A Chemical, Biological and Radiological Modelling Capability to Support Acquisition Advice and Re-use as a Common Cross-Domain Capability

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ABSTRACT: *The United Kingdom (UK) Defence Science and Technology Laboratory (Dstl) has developed a Chemical, Biological, and Radiological (CBR) Modelling and Simulation (M&S) capability titled the CBR Virtual Battlespace (CBR VB). The CBR VB is a modelling framework that includes a dispersion engine for simulating the transport of CBR materials within a synthetic natural environment. The synthetic environment drives a number of mathematical models to calculate the effects of the dispersion across the defence battlespace to produce measures of effectiveness such as casualties or sensor alarms.*

This paper details how the CBR VB is used to give advice to CBRN Defence equipment acquisition programmes through its capability to provide sensitivity analysis on certain parameters within CBRN vignettes. The capability has provided advice to the United Kingdom (UK) Ministry of Defence (MOD) for the procurement of individual protective clothing suits, body armour, medical countermeasures and sensor technologies. It has achieved this by providing performance analysis and cost/benefit analysis of various CBRN equipment options, and as such has played a key role in procurement decisions.

A key requirement of the CBR VB framework is to support a range of different use cases and questions to cover the CBRN domain. Therefore it needs to be as agile as possible to interoperate with different tactical, operational and strategic modelling systems to provide the necessary modelling capability. As such, this talk will also discuss how the system has been developed as a common CBRN M&S component that can be utilised as a modelling service by other systems, and how this has led to the development of CBRN simulation interoperability standards for use in distributed simulation in North Atlantic Treaty Organization (NATO). This has enabled the use of the CBR VB in other domains outside of Operational Analysis, such as training and experimentation where it can be used as the common CBR M&S component within various different systems.

1. Introduction and Background

Dstl is an agency of the UK Ministry of Defence (MOD) whose purpose is to ensure that innovative science and technology contribute to the defence and security of the UK. Among other roles, Dstl provides advice to MOD with regards to the effectiveness of future military equipment options to help MOD make informed procurement decisions. Dstl therefore undertakes this advice role to aid the procurement of future CBR defence equipment.

In order to inform the advice Dstl gives to the procurement of CBR defence equipment, Modelling and Simulation (M&S) is utilised to aid in the assessment of the effectiveness of various equipment options. This has resulted in the development of a synthetic environment modelling and simulation capability titled the CBR Virtual Battlespace (CBR VB).

In 2010, the UK MOD conducted a Strategic Defence and Security Review (SDSR). The SDSR identified that MOD should embrace a step change in its exploitation of modern simulation systems in order to increase operational effectiveness, reduce costs and minimise the MODs environmental footprint.

The SDSR recommended that MOD's future simulation technology and tools should be based on enterprise solutions to decrease diversity and maximise interoperability, collaboration and re-use. Policy was established to ensure simulation systems and tools were developed in line with these recommendations.

Many of the recommendations that came out of the SDSR were aimed to align the future acquisition of simulation technology more closely with the System of Systems Approach (SOSA) to capability acquisition [1] defined within the Acquisition Operational Framework (AOF).

SOSA is defined in the AOF as the "enabling way of working by which Defence will ensure that all delivered systems are procured and built". This is in accordance with the SOSA Vision to "enable enhanced capability through achieving commonality, reuse and the interoperability of independently procured systems".

In order to comply with this strategic policy there was a need to develop CBR M&S capabilities that could be re-used in this way at the Enterprise level. The CBR VB had become established as a successful simulation capability in the analysis and acquisition domains and therefore was used as the starting point for an Enterprise Approach to a CBR M&S capability. However, the CBR VB needed to be further developed to enable its exploitation in other M&S domains, such as Training and Education, Experimentation Test and Evaluation, Mission Rehearsal etc.

This paper discusses how Dstl has developed a CBR M&S capability to support Acquisition advice and how this has been further developed so that it can be reused to support CBR M&S use across different M&S domains, including:

- Undertaking Operational Analysis Studies;
- Providing CBR Equipment Acquisition Advice;
- Supporting Experimentation;
- Supporting CBR Training and Education;
- Developing a CBR Mission Rehearsal capability.

2. CBR Virtual Battlespace

The CBR VB is a modelling framework that allows the user to estimate the effects of introducing CBRN agents into a battlefield. The framework of the CBR VB is based upon representing individuals and equipment, such as chemical or biological detectors, as entities within a synthetic environment. A number of mathematical models have been developed within the CBR VB to simulate the effects of a CBR release on these entities.

The framework has been developed to allow different mathematical models to be plugged in and used as dictated by study requirements. To ensure the framework is as flexible as possible, the CBR VB has an open interface which allows models to be written in any language.

