement-level simulation software.

9.3 Discussion and Conclusion

This paper suggests a procedure and tasks to evaluate weapon effectiveness for high-resolution engagement simulation. Although types of munitions and targets are confined (Table 1), AddSIM users can construct or modify damage assessment players easily. Through this project, we expect AddSIM to produce high-resolution Pk values while considering environmental and operational factors of an engagement.

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10. NATO AND EVIDENCED BASED MILITARY AND DISASTER MEDICINE: THE CASE FOR THE VIGOROUS WARRIOR LIVE EXERCISE SERIES

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Abstract

The North Atlantic Treaty Organization (NATO) is the premier and only security alliance uniting 29 countries and many partner states in the provision of collective security and against threats posed by conflict and natural disasters. Security of countries and communities is increasingly threatened by a broad spectrum of unconventional types of war - from hybrid and asymmetric to multi-domain and peer-to-peer / near-peer conflict. The NATO Centre of Excellence for Military Medicine Center of Excellence (MILMED COE) is the center of gravity for medical best practices and promotion of medical doctrine across the NATO alliance. Disaster Medicine is multidisciplinary and in NATO, multinational, requiring best practices that are driven by data and evidence to prevent death on the battlefield and prepare for future conflicts. "Vigorous Warrior" is a live military and disaster medicine exercise series using both civilian and military actors across all sectors of health focused on health security and identifying lessons learned to ready the alliance for future threats. In this brief report, we make the case that the Virgous Warrior exercise exposes gaps, highlights challenges and generates an evidence base to make NATO military medicine systems more robust, more efficient and in provision of best medical practices. We specifically argue that clinical data capture must be duplicated and continuous across the alliance to ensure evidence based medicine stays current in NATO military medical doctrine.

Keywords : Military Medicine; NATO; battlefield Medicine; health security; Lessons Learned; Hybrid and Asymmetric war; peer-on-peer / near-peer conflict; multi-domain battle; Civ-Mil interoperability

10.1 Introduction – The Event

Military and Disaster medicine are seated inside the broad discipline of prehospital medicine.

This inherently multidisciplinary clinical approach to patient care in resource-poor, sometimes dangerous, austere and challenging environments, requires specific evidenced-based approaches, clinical treatment protocols and guidelines that collectively help deliver best practices. These best practices must be based on evidence, be continuously reviewed and tested in live exercises and deployments and be vigorously challenged. The Vigorous Warrior (VW) Medical exercise series is conducted biennially, with five successful iterations since 2011.

These exercises include medical actors from NATO, NATO partners nations, military and civiliandisaster, search and rescue (SAR) teams and myriad other health partners.

In general, the medical exercises are designed to enhance NATO's capabilities and ensure that NATO's medical concepts, equipment and interoperability are drilled and tested across the full capability requirement spectrum in the event of a NATO Article 5 scenario or sub-threshold security event. The primary aims of these exercises are to provide NATO and partner nations a multipurpose platform to collectively train their medical forces and personnel; test and experiment new concepts and medical doctrine; medically evaluate national and multinational medical treatment facilities in accordance with NATO doctrine; produce medical lessons identified and lessons learned (LL); and provide participants with multinational experience to enhance the provision of health care in NATO operations (Fazekas, et al 2019).

The tangible outcome from the Vigorous Warrior series directly strengthens partnerships at the military to military (M2M) and civilian-military interface (Civ-Mil), improves medical interoperability, and demonstrates the Alliance's commitment to improving international military medical collaboration to prevent death on the battlefield and in disaster (Fazekas, et al 2019). More than 2600 medical and ancillary personnel from 39 NATO and partner nations successfully conducted the joint, multilevel, multinational, Vigorous Warrior Exercise 2019 (VW’19) medical exercise in Romania from April 1st -14th, 2019.

10.2 Leadership of VW’19

NATO Centre of Excellence for Military Medicine (MIlMed CoE), COMEDS and the Lessons Learned Process

Rooted in NATO medical military doctrine are the "Principles and Policies of Medical Support" (MC 326-3) which are being challenged in the changing

global security environment, and specifically by the increasing threat of hybrid war (NATO, 2018). This dictates that both public and NATO partner nations expectations of high quality medical support is increasing while risks are growing across all sectors (Gubás, 2015 and Ruzicka, Humlicek and Witt, 2012). Military Healthcare is a patient-centric health service provision by military healthcare professionals for the defined populations at risk; it encompasses preventive health protection, prehospital emergency care, primary healthcare, hospital care and rehabilitative care; military healthcare incorporates the full range of military operations including humanitarian assistance (Ciottone, et al, 2015). The highest medical decision-making body in NATO, the Committee of the Chiefs of Military Medical Services (COMEDS), supported the establishment of the NATO Centre of Excellence for Military Medicine (MILMED COE) to coordinate efforts to advance Military Medicine across the alliance. Hungary as the Framework Nation, along with the Sponsoring Nations have created MILMED COE which remains the marquee venue for academics, researchers, warfighters, command staff and all voices in support of medical best practices to exchange ideas and incubate medical innovation and lessons learned to save life on the battlefield (Quinn, et al, 2018).

The purpose of the NATO standards is to offer guidance to physicians and other healthcare providers. Single nations will have their own standards of care , but NATO standards are designed to promote standardization and interoperability for NATO operations (Balázs and Kopcsó, 2016 and Bedubourg et al, 2018). The requirement for MilMed COE to prepare for future military medical support is acute and requires continuous medical debate and polishing of NATO medical doctrine in order to save lives. Unanticipated risk and consequences from hybrid warfare make this growing threat to health and health security more complex.

