NORTH ATLANTIC TREATY ORGANIZATION

SCIENCE AND TECHNOLOGY ORGANIZATION

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STO TECHNICAL REPORT **TR-MSG-147**

Modelling and Simulation Support for Crisis and Disaster Management Processes and Climate Change Implications

(Aide apportée par la modélisation et simulation aux processus de gestion des crises et des catastrophes et aux implications du changement climatique)

This report describes the outcomes of the activity performed during the study.

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The NATO Science and Technology Organization

Science & Technology (S&T) in the NATO context is defined as the selective and rigorous generation and application of state-of-the-art, validated knowledge for defence and security purposes. S&T activities embrace scientific research, technology development, transition, application and field-testing, experimentation and a range of related scientific activities that include systems engineering, operational research and analysis, synthesis, integration and validation of knowledge derived through the scientific method.

In NATO, S&T is addressed using different business models, namely a collaborative business model where NATO provides a forum where NATO Nations and partner Nations elect to use their national resources to define, conduct and promote cooperative research and information exchange, and secondly an in-house delivery business model where S&T activities are conducted in a NATO dedicated executive body, having its own personnel, capabilities and infrastructure.

The mission of the NATO Science & Technology Organization (STO) is to help position the Nations' and NATO's S&T investments as a strategic enabler of the knowledge and technology advantage for the defence and security posture of NATO Nations and partner Nations, by conducting and promoting S&T activities that augment and leverage the capabilities and programmes of the Alliance, of the NATO Nations and the partner Nations, in support of NATO's objectives, and contributing to NATO's ability to enable and influence security and defence related capability development and threat mitigation in NATO Nations and partner Nations, in accordance with NATO policies.

The total spectrum of this collaborative effort is addressed by six Technical Panels who manage a wide range of scientific research activities, a Group specialising in modelling and simulation, plus a Committee dedicated to supporting the information management needs of the organization.

- AVT Applied Vehicle Technology Panel
- HFM Human Factors and Medicine Panel
- IST Information Systems Technology Panel
- NMSG NATO Modelling and Simulation Group
- SAS System Analysis and Studies Panel
- SCI Systems Concepts and Integration Panel
- SET Sensors and Electronics Technology Panel

These Panels and Group are the power-house of the collaborative model and are made up of national representatives as well as recognised world-class scientists, engineers and information specialists. In addition to providing critical technical oversight, they also provide a communication link to military users and other NATO bodies.

The scientific and technological work is carried out by Technical Teams, created under one or more of these eight bodies, for specific research activities which have a defined duration. These research activities can take a variety of forms, including Task Groups, Workshops, Symposia, Specialists' Meetings, Lecture Series and Technical Courses.

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List of Acronyms

C2	Command and Control
C-BML	Coalition Battle Management Language
CBRN	Chemical Biological Radiological Nuclear
CCI	Climate Change Implications
CDM	Crisis Disaster Management
CIS	Communication Information System
CRISMA	Crisis Management for Improved Action and preparedness
DeMIST	Disaster Management Interoperability Simulation and Training
DIS	Distributed Interactive Simulation
DMIS	Disaster Management Information Systems
DRA	Disaster Risk Assessment
DSS	Decision Support Systems
DSSEP	Distributed Simulation Engineering and Execution Process
FOM	Federation Object Model
GIS	Geographic Information System
GRCM	Generic Response Capability Model
GRIM	Guidance, Rationale, and Interoperability Modalities
HLA	High-Level Architecture
IFRC	International Federation of Red Cross
JALLC	Joint Analysis and Lessons Learned Centre
JCATS	Joint Conflict and Tactical Simulation
JFTC	Joint Force Training Centre
JTLS	Joint Theater Level Simulation
JWC	Joint Warfare Centre
LOE	Limited Objective Experiment
M&S	Modelling and Simulation
MIM	Management Information Model
MOM	Management Object Model
MRM	Multi-Resolution Modelling
MSDL	Military Scenario Definition Language
NETN	NATO Education and Training Network
NIEM	National Information Exchange Model
RPR FOM	Real-Time Platform Reference Federation Object Model
RTI	Run Time Infrastructure
SCP	Service Consumer Provider
SEDM	Southeastern Europe Defence Ministerial
SEDRIS	Synthetic Environment Data Representation and Interchange Specification
SEEBRIG	South Eastern Europe Brigade

SOM	Simulation Object Model
SPARC	Spatial Risk Calendar
SSTR	Support for Stability, Security, Transition
TMR	Transfer of Modelling Responsibility
WFP	World Food Programme

Glossary

For the study, the following list has been compiled from existing glossaries and other reference material available to the public, with a focus on their common usage relating to natural disasters and complex emergencies.

Civil Protection	Activities undertaken by emergency services to protect populations, properties, infrastructure and the environment from the consequences of natural and technological disasters and other emergencies [1]. The package of measures that ensures the protection of citizens, and their environment, vis-à-vis natural and technological risks [2]. Any civilian measure taken to protect the population and its livelihood from the impact of wars, armed conflicts, disasters and other major emergencies as well as any measure taken to prevent, mitigate the impact of and cope with these events (Civil Protection in Germany). The complex concept refers to activities which protect civil populations against natural and technological disasters [3].
Complex Emergency	The official definition of a complex emergency is "a humanitarian crisis in a country, region or society where there is a total or considerable breakdown of authority resulting from internal or external conflict and which requires an international response that goes beyond the mandate or capacity of any single agency and/ or the ongoing United Nations country program" [4]. Such "complex emergencies" are typically characterized by: • Extensive violence and loss of life; massive displacements of people; widespread damage to societies and economies; • The need for large-scale, multi-faceted humanitarian assistance; • The hindrance or prevention of humanitarian assistance by political and military constraints; and • Significant security risks for humanitarian relief workers in some areas.
Crisis	A time-bound state of (objective or subjective) uncertainty and major non-routine events putting to the test the overall resilience and preparedness of a system and its established procedures [5].
Crisis Management	The coordinated actions taken to defuse crises, prevent their escalation into an armed conflict and contain hostilities if they should result [1]. An iterative process of organized and coordinated actions, by and among all responsible stakeholders at the local, national, regional and international levels, aimed at handling a crisis at all its phases [5].

Disaster	A serious disruption of the functioning of a community or a society causes widespread human, material, economic and/or environmental losses which exceed the ability of the affected community or society to cope using its level of resources [6]. A sudden change or failure in collective routines caused by an extreme event – natural or human-induced, or a multitude of events, which disturb system functions and thereby necessitate urgent collaborative intervention to reinstate routine or to adapt to disruption [5]. Situation or event, which overwhelms local capacity, necessitating a request to the national or international level for external assistance [7].
Disaster Response	A sum of decisions and actions taken during and after disaster, including immediate relief, rehabilitation, and reconstruction [6]. Coordinated, targeted, tailored, and timely decisions and (re)actions during and/or immediately following a disaster taken by disaster management actors to expediently cope with immediate effects [5]. The set of activities implemented after the impact of a disaster to assess the needs; reduce the suffering; limit the spread and the consequences of the disaster; open the way to rehabilitation [2]. Disaster response is predominantly focused on immediate and short-term needs and is sometimes called "disaster relief." The division between this response stage and the subsequent recovery stage is not clear-cut. Some response actions, such as the supply of temporary housing and water supplies, may extend well into the recovery stage [6]. The provision of emergency services and public assistance during or immediately after a disaster to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected.
Disaster Relief	Assistance and/or intervention during or after disaster to meet life preservation and basic subsistence needs [6]. The organized response to assist those affected by a disaster. DR is one of the most prevalent types of HA. It requires rapid reaction, and often includes services and transportation, rescue and evacuation of victims, the provision of food, clothing, medicine and medical services, temporary shelter, technical assistance, and repairs to essential services [8].
Emergency	An emergency is an event that can be responded to using the resources available at hand, implying that there is no need to request external assistance.
Federation of Networks	Collection of capabilities in which independent constituent systems are centrally managed into a coherent capability. In the NATO Network Enabled Capability (NNEC), NATO performs the functions that federate these capabilities without commanding national components [9].
Federation of Systems	A set of systems connected or related to produce results unachievable by the individual systems alone, that is managed without central authority [10].

Humanitarian Assistance	Aid is provided to a crisis-affected population that seeks, as its primary purpose, to save lives and alleviate suffering of a crisis-affected population. Humanitarian assistance must be provided in accordance with the basic principles of humanity, impartiality, neutrality and independence. Inter-Agency Standing Committee [4]. As part of an operation, the use of available military resources to assist or complement the efforts of responsible civil actors in the operational area or specialized civil humanitarian organizations in fulfilling their primary responsibility to alleviate human suffering [1]. Specific types of military support to Humanitarian Assistance: • Disaster Relief; • Support to dislocated civilians; • Technical assistance and support; • Chemical, Biological, Radiological, and Nuclear (CBRN); Consequence Management (CM); and • Security [8].
Interoperability	The ability to act together coherently, effectively and efficiently to achieve Allied tactical, operational and strategic objectives [1]. The ability of systems to provide and receive services from other systems and to use the services so interchanged to enable them to operate effectively together [11].
Military and Civil Defence Assets	Comprises relief personnel, equipment, supplies and services provided by foreign military and civil defence organizations for international humanitarian assistance. When these assets are under UN control they are referred to as UN MCDA [12].
Model	A physical, mathematical or otherwise logical representation of a system, entity, phenomenon, or process [13]. A representation of a subject of interest. A model provides a smaller scale, simplified, and/or abstract representation of the subject matter. A model is constructed as a "means to an end." In the context of enterprise architecture, the subject matter is a whole or part of the enterprise and the end is the ability to construct "views" that address the concerns of particular stakeholders; i.e., their "viewpoints" in relation to the subject matter [11].
Other Deployed Forces	All military and civil defence forces deployed in the region other than UN MCDA [12]. The National Academy of Sciences (NAS) defines disaster resilience as "the ability to plan and prepare for, absorb, recover from, and adapt to adverse events" [14]. The four phases of resilience are: plan – absorb – recover – adapt. The ability of a functional unit to continue to perform a required function in the presence of faults or errors [14]. The capability to anticipate risk, limit impact, and bounce back rapidly through survival, adaptability, evolution and growth in the face of turbulent change [15].

System

An assembly of doctrines, methods, personnel, procedures, equipment, or facilities organized to accomplish specific functions [16].

In CIS terms, a system is generally interpreted as an integrated set of (usually domain specific) functions and services to support a capability (as described above) together with their materiel elements (personnel and other resources); examples of such are the Bi-SC AIS (Bi-SC Automated Information System), NGCS (NATO General Purpose Communications Segment) and SATCOM (Satellite Communication) systems. The scope and boundaries, by which a system is described, whilst never fully or rigidly defined, are usually denoted by a set of related operational support functions and established through one or more Capability Packages (CP). The implementation of a system (or components thereof) is the contributory elements of a fielded capability [17].

REFERENCES

[1] NATO Standardization Office (2021). AAP-6: NATO Glossary of Terms and Definitions.

[2] Assar, M. (1971). Guide to Sanitation in Natural Disasters, WHO, Geneva.

[3] Alexander, D.E. (2002). Principles of Emergency Planning and Management. Oxford University Press on Demand.

[4] Inter-Agency Standing Committee (IASC) Working Group XVIth Meeting (30 November 1994). Definition of Complex Emergencies.

[5] Crisis Management and Disaster Response Centre of Excellence (CMRE COE) (n.d.). Crisis and Crisis Management.

[6] UN International Strategy for Disaster Reduction (UNISDR) (2009). UNISDR Terminology on Disaster Risk Reduction.

[7] Centre for Research on Epidemiology of Disasters (CRED) (2019). International Emergency Disasters Data Base (EMDAT), Brussels, Belgium.

[8] NATO Standard AJP-3.4.3 Allied Joint Doctrine for the Military Contribution to Humanitarian Assistance. Edition A Version 1, October 2015. NATO Standardization Office, (NSO).

[9] NATO Network-Enabled Capabilities Concept (NNEC) Vision & Concept.

[10] DeLaurentis, D., Callaway, R.K. (November 2004). A System-of-Systems Perspective for Public Policy Decisions, 21(6), Review of Policy Research, pp. 829-837.

[11] TOGAF® 9.1 The Open Group, Specification.

[12] Office for the Coordination of Humanitarian Affairs (OCHA), (2007). Oslo Guidelines. Guidelines on The Use of Foreign Military and Civil Defence Assets In Disaster Relief. Revision 1.1. United Nations.

[13] Wikipedia (4 May 2023). Modeling and Simulation.

[14] National Research Council (2012). Disaster Resilience: A National Imperative. Washington, DC: The National Academies Press.

[15] Plodinec, J. (2013). Definitions of Community Resilience, an Analysis, p. 10. The Community and Regional Resilience Institute (CARRI).

[16] NATO – AAP-31(A). (2001). NATO Glossary of Communication and Information Systems Terms and Definitions.

[17] NATO CIS Policy in Support of Capability Management, version 1.3 of 31 March 2009.

