Outside-The-Box Approach to Modeling Persistent Chemical Hazards

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ABSTRACT

During the Unified Challenge (UC) 15 simulation experiment, we faced a requirement for a persistent chemical event to stimulate Commanders and Staffs at multiple echelons (Brigade-Corps). This was used to improve the representation of Maneuver Support equities. We found that none of the simulations available to the Community of Practice (CoP) had the ability to model persistent chemicals and effects within the Training and Doctrine Command (TRADOC) Battle Lab Collaborative Simulation Environment (BLCSE), and our current resource-constrained environment made development of a new simulation unfeasible. Therefore our team began looking at simulation software re-use to enable the CoP to modify current simulation software that would provide the required capability.

This paper describes the development process and the simulation design patterns used to provide lessons learned, which can be shared across the CoP, in order to enhance other simulation software re-use activities.

ABOUT THE AUTHORS

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James Richards is a Senior Simulation Engineer with CF Day LLC at the Maneuver Support Battle Lab (MSBL) Fort Leonard Wood, MO. He has a Master in Computer Resource and Information Management from Webster University, and a Bachelor of Science in Business Administration from Columbia College Missouri. He first joined the MSBL team in 1995, and currently provides simulation expertise for system architecture design; subject matter expertise with Linux OS, OneSAF, and integration of HLA Federations on the BLCSE to support Analysis using Modeling and Simulation for the Maneuver Support Center of Excellence (MSCoE).

John Schwartz has been a contractor at Fort Leonard Wood, MO since 2008. After graduating from Missouri State University in 2007 with a Bachelor of Science in Electronic Arts, he worked as an IT Technician and Server Administrator. He joined the Maneuver Support Battle Lab in 2013, where his computer simulations expertise is invaluable.

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BACKGROUND

The US Military utilizes models and simulations to conduct individual and collective training, pursue new capability development, and to conduct analysis across the Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel, Facilities and Policy (DOTMLPF-P) (CJCSI 3170.01I) spectrum. Although training has the largest demand for models and simulations, some of the more challenging analytical questions about concepts and capabilities also need to be answered. Unified Challenge (UC) is the U.S. Army's experimentation program that is run to explore what future military challenges will be and how best to shape the force to overcome them.

UC is led by the Army Training and Doctrine Command's (TRADOC) Army Capabilities Integration Center (ARCIC) Concept Development and Learning Directorate and is a continuing effort to examine the requirements needed to build an agile and adaptive future Army of 2030. ARCIC performs an annual UC event; for fiscal year 15 the UC Experiment was composed of three Army-level experiments: a seminar/war game, a simulation-based experiment and a game-based experiment. These experiments used a Defense Planning System compliant scenario to create realistic starting conditions reflecting the impacts of a reduced force structure within a global context and include joint and inter-organizational participation. These experiments provided an Army-level platform for all warfighting functions to execute Army core competencies, such as shape the security environment, set the theater, project national power, conduct combined arms maneuver, wide-area security, cyber operations and special operations.

To address some of the core competencies and address some of the latest questions regarding how to deal with chemical hazards on the battlefield, there is a need to simulate persistent chemical hazards within a distributed simulation event. The US Military has several high fidelity capabilities to simulate chemical hazards and their effects; however, these simulation capabilities are unable to federate into a distributed, force-on-force simulation event.

THE PROBLEM

During the UC 15 simulation experiment, we faced an experimentation requirement for a persistent chemical event to stimulate Commanders and Staffs at multiple echelons (Brigade-Corps). This was needed to improve the representation of Maneuver Support equities. We found that none of the simulations available to the CoP had the ability to model persistent chemicals and effects across the Training and Doctrine Command (TRADOC) Battle Lab Collaborative Simulation Environment (BLCSE), leaving us with a significant simulation capability gap.

THE APPROACH

Working in a resource constrained environment, development of a new simulation was not feasible. Therefore the Maneuver Support Battle Lab (MSBL), together with US Army Research, Development and Engineering Command *(*RDECOM*)*, Communications-Electronics Research, Development & Engineering Center (CERDEC), Night Vision Electronic Sensor Directorate (NVESD), Edgewood Chemical Biological Center (ECBC) and Joint and Army Modeling and Simulations Division (JAMSD), began looking at existing simulations (re-use) that could be modified in order to provide the required capability.