The North Atlantic Council accredited and activated the NATO MILMED COE in Budapest in 2009. The position of Director of MILMED COE rotates between Hungary and Germany, and currently it is Director Col. Dr. László Fazekas, the Deputy Director is Col. Dr. Salvatore Schmidt (DEU) and the Chief of Interoperability Branch is Col. (GS) Dr. Petr Kral. Under the leadership of Col. Fazekas, the MILMED COE has ushered in a Lessons Learned (LL) process where Subject Matter Experts (SMEs) can share the clinical and medical command across disciplines to help mitigate mortality and morbidity from war and disaster where NATO forces respond and deploy.

The Concept Development and Experimentation (CD & E) seated in the MILMED COE conducts experiments on civil military collaboration throughout VW and the observations and LL are shared to enhance practice.

The civil-military interface is led by US Navy Captain John Taylor in command of multiple processes to encourage information sharing and overall enhancement of NATO medical structures through the Lessons Learned process. MILMED COE is driving the way to prepare NATO with the best tools for medical best practices and processes with evidence-based medical practices.

10.3 Basic Definitions

Evidence based medicine

Evidence-based medicine (EBM) is the care of patients using the best available research evidence to guide clinical decision making; the focus is upon applying the results of research involving patients and clinical outcomes, such as mortality, morbidity, symptomatology, and loss of function (Sackett et al, 2000 and Straus, et al 2018). Pragmatic solutions in war and warfighting for medical standards are challenging. MILMED COE deploys EBM to identify mixed-strength research results and levels-of-evidence, enabling practitioners to quickly form clinical guidance and recommendations that constitute NATO Military Medical Doctrine. VW offers a venue for all alliance and partners to share their clinical practice and experience in a training environment.

Health and Security

Definitions of global health security are hotly debated and still under review in the operational and academic sectors (*see* e.g. Heldbaum and Lee 2004, Aldis 2008, Rushton 2011, Rushton and Youde 2015). Global health security is defined as the activities required to minimize the danger and impact of acute public health events that endanger the collective health of populations and communities across geographical regions and boundaries (Aldis, 2008). Definitions, however, broadly focus on preventing infectious diseases originating in or affecting the Global South from spreading to the Global North or further across the South (Weir 2015: 27). Such a view of global health security is very narrow and limiting. An expanded concept of health security is needed to include epidemiological considerations such as the shift from expert knowledge to algorithmic decision making for health security threats, the securitization of global health, and the expansion of hybrid threats impacting health (Eckmanns, Füller and Roberts, 2019) as well as the challenges affecting populations caught up in non-traditional conflict - e.g. non-international armed conflict, hybrid and asymmetric war. In the context of this work, it is paramount to pay special attention to the challenges to the delivery of health services in insecure environments - including natural disasters and conflict zones. We argue for the significance of evidence-based medicine and for examining the increasing operational needs of civil-military

interoperability and collaboration, not only in humanitarian crises but also in defense, security and disaster prevention and response. Insight from VW can support NATO operations and mitigate mortality and morbidity on the battlefield, including all combatants and civilians. This needs to be expanded to noncommunicable and chronic disease for deployed personnel into a theater of operations, and also in quantifying the health risk on individual and disease characteristics (Russel, et al, 2014).

NATO military medical doctrine

Military Medical Doctrine is the organization, preparation, prevention, execution and medical support of military operations updated through evidence based doctrine and offered to Allied, multinational and coalition forces (Aspin, 2017). Allied Joint Publication-01 (AJP0X) provides this working document to prepare for war and although AJP-0X is intended for NATO forces, the doctrine is malleable and can be shared with participating partner nations, for war and disaster operations under a coalition of NATO and non-NATO nations through a Combined Joint Task Force (CJTF) (Mann-Salinas, E. (2016). Thus, no distinctions are drawn within the document between solely NATO operations, non-Article 5 Crisis Response Operations (CRO) by Allied forces and CJTF operations (Franzen, 2004). NATO medical doctrine is updated and the MILMED COE supports this process with COMEDS the final point on the process and is inclusive of evidence based medicine.

Roles / Echelons of care: the Role 2 medical treatment facility (MTF) and VW'19

NATO Military doctrine supports an integrated health services support system to triage, treat, evacuate, and rehabilitate the wounded efficiently; which begins with the warfighter on the battlefield and ends in tertiary and definitive care facilities (Cubano et l, 2014). This care begins with first aid (self-aid / buddy aid, and combat lifesaver) which includes Tactical Combat Casualty Care (TCCC), and prolonged field care (PFC) and rapidly progresses through a spectrum of Damage Control Resuscitation (DCR) and Damage Control Surgery (DCS). Different roles denote differences in capability, and at each level of capability warfighters are treated and return to duty or are prepared and packaged for evacuation with medical care administered while en route to a higher role / level (Zielinski, 2015). VW'19 focused on medical activities across all levels and roles of care from point of injury to Role 4. Level / Role 1 provides immediate first aid delivered at the point of injury with application of principles Remote Damage Control Resuscitation (RDCR). Per NATO doctrine, Role 2 must be 100% mobile and is divided between "basic" and "enhanced" (R2B / R2E). These Roles offer an increased medical capability and limited inpatient bed space and

provide DCR and DCS, basic primary care, occasionally optometry, combat operational stress control and mental health, dental support, variable laboratory and X-ray capability. Each NATO state and partner nation may offer a slightly different capability at the R2B/R2E MTFs. Level / Role 3 represents the highest level of medical care available within the combat or disaster zone with the bulk of inpatient beds and expanded surgical and diagnostic capability. In VW'19, one Romanian Role III was deployed with multinational staff and offered advanced surgical capabilities augmented by multiple nations and medical specialties. Strategic Medical evacuation (STRATEVAC) were also simulated to patients' countries of origin to Role 4 during VW'19. Role 4 provide definitive medical care and rehabilitation.

