# Modelling & Simulation in support of a comprehensive CBRN Layer development

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## ABSTRACT

Modelling & Simulation in support of CBRN and Environmental Protection has not been fully exploited to its maximum potential in the military domain; namely, Education and Training (Exercises), Support to Operations, Planning (Course of Action Analysis), Execution (Decision Support), Mission Rehearsal, Concept Development & Experimentation (CD&E) and Procurement. Many CBRN tools already exist, such as those providing models to simulate the dispersion of CBRN Agents, or the wearing of IPE during training. However, a comprehensive list of these types of tools, fully integrated to maximize its effectiveness, is still missing.

This innovative approach, which integrates existing tools and provides those not yet developed, represents a powerful M&S asset to fill the gap of this military problem. The purpose of this project was to develop and test, in a synthetic environment, a CBRN layer integrating the available tools, such as CBRN Analysis or Computer Generated Force Tools, to maximize their capabilities and to perform missing CBRN related activities. For example, to determine the effects of chemical compounds on military units or developing a plug-in software to integrate the existing database and perform specific computations.

The CBRN layer will be developed using the SWORD simulation software developed by MASA Company and the CBRN Analysis developed by BRUHN NEWTECH Company. The scenario will be built to simulate a synthetic CBRN environment with contamination and diffusion data. CBRN Analysis will provide this data and the military assets will be created by SWORD with the final objective of giving the Commander a comprehensive visualization of the CBRN framework in the battlefield.

Keywords: CBRN layer, M&S, Integration, Comprehensive Approach.

## ABOUT THE AUTHORS

**Author1**: **LTC (ITA – OF4) Piergiorgio Ventura** graduated in physics in 1998 with a specialization in Nuclear Physics. He then joined the Italian Army in 1999 with the rank of Lieutenant and began working within experimental firing ranges where missiles, weapon systems and ammunition were tested. After taking a PhD in quantum electronics and plasma physics in 2010, during which a remote sensing detection system to detect and identify chemical compounds, based on optical detection, was developed, he started working in the CBRN field for research, testing and procurement activities. Since January 2022, he has been assigned to the M&S COE as the M&S Concept Development Section Chief, where he is trying to develop new concepts based on his expertise.

**Author2**: **CPT (ITA – OF2) Salvatore De Mattia** is an electronic engineer of the Italian Army, with specialization in radio frequency circuits. He is currently working at the NATO M&S COE since October 2020, in the Concept and Experimentation Branch. In his first position, he was in charge of the Electronic Warfare (EW) sector, where he is mainly involved in the jammer systems configuration, for the protection against the RCIED (Radio-Controlled Improvised Explosive Device) threat. During this period, he worked both in Italy and abroad in various Operational Theaters in Afghanistan, Somalia, Lebanon (UNIFIL) and Iraq. He is currently working as Subject Matter Expert on projects concerning the use of Modelling & Simulation for EMSO (Electromagnetic Spectrum Operations) and CBRN.

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## 1. INTRODUCTION

CBRN Military readiness is critical to both the NATO and the Partnership for Peace (PfP) countries. For this reason, several working groups (WG) within the NATO community have developed numerous documents (STANAG, STANREC, Standard Related Document, etc..) which try to fulfill needs concerning Detection, Identification and Monitoring of CBRN threats, Protection, Hazard Management, Training and Education, CBRN Doctrine and Terminology. In addition, environmental protection is increasingly becoming an important activity to be taken into account during NATO led activities, especially during "non art. 5" operations. Also for this field, some WGs have developed the relative doctrine. In other words, CBRN and environment related military activities have been exploited quite deeply covering the full DOTMLPFI approach.
Nevertheless, CBRN and Environmental M&S have not been fully exploited within its potential in the military domain, namely, Education and Training (Exercise), Support to Operations, Planning (Course of Action Analysis), Execution (Decision Support), Mission Rehearsal, Concept Development & Experimentation (CD&E) and Procurement. Many tools do exist, such as models to simulate the dispersion of CBRN Agents, or the wearing of Individual Protective Equipment (IPE) during training and many others. However, there is not a full integration of these tools, and many are still missing. A comprehensive approach, which integrates all existing tools, including any that are missing, could be a powerful way to cover this important gap. A description of what can be included in this future CBRN layer, starting from the existing M&S tools (GAP analysis) is provided in this paper, including a road map to achieve it.