The chemical event was designed to model a persistent chemical hazard that would constrain friendly maneuver. Since the NVESD toolset simulates minefields and interacts with all of the simulations in the BLCSE federation, we decided it would be more cost effective and faster to create a chemical hazard area based on the existing capabilities provided by the Comprehensive Munition and Sensor Server (CMS2), which is part of the NVESD toolset. This would meet the requirement for modeling a persistent chemical hazard during the Unified Challenge simulation experiment.

The desired effect required that a proper chemical dispersion be calculated by ECBC. NVESD would then need to make the modifications to properly model it using CMS2. While initial testing was being done, MSBL worked with ECBC to determine the specifics for proper dispersion and toxicity levels needed by NVESD in order to create the desired effect.

MSBL coordinated with JAMSD to ensure that the effects of the chemical event would be properly distributed across the BLCSE federation. This involved programming and reconfiguring the Damage Effects Server (DES) so that it could manage the effects of the chemical on unprotected life forms. MSBL and NVESD, along with the CoP, collectively worked to ensure that all of the simulations communicated correctly across the BLCSE. This was a critical step and provided for proper detection and reporting of the chemical hazard. MSBL coordinated the development and implementation of the chemical model, then conducted validation testing prior to execution.

For the first time, MSBL was successful in modeling persistent chemical agents and effects across the BLCSE federation using the NVESD toolset. Entities could detect, report and be affected by chemical agents on the battlefield.

During the collaboration, the team identified three requirements. 1) Create a realistic dispersion laydown of the chemical hazard. 2) Simulate the chemical hazard and detection on the BLCSE using High Level Architecture (HLA) messages. 3) Use a Force-on-Force, entity based simulation (OneSAF) to represent entities with varying levels of chemical protection and the effects/damage to them from the chemical hazard. The BLCSE operational view diagram (Figure 1) shows the interactions between all of the systems in the BLCSE federation.