Collective Self-Defense

Collective self-defence means that an attack against one ally is considered as an attack against all Allies of the NATO Alliance (NATO, 2019). The principle of collective self-defence is enshrined in Article 5 of the Washington Treaty and relies on deterrence, or primary prevention to the threatof attack or invasion in any battle domain (please see below). The preparation for a sub-threshold Article 5 event, not meeting the requirements for a full blown Article 5 enaction is an increasing risk through hybrid warfare and open activities by aggressor states. Primary prevention are defined as those actions that prevent a security crisis from taking place in the first place. Since Russia's illegal annexation of Crimea in 2014 and the rise of security challenges from the south, including Islamic State in Iraq and the Levant (ISIL) / Islamic State in Iraq and Syria (ISIS) and other terrorist groups across several continents, NATO has implemented the biggest increase in collective defence activities since the Cold War (NATO, 2019). Some measures implemented include Joint Intelligence, Surveillance and Reconnaissance and more recently at the Warsaw Summit in July 2016, Allies also recognised cyber defence as a new operational domain, to enable better protection of networks, missions and operations (Shea, 2018; Minchev and Bogdanoski, 2018). The purpose of VW'19 is to best support medically all NATO anticipated security operations and mitigate death and morbidity. VW is a series that can test medical systems when multi-domain battle activities are occurring concurrently.

Multi Domain Battle and Warfare (MDB/MDW)

Operationaly, Multi-Domain Battle (MDB) allows defense forces to outmaneuver adversariesphysically and cognitively, applying combined arms in and across all domains (i.e. land, space, air, sea and cyber); it provides a flexible means to present multiple dilemmas to an enemy and create temporary windows of localized control to seize, retain and exploit the initiative (Marr, 2018; Battle, 2018). Medically, MDB/MDW is the future

and NATO must navigate and thrive in this multi-threat environment for all future operations. Any Article 5 or sub-threshold event will require joint commitments from NATO states and this 'jointness' for medical operations, force health protection to medical evacuations will require interoperability (Perkins and Olivieri, 2018).

Asymmetric and Hybrid Warfare

Asymmetric warfare can be simply described as conflict between opposing forces (two or more) which may differ greatly in military power and capabilities. Conventional logic dictates that such conflicts should not happen (Allen and Fordham 2011: 1026). As a result of the significant discrepancies in capability between opponents, such conflicts typically involve the use of unconventional operations and tactics, but also tend to spill beyond conventional actors to affect civilian populations (Arreguin-Toft 2005). Such warfare is usually between a larger power and smaller force, and may reside within one state or across many in semi-autonomous regions or ungoverned spaces in fragile and failed states. While there are many definitions of hybrid warfare (Wither 2016: 74), the term is simply defined as a military strategy in which conventional warfare is integrated or mixed with unconventional warfare orcovert tactics, countermeasures and unconventional operations across domains of battle (i.e. land, seas, air, space and cyber ect) (Johnson, 2018). The term 'hybrid warfare' is credited to Nemeth (2002), who used it in reference to the conflict in Chechnya. Prior to 2014, the term was most frequently used to describe the strategy used by the Hezbollah in the 2006 Lebanon War (Wither 2015: 75). Subsequently, Russia's hostile actions in Ukraine and the violence perpetrated by the Islamic State of Iraq and the Levant (ISIL) have also been designated as examples of hybrid war (Andresson and Tardy 2015: 1). A potential adversary, Russia, deployed hybrid warfare globally with the main characteristics of economizing force or minimizing traditional military presence. Hybrid warfare is also characterised by 'the aim of creating ambiguity and confusion on the nature, the origin and the objective of the threat; the ability to identify and exploit the vulnerabilities of the targets; the capacity to keep the level of hostility *below* the threshold of conventional war' (Andresson and Tardy 2015: 2). Hybrid warfare is persistent in breaking down the traditional binary delineation between war and peace through a dynamic intensity of conflict; and is population-centric (Chivvis, 2017). The term "hybrid" has dominated much of the discussion about modern and future warfare (Van Puyvelde, 2015). One key concern of relevance here is that 'modern weapon systems have greatly increased the lethality of non-state actors' (WIther 2015: 75). Medical operations, therefore, are greatly hindered by these lethal concepts of warfare and pose specific challenges to the treatment, transportation and prevention of death for all medical operations. NATO must design strategies

on how to operate within these areas of warfare and provide clinical best practices in a thorough dynamic environment.

10.4 Medical Innovation and Emerging Technologies: *NATO leads the way*

One key feature of the VW series is the ability to test new medical ideas and equipment and to experiment with new process and protocols where M2M and Civ-Mil may have gaps. The sections below describe some of the highlights from the VW'19 related to medical innovation, emerging trends in military medicine and prehospital medical provision.