## 2. WHAT COULD BE PROVIDED BY A CBRN LAYER (NICE TO HAVE)

A brief description of the new integrated approach is described as follows.
A CBRN and Environmental specific layer is added to the virtual reality, so that in the case of a CBRN release or environmental problem, whatever the type and origin, can be properly modelled and thus simulated, considering the effect of the others layer (e.g., detailed weather conditions). The effect of this layer is then used for:

- Education and Training (Exercise): the ability to give orders properly (and timely) to don or undon Individual Protective Equipment (IPE) and/or activate Collective Protection Equipment can be exploited. If you do not give the order to don, you lose personnel and capabilities, but on the other hand, if you are too cautious your ability to operate is reduced (simulation should include degradation as provided by STANAG at ref. [2]) resulting in lost personnel and capabilities for other reasons on the battlefield. CBRN personnel can be trained so that they have to decide how to operate to evaluate and mitigate risks (where to send sampling teams, where to organize decontamination activities, etc.). Many advanced tools can be built (e.g. considering the efficiency of the filtering systems depending on the concentration of chemical compounds over time, the filtering saturation expected, and the route employed by the vehicles or personnel, etc.).
- Support to Operations: The CBRN and environmental layer can be used the same way to make real decisions, so that in case of a real CBRN release the dispersion model and consequent simulation can be used to decide which troops should don IPE or not. This would take into account their degradation in terms of operability, need to change routes depending on the concentration of the CBRN threat, to verify the performance of the protection system (e.g. filter residual protection after exposure to a concentration as a function of time) and many other operative decisions. The environmental side of the simulation can be used to calculate the environmental problems arising during operations to take the proper decision to mitigate the effects.
- Planning (Course of Action Analysis): In the same way, several different scenarios can be employed to properly address the decision making process for CBRN experts and decision makers in general.
- Mission Rehearsal: wherever and whenever a risk of a real use of a CBRN agent or the risk of a CBRN release is involved (e.g., an action where a chemical plant or depot is hit or destroyed), proper mission rehearsals should include actions to take to mitigate the CBRN risk.
- Concept Development & Experimentation (CD&E): new capabilities in the CBRN field should be analysed with all CD&E M&S tools (Visualization, Conceptual Modelling, Simulation-based

Experimentation, Analysis) in order to test disrupting technologies in this field (e.g. remote sensing, use of UAV integrated detection systems, widespread mini-detectors, etc..) or new doctrine (e.g. Multi Element Recce Team).
- Procurement: the capability of a new CBRN system (Protection, Decontamination, Detection, etc.) can be exploited with this approach, simulating its real use in a contaminated environment.

In particular, the requirements are as follow:
- develop the capability to calculate, properly and realistically, the behaviour of a CBRN agent in the environment in order to replicate it in a synthetic environment;
- federate the tool used to generate the CBRN agent dispersion, generally called an expert system, with a Computer Generated Forces (CGF) System able to replicate military behaviour. This integration will allow the visualisation of the CBRN Agent specific effects on the battlefield in real time.
- Make the simulation as much realistic as possible by using the above mentioned CBRN effects obtained with our M&S tools and combine them with the aspects already determined for civilian applications perfectly described in the document "Modeling and Simulation of Hazardous Material Releases for Homeland Security Applications " (ref. [1]).

Other aspects, closely related to military applications to consider are:
- physical effect on personnel protected with IPE, inside a shelter or a vehicle, with CBRN filtration system or not, etc. In more advanced version, the system should take into account the effects on human beings, e.g. LD50 (Lethal Dose for 50% people) provided by STANAG in ref. [3]. The number of death, wounded and inability to fight of personnel should be as precise as possible. A properly developed tool to be connected with HLA, modifying also CBRN NET FOM, could be a solution.
- physical effects on personnel wearing IPE already considered in other M&S tools, but not verifying the realism of the activity, also considering the STANAG in ref. [2]
- CBRN platform protection, filter duration/filter saturation related to time, route and speed.