Foreword

The responsibility for crisis management and disaster response is different for every nation and may involve several ministries and agencies. It is also a core task of the Alliance. Today the Alliance can take decisions in crisis and emergencies, and act under significant threat and time pressure. NATO develops capabilities to be ready, on a case-by-case basis and by consensus, to contribute to effective crisis and disaster prevention. This enables the Alliance to engage actively in crisis management and disaster response, including through non-Article 5 crisis response operations. The Alliance is therefore encouraging the joint training of military and civilian personnel to help build trust and confidence.

NATO's role in crisis management and disaster response goes beyond military operations and includes crisis and disaster response operations, meant to prevent and protect against natural or manmade disasters. A crisis can be political, military, social, or humanitarian, and therefore the NATO Crisis Response System covers different means and capabilities for dealing with these diverse forms of crises, including disaster response.

Based on the recognition that military intervention alone cannot resolve a crisis or ensure recovery after disasters, the NATO Summit Declarations and the Strategic Concept emphasize the need for NATO to enhance its contribution to the Comprehensive Approach to crisis management. As a result, NATO is currently putting a lot of effort into the Comprehensive Approach. The goal is to anticipate and enhance the Alliance and Nations' civilian and military capabilities for crisis management and disaster response.

Close cooperation in the crisis management and disaster response domain requires forming appropriate military and civilian capabilities. These capabilities will include information and intelligence sharing, developing and operating early warning systems (in support of building common situational awareness), as well as conducting crisis and disaster planning and response and preparedness for Climate Change.

Any creation of a CMDR M&S Laboratory should have its operational capability established and operational in time to support the planned NATO Crisis Management Exercises as well any regional Network projects or exercises and training.

Enhanced NATO Policy on NATO Crisis Response System (NCRS) and Civil Emergency Planning in NATO according: C-M (2001)63 NCRS: Policy Guidelines; NATO Crisis Response System AC/237 D(2012)001, 04 May 2012; PO(2000)30-Rev 2, Role of Civil Emergency Planning in NATO.

The ability to respond to crisis management and disaster response inquiries will be rich with operational opportunities for providing subjective responses and training activities. However, this gap will require a pre-feasibility and scoping study to determine if it is eligible for support using M&S.

That said, the capabilities of the CMDR Training and Climate Changes preparedness can be greatly enhanced and increased with the addition of some unique crisis management and disaster response tools, software and simulation systems.

The additional creation of an M&S Laboratory specialized for CMDR Training and Climate Change preparedness would provide NATO with a unique comprehensive training and analytical capability unmatched anywhere in the world and applicable to non-military type operations. This M&S Laboratory would be able to support large-scale CMDR distributed exercises and analyses with specific crisis management and disaster response tools and simulations. This new crisis management and disaster response The laboratory should also be supported by operationally experienced simulation subject matter expert personnel to ensure successful operations, exercises, and support activities right from the beginning of the operation.

By more effectively integrating this aspect, the NATO force structure can be more prepared for the next conflict by providing support for capability building; improving interoperability and supporting capability development through education and training for NATO and partner leaders and units; testing doctrines; developing and validating concepts through experimentation; providing lessons learned, evaluations, and assessments.

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Modelling and Simulation Support for Crisis and Disaster Management Processes and Climate Change Implications

(STO-TR-MSG-147)

Executive Summary

Crisis management is a core task of NATO. Today, the Alliance is confronted with crises and emergencies 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 through 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 and disaster decision-making support.

The objective of the MSG-147 project and the CMDR CoE was to develop a reference architecture and implement a technical platform to enable rapid and effective testing of crisis/disaster and climate change response plans. 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 on disaster-related events in an 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.

This document describes the challenges, the work carried out and the results achieved as a German contribution to support the NMSG-147 project. The German contribution included both conceptual and technical achievements. CD&E (Concept Development and Experimentation) methods were used to investigate and validate the resulting conceptual requirements and technical solutions.

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.

Aide apportée par la modélisation et simulation aux processus de gestion des crises et des catastrophes et aux implications du changement climatique

(STO-TR-MSG-147)

Synthèse

La gestion de crise est une tâche centrale de l'OTAN. Aujourd'hui, l'Alliance est confrontée à des situations de crise et d'urgence et doit agir dans un contexte de risque élevé, avec des contraintes temporelles considérables. L'OTAN met au point des capacités qui contribuent à une gestion efficace des crises et à la prévention des catastrophes au cas par cas et de manière consensuelle. Cela permettra à l'Alliance de participer activement à la gestion des crises et des catastrophes, y compris par le biais d'opérations d'intervention en cas de crises ne relevant pas de l'article 5. L'Alliance promeut donc la formation mixte du personnel militaire et civil pour contribuer au renforcement de la confiance. Ces exigences opérationnelles doivent être traduites en capacités techniques des systèmes, ce qui signifie qu'il faut mettre en œuvre des solutions techniques dans le cadre de la formation et de l'aide à la prise de décision en cas de catastrophe.

L'objectif du projet du MSG-147 et du CoE CMDR était de développer une architecture de référence et de mettre en œuvre une plateforme technique permettant d'essayer de manière rapide et efficace les plans de réaction aux crises/catastrophes et au changement climatique. Le projet comprenait des activités de recherche, d'élaboration théorique et conceptuelle, de normalisation et d'amélioration de l'interopérabilité. Ces activités devaient être mises en place à l'aide de divers outils et simulations propres à l'OTAN, destinés à la gestion de crise et la protection civile et facilitant les opérations non militaires.

Dans ce contexte, les prestations techniques du groupe MSG-147 se sont révélées excellentes, à travers la création d'unités de simulation permettant l'échange de données d'événements liés à des catastrophes dans un environnement HLA et la transmission simultanée de ces informations (rapports/état des unités) aux systèmes militaires (OTAN et nationaux) et civils C2. Le présent document décrit les difficultés, le travail effectué et les résultats de la contribution allemande au soutien du projet du MSG-147. La contribution allemande comprenait à la fois des réalisations conceptuelles et techniques. Des méthodes d'élaboration et expérimentation de concepts (CD&E) ont été utilisées pour étudier et valider les exigences conceptuelles et les solutions techniques qui en ont résulté.

Afin de proposer une solution mise en œuvre, le module FOM pour les catastrophes (compatible et intégrable dans le FOM NETN v2) a été développé et testé en tant que contribution allemande à l'assistance technique du projet du MSG-147. L'application de la méthode et des procédures CD&E à l'évaluation de nouvelles solutions techniques dans le domaine de la M&S et la mise en œuvre de ces dernières a constitué une innovation particulière de l'investigation technique du concept.

MODELLING AND SIMULATION SUPPORT FOR CRISIS AND DISASTER MANAGEMENT PROCESSES, AND CLIMATE CHANGE IMPLICATIONS

1.0 INTRODUCTION

1.1 Background and Operational Context

As outlined in the 2010 Strategic Concept as well as in subsequent documentation, crisis management is one of NATO's fundamental security tasks and capabilities. NATO's role in crisis management goes beyond military operations and is aimed at deterring and defending against threats to Alliance territory and the safety and security of Allied populations. It can involve military and non-military measures to address the full spectrum of crises – before, during, and after conflicts. A crisis can be political, military, or humanitarian and can also arise from a natural disaster or as a consequence of technological disruptions.

One of NATO's core strengths is its inherent crisis management capacity. It is based on established operational and institutional experiences, tested crisis management procedures, and an integrated military command structure. NATO develops capabilities to be ready to contribute to effective crisis management and disaster prevention when needed. This enables the Alliance to actively engage in crisis management and disaster response, including through non-Article 5 crisis response operations. These capabilities allow NATO to deal with a wide range of crises in an increasingly complex security environment, employing an appropriate mix of political and military tools to help manage emerging crises, which could pose a threat to the security of the Alliance's forces, territory and populations. Some operations may also include partners, non-NATO countries and other international actors such as Non-Governmental Organizations (NGOs). NATO member states have recognized that the military alone cannot resolve a crisis or conflict, and lessons learned from previous operations highlight that a comprehensive political, civilian, and military approach is necessary for effective crisis management.

The challenges of natural disasters as well as climate change implications in the course of NATO operations highlight the necessity of sound strategic, operational, organizational, and logistical planning. In light of the potentially widespread nature of any given crisis as well as the associated time-criticality in decision-making processes, a comprehensive approach to the utilization of data, standardization of information-gathering processes, Modelling and Simulation (M&S), and ultimately training for the benefit of disaster risk analysis and management is necessary.

1.2 Aim of this Project and Requirements

At a conceptual level, this report outlines the required framework, development, and analytical and methodological background necessary to enhance NATO's crisis and natural disaster management and mitigation capabilities. The concrete goal of the project is to develop a technical platform capable of supporting and conducting crisis management and disaster response exercises and analysis. It should be established with several federated crisis management and disaster response tools and simulations that are unique to NATO and enable military and non-military-type operations in the course of natural disasters. The conceptual elaboration of the theoretical, methodological, and technical framework has the benefit of bringing a more holistic approach to the concrete goal of establishing a crisis decision-making support mechanism. The intended objectives are to:

- Establish a standardized dataset to facilitate natural disaster analysis;
- Predict crisis development and trends in the course of natural disasters that might impair NATO missions and operations, including non-Article 5 operations;

- Evaluate available tools based on using specific system solutions to model and simulate natural disasters and their effects on NATO operations;
- Support crisis readiness by providing disaster models to simulation systems;
- Facilitate training and exercises to prepare and educate commanders adequately about the implications of climate change implications and natural disasters in any operational environment;
- Support decision making by providing disaster models and simulations for decision making before, during and after natural disasters;
- Develop a dynamic and adaptive crisis management process for any given natural crisis or disaster to reduce its effects on NATO operations;
- Derive solutions that may improve existing SOPs and best practices of military and crisis management operations during natural disasters; and
- Deduce recommendations for NATO-CIMIC operations during natural disasters.

1.3 Target Audiences of this Concept

This concept aims to outline the required framework, development, and analytical and methodological background necessary to enhance NATO's crisis and natural disaster management and mitigation capabilities. This concept targets responsible political, military, and civilian decision makers in NATO member states. In addition, all training and exercise facilities within NATO, as well as all national training facilities addressing training and exercises in preparation for operation before, during, and after natural disasters, are considered as an audience.

1.4 Conceptual Parameters, Synergy and Delimitation

This concept aims to have a broad range of scenario applicability as well as flexibility through fluid parameters. Wherever possible, this will be achieved through the use of open standards and data exchange formats. In addition to its special focus on Climate Change Implications (CCI), which can be considered as simulating and analyzing long-term effects, it also strives for solutions in decision-making support for rather short-term direct effect scenarios or (mainly for training/exercise purposes) for ad hoc situations.

Furthermore, the concept strives to dissolve delimitations related to narrowed viewpoints about the source of a crisis or specific disaster, which can be natural or accidental vs. purposely man-made. Moreover, it aims at the full inclusion of relevant stakeholders from all related communities of interest. Against this background, it tries to create and use synergies between the various subject matter experts involved, from academia, industry, and, last but not least, the NATO Centre of Excellence community.

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 to be able to plan and conduct multinational crisis management operations, often on short notice. In this context, NATO is an enabler, helping 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 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 adapting to the evolving security context. Over time, NATO has led and conducted several crisis management operations, including beyond the Euro-Atlantic area.

Shortcomings, however, presently exist in the degree of data standardization, accumulation, accessibility, and validation, as well as harmonization. In addition, no NATO-wide-accepted computer-based M&S system is in place to comprehensively support training, exercises and decision-making processes before, during or after natural disasters. Thus, no NATO-based exercises and training standards for natural disasters can be established, nor can existing SOPs and best practices be tested or enhanced. This project aims to increase NATO's capabilities to adequately prepare for any given military lead or supported crisis operation in the course of a natural disaster by providing a technical framework of simulation tools to be used, both for training and decision-making support purposes.

2.1 Findings, Current Stage of Proceedings, and Shortcomings

Appropriate approaches and tools are currently not available to significantly support 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, reducing force protection and survivability as well as the sustainability of operations in light of any given CCI crisis. Current approaches in crisis management decision-making support are not based on 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.

An overarching part of this concept is to address those shortcomings to channel information to member states through data standardization and provide a generally accepted M&S architecture. Based on such a system, decision-making support processes for CCI-related crises can be established and ultimately improve SOPs when dealing with natural disasters.

A capability gap in the use of M&S exists in 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, and expertise. Efforts have been made to provide military simulation support to training and exercises involving emergency managers. For example, since 2002 the Southeastern Europe Defence Ministerial (SEDM) has organized the SEESIM series of interagency exercises with the military, ministry of interiors (including fire and police departments), and civil protection departments of several countries of southeast Europe. Through effective use of computer M&S, SEESIM aimed to promote cooperation, coordination, and interoperability among the SEDM nations and the SEDM initiatives, among others, the South Eastern Europe Brigade (SEEBRIG). However, participation by civil protection and the Ministry of Interiors in the planning phase of exercises has usually been limited, with more attendees present during the exercise execution. While civilian agencies operate on the business model of a Police Department with continuous full employment of resources, little slack in the system, and focus on the steady state, the military operates more on the business model of a Fire Department preparing for a contingency and with a focus on contingency response.