Blood and blood products (Class 8A) logistics

EX VW 19 was the first time a medical logistics tabletop exercise (MEDLOG TTX) was specifically planned and executed. The task was to create a TTX that demonstrated the limitations of class 8A logistics on the Article V battlefield. The eventual product was a time based war game whose participants consisted of four R2B deploying to EX VW 19. Selection of the participants was deliberate: both a US and Swedish R2B were asked as they represented relatively mature Class 8A practice; the remaining two R2B were from two Baltic states. The Baltic states represented participants with relatively less developed Class 8A doctrine and practice (but nevertheless , no less professional as the TTX showed). The main aims of the TTX were to demonstrate to the participants that there would be several major restraints/ constraints operating in this particular battlespace. The four most likely article 5 tactical situations affecting Class 8A logistics were considered to be:

1. Limited movement from R1 to R2 and vice-versa
2. Limited rearwards movement from R2 to R3
3. Limited to no air movement in the tactical battlespace
4. Limitations of Emergency donor pools on the battlefield

As Class 8A items of supply (=blood and blood products) are thermolabile items, it was important to introduce a time-space construct to this TTX. It was necessary for participants to track patients (as blood follows patients) but it was also important not to turn a fundamentally logistic-based TTX into a clinical patient based one. The results of the MEDLOG TTX were validated by both pre and post surveys as well as detailed one on one debriefs. The MEDLOG TTX achieved its primary aim of making participants more aware of the restrictive nature of the ART V battlefield. The main aim of the MEDLOG TTX was hence as a training tool. Unfortunately the very limited time allocated prevented more sophisticated work, but it is intended to expand this TTX into a more "granular" and detailed MEDLOG CPX with one or more of the participants.

Blood and blood products.

VW'19 was an excellent petri dish to test the pressing concepts of blood and blood products prepared, transported and administered at the Role I and Role II settings. Trauma Hemostasis and Oxygenation Research (THOR) Network and Remote Damage Control Resuscitation (RCDR) provide concepts that NATO military medical doctrine must promote and must root in evidence (Woolley, et al 2016; Rappold and Spinella, 2018). The lethal triad in hemorrhagic trauma is hypothermia, acidosis and coagulopathy and rapid access to blood and blood products extremely early and closer to the point of injury may decrease mortality (Yazer, Cap and Spinella, 2018). Despite advancements in battlefield medical interventions at point of injury and Role 1, major hemorrhage persists as a major cause of death from warfighting injuries. Transfusion support across the alliance and translation to military prehospital resuscitation and RDCR were challenged and many lessons were learned at VW'19. Integral part of hemostatic resuscitation protocol is using of Tranexamic acid (TXA) within 3 hours of injury and NATO forces should include TXA in the treatment of trauma patients with uncontrolled bleeding (Heier, et al 2015) Only some allied forces had a declared and active walking donor protocol - USA, Canada, Norway, France and UK. The Estonia team stated they are starting to integrate a legal framework for a walking donor program,WBB is also introduced in the Czech Republic . There is an inadequate basic load of blood and blood products. The logistics chain for blood and blood products should be robust, interoperability must address the ability to send Estonian blood to a Romanian hospital – legally – as well be able to tap into the civilian health system without middlemen and establish a cold chain system within hours, not weeks, to facilitate DCR/DCS. 40 units, 120 units. These numbers are anecdotal but are inadequate for an article 5 scenario. More blood products, a legal framework for instant access to the civilian system and blood, within hours is vital and key for NATO and NATO partner nations in the event of a deployment or hybrid deployment, non-article 5 or sub-threshold article 5 scenario. Blood and blood products: need a legal framework / MOU between military and host/partner nations on blood access, administration and walking donor. Walking donor protocol can be taken from above mentioned nations and provided to COMEDS for consideration to put into military medical doctrine. The use of cryopreserved blood products (RBC, PLT) is also a relevant method, which is used in Netherland and Czech military. THOR network can lead on best practices and feed into the MilMed CoE process.

Diagnostics

VW'19 was an excellent opportunity to challenge the paradigm of each nation at the Role 2 MTFs and that of clinical diagnostics related to trauma. Unification in practice remains a challenge and the VW series offers a venue for gap identification and process alignment. For example, thoracic,

abdominal and pelvic trauma and the capability to conduct the extended Focused Assessment with Ultrasound in Trauma (eFAST), point of care (POC) lactate and hemoglobin (Hb) may serve as clinical bellwethers. Bedside or POC lactate via rapid test in trauma helps indicate response to DCR, especially when offered in the form of ABG with multiple other parameters. Bedside and POC Hb can help guide decision making in blood and blood products and response to RDCR. Part of the WBB protocol is rapid test for blood typing, possibly tests for transfusion transmissible diseases (VHB, VHC, HIV, malaria).

Lactate

Most Role 2's deployed at the VW'19 had an commercially purchased iStat portable machine for arterial blood gas (ABGS) / venous blood gas (VBG) with lactate, many also had cartridges that test pH, base excess, bicarbonate, partial pressure of oxygen and carbon dioxide, among others. All Role 2's had various amounts of blood test cartridges. One local national facility had lactate tests but by reagent, not a rapid test. Lactate in trauma and response to RDCR helps dictate treatment and having lactate, accurate measurements can help prioritize patient movement in times of resource poor medical evacuation chains and support decision decision making (Fisher, 2018).

Hemoglobin

Hb is on most iStat cartridges as well for a full or complete blood count, one unit deployed at VW'19 used only blood film and reagent, no rapid test. Blood and blood products (including walking donor protocols): all units brought blood and blood products (training purpose bloods), most bought RCCs and plasma as well. The number / basic load across many ranged from 40 units, 80 units all the way to 120 units.

eFAST

eFAST is a rapid bedside ultrasound (US) examination that uses minimally invasive ultrasound to screen for pericardial effusion or blood/fluid in the abdominal cavity and air or blood in the chest in the presence of trauma. All Role 2 MTFs reviewed had access to ultrasound. Some ranged from two units, in the form of sonosite "laptop" style to larger / "breadbox" sized older ultrasound. One unit had the handheld device only, which requires cables and a smartphone with the downloaded application to view. Most units had the curved array probe, some had the linear. No cardiac probes were observed. Without CT capabilities in the Role 2 paradigm, Ultrasound
should be flooded in the clinical space. US broad training across all practitioners (nurses, paramedics, logistics/technicians and of course doctors) must be a mainstay. Portability, battery power and fluency with the eFAST, in addition to other basic procedures (optic nerve for increased cranial

pressure (ICP), basic or nuanced fractures, cardiac exams etc) should be commonplace and integrated into practice across the alliance. Identifying life threatening injuries that can be fixed quickly (i.e. pneumothorax, pericardial effusion etc) and are minimally invasive should become common practice in NATO military medical doctrine.