From the decision maker point of view, the system should help the commanders to take decisions or verify the decision taken during training. Among the decisions that can be taken, the following are relevant:
- Determine where and when military personnel or civil servant should don IPE;
- Determine where and when military personnel or civil servant should not don IPE anymore;
- Determine mask's filter duration as a function of the concentration and time of exposure (integral C(t)dt > Filter saturation );
- Determine where and when Vehicle should employ CBRN Filtration Systems;
- Determine where and when Vehicle should stop employing CBRN Filtration Systems;
- Determine vehicle's filter duration as a function of the concentration and time of exposure (integral C(t)dt > Filter saturation );
- Determine the best route (as a function of speed, also) to go from a starting point to an ending point avoiding as much CBRN contamination as possible;
- Determine the burden and operativity limitation for personnel, vehicle or other equipment during CBRN exposure (it exist to some extend); consequently, determine the effect on operation (training, exercise, mission rehearsal) so as to assess the risk balance;
- Determine deaths and casualties if CBRN procedures are not well followed during virtual exercise (e.g. IPE don or not don, filters durations, filtration systems employed, etc.).

In order to take into account also the needs of the specialist CBRN troops and technical personnel, also the following capabilities should be taken into account:
- Determine where to send SIBCRA Teams, UAV, UGV or any other useful tools to detect the threat, sample soil, water or gas, so as to confirm the predicted contaminated area and delimitate the exact contour;
- Use the information provided by detectors and sampling analysis to adjust M&S input so as increase the reliability of prediction on contaminated areas.
- Determine weather effects on CBRN Agents, such as degradation of chemical compounds due to the temperature, direct sunlight, water, etc... or the survivability of spores, viruses and bacteria.

## 3. ANALYSIS OF EXPERIMENTAL ACTIVITIES

There are too many M&S tools to analyse all of them from a CBRN perspective. Each tool would need to be explored to fully understand it's potential. For this reason, attention was focused only to the experimental activities already performed, which demonstrates the real capabilities of "Expert Systems", used for CBRN activities, and CGF tools and thus their ability to exchange effectively information which could be used to generate effects.

Among experimental activities, several M&S group were organized along the years by NATO STO in order to deal with CBRN activities. Originally, NATO MSG-049 - Modelling and Simulation System for Emergency

Response Planning and Training in 2011 identify a lack of interoperability to share CBRN tools and information. Then, NATO MSG-096 (Consequence/Incident Management for Coalition Operations) investigated how CAX simulation systems can be developed to support enhanced modelling of CBR scenarios relevant to NATO operations to provide training benefit. A key objective of this group was to provide recommendations on how CAX simulation systems interoperate with specialised CBR simulation systems through common NATO standards. Among these recommendations, the most relevant were the following, related mainly to interoperability:

- CBR Executable Scenario Description: the Military Scenario Definition Language (MSDL) to define the Executable Scenario description should be updated to include CBR content.
- CBR M&S Interoperability: 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 started within NATO MSG-106 to follow up on the recommendations of NATO MSG-096.

A CBR FOM module was developed by DSTL and Riskaware Ltd. to allow CBR modelling information to be exchanged within HLA federations. This built upon previous work undertaken by Dstl and QinetiQ to develop an Atmospheric Dispersion Base Object Model (BOM). 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.

Starting from a different point of view, also MSG-147 worked more recently on CBRN related M&S activities. MSG- 147 is dedicated to develop and test a concept for M&S decision-making support for Crisis 4 Disaster Management & Climate Change Implications. Part of these activities were triggered by a CBRN incident. The project is described in ref. [7] and NATO internal documents.

Specifically, a good number of testing to connect through HLA different tools also involving CBRN information were performed along three years. The main objective was to give the leadership of all tools to a specific tool, called Disaster Management (DM) and developed at NATO Crisis Management and Disaster Response Centre of Excellence (CMDR COE). The M&S tools involved were HPAC (Hazard Prediction and Assessment Capability (HPAC) - Ref. [9]), VBS3 (Ref. [10]), MASA SWORD (Ref. [11]), JCATS (Ref. [12]), ST-CRISOM (Ref. [13]), EMERSIM (Ref. [14]), EDMSIM (Ref. [15]), MILSIM (Ref. [16]), COBRA (Ref. [17]) , KORA (Ref. [18]) and ARCHARIA (ref. [19]). For each tool, a description is provided as well as the characteristics and drawbacks emerged during testing which determined also recommendations.