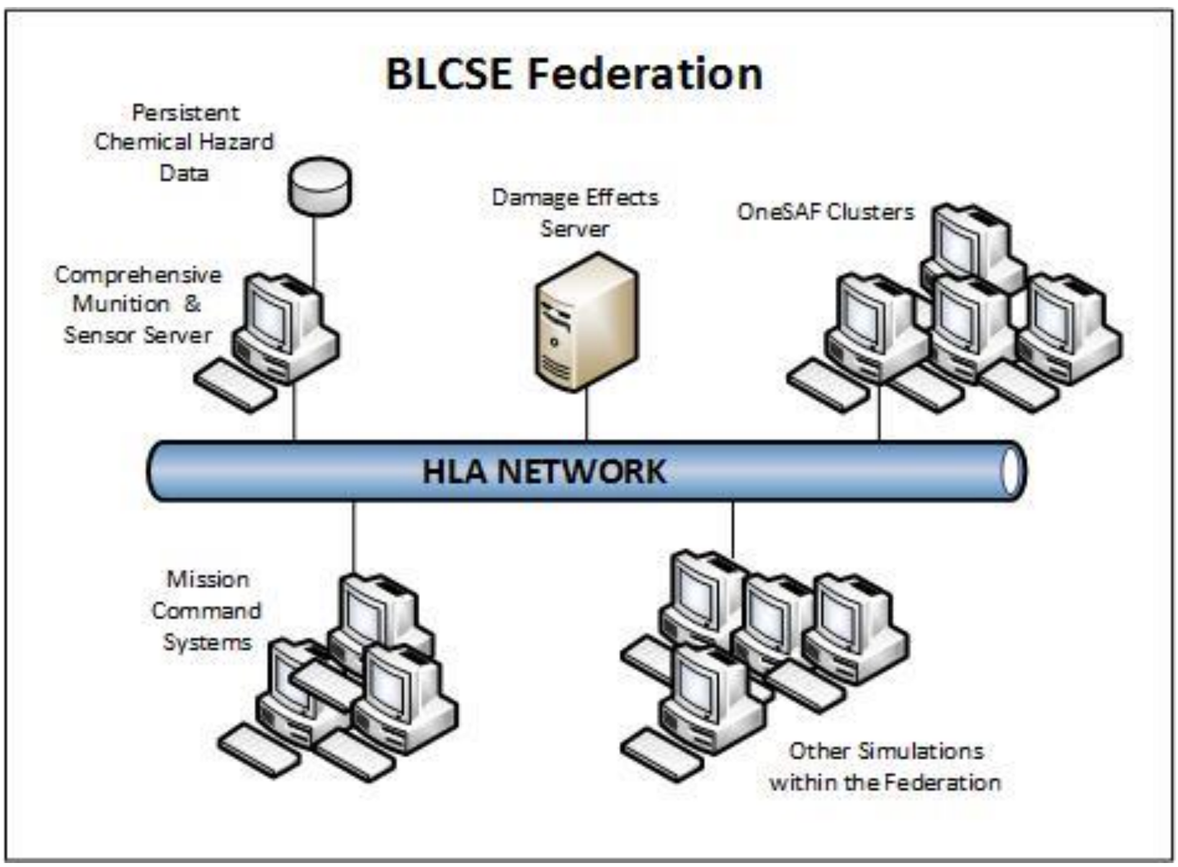

Figure 1. BLCSE Operational View Diagram

SIMULATION COMPONENTS

Comprehensive Mine and Sensor Server

CMS2 has been used for many years in the BLCSE federation to simulate mines, improvised explosive devices (IED), and unattended ground sensors (UGS). CMS2 simulates each of these systems at the individual (or component) level instead of the aggregate level typically seen in constructive simulations. Because of this and the fact that CMS2 publishes and listens to the entire BLCSE federation, it was able to be modified to simulate persistent chemical events for the UC15 simulation experiment.

Because there was neither time nor funding to add a completely new module to CMS2, we needed to figure out a way to model the chemical events and their effects within the existing CMS2 infrastructure. To accomplish this, we realized that the way we would simulate a stationary chemical event was quite similar to the way CMS2 modeled mines and sensors. A chemical field would have a single impact or center point. The chemicals would then dissipate or contaminate areas outward from that center point, with stronger concentrations in the center and lower concentrations at the outer edge of the "field". Unattended Ground Sensors within CMS2 are simulated in a similar fashion. The individual sensor is simulated at a specific location on the battlefield and detects vehicles and/or individual combatants, based on high probabilities near the sensor and low probabilities at the sensor's maximum ranges.

Using this principal, a new chemical event component was added to CMS2 based on the existing UGS module. The chemical event component used "detection" data provided by ECBC for both un-protected vehicles and life forms in place of the sensor detection range data.

During runtime, the CMS2 operator would simulate the chemical event by manually inserting it, using CMS2s GUI. Once the chemical event was simulated, CMS2 would publish the entity and associated field (hazard area) to the BLCSE federation. When an entity entered the "max-range" of the chemical event and the entity was unprotected, CMS2 would begin "rolling the dice" to determine if the entity was "detected" by the chemical event. If the entity was detected, CMS2 would send a message to the BLCSE Damage Effect Server to adjudicate damage to the entity. If the entity was not detected, the entity would continue in the game unharmed.

Detection Data

ECBC's role in this collaboration was to provide realistic data that would portray the hazard effects in an operationally correct manner. The liquid or ground contaminating portion (persistent hazard) of a chemical attack could be compared to a puddle on the ground. For this experiment, the MSBL was exclusively concerned with agents that were ground contaminating and provided a durable hazard for life forms or vehicles traversing the contaminated terrain.

A real world ground contaminating hazard would likely be a very irregular shape and would vary from instance to instance dependent on agent type, munition type, number of munitions, weather, and a host of other variables. In this experiment, we only needed to get the shape, duration, and operational impact correct enough to stimulate the commanders and staff. The type of release to model was arrived at via discussions with the MSBL. The weapon chosen was a small improvised device that could be replicated in the experiment as needed, in order to simulate larger or smaller overall hazards.

Once the meteorology (temperature, wind speed, atmospheric stability, etc.) had been agreed on, we used the Hazard Prediction and Assessment Capability (HPAC) version 5.2 to simulate the hazard. HPAC was developed by the Defense Threat Reduction Agency (DTRA) and uses the transport and dispersion (T&D) model Second-order Closure Integrated Puff (SCIPUFF) to predict the size, duration, and possible movement of the chemical hazard generated from the weapon functioning. For this experiment, the agent under investigation was primarily a ground-contaminating agent with little vapor hazard, although some limited evaporation will occur under the conditions investigated. Once the hazard T&D (in this instance, mostly ground contamination) was produced, ancillary codes predicted the impact on un-protected or protected life forms. To determine if a hazard was capable of being detected requires some off-line calculations but this can be aided by other optional output files from HPAC.

