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EPIC GAMES

The NATO Modelling and Simulation Centre of Excellence wishes to thank the sponsors

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Michele TURI
Col. ITA Army
NATO M&S CoE DIRECTOR

This book contains the proceedings of NATO M&S CoE's Computer Aided Analysis, Exercise, Experimentation annual conference held at the École Militaire, in Paris, France from 24 – 26 September 2019.
The principal theme for the conference was:

'Transformational Power of Simulation'

Considering that the conference was a great success resulting with a record number of participants, this is the first time we have collected studies and papers presented to publish them as conference proceedings.
We hope that collection will be the first of a long series.

It was a significant effort for us to make this published edition that recounts the panel discussions. We hope this makes it easier for our readers to identify the key takeaways and provides a favorable introduction for future CA2X2 Forum.

We thank those of you who joined us for your contributions to the discussion and hope that those of you who were unable to participate, will find this summary informative, inspiring and stimulating for the future challenges.

If you wish to provide feedback, please send it to us at: info@mscoe.org.

Thank you and good reading!

The NATO Modelling and Simulation Centre of Excellence

CA²X² FORUM 2019

Computer Aided Analysis, Exercise, Experimentation

Transformational Power of Simulation

Opening Address by Colonel Michele Turi
Director, NATO Modelling and Simulation Centre of Excellence.

Introduction

Dear Sirs, Stakeholders and NATO M&S COE friends,

We are presenting the 2019 C2A2X Forum Review to publish research, papers and studies presented during the event. We are proud of this collection, that underlines the exponentially rising importance of M&S as a service architecture and key technology to implement all other emerging and disruptive technologies that NATO watches in order t\to maintain and elevate its military and technological advantage versus competitors.

Today M&S is becoming more important due to its atypical and transversal nature in that it can be applied to many doctrines, serving as the third pillar of scientific experimentation. The application of M&S into open innovation enterprises will permit a faster implementation, more credible capabilities studies and tests for minimum viable products faster and more complete than ever.

The 2019 C2A2X Forum was an important event to push the use M&S in different fields and to accelerate capability development and adaptation into the new "fluid multi-domain environment". The results of the event are clear: more than 360 participants, 22 companies and more than 60 different papers and research efforts selected and presented over three days of meetings. These great results are the best viaticum for the 2020 event, even under the limitation forced by the COVID – 19 virus pandemic.

We will continue to support NATO and Nations in their transformation efforts by providing subject matter expertise in all aspects of Modelling and Simulation and our concern is to be able to ensure also good scientific production and "food for thought" that evolves M&S applications in the Defense world.

I am pleased to promote our publication to your attention, considering all the care and devotion that our crew dedicated to its collection in hopes of stimulating more M&S research and experimentation activities. I wish you good reading and hope that it will give you inspiration while waiting for the next edition of C2A2X Forum 2020.

Best regards,

P(h)D Col. Michele TURI

NATO M&S CoE Director

THEME 1: C2

Smart Simulation for Enhanced Situation Awareness at HQ

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Abstract

While serious games are being widely adopted by NATO and partner nations, their use is currently limited to training and operations planning. In this paper, we explain the first results of our research project that uses simulations for decision support and situation awareness support during the execution of military operations. During this phase, the commander makes decisions based on knowledge of the situation and the primary objectives. We propose here to take a simulation containing smart and autonomous units, and use it to create new kinds of decision-support tools capable of improving situation awareness, and consequently the quality of decisions. The breakthrough behind this initiative is the realization that we can provide HQ decision makers with access to a version of the information that smart simulated units use to make decisions. Having studied decision-making processes, we are now able to present our first results, producing genuinely innovative information, computed by the SWORD simulation (Simulation Wargaming for Operational Research and Doctrine), and endorsed by reports from military officers. Based on the current situation (intelligence, operational state, logistic, …) and the current maneuver (current task), examples of what we are now capable of are as follows: provide an immediate local force ratio map, produce a capacities map (detection, combat), compute contextual n fire or logistic support time required, automatically generate lines of battle such as the Forward Line of Own Troops (FLOT), Limit Of Advance (LOA), Line of Contact (LC), FEBA (forward edge of battle area), or propose an effect based maneuver map in order to understand the current effect of the force on the ground... We then propose a prerequisite architecture for use as a decision-support system at HQ, and describe the next smart layers that we believe should be developed for optimal results.

1 Improving Decision Support by Resolving Information Overload

1.1 Supporting the decision by enhancing situation awareness

Situation awareness is the main precursor to decision-making, and is the key factor determining decision quality. The decision-maker must detect and use only a specific fraction of this information to enhance his/her decision making processes. Such considerations lead to the concept of "*the right information, at the right place, at the right time*", as opposed to "*all information, everywhere, all the time*".

1.2 Using constructive simulation services for giving sense to the information

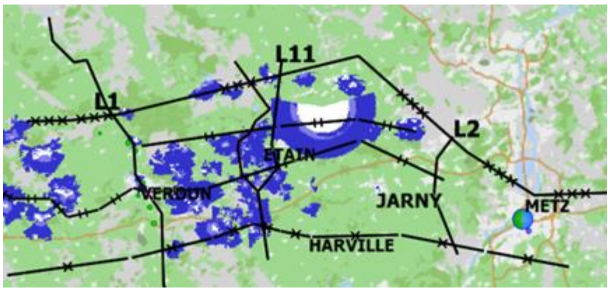
In a typical multi-agent simulation, the situation representation layer, also termed the 'low level AI' layer, is traditionally used by the simulated agent to make sense of raw data from the simulation, allowing the agent to make the best possible decisions and take the right actions. Our idea consists of going beyond the traditional use of a simulation by providing the officers at headquarters access to the situation representation layer, which improves their understanding of the current position in the field.

To achieve our aims we decided to consider the SWORD simulation - currently in use in many armies - as it is a multi-agent simulation which calculates a battlefield representation for each simulated agent, allowing each one to autonomously decide on their behavior, in accordance with their doctrine. We believe that we can offer HQ officers an innovative battlefield representation based on the one already used in SWORD's situation representation layer.

2 Proof of concept: construction of innovative layer for understanding complex tactical situations

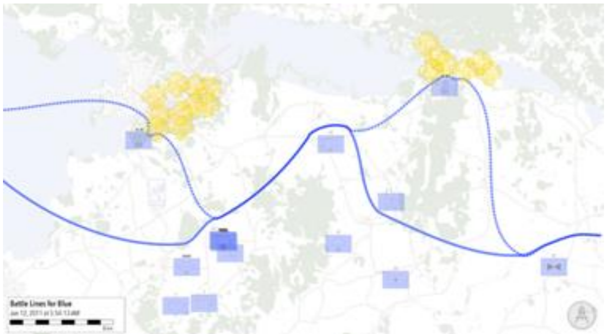
2.1 Direct fire and detection capacities layer

Based on the terrain, the elevation but also the current capacities, mission and action of the units it is possible to provide a realistic map of the zone that can be covered by the units (direct fire, detection, communication, etc.).



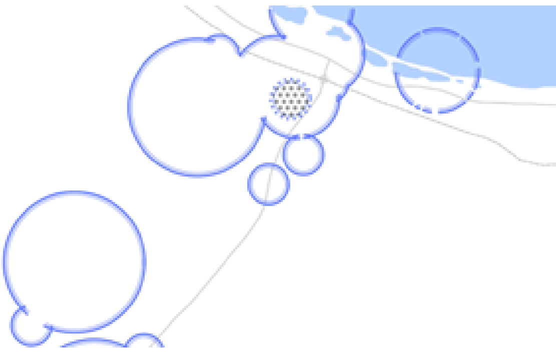
2.2 Battle lines layer

Based on current missions, knowledge of enemies, and capacities of units, we can generate a global maneuver summary, which includes a calculation of tactical lines, such as the Forward Line of Own Troops (FLOT), Limit Of Advance (LOA), Line of Contact (LC)



2.3 Local force ratio layer

Based on the intelligence work, the current capacities and positions of the units, we can provide a local force ratio map. It offers a smart alert where the force ratio is low indicating that the units certainly won't be able to achieve their missions.

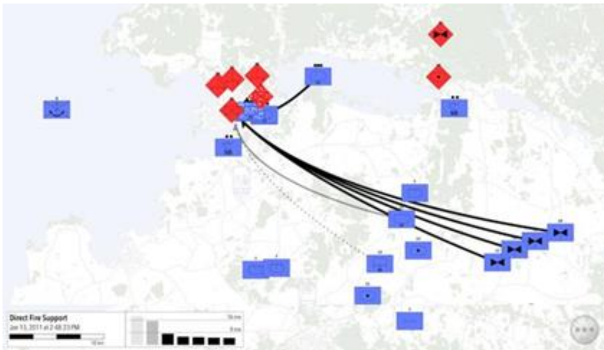


2.4 Enemy fire historic

For helping the intelligence a history of the enemy fire indicating the supposed position of the enemies.