All These experimental activities are described in details in ref. from [4] to [7].

In the USA, a specific project was developed to integrate as much CBRN specific information as possible in their CBRN M&S layer. Compared to the other testing activities, they stressed less their system for interoperability, yet it was interoperable, but they were able to include specific develop tools to take into account filter duration, the effect of weather conditions on agents and many others detailed considerations. The CBRN agent diffusion was simulated by HPAC (Hazard Prediction and Assessment Capability), while the CGF M&S Tool was OneSaf. Details are not available for NATO partners yet, but general information can be found in ref [8] where the system of system developed is described from the procurement perspective.

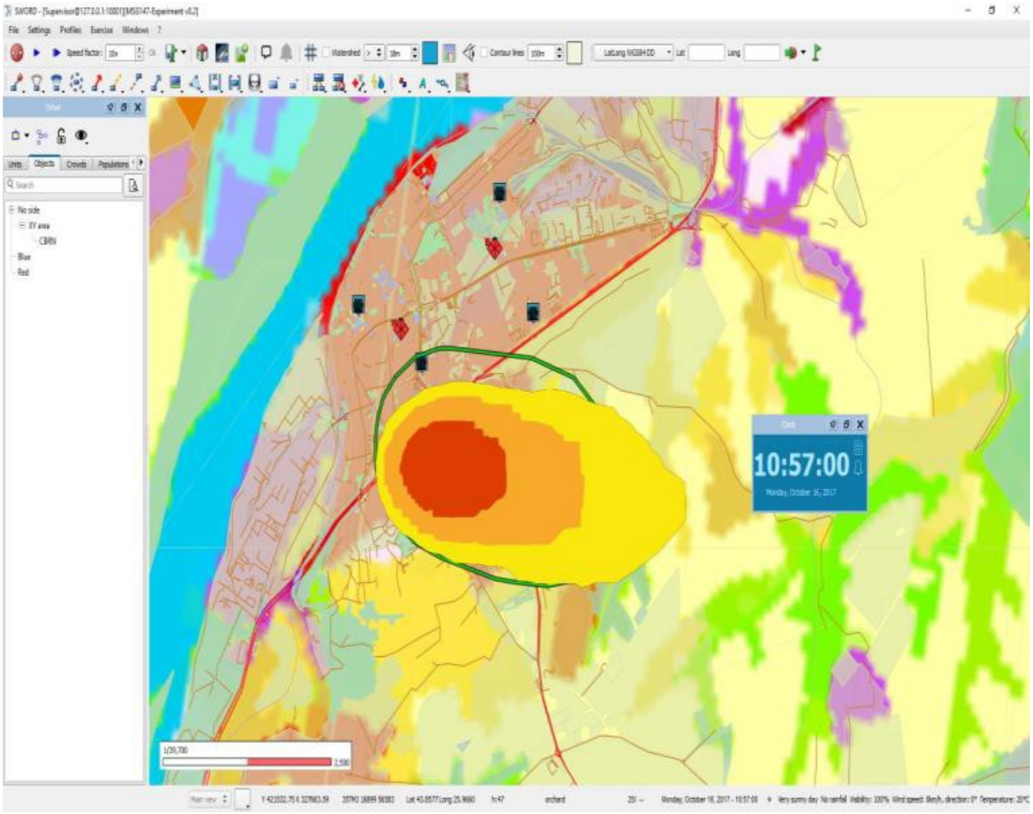


**Figure 1**. CBRN plume produced by HPAC projected within SWORD (From [4]).

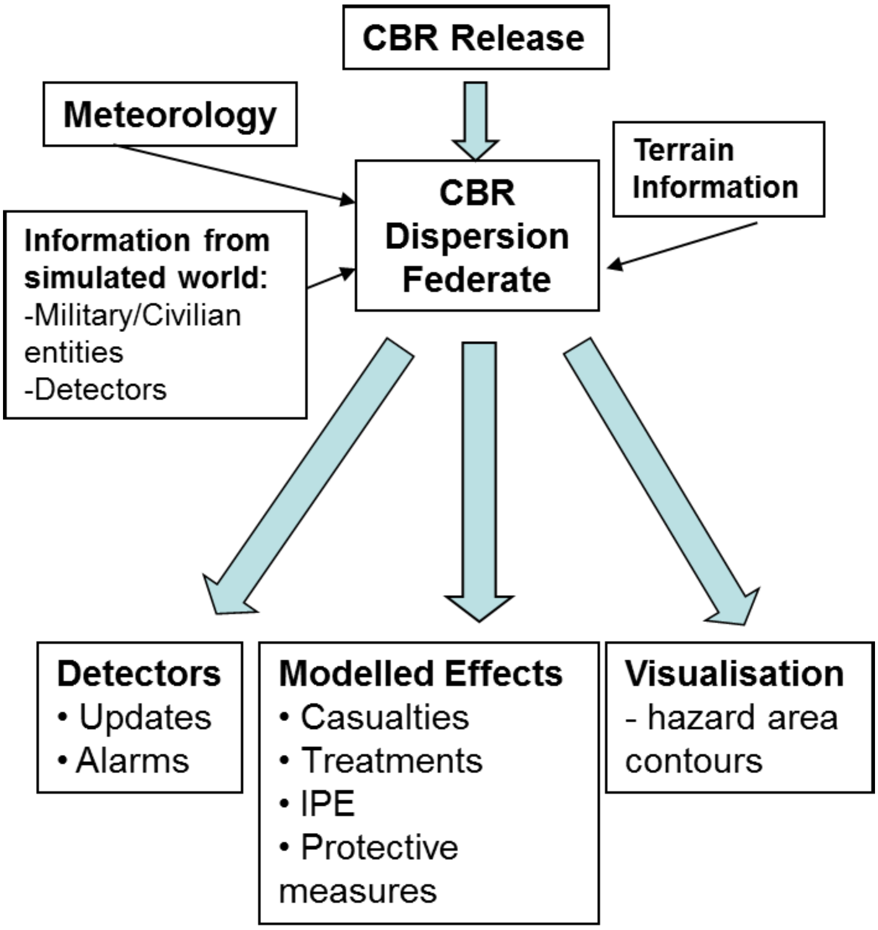


**Figure 2**. CBRN FOM module overview (From [5]).

## 4. GAP ANALYSIS

The existing capabilities, despite experimental, should be compared to what could be provided by a CBRN layer (nice to have), described in paragraph 2. After that, the list of capabilities were reported on the left side and comment on the availabilities, as far as possible now, on the right side of the following table:

| Capability | Gap Analysis (mainly military perspective) |
|---|---|
| Provide real-time access and automated reach-back to plume modelling capabilities with the incorporation of real-time weather data. | Achieved at experimental level. |
| Establish situational awareness of current/forecast plume transport direction and hazard areas. | Achieved at experimental level, but not real time. Projection of information in real time to provide assessment for military application could be critical. Need testing to verify current operations application. |
| Support contingency planning, damage assessment, development of response strategies, and consequence management as well as the development of protective action guides/ recommendations to deal with the short and long-term health and other adverse effects of a hazardous release. | Support is possible, but there is a clear lack of connection with software used to calculate long-term effects. Specific bridges need to be developed within the CBRN layer. |