2.2 Conceptual Requirements

The capabilities of each tool and simulation will be described and outlined and its applicability to NATO purposes will be assessed using Limited Objective Experiments (LOEs). The software environment requirements are as follows:

- Automated data collection;
- Engine for modelling with defined triggers;

- C2 logic and SOPs implementation;
- A dynamically generated plan for Crisis/Disaster Response; and
- Prognosticate and climate change analyses.

2.3 Conceptual Solutions

The conceptual approach aims to develop solutions to enhance the crisis management capabilities of NATO member states, including non-Article 5 crisis response operations and especially those related to 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 as the profession. The Alliance also encourages joint training of military and civilian personnel to help build trust and confidence.

The scenarios that armed forces face in the 21st-century call for **credible, federated, aware, resilient** and **agile** responses [1]:

- **Credibility** refers to the ability to deter and defend against potential adversaries [1];
- **Federated implies dialogue, linkages, synchronization**, and collaboration with a broad community of internal and external stakeholders, to promote the unity of effort and improve efficiency in achieving a well-defined operational end-state [1];
- **Aware** refers to developing a comprehensive and accurate shared understanding of the operational environment to enable accurate and timely decision making [1];
- **Resilient** stresses the ability to retain capable forces and conduct successful operations despite surprise or strategic shock [1]; and
- **Agile** refers to the ability to respond effectively to dynamic, complex and uncertain operational challenges with appropriate, flexible, and timely actions [1].

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

- Conceived and usable also for non-military purposes (**multi-purpose by design**);
- Able to integrate with civilian components according to a “preventive” collegial approach; and
- Flexible and multi-faceted, so their high cost can also be translated into more services for the benefit of the community.

Mission Command implies that the future security environment will be characterized by rapidly changing situations that are fluid and dynamic and which may require decentralized execution, the application of a mission command mindset, and flattened command structures where appropriate. A mission command culture often improves resilience by enabling forces to perform the correct actions that lead to mission accomplishment when a centralized command system is not optimal [2]. Accordingly, Multi-purpose by design is one of the prerequisites for Agility [1].

In conjunction with CCI, the approach laid out in this concept will increase the proactive reduction of vulnerabilities and may serve as a 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 will concentrate 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 to preserve freedom of action and operational effectiveness thereby contributing to mission success.
- **Resilience:**
  - The capability to anticipate risk, limit impact, and bounce back rapidly through survival, adaptability, evolution and growth in the face of turbulent change;
  - Resilience can also be defined as the ability of a system to perform four functions to adverse events: planning and preparation, absorption, recovery, and adaptation [3].
- **Sustainability of operations:**
  - The aim is to improve and, where appropriate, develop the enablers that enhance NATO's ability to support expeditionary forces and sustain them for extended periods while retaining the ability to support large-scale high-intensity operations following 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. The expected benefits are:

- Reduction in human error during data collection and modifying process;
- Crisis/Disaster evolution trend forecast, synthesizing and usage of best practices experience and knowledge related to specific system conditions;
- Fast and accurate calculations for support of decision makers;
- Enhancing CMDR exercises, experiments, tests, evaluations and analyses towards a realistic environment;
- Prognostication and evaluation of disasters in support of decision makers; and
- Evaluation of Climate Change Implications on military activities.

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

3.1 Project Outline

The project has three main directions for analyzing CDMP in NATO 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; and
- 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 proposal for Response Plan; and
- LL process.

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

The following software components (as shown in Figure 1) should be developed 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 mathematical representations as possible 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 response. To each elementary action of the SOPs, metadata containing relevance to the event, priority and sequence, and dependences will be added; and
- **Filtering and Distribution Module** – will filter the relevant elementary response actions and will dynamically generate a proposal for a Response Plan or a Prevention and Preparedness Measures proposal. The generated analysis and disaster development forecasts will be distributed to defined clients.

The technical architecture should include a database holding data from mathematical models for different disaster types which will be visualized in an interface. The collected results will be compared with statistical and historical data from events that have already occurred. Depending on constant indexes such as infrastructure, Geographic Information Systems, vegetation, and others, a probability in per cent for the exactness of the model will be shown. The Human impacts will be assessed by the decision makers. In that way the architecture will define the accuracy of different models for different disasters and each decision maker can choose what kind of model to work for different situations.

A disaster risk management assessment will be made depending on a given task, whereas during the operation planning phase, statistical data, and through the operation phase, real-time field data will be used. Firstly, the architecture will be tested through training and exercises and if the results are satisfactory, then it will be implemented on the operational (strategic) level. The repository with disaster models will be connected through HLA with federated simulation systems and tools that have been proven useful for different disasters or crises. The calculated results of the models will be published in the simulations as objects. For that purpose, a Federation Object Model (FOM) for different disasters should be created. According to the AMSP-04 [4] 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 [5] to specify available infrastructure services and APIs for accessing them. The HLA standard also specifies how to document information exchange using a FOM.

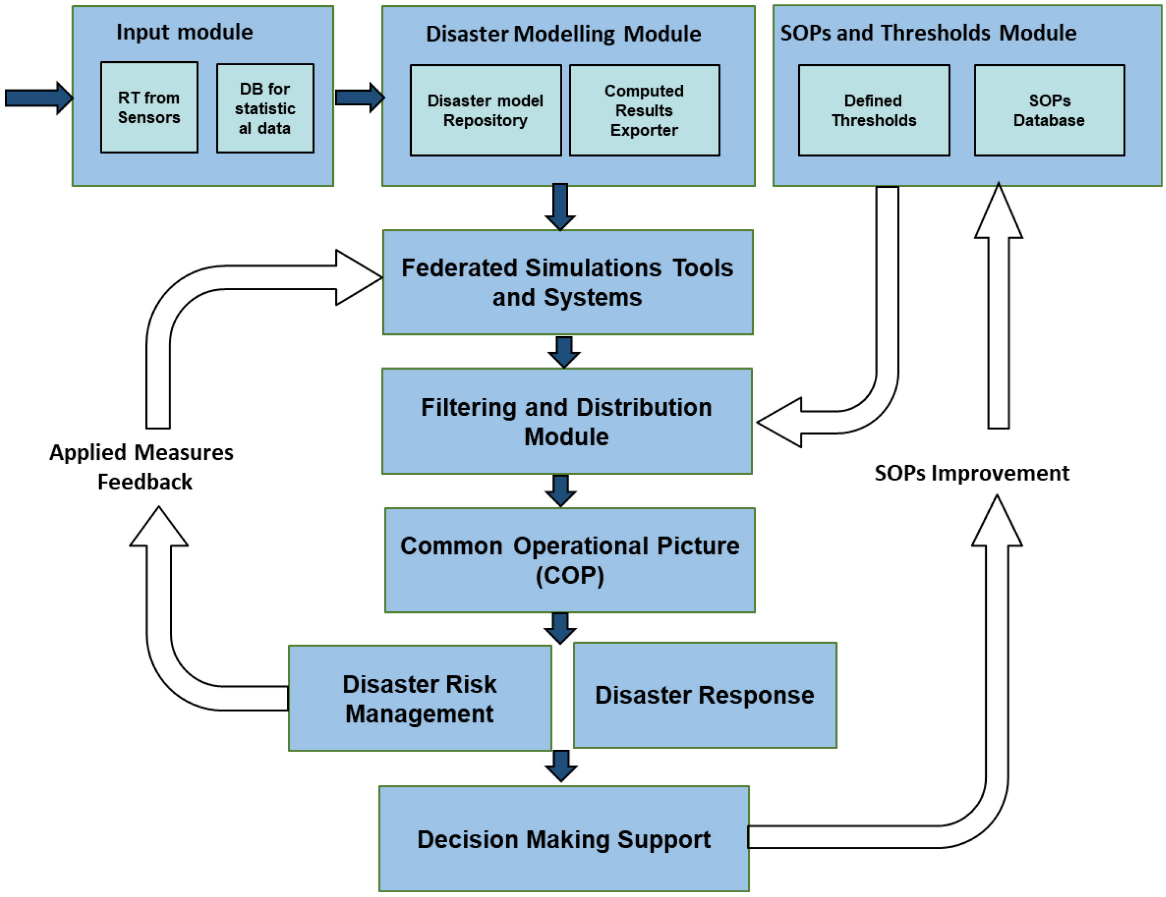

Figure 1: Technical Architecture for CDMP and CCI.

3.2 Project Objectives

The project aims to develop a reference architecture and demonstrate a technical platform that enables prompt, reasonable, and effective tests of Crisis/Disaster and CCI response plans on a conceptual level. This development includes theory and concept creation, standardization and interoperability improvements.

3.3 Project Tasks

The project consists of the following tasks and objectives, some of them enabling parallel development:

- To develop a reference architecture for CMDR exercises and analysis in support of the CMDR community (NATO, EADRCC, EDRC, etc.);
- To demonstrate a technical platform that enables prompt, reasonable and effective tests of Crisis/Disaster and Climate Change Implication (CCI) Response plans;
- To develop a concept and relevant/unified SOPs/SOIs for the simulation/technical platform;
- To develop a database for storage and management of the information and data related to crises and disasters;
- To develop the capability to determine players, objects, infrastructures, and systems. The following should be defined: location, form, vulnerability, and relations with other objects/systems. (Capability to include data import from different sources like GEO information);

- To develop the capability for implementation of control logic (command and control system, decision making and supporting system);
- To develop capabilities for modelling and simulation of crisis and disaster events:
- Module for modelling environment parameters under defined initial conditions;
- Engine for model generation based on statistical data;
- Replay the events using the stored information in the database.
- To develop capabilities for education and training;
- To develop artificial intelligence for simulating the actions of individual or collective players;
- To develop a report-generating module for the environmental parameters; and
- To facilitate the integration with other software tools used in NATO.

3.4 Project Scope, Exclusions, Assumptions, and Constraints

3.4.1 Scope and Exclusions

The project combines the NATO Crisis Response Process with industrial theory for system control in predefined parameters. The task is significantly large in scale and originates from the CMDR COE capabilities. However, it could be easily divided into subtasks and spread among NATO nations, bodies, organizations and partners. A technical platform available for support will ensure the success of the key capabilities.

3.4.2 Constraints

- A maximum of 3 or 4 “live” meetings per year;
- The group is international and needs to work online for the majority of the time;
- Meetings and working in the group are not funded;
- Lack of NATO definitions of Crisis and Disasters;
- M&S world faces problems including predictive analysis;
- Each nation is encouraged to participate with two persons and decide which sub-group to sign up for; and
- Emphasis on analysis and training focus in the deliverables because these are different aspects of the work.

3.4.3 Assumptions

- External SMEs from companies and industries;
- Using WEBEX or other tools for online conducting meetings;
- The appointed persons will be funded by their respective nations to attend/host meetings for the full duration of the working group;
- Usage of national definitions for crisis and disasters. Interconnection between different types of hazards and disasters to be also looked upon;
- Creation of a repository database for existing tools in NATO (JCATS) to give the Decision-Making choice to pick the most appropriate;

- The research will be required for a clear understanding of existing data and to clarify what is to be collected for the support of the group;
- Experience to be shared to avoid duplication of effort;
- Categorize existing M&S solutions and develop missing human society models;
- Even with NATO as the main end user, civilian actors should be involved. To this extent, CMDR COE should in the end become the custodian of the product developed by MSG-147. NATO HQ (CMX) should be one of the main customers;
- Because the military would be always in support (NATO not being a major stakeholder in the field of disaster response) it is favorable to check how MOIs or equivalent agencies are dealing with the problem to better start with the concept development for the project;
- Opportunities to be explored for test cases and possible scenarios creation; and
- Participants in the group have basic knowledge and need more specific training and education for different types of M&S systems and tools.

3.4.4 User(s) and Other Known Interested Parties

- NATO training centers (JFTC, JWC, JALLC) could be the main end user;
- CMDR COE could become the custodian of the product developed by MSG-147;
- COEs related to disasters and CCI could become technical architecture users;
- NATO HQ is one of the main customers;
- Industry and other educational and training centers;
- MOIs/MODs or equivalent agencies; and
- Others.

3.5 Project Timeline/Activities

The MSG-147 group was formed in March 2016. The duration of MSG-147 was originally set to three project years. In 2018, an extension for another year was requested and approved. The initial timeline planning was linked to the operational support for key events in the crisis management and disaster response community (NATO CMX, EADRCC exercises, others) as the major Initial Operational Capability (IOC) milestone. The three (3) phases of this project were synchronized and overlapped to move forward at a rapid pace:

- **Phase 1:** twelve (12) months in length to result in the development and approval of a Master Plan to guide and direct this project. It would also produce all the requirements, identifying the products and specifications for support of the crisis management and disaster response technical platform;
- **Phase 2:** twenty-four (24) months in length to result in the IOC of the crisis management and disaster response technical M&S platform. Planning experimentation, testing and training for CMXs would be conducted as well during this phase; and
- **Phase 3:** twelve (12) months in length and results in successful support and execution of CM exercises and analysis efforts as part of the operational support of the crisis management and disaster response technical platform. During this phase, experienced subject matter experts in the operational use in support of real-world customers will support the platform. They will also conduct advance training in the use of the fielded simulations and tools.