2.5 Direct fire support delay layer

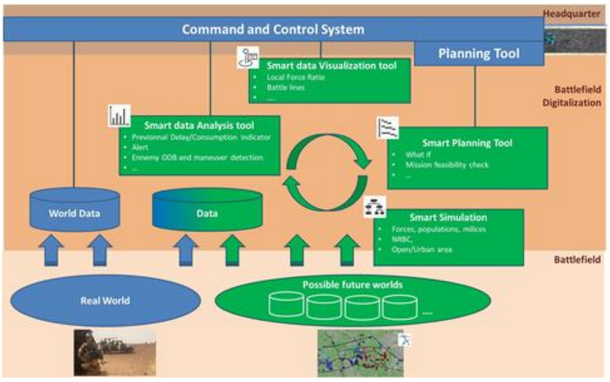
Thanks to the simulation, it is possible to identify easily who could support a unit or apply fire on a enemy and within which timeframe considering the terrain and the capacities of the units.



2.6 Current effect applied layer

According to the past and current missions of the units it possible to provide a view of the main effects applied by units on the field : intelligence, attack, support, defence, engineering, …

3 Architecture



Raw data is processed by algorithms and simulation services, which gives them sense and allows for immediate use through synthesis, alert generation, etc.

4 Conclusions

All innovative methods proposed here depend on two principal prerequisites: 1) a database containing all friendly equipment, plus presumed enemy equipment. Descriptions of all types of equipment must be accompanied by effect descriptions, to enable the simulation of the battlefield. 2) the integration of the command and control systems within the tools described above, with a view to importing all data into the simulation: unit positions, logistic states, enemy knowledge, engineering work, NRBC zones, available missions, etc.

We then have to design a data representation that provides an easy-to-understand, intuitive display of processed information.

Then we want to go further and to propose use these layer as a context in order to alert or adjust the importance of reports.

Acknowledgements

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Integration of Constructive Simulations to Logistics Command and Control Training Design and Execution

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Abstract

This research was conducted to examine the potential for constructive simulation to increase the efficiency at which logistics command and control (C2) training objectives are achieved. Five analyses were conducted on three Department of Defense (DoD) simulations to determine the utility of individual or federated systems in logistics C2 training. The Marine Air Ground Task Force (MAGTF) Tactical Warfare Simulation (MTWS), the Joint Conflict and Tactical Simulation (JCATS), and the Joint Deployment Logistics Model (JDLM) were evaluated individually, and as federated systems with MTWS connected to JDLM and JCATS connected to JDLM. Gap analysis was used to examine the Marine Corps Logistics Operations Group (MCLOG) logistics C2 training design, identify limitations, and determine where constructive training tools can be used to enhance training. The analyses resulted in the recommendation that MCLOG incorporate JDLM into the current training design via an HLA federation with MTWS. The recommended configuration accounts for ease of integration, the fidelity of logistics data generated by the simulations, and the capability of the configuration to support simultaneous training of logistics components across the MAGTF.

Keywords

Constructive simulation; federation; Marine Air Ground Task Force (MAGTF) Tactical Warfare Simulation (MTWS); Joint Conflict and Tactical Simulation (JCATS); Joint Deployment Logistics Model (JDLM); Logistics; Command and Control (C2); Training

1 Introduction

The purpose of this research was to examine the potential for integration of constructive simulation into logistics C2 training design and execution.

1.1 Problem Statement

Military logistics is comprised of all actions required to sustain a force (United States Marine Corps [USMC], 1997). It is grounded in four principle concerns: time, space, consumption rates, and resources. Successful logistics occurs when both resources are maintained in balance with consumption rates, and time and space are managed to effectively distribute those resources. Therefore, logistics C2 decision making is driven by the allocation of assets to sustain consumption rates across the battle space, and correspondingly training must represent operational actions over time, report resources consumed, and have resources for distribution. This makes the use of live units to support logistics C2 training a near impossible task. This is generally due to three primary reasons: cost, secondary effects, and priority of training. First, the cost of distributing resources in mass across a space is disproportional to the training value gained by a logistics C2 watch floor. Second, using live units gives no room for error. If the logistics C2 training audience fails, the secondary effects degrade the operational units. Finally, due to the nature of military organization, ground units should and will always take priority; thus, once a ground unit is introduced, logistics is no longer the primary focus of the training. Ultimately, live logistics C2 training is only appropriate as a secondary benefit in support of larger scale training.

The solution which the DoD is currently utilizing is simulation. The logistics C2 watch floor can be isolated by using simulation to represent operational forces, resources being distributed, and the assets being allocated. This allows logistics C2 to remain the training priority, and work across the principle concerns without physical consequence for mistakes. Additionally, simulation drastically reduces the cost of training. However, the question still remains which simulation is most capable of supporting the training objective? Is there an existing simulation that can be utilized ubiquitously within the logistics community? Does one simulation provide better training for operational logistics and another simulation provide better training for tactical logistics? If simulation is the toolbox, what tool goes with each type of logistics training?

1.2 Requirement for Realistic Logistics C2 Training

Marine Corps Logistics Operations Group (MCLOG) is the primary provider for logistics C2 training in the Marine Corps with the mission:

> "MCLOG provides standardized, advanced individual training in MAGTF logistics operations and unit readiness planning at the Battalion and Regimental levels, conducts Battle Staff Training, facilitates logistics education and manages doctrine, training standards, tactics and institutional training programs in order to enhance combat preparation and performance of Logistics Combat Element units in MAGTF operations." (MCLOG, 2019, para1)

MCLOG has started the process of examining how to adapt logistics C2 training to meet future needs.

This research supports three areas of interest for MCLOG: analyzing the logistics capability of existing DoD constructive simulations, the potential for simultaneous training across MAGTF logistics units utilizing constructive simulation, and the benefits of simulation interoperability to support training.

2 Marine Corps Logistics and C2 Training

The ability to solve problems is the foundation of Marine Corps logistics. Across the spectrum of logistics operations there remains a constant problem in the ability to sustain consumption rates across the battle space. Dynamic critical thought at every level of leadership throughout the logistics element is the solution. Therefore, proper training in logistics C2 requires every member of the staff to be challenged mentally. During training, the consumption rates must force difficult decisions which stress leaders to make prioritized allocations of limited resources over large spaces. To ensure logistics does not inhibit maneuver, training must push the boundaries of distribution to prevent the development a "false sense of security in the minds of supported commanders" (USMC, 1997, p. 108) and in the logistics staffs themselves.

2.1 Marine Corps Logistics

> "Marine Corps' logistics mission, at all command and support levels, is to generate MAGTFs that are rapidly deployable, self-reliant, self-sustaining, and flexible and that can rapidly reconstitute" (USMC, 2016a, p. 1-1).

This means that the purpose for operations at all levels of logistics is the support of tactical level operation. With a unified focus, Marine Corps doctrine establishes a basic philosophy of logistics that sets the foundation for all decision makers.

The basic process is a cycle of four stages: acquisition, distribution, sustainment, and disposition (USMC, 1997). To execute this cycle logistics operations contain two elements: a distribution system and C2 (USMC, 1997). The distribution system consists of a base which receives and stores resources and a distribution procedure which manages those resources. Logistics C2 regulates the logistics process based on quantitative logistics data collected from the operating forces.

Marine Corps logistics is organized to mirror the levels of war: strategic logistics, operational logistics, and tactical logistics. These levels form the logistics continuum, Figure 1, shows the cycle of tactical operations creating requirements and national resources filling those requirements.

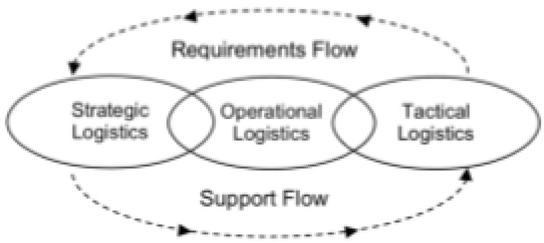

Fig. 1. Logistics continuum. Source: USMC (2016b, p.1-2)

Strategic logistics is the national perspective of converting the nations resources into military power. At this level the areas of interest are acquisitions, recruiting, and sustainment of permanent bases (USMC, 1997). Strategic logistics is focused on both the advancement of the Marine Corps to address the future fight, and maintaining the overall force to sustain current worldwide operations. Operational logistics is the theater or campaign perspective providing a transfer point between national resources and the individual operations occurring within geographical regions (USMC, 1997).

3 Analysis Methodology

The analysis methodology for this research was custom designed to support the areas of interest established by MCLOG and the specific research questions addressed in Section 1.1. Gap analysis provided the organizational structure to examine the current capability of training compared to four alternative uses of constructive simulation. Each configuration was implemented in the MCLOG training design for testing using the current training model as a baseline for comparison.

Correspondingly, a tactical scenario was developed and played out in each configuration to support three aspects of analysis: the ease of integration into MCLOG infrastructure, fidelity of logistics data produced, and the potential to support simultaneous training across MAGTF logistics components.

3.1 Constructive Simulation Configurations

The five configurations were arranged using three constructive simulations. MTWS, JCATS, and JDLM are the primary constructive simulations utilized by the Marine Corps for training, and provide a well-rounded examination of existing DoD simulations.

The MTWS individual analysis established the baseline and represented an aggregate based combat model designed to support higher echelon training at the Marine Expeditionary Force (MEF) level. In contrast, JCATS as an individual system presented an entity-based combat model designed to support brigade level training and below. The individual analysis of JDLM advanced Conard's (2018) research and represented an entity-based logistics model. Additionally, federations between combat and logistics models were tested in accordance with Conard's (2018) findings. The federated analyses demonstrated the potential for increased capability of logistics training through interoperability.