| Estimate potential damages, casualties, illnesses, fatalities. The calculation could be assigned to specific tools inserted within the Architecture. | Potentially possible, the level of accuracy strongly dependent on the SW used. Need to develop a platform that can potentially include assessment of situation if personnel wear or not wear IPE. Need to use realistic database to calculate the effect of the agent and the time correlated beneficial of IPE (filters duration) |
| Estimate emergency assistance requirements. | Not essential. Future assessment. |
| Project areas where buildings, land, agricultural crops, bodies of water, and other man-made or natural resources are or will be contaminated. | Possible. |
| Select locations for incident command sites, decontamination facilities, sheltering, and evacuation areas. | Possible, with human contribution. Artificial Intelligence could be an added value. |
| Determine emergency response and health services facilities impacted by the release. | Possible. |
| Make shelter-in-place, evacuation, and personal protective equipment use decisions. | Support human to take decision. Artificial Intelligence could be an added value. |
| Identify safe approach and evacuation routes. | Support human to take decision. Artificial Intelligence could be an added value. |
| Guide field measurement and aerial sampling teams. | Support human to take decision. Artificial Intelligence could be an added value. |
| Determine radiological monitoring requirements. | Possible. |
| Estimate the source amounts and locations of unknown releases. | Not useful for military applications. |
| Obtain information for communications with the public to allay concerns. | Not useful for military applications. |
| Support post-event analysis for exercises and actual incidents. | Possible, using some post analysis tool embedded in some tools (e.g. MASA SWORD). Improvement could be achieved using Artificial Intelligence. |