This modelling framework includes a dispersion engine for simulating the transportation of CBR materials. This dispersion engine enables a variety of different atmospheric dispersion models to be included within the CBR VB and therefore provides the user with a wide range of capability. These capabilities include:

- The ability to model atmospheric dispersion across either open terrain or within a confined urban environment;
- Defining a variety of source term models, depending on how the CBR material has been released;
- Modelling the interaction between the local terrain and the CBR release;
- The ability to utilise different meteorological inputs, such as real-world data or output from a Numerical Weather Prediction (NWP) model.

The following models are used within the CBR VB to calculate the effects of the dispersion on entities within the battlespace:

- CBR Casualty Model – this model uses toxicity data to predict the likelihood that an individual would become a casualty due to inhalational or percutaneous exposure to a CBR agent. The model provides output for different effects levels, and uses a protection factor due to wearing CBRN Individual Protective Equipment (IPE).
- Method for Evaluation of Total Heat Strain (METHS) model – this model estimates the level of physiological burden imposed on an individual resulting from different CBRN protective postures. The main output from the model is a prediction of how an individual's core temperature profile varies over time. This data is subsequently used to assess whether military personnel could encounter excessively high levels of heat stress whilst conducting missions in CBRN IPE. The model uses four different types of input data:
    - Clothing data – the amount of resistance which clothing imposes against the flow of heat and water vapour will affect how effectively an individual can regulate their core temperature. This clothing data is calculated using trials on thermal manikins;
    - Mission profile – defining the intensity of work being undertaken;
    - Meteorological data – defining the ambient temperature and relative humidity of the local environment;
    - Anthropometric data – defining the height, body type and aerobic fitness of the individual.
- CBR sensor model – different types of sensor models can be plugged into the CBR VB framework. Dstl are investigating a range of CBR sensor technologies within the current S&T research programmes, and therefore a number of different mathematical models for detectors have been developed. The commonality between these models is that they use the underlying mean concentration (and variance) of CBR agent

produced by a dispersion model to calculate the probability that the sensor will alarm. These probabilities can then be analysed to predict the probability that a network of CBR sensors will detect the release of a CBR agent.

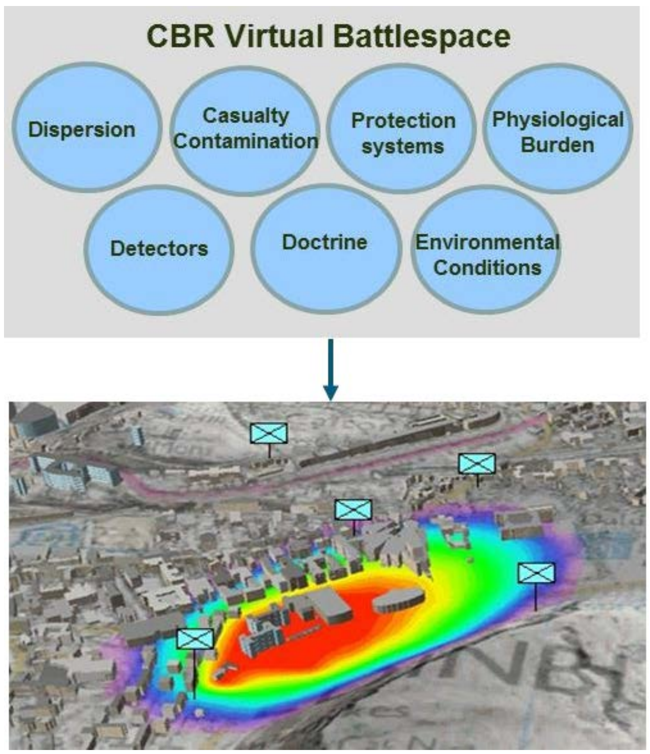

Figure 1: CBR Virtual Battlespace Overview

3. Operational Analysis Mode

The CBR VB is used to provide modelling output for Operational Analysis (OA) studies within Dstl's Science and Technology research programme.

When running the CBR VB for OA studies the CBR VB is initialised with static data, such as entity and detector locations. The source term for the CBR release is then generated at the start of the run and output is produced at variable time-steps as the CBR material is transported downwind.

To provide a robust experimental design on OA studies it is often necessary to investigate different permutations of inputs within the source term or model different meteorological conditions. In order to conduct these large numbers of CBR VB simulations, the CBR VB is written such that it can be run across different networks, as well as be run using Dstl's High Performance Computing capability.

The output from the CBR VB is used in conjunction with other M&S capabilities within Dstl to provide the following Measures of Effectiveness:

1. The proportion of military personnel able to adopt protective measures due to detectors alarming;
2. Proportion of casualties prevented by wearing CBRN IPE;
3. Proportion of casualties prevented by pre- and post-treatment medical countermeasures.

