M&S Decision Making Support for Crisis Disaster Management and Climate Change Implications

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ABSTRACT

Appropriate approaches and tools are currently not available to significantly support NATO disaster and crisis management decision-making, education, training and operationalized processes. Even though NATO possesses considerable crisis management capabilities, the lack of a comprehensive and standardized process hampers mission performance, reduces force protection and survivability as well as sustainability of operations in light of any given natural disaster. The lack of a comprehensive and accepted M&S analysis methodology as well as the non-existence of an institutionalized decision-making support process also *hampers the applicability of NATO crisis and disaster management capabilities to their fullest extent.*

In this context, the establishment of simulation federations allowing data exchange of disaster related events in a 'High-Level-Architecture (HLA)' environment on the one hand and the simultaneous transfer of these information (unit states, reports) to military (NATO and national) and civilian C2 systems on the other hand, is a distinguished result of the MSG-147 group technical achievement. To offer an implemented solution the Crisis Management Disaster Response Integrated Development Environment (CMDR IDE) and the 'Disaster Federation Object Model (FOM)' Module which are both compatible to the 'NATO Education and Training Network (NETN) FOM v2' have been developed and tested successfully.

Key words:
Crisis, natural and man-made Disasters, Climate change, Management, Technical architecture, Modelling and Simulation, Decision making processes, Risk analysis, Risk assessment, Technical architecture, Simulation platform, Civil-Military Interoperability, HLA, NETN, CMDR IDE

1.0 INTRODUCTION:

Crisis management is a core task of NATO. Today, the Alliance is confronted with crises and emergency situations and must act under considerable risk and time pressure. NATO is developing capabilities to contribute to effective crisis management and disaster prevention on a case-by-case and consensual basis. This will enable the Alliance to participate actively in crisis management and disaster management, including non-Article 5 crisis response operations. The Alliance therefore promotes the joint training of military and civilian personnel to contribute to confidence-building. These operational requirements need to be translated into technical systems capabilities, this means implementing technical solutions for use in training as well as disaster decision-making support.

In that regard developing a reference architecture and implementing a technical platform to enable rapid and effective testing of crisis/disaster and climate change response plans was a defined gap in order to support decision-makers in case of disasters in time of conducting or planning an operation. MSG-147 was formed with the participation of Crisis Management and Disaster Response Centre of Excellence (CMDR CoE), Bundeswehr University Munich, Germany MoD, Bulgarian MoD, IABG, Massa and with the support of Austrian, USA and Slovenian MoDs. The group developed, experimented and validated a concept for M&S Decision Making Support for Crisis Disaster Management & Climate Change Implications. The development included research, theory and concept development, standardization and improvement of interoperability. It was to be set up with various tools and simulations for crisis management and civil protection that are unique to NATO and enable non-military operations.

In this context, the establishment of simulation units that enable the exchange of data of disaster-related events in a HLA environment and the simultaneous transmission of this information (reports/unit conditions) to military (NATO and national) and civilian C2 systems was an outstanding result of the technical performance of the MSG-147 group.

In order to be able to offer an implemented solution, the Disaster FOM module (compatible and integrable in NETN FOM v2) was developed and successfully tested as the German contribution to the technical support of the MSG-147 project. A special innovation in the technical investigation of the concept was the application of the CD&E method and procedures for the evaluation of new technical solutions in the field of M&S and their implementation. In order to improve the decision-making process and to increase the objectivism, CMDR COE designed and developed a Disaster Module application called Integrated

Development Environment (IDE).

2.0 DESCRIPTION OF THE PROBLEM AREA

The responsibilities in disaster and crisis management vary significantly in NATO member states and are often divided between different ministries and government agencies. Within the framework of the Alliance, members work and train together in order to be able to plan and conduct multinational crisis management operations, often on short notice. In this context, NATO is an enabler which helps members and partners to train and operate together, sometimes with other governmental or private actors where appropriate, for combined crisis management operations and missions. Many crisis management operations have their own objectives and end-state depending on the nature of the crisis, which will define the scope and scale of the response. To ensure effectiveness and resilience, NATO's crisis management instruments are continuously adapted to the evolving security context. Over time, NATO has led and conducted a number of crisis management operations, including those beyond the Euro-Atlantic area.

Appropriate approaches and tools are currently not available to significantly support a NATO disaster and crisis management decision-making processes. Even though NATO possesses considerable crisis management capabilities, the lack of a comprehensive and standardized process hampers mission performance, reduces force protection and survivability as well as sustainability of operations in light of any given disaster or Climate Change Implications (CCI) crisis. Current approaches in crisis management decision-making support are not based on either standardized datasets or data formats, and thus can vary significantly. In addition, decisions are primarily based on subjective assessments due to the lack of a widely accepted and standardized understanding and evaluation of such natural disaster data. The lack of a comprehensive and accepted M&S analysis methodology as well as the non-existence of an institutionalized decision-making support process also hampers the applicability of NATO crisis management capabilities to their fullest extent. These shortcomings also influence NATO's analysis and planning capabilities, its training, exercise and education domain, and ultimately its performance in crisis management operations

A capability gap in the use of M&S exists in the civilian entities as well, due to the constraints that many governmental agencies, NGOs and international organizations face in terms of limited budget, time, availability of skilled manpower, expertise. Efforts have been made to provide military simulation support to training and exercises involving emergency managers. However, the participation in the planning of exercises of civil protection and the ministry of interior has usually been limited during the planning phase of the exercises with more attendees during the exercise execution.