**Table 1:** Gap analysis on the required capabilities.

The next table provides a first gap analysis on technical requirements:

| Technical requirement | Gap analysis |
|---|---|
| Predict the initial direction, travel, and dispersion of a plume over time from a single or multiple sources taking into account the type of source, material/chemical properties, release location, weather conditions, terrain, urban areas, and other man-made structures. | Possible (e.g. HPAC) |
| Predict the concentration of the chemical or biological agent within the plume and flow through drainage areas over time. | Possible (e.g. HPAC) |
| Estimate deposition and contamination levels for air, water, ground, and building surfaces. | Possible (e.g. HPAC) |
| Identify exposed population and predict exposure levels over time. | Possible (e.g. HPAC) |
| Identify the time when the sensors placed in the area of interest will be triggered following the release of the plume. | Possible (e.g. HPAC) |
| Provide for reverse simulations to estimate unknown source amounts, probable release locations, and support event reconstruction. | Not useful for military applications. |
| Provide capabilities to refine simulations based on field measurements and other sensor data. | To be investigated. |
| Support a number of different established problems, models, representations, and techniques including chemical, biological, radiological, nuclear, and explosives (CBRNE) source characterizations, Gaussian-plumes, dense gas dispersion physics, boundary layer meteorology, atmospheric turbulence, urban flow and dispersion, high altitude dispersion, time integrated dosages, inverse modeling and event reconstruction. | Need further investigation, but it is not essential for military application. It could be valued for specific application integrating several expert systems, e.g. CD&E applications. |
| Automate the utilization of sensor field measurements to estimate source terms and optimize predictions. | Useful for CBRN specialist troops. To be investigated. |
| Couple sensor data and simulations via Bayesian inference, stochastic sampling, and optimization methods. | Useful for CBRN specialist troops. To be investigated. |
| Perform backwards analyses to determine probabilistic distribution of unknown source characteristics. | Not useful for military applications. |
| Generate optimal and probabilistic forward plume model predictions. | Possible (e.g. HPAC) |
| Use Markov chain sampling to determine probabilistic source locations based on sensor readings, Green's function methodology (heat conduction and diffusion), fate and transport models. | Useful for CBRN specialist troops. To be investigated. |
| Provide source characterization models for explosive dispersal devices that predict airborne fractions and particle-size distribution. | Useful for CBRN specialist troops. To be investigated. |
| Provide fast-running empirical urban models and high-resolution building-scale computational fluid dynamics models use finite element modelling (FEM) techniques. | Useful for CBRN specialist troops. To be investigated. |
| Support vector and raster representations of geography, buildings, and other structures. | Possible. |
| Support a range of different grid resolutions, e.g., 30 meter, 100 meter, 1 kilometre, and 10 kilometre. | Possible. |
| Model indoor exposure levels due to the effects of building leakiness, i.e., outdoor plume air concentration versus corresponding indoor air concentration. | Possible using civil application SW. |
| Support the integration and/or distributed execution of interrelated models including dispersion, weather, exposure and hazard effects, watershed flows. | Possible for military tools, to be investigated for specialized tools. |
| Support various release mechanisms including explosions, fires, volcanic eruptions, gas cylinders, sprayers, manual methods, tank ruptures, and building collapses. | At least partially possible (e.g. HPAC). Further analysis needed. |
| Support micro and meso-scale forecasts (10 km). | To be evaluated. |
| Model radiation effects including fallout, wet deposition hotspots, ground shine, cloud shine, and inhalation doses. | Possible (e.g. HPAC): Military relevance to be assessed |
| Identify regions where the exposed population will experience life threatening, serious long lasting, or notable discomfort effects. | Possible. |