3.2 Tactical Scenario

The tactical scenario was scripted to depict a single combat engagement involving each element of the MAGTF, Figure 2. This provided both a manageable collection of logistics data stretching across four of the six functional areas, and an opportunity to assess the ability of the configuration to support simultaneous training. The four functions of logistics represented during the scenario are supply, maintenance, health services, and services. The scheme of maneuver consisted of a sequence of events forming a combined arms attack on an objective, listed below.

- Two combined anti-armor teams (CAAT) advance north to provide reconnaissance on enemy forces occupying the objective.
- Two mechanized infantry companies advance north following the CAATs at approximately one-kilometer distance.
- Upon arrival of the CAATs a close air support (CAS) mission is requested, and the Marine Attack Squadron dispatches an aircraft.
- After the CAS mission is complete, indirect fire is requested from the artillery battery and three volleys are fired on the objective.
- The mechanized infantry companies then close with and destroy the enemy.

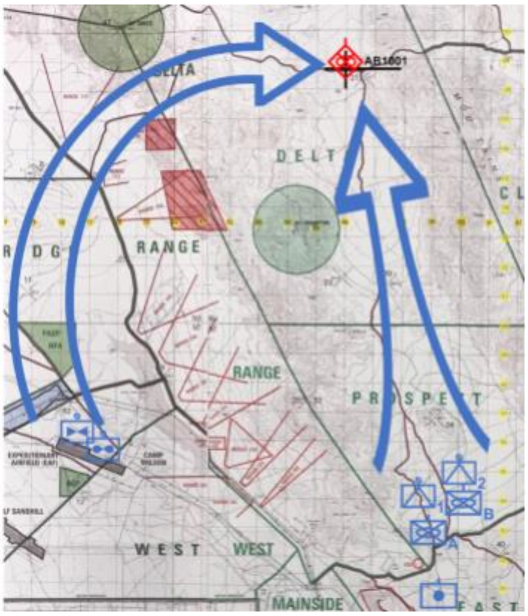

Fig. 2. Tactical Scenario Overview

The primary purpose of the tactical scenario was to generate logistics data, in accordance with the MCLOG training process. The comparison of the fidelity of logistics data from each alternative configuration to the baseline was the foundation of the analysis. By aligning the configuration with the current training process, it directly addressed the limitation of low fidelity data.

4 Individual Analyses

4.1 MTWS Analysis

4.1.1 - Background

> "The MTWS is the Marine Corps only constructive, aggregate resolution simulation system used to support the training of Marine commanders and their battle staffs in MAGTF warfighting principles/concepts and as well as associated command and control procedures" (USMC Concepts & Programs, 2019c, para1).

The simulation was designed by Cole Engineering Services, Inc. (CESI) as a full member of the J7 Joint Live Virtual Constructive (JLVC) federation to support staff training for battalion level and above, and is maintained as a Marine Corps program of record (CESI, 2019). MTWS is a combat simulation that represents friendly, enemy, and neutral units across land, air, and maritime operations (USMC Concepts & Programs, 2019c). The simulation provides both real time simulation of combat simulation and play back capability to support after action de-briefs.

MTWS provides multiple interfaces to operate with C2 systems both directly including Command and Control Personal Computer (C2PC) and the Advanced Field Artillery Tactical Data System (AFATDS), and indirectly through systems such as the Global Command and Control System –Tactical Combat Operations (GCCS-TCO).

4.1.2 - Tactical Scenario Implementation

To create the synthetic environment MTWS contains a parametric database which houses extensive and detailed information concerning all possible occurrences of objects, events, interactions, and behaviors. The scenario was played out by initializing the force layout and running the simulation. The units were maneuvered according to the tactical scenario script through commands given by the user (human-in-the loop). As a combat model, MTWS conducts automatic engagement between hostile forces when the forces detect each other. The movement of the units and the engagement resulted in the production of logistics data.

4.1.3 - Logistics Capability

Logistics data in MTWS is collected through the personnel and asset reports for each unit. Reports for each unit were gathered before and after the scenario was played out for analysis. Figure 3 is an example report.

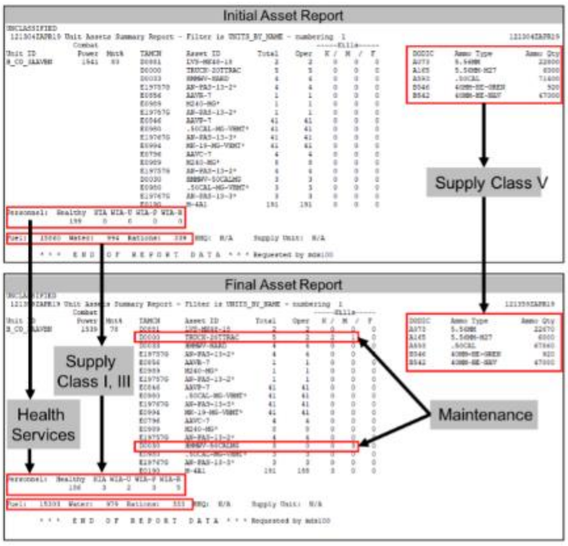

Fig. 3. MTWS logistics data from the asset and personnel solicited reports

4.1.3.1 - MTWS Supply Capability

MTWS captured supply classes I (food & water), III (fuel), V (munitions), and VII (equipment) during the analysis. The data was quantitative in nature and consumption was demonstrated over time and through the engagement for all units in the scenario. Unit behavior is affected by decreasing supply levels in MTWS, without water, rations, or ammunition units have a combat power of zero. Likewise, units without fuel are unable to move in the simulation.

4.1.3.2 - MTWS Maintenance Capability

MTWS contains three categories for damage of equipment: catastrophic kill, mobility kill, and firepower kill. During engagement, when equipment is reported damaged, it is listed in the asset report under one of the categories.

- Catastrophic kill: Equipment is damaged beyond repair (CESI, 2018).
- Mobility kill: Equipment is no longer mobile and requires a tow and repair (CESI, 2018).

- Firepower kill: Equipment weapon systems are damaged and require repair (CESI, 2018).

4.1.3.3 - TWS Health Services Capability

Health services requirements are documented in both the asset report and the personnel report for each unit. The details of the casualty are listed in the personnel report by generic name and rank. During engagements personnel casualties are classified into one of four categories:

- Killed in Action (KIA)
- Wounded in Action (WIA) Urgent
- WIA Priority
- WIA Routine

WIA casualties are evacuated through executing a casualty evacuation order, and treated through the combat support services orders.

4.1.3.4 - TWS Services Capability

MTWS handles personnel in a generalized manner. The personnel report covers the type of lifeform and how many of a specific rank exist in the unit. When casualties occur, it is quantified but not specific in the report.

4.1.4 - Summary of Findings

MTWS is the current system used at MCLOG for training and is the control group for this research. The supply levels represented in the scenario include class I, III, and V consumed over time, and class VII assigned within unit table of equipment. The maintenance capability includes three classification of quantitative data assigned by the table of authorized material control number (TAMCN). The health service capability includes four classifications of casualty assigned quantitatively by personnel type and rank. The services capability includes only the limited ability to conduct numerical personnel administration. The logistics data collected during analysis support Conard's (2018) conclusion that MTWS has limited fidelity of logistics data and is only representing generalized information that requires alteration to increase fidelity for logistics C2 use.

4.2 JCATS Analysis

4.2.1 - Background

JCATS is a combat model at the entity level (MAGTF Training Directorate [MTD], 2019). Developed by the Lawrence Livermore National Laboratory (LLNL), "JCATS is a discrete event, constructive simulation that simulates actions and events of people and systems in specified environments" (LLNL, 2019, para 1). As a member of the JLVC federation, JCATS is sponsored by the J7 and is currently utilized as the primary entity ground simulation during joint exercises (LLNL, 2018). While the system is entity based, users have the capability to wrap units into higher echelons providing extensive flexibly to train a variety of audiences. JCATS is widely used across the DoD and internationally including 30 allied nations (LLNL, 2018). The system provides wargaming as a "man-on-man simulation" (LLNL, 2018, p. 2) allowing for a friendly and enemy force that can be played out and reviewed through after-action features.

The Marine Corps maintains minimal use of JCATS. However, it is utilized as a ground simulation for low level unit training through the MAGTF Training Command and formally used by the Marine Corps Tactics and Operations Group (MCTOG) during training exercises for GCE operations officers (MTD, 2019). While the Army is transitioning to the Joint Land Component Constructive Training Capability (JLCCTC), JCATS remains widely used for both unit training and formal training exercise.

4.2.2 - Tactical Scenario Implementation

A JCATS scenario is built through three editing tools: the terrain editor, VISTA editor, and symbol editor (LLNL 2017c). The terrain editor houses data concerning the physical environment to include buildings, terrain features, roadways, and other infrastructure (LLNL 2017c). The data containing graphics for each entity in the simulation are contained in the symbol editor (LLNL 2017c). The VISTA editor controls "capabilities and parameters of the specific game to be played" (LLNL, 2017c, p. 2-2). All files concerning the scenario are contained in the VISTA editor including the data from the symbol and terrain editor. These files combine to form the scenario file executed in the JCATS server.

To play out the scripted scenario, units were given orders through the client workstation. Entities are collected into a unit for the user to control using the tools within the interface. JCATS, as a combat model, initiates an engagement when hostile units are within range of each other. Logistics data is a result of engagements and operational maneuver. JCATS contains a casualty play feature which is turned on to produce higher fidelity logistics data and allow JCATS to fix damaged equipment and treat wounded personnel.