The phases were adjusted in the course of the project to reflect necessary changes during the development and examination of the core conceptual and technical requirements. Each phase was concluded with a Limited Objective Experiment. In addition, during each phase, multiple conceptual workshops, planning conferences, technical workshops and pre-tests were conducted before each respective LOE. The group members held numerous WebEx meetings monthly for the duration of the project to facilitate the necessary workflow.

To address the interested M&S community as well as other stakeholders, MSG-147 group members presented their progress and findings at various conferences, such as I/ITSEC, CMDR COE Annual Conference, ITEC and NATO-CAX Forum.

Table 1 lists the project groups' workshops, meetings, conference attendance and experiments by date.

Table 1: Lists the Project Groups' Workshops, Meetings, Conference Attendance and Experiments by Date.

No.	Location	Dates
1.	Sofia, Bulgaria	17 – 19 March 2016
2.	Sofia, Bulgaria	02 – 04 June 2016
3.	Ottobrunn, Germany	19 – 20 September 2016,
4.	I/ITSEC, Orlando, USA	28 – 30 November 2016
5.	Rome, Italy	01 – 03 February 2017
6.	Sofia, Bulgaria	20 – 24 March 2017 LOE1
7.	Rotterdam, NED	16 – 18 May 2017 (ITEC)
8.	Sofia, Bulgaria	29 – 30 May 2017
9.	Bydgoszcz, Poland	16 – 20 October 2017 LOE1a
10.	Orlando, USA	01 December 2017
11.	Vyškov, CZE	19 – 22 February 2018
12.	Sofia, Bulgaria	16 – 20 April 2018
13.	Stuttgart, Germany	16 May 2018 (ITEC)
14.	Ottobrunn, Germany	17 – 18 May 2018
15.	Sofia, Bulgaria	07 – 08 June 2018
16.	Sofia, Bulgaria (Test)	03 – 07 September 2018
17.	Sofia, Bulgaria	15 – 19 October 2018 (LOE2)
18.	I/ITSEC, Orlando, USA	28 – 30 November 2018
19.	Ottobrunn, Germany	26 – 28 February 2019 (IPC LOE3)
20.	Sofia, Bulgaria	03 – 06 June 2019 (MPC LOE3)
21.	Ottobrunn, Germany	05 – 07 August 2019 (Technical meeting)
22.	Bydgoszcz, Poland	07 – 11 October (FPC and Pre – test LOE 3)
23.	Sofia, Bulgaria	20 – 24 January 2020 (LOE 3)
24.	Sofia, Bulgaria	17 – 20 February 2020 (Final meeting)
25.	WebEx Meetings	Every month

3.6 Expected Project Outcomes

- Creation of reference architecture/platform for a proof-of-concept;
- Categorizing existing M&S solutions and developing missing ones;
- Computer shaping of C2 logic for Crisis/Disaster Response;
- Fast and accurate calculations and predictions in support of decision makers;
- Investigate, categorize, and catalogue data sources available for Disaster Response;
- Reducing human influence over data collection and modifying process;
- Analyze existing standards in common vocabulary and investigate for new ones to adapt existing ones for NATO purposes;
- Demonstration (contribution to multinational exercises) as a test bed for analysis and training to support Crisis/Disaster Management and CCI;
- Crisis/Disaster evolution trend forecast, synthesizing, and usage of best practices, experience, and knowledge related to specific system conditions;
- Conducting CMDR exercises, experiments, tests, evaluation and analysis in a proper close to reality environment; and
- Evaluation of disasters on Military activities.

4.0 TECHNICAL FRAMEWORK

4.1 Modelling and Simulation, and Their Use for Capability Development

A Model is an abstraction for a system, or for a part of the real world (Figure 2). This abstraction and idealization are achieved to obtain a more or less simplified description of the system under consideration. Through calculations and/or experimentations, model results are then obtained which can be analyzed and interpreted and then compared to the observations collected through measurements and/or experimentations on the “real” system under study. Through several increments, the obtained model can be optimized continuously.

The simplifications of complex realities in the modelling process through a Limited projection of the reality can be made, for example, by:

1) The reduction to relevant parameters;
2) Non-representation of random or irrational events;
3) Non-representation of human factors;
4) etc.

The M&S Development Process should follow a process-oriented scientific approach, as depicted in Figure 3, beginning with the problem definition and analysis, and ending with report generation and documentation. The process must involve persons with different expertise and specialities.

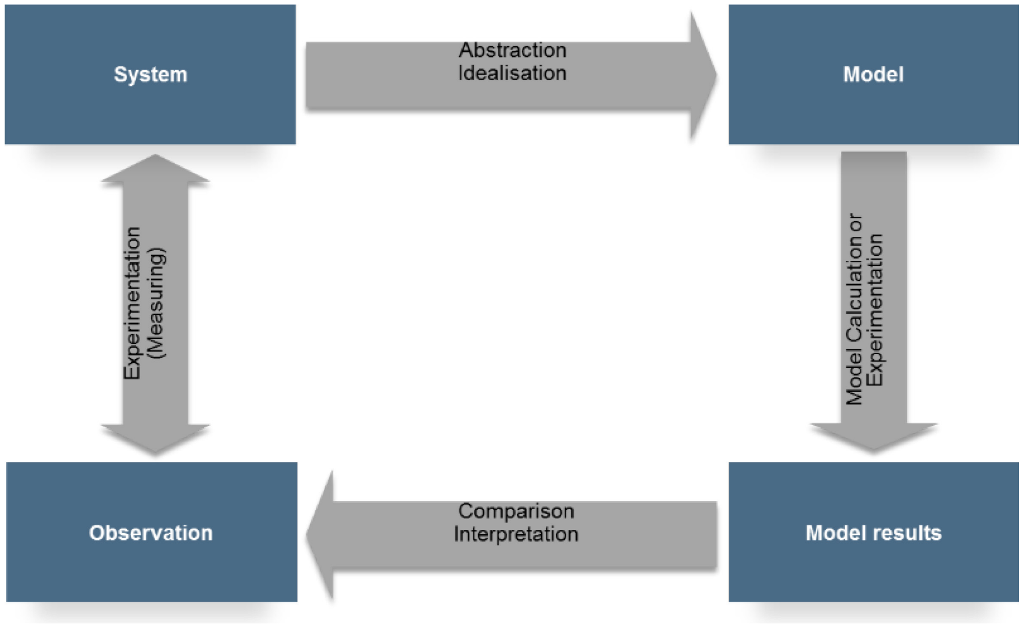

Figure 2: Simplified Definition of a Model.

The Use of Modelling and Simulation for capability development can be used for:

1) Support to Analysis and Planning:
   - Analysis of strategic issues;
   - Analysis of capabilities;
   - Optimization of processes, procedures and organizational structures; and
   - Evaluation of concepts.
2) Support to Training and Education:
   - Modern (IT-based) training technologies;
   - Rehearsal and realistic environment;
   - Time and cost-effectiveness; and
   - Documentation and reviews.
3) Support to Operations:
   - Decision support;
   - Forecasts;
   - Comparison of Courses of Action; and
   - Optimization of processes, procedures and organizational structures.
4) Support to Analysis and Fulfilment of Requirements:
   - Identification and operationalization of capability gaps;
   - Definition of requirements;
   - Evaluation of possible solutions;
   - Assessment and verification of solutions; and
   - Life Cycle Cost Analysis.

As mentioned above, the focus of the project here is:

1) Analysis and Planning;
2) Training and Education: and
3) Support to Operations;

which means that we also have to deal with the sub-terms introduced here (like the optimization of processes and procedures, the development and use of IT-based training technologies, and tools for Decision support).

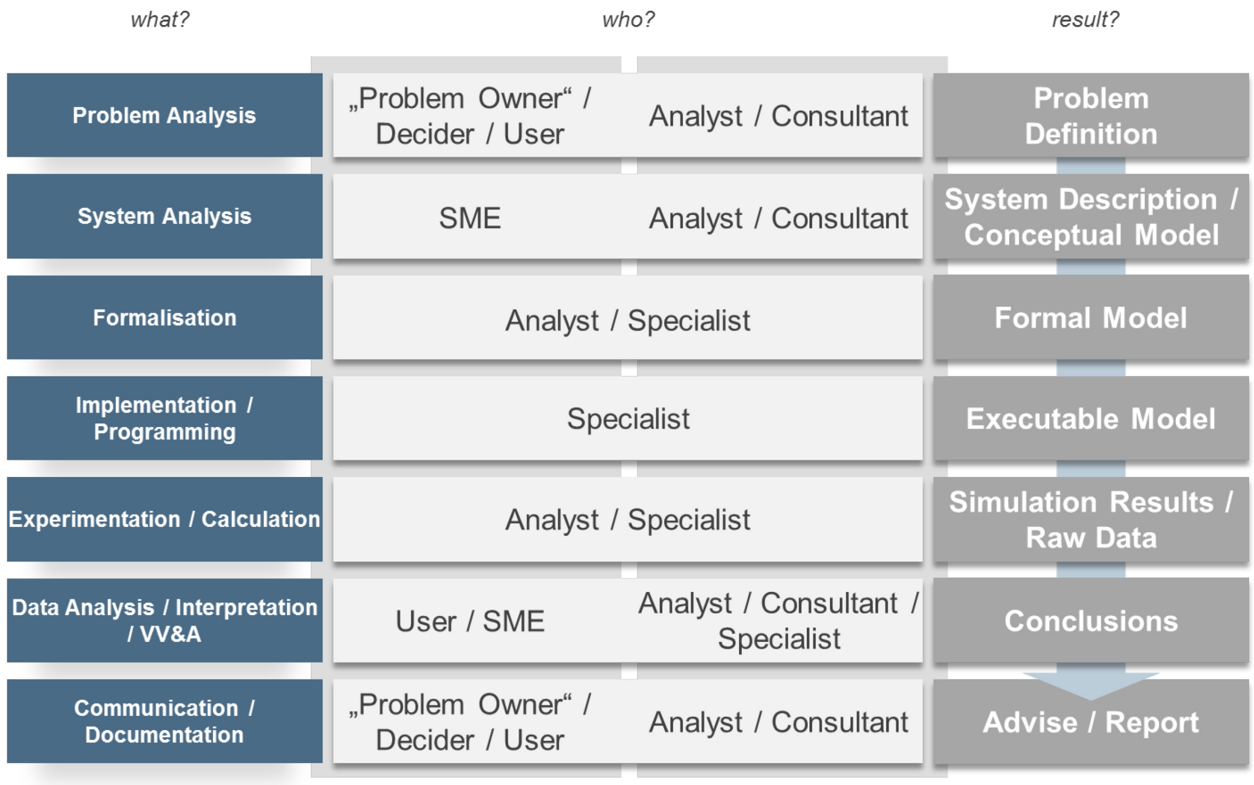

Figure 3: Workflow for Modelling and Simulation.

4.2 Introduction to Simulation Connectivity

Distributed simulations have become very important in the last years, especially when:

- Multiple reuses of single model components (or simulations modules) of certain systems are desirable;
- High scalability of complex simulation applications is required (exercises, simulators, mission support); and
- Different users, local or distributed, act together as a federation (multinational, Joint, Combined).

The coupling of already existing simulations requires their interoperability. This means that these simulation systems (or simulators), mostly from different producers, have to work and interoperate together in the same network environment. This can be reached through the definition of appropriate interfaces and protocols.

Especially in a military context, there are many simulation systems from different producers and nations. Here there is a huge interest in connecting the older existing simulators with the new ones to achieve new experiments or to run exercises. Therefore, it is mandatory that these simulators can exchange messages with each other over a communication network (WAN) or Local-Area Network (LAN). To guarantee that these messages can be interpreted correctly by each participant, it is necessary to define some standards, which prescribe the format (Syntax) and content (Semantics) of these messages. The solution to this complex issue constitutes the core of the existing standards, like Distributed Interactive Simulation (DIS) [6] and HLA (High-Level Architecture) [5]. The DIS Standard comprises a set of predefined messages, the so-called Protocol Data Unit (PDU), which can be exchanged between the interconnected systems. A PDU defines the coding of the information (syntax) as well as the message content (semantic).

In HLA, the exchanged data are described through object models. In contrast to DIS, these object models are not defined in the standard and must be explicitly agreed upon in each concrete connection of simulation systems. In the HLA world the following terminologies have been established [6]:

- **The Simulation Object Model (SOM):** Defines the information, which a single system can provide as a participant in a federation;
- **The Federation Object Model (FOM):** Defines the objects, attributes and interactions for the whole federation; and
- **The Management Object Model (MOM):** Describes the federation itself and the management of federations.

To develop and execute a federation, a process called "Distributed Simulation Engineering and Execution Process DSEEP" [7], was created. It is a process model for the development and execution of a distributed simulation environment. It describes the steps in the process model, as well as activities, tasks, work products, and roles, and provides extensive guidance including templates, guidelines, and supporting materials for architecture development (Figure 4).