**Table 2:** Gap analysis on the technical requirements.

Other important pieces of information to be taken into account in our gap analysis are reported in the following table:

| Constrain on data input | Gap analysis (mainly military perspective) |
|---|---|
| Meteorological data: observed and forecast weather conditions that may affect a plume including wind speed, direction, and precipitation | Possible. |
| Plume release mechanisms and their attributes: explosions, fires, compressed gas cylinders, tank ruptures, and manual release of powders | Possible (e.g. HPAC). |
| Specifications of characteristics of an explosive release: detonation point, explosive source characteristics (particle size distribution and spatial distribution of mass from surface to several hundred meters above ground) | At least partially possible (e.g. HPAC). Further analysis needed. |
| Hazardous agent characteristics including form (gas, liquid, or powder), chemical properties, particle size and weight distributions, cohesion, and lethality | At least partially possible (e.g. HPAC). Further analysis needed. |
| Specification of the incident area including location of source, terrain, and buildings | Possible. |
| Demographics data – population location, density, and attributes by time of day | Technically possible, but problem could arise with data source. |
| | |
| **Setup requirements** | **Gap analysis (mainly military perspective)** |
| Provide capabilities to configure simulation runs with specific release incident parameters, weather conditions, and geographic regions. | Possible. |
| Provide a capability for modifying of key release parameters including location of source, agent characteristics, and location of sensors. | Possible. |
| Generate graphical views of plume dispersion over a 2D or 3D representation of area of interest. | At least partially possible (e.g. HPAC). Further analysis needed. |
| Provide user control mechanisms that effect rapid execution/playback of simulation runs to move forward and back to desired points in time. | Possible. |
| Use various representation schemes to display release effects including chemical concentration, radiation intensity, toxicity, lethality, and exposure levels, e.g., colours, shading, contour lines. | Possible. |
| Provide interfaces to generate still image and video files that can be used to transfer results for viewing or playback using other software tools. | At least partially possible (e.g. HPAC). Further analysis needed. |
| | |
| **Considerations on performance** | **Gap analysis (mainly military perspective)** |
| Support fast running local models that generate predictions in 5-15 minutes. | Possible. |
| Provide for updates from real time meteorological databases and observations. | Possible. |
| Share model predictions with other software applications, e.g., incident management applications. | Possible. |

**Table 3:** Gap analysis on constrain on data input, setup requirements, consideration on performance.

The following table is devoted to perform a gap analysis on the capability more strictly related to military applications:

| Capability more related to military applications | Gap analysis (mainly military perspective) |
|---|---|
| Determine where and when military personnel or civil servant should don IPE; | Existing with a certain level of accuracy. To be verified and eventually implemented, using existing tools or developing specific tools, with high accuracy. |
| Determine where and when military personnel or civil servant should not don IPE anymore; | Existing with a certain level of accuracy. To be verified and eventually implemented, using existing tools or developing specific tools, with high accuracy. |
| Determine mask's filter duration as a function of the concentration and time of exposure (integral C(t)dt > Filter saturation ); | Existing with a certain level of accuracy. To be verified and eventually implemented, using existing tools or developing specific tools, with high accuracy. |
| Determine where and when Vehicle should employ CBRN Filtration Systems; | Not available |
| Determine where and when Vehicle should stop employing CBRN Filtration Systems; | Not available |
| Determine vehicle's filter duration as a function of the concentration and time of exposure (integral C(t)dt > Filter saturation ); | Not available |
| Determine the best route (as a function of speed, also) to go from a starting point to an ending point avoiding as much CBRN contamination as possible; | Not available |
| Determine the burden and operativity limitation for personnel, vehicle or other equipment during CBRN exposure (it exist to some extend); consequently, determine the effect on operation (training, exercise, mission rehearsal) so as to assess the risk balance; | Not available |
| Determine deaths and casualties if CBRN procedures are not well followed during virtual exercise (e.g. IPE don or not don, filters durations, filtration systems employed, etc.). | Not available |
| Determine where to send SIBCRA Teams, UAV, UGV or any other useful tools to detect the threat, sample soil, water or gas, so as to confirm the predicted contaminated area and delimitate the exact contour; | Not available |
| Use the information provided by detectors and sampling analysis to adjust M&S input so as increase the reliability of prediction on contaminated areas. | Not available |
| Determine weather effects on CBRN Agents, such as degradation of chemical compounds due to the temperature, direct sunlight, water, etc... or the survivability of spores, viruses and bacteria. | Not available |