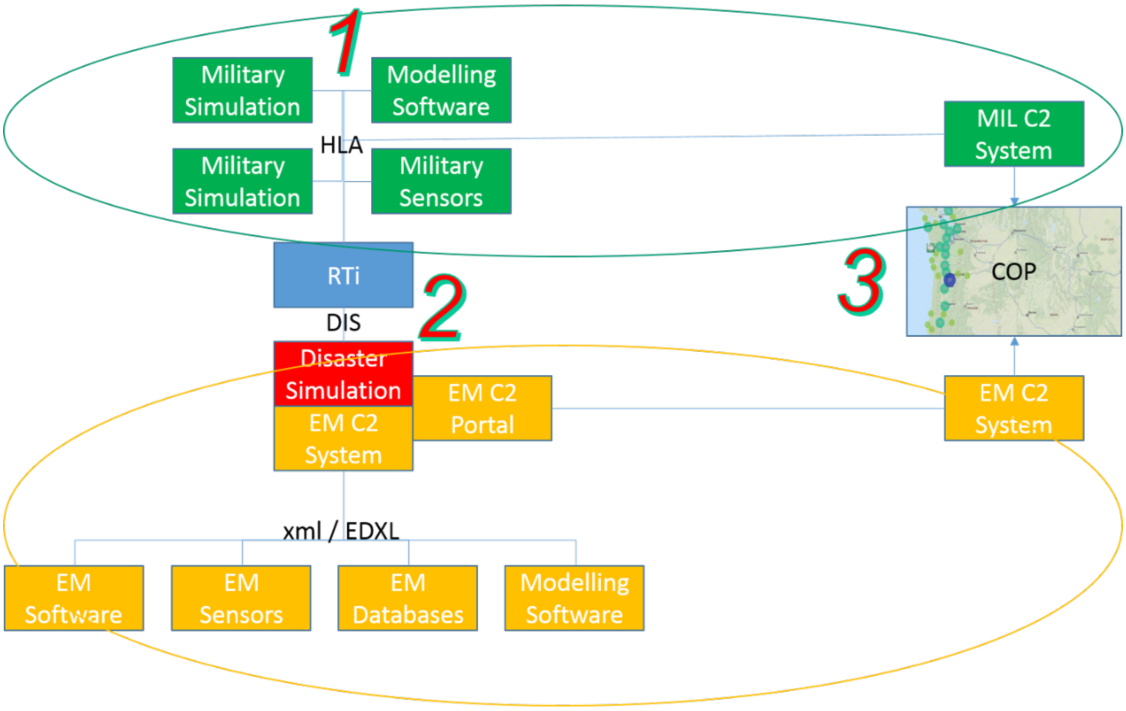

Figure 1: Defined gaps

Through the work of the group were defined more problems which should be resolved in the near future:

1. Transfer the result information from disaster models to military simulations and visualizing it on the C2 systems
2. Transfer and share the information between military and civilian simulations and models because of using different standards
3. Sharing and visualizing the results from different national C2 systems as well connected with NATO C2 system

That was the reason the CMDR COE to work on the development of an application (IDE) which to provide environment to connect models with simulations and C2 systems.

The conceptual approach aims at developing solutions to enhance crisis management capabilities of NATO member states, including non-Article 5 crisis response operations and especially those related to disasters and CCI. These capabilities, which enable member states to deal with a wide range of crises ranging from political, civilian and military, will be structurally utilized to operate under the conditions of CCI on the same level of profession. The Alliance also encourages joint training of military and civilian personnel to help build trust and confidence.

As a consequence of the concept the operational commander requires military capabilities for every need that are:

- conceived and usable also for non-military purposes (multi-purpose by design[1]);
- able to integrate with civilian components according to a "preventive" collegial approach;

[1] NATO FFAO ed. 2018 - Chapter 2

- flexible and multi-faced, so their high cost can also be translated into more services for the benefit of the community.

In conjunction to CCI, the approach laid out will increase the proactive reduction of vulnerabilities and may serve as reference architecture to demonstrate a technical platform that enables prompt, reasonable and effective tests of Crisis/Disaster and CCI Response plans. Therefore, this MSG-147 crisis and disaster management process research project was concentrated on the following pillars of NATO crisis capabilities under the condition of CCI:

Force protection

- Measures and means to minimize the vulnerability of personnel, facilities, equipment, materiel, operations, and activities from threats and hazards in order to preserve freedom of action and operational effectiveness, thereby contributing to the mission success;

Resilience

- The capability to anticipate risk, limit impact, and bounce back rapidly through survival, adaptability, evolution and growth in the face of a turbulent change;
- Resilience can also be defined as the ability of a system to perform four functions with respect to adverse events: planning and preparation, absorption, recovery, and adaptation (Linkov et al., 2013);

Sustainability of operations

- The aim to improve and, where appropriate, develop the enablers that enhance NATO's ability to support expeditionary forces and to sustain them for extended periods, while retaining the ability to support large-scale high intensity operations in accordance with the agreed NATO Level of Ambition (LOA). It facilitates logistic support to operations by identifying logistic support challenges and developing solutions to them. It seeks to optimize the delivery of logistic support through multinational solutions, contractor support and other support arrangements. It promotes logistics transformation through the identification and adaptation of technological and commercial solutions.

The main purpose of the software environment to be developed is not to substitute the human decision-maker within crisis management. The main goal is to reduce the number of problems that decision-makers have to confront when dealing with crisis response operations.

3.0 M&S DECISION-MAKING SUPPORT SYSTEM FOR CDMP&CCI

The project has three main directions for analysis CDMP in NATO in order to improve E&T and support the decision-making process in the Alliance.

The first pillar is the analysis of Disaster Risk Management (DRM) processes, preceding the development of the Operations Plan. This includes:

- Fast and accurate Disaster Risk Analysis;
- Comprehensive approach and correlation assessment among hazards;
- Prevention and Preparedness Measures proposals.

The second pillar concentrates on Disaster Response during NATO operations by assessing:

- Fast and accurate Disaster Assessment (DA);
- Dynamically generated proposals for Response Plan

- LL process

The third pillar focuses on the development of a module for realistic modelling and presentation of different types of disasters for the purpose of education and training, experimentations, tests and validations.