4.2.3 - Logistics Capability

Logistics data in JCATS is contained in four reports: the entity carry report, entity ammo report, entity casualty report, and unit personnel report. Reports in JCATS are organized as comma separated files and displayed as a spreadsheet for the user. For the analysis, reports were pulled for each unit before and after the scenario was played out.

4.2.3.1 - JCATS Supply Capability

Two categories of supply are represented in JCATS: carried supplies and personal supplies. Carried supplies consist of items contained within a unit meant specifically for resupply (LLNL, 2017a). Personal supplies consist of the supplies carried by the individual entity and consumed over time and operation (LLNL, 2017a). The force layout used in the tactical scenario established the only carried supplies at the unit level for the analysis. JCATS has the capability to represent classes I, III, IV (construction material), V, VII (major end items), VIII (medical), and IX, however, class IX was not used in the scenario (LLNL, 2017a). The ammo report publishes the personal class V load of each entity within a unit (LLNL, 2017b).

4.2.3.2 - JCATS Maintenance Capability

By enabling casualty play when the scenario was set up in the VISTA editor, fidelity of maintenance was increased. Vehicle damage is contained in the casualty report by entity. The report displays the item damaged and provides the type of damage, a description of the damage, and time of repair. JCATS classifies system status as mobility, firepower, or dead. Repairable entities can be repaired by a user through the logistics commands in the client workstation.

- Mobility: Entities classified as mobility damage cannot move but maintain the ability to employ attached weapon systems.
- Firepower: Entities classified as firepower damage are mobile, but do not have the ability to employ weapon systems.
- Dead: Entities classified dead, can neither move or employ weapon system. When an entity is classified as dead it cannot be repaired.

4.2.3.3 - JCATS Health Services Capability

Similar to the maintenance capability, enabling the casualty play increases the fidelity of medical data. JCATS classifies personnel casualties the same as maintenance casualties as mobility, firepower, or dead. However, when a lifeform status is classified as mobility it reflects as a WIA in the personnel reports. JCATS identifies specific casualties by entity general name and identification number, and assigns a specific injury coupled with treatment time, and time before death if untreated. If the lifeform is left untreated for the specified time the status will change to dead in the casualty report and KIA in the personnel report. While not used in this scenario, JCATS has the ability to assign gender and blood type to an entity. Users can repair lifeform casualties through the logistics commands in the client interface.

4.2.3.4 - JCATS Services Capability

The primary capability in JCATS for logistics services is personnel administration. Each lifeform entity is assigned a specific identification number and represented using billet description, grade, and military occupational specialty (MOS). While KIAs are recorded and can be replaced, mortuary affairs is not represented in JCATS. The JCATS personnel report displays the lifeform entities in each unit and the overall percentage of the unit.

4.2.4 - Summary of Findings

While JCATS logistics capability is more advanced than MTWS, the implementation of JCATS into the MCLOG infrastructure requires a complete overhaul of the existing layout both in hardware and software. The secondary concern with switching from MTWS to JCATS is starting from a baseline data source. Starting from baseline data, it is likely that the VISTA editor files require some level of adjustment to suit the needs of MCLOG and prevent unrealistic behavior in the model.

The fidelity of logistics data in JCATS is increased compared MTWS. The classes of supply were increased to include classes IV, VIII, and IX. The maintenance information was increased to a specific casualty code and required repair time, however TAMCN were not included in JCATS. While health services casualties did not include classification as routine, priority, or urgent, the fidelity of data increased to include specific injury, blood type, gender, and religion of the casualty, treatment time, and time before death if untreated. Services information was also increased to include Military Occupational Specialty (MOS), gender, and religion.

The capability for simultaneous training is similar to MTWS with no advantage between the two simulations established. As both simulations are combat models, they are both designed to support Ground Combat Element (GCE) and Air Combat Element (ACE) operations differing only in LCE support. JCATS presents an increase in fidelity of logistics data, but at the cost of time to retrain the staff, outfit the hardware, and adjust new databases to MCLOG needs. The increase of training capability does not validate the time and cost requirements to adjust the infrastructure for implementation.

4.3 JDLM Analysis

4.3.1 - Background

The JDLM is a logistics entity-based constructive simulation designed by Tapestry Solutions, a Boeing Company, "that enables logistics personnel to exercise their C2 systems in a realistic combat environment" (Tapestry Solutions, 2019b, para 7). The system was originally funded by United States Army Europe (USAEUR) to provide a logistics training tool for commanders and their staffs "when conducting mission planning, rehearsals, and training associated with power projection" (Swan, 2006, para 2). The system caters to all levels of command and is specifically designed to provide detailed logistics capability in transport, supply consumption and operations, medical services, medical supply consumption, maintenance, and personnel treatment and replacement (Tapestry Solutions, 2016). As a member of the JLVC federation, JDLM is used as the primary logistics model during J7 exercises and contains gateways to High Level Architecture (HLA), Distributed Interactive Simulation (DIS), and GCCS-TCO.

There is limited use of JDLM in the Marine Corps, however it is used extensively in the Army and for joint exercises.

4.3.2 - Tactical Scenario Implementation

JDLM scenarios are driven through databases, or repositories, that hold all the entities, or prototypes, in the scenario, and all the events, or conditions, that can occur to those entities. The repositories used in the scenario were acquired from the J7.

Logistics data in JDLM cannot be generated through combat, as JDLM is a logistics model, therefore, to generate logistics data an alternative method is used. Consumption regions were used to replace combat and generate logistics requirements for this analysis. JDLM utilizes region agents to manually set rates of specific consumption events, such as fuel consumption, ammunition consumption, casualty rates, vehicle damage, etc. The agents are applied to geographical regions, which impact units within the area. This method replaces combat and is designed to stimulate logistics requirement over time. The units were maneuvered through these regions in accordance with the scripted tactical scenario to collect data for analysis.

4.3.3 - Logistics Capability

JDLM generates logistics data from specific consumption rates defined by the user or from conditions contained in the repositories. A condition in JDLM is the description of a consumption event including all low-level details of the event. As a logistics model, JDLM can represent all functions of logistics in detail. Of the four functions of logistics examined in the analysis, JDLM provides an extensive amount of information.

4.3.3.1 - JDLM Supply Capability

JDLM has the capability of representing all classes of supply, blood, mail, and miscellaneous items. While class II, VI, and X are available in JDLM only class I, III, IV, V, VII, VIII, and IX (repair parts) were observed in the scenario.

4.3.3.2 - JDLM Maintenance Capability

JDLM describes maintenance requirements in the form of maintenance conditions. These conditions are specific to individual pieces of equipment and contain the detailed requirements to repair the damage. When a piece of equipment is damaged in the system, a maintenance condition is selected at random and assigned to the entity. The condition includes the name of the repair, the time of repair, the assigned maintenance unit, and the specific supplies that will be expended during the repair. If the unit does not contain the supplies required to fix the maintenance condition the repair does not start. The maintenance condition also contains a chronological record of events associated with the repair of the entity. For entities that are beyond repair, JDLM contains the ability to replace the equipment. Damage occurs to equipment by user input through a consumption event or region.

All maintenance conditions are contained in the maintenance repository. This repository can be customized by the individual user to contain all maintenance conditions for equipment used in exercises.

4.3.3.3 - JDLM Maintenance Capability

JDLM provides health services capability in the same form as maintenance capability. The medical repository contains all injuries that can occur to a lifeform in the scenario referred to as treatment briefs. When a lifeform is registered as a casualty a treatment brief is randomly assigned to the entity. Similar to maintenance conditions, treatment briefs contain specifically what injury was sustained, which triage of care is required, estimated time before death if not treated, estimated time of treatment, and medical supplies required.

Lifeforms in JDLM contain detailed information including a specific name, social security number, rank, MOS, blood type, gender, and religion. When a lifeform sustains a casualty and is assigned a treatment brief, JDLM represents the consumption of the class VIII required, and if the medical unit does not have the required supplies it does not treat the casualty. JDLM contains the capability to represent WIA, illness, general injury sustained in a non-combat environment, KIA, and death occurring due to natural or non-combat occurrences. The treatment report for the user contains the specific treatment brief and a list of events associated with the progression of the casualty. Casualties in JDLM are generated by user input through consumption events.

4.3.3.4 - JDLM Services Capability

During the scenario JDLM displayed the capability to represent personnel administration, postal, and mortuary affairs. Personnel conditions in JDLM are defined in the personnel repository to represent required personnel movement due to noncombat requirements. Combined with the health services capabilities, JDLM provides full capability to stimulate personnel administration. The mortuary affairs repository processes KIA and other personnel death. When executing mortuary affairs, the information is processed through treatment briefs. Supplies associated with mortuary affairs are represented in the supply repository and are expended as casualties are processed. Postal services are stored in a separate repository, and, while the repository was contained in the scenario, it was not used during the scenario.

4.3.4 - Summary of Findings

Of the three constructive simulations examined, JDLM contains the most useful and highest fidelity logistics data. However, as a standalone system it is not sufficient to meet MCLOG training requirements. To implement JDLM into the physical infrastructure requires a full overall of hardware and software install, furthermore, the training support staff requires re-training. This requires time and disturbance to the current training cycle. Furthermore, similar to JCATS, the repositories require alterations and expansions to match Marine Corps equipment and MCLOG specific requirements. Customization of the multiple databases in JDLM requires significant time allocation and experimentation.