**Table 4:** Gap analysis on military capabilities.

## 5. NEXT STEPS

In the next future, we will try to revitalize the architecture organized during the MSG-147 possibly integrating also, what was done within MSG-126. The idea is not only to organize other testing activities, bringing together as much tools and databases as possible, but also to check point by point all the elements determined in the Gap analysis provided in the previous paragraph. The identified solutions should then be fixed in the architecture and the associated documents. Whenever a solution for a specific gap has not been identified with the available tools, a tentative to fill the gap will be performed programming a custom solution (e.g. Matlab, C, specific API to integrate SWs or database). If it is not possible to develop a solution with the available resources, a way ahead will be identified to start a procurement process to acquire the SW tool development.
In the long term perspectives, the architecture, with all databases and SW included, will be shared within NATO Community of Interest for testing, verification and validation by Subject Matter Experts (and to start being a

useful system), eventually employing the capability provided by current technologies to share resources remotely (Modelling and Simulation as a Service – MSaaS approach).

## 6. CONCLUSION AND PERSPECTIVES

CBRN and M&S should be integrated to fully exploit, within their potential in the military domain, using ideas that have already been developed and explore how to improve or shape for different military requirements. Nevertheless, there is still the need to integrate all the activities in one-concept, bringing all the stake-holders around the same table, with the objective to further develop a comprehensive CBRN Layer, taking into account any missing capabilities and sharing the existing resources to finally achieve a tool usable within the NATO Community of Interest. The first step of this process could be to activate a clear procedure to have access and the possibility to explore new applications into the architecture developed within MSG-147 in the CMDR COE. This will facilitate a way ahead to fill the gap, involving as many stakeholders as possible in the project. The involvement of the USA in this effort would raise the level of the project considering their comprehensive approach in this field.

A final analysis of each available capability, and the system as a whole, should be performed to clearly identify further capabilities to be included or developed while also addressing any interoperability issues.

Testing each capability and the system for verification and validation purposes should be planned as well.

Finally, availability and use of the system from a wide Community of Interest needs to be considered in order to have the maximum benefit for NATO and Nations and to continue improving the system itself through suggestion and contribution from users and developers. A general layout of the CBRN layer is provided in the following picture.

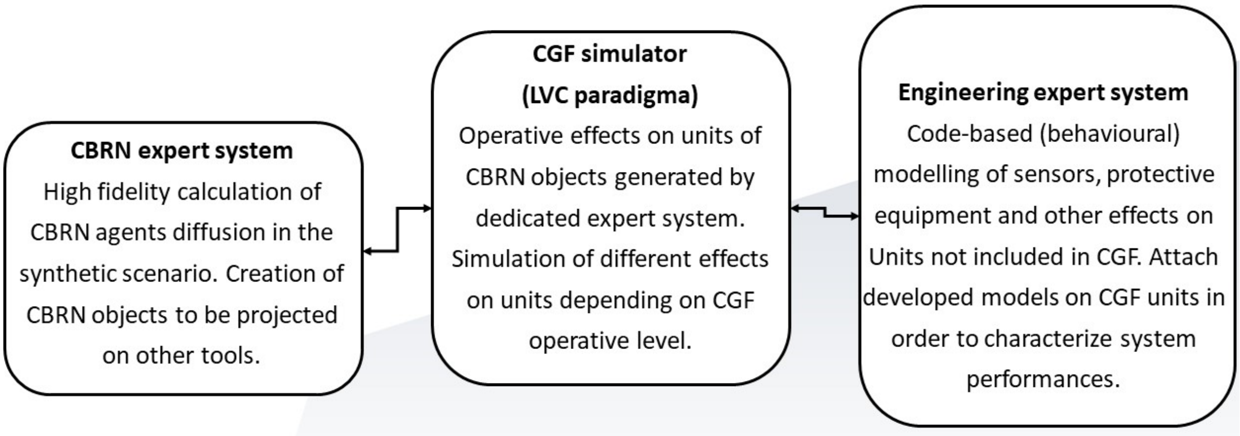


**Figure 3:** General Layout of a CBRN layer.

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