To provide input to the modified CMS2 algorithms, we used the isopleth outputs from HPAC to determine the extents of the hazard that would impact unprotected life forms at various levels of severity and reported these as the "effects radii" or "detection distances" needed by the CMS2 module. An example of such contour output is provided in figure 2. This specific example is for a nuclear dispersion event, but the concept and graphic/tabular output holds for chemical releases also. For this initial implementation of the method, hazards were assumed to consist of concentric radii (effect or detection) centered on the attack coordinates. At the largest radius, life forms may be mildly affected, at an intermediate radius they may be incapacitated but could recover with treatment, and at the smallest radius they would be potential fatalities if they were not in an adequate chemical protective state. These radii can be reported at various levels of risk such as 50% probability of incapacitation or 90% probability of lethality. For this implementation, the radii were set equal to the greatest downwind extent of the HPAC/SCIPFF contours for the effect of interest. Future enhancements of this method would include the ability to represent oval, oblong, or more sophisticated shapes for the hazards.

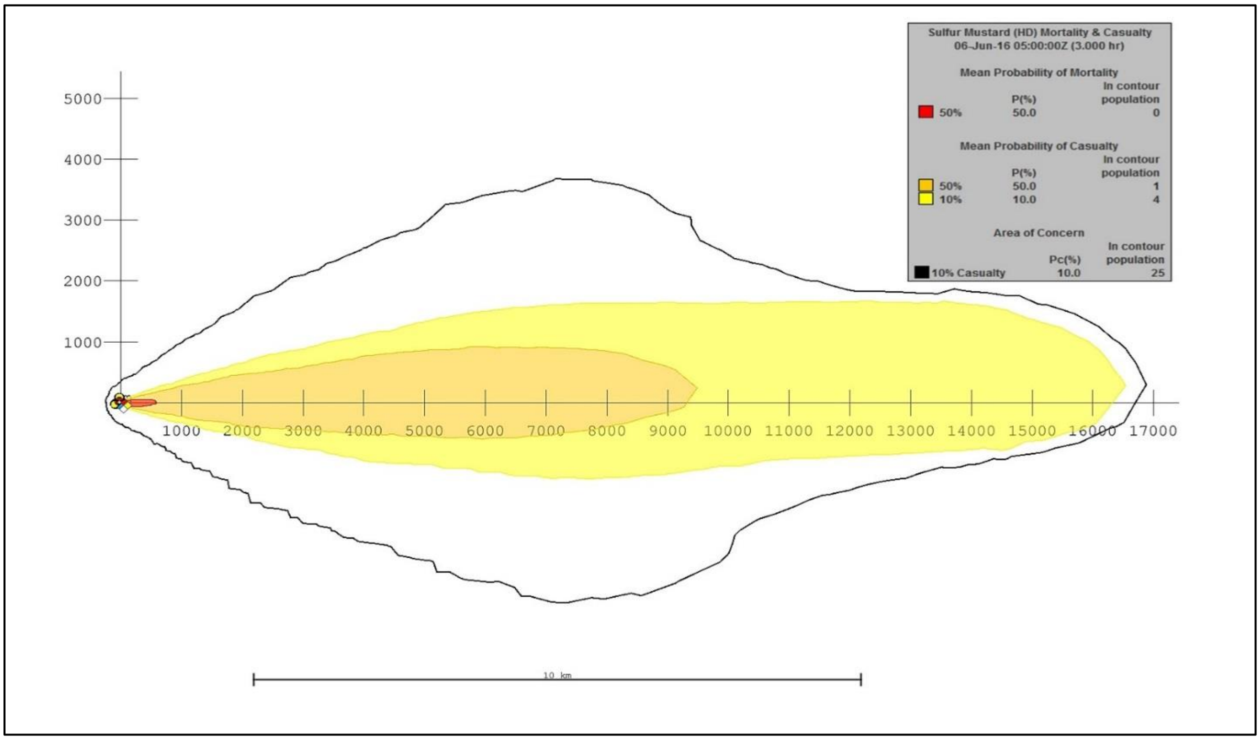

Figure 2. A Sample HPAC Contour Output

The same method was used to determine detectability radii, considering factors like: would a detector "see" liquid, vapor or both; what level of agent could be detected; how much liquid, vapor, or both were present at that point in space; and does the detector trigger on an instantaneous value of concentration/deposition density or does the sensor need to accumulate dose over time. The worst case would be an agent with substantial effects radii but little or non-existent detection radii. The actual agent portrayed and associated radii cannot be discussed in this forum.