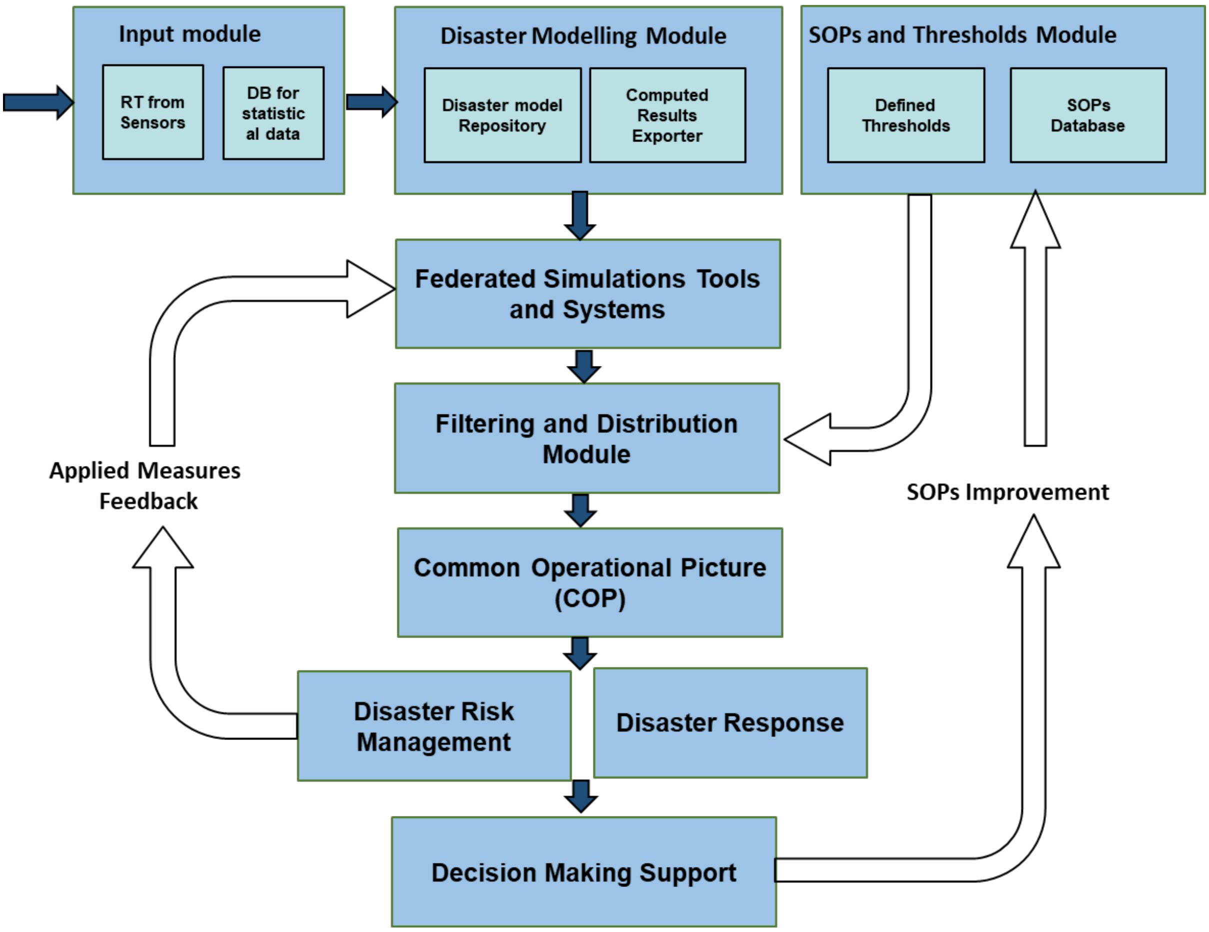

Figure 2 Technical Architecture for CDMP and CCI

The following software components (as shown in Fig.2) was developed in order to achieve the above-mentioned results:

- **Input Data Module** – database for statistical (history) and real-time natural data. The database should have standardized properties and interface.
- **Disaster Model Engine** – combines input interface (accepts data from the database), disaster model repository (as many as possible mathematical representations of different types of disasters), and output interface. The output interface should be able to send information in varied formats – text reports, e-mails, HLA objects, etc.
- **Decision-Making Support Module** – database with fragmented SOPs and defined triggers for disaster alerts and responses. To each elementary action of the SOPs, metadata containing relevance to event, priority and sequence, dependences will be added.
- **Filtering and Distribution Module** – will filter the relevant elementary response actions and will dynamically generate proposals for the Response Plan or Prevention and Preparedness Measures proposals. The generated analysis and disaster development forecasts will be distributed to defined

clients.

The technical architecture includes a database holding data from mathematical models for different types of disasters which visualize in an interface. The collected results will be compared with statistical and historical data from events that have already occurred. Depending on constant indexes as infrastructure, Geographic Information Systems, vegetation, and others, a probability in percent for exactness of the model will be shown. The human impacts will be assessed by a taken decision from the decision-makers. That way the architecture will define the accuracy of different models for different disasters and every decision maker could select which kind of model to choose to work with for different situations.

A disaster risk management assessment could be made depending on any given task, whereas during the operation planning phase statistical data or through the operation phase real time field data will be used. Firstly, the architecture is testing through training and exercises and if the results are contented, then it will be implemented on operational (strategic) level. The repository with disaster models could be connected through HLA with federated simulation systems and tools proved to be usable for different disasters or crises. The calculated results of the models are published in the simulations as objects. For that purpose, a Federated Object Model (FOM) for different disasters should be created. According the AMSP-04[2], a Federation is a union of essentially independent applications (Federates) interoperating using common infrastructure services accessed through well-defined standard interfaces and governed by common agreements on modelling responsibilities, the commonly used Data models and information exchange. A High-Level Architecture (HLA) Evolved Federation is a federation using the HLA standard (IEEE 1516-2010) to specify available infrastructure services and APIs for accessing them. The HLA standard also specifies how to document information exchange using a FOM.