Retrograde Endovascular Balloon Occlusion of the Aorta (REBOA)

Pushing future capabilities and instruments for RDCR/DCR and DCS is best performed conceptually in a triang environment, not open combat. No better place to consider the invasive yet potentially life saving intervention of REBOA in aorta and major vessel trauma in the pelvis and abdomen.

10.5 The Future

MILMED COE provides key leadership that dictates evidenced based medicine into NATO Military Medicine Doctrine. Multiple challenges are growing to provide expert medical care from point of injury to Role 3 and onwards to Role 4. The Vigorous Warrior series is an excellent venue to push limits, test process and procedures and theorize what medical innovation is needed that enhance best practices. Article 5 and subthreshold article 5 scenario pose potential challenges in provision of medical care across the alliance. The principle of collective defence is at the very heart of NATO's founding treaty and medically all nations must be ready to provide rapid warfighting medical support in the face of war and disaster.

10.6 Conclusion

NATO remains the premier security alliance uniting states to ensure collective security and medical best practices. Hybrid, asymmetric and the multi-domain battlefield in the future pose significant challenges in offering clinical best practices for NATO warfighters. The NATO Centre of Excellence for Military Medicine provides leadership in the provision of medical best practices and promotion of medical doctrine across the NATO alliance. "Vigorous Warrior" is a live military and disaster medicine exercise series using both civilian and military actors across all sectors of health focused on health security and identifying lessons learned to ready the alliance for future threats. In this brief report, we make the case that the Virgous Warrior exercise exposes gaps, highlights challenges and generates an evidence base to make NATO military medicine systems more robust, more efficient and in provision of best medical practices. Clinical data capture must be duplicated and continuous across the alliance to ensure evidence based medicine stays current in NATO military medical doctrine.

Abbreviations

Civ-Mil - civilian military interface

CD&E - Concept Development and Experimentation
COMEDS - The Committee of the Chiefs of Military Medical Services NATO
CJTF - Combined Joint Task Force
CRO - Crisis Response Operations
EBN - Evidence-based medicine
eFAST - extended Focused Assessment with Ultrasound in Trauma
Hb - hemoglobin
ICP - increased cranial pressure
ISIL - Islamic State in Iraq and the Levant
ISIS - Islamic State in Iraq and Syria
LL - Lessons Learned
LIVEX - live exercise
MEDEBAV - medical evacuation
MilMed CoE - NATO Centre of Excellence for Military Medicine (MIlMed CoE)
M2M - Military to military
MDB - Multi Domain Battle
MDW - Multi Domain Warfare
NATO - North Atlantic Treaty Organization
POC - point of care / point of contact
R2B - Role II Basic
R2E - Role II Enhanced
SAR - search and rescue
SME - Subject Matter Experts
STRATEVAC - Strategic Medical Evacuation
VW'19 - Vigorous Warrior 2019 Live Exercise

Authors Contributions

All the authors have contributed towards the design of study, collection, analysis andinterpretation of data. All authors read and approved the final manuscript.

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11. "TRAIN AS YOU FIGHT" - DID WE FIGHT AS WE TRAINED? RSM & CAX

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Abstract

CAXs' end state is to provide training for all three levels, in order to exercise not only the decision making process, but also all the cycles run within a headquarters to support it, based on a scenario and a set of training objectives (TO). Simulation systems' job is to provide a realistic training environment by using proper settings, programs and auxiliary tools which allow training audiences (TA) to apply and exercise their internal processes while using specific functional area services to support their work and meet the established requirements/TOs. The closer we can model reality within a CAX, the better the training provided.

11.1 Purpose/ Benefits/ Key Take-away

The purpose of this project is to answer the following question: "Did we fight as we trained?" In order to provide an answer, we compared not only the systems and their architectures used in real life (Resolute Support Mission - RSM) versus CAX, but also the steps and procedures followed by Intel and targeting cycles, the importance of a key leader engagement process, as well as the impact that media and the political level have on military operations. By doing this, we were able to highlight the similarities and especially the differences between CAX environments and the operational theatre in order to eventually provide more realistic training for the units within future exercises.

The takeaway is the importance and the need of training through simulation. This project is meant to raise further questions and research directions, in terms of how CAX and simulation systems can shape/ adjust in order to provide a "train as you fight" environment for NATO troops, taking into consideration the real life political and strategic environments.

11.2 Approach/Results and Discussion

RSM is the place where NATO's personnel level of training speaks for itself. The mission is the opportunity to apply the knowledge gained by training and support COM RS in the decision making process. This project speaks about the challenges encountered from the Intel domain perspective, comparing

them with CAX's experiences.

11.2.1 Common Intelligence Picture (CIP)

Intelligence is pivotal to joint action. It allows the commander to conduct decision-making based on a comprehensive understanding. It helps to both frame the problem and illuminate its specific elements. [1]

The CIP is the result of a whole process, based on the intelligence products disseminated within the mission. Fig.1 represents roughly how the CIP is built, as well as intelligence's flow within RSM. The cycle used and the information's dissemination follow the same steps that we usually see in NATO exercises.