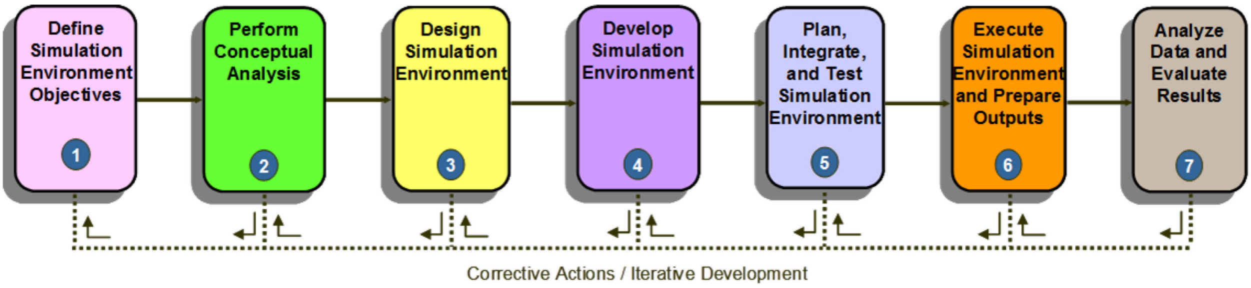

Figure 4: Steps of the DSEEP (Distributed Simulation Engineering and Execution Process).

The steps introduced in Figure 4 contain the following sub-steps:

1) **Step 1: Define Simulation Environment Objectives:**
   - Identify Needs;
   - Develop Objectives; and
   - Conduct Initial Planning.
2) **Step 2: Perform Conceptual Analysis:**
   - Develop Scenario;
   - Develop a Conceptual Model; and
   - Develop Simulation Environment Requirements.

3) **Step 3: Design Simulation Environment:**
    - Select Member Applications;
    - Design Simulation Environment; • Design Member Applications; and
    - Prepare Detailed Design.
4) **Step 4: Develop Simulation Environment:**
    - Develop Simulation Data Exchange Model;
    - Establish Simulation Environment Agreements;
    - Implement Member Application Designs; and
    - Implement Simulation Environment Infrastructure.
5) **Step 5: Integrate and Test Simulation Environment:**
    - Plan Execution;
    - Integrate Simulation Environment; and
    - Test Simulation Environment.
6) **Step 6: Execute Simulation:**
    - Execute Simulation; and
    - Prepare Simulation Environment Outputs.
7) **Step 7: Analyze Data and Evaluate Results.**

As you have noticed, the FOM Definition is also a part of the DSEEP Process (Step 4). The DSEEP process is a comprehensive process which is very helpful and useful for developing a distributed simulation environment. It should as far as possible be considered in this project for federation establishment too.

4.2.1 Interoperability

The LCIM model [9] is commonly used to classify the degree of interoperability. In Figure 5, the known standards DIS and HLA for the networking of simulation systems are compared with the interoperability degrees defined there. It should be borne in mind that interoperability can only be assessed bilaterally between the systems or between a system and a convention adopted for the overall network and that there are numerous possibilities for realization within each degree so that strict transitivity is not given. Therefore, if System A is systematically interoperable with System B, and System B with System C, it does not follow that System A is interoperable with System C.

The LCIM model distinguishes the following levels (better aspects) of interoperability:

- Technical, there is a technical coupling as well as a common communication protocol;
- Syntactically, there is a common data format;
- Semantically, there is a common reference model for exchanged data and an agreed meaning of the data;
- Pragmatic, there are concerted methods and procedures for the use of exchanged data;
- Dynamic, assumptions and boundary conditions concerning the temporal behavior and the state development of the systems are coordinated; and
- Conceptual, independent of implementation, there is an agreement on the boundary conditions, behavior and degree of abstraction of the models used.

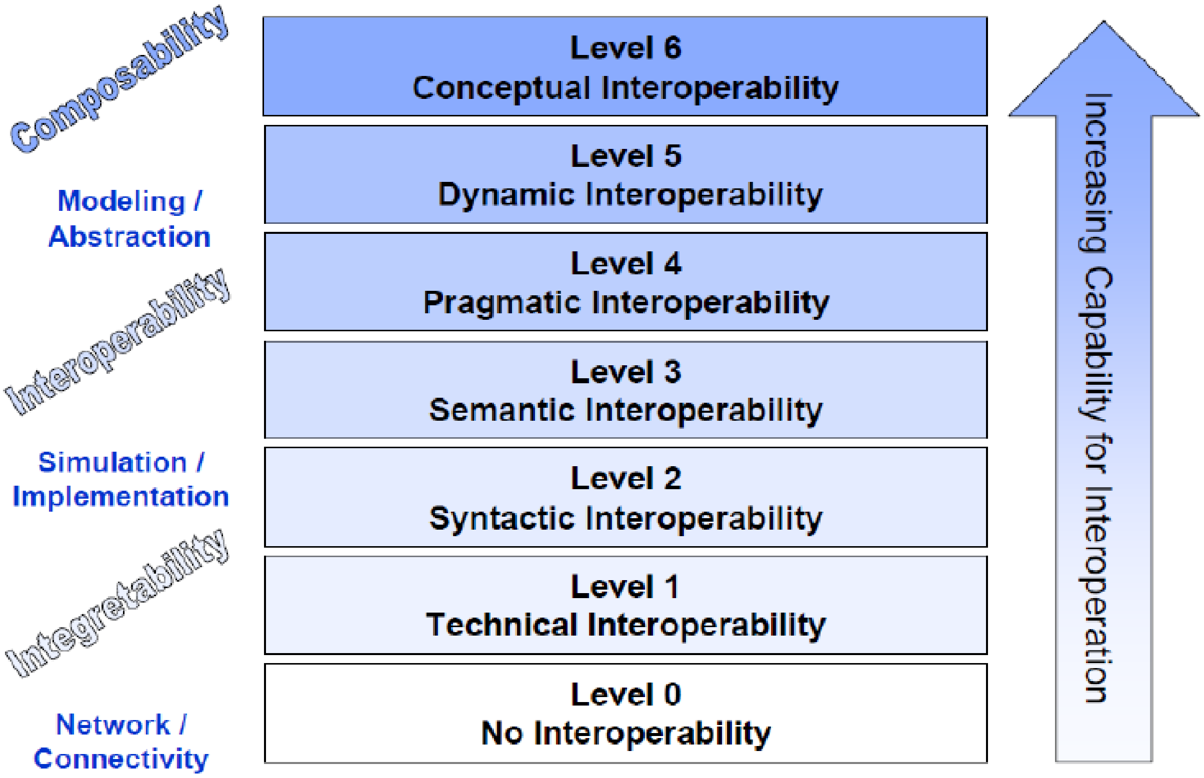

Figure 5: Interoperability Levels.

It is obvious that within this gradation the upper planes are determined by the model behavior and do not reappear directly on an interface of the system. Similarly, pure network technology is a necessary condition for achieving technical interoperability. The intervening planes are covered by the known crosslinking standards DIS and HLA. In the DIS Standard, the technical level is covered by the definition of the network protocol and the definition that data is to be exchanged in the form of individual data packets (PDUs). Syntax and semantics are achieved by defining specific PDU content as well as by agreeing with values (DIS-ENUMs).

In addition, the DIS Standard defines numerous rules for interpreting the exchanged data as well as the expected behavior of the sending and receiving simulation systems. This enables interoperability up to the pragmatic level, although only within the framework provided by DIS or the specified application (Figure 6).

A similar division is given in the HLA. Technical interoperability is ensured by the RTI, which handles the actual communication among the connected systems. Syntax and semantics are defined for a federation via a FOM or from a single system view via a SOM. In contrast to DIS, these are freely selectable in the HLA, so that the standard can be used for different application domains. Details on usage and behavior are usually defined in a GRIM document as well as supplementary agreements for a federation, whereby the pragmatic interoperability level can finally be achieved. For the connection of legacy systems, this means that for the individual case, the extent to which the available interfaces meet the interoperability requirements determined by the requirements for the simulation environment (i.e., the target of the simulation), or to what extent the existing abilities of the legacy system are a limitation. Not only does the interoperability level depend on the respective interoperability level, but the degree of consistency must also be considered within each level. Thus, for example, a logistics simulation, and an air combat simulation are not interoperable either when they are based on HLA, the RPR-FOM, or the associated GRIM because they model different application domains (i.e., the models do not conceptually match or interact).

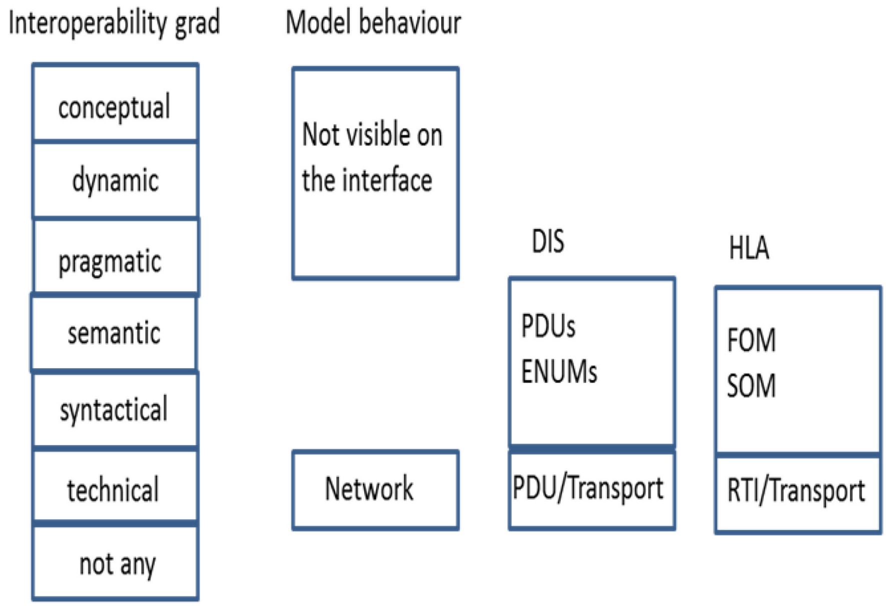

Figure 6: Relationship between Interoperability Grad and Model Behavior.

4.2.2 Relationship Between SOM, FOM, and Reference FOM

The basic principle for building a connected simulation environment (e.g., HLA Federation) is described through the DSEEP process model [7]. 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, 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 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 the explicit purpose of interconnection. Typically, existing systems are already deployed with a complete set of capabilities at their disposal, thereby defining a certain SOM for each system. The use of such a system in a bilateral interconnection is limited by the intersection of the System's SOMs so these SOMs must comprise all the object data and interaction needed to accomplish the coupling aim. The FOM is then determined through the conjunction of all the intersecting SOMs. The effective use and relevant conjunction of the bilateral intersections of the SOMs build just a subset of the FOM. It means that the whole FOM is not 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. Thereby the probability is increased significantly that two simulation systems developed independently 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. On the other hand, the reference FOMs influence the capability of the simulation systems and thereby 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 depend on each other and are mutually effective.

4.2.3 FOM Structure and Content

As introduced in the last section, a FOM describes the set of objects, attributes, and interactions, which have to be commonly used within a federation. On the whole, not all data and interactions of the FOM have to be used (depending on the extent and aim), but just a subset of them is needed for the exchange in the federation being considered.

For a formal FOM/SOM description, the HLA standard defines the so-called Object Model Template (OMT). It contains the object and interaction class structures as well as some details regarding the type and meaning of the object attributes. Typically, the OMT defines tables whose contents determine a concrete FOM:

- **Object Class Structure Table:** Class structure for the exchanged objects;
- **Attribute Table:** Description of the deployed object classes attributes;
- **Interaction Class Structure Table:** Class structures for the exchanged interactions;
- **Parameter Table:** Description of the deployed parameters of the interaction classes;
- **Object Class Identification Table:** General information about the FOM, Name, Aim, version, etc.;
- Routing Space Table Description of the “Routing Space” for the specific HLA service of the Data Distribution Management; and
- **FOM/SOM Lexicon:** Description of the meaning of the object and interaction classes, attributes and parameters.

Today, FOMs are described in XML format. The information from the above-mentioned tables is then assigned to the appropriate XML elements and increases the readability of the FOM data; the object class hierarchies are then mirrored in the hierarchy of the XML elements as well as the hierarchy of the implemented attributes and parameters for each class. From this description, it is clear that a FOM solely guarantees interoperability on the syntactical and semantical levels. From prevalent concepts for simulation systems interoperability, it is known that further interoperability aspects also exist, which cannot be satisfied just through agreement on a FOM. In a FOM Context, that will mean that additional agreements must be reached; how the exchanged data are to be interpreted by the systems, when and by whom they are to be updated and how the system might react to a change of data or by the reception of interactions. These agreements complement the actual (reference) FOM and are defined in a so-called Guidance, Rationale, and Interoperability Modalities (GRIM) document, which forms an integral part of the FOM specification.