In the OA mode, the CBR VB aims to provide an element of uncertainty and risk in its modelling. This means the modelling is deliberately not representative of a particular instance in the real world. Specifically, the dispersion modelling of the CBR hazard is calculated as an Ensemble Average, which is a statistical representation of the release based on the mean average distribution within a number of states.

4. Use to support CBRN Equipment acquisition

4.1 Assessment of CBRN protection capability

One of Dstl's major functions is to support the UK MOD in capability management and planning across defence. The MOD conducts a regular assessment of its CBRN Protection capabilities across the Defence Lines of Development (DLODs) through a Capability Audit. The MODs uses the DLODs to classify the eight constituents of defence capability:

1. Training
2. Equipment
3. Personnel
4. Information
5. Doctrine and concepts
6. Organisation
7. Infrastructure
8. Logistics

The CBRN Protection capability is defined by the second level capabilities Sense, Knowledge Management, Hazard Management, Medical Countermeasures and Physical Protective Measures.

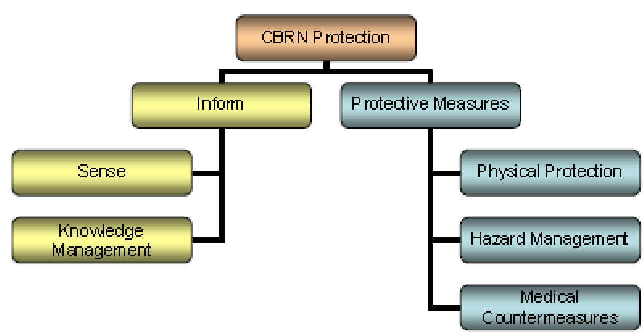

Figure 2: Overview of the CBRN Protection capability

Part of the evidence used to identify the priorities within the UK MOD's CBRN Protection capability is provided by the CBR VB in conjunction with other Dstl M&S capabilities.

4.2 CBRN protective clothing

The modelling capabilities within the CBR VB have been used to understand the trade-off between protection and physiological burden associated with an individual wearing CBRN IPE.

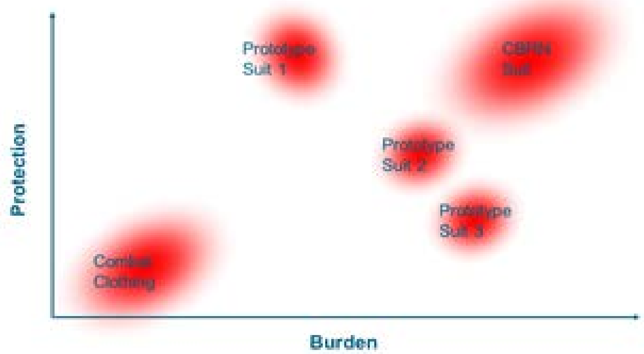

Figure 3: Trade-off between CBRN protection and physiological burden

An illustration of this trade-off is given in Figure 3, which shows the general trend that by increasing the level of protection of the suit the physiological burden increases. Model runs using the CBR VB have allowed the performance of prototype CBRN protective suits to be assessed in a range of different climatic conditions and activity profiles.

4.3 Medical countermeasures

The CBR VB has been used to provide evidence which supports both the development and procurement of medical countermeasures against CBRN agents. Previous CBR VB studies have investigated the quantity of medical countermeasures which would need to be deployed in certain scenarios to mitigate against different CBRN threat levels.

4.4 Future sensor technologies

The CBR VB has been used to produce a large dataset of biological and chemical dispersion, including different meteorology and source term parameters. This data included concentration time series at grid of sampler points, which were used to provide realistic challenge levels for sensor technologies. This data was subsequent used within the assessment of the UK MOD’s current sense capability and to evaluate novel technologies.

5. Development as a common CBR M&S component

The mode of use of the CBR VB for undertaking OA studies is very much as a discrete standalone system. In order to research if the modelling capability could be re-used as a common component across multiple M&S domains, the CBR VB needs to be developed to interoperate with a range of third party systems that are commonly used in these M&S domains.

The concept of use for this mode of the CBR VB is to utilise this discrete system as a common CBR modelling component within a third party system through a tightly coupled (if computing resources allow) or a distributed approach. In either approach the third party simulation is responsible for modelling of the more generic tactical or operational vignette (i.e. Force manoeuvre, Tactics Techniques and Procedures (TTPs), Pattern of Life etc.) and the CBR VB only models the CBR specific aspects of the vignette. The CBR VB is therefore used to provide enhanced modelling of CBR aspects of the Vignette, where the third party simulation system do not have CBR content or where its implementation is very simplistic.