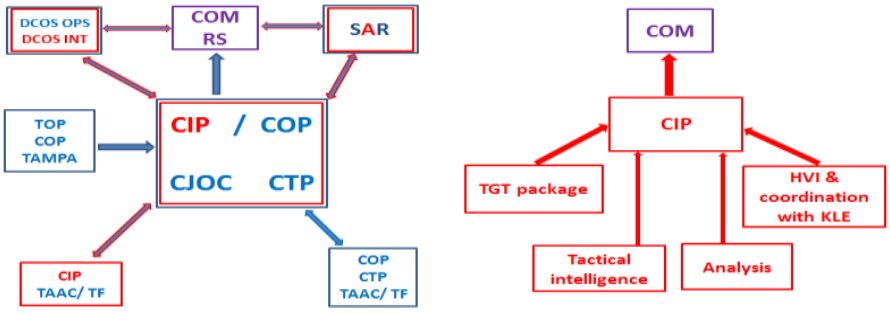

Fig. 1. CIP in RSM.

In conventional war, intelligence is focussed on providing information regarding two complementary subjects: the actors and the operational environment. While in an asymmetric war like RSM, an important role is played by the informational environment (how the actors receive information and transmit their narratives). Here is the field where the intelligence domain comes together with public affairs and the key leader engagement team in order to disseminate information, or manipulate perceptions in order to affect understanding and achieve mission accomplishment.

11.3 Key Leader Engagement Process

RSM was the proof of the power in the information environment and O/S media. We faced the reality where media actually became a weapon in enemies' hands. If you think that we play media too much during CAX well, real life uses it even more, having a major impact from the tactical up to political level. At some point, in order to get a peace agreement, our mission focus was the deliberate use and orchestration of military capabilities and activities to affect both insurgents and Afghan political leaders' will,

capability and understanding, in order to achieve influence [2]. Within RSM, influencing Afghan leaders was the Key Leader Engagement (KLE) team's objective and you can see the process used depicted in Fig. 2.

Fig. 2. KLE process in RSM

Just like the targeting (TGT) process, it is also well structured and involves package development, an execution phase and reengagement possibilities. The KLE team is usually under STRATCOM and in real life they represent the link at the strategic and operational level between the mission CDR and the leadership, officials and religious leaders from the country.

11.4 Targeting Cycle NATO / RSM

The TGT cycle is one of the most important training objectives played in a CAX, and during the RS mission we observed that the TGT cell followed approximatively the same steps from the process used by NATO. RSM HQ was the authority at the operational level, and TAACs, TFs, SOF and TF-AVN for the tactical level. Apart from the small differences in terms of TGT lists development and battle damage assessment tracking, one thing that captured our attention was the importance of SOF. Based on the previous NATO CAX experiences, we can affirm that SOCC's role within an exercise is smaller compared with their role and responsibilities in an operational theatre. From a systems perspective, in RSM there wasn't a functional area service (FAS) to support TGT cycle, (Joint Targeting System - JTS), just Excel documents and Microsoft Access databases, which leads us to the next topic of our project, the Intel system architecture.

11.5 Intel Systems Architecture RSM/ NATO

From a systems perspective, in both cases (CAX and RSM), the goal is to have all the FASs linked and able to speak with one another. During exercises

we are using the best case scenario where NATO systems are interconnected, fully able to support the decision making process. In real life, we faced some differences in terms of Intel systems. We did have some FASs, but older versions, which were also able to communicate with one another in order to provide both the COP and CIP.
As you can see in Fig.4, among NATO FASs we find an additional database called CIDNE. It was used to merge the information received from NATO networks with the information from national networks (US, UK, DEU, ITA).

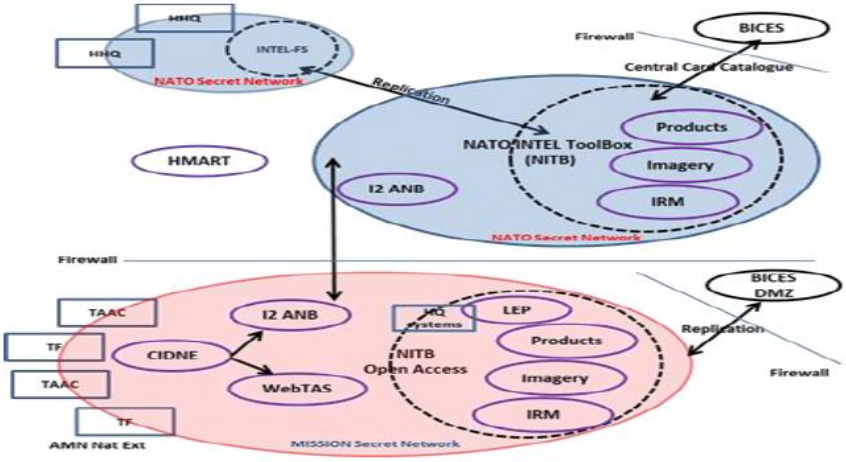

Fig. 4. Intel Systems Architecture in RSM

Even with this DB, the reporting outcome at some point was two different intelligence pictures (NATO and national networks). Supporting operations in the CJOC with two Intel pictures and different access to information was an unexpected challenge.

11.6 Conclusions / Lessons Learned

One of the first conclusions apparent after the RSM deployment was that during CAX we are providing TA perfect conditions to conduct the fight. From a scenario perspective, TA usually has plenty of information for IPB development and the political level is not changing much when it comes to conventional war. In RSM, we faced hybrid threats, in a country where everything constantly changed and every decision made at a political level directly impacted our OPS.
Systems architecture experience within RSM can be taken as a lesson learned. During CAX, TA have all FASs set up, functional and interconnected. In real life we have PowerPoint, excel, access DBs and older versions of those FASs, in an attempt of interconnectivity. Also, security clearance and different

networks used within NATO countries lead to different COPs, or CIPs. From our perspective, the information flow was the most challenging part of my deployment and highlighted the fact that we are training in ideal conditions during the exercises.