4.3 Representation of RPR and NETN-FOMs

This section introduces the most important and most used FOM in the NATO domain, namely the RPR-FOM and the NETN-FOM

4.3.1 RPR-FOM 2.0 Draft 20

The Real-Time Platform Reference Federation Object Model (RPR-FOM) [10], [11], has been developed to allow a distributed simulation interconnection between discrete entities like ships, aircraft, and tanks. Before the existence of HLA, such DIS-based distributed environments were deployed for driven training and exercises in real-time. With HLA the data model was introduced into the simulation.

With the introduction of the HLA, the data model in the simulation environment was freely selectable and the introduction of a reference data model was necessary to ensure interoperability. It was therefore obvious to adopt the semantics of this reference data model from the already existing and common DIS standard and to transfer it into the HLA-specific structure of object and interaction classes and their attributes and parameters. The RPR-FOM was therefore designed with the following objective:

- Support for the transition of legacy DIS systems to HLA.
- Improving a priori interoperability among RPR-FOM users.
- Support for newly developed federations with similar requirements.

The RPR-FOM is divided into individual modules, whereby "higher" modules use definitions of "lower" modules so that there is a dependency between the modules.

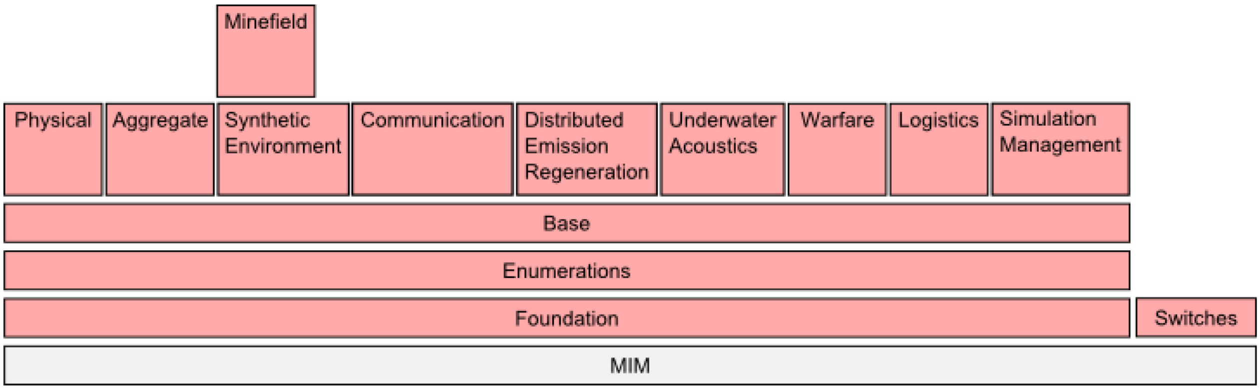

Figure 7: Module Structure of the RPR-FOM with Module Dependencies.

Figure 7 shows this module structure, in which individual modules build on each other. Only on the top level are the modules independent of each other. The content of the individual modules is briefly described below:

- **MIM** is the "**Management Object Model and Initialization Module**": This module is not part of the RPR-FOM but is defined by the HLA standard itself. It includes object and interaction classes that describe the federation itself, as well as the definition of base classes (such as HLAObjectRoot) from which the actual classes of the FOM are derived.
- **Foundation:** This module forms the basis of the RPR-FOM. It contains definitions of data types for the superordinate modules (e.g., representation of integer and floating-point values).
- **Enumerations:** This module contains the values of enumeration (enum) types that are defined in the "Enumerations for Simulation Interoperability" reference document [11]. This reference document was developed by SISO primarily to improve semantic interoperability to complement the DIS Standard. However, it is not DIS-specific and can generally be used as a reference for common semantics of simulation environments. Integration into the RPR-FOM was therefore close.
- **Base:** The module defines the basic object classes "BaseEntity" and "EmbeddedSystem," as well as a series of additional data types (for example, representation of angles) based on the data types from the Foundation module.
- **Physical:** The module contains the basic object classes for representing physical objects as well as interactive classes that apply to all physical objects (e.g., collision).
- **Aggregate:** Used to display aggregated objects.
- **Synthetic Environment:** Represents objects of the environment (e.g., points, lines, surfaces, craters, bridges, smoke, and related events).
- **Minefield:** depict minefields or individual mines.
- **Communication:** Radio receivers and transmitters and representation of radio signals.

- **Distributed Emission Regeneration:** It is used to simulate electromagnetic emissions and their effect on receivers. This mainly concerns radar radiation and its detection (radar warning, jamming).
- **Underwater Acoustics:** Simulation of acoustic emission and signatures of ships and submarines (active and passive sonar) as well as driving noises and their detection.
- **Warfare:** Simulation of ammunition, bombardment and detonations.
- **Logistics:** Simulation of logistical procedures, repair and supply.
- **Simulation Management:** This module contains interactions that are used for sequence control in the network (Start, Stop, Request, Response, DataQuery) and which have nothing to do with the actual simulation or the representation of the real world.
- **Switches:** The module is required by the HLA standard and contains some global technical settings for the simulation network. NETN 2.0 Draft.

4.3.2 NETN 2.0

The NETN- FOM [11], [12] is one of the results of the NATO project "Snow Leopard," which aimed at common distributed networking and use of simulation systems and devices from NATO and partner countries. A reference FOM (NTF-FOM: NATO Training FOM) for connection to the NETN (NATO Education and Training Network) was developed as part of the MSG-068 working group. The new NTF reference FOM should be based on the RPR-FOM 2.0 and was named NETN-FOM. A further development to the NETN-FOM 2.0 took place within the scope of the MSG-106 SPHINX. Modularization of the FOM, following the new concept of modular FOMs in the HLA, has been added as well as new modules.

The red modules in Figure 8 originate from the RPR-FOM; the blue modules were added by the NETN-FOM. The blue-and-white modules refer to several other modules and are therefore represented several times to improve clarity.

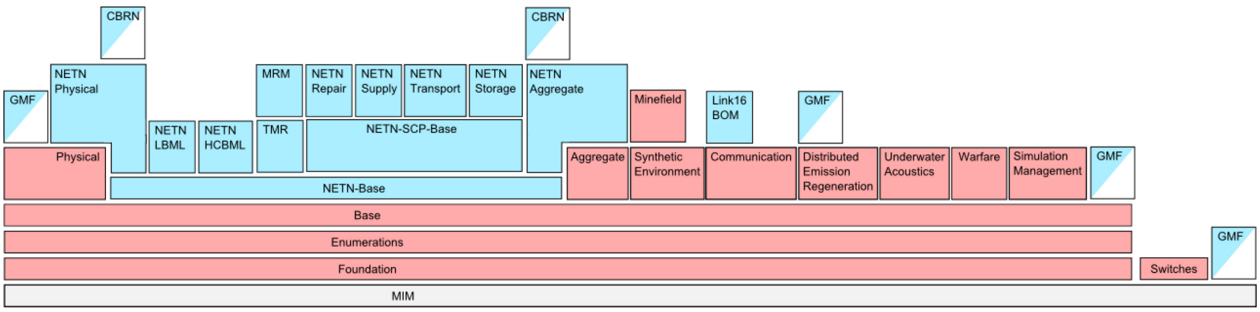

Figure 8: Structure of the NETN-FOM v2.

The current structure of NETN-FOM v2 is shown schematically in Figure 8. The NETN-FOM relies on modules of the RPR-FOM and extends these in some places. The following properties characterize the NETN-FOM:

- The Module NETN-Base supplements the RPR modules Base and Enumerations with additional data types and enumeration values.
- The Module NETN-Physical and NETN-Aggregate expand the object types specified in the RPR modules Physical or Aggregate by adding additional attributes, e.g., to indicate callsign or allocation to military units (units).

- The NETN-LBML and NETN-HCBML modules integrate the Battle Management Language (BML) into the FOM. This is divided into basic statements (low-level BML Orders / Tasks / Reports, LBML, e.g., MoveToLocation, FireAtUnit) implemented exclusively as interactions and the larger BML language range in the form of general reports (implemented as interactions) Object classes for orders, requests and notifications (order, request, message).
- The NETN-TMR module (Transfer of Modelling Responsibility) supplements and extends the already existing ownership management in the HLA by additional interaction patterns. The NETN-TMR module works at the level of the individual simulated objects while the latter operates only on the level of individual attributes and thus allows a very fine-granular transfer of the modelling among the federates (and thus also requires very precise and fine-granular coordination and definition) and allows them to be transferred from one simulator to another.
- The NETN-MRM module implements "Multi-Resolution Modelling (MRM)." It uses some data types from NETN-TMR and is therefore displayed above it. The interaction classes defined in NETN-MRM, however, do not have any dependencies to those of NETN-TMR, so the module should be "next to" TMR rather than above.
- NETN-SCP-Base forms the basis of the Service-Consumer-Provider Pattern. "Service" here refers to the modelling of "services" that provide objects of the real world for each other in the simulation. In the higher-level modules, the general interaction pattern and the corresponding interaction classes are further specialized in the implementation of simulated repair procedures, supply, transport and storage (NETN repair, NETN supply, NETN transport, NETN storage). Since the NETN-FOM depicts these operations in a very detailed manner, the "Logistics" module originally contained in the RPR-FOM is not part of the RPR-FOM.
- NETN-CBRN module specializes in object and interaction classes from RPR-Base, RPR-Physical, and NETN-Physical for the mapping of Chemical, Biological, Radiological and Nuclear (CBRN). Data types from NETN aggregates are also used so that a (weak) dependency exists here as well.
- The NETN-FOM also includes the Link16 BOM module, which extends the RPR module Communication for mapping Link16 networks. The Link16 BOM is developed and maintained independently of the NETN-FOM, so there are no dependencies on other parts of the NETN-FOM.
- Similar to the German Maritime FOM (GMF), which is officially part of the NETN-FOM, it is based on the RPR-FOM and extends it at various points so that it is also independent of the other modules of the NETN-FOM.

Notes on the integration of the NETN modules with the RPR modules:

- The GMF has significant semantic overlaps as well as some incompatibilities with the RPR modules. In the FAFD of the NETN-FOM, these are described in more detail along with possible solutions.
- The logistics domain is represented by the SCP pattern and modules placed on it in much more detail than in the original RPR-FOM. It is therefore logical to omit the original logistics module of the RPR-FOM. However, an incompatibility with simulation systems that use this module may then arise.

There are of course other FOMs which are often used for specific applications. For example, the SEDRIS (Synthetic Environment Data Representation and Interchange Specification) FOM (Figure 9) was developed for the representation and exchange of environmental data. Since these data in a federation can have a considerable influence on the plausibility of the simulation results and are subject to dynamic changes, a FOM was developed to exchange such information between the federates. The SEDRIS FOM file is created directly from the SODB (Simulation Object Data Base) using special software (SgjSedrisTool). All (3D) objects (such as trees, houses, or barriers) are also represented by the special class Classification Related Geometry (CRG).

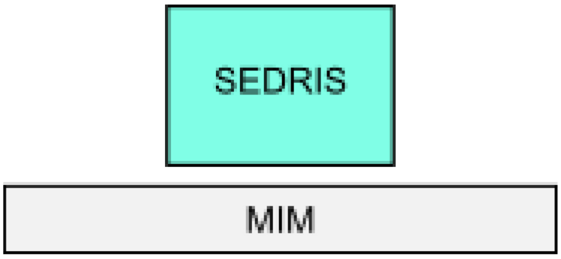

Figure 9: SEDRIS FOM.

The SEDRIS FOM is a stand-alone development that has no dependencies on other known FOMs. The SEDRIS FOM in its current state has no structural dependency on other FOMs and also does not refer to known standard/reference FOMs as shown in Figure 9. Here are some comments about SEDRIS FOM:

- The FOM maps environmental objects and their temporal changes to the HLA. It is therefore assumed that each Federate has its own internal, SEDRIS-compliant description of the environment and offers the possibility to synchronize and change it.
- The basic idea thus corresponds exactly to that of the “Synthetic Environment” module of the RPR-FOM, but this does not use the SEDRIS semantics.
- The semantics for the transmission of position and orientation of objects also does not correspond to the common schema in distributed simulation environments (DIS, RPR-FOM).
- The advantage of the use of the SEDRIS semantics is the disadvantage of the break with already existing FOMs.

4.3.3 Bilateral Relationships Between FOMs

Some conclusions can be drawn at this point:

- The RPR-FOM is developed by the SISO Community. This process came to a standstill for a certain period, which is why version RPR-FOM 2.0 Draft 17 was used in many simulation systems and as a basis for FOM development. This was developed before the introduction of the IEEE 1516-2010 (HLA Evolved) standard and therefore does not yet make use of the FOM modularization introduced with HLA evolved in a standardized form. It was only with the further development of the RPR-FOM (up to version 2.0 Draft 20 considered here)
- The HLA standard IEEE 1516-2010 [5] does not allow the addition of attributes (or parameters) to object classes (or interaction classes) by additional FOM modules. If an existing class is to be extended by a FOM module, the new module must necessarily define a new class, which is derived from the existing one. This leads to the problem that independent FOM modules that want to extend the same base class by different attributes independently define a new class for the same object type, respectively, thus creating an unintentional splitting of the class hierarchy. This decomposition is purely technical but leads to potential incompatibilities of the simulators since the same object type appears twice in the class hierarchy, which must be considered in the simulation system. This can only be done by following a strict hierarchy of FOM modules.
- The expansion of a class in the FOM by additional attributes by FOM modules potentially leads to a split of the class hierarchy. This can only be avoided by adhering to a strict hierarchy of FOM modules.