The fidelity of logistics data is far superior to the current configuration of MTWS, and the information produced in JCATS. JDLM increases the supply data to include all classes of supply among other miscellaneous supply items commonly used in logistics operation. The maintenance capability is increased from basic classification to specific conditions including the supplies required for repair. Information specific to the equipment is increased from TAMCN to TAMCN and serial number. Health services information is increased from basic classification to specific treatment conditions coupled with required supplies for treatment and triage. Information specific to the casualty is increased from generalized numerical data, to lifeform specific information. Services capability is increased from generic numerical data concerning personnel to detailed documentation including name, social security number, rank, MOS, blood type, gender, and religion. Furthermore, services are increased to include personnel administration, mortuary affairs, and postal.

The inability of JDLM to represent combat prevents simulations training. While it is possible to stimulate the GCE and ACE using consumption regions the operational picture is not reflective of real life, and a distraction to training. Furthermore, Marine Corps logistics is driven by the operations of the MAGTF, which includes combat and general maneuver. Consumption regions are not a sufficient substitute to a combat model.

5 Federated Analysis

5.1 HLA Federation

Each constructive simulation, as a member of the JLVC federation, contains organic capability to pass information in accordance with the HLA standard. Therefore, HLA was used to federate the simulations mirroring the J7 JLVC federation.

HLA federations are linked through a common FOM and RTI stored and executed within each federate. FOMs and RTIs are either custom built for a specific federation or an existing standard approved by the Simulation Interoperability Standards Organization (SISO). The FOM and RTI used for these analyses are specific to the JLVC federation published by the J7. Information is sent in accordance with the FOM to the RTI from a single point within the federate. The FOM dictates a common language for the federation, establishing how objects and events are described and communicated through an extensible markup language (XML) file (Dahmann et al., 2000). While federates identify and describe objects and events within the synthetic environment uniquely, the system is required to translate internal data into the HLA standard designated by the FOM. Information is passed across the federation through the RTI software running within each federate via an HLA bridge. The RTI not only collects all information from the federates, it provides a variety of services which filter data allowing the federates to subscribe to only the services specific to that federate (Dahmann et al., 2000). This customization for each federate prevents the system from becoming overloaded with useless information.

HLA federation standards require that objects are controlled, or owned, by a single federate (Dahmann et al., 2000). Furthermore, it is required that object ownership is dynamically transferable from one federate to another while operating within the federation (Dahmann et al., 2000). All federates receive updates concerning object information via the RTI, however, only the owning federate publishes information concerning a specific object.

5.2 JCATS Federated with JDLM

The JCATS JDLM federation was establish through the JCATS HLA bridge and the JLDM HLA listener. The JCATS workstation published directly to the RTI through the JCATS HLA bridge, and the JDLM workstation published indirectly through the JDLM HLA listener.

In accordance with HLA standards, JCATS and JDLM are required to have the functionality to transfer objects, or in this case, entities. Entity transfer occurs via logistics nodes established within JDLM containing a specific logistics capability. During this federated analysis, a maintenance node, medical node, and personnel node were created. The maintenance node received all damaged platforms, the medical node received all wounded lifeforms, and the personnel node received all KIA lifeforms. JDLM has multiple functions that control the automation of entity transfers to support logistics and the display of entities owned by other federates.

5.2.1 - Federation Behavior

During the exercise JCATS casualty play was turned off, and the automatic transfer of platform and lifeform entities was enabled in JDLM. It is recommended that the casualty play in JCATS is disabled while federated to enable JDLM to adjudicate logistics requirements (Tapestry Solutions, 2016).

JDLM tracked all unit movement and combat engagements that occurred in JCATS during the scenario. As combat occurred in JCATS, damaged entities where automatically transferred to JDLM for logistics diagnostics including repair, treatment, or mortuary affairs in accordance with the JDLM federation properties.

When entities were transferred to JDLM maintenance or treatment conditions were assigned, increasing the fidelity of the logistics data from generic in JCATS, to specific in JDLM. JCATS handles the operational expenditure of supply classes I, III, and V, and the initial damage and casualty reports resulting from combat. JDLM is responsible for resupply, and establishing the specific logistics requirements of maintenance, health services, and services. This division of effort between operational action and logistical response provides a complete view of the battle space for the training audience.

As entity level simulations, JCATS and JDLM publish information concerning all owned entities. This provides fluid information transfer across the federation and a clear operational picture for both JCATS and JDLM users.

5.2.2 - Summary Findings

The federation of JCATS and JDLM provides an increase in the fidelity of logistics data along with an increase in simultaneous training capability. To support simultaneous training across the MAGTF, the JCATS model contains sufficient data to simulate a logistics component of the ACE and GCE, while JDLM provides the information necessary to simulate the C2 of the LCE. However, the requirement to implement the configuration into the existing MCLOG infrastructure requires hardware and software overhaul of all systems, and training requirements for support staff. Furthermore, as discussed in the individual analyses of JDLM and JCATS, the data bases of each system require adjustment to meet specific MCLOG needs. While the training capability is increased using the JCATS and JDLM federation, time and extensive training of personnel are required for implementation.

5.3 MTWS Federated with JDLM

The MTWS JDLM federation was establish through the MTWS HLA bridge and the JLDM HLA listener. The MTWS Model Application Network (MAN) published directly to the RTI through the MTWS HLA bridge controlled through the Model System Control (MSC). Similar to the JCATS JDLM federation, the JDLM workstation published indirectly through the JDLM HLA listener.

Transfer nodes were established in JDLM following the same design outlined in the JCATS JDLM federation analysis. The nodes were established to support the transfer of objects concerning maintenance and medical requirements. MTWS transfers only platform and lifeform entities which can be repaired. Equipment classified as a catastrophic and casualties classified as KIA cannot be transferred to JDLM, therefore, a personnel node was not required to conduct mortuary affairs.

5.3.1 - Federation Behavior

During the scenario JDLM tracked the movement of the headquarters element of each unit and limited combat engagement from MTWS. Due to MTWS publishing information only concerning units at the aggregate level to the federation, the JDLM operational picture often did not match the operational picture in MTWS, displaying the lower echelon units separated from their headquarters element. The combat events registered in JDLM from MTWS were limited to only the close air support and indirect artillery fire.

To transfer a specific platform or lifeform into JDLM following the engagement in MTWS, the user is required to conduct a casualty evacuation or unit movement to a transfer node and manually transfer the object through a command entry. While the general publication of MTWS does not account for lower echelons, when MTWS conducts a transfer the lifeform or platform is identified as belonging to a specific unit under the aggregate level which JDLM identifies as a specific entity. When the transfer occurs and JDLM receives the item, a maintenance or treatment condition is established increasing the fidelity of logistics data.

The federation of MTWS and JDLM increased the fidelity of logistics data to include the supply, maintenance, and health services capabilities of JDLM. However, as KIA casualties are not transferred to JDLM, mortuary affairs and personnel administration capabilities remain limited (CESI, 2018). Similar to the JCATS JDLM federation, a combination of the two individual logistics capability is achieved through the MTWS JDLM federation. MTWS handles combat adjudication, the operational consumption of classes I, III, and V, and the initial maintenance and casualty reports. JDLM increases the fidelity of the initial reports concerning maintenance and health services, and provides resupply capability. The division of logistics responsibility mirrors the difference between MAGTF operations of GCE and ACE, and the detailed requirements of the LCE.

5.3.2 - Summary of Findings

The federation between MTWS and JDLM increased the fidelity of logistics data and the capability to train MAGTF logistics components simultaneously compared to the current MTWS standalone design. With the limited increase of fidelity concerning logistics services data, the MTWS JDLM federation contains less logistics fidelity than the JCATS JDLM federation. However, the requirement for implementation of the MTWS JDLM federation is far less time and training intensive than the JCATS JDLM federation. Adding JDLM to the existing MTWS infrastructure requires limited disturbance to the current training cycle and can be incorporated slowly to account for staff training requirements, and adjusting the JDLM repositories to fit MCLOG training needs. The unique capability of MTWS to represent MAGTF operations, combined with the logistics information stored in JDLM provide the opportunity to train various logistics components within the MAGTF.

6 Conclusion

6.1 MTWS JDLM Federation Reccommendation

Based on the three aspects of analysis, the recommended training alterations for MCLOG to conduct logistics C2 training is the incorporation of JDLM through an HLA federation with MTWS.

The current MCLOG infrastructure is designed to support MTWS as a standalone system utilized for both generating logistics data and stimulating C2 systems. The training support staff are familiar with MTWS and have had time to structure the parametric data based on specific MCLOG requirements. The JCATS JDLM federation contained only minor improvements in the fidelity of logistics data within mortuary affairs and personnel administration compared to the MTWS JDLM federation. The increase to training efficacy by switching to JCATS as a primary combat system does not overcome the disruption to the current training cycle, and the time required for full implementation of a JCATS JDLM federation. By maintaining the current infrastructure and adding JDLM, alterations can be made in conjunction with the training cycle with the use of JDLM increasing over time as staffs are trained and JDLM repositories are adjusted. Overall, the MTWS JDLM federation analysis resulted in the lowest estimated infrastructure alteration for implementation apart from the baseline.