- The basic principle for building a connected simulation environment (e.g. HLA federation) is described through the DSEEP[3] process model. The essential step thereby is to define the FOM for the federation by taking into account the following considerations:
- Based on the purpose for which the simulation environment is built for, the simulation systems to take part in the federation must be chosen as well as the interactions between them. These again define for each system the data to be sent and received (SOM: Simulation Object Model). The conjunction of these SOMs determines the Whole set of the object data and interactions in the simulation network, the so called FOM (Federation Object Model).
- In most cases, the participating simulation systems in a federation are not created for an explicit interconnection purpose. In fact, typically, already existing systems are deployed which dispose about a whole set of capabilities defining thereby a certain SOM for each system. The use of such a system in a bilateral interconnection is limited through the intersection of the System's SOMs so that these SOMs must comprise all object data and interaction needed to accomplish the coupling aim. The FOM then is determined through the conjunction of all the intersection SOMs. It is clear that the effective used and relevant conjunction of the bilateral Intersections of the SOMs builds just a subset of the FOM. It means that the whole FOM is not actually used for the data exchange.
- In the development phase of simulation systems, the requirements for the data to be exchanged are mostly not a priori known, since these are derived from a concrete need for the intended concrete systems connectivity. Therefore, to deploy a system in a federation the implemented System SOM is chosen as a sub set of a so-called reference FOM. Therewith the probability is increased significantly that two independently from each other developed simulations systems will be able to exchange data and Interactions.

The requirements set for an interconnection environment affect the SOMs and therefore also indirectly the development of the reference FOMs. Then again, the reference FOMs influence on the other hand the

[2] AMSP-04 NATO Education and Training Network Federation Architecture and FOM Design

[3] IEEE Std. 1730 Distributed Simulation Engineering and Execution Process

capability of the simulation systems and therewith the simulation environment to be realized. The time related development of the requirements for a simulation environment, the contents of reference FOMs and the connectivity capability for simulation systems are dependant from each other and affect themselves mutually.

4.0 CRISIS MANAGEMENT AND DISASTER RESPONSE INTEGRATED DEVELOPMENT ENVIRONMENT (IDE)

The importance of the disaster events, their influence and severe impact over human life is indisputable and largely taken under consideration. The planning process and performance of NATO military operations also do not exclude disaster management.

The significant unpredictability, concerning the time and space of occurrence, and the event parameters, makes the risk management and disaster management a difficult and resource consuming process. The evaluation of the dynamic impact over a planned and performed military operation is almost impossible without the usage of appropriate M&S tools and software. Such applications are military oriented software allowing realistic war-gaming and based on the implemented military units model database and behavior.

During the first phase of the MSG-147 project it was recognized that there is no existing military-oriented simulation on the market capable to accurately model and simulate all variety of disaster types. In addition, it was realized that the few models (flooding for example) built-in are inaccurate and with deviation from one to another simulation.

This renders the creation of simulation federation, war-gaming, and following analyses regarding disaster events during military operations impossible.

In order to improve the decision-making process and to increase the objectivism a Disaster Module application was developed. It is software with unique capabilities. It can compute and model different disaster events using its own or external mathematical models and publish the achieved results as standard for the simulations object with all predefined characteristics and attributes. These attributes defining the disaster simulation object are updated frequently. In such a manner, the Disaster Module could distribute one or more disaster objects to many simulations connected to a federation, using standard HLA interface. The mathematical model computing the event is external to the simulations and its responsibility is to estimate the impact over military units, civil society and infrastructure. The Disaster Module provides the software engine for calculations and the necessary operator interface to tune and change parameters. Such approach has many advantages:

- Publishing the disaster as an object into a federation of different federates is synchronized and its subsequent updated;
- The object is the same for every federate subscribed to it and does not depend on a specific simulation system;
- It is not necessary for the federate to have its own model for the specific event/object/disaster;
- Every disaster mathematical model implemented into the Disaster Module is open, very precise and easily exchanged, if it is necessary, without changes to the source code of every federate;
- Operators can change the parameters or input data of the mathematical equations describing the disaster mathematical model or to change one model with another if it is more suitable;
- The Disaster Module could publish computed HLA object representing the desired disaster from its own engine and respective model or using data from another source (like it was experimented with

HPAC (with artificial initial conditions and scenario) provided by JCBRND COE). In this case the Disaster Module serves as a bridge for modelling software and applications not having HLA interface. During the experiments all technical problems concerning this functionality were solved and finally the data was published and updated as it should be.

Later on, to the Disaster Module other modules with different functionalities were attached. Such functionality was the mentioned bridge service allowing transfer of data from not HLA compliant applications to federation. In that regard, the necessity of services capable to inject information in the Command and Control System, to generate the Situational Awareness Report, to propose Response Measures and to visualize them again in the C2 environment was recognized. Something more, a development of SOP Database started and the first disassembled to rudimentary measures SOPs were provided by SEEBRIG for tests and training support during Balkan Bridges 19 exercise.

It changed the focus of the application. In addition, the interface was not that friendly and understandable. A decision to make different modules representing the conceptual schema was taken and the name of the software was transformed to Crisis Management and Disaster Response Integrated Development Environment. It elaborates much better not only the current implemented capabilities and functionalities, but also describes the concept of the product. It is necessary to emphasize again the strictly followed standard interface approach of the development reference architecture. It allows to connect different software and applications with different functionalities and capabilities. Thus, increases significantly the chance for a cohesion coordination or synergy.

The CMDR IDE has two main roles. The first one is to connect useful and relevant existing applications like military simulations for example. In such a manner, CMDR IDE configures the necessary framework capable to run war-gaming, to publish into the network disaster events of different types, to collect reports about the impact, behavior and development of the crisis, to run the information through Command and Control systems, etc.