4.3.4 Trends DIS, HLA and RPR-FOM

The following impressions, aspirations and tendencies were taken from the meetings, lectures and discussions:

- DIS is supported, maintained and actively developed by a broad community. It has by no means become obsolete with the advent of the HLA; in part, it even appears that there is a regular counter-movement to the HLA.
- DIS is an IEEE standard. Changes must therefore follow the processes of the IEEE (in addition to the SISO processes), which are designed for significantly "larger" standards and communities so that changes can only take place comparatively slowly. In addition, IEEE voting (not SISO voting) Must be voted on the standard so that only IEEE members are allowed to vote.
- As an advantage of DIS, it is seen that the standardization, unlike HLA, includes the network protocol so that standard-compliant implementations are interoperable independently of the manufacturer.

In DIS PSG, there are initial ideas for further development in the direction of DIS v8:

- Improvements in the modelling of radio signals;
- Improvements in voice transmission;
- Integration of tactical data links;
- Extensions in navigation (GPS, TACAN);
- Machine readability of the standard (see HLA: Serialization of FOMs in XML); and
- Considerations to speed up the standardization process.

4.4 Recommendations

The requirement of a clear hierarchical structure and the above-mentioned necessity of setting up FOM modules on the international FOMs creates a dependence in the future Disaster FOM (NMSG-147 FOM) on the international RPR-FOM and NETN-FOM. This means that changes in the international base necessitate a corresponding change to the Disaster FOM modules to maintain compatibility. The working groups behind the international FOMs are very concerned about maintaining backward compatibility to protect investments in existing simulation systems and to avoid unnecessary adaptation work. In this respect, only a small adjustment effort is to be expected in the future.

However, the situation is different in the case of innovations introduced at RPR-FOM or NETN-FOM in the future. For example, in NATO, the introduction of services into simulation environments is investigated, and resulting extensions of the NETN-FOM or the RPR-FOM are likely. To avoid incompatibilities and significant adjustments to the Disaster FOM, close collaboration between the CDMR FOM development and the developer groups on the international level is essential. In this context, efforts should be made to integrate the developed FOM modules as far as possible into international developments.

For MSG-147, it is desirable to add a new Disaster Module, analogue to the CBRN on the top of the NETN-Aggregate module, allowing the modelling of different Disaster aspects (CBRN is just one of those aspects). As a starting point, the flooding can be considered in more detail. For that, we have to achieve the following tasks for flooding:

- Define the object and interactions classes, data types and attributes;
- Try to reuse a similar modelling paradigm as by CBRN, if possible. For that it is necessary to start by studying the CBRN module in more detail;

- Try to implement the necessary simulation interfaces to be able to deal with the required data for achieving interoperability by taking into account the flooding model;
- Run some small experiments to test and evaluate the proposed NETN extension; and
- Follow the DSEEP Process (as far as possible).

5.0 CRISIS MANAGEMENT AND DISASTER RESPONSE INTEGRATED DEVELOPMENT ENVIRONMENT

The importance of disasters, their influence, and their capacity to have a severe impact on human life is indisputable and has largely been taken into consideration. The planning process and performance of the NATO military operations also include disaster management.

The significant unpredictability of disasters, with regards to occurrence in time and space and event parameters, makes risk management and disaster management a difficult and resource-consuming process. The evaluation of the dynamic impact of a planned and performed military operation is almost impossible without the use of appropriate modelling and simulation tools and software. Such applications are military-oriented software allowing realistic war gaming based on an implemented database containing models of military units and behavior.

During the first phase of the MSG-147 project, it became evident that a military-oriented simulation capable of accurately modelling and simulating all disaster types does not currently exist on the market. Furthermore, it was noted that the few models (flooding for example) built-in are inaccurate and that the simulations deviate from one to another.

This lack of appropriate simulations makes it impossible to create simulation federations, war gaming, or make analyses following disaster events occurring during military operations.

To improve the decision-making process and to increase objectivism, a Disaster Module application was designed and developed. This software has unique capabilities. It can compute and model different disaster events using its own or external mathematical models and later publish the results as standard for the simulations object with all predefined characteristics and attributes. These attributes defining the disaster simulation object are updated frequently. In this way, the Disaster Module can distribute one (or more) disaster objects to many simulations connected to a federation using a standard HLA interface. The mathematical model computing the event is outside the simulations which are responsible for estimating impact upon 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. This approach has many advantages:

- The publication of the disaster as an object within a federation of different federates is synchronized as are its subsequent updates;
- The object is the same for every federate subscribed for it and does not depend on a specific simulation;
- It is not necessary for the federate to have its model for the specific event/object/disaster;
- Every disaster mathematical model implemented into Disaster Module is open, very precise, and easily changed, if necessary, without changes in the source code of every federate;
- The Operator can change the parameters or input data of the mathematical equations describing the disaster mathematical model or change one model for another if it is more suitable; and

- The Disaster Module can publish a computed HLA object representing the desired disaster from its own engine and respective model or using data from another source (as 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 without an HLA interface. During the experiments, all technical problems concerning this functionality were solved and finally, the data were properly published and updated.

Later on, other modules with different functionalities were attached to the Disaster Module. This functionality was the previously mentioned bridge service allowing the transfer of data from non-HLA-compliant applications to the federation. Later on, a need was recognized for services capable of injecting information into the Command and Control System, to generate a Situational Awareness Report, propose Response Measures, and visualize them again in the C2 environment. Moreover, development of the SOP Database began and the first disassembled rudimentary measures SOPs were provided by SEEBRIG for tests and training support during exercise Balkan Bridges 19.

This changed the focus of the application. The interface became less user-friendly and understandable. A decision was made to make different modules representing the conceptual schema and the name of the software was transformed to “Crisis Management and Disaster Response Integrated Development Environment.” The new name is not only an improved elaboration of the current implemented capabilities and functionalities, but it also describes the concept of the product. It must be emphasized that the standard interface approach of the development reference architecture was strictly followed, allowing connections with different software and applications with different functionalities and capabilities. In this way, the chance for cohesion coordination or synergy was significantly increased.

The CMDR IDE has two main roles. The first one is to connect useful and relevant existing applications like military simulations, for example. In this way the CMDR IDE configures the necessary framework capable to run wargaming, publishing into the network disaster events of different types, collecting reports about the impact, behavior and development of the crisis, and running the information through Command and Control systems, etc.

The first role is achieved by increasing interconnections between clients of the framework. Because of the large scale of the project, it was agreed that it would save time to use the currently available simulation systems, command and control systems, and network for information exchange. This decision not only improved the development velocity significantly but also gave highly advantageous flexibility. Nowadays the CMDR IDE could connect many clients and could transform the final schema easily. This kind of open architecture allows interoperability with different applications which is proportional to the potential synergy of the project. It could be elaborated as a function of the common domain of interest and different capabilities.

At the beginning of the project, a schema of 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 architecture can be fully activated or just part of it. For example, the war-gaming process can start without using the module for dynamic plan generation.

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

This interface can transform data into simulations compatible with different sources. What makes it possible is that the module can receive the data in various formats. Most of the time the synchronization depends on operator manipulation which is an advantage and makes the module more flexible.

Another interface is the simulation-C2 system gateway. It can transfer information from the simulation system to the C2 and vice versa. It is HLA-REST API-based and connects many simulations and C2 systems making a large number of possible combinations. For example, as this report is being written, the current version of the concept under development is an interface connecting the CMDR IDE with EXIS, which will allow connections with many C2 systems currently used 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 to extend the invented architecture.

The first one is the Disaster Module which consists of several submodules: engine running open-source disaster mathematical models, operator interface, and almanac database. The operator interface allows control over some of the coefficients of the mathematical models, to set up the initial parameters (like weather conditions, for example). The simulation network gateway is no longer a part of the module and now is part of the Interface Module.

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 disaster or from EXCON if the reference architecture is used for training. It has a simple interface which at the moment is based on the Common Alerting Protocol. During the experiments performed, the module had a simple interface and functionality. The next version of the module is now under development. In it the EXCON could have a list of preplanned injects making the duties easier and replicable. This would save time and effort.

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

The process of feeding the reference architecture with real live/time data is also under development, but some work has been done in that direction. CMDR COE has an agreement with organizations holding sources of such information. Initial information about the standards and test sets of data has been exchanged. The CMDR COE's OpsLab also plans to develop 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 previously explained, the Disaster Module could run its engine with implemented disaster mathematical models or serve as a bridge between modelling applications without an HLA interface and military simulation federation. The advantages of using internal models are knowing the disaster model's mathematical logic and coefficients, its accuracy, and having the opportunity to modify it when necessary. Under specific conditions one mathematical model may be preferable to another: an internal model gives flexibility to the decision makers. The Disaster Module also has a database with reference data for the specific parameters. For example, it could highlight the value of the gravity acceleration, or the physical parameters of specific toxic gas. 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 an operation, during the planning process) and in real-time during the actual performance of the military operation.

Database Module: The Database Module contains a variety of information. It stores almanac data related to specific disasters and is necessary for the mathematical models. For example, it could highlight the saturation point of a specific kind of soil when the modelled event is flooding.

Another set of tables contains statistical data for the previous disasters. They can be used for analysis, experiments, training, etc. The reasons for using such statistical data are realism and objectivism – two trends hard-coded into the project concept. This data, however, could be modified. For example, the location could be shifted according to the scenario requirements. This gives flexibility and full control when conducting a beneficial training or experiment process.

An important part of the Database schema relates to the Standard Operating Procedures (SOPs). The database contains defragmented SOPs with rudimentary response measures at specific levels – tactical, operational, and possible. Metadata is added to each response measure which makes selective usage possible.

This approach is innovative – no similar solution exists. However, additional shaping of Disaster Management knowledge, experience and theory should be done.

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

Artificial Intelligence Module: The purpose of this module is to generate a 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 writing this report, the AI Module is at an initial stage of development. Some tests have been performed using the basic schema of thresholds-comparators-triggers. The mentioned target list in the Database Module and the rudimentary response measures provide feed data for the process.

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

6.0 DISASTER FOM DEVELOPMENT

This Crisis Management and 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 is therefore highly applicable in the context of NATO Computer Assisted Exercises (NATO-CAX). To some extent, it also may be used in national CAX as well as for more general use cases in the field of distributed simulation, for example, analysis and operational planning.

6.1 Requirements and Design Overview

The major requirements for 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; and
- The CMDR-FOM module shall be compatible with 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 for a detailed representation of CBRN material and its distribution in a synthetic environment.

By contrast, the CMDR-FOR 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 to the represented threats or disasters.

6.2 CMDR Hazard Events

Using the CMDR_HazardEvent interaction class, the source event of environmental hazard can be communicated in a simulation federation (Figure 10).

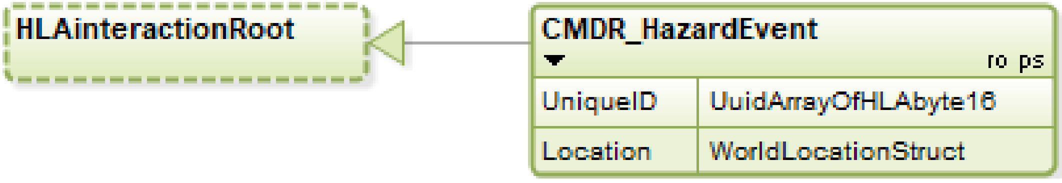

Figure 10: CMDR_HazardEvent.

Typical examples would be the failure of a dam that leads to flooding, the location where a fire originally started, or the location where a chemical substance was released into the environment.

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

Note that the CBRN_v1.1.9 module contains a CBRN release interaction dedicated to the communication of a CBRN release event. There is a semantic overlap when using CMDR_HazardEvent to communicate the release of toxic substances, which could also have been modelled using the CBRN_Release event. However, the CMDR_HazardEvent had to be introduced to model other CMDR events like fires, bursting of dams, etc. which the CBRN_Release is not suitable. If the release of toxic substances is to be modelled, it must be noted in the federation agreements which one of the two events is used in the federation.

6.2.1 CMDR Hazard Regions

The CMDR_HazardRegion is used to represent the geographical region of a CMDR hazard in a synthetic environment (Figure 11).

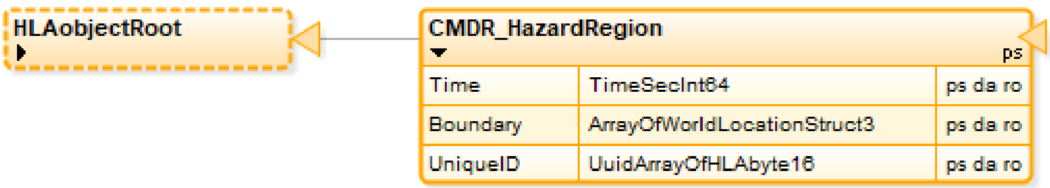

Figure 11: CMDR_HazardRegion.