In order to achieve interoperability with a range of different third party simulation systems it is important to specify a common Application Programming Interface (API) for the CBR VB to enable re-use as a common component. To inform development of this API, Dstl performed an assessment of common simulation interoperability protocols to see if any standards existed. This assessment identified that simulation interoperability standards for CBR M&S systems did not exist, or were not published in the international simulation community. Therefore Dstl developed their own approach and looked to the North Atlantic Treaty Organisation (NATO) M&S community to for help on standardising this approach

5.1 NATO M&S Group 096

Work conducted by NATO MSG 049 [2] (Modelling and Simulation System for Emergency Response Planning and Training) also highlighted that there was a lack of standards for interoperating CBR M&S systems using distributed simulation. Where interoperability mechanisms did exist, they were not aligned to NATO M&S guidance on use of standards.

Therefore Dstl submitted a proposal for a NATO M&S Group to overcome these identified capability gaps. As a result of this, NATO MSG 096 (Consequence/Incident Management for Coalition Operations) was initiated to research how generic simulation systems can be developed to support enhanced modelling of CBR scenarios. A key objective of this group was to provide recommendations on how generic simulation systems interoperate with specialised CBR simulation systems through common NATO standards.

A recommendation from MSG-096 was that no standalone CBR standards should be developed to support CBR M&S interoperability, instead the recommended M&S standards for NATO Computer Assisted Exercises (CAX) specified in Annex C of Allied Modelling and Simulation Publication 03 (AMSP-03) [3] should be updated to provide specific CBR content.

Notably, recommendations were made for the use of the following standards for CBR M&S Interoperability:

- The Institute of Electrical and Electronics Engineers (IEEE) 1516-2010 version of the High Level Architecture (HLA) standard is identified in AMSP-03 as the recommended standard to be used for interoperability between models and simulations in NATO/Multinational exercises. However, a CBR Information Exchange Data Model did not currently exist within the standard. Therefore, it was recommended that a CBR Federate Object Model (FOM) was developed and integrated within the NATO Education and Training Network (NETN) FOM as the recommended Information Exchange Data-Model.
- The IEEE 1278 Distributed Interactive Simulation (DIS) standard was identified as an alternative approach but likewise does not have any CBR capability and would need to be extended to include a CBR DIS enumeration set within a CBR Protocol Data Unit (PDU).

Following these recommendations, a CBR Task Team was initiated within NATO MSG-106 to follow up on the recommendations of NATO MSG-096.

5.2 CBR FOM Module

A CBR FOM module was developed by Dstl and Riskaware Ltd. to allow CBR modelling information to be exchanged within HLA federations [4]. This built upon previous work undertaken by Dstl and QinetiQ to develop an Atmospheric Dispersion Base Object Model (BOM) [5]. The CBR FOM Module covers a description of the initial CBR event through to the effects of that CBR event. The CBR FOM module can be broken down into the following sections:

- **Source release modelling:** Enables the transfer of information regarding a CBR release i.e. the source term parameters for an instantaneous chemical release (such as the mass and release location).
- **Detector modelling:** Enables the transfer of information required to perform detector modelling and the outputs from a detector model i.e. the CBR materials that a detector can detect or a detector's alarm state.
- **Effects modelling:** Enables the transfer of information that is output from a CBR effects model i.e. the exposure data for a human or contamination status of a platform.
- **Protective measure modelling:** enables the transfer of information required to perform the modelling of protective measures as well as the output of the models i.e. individual and collective protective posture and protection factors.
- **Hazard area information:** enables the transfer of contour information for a CBR release i.e. the contours of the concentration, deposition and dosage of a CBR release as calculated by a dispersion model.

This information is summarised as the information that is imported in to a CBR M&S simulation federate so that it can perform dispersion modelling of the release, and the resulting information that can be extracted from this dispersion modelling. This is summarised in Figure 4.

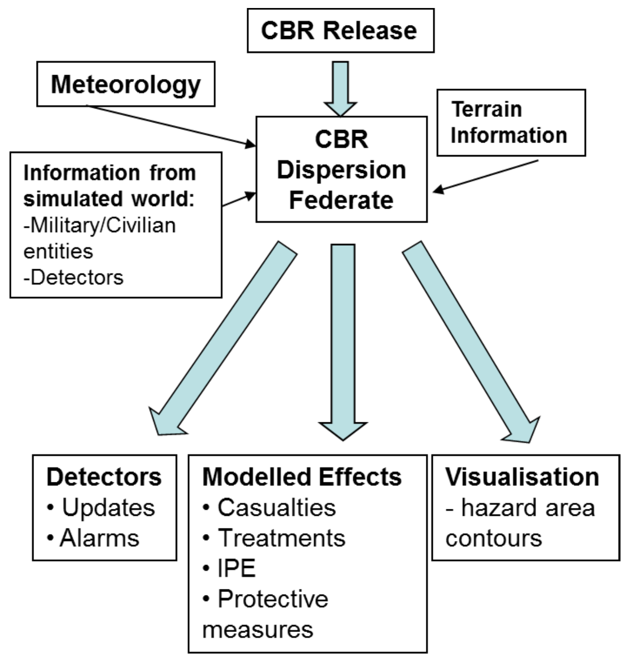

Figure 4: CBR FOM Module overview.