This is done through rising interconnections to the clients of the framework. Because of the project big scale, it was confirmed that the time-saving approach is to use what is currently available like simulation systems, command and control systems, networks for information exchange. It was realized that it not only improved significantly the development velocity, but also gave highly advantageous flexibility. Nowadays the CMDR IDE could connect many clients and could transform the final schema easily. Such an open architecture allows for the interoperability with different applications, which are proportional to the potential synergy. It could be elaborated as a function of the common domain of interest and different capabilities.

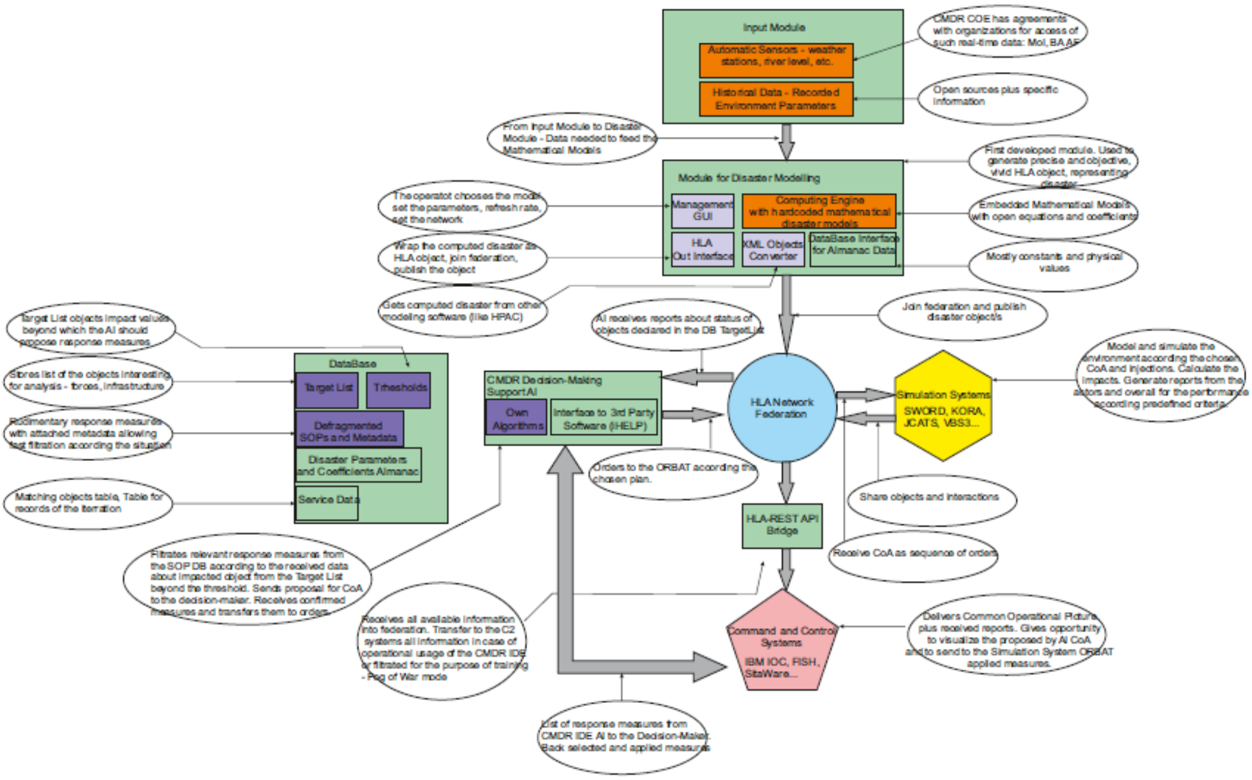

Figure 3 Schema of the IDE reference architecture

In the beginning of the project, the schema of the reference architecture was proposed, covering the cycle of Crisis and Disaster Management. CMDR IDE provides the necessary components to build it. By attaching different tools and software to the framework, the entire architecture or just a part of it could be activated. For example, the war-gaming process could start without the usage of the module for the dynamic plan generation.

This part of the CMDR IDE has a module for transferring of modelled data (computed disaster as an object with specific parameters) to the reference architecture.

This interface is capable to transform data from different sources into the simulation compatible. It is possible because the module can receive data in various formats. Most of the time the synchronization depends on operator manipulation, which actually is an advantage and makes the module more flexible.

Another interface is the simulation-C2 system gateway. It could transfer information from the simulation system to the C2 and vice versus. It is HLA-REST API based and connects many simulations and C2 systems making a large number of possible combinations. As an example, during writing the current version of the concept under development, it is an interface connecting the CMDR IDE with EXIS. It will allow the connections with many C2 systems used currently by NATO and its members.

The second role of CMDR IDE is related to the innovative part of the project. It was necessary to build a few new applications as additional modules in order to rise the invented architecture.

The first one is the Disaster Module consisting of several submodules: engine running open source disaster mathematical models, operator interface, and almanac database. The operator interface allows to control some of the coefficients of the mathematical models, to set up the initial parameters (e.g. weather conditions). The simulation network gateway is no more a part of the module and is now a part of the

Interface Module.

The Module for Information feeding. This module publishes information into the Command and Control System. It is used to transfer data from people on the ground in case of a disaster or from EXCON if the reference architecture is used for training. It has a simple interface which currently is based on Common Alerting Protocol. During the performed experiments, the module had simple interface and functionality. Now, the next version of the module is under development. In it the EXCON could have a list of preplanned injects making the duties easier and replicable. It saves time and efforts.

The CMDR IDE has a main operator interface allowing the user to choose what module related with Crisis/Disaster Management cycle to start. The CMDR IDE configures the necessary framework disaster mathematical model input data modification or automat feeding from a sensor network.