The fidelity of logistics data is greatly enhanced by the incorporation of JDLM. The increase of supply classes from I, III, V, and VII represented in MTWS, to all classes of supply including blood products represented in JDLM. The increase of maintenance and health services information from a generic category in MTWS to a specific condition in JDLM. With MTWS limitation preventing the transfer of KIA and catastrophic equipment damage to JDLM, the increase to logistics data increases the logistics C2 training capability drastically.

The capability for a MTWS JDLM federation to support simultaneous training both laterally and vertically across the MAGTF is increased compared to the current training design. Both federated analyses resulted in similar simultaneous training, the MTWS JDLM federation was selected based on the ease of implementation. By combining combat and logistics simulations MAGTF operations are represented for context through the combat simulation provided operational consumption rates. Specific logistics requirements resulting from MAGTF operation are generated in the logistics simulation providing the appropriate level of logistics fidelity for each logistics component.

Ultimately by federating two simulations with different strengths, the capability of the federation will exceed the capability of the individual simulations. As Marine Corps logistics is driven through tactical operation, it is required that a combat model produced the initial level of logistics data. To reduce the requirement on training support staff to generate higher fidelity data of use to a logistics C2 training audience, a logistics model is incorporated to automate the process.

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to gain fundamental knowledge in how constructive simulations are used in training operations, both as standalone simulations and widely distributed federations. Personnel from all units and companies listed provided constant assistance, ensuring the complete development of the constructive simulation lab and that all requirements were met to conduct analyses. Without their diligent and patience assistance, this work would not have been possible.

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THEME 2: CAX

"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.

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.

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.

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.

In conventional war, intelligence is focused on providing information regarding two complementary subjects: the actors and the operational environment.

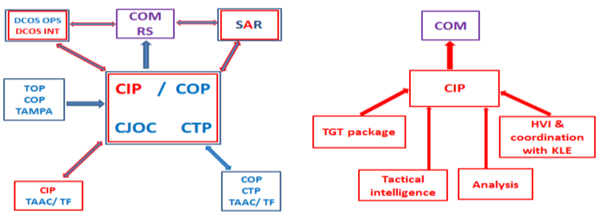

Fig. 1. CIP in RSM.

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.

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.

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.

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.3, among NATO FASs we find an additional database called CIDNE.

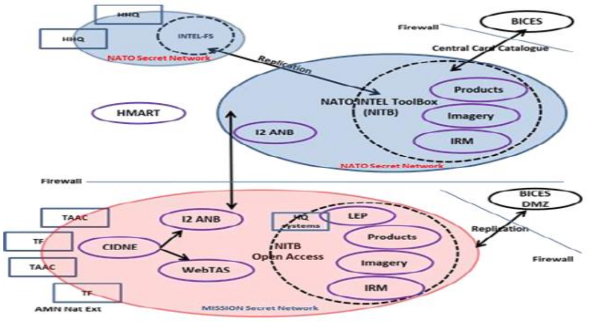

Fig. 3. Intel Systems Architecture in RSM

It was used to merge the information received from NATO networks with the information from national networks (US, UK, DEU, ITA).

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.

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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THEME 3: Innovations VR/AR/Simulators

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.

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].

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.

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.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.

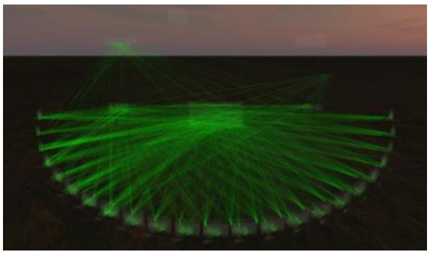

Fig. 2 - 3D display of LS18PR network topology and network traffic using VDE, displaying an overall view of the meta-shape – a datashape consisting of multiple datashapes.

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.

Author/Speaker Biographies

Matt Ryan is a DoD Information Security Specialist currently serving as Deputy CSSP Manager of the C5ISR Center CSSP within the United States Army. He's worked in defensive cyber operations since 2010 as an intrusion detection analyst, Watch Officer, and defensive cyber operations manager. Mr. Ryan is a Doctoral candidate, currently studying Defensive Cyber Operations at Dakota State University. He holds a MSc in Cybersecurity and a MBA from the University of Maryland.

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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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.

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.

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

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.

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.

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.

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.

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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Decision making in a Synthetic Training Environment: Where does Simulation fit?

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Abstract

As training solutions evolve and become more "learner-centric", interactive and real, the seamless integration of simulation as part of the blend presents some unique challenges. Is simulation driven by the E3D process (exercise design, development and delivery)? Or is the process driven by the simulation? The variety of simulations, C2 systems and exercise development tools that support training adds to the complexity of this environment. Delivering the best training at reasonable costs in terms of effort, resources and manpower; while providing oversight, post exercise observations and support to after action review are factors that need to be addressed and resolved. We know that technology can help and there are many options to chose from; but is our focus where it needs to be? Who and what process are at the centre of every decision that gets made during the design, development and delivery of training?

1 Introduction

We all want to achieve exceptional training that makes effective use of simulation and is interoperable, while closing "the effects gap"; that gap between what the exercise writers develop and what the exercise controllers deliver. In this presentation, we examined how we tackle many of these current challenges and how we are transforming ourselves for the future at the Canadian Army Simulation Centre – a Centre of Excellence for simulation enhanced collective training and professional military education.

1.1 About Calian Group Ltd

Since 1982 Calian has delivered diverse products and solutions for private sector, government and defence customers in North American and global markets. Calian's core purpose is to help the world communicate, innovate, lead healthy lives and stay safe. The Company's diverse capabilities are delivered through four segments: Advanced Technologies, Health, Learning and Information Technology. The Advanced Technologies segment provides innovative products, technologies and manufacturing services and solutions for the space, communications, defence, nuclear, government and agriculture sectors. The Health segment manages a network of more than 1,800 health care professionals delivering primary care and occupational health services to public and private sector clients across Canada. Learning is a trusted provider of emergency management, consulting and specialized training services and solutions for the Canadian Armed Forces and clients in the defence, health, energy and other sectors. The Information Technology segment supports public and private-sector customer requirements for subject matter expertise in the delivery of complex IT and cyber security solutions. Headquartered in Ottawa, Calian's offices and projects span Canada and international markets.

2 Considerations when planning an exercise

Our presentation highlighted the many factors for which those responsible for planning and conducting complex exercises must contend and described an exercise design, development and delivery (E3D) process that achieves successful outcomes. It was basically:

- Identify and analyze the exercise aim, scope, training objectives and participation;
- Use a systems approach to training process identifying the conferences, meetings and development sessions through which you build the exercise;
- Analyze each element required to replicate the operational environment within which the training will take place in order to determine the requirements for progressive training, personnel support (controllers, SME's, role players, observer controllers as examples), simulation, real life support; documentation, management, AAR and other post exercise activities to name a few;
- Determine the network architecture for the simulation and C2 systems within which the training audience will be wrapped;
- Accept and deal with the dynamic influences ("Challenges") on your E3D process such as constant

changes, increased training demands, higher expectations of what can be achieved, direct leadership engagement and the fact that these complex exercises never unfold the same way twice.

2.1 The E3D process drives simulation requirements

Our conclusion was that the E3D process drives the simulation requirements and not the other way around. A graphic of this conclusion is depicted below:

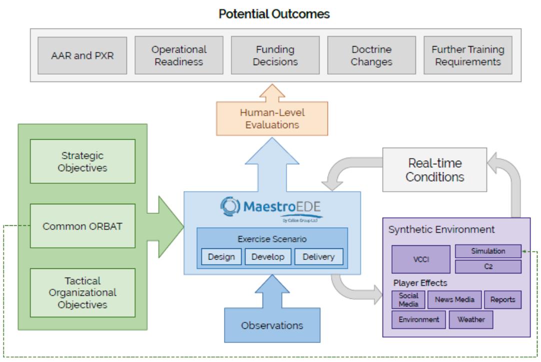

Fig. 1 - E3D process as centre of solution

2.2 How the E3D process works

The E3D Process represented by MaestroEDE™ in this case, is the centre of the solution. It takes the inputs and analysis, accounting for the "challenges" including observations throughout the E3D process then manages and drives the interaction between those engaged in scenario design, development and delivery and those delivering simulation/C2 and other player effects. It collates the observations outside of simulation, AAR screen or video capture and informs the evaluations that result in outcomes. The complexity of these interactions is such that automation using a computer-based exercise delivery tool is required.

2.3 MaestroEDE™ as an E3D tool

MaestroEDE™ was designed by Calian, to be used by us to deliver complex, multi-agency, high fidelity collective training, with or without sim. An E3D toolset is core to exercise success. All others, such as simulations, C2 systems, player effects and real-time conditions depend on the environment created through the E3D process.

3 Conclusion

Exercise conduct is a complicated business given today's training audience expectations and the need to replicate the complex environment within which they conduct operations. Training solutions using a disciplined E3D process driving the design, development and delivery is key to exercise success. A federated toolset (E3D, simulations, C2) overcome the "effects gap" between scenario development and effects delivered through simulation/C2 and other real-world interfaces like social media, is the solution. Our goal is to set an example through meaningful, high quality training and great people using great tools are fundamental to that goal.