5.3 Incorporation into NMSG-106 NETN FOM

NATO MSG-106 (Enhanced CAX Architecture, Design and Methodology) was established to: provide recommendations for the Governance of NATO CAX; provide guidelines for Exercise Controllers and Simulation Controllers; and develop a reference federation architecture and implementation for use in NATO distributed simulation.

The reference architecture built upon work conducted in NATO MSG-068 to develop an IEEE HLA 1516-2010 FOM for use in NATO Education and Training Networks (NETN) (termed the NETN FOM). This work built upon the Real-time Platform Reference (RPR) FOM to exploit the new capabilities introduced HLA-Evolved, mainly the use of FOM modules. The NETN FOM was developed by first breaking down the RPR FOM into FOM modules; the NETN FOM then extended these modules to add new functionality.

NATO MSG-106 took the NETN FOM developed by NMSG-068 and developed Version 2 (V2) of the NETN FOM. V2 further extended the capability of the NETN FOM by adding new FOM modules.

The CBR FOM module developed by Dstl and Riskaware Ltd. was peer reviewed by the nations participating in the group and also incorporated into the NETN FOM. The NETN FOM dependencies of the CBR FOM Module are shown below in Figure 5.

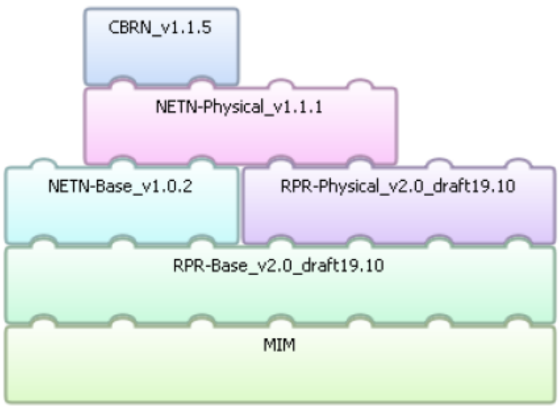

Figure 5: CBR FOM Module dependencies within the NETN FOM.

6. Use to support Experimentation

To support the onwards acceptance and exploitation of the NETN FOM by partner nations, a verification experiment was undertaken to integrate the full set of developments undertaken through MSG-106 and to exercise them within a representative operational context (scenario) [6]. Its purpose was to prove that the developments not only worked in isolation, but as a coherent whole, thereby raising the technology readiness level of the group's output.

A scenario based on a CBR incident was implemented in order to exercise the technical developments, and was split into the following five mission phases:

- Initiation;
- Ingress & Rendezvous;
- CBR Event & Dispersion;
- Blue Forces at Risk;
- Embarkation and Egress.

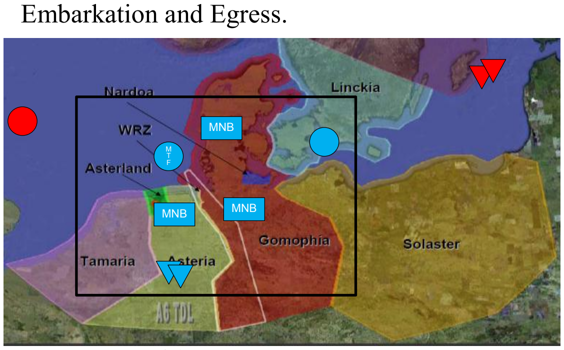

Figure 6: Overview of the NETN FOM Experiment Scenario.

Operational simulation systems were used to exercise the developments, including:

- **OneSAF**: The One Semi Automated Forces (OneSAF) system is an entity level Computer Generated Forces (CGF) system developed by the United States (US) Army Program Executive Office for Simulation Training and Instrumentation (PEO-STRI).
- **SWORD** [7] is a Land constructive simulation developed by the MASA Group and designed for command post training (at division or brigade level). Units in SWORD are aggregated at company or section levels and include a doctrine compliant intelligent automation.
- **Pitch Actors** is a CGF system mainly used in testing as a federate to stimulate other federates and for demonstration purposes.
- **Virtual Battlespace 2 (VBS2)** is a virtual reality battlefield simulation system developed by Bohemia Interactive [8].
- **CBR VB** is a CBR M&S federate developed by Dstl.