The process of feeding the reference architecture with real live/time data is also under development. Still, some work has been done. CMDR COE has an agreement with organizations, sources of such information. Initial information about the standards and test sets of data were exchanged. The CMDR COE's OpsLab also plans to develop a hardware capable to monitor objects or subjects and to transfer the data remotely to the technical reference input gateway. It could be used for training, but the main purpose and usage will be for operational activations.

As it has been explained, the Disaster Module could run its own engine with implemented disaster mathematical models or serve as a bridge between modelling applications without HLA interface and a military simulation federation. The advantages of using internal models are knowing of the disaster model mathematical logic and coefficients, its accuracy and the opportunity to modify it when it is necessary. At specific conditions, one mathematical model could be preferred to another. It gives flexibility to the decision-makers. The Disaster Module has also a database with reference data for the specific parameters. As examples, the value of the gravity acceleration or the physical parameters of a specific toxic gas could be pointed. The necessary input data depends on the disaster mathematical model requirements. It could be statistical/historical or real-time data. Statistical data is used during Risk Management Analyses (before operation, during the planning process) and real-time data - during the actual performance of the military operation.

Database Module. The Database Module contains variety of information. There the almanac data related with specific disasters and necessary for the mathematical models is stored. As an example, the saturation point of specific soil when the modelled event is flooding could be mentioned.

Another set of tables contains statistical data gathered from previous disasters. It can be used for analysis, experiments, training, etc. The reason to use such statistical data is its realism and objectivism – two trends hardly coded into the project concept. This data, however, could be modified. For example, the location could be shifted according to the scenario requirements. It gives flexibility and full control in order to conduct beneficial training or experiment process.

An important part of the Database schema relates with the Standard Operating Procedures (SOPs). The database contains defragmented SOPs with rudimentary response measures at specific levels – tactical, operational, and strategic. Metadata is added to each response measure, which makes possible its selective usage. Such an approach is innovative since there is no existing similar solution. However, additional formalization of the Disaster Management knowledge, experience and theory should be done.

The Database Module contains also a Target List, which is used for generating the Dynamic Response Plan. Last but not least, here are stored service data related with the transfer of information from simulations to C2 systems and vice versus, preliminary written lists of injections and orders, etc.

Artificial Intelligence module. The purpose of this module is to generate the Dynamic Response Plan. This plan is relevant and adequate to the specific parameters and conditions. It is generated according to the implemented management logic. At the moment of composing of this edition, the AI Module is in initial stage of development. Some tests were performed using basic schema of thresholds-comparators-triggers. The mentioned target list in the Database Module and the rudimentary response measures are feeding data for the process.

The proposed measures, combined as a raw plan for disaster response, are depicted on the C2 screen making its implementation or rejection possible.

The next step is the development of a smart AI collecting modern management theory, expertise and knowledge about disaster events and generation of necessary capabilities for response in case of a resource shortage.

The desired goal is the AI Module to be capable to perform brute-force selection of the best CoA according to predefined criteria.

5.0 DISASTER FOM DEVELOPMENT

This Crisis Management & Disaster Relief Federation Object Model (CMDR-FOM) design document provides guidance and rationale for the design and intended usage of the CMDR-FOM. The CMDR-FOM integrates seamlessly with the NATO Education and Training Network Federation Architecture and Federation Object Model (FAFD, NETN-FOM) and therefore is well applicable in the context of NATO Computer Assisted Exercises (NATO-CAX). To some extent, it may also be used in national CAX as well as more general use cases in the field of distributed simulation e.g. analysis and operational planning.

The Federation Object Model (FOM) defines the objects with attributes and the interactions with parameters that can be exchanged within a federation and is therefore known federation-wide.

5.1 Requirements and design overview

The major requirements on this newly designed FOM module were:

- The CMDR-FOM module shall model Flooding, Fire and Toxic Clouds
- The CMDR-FOM module shall be based on the NETN-FOM v2
- The German simulation system KORA shall serve as a reference system for the CMRD-FOM module
- The CMDR-FOM module should serve as a reference for future implementations and adaptions of existing simulation systems like e.g. JCATS, SWORD, VBS3 and MILSIM.
- The CMDR-FOM module shall be compatible to the MSG-147-DM application

The design rationale therefore suggests building the newly created CMDR-FOM as a separate module on top of the NETN-FOM. As the NETN-FOM already contains a module related to Chemical, Biological, Radionuclear and Nuclear (CBRN) events, some semantic overlap is expected and re-use of existing entities or data types from the CBRN-FOM module should occur.

A more detailed analysis of the CBRN-FOM module shows that this module strongly focuses on modelling the effects of CBRN exposure on humans (i.e. casualties, injuries) and material (i.e. contamination). It also addresses the detection (i.e. sensors) and handling of these events (i.e. decontamination, protection, treatment). It is however not directly intended towards a detailed representation of CBRN material and its distribution in a synthetic environment.

The CMDR-FOR in contrast will need to model the presence of flooding, fire and toxic clouds in a synthetic environment. It should be noted here that the main purpose of the CMDR-FOM is to share the (detectable) effects of the represented events in a synthetic environment. It is not meant to distribute model parameters or be a distribution or spreading model itself, rather it represents the output of such a model in a simulation network (i.e. the physical effects) thus enabling connected simulation systems to react upon the represented threats or disasters.

5.2 Disaster/CMDR Hazard-Events

Using the interaction class CMDR_HazardEvent the original source event of an environmental hazard can be communicated in a simulation group.

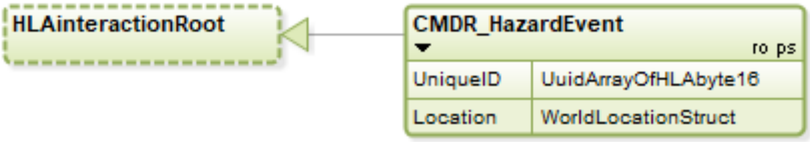

Figure 4: interaction class CMDR_HazardEvent

Typical examples would be the failure of a dam leading to a flood, the place where a fire originally broke out, or the place where a chemical substance was released into the environment.