For more information contact David Chupick at d.chupick@calian.com

Author/Speaker Biographies

Dave Chupick is the Senior Advisor for Emergency Management and Training with Calian Group Ltd. For several decades he led and managed a diverse range of teams to design, develop and deliver training events from professional development sessions to large complex international exercises for clients both military and civilian. Calian Group Ltd headquarters are in Ottawa, Ontario, Canada.

Military applications for machine learning

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Abstract

Recent advancements in Machine Learning (ML) have enabled many impressive civilian applications such as autonomous vehicles, machine translation, speech recognition, and agents capable of beating human experts at strategic games such as Go. Therefore, there is great potential for military applications of ML. This presentation focuses on two military applications: (a) military decision-support exemplarily applied for intelligent fire distribution of combat vehicles and (b) classification of military vehicles in images. The first goal is to examine the potential of Reinforcement Learning (RL) methods to improve decision support for the fire distribution of combat vehicles. The game engine Unity is used to simulate a combat scenario between two groups of tanks equipped with various weapons and protection systems. The Unity Machine Learning Agents Toolkit (ML-Agents) [1] provides the framework to implement different RL agents and to evaluate their performance. The second goal is to explore to what extent synthetic data can supplement and/or substitute human-annotated data to train Deep Neural Networks (DNN) for classification of military vehicles in images. DNN for Image Classification (IC) has already proved to be highly useful in industrial applications but require vast amounts of human-labelled images to be reliable. The military tactical shooter video game ArmA3 is used to generate synthetic training images of various military vehicles in diverse situations. The synthetic data is used to train DNN, and their performance is evaluated on real-world data. This work is based on a collaboration between the Army Concepts and Capabilities Development Centre, Airbus Defence and Space and the University of Central Florida.

1 Purpose & Introduction

The purpose of this extended abstract is to summarize to what extent selected military capabilities can be improved by using ML techniques such as RL and IC.

RL studies algorithms for training agents how to take actions in an environment to maximize some cumulative reward. In the present context, the environment is a simulated battle between two groups of tanks, the agent's actions involve selecting which weapons to use when against which opponents, and the reward signal is sparse and time-delayed indicating only at the end when the battle was lost or not.

IC was one of the earliest successes of deep learning, which enabled computers to solve hard vision problems for the first time. In this work, we start with on a state-of-theart DNN for IC and adapt it to recognize military vehicles using a method called transfer learning.

Both RL and IC algorithms require large amounts of data to achieve a high degree of accuracy. However, generating high-quality real-world hand-annotated labelled data for training tasks is difficult. For Modeling & Simulation for training applications, RL and IC must interact with its environment and most publicly available datasets are not sufficient for military applications. Therefore, we generate synthetic data digitally utilizing 3D game engines to power these algorithms by leveraging sophisticated simulation environments. The 3D engines produce photorealistic image data rapidly that can be used to train IC algorithms. Synthetic datasets can be more diverse than hand-labelled imagery since they can be easily generated in large numbers.

2 Intelligent fire distribution

The conduct of firefighting by combat vehicles requires a high degree of coordination from the military leader. The target assignment must be chosen intelligently so that enemy combat vehicles can be fought as quickly and efficiently as possible. In this research, we used RL methods to achieve a better fire distribution coordinated by a learning agent compared to a human-coded heuristic.

2.1 Unity simulation model

Unity is a cross-platform game engine released in June 2005 which can be used to create three-dimensional, twodimensional, virtual reality, and augmented reality games, as well as simulations and other experiences. The engine has been adopted by industries outside video gaming, such as film, automotive, architecture, engineering and construction and through ML-Agents also for ML projects, especially for RL.

Fig. 1 - Screenshot of the unity simulation model

Figure 1 depicts the tank combat scenario realized in Unity by Airbus with all required tank, motion, sensor, weapon and vulnerability models. The integration of ML-Agents with observation space, action space as well as the reward function for the fire distribution was developed, tested and improved in multiple experiments.

2.2 Reinforcement learning with ml-agents

Proximal Policy Optimization (PPO), provided by MLAgents was used to train the blue force agents for 135 hours, 12 times in parallel (practically 1620 hours) on an Intel I7-8750H processor. 1000 episodes were simulated with a heuristic controlling blue force and then 1000 episodes were simulated with the trained agent controlling the blue force. The trained agent performs significantly better than the heuristic, both in the mean reward and in the number of episodes won. The use of RL-methods to train agents for decision support tasks to control combat vehicles is advantageous within a simulation environment and promising for real-world military applications.

3 Image classification of military vehicles

A correct evaluation of visual impressions on the battlefield is indispensable for an agent to first gain a consistent assessment of the situation and to subsequently perform optimal actions. The automatic classification of military objects could assist it in evaluating the situation.

3.1. Creating a synthetic image dataset

Training DNN for IC of military vehicles requires a largenumber of training images. Gathering real training images is time-consuming and costly. Therefore, mostly synthetic training images were used in this research. The created dataset consists of 7 classes (Background, BMP-2, Buk-M1-2, Civilian Car, T-14, T-90, and ZSU-23-4) with 7000 training images per class. All training images besides the class “Civilian Car” [2] were created with ArmA3. Figure 2 shows a selection of training images. 105 real images (15 per class) were obtained from Wikimedia Commons and used as test images.

Fig. 2 - Sample of training images

3.2 Deep learning using transfer learning

The Python packages Keras 2.2.4 and Tensorflow-gpu 1.14.0 were used to fine-tune [3] the pretrained network NASNet [4]. Test accuracy of 91% was achieved after 519 minutes training on a Nvidia Geforce RTX 2060. Figure 3 shows a T-14 test image [5] with predicted labels.

Fig. 3 - Test image 72 with predicted labels

The results of this research have shown that synthetic data can be used to train DNN to identify military vehicles in real-world images.

4 Conclusions & Future Work

This research has demonstrated that ML techniques have the potential to greatly improve military capabilities. Unity combined with ML-Agents has proven useful for training agents to perform complex tasks by learning efficient strategies in a simulation environment. ArmA3 has made it possible to generate synthetic images for IC. In the future, we will investigate the generation of synthetic data for training robust DNN models for the more advanced tasks of Object Localization/Detection. We are confident that ML will decisively shape the future battlefield.

Acknowledgements

We would like to thank Lieutenant-Colonel Doll, who is pushing the topic of AI in the German Army and has enabled us to participate in this research.

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THEME 4: M&S Professional

Air Warfare Simulation for Command Staff Training

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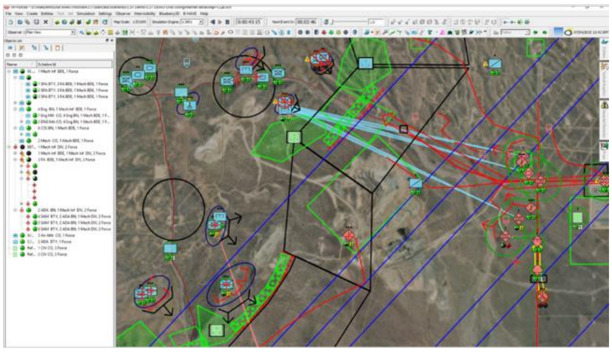
Abstract

Many Constructive Simulations used for Command Staff Training focus on the land domain and perhaps only provide air assets in a supporting role. VT MAK has recently added a complete Air Warfare capability to our VR-Forces simulation. This has been delivered to two Asian countries and has been integrated with their national C4I systems to provide a comprehensive Air Warfare training capability.

VR-Forces is a powerful computer-generated forces application that fills your synthetic environment with urban, battlefield, maritime, air, and space activity. VR-Forces is unique in that it provides both entity level and aggregate level simulations on whole world terrains. We believe that VR-Forces is the only SAF/CGF that can support both "true constructive" (i.e., aggregate-level) simulation and entity-level simulation (i.e., the constructive element in virtual training applications) within a single common engine and framework.

This paper will go into specific details on how VR-Forces has been enhanced to provide an aggregate-level Air Warfare capability.



1 VR-Forces Aggregate Level Simulation

VR-Forces supports a warfare model for aggregate-level scenarios. The aggregate warfare model uses HLA Evolved FOM extensions for distributed simulation communications.

The aggregate warfare model is data-driven. Simulation objects have combat power and combat vulnerability. Their overall state is expressed as their health. These are abstract values that represent relative strengths of different units. When opposing force simulation objects come into contact, they inflict damage on each other until one of the simulation objects is destroyed or breaks off combat. Some of the features that distinguish aggregate-level scenarios from entity-level scenarios include:

- Footprint. The area occupied by the unit.
- Posture. The unit's mode of interaction with the environment.
- Logistics. Management of personnel and matériel.
- Combat engineering objects. Tactical graphics that affect simulation object movement and health.
- Reports. Some data tracked in a simulation, such as personnel levels and pacing and tracking, is sent over the network to be used by command and control systems and human participants.

2 The Aggregate Air Combat Model

Air-to-air and air-to-ground engagements are executed using the munitions attack capability in the aggregate model - a single munition is fired at a time and a hit calculation is performed. The hit calculation uses the hit-factor of the shooter and compares it to the defense factor of the target to determine a probability of hit.

A random draw is done and compared to the probability of hit to determine if an actual hit takes place. If the hit occurs, then the attack power of the munition is applied to the target.

Aircraft units can represent one or more aircraft. Each aircraft has a primary equipment attribute, which is usually the airframe. Aircraft loadouts specify the equipment and weapons for the aircraft. The loadout for an aircraft unit can be set at runtime and determines how effective it is when it attacks another simulation object.