The following architecture was represented in the experiment:

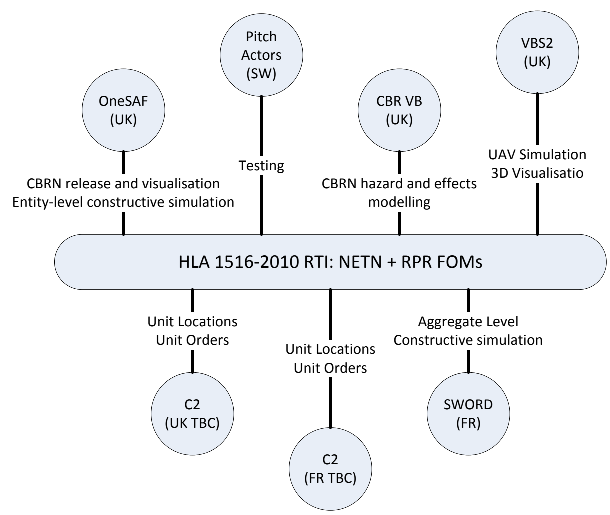

Figure 7: MSG-106 Experimentation Federation architecture and federate responsibilities

The CBR VB was used as the common CBR M&S component as part of the development of the experimental federation. As part of this experiment a number of distributed and face to face tests were performed to verify and validate the design of the CBR FOM module and other FOM modules within the federation. The tests performed focused on verifying the exchange of CBR release, CBR effects and CBR contour information between the systems. Later tests investigated how the benefits of the HLA 1516-2010 standard and the NETN FOM could be demonstrated through CBR use cases. These use cases included the use of the following capabilities:

- Transfer of Modelling Responsibility (TMR) was used to enable the CBR VB to take ownership of the CBR attributes of entities owned by the other systems. This allows the other systems which cannot model CBR to hand over the CBR modelling aspects of the federation to the CBR VB which is specialised in CBR modelling.

- Multi-Resolution Modelling (MRM) was used to allow CBR modelling effects to be calculated on an aggregated unit. In this case the CBR VB disaggregates a unit when it reaches a CBR hazard and performs the CBR modelling for the individual entities. Once the unit has cleared the hazard the CBR VB will aggregate the unit back to its original state to pass back to the owning system with the CBR effects included.

The experiment concluded in October 2014. Following analysis of outputs it is expected that some minor updates to the NETN FOM Version 2 may be required and that an evidence base will be captured to support nations' acceptance requirements of the NETN developments. The CBR VB played a key role in enabling the team to verify and validate the CBR aspects of the NETN FOM.

7. Development to Support Training and Education

Following the SDSR described in Section 1, the Defence Training and Education Capability (DTEC) Operating Model was established in 2013 to provide governance to deliver Defence Training and Education. DTEC has a vision to deliver Training and Education through simulation technology and tools using:

- Conformance to agreed standards;
- Commonality and re-use of data models and platforms;
- Consistent enduring accessible agile and adaptable solutions;
- Value for money at the Enterprise level.

One of the concepts of DTEC is to have a Catalogue of common simulation products and services that can be re-used across Defence to support Training and Education.

The catalogue will contain common tools and technologies that enable delivery of Live, Virtual, and Constructive (LVC) simulations to support Training and Education:

- Live Simulation: Real people in real locations, using real equipment with simulated effects.
- Virtual Simulation: Real people in a simulated environment, using simulated equipment.
- Constructive Simulation: Simulated people in simulated environment, using simulated equipment.

CGF systems are computer applications that provide the Constructive simulation in training environments. They are synthetic environments to create a representation of the battlespace and the natural environment. This environment has the ability to model simulated military and non-military entities (e.g. simulated humans and vehicles), weapon systems and their effects, sensors, and behaviours (military and non-military).

CBR content of many CGF systems is either non-existent or very limited. Therefore the CBR VB was developed as a common CBR M&S component that could be re-used within the DTEC catalogue to provide CBR M&S within CGF systems.

The CBR VB has been linked to the OneSAF CGF system to demonstrate how the CBR VB could be re-used to provide a constructive simulation training capability.

7.1 OneSAF

The MOD has funded development of a HLA 1516-2010 interface for OneSAF and integration of this capability to the CBR VB to enhance the modelling of CBR vignettes.

Figure 8 below shows the information flow between OneSAF and the Common CBR M&S Component when interoperated together, which is similar for when the CBR VB is linked to different CGF LVC simulation systems.

- The LVC system provides the Common CBR M&S Component with scenario information such as an entity location, a detector location, or the location and source term information of a CBR release.
- Once the Common CBR M&S Component is informed of a CBR release it starts to model the effects of the release through its modelling framework.
- The Common CBR M&S component then sends the outputs of the modelling back to the LVC system. All of the CBR effects would be displayed within the host LVC system.
- In this mode of operation the CBR VB is sitting in the background performing its modelling and would not be seen by the user. This allows the CBR effects to be fully integrated into the LVC system without the operator needing to have knowledge of how to operate the Common CBR M&S Component.