The parameters identify the event and its location and are technically reused from the FOM modules RPR-Base_v2.0 or NETN-Base_v1.0.2.

The CBRN_v1.1.9 module contains a CBRN release interaction intended for the communication of a CBRN release event. There is a semantic overlap when using CMDR_HazardEvent to communicate the release of the toxic substance, which could also have been modeled with the CBRN_Release event. However, the CMDR_HazardEvent had to be introduced to model other CMDR events like fires, dam bursts, etc. for which the CBRN_Release is not suitable. If the release of toxic substances is to be modeled, the association agreements must state which of the two events is used in the association.

5.3 Disaster/CMDR Hazard-Regions

The CMDR_HazardRegion is used to represent the geographic region of a CMDR hazard in a synthetic environment.

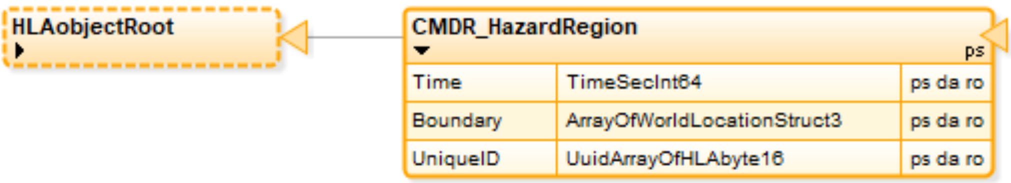

Figure 5 Disaster FOM: Hazard-Regions

It includes the simulation time when the region was first created and its geographical boundaries. This allows the ArraOfWorldLocationStruct3 from the FOM module NETN-Base_v1.0.2 to be reused and which actually contains locations in three dimensions. It is to be expected that in a simulation application these three dimensional coordinates have to be projected onto the actual terrain used in the simulation to form the actual boundary of the hazard region.

A spatial overlap of several CMDR_HazardRegion objects may not be useful in many cases. However, it could be used to model more complex geometries, and of course, it is possible to obtain overlaps/mixtures of toxic clouds formed by different substances. Therefore, it is a prerequisite for a concrete Federation Agreement to clarify these details.

The CMDR_HazardRegion object is further specialized to represent the individual types of hazards according to the requirements mentioned above.

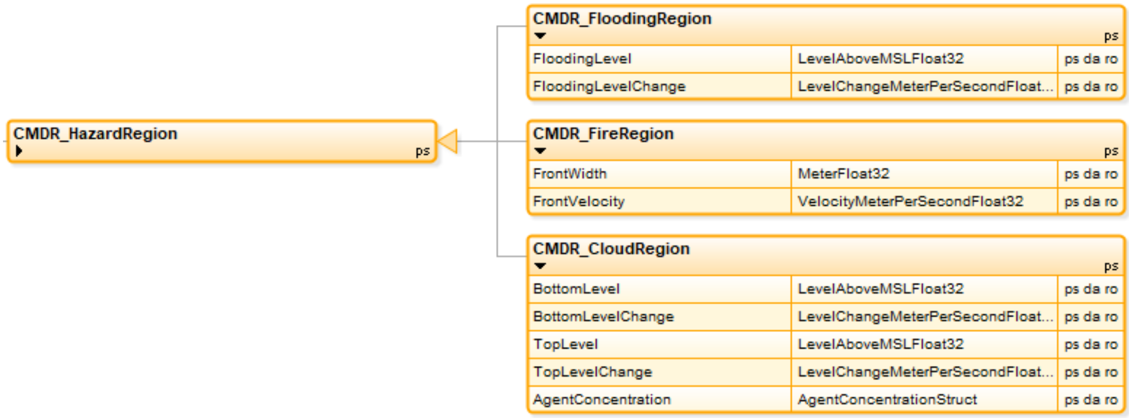

Figure 6: Details regarding Disaster/CMDR_HazardsRegion

5.4 Dsaster-FOM: further specifications regarding flooding, WildFire and toxic clouds

5.4.1 Flooding:

The object class CMDR_FloodingRegion is derived from the object class CMDR_HazardRegion and introduces additional attributes:

- FloodingLevel represents the water level of the flooding relative to the mean sea level (MSL)
- FloodingLevelChange represents the change of the water level over time. An observer can thus determine whether the flood level will rise (and further action/preparedness may be necessary) or whether the water will drain away and thus the restoration measure can start soon.

5.4.2 Wildfire:

The object class CMDR_FireRegion is derived from the object class CMDR_HazardRegion and introduces additional attributes.

- FrontWidth specifies the thickness of the actual ring of fire surrounding a region that is no longer burning. It is assumed that a fire starts at one or more locations and then spreads in a circular fashion with a fire front of a certain thickness and burnt land behind the front line. The Boundary attribute from CMDR_HazardRegion specifies the outer shape of the entire region, assuming that the flame front of the specified thickness extends into the region from within the boundary.
- FrontVelocity specifies the propagation velocity of the front line. This allows an observer to estimate when the fire will hit a certain location. The actual boundary and the velocity are in the

same relation as position and velocity of a physical unit, although it is assumed here for simplification that only one single propagation velocity is valid.

5.4.3 Toxic Clouds:

- The object class CMDR_CloudRegion is derived from the object class CMDR_HazardRegion and introduces additional attributes.
- BottomLevel and TopLevel denote the height of the toxic cloud from bottom to top.
- BottomLevelChange and TopLevelChange each indicate their change over time.
- The AgentConcentration structure is reused from the FOM module CBRN_v1.1.9 within NETN FOM v2 and defines the released active ingredient and its concentration within the cloud.

It should be noted that this simple model of a toxic cloud assumes a flat top/bottom side of the cloud and the same concentration of an agent within the cloud. Should it be necessary to include spatial variations of the parameters, this can easily be achieved by stacking several CMDR_CloudRegion objects vertically or laterally.