OneSAF with Damage Effects Server

The experiment was designed around a division fight. This included a Chemical Company which supported the main force, providing Recon and Decontamination Assets within the battle space. MSBL utilizes OneSAF and CMS2 to simulate the persistent chemical hazard and effects with HLA messaging on the BLCSE. OneSAF is a next-generation, entity-level simulation that supports both computer generated forces and Semi-Automated Forces applications. OneSAF was built to represent the modular and future force and provides entities, units and behaviors across the full spectrum of military operations using the HLA standard. OneSAF has built-in behaviors for a simulated Individual Combatant (IC) to don MOPP gear. This process allows the simulation operator to review IC basic load and ensure each IC has a chemical suit; then the simulation operator can set the desired MOPP level from 0 to 4. Once the programmed time for donning MOPP is met, the IC is protected from exposure to and damage from the chemical hazard. During the experiment, vehicles that had an overpressure capability were configured to have overpressure activated at all times.

BLCSE uses the DES to propagate effects/damage to the OneSAF entities. Working with JAMSD developers, MSBL coordinated the changes/updates that were required to mimic the incapacitation effects to the unprotected ICs. To communicate the exposure of unprotected entities, CMS2 sent an HLA message containing entity status updates to the DES. CMS2 also maintained a configuration file with a list of all overpressure vehicles; this way effects on mounted ICs (vehicle passengers) would only occur in non-overpressure equipped vehicles. CMS2 also provided the sensor capability so entities with chemical detectors would be simulated. This allowed MSBL to represent the impact of Maneuver Enhancement Brigade chemical assets to protect the force.

THE OUTCOMES

Benefit to the Army Related to M&S

Commanders are still asking many hard questions: How does a commander deal with a chemical event on the battle field? Can we properly detect and report the chemical event? Do we wait or bypass? Do we assume risk by fighting while contaminated, and then conduct decontamination efforts when conditions allow? How do we adequately protect our soldiers while maximizing lethality and maintaining an aggressive operational tempo?

It has been years since the US Military has had to deal with chemical warfare; however, the threat of chemicals being used against US Military forces persists. It is our responsibility as modeling and simulation professionals to enable decision makers to answer those hard questions and protect the future force.

The success of the simulated chemical event in the UC 15 experiment demonstrated how M&S capabilities provided critical data for analysis and thusly provided answers to specific Protection Warfighting Function learning demands. It is our goal to enable capability development in order to better protect future soldiers on the battlefield. Further advancement of chemical modeling and effects using OneSAF and the NVESD Toolset will enable the community of practice to do so.

Where We Go From Here

We were successful in modeling a distributed persistent chemical hazard through re-use of existing simulations and with limited resources, but we cannot stop there. We are working to further mature the capability by increasing the fidelity of chemical effects on entities in the BLCSE simulation federation including enhancements within OneSAF itself. The more robust modeling effects would include varying levels of damage to ICs in various MOPP levels, as well as vehicles that do not have organic over pressure systems, to include crew and occupants. Besides addressing the effects from the hazard, the CoP is working on enhancing degradation effects for tasks like acquiring and engaging a target while in MOPP gear. There will still need to be some enhancements to the incapacitation levels of the ICs. These need to be modified to match the levels of incapacitation associated with toxicity levels from a CBRN exposure. It is our goal to develop a higher fidelity CBRN simulation capability which supports analysis as part of the BLCSE federation.

CONCLUSION

Department of Defense (DoD) has emerging CBRN simulations which could provide a very valuable capability to the study of chemical effects. However, these simulations generally lack the ability to be distributed across the BLCSE federation of simulations. This did not allow CBRN effects to be applied during a force-on-force simulation. In the past, this capability gap was mitigated through manual adjudication, which would then lead to disagreements amongst the participants regarding the application of the process. Developing this capability, although rudimentary, automated this process. This was a first for the CoP and a substantial improvement over the manual adjudication method.

Besides improving the adjudication process, another benefit to modeling the CBRN hazards was to provoke thought among the decision makers, commanders and their staffs. This was the first successful distributed force-on-force simulation experiment that had a chemical event which forced commanders to react in real time. With the simulation adjudicating the chemical casualties leadership was forced to make the hard decisions, weighing tempo verse casualties, and could no longer say the manually entered chemical effects were unrealistic.

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