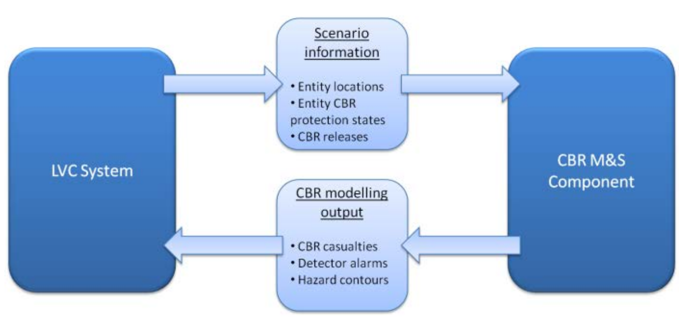

Figure 8: Example CBR M&S Federation Information Exchanges

The project has also developed a CBR extension of

OneSAF that contains a set of CBR behaviours that represent CBR Doctrine and Tactics, TTPs i.e. Masking up procedures for a soldier in the event of receiving an order.

The OneSAF Graphical User Interface has also been updated so that it is able to visualise the outputs from the common CBR M&S component i.e. Hazard contours, effects to lifeforms and platform entities.

8. Development to support CBR Command and Control Training and Mission Rehearsal

In the UK MOD CBR Command and Control (C2) systems are used to provide Situational Awareness and decision support in the event of a CBR event. The current in service CBRN C2 system is the CBRN Battlefield Information System Application (BISA). CBRN BISA provides CBRN Warning and Reporting and Situational Awareness through incorporation of Bruhn Newtech's CBRN Analysis system as part of the procured solution.

CBRN Analysis implements NATO CBRN doctrine detailed within Allied Tactical Publication 45 (ATP-45) for CBRN Warning and Reporting Procedures [9]. ATP-45 defines a set of data that can be captured in the event of a CBRN incident as a result of reported observations or from a CBRN detector alarming. This information can then be used alongside meteorological information to provide a prediction of the CBRN hazard posed. This can subsequently be used to make Command decisions as a result of that hazard i.e. Warn Unit, Mask Up, Move to a location / decontamination area.

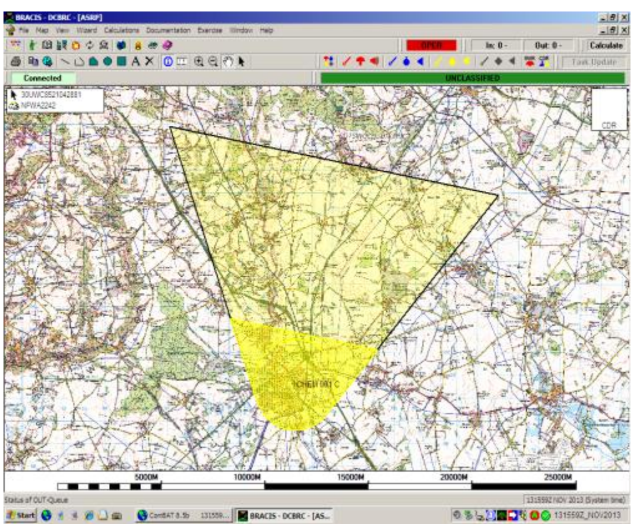

Figure 9: CBRN Analysis plotting an ATP45 Hazard Warning area

Interoperability of CBRN simulation systems and CBRN C2 systems can enable support to CBRN C2 operator training and can stimulate training of Commanding Officers decision making process in response to a CBRN incident by allowing them to see the consequences of decisions made.

The CBR VB has been developed to provide stimulation of CBRN Analysis through synthetically generating the information it requires to drive the system. This focuses on stimulating CBRN Analysis with synthetically generated Adat-P3 messages that are detailed within the ATP-45 doctrine. CBRN Analysis can then use this information to calculate CBRN Hazard Warning Areas and issue orders to affected units. These orders can then be issued to a constructive simulation to model (not implemented at the time of writing). The status of the unit in terms of health would then be calculated by the constructive simulation and communicated back to CBRN Analysis.