It comprises the simulation time at which the region was first created and its geographical boundary. Note that the ArraOfWorldLocationStruct3 is reused from the NETN-Base_v1.0.2 FOM module and that it holds locations in three dimensions. Obviously, in a simulation application, these three-dimensional coordinates need to be projected onto the terrain used in the simulation to form the real boundary of the hazard region.

Note that a spatial overlap of multiple CMDR_HazardRegion objects doesn't make sense in many cases. It could, however, be used to model more complex geometries, and obviously, it is also possible to have overlapping/mixing of toxic clouds formed from different substances. Thus, the federation agreements require a concrete federation execution to sort out these details.

The CMDR_HazardRegion object is further specialized to represent the particular types of hazards according to the requirements stated earlier (Figure 12).

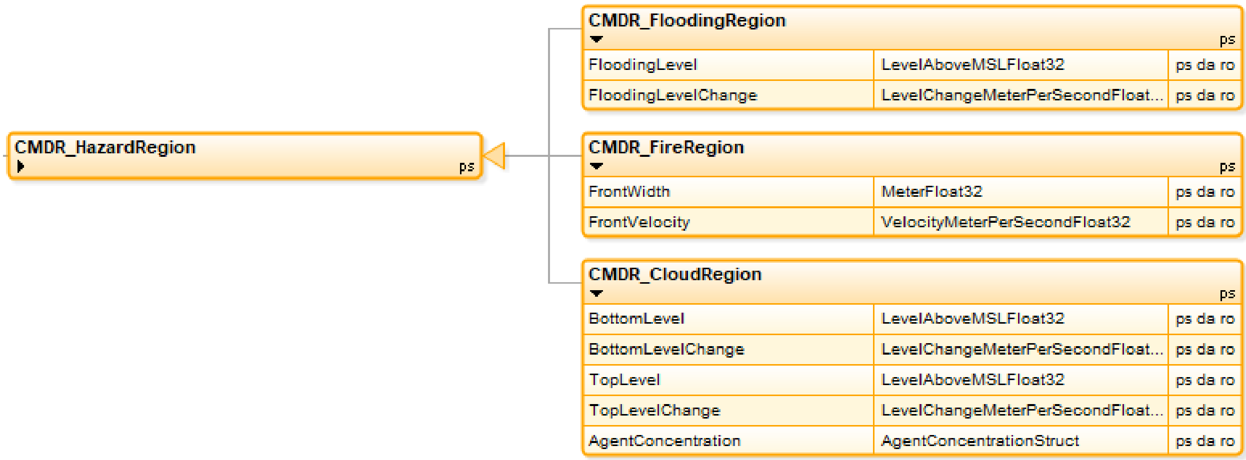

Figure 12: CMDR_HazardRegion.

6.2.2 Flooding

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

- FloodingLevel represents the water level of the flooding relative to Mean Sea Level (MSL); and
- FloodingLevelChange represents the change in the water level over time. An observer can thus determine if the flood level is going to rise (and further actions/precautions may be necessary) or if the water is draining and thus a recovery measure can start soon.

6.2.3 Fire

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

- FrontWidth indicates the thickness of the actual fire ring surrounding a no longer burning region. It is assumed that a fire starts at one or more spots and then spreads in a circular shape with a fire front of a certain thickness and burnt land behind the front line. The Boundary attribute from CMDR_HazardRegion denotes the outer shape of the overall region, the front of flames in the denoted thickness is assumed to extend from inside the boundary into the region; and
- Front velocity denotes the spread velocity of the front line. Thus, an observer can estimate when the fire will hit a certain location. The actual boundary and the velocity hereby have the same relationship as the position and velocity of a physical entity, although here in a simplifying assumption, only one single speed of spreading is assumed to hold.

6.2.4 Toxic Clouds

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

- BottomLevel and TopLevel denote the bottom/top height of the toxic cloud;
- BottomLevelChange and TopLevelChange indicate their timely variation respectively; and
- The AgentConcentration struct is reused from the CBRN_v1.1.9 FOM module within the NETN-FOM v2 and defines the released agent as well as its concentration within the cloud.

Note that this simple model of a toxic cloud assumes a flat top/bottom of the cloud and an equal concentration of an agent within the cloud. Should there be a requirement to incorporate spatial variations of the parameters this can easily be achieved by vertical or lateral stacking multiple CMDR_CloudRegion objects.

7.0 PROJECT OUTCOMES AND FINDINGS

7.1 MSG-147-Related Findings

1) Prioritization of perspectives of MSG-147 for CMDR COE (in-house expertise, training, in-theatre support / reach-back). Neglected one issue (operational support) to reduce complexity. This issue could be part of a 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 the establishment of a federation between distributed simulation systems addressing disaster management requires:
   - Awareness of the preprogrammed SOPs representing the inherent national doctrines;
   - The need for a clear federation agreement;
   - Standardized interfaces (bridges);
   - Consideration of the original nature or purpose of participating tools 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; and
   - End-user evaluation of the operational benefits of implemented new features.

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

7.2 Technical Findings

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

2) Most tested tools cannot 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;

3) 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;

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

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

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

7) 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 increase the added value for all systems in that environment.

7.3 Operational Findings

1) Comprehensive modelling at the tactical level of the environment, actors and external influences provides an operational overview, results and outcomes;

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

3) 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 crises;

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

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

6) Crisis and crisis management definitions were transmitted to NATO Standardization Office, NATO HQ for consideration.

Table 2: Project Outcomes and Findings.

TAP-TOR Requirements and Tasks	Project Deliverables	Shortcomings
Database for storage and management of the information and data related to crises and disasters.	CMDR COE IDE database includes statistical data, SOPs, a target list with threshold levels and almanac model data.	Automated SOP recommendation is underdeveloped.
Capability for determination of players, objects, infrastructures, and systems. Should be defined: location, form, vulnerability, and relations with other objects/ systems. Capability for data import from different sources like GEO information.	Sample scenarios with three different disaster types experimented during LOEs highlighted this capability (see Annex LOE 3 findings). HPAC, for instance, took into consideration, weather data and GEO information.	The current situation was not transferred automatically from the C2 system to the simulation.
Capability for implementation of control logic (command and control system, decision making and supporting system).	Tested and proven in LOE 2 and LOE 3.	Automated SOP recommendation is still under development.
Capabilities for modelling and simulation of crisis and disaster events. • **Module for modelling environment parameters under defined initial conditions.** • **Engine for model generation based on statistical data.** • **Replay the events using the stored information in the database.**	M&S capabilities are shown in JCATS, KORA, SWORD, and CMDR IDE. Environment parameters are shown in JCATS, KORA, SWORD CMDR COE IDE, HPAC, ST CRISOM, Tiger. CMDR COE IDE and simulation systems showed this capability during experimentation.	Engine for model generation based on statistical data is pending.
Capability for education and training.	The technical platform provides the capability for education and training. The experimented scenarios allow basic training for decision makers.	The group conducted experiments, but it is more feasible to test the education and training capability in an exercise (MiniCAX).
Artificial intelligence for simulating actions of individual or collective players.	CMDR IDE and all Sims usually use automats and rule-based decision making inherently.	The used Sim Systems do not have real AI.
Report generating module for the environmental parameters.	Incorporated in all simulation systems.	
Integration with other used in NATO software tools.	Proven in LOE 1a, LOE 2, and LOE 3 with JCATS, EXIS and iGeoSit (as a C2).	JCATS was not able to be fully integrated into the federation with other simulation systems by consideration of disaster events/FOM.

7.4 Outlook for Further Research and Development

- Application of the technical platform in the 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 through the use of drones as sensors and computer vision technology to augment crisis data collection and situational awareness;
- Augmentation of training by VR-training scenarios and/or gamification;
- Establishment of a resilience assessment model for potentially 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); and
- Development of a concept for CMDR COE (Disaster and Climate Change Implications on Military Activities) under NATO CD&E Methodology.

8.0 REFERENCES

[1] Scaparrotti C., Mercier D. (2018). NATO Framework for Future Alliance Operations.

[2] NATO (2015). FFAO Framework for Future Alliance Operations.

[3] Linkov, I., Eisenberg, D.A., Bates, M.E., Chang, D., Convertino, M., Allen, J.H., Flynn, S.E. and Seager, T.P., (2013). Measurable Resilience for Actionable Policy. Environmental Science and Technology vol. 47, no. 18, pp. 10108-10110.

[4] AMSP-04 NATO (2018). Education and Training Network Federation Architecture and FOM Design.

[5] IEEE SA (2010). High-Level Architecture Standard (IEEE 1516-2010).

[6] IEEE SA (2012). 1278-2012 – IEEE Standard for Distributed Interactive Simulation.[1]

[7] Menzler, H.-P., Krosta, U, and Pixius, K. (2000). HLA in a Nutshell: PSI-SA Proposed Standard Interface for Simulation Applications. Proceedings of the 2000 Spring Simulation Interoperability Workshop, Simulation Interoperability Standards Organization.

[8] IEEE 1730-2010, IEEE Recommended Practice for Distributed Simulation Engineering and Execution Process (DSEEP).

[1] Revision of IEEE Std. 1278.1-1995.

[9] Wang, W., Tolk, A., and Wang, W. (2009). The Levels of Conceptual Interoperability Model – Applying Systems Engineering Principles to M&S, Proceedings Spring Simulation Multiconference (SpringSim'09). San Diego, CA, USA.

[10] SISO (2013). SISO-STD-001.1-2013, Standard for Real-Time Platform Reference Federation Object Model (RPR FOM).

[11] SISO (2015). Guidance, Rationale, and Interoperability Manual for the Real-Time Platform Reference. Federation Object Model (RPR-FOM) Version 2.0D17v3.

[12] SISO (2011). SISO-REF-010-2011.1, Enumerations for Simulation Interoperability.

[13] NATO STO (2016). Enhanced CAX Architecture, Design, and Methodology. NATO STO Technical Report STO-TR-MSG-106. NATO Science & Technology Organization, Neuilly-Sur-Seine, France.

[14] MSCOE (2014). NETN Federation Architecture and FOM Design v2.0 as of 05 Nov 2014.

9.0 BIBLIOGRAPHY

Assar, M., (1971). Guide to Sanitation in Natural Disasters, WHO, Geneva.

David, W., (2016). M&S Support to Disaster Management and Humanitarian Logistics in Interagency Interaction: Challenges and Opportunities. CMDR COE Proceedings Sofia, 2016, pp.164-187.

Evensen, P.I. and Bentsen, D.H., (2016). Simulation of Land Forces Operations – A Survey of Methods and Tools. FFI-rapport 2015/01579. Forsvarets Forskninginstitut.

CMDR COE (2015). Study South Eastern Europe Education and Training Network (SEEETN), November 2015.

Holling, C.S., (1973). Resilience and Stability of Ecological Systems. Annual Review of Ecology and Systematics, Vol. 4, pp.1-23.

Jeremias, G., Martin, H., (2020). Bio-Hazard Disaster Risk Governance Through Multi-Agency Cooperation. Online at: https://www.unisdr.org/files/66058_fjeremiasmartinbiohazarddisasterris.pdf (Accessed 17 Feb 2020).

Linkov, I., Trump, B.D., and Fox-Lent, C. (2016). Resilience: Approaches to Risk Analysis and Governance, IRGC Resource Guide on Resilience. Lausanne: EPFL International Risk Governance Center.

Mardirosyan, G., Rangelov, B., Bliznakov A., (2011). Natural Disasters. AVIT CONSULT, Sofia.

NATO RTO, (2011). Modelling and Simulation System for Emergency Response Planning and Training, NATO RTO Technical Report, RTO-TR-MSG-049, NATO Research & Technology Organization, Neuilly-sur-Seine, France.

NATO RTO, (2012). NATO Education and Training Network, NATO RTO Technical Report, RTO-TR-MSG-068, NATO Research & Technology Organization, Neuilly-sur-Seine, France.

NATO Standardization Office, (2014). AMSP-05 Handbook (Best Practice) for Computer Assisted Exercises (NATO M&S CAX Handbook) Edition (A), STANREC 4801.

National Academy of Sciences NAS, (2013). Report on "Disaster Resilience," Risk Analysis, Integrating Risk and Resilience Approaches to Catastrophe Management in Engineering Systems Vol. 33, No. 3.

Nelson, S., (2018). Meteorites, Impacts, and Mass Extinction. https://www.tulane.edu/~sanelson/Natural_Disasters/impacts.htm (Accessed 17 Feb, 2020).

Plodinec, M.J. (2013). Definitions of Community Resilience: An Analysis. The Community and Regional Resilience Institute (CARRI).

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14. Abstract

The objective of the MSG-147 project and the CMDR CoE was to develop a reference architecture and implement a technical platform to enable rapid and effective testing of crisis/disaster and climate change response plans. 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 an 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 offer an implemented solution, the Disaster FOM module (compatible and integrable in NETN FOM v2) was developed and successfully tested to provide technical support for 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.

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