6.0 PROJECT OUTCOMES AND FINDINGS

This section comprehensively presents the findings of the study and their benefits to the (NATO) international community (specifically the NMSG-147 Working Group and CMDR CoE), from a technical and operational point of view, as well as for potential national use.

6.1 MSG-147 related findings

1) Prioritisation of perspectives of MSG-147 for CMDR COE (in-house expertise, training, In-Theatre-support/Reach-back). Neglected one issue (operational support) in order to reduce complexity. This issue could be part of new study.

2) The study focused only on NATO operations, first as being affected and secondly when giving support in advance of and during operations. The civilian picture had to be neglected due to complexity and limited resources.

3) Successful implementation of the technical architecture, including establishment of a federation between distributed simulation systems addressing disaster management requires:

- Awareness of the preprogramed SOPs representing the inherent national doctrines;
- The need for a clear federation agreement;
- Standardised interfaces (bridges);
- Consideration of the original nature or purpose of participating tools in order to avoid overambitious performance expectations;
- Preliminary and timely preparation and communication between technicians/ industry/academia ("not just plug and play");
- Strong involvement of system developers for the development and implementation of new features supporting end-users evaluating those features;
- End-user evaluation of the operational benefits of implemented new features.

4) The application of the CD&E methodology proofed vital for the conduct of this study. Concept development, experimental examination, data collection and analysis enabled a structured and comprehensive approach as well as a stringent progress.

6.2 Technical findings

5) The main objectives (federation of JCATS-ST CRISOM, HPAC-KORA/SWORD and JCATS-SWORD-KORA) were reached on a proof-of-concept level.

6) Most tested tools lack the capability to accurately simulate disasters. Most tools also fail to exchange disaster related data in a federated environment. The group also found that a necessary Federation Object Model (FOM) does not exist for most disaster types.

7) The lack of a FOM module standardizing the exchange of disaster specific data (except CBRN) was overcome by developing such FOMs (flooding and wildfire) within this study.

8) The newly developed FOMs covering flooding and wildfire worked properly in a federation of all systems (SWORD, KORA, CMDR COE IDE) with the exception of JCATS. This means that the ambition to fully support NATO training regarding disasters management is limited until JCATS is being optimized.

9) Situation reports and disaster effects based on simulation data were also transferred to C2 Systems (iGeoSit, IBM IOC, FIS H) successfully.

10) CMDR COE IDE proved functional in supporting the workflow in MSG-147s technical platform architecture, as middleware and/or service manager between simulation systems and as a simulation system itself.

11) The successful federation of different simulation systems and C2 software tools proved added value. It made individual advantageous services available to the whole cooperating suite. The complementarity and diversity of services of simulations in a federation increases the added value for all systems in that environment.

6.3 Operational findings

12) Comprehensive modelling at tactical level of the environment, actors and external influences provides operational overview, results and outcomes.

13) Some proposed courses of action were not feasible due to national doctrinal restrictions incorporated in the respective simulation system.

14) Combination of multiple disaster models, for instance, flooding in combination with CBRN led to overcomplex scenarios and situation reports, that impair the ability of decision makers to deal with such crisis's situations.

15) Including disaster effects in wargaming allows more realistic evaluation of different courses of action. This provides substantial decision-making capability.

16) Crisis, crisis management, disaster and disaster response definitions were developed in the course of the project by CMDR COE.

17) Crisis and crisis management definitions were transmitted to NATO Standardization Office, NATO

HQ for consideration.

6.4 Outlook for further research and development

In this section possible future research questions and development possibilities are presented. It also identifies challenges that are of utmost importance and should be addressed in the near future.

The CMDR CoE can use the application of the technical platform in the context of CAX for decision support and training. The extension of the CMDR IDE interoperability enables the implementation of further models. In addition, the basis was created for the development of automatic SOP recommendations selected by artificial intelligence.

The extension of the disaster module in the CMDR IDE, which is intended by CMDR CoE, allows the processing of further disaster types and forms the basis for the creation of a disaster database. This is intended to improve the capability of C2 systems with dynamic disaster information. Furthermore, the use of drones as sensors and computer vision technology to enhance crisis data acquisition and situation awareness is planned to sustainably expand the support of decision-making capabilities by real-time data.

The first task would be to implement the results of the NMSG-147 while respecting NATO and national guidelines and requirements. The disaster simulation FOM developed within the framework of the study should be made available to all national systems. In addition, the types of natural disasters covered should be expanded to cover other disasters. In addition to natural disasters, it is also possible to simulate pandemics, hybrid risks and humanitarian crises in order to sustainably expand NATO and national capabilities in the area of administrative assistance and crisis support.

The following list gives a detailed overview of the usage ideas and research challenges directly identified from the MSG-147 activities and lessons identified/Learned:

- Application of the technical platform in context of CAX, decision-making support and training
- Selection of SOP by artificial intelligence
- Extension of CMDR IDE interoperability to accommodate more models
- Extension of the disaster module in CMDR IDE to deal with further disaster types
- Extension of the established disaster database
- Enhancement of C2-Systems capability to deal with dynamic disaster information
- Support of decision-making capability by the use of drones as sensors and computer vision technology to augment in crisis data collection and situational awareness
- Augmentation of training by VR-training scenarios and/or gamification
- Establishment of a resilience assessment model for potential affected areas → Simulate resilience level of affected areas → Consult decision-makers based on estimated resilience levels of affected areas to recommend different courses of action during disasters
- Development of HLA Commander, transferring orders back to the HLA federated simulation system. The IABG not only developed FOM which standardized the transfer of information about disaster objects but also to handle and depict the disaster management (disaster related orders and reports).
- Development of a concept for CMDR COE (Disaster and Climate Change Implications on military activities) in accordance with NATO CD&E Methodology.

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