An example of the information exchange requirements between a CBRN C2 system and CBRN simulation system are detailed in Figure 10:

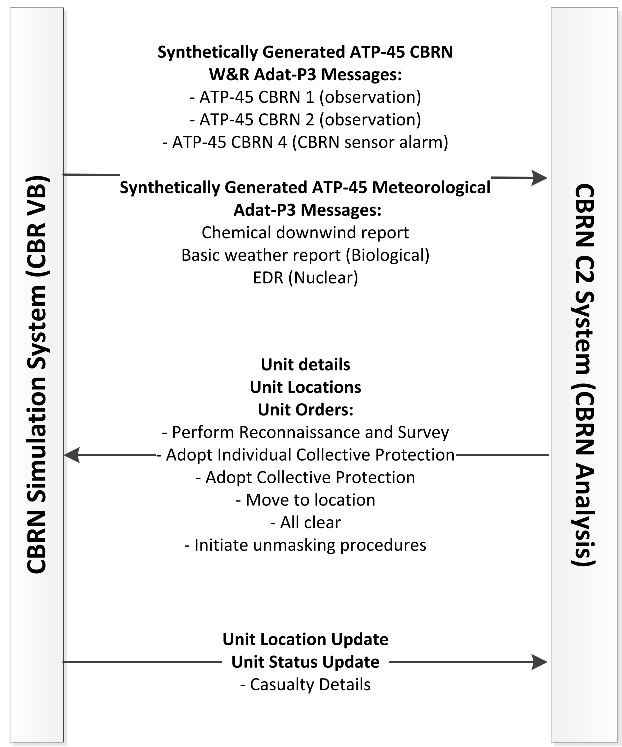

Figure 10: Example CBRN C2 System and CBRN Simulation System Information Exchange Requirements

9. Summary and Observations

Dstl have developed a CBR Synthetic Environment, the CBR VB, that can be used for the M&S of CBR incidents in the Defence Battlespace.

The CBR VB can be used to provide advice to the UK MOD acquisition community with regard to the procurement of future CBR Equipment options. This paper has demonstrated its use in this capacity to provide high-level analysis, such as providing evidence for the regular audits of the UK MODs CBRN Protection capability. This is in addition to the CBR VB providing specific evidence on CBRN equipment acquisition programmes such as CBR

IPE, medical countermeasures and future sense technologies.

The utility of the CBR VB as an enterprise approach to CBR M&S has been demonstrated and it has been developed to support use outside of the Acquisition and Analysis M&S domains.

To enable this enterprise use, a common API for interoperating the CBR VB with third party simulation systems has been developed. This has been developed as a CBR FOM Module within the HLA 1516-2010 simulation interoperability standard and incorporated in the NETN FOM to support Training and Experimentation use.

The CBR VB has demonstrated how it can be used in this manner to support Training and Experimentation through interoperating it with the OneSAF, SWORD, and VBS2 simulation systems.

The CBR VB has also been partially developed to interoperate with CBRN C2 systems to demonstrate its utility as a simulated CBRN C2 operator training and Mission Rehearsal capability.

Observations from the use of the CBR VB as an enterprise approach to CBR M&S are discussed below:

- The key drivers for the Operational Analysis mode are the ability to provide multiple replications of runs. These multiple runs are used to generate measures of effectiveness to support studies trying to answer specific questions. This requires the modelling to be able to be run deterministically and as fast as possible.
- In Operational Analysis mode the CBR VB aims to provide an element of uncertainty and risk in its modelling. This means the modelling is deliberately not representative of a particular instance in the real world. Specifically, the dispersion modelling of the hazard is calculated as an Ensemble Average, which is a statistical representation of the release based on the mean average distribution within a number of states.
- The key drivers for the Training and Experimentation mode are the ability to run in real time and generate CBR effects that can be used to stimulate a training response/effect or generate a verification/validation test effect.
- For Training and Experimentation the CBR VB needs to be synchronously interoperated with heterogeneous third party simulation systems and run in a real time war gaming mode. In this mode it is desirable to have the CBR VB running in the background and controlled by the host simulation (so as to not add management/operator overhead).
- The modelling in the Training and Experimentation mode only needs to be fit for purpose to generate the intended training/test effect. However a cautionary note exists here that the ensemble average modelling mode is not suited as it may give an impression of a specific scenario that is not realistic due to the nature of the modelling. This may result in negative training or an incorrect series of events occurring in a given timeline. In the Training and Experimentation mode the dispersion should be run in non-ensemble average mode or some sort of concentration realisation modelling should be used alongside the Ensemble Average modelling. This will help to ensure that the dispersion output for display and generation of effects such as sensor alarms is more realistic and fit for purpose.

In summary, this work has demonstrated the re-use of CBR models from the Acquisition and Analysis M&S domains within the Training and Experimentation domains. This re-use provides cost effectiveness but the modelling fidelity and Synthetic Environment architecture requirements employed in the acquisition and advice domains are different to those in the Training and Experimentation domains. Careful consideration needs to be given to the intended use of the models to ensure that they are fit for purpose to meet the intended requirement. In this instance some model changes were required; however the re-use of the models was achievable. It has also been demonstrated that the CBR VB also can operate as a Synthetic Environment architecture for a multi-replication analysis mode or as a real time war gaming mode.

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