3 Air Engagements

The results of air-to-air engagements are determined by the following rules:

• Sensor capabilities. The sensor range and sensitivity, and the sensor signature of the target determine the maximum range for detection, and therefore the maximum range for engagement of a target.

• Weapon type. The weapon types on the aircraft determine the maximum engagement range when engaging with a weapon. The weapon type also determines the hit factor that affects the chance of a weapon hitting, and the total damage done if the weapon does hit.

• Tactical Data Link. If the aircraft unit is equipped with a Tactical Data Link combat system, the unit receives a bonus to its defense factor.

• Number of aircraft. Defending aircraft units receive a combat maneuvers bonus to their defense factor. Attacking aircraft have a smaller attack interval when the number of aircraft is larger, causing them to fire more missiles in a shorter period of time. This bonus is based on the current number of aircraft in the unit. It is reduced if some of the aircraft are destroyed during combat.

• Battle management support. If the attacking unit has active spot-report data on the target aircraft from other units in the scenario, it receives a hit factor bonus when engaging the target. A defending unit also receives a defense-factor bonus if it has active spot reports on the attacking entity.

4 Loadouts

Aircraft loadouts are defined in the Simulation Object Editor for each aircraft type. Each defined loadout specifies the quantity of weapons and equipment in the loadout. At scenario runtime, you can set the loadout for an aircraft unit and the unit will be equipped with the predefined loadout items. The weapons and equipment determine the effectiveness of the attacks a unit can make. Additional fuel tanks can increase the range of aircraft. Jammer pods increase defense against radar guided weapons.

5 Air Missions

Missions link together aircraft that will be launched as a flight. Air missions are carried out by aircraft units. A mission can be carried out by a single unit (which can represent multiple aircraft) or by multiple units. A multiple unit mission consists of multiple single units and a single "Mission Superior" object that is the superior of all the single units that are part of the mission.

The icons for air units have graphics that indicate the number of aircraft in the unit. Information dialog boxes also show the number of aircraft. If a unit suffers attrition, the number of graphics is reduced.

6 Fuel and Refueling

Air units use fuel based on their altitude and speed.

An aircraft unit can refuel other aircraft if it is configured with an aerial refueling system. The fueling system can be a flying boom type, a drogue-and-probe type, or a combination. The configuration cannot be changed during a simulation run.

The boom system specifies a maximum fuel transfer rate. It can also be configured to have drogue lines on it, with a different transfer rate for the drogues. Drogue systems define the number of drogues and the fuel flow rate for each fuel line.

Aircraft that are to receive fuel must be configured with an aerial refueling receiver system. The aerial refueling receiving system specifies whether the system is a boom or drogue system and what the maximum fuel transfer rate is.

Air units may only refuel from tankers that have compatible refueling equipment.

7 Air Bases

Air bases have a variety of resources that they can use to prepare, launch, and recover air missions.

An air base represents the following physical features:

• Apron. The aircraft that are assigned to an air base wait on the apron to be assigned to missions, prepared for launch, or sent to a hangar to be repaired.

- Hangar. When a damaged aircraft is actively undergoing repair, it is moved to a hangar

- Runway. Aircraft that are prepared for a mission taxi on the runway area for a few minutes before taking off.

- Operational Readiness Platform (ORP). The location at the end of a runway where aircraft on Quick Reaction Alert (QRA) are stationed.

Air bases have the following types of resources:

- Aircraft. Aircraft have the following attributes. An aircraft can be in one of the following states:

- Available. The aircraft is at 100% health and is available to be assigned to a mission.

- Assigned. The aircraft has been assigned to a mission. Some time before the mission launches, an assigned aircraft begins fueling and arming and its air crew gets ready.

- In Repair. The aircraft is in this state if its health is less than 100%. It can only be actively repaired (have its health improved) if it is in a hangar and has ground crew assigned to it.

- QRA. The aircraft has been assigned and prepared, and is waiting at the ORP.

- Air crews. Each aircraft must be manned by one air crew. An air crew can man any type of aircraft. Air crews can be available or assigned. Air crews are assigned (to missions) when the air base is tasked to launch aircraft.

- Ground crew personnel. Ground crew personnel are used to repair, fuel, and arm aircraft. They may be available, in a hangar repairing aircraft, on the apron fueling and arming aircraft.

- Fuel. A single type of fuel is used to fill all aircraft prior to launching them on a mission.

- Munitions. When an aircraft is assigned a mission and given a loadout, the quantity of munitions in the loadout is deducted from the base munition count.

- Runways. An air base can have one or more runways. Runways have a length and a heading. The length of a runway determines whether aircraft can land at the air base.

8 Air Base Activity

When an air base has pending missions, the Manage Air Base process handles the preparation of the aircraft as follows:

1. It estimates the preparation time and sets a time to begin preparation so that the flight can launch at the desired time.

2. When the preparation time arrives, the process assigns ground crew to the aircraft and computes the time at which fueling, arming, and preparing the air crew will complete. These tasks occur in parallel.

3. When all preparation tasks are complete, the ground crew is made available to the air base.

4. When all aircraft in the flight are ready, they taxi onto the runway.

5. An air unit is created and the aircraft counts in the air base are decremented to remove the flight from the air base.

When an air unit wants to land at an air base (Land at Air Base task), it sends a message to the air base requesting to land. It tells the air base the number of aircraft in the unit and how long the runway needs to be for it to land. If the air base has room for the aircraft and its runway is long enough, it tells that air unit that it can land. The air unit flies to the air base and then requests final permission to land.

When the air unit lands, the air base adds the aircraft to its list, and makes them either available or in-repair (if they are damaged). An air crew is added to the available air crews for each aircraft. Fuel and munitions are added to the air base's fuel and munition counts. The count of aircraft on the apron is incremented for each aircraft.

When an air base has damaged aircraft, it moves them into the hangar and assigns ground crew personnel to them. The process can only start this repair if there is space in the hangar and ground crew available. Aircraft in the hangar are repaired at a rate that is proportional to the number of ground crew assigned. When the aircraft is at 100% health, the ground crew are made available again, and the aircraft is moved back to the apron and becomes available.

When aircraft are assigned Quick Reaction Alert (QRA) status, they prepare to take off and taxi to the

Operational Readiness Platform (ORP), which is a set of parking spaces at the end of the runway. When events require it, one or more aircraft are ordered to take off and intercept a target. Aircraft and crews cannot remain prepared indefinitely, so after some time they must be returned to unprepared status at the base. You can specify a level of quick reaction capability. For example, some QRA aircraft might keep their engines running, while others are fueled and armed on the apron with the crew in a ready room. In general the faster the reaction capability, the less time the aircraft can be on QRA.

9 Sensors and Electronic Warfare

Simulation objects in aggregate-level scenarios have Sensor systems that allow them to detect other simulation objects in various domains (visual, radar etc). Sensor signatures indicate how detectable they are by other simulation objects in the applicable domains. Simulation objects do three checks – from the center of the outer ring of the footprint and from the edges of the circumference of the footprint.

The aggregate warfare model supports three types of electronic warfare – communications jamming, radar jamming, and sensing electronic emissions.

THEME 5: Medical

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

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.

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.

3 Basic Definitions

3.1 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.

3.2 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).

3.3 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.

3.4 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 I 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.

3.5 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.

3.6 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).

3.7 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.

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.

4.1 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.

4.2 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 I, 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.

4.3 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).

4.4 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).

4.5 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.

4.6 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.

4.7 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.

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.

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 Vigorous 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 and interpretation of data. All authors read and approved the final manuscript.

[Please refer to lead author to get the complete listing of authors - Ed.]

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The authors state they have no conflicts of interest. No outside funds or human subjects were used in the methodology or analysis of the drafting of this brief report.

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THEME 6: Decision Support Tools

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.

1 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).

2 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.

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.

3 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].

4 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.

4.1 The Competition

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.

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.

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.

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.

5 Conclusions

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).

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THEME 7: M&S Myriad

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.

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].

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.

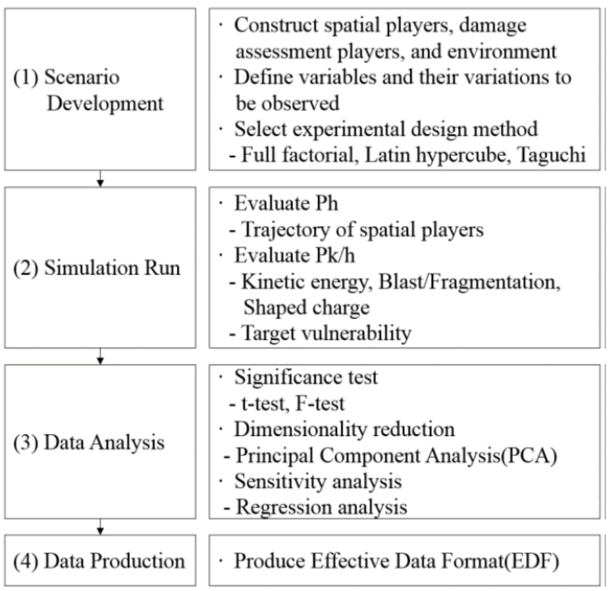

Fig. 1 - Weapon effectiveness analysis procedure

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.

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.

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.

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.

3 Discussion and Conclusions

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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