Nevertheless, the most important feature, for both CAX and real life, are people's training and background sand it has been proven that training only in national exercises does not necessarily help in a multinational mission. [3] We can fight with fewer systems, we can adjust our OPS based on the operational environment, we can adjust our SOPs, processes and cycles IOT make it work and support the COM in the decision making process, but still my question is: do we train as we fight? OR do we fight as we train?

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12. AGENT-BASED SIMULATION FOR AMMUNITION CONSUMPTION ESTIMATION

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Abstract
A new concept for deducing ammunition (ammo) requirements in case of high-intensity defence scenarios has been examined by a simulation-based analysis. In a stochastic data farming approach, weapon systems and effectors in army missions according to existing concepts of ammo supply were simulated, starting from 30 mm calibre for main weapon systems and effectors of a reinforced combat battalion, and were rated in target-oriented manner. The ammo requirements of a reinforced tank battalion has been evaluated in a scenario of a brigade's counter attack, depicting combined force elements interdependencies in the expenditure of ammo in combat. We highlight three key challenges that the analyses faced with a stochastic data-farming approach at high complexity level.

12.1 Introduction

According to annual calculations of the required ammo stockpile for the German Armed Forces until 2009, the determined figures where substantially higher than the inventory. Moreover, ammo related demands according to specific tasks addressing optimized compositions of effectors were in the focus of interest. While the demands for training, guarding and other permanent tasks can be evaluated based on data from previous years, there is no data for worst-case scenarios in crisis management and national or NATO defence scenarios. However, the latter two are of high interest with emphasis on high intensity warfare scenarios. Hence, we applied a stochastic data farming approach using IABG's Joint Agent-based Simulation System (JASS) and comprehensive data analysis techniques to evaluate the amount and kind of ammo necessary to restock the inventory appropriately.

12.2 Stochastic data farming using JASS

The conventional expenditure-based method is easy and fast to perform. However, it neglects involved dynamic effects, combined arms efforts or time-based intensity measures. Instead, we used a target-oriented method for ammo consumption determination with a focus on crisis prevention and Art. 5 Ops scenarios focusing on ammos calibre 30mm and larger. We incorporated scenarios for dynamic determination and simulation of

combined arms effects and considered dynamic changes. However, a conscientious analysis of data obtained by the methodology using stochastic data farming is necessary, in order to ensure validity of results as well as value of information and insight derived.

To cope with the complex task of simulating high-intensity defence scenarios on battalion and brigade level, we defined and tailored different scenarios and implemented their force structure in JASS. JASS is a modular tool for tactical and technical analysis, experiments and tests providing, amongst others, configurable functions for e.g. terrain, reconnaissance, movement, communication, commands, behavior, C2, effects, transport and camouflage. JASS supports data farming capabilities, such as closed simulation capability, automatic parameter configuration, high performance, output filters and reproducibility of simulation runs.

We modelled a C2 structure and processes within the simulation with the semi-automated agents in JASS resulting in realistic processes and fine grained tuning of effectors. In a first study, we focused on implementing a scenario on battalion level exhibiting 12 parameters with 2-5 parameter variations yielding 2.080 output parameters per simulation run (including ammo consumption of effectors red/blue, hit rates, kill rates, and others). A full-factorial design (FF-D) of experiments would have generated a huge amount of simulation runs. Hence, we selected two different design of experiments (DOE), Centre-Paribus Design (CP-D) and Latin Hypercube Design (LH-D), to reduce the number of simulation runs (see Table 1).

DOE	**parameter variations**	**simulation runs (100 random seeds)**
FF-D	414.720	> 41 million
CP-D	23	2300
LH-D	33	3300

Table 12-1 - Different Designs of Experiments considered in the first study.

12.3 Three challenges

There are some challenges when conducting complex simulation for gaining insight in interdependencies, what-if questions and reasons for effects, not only in ammunition estimation. However, we come across at least three challenges that seem to be worth bringing up when talking about scenario implementation as well as analysis for complex simulations. Hence, in the ongoing second study dealing with ammo consumption estimation on brigade level we followed the lessons learned from the first study by finding solutions for the raised challenges of stochastic data farming in high intensity warfare

scenarios of deep complexity.

12.3.1 The challenge of high data-volumes

The challenges of high data-volumes are at least to reduce the data with focus of *interesting* data (which in general is sparse compared to available real world and output data) with respect to the questions to answer and to handle data efficiently. This affects the information density in tactical scenarios as well as outputted high-data volumes. Solutions to address the challenge of high data-volumes, which have proven to be appropriate, are:

- *Reduction:* Minimizing the number of input parameters for the simulation in the scenario before choosing a DOE [1], by techniques of elimination, substitution and conflation. Moreover, we categorize the input parameters according to their expected/tested influence on the output data.

- *Balancing:* Choosing a best fitting DOE with respect to the remaining input parameters and the response-surface complexity of the simulation scenario [2], in order to balance the number of design points with the validity and value of the outcome.

- *Automation:* Differentiating output data (raw data), measurement data (aggregated output data) and target data (aggregated output and measurement data). Building a data model that automatically imports output data *and* frequently applied measurement data into a database. Afterwards, it is easier and faster to work on the pre-aggregated data in the analysis.

12.3.2 The challenge of complexity

The simulation scenarios on battalion and brigade level are not only complex in the number of placed intelligent agents and automata. In our approach, we defined a complex interplay of several component models for behavior of agents, environment, characteristics, and strategies. Such an interplay causes a variety of interferences that one has to get a grip on in order to produce high-quality results (see 3.3). Solutions to address the challenge of complexity, which have proven to be appropriate, are:

- *Divide and Conquer*: Simulation and analysis of small component models to test the intended behavior and quality of output data of the component model in small subordinate scenarios.

- *Optimization*: Input parameters, which are strongly related to a single component model and are expected to be of less influence on the output data of the full simulation are transformed to constants.

Such parameters are varied in the component model in order to find an optimal assignment with regard to a desired behavior. The constants then are used to substitute input parameters in the full simulation scenario.

- *Keep it Simple*: As a simulation always is an abstraction of reality, it has to be ensured that the content of this abstraction is on the one hand of high impact on valuable information in the output data and on the other hand neglects all influences that are of minor impact. An overfitting of the simulation

scenario does not only produce useless data covering interesting information, but also impairs a proper statistical analysis, since assumptions that have been derived from the output data could not draw a conclusion about reality.

12.3.3 The challenge of quality

The quality of simulation insight covers at least two aspects. The first is the availability of high quality model data for configuring simulation entities, the other is the quality of analysis, which is performed on the output data. Unrevealed correlation between parameters, interferences between effects and impact of disturbance variables have to be critically observed particularly in stochastic simulation models. Solutions to address the challenge of quality, which have proven to be appropriate, are:

- *Availability*: Verified data on model behavior and characteristics could however not always be captured by experiments or monitoring current events. In these cases, verified data is analytically derived by a combination of physical laws and statistical estimations of model behavior and characteristics.
- *Validity*: Testing the validity of the cause-effect relationship between input variables and output data. Results should be normal distributed (otherwise assertions derived from the output data are of limited significance), homoscedastic (otherwise results of statistical tests lead to distorted confidence intervals/significances, and a regression function will not fit well), free of autocorrelation (otherwise the diversification of results will impair measurement errors) and free of outliers (otherwise the representatives of results is affected).
- *Plausibility*: Consolidating output data by uncovering obvious errors and inconsistencies, unrealistic results, extreme outliers (and their cause) and gaps.

12.4 Conclusions and ongoing work

Using the simulation-based target-oriented rating of ammo requirements in national and NATO defence scenarios turned out to be an alternative to expenditure-oriented methods even in very complex scenarios. Beside the challenge of target-oriented transformation of real-world complex scenarios into a simulation model balanced between as much abstraction as possible and as much realism as necessary, challenges raising from the task of complex stochastic data farming have to be tackled. In the ongoing study, the simulation is extended to brigade level to evaluate combined arms effects.

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13. WHY AI, WHY NOW?

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Abstract

With a renewed focus on the return to peer competition, the U.S., Russia, and China are in a virtual arms race to become the world leader in artificial intelligence. Military use of AI has evoked government spending, emotions, and several potential uses in a world that is dependent on a flood of information.

13.2 The leader of AI will rule the world

As the volume and velocity of information continues to increase, the commander's decision timeline has continued to shrink. It appears that the future of warfare is tied to technological advance like artificial intelligence. Hollywood has given viewers fantastical views of AI and robot wars, and perhaps tied emotions to these advances that are unjust. AI is a "must have" in the military, and its effects will be felt in a variety of uses: weapons platforms, cybersecurity, logistics and transportation, target recognition, battlefield healthcare, combat simulation and training, threat monitoring and situational awareness, and processing data (Intelligence).

13.3 The Military

The military is a country's shield and sword. Artificial intelligence, through the cited examples, will aid in the provision of the shield and sword, either through a collective or singular action.

13.2.1 Fear and wonder

Artificial intelligence evokes high levels of fear from some while stirring wonder in others. The fear may be rightly held as the debate over human and AI interaction continue.

13.4 Why AI?

The volume, velocity, veracity, variety and value of the information (all tenets of big data analysis) gathered by the myriad sensors employed by our governments and militaries is phenomenal. How can our operators sift through this unorganized data and bring forth solutions for the commander to ponder and put back out for tactical execution? With AI as an active partner, this information is sorted and prioritized in such a manner that our operators can still critically analyse, think about, and form various COAs for the

commanders to contemplate. AI requires algorithms that learn to recognize patterns through machine learning. Big data, machine learning, cybersecurity, AI, and autonomous systems are all tied together and require each other to be practical and usable[1].

13.5 Why Now?

We have watched idly as peer competition has risen again. Money and resources are consumed rapidly as we all search (independently) for solutions to the AI problem.

- **13.4.1 The Competition**
  - **13.4.1.1 Russia**

    Russia has not released a national AI strategy, but President Putin does view AI as the race that will determine the future global leader [2]. Spending is far below what others are spending globally, but Russia will do what Russia does best: take an idea and make it better.
  - **13.4.1.2 China**

    China outspends everyone on AI [3], and is capable of applying the technology quickly and efficiently due to its governmental control of industry. Like Russia, China is better at taking an idea and applying it.
  - **13.4.1.3 United States**

    A spender [3] looking to spend more in the next few years, and arguably the lead innovator in the field. A national strategy with the ability to fund military and private projects.
  - **13.4.1.4 NATO**

    Several NATO members and partners have national strategies and line items on their budgets for AI development. ACT leads the Military Use of Artificial Intelligence, Automation and Robotics (MUAAR) to develop a guidebook for a repeatable, standardized process for AA&R projects.

13.6 Conclusion

Without AI (and its required foundations in big data and cybersecurity), the future military will be incapable of fighting our competitors. It makes sense that future battles may be won without a single munition being fired, as AI would posture military response with appropriate troop and equipment movement in response to changes in patterns in intelligence (imagery,

signals, communication, and human).

13.7 Acknowledgements

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PART I — PAPERS

PART II — CA2X2 FORUM 2019

Extended Abstracts

NATO M&S COE

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