A Reference Framework of Netcentric Principles for NEC Concept Development and Experimentation.

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ABSTRACT: *The starting point for the development of future Network Enabled Capabilities (NEC) is a well founded description of the operational environment, net-centric concepts of operations, and netcentric systems. We have started to define a reference framework for NEC concept development to help guide*

- *The identification of the basic concepts of NEC operations;*
- *The specification of the fundamental functions in a NEC environment;*
- *The definition of the basic building blocks of NEC.*

A description of basic NEC concepts in the reference framework should also help in identifying impacted areas (e.g., R&D, system development, doctrine development) where follow-on work is required. One of these follow-on activities is experimentation with selected NEC concepts.

Modeling and Simulation are two corner stones upon which the development of future Networked Enabled Capabilities will heavily rely. We intend to use the NEC concepts, as developed in our reference framework, as a starting point for simulation based experimentation to assess the feasibility, effectiveness, and performance of their implementation in terms of virtual systems-of-systems and the associated command & control processes. Through M&S based experimentation, the required capabilities that will enable the Netherlands armed services to take part in future net-centric coalition operations, will be developed in an evolutionary and pragmatic manner.

1. Introduction and Background

One of the most important topics currently under study within the Netherlands Ministry of Defense is related to the question: *"Which measures are required in order for the Netherlands to be able to join and contribute to the international development of Networked Enabled Capabilities (NEC)?"* Answering this question will require both *research* into new NEC concepts and *operational experiments.* Research into new NEC concepts has a top priority for the immediate and near-term future, based on the realization that these new concepts and new technologies are the basis on which NEC is to be founded. Similarly, the ability to test and validate these new concepts and technologies *more rapidly, less costly, and with fewer risks than currently possible* also has a high priority. It is expected that this can be achieved by using (simulated) operational experiments, using a mix of real and simulated systems.

In order to be able to answer NEC related questions (or any question in general) using simulation based experimentation nearly a simulation configuration is usually required that is specific to the characteristics and context of a particular question. However, there currently is a large variety of NEC related questions, and each of these has its own requirements with respect to accuracy, fidelity, and validity of the simulation used. Developing or configuring these simulations "from scratch" for each individual NEC-related question would require large amounts of time and budget. Instead, it has been decided to create an *independent national simulation environment* to support the rapid and cost-effective development, assembly and execution of simulation experiments for the assessment of NEC related issues.

The NEC simulation environment consists of three parts:

- An integrated set of simulation development tools, tailored for NEC characteristics, to support the development and execution of simulations in a structured and reproducible manner;

- A repository, containing an evolving set of references to available models, simulations, and support tools for creating NEC experiments, e.g., sensor, weapons systems, C2 systems, communications infrastructure, but also environment models;
- An infrastructure, consisting of the basic hard- and software for deploying and managing distributed simulation experiments. The infrastructure links simulation centres of the Netherlands armed services, research institutes, and industry.

The name that has been coined for this simulation environment is *SENECA (*Synthetic Environment for Networked Enabled CApabilities).

The process that is envisioned for the use of SENECA in the evaluation of operational and technical NEC concepts consists of two stages:

1) Simulation development, and
2) Simulation execution and evaluation.

Given a NEC related concept that is to be evaluated, the first step in stage 1 is a decision on whether this particular concept can effectively and efficiently be evaluated by means of a simulation experiment. If so, the ensuing development phase of the process entails:

- Selecting a suitable scenario and/or vignettes that provide a valid operational context;
- Determining the evaluation criteria (measures of merit, effectiveness, or performance);
- Developing functional and performance requirements for the simulation configuration;
- Identifying relevant models and simulations and to be federated for the experiment;
- Agreeing on interoperability requirements (both technical and substantive);
- Determining logical configuration of the particular SENECA instantiation for the experiment;
- Designing the physical configuration of the experimentation environment.

The second stage then focuses on the implementation and execution of the simulation experiment, and the subsequent analysis of the results against the evaluation criteria. This process is inspired by the HLA FEDEP model, tailored to meet NEC-specific requirements such as the integral involvement of command and control processes and C4ISR systems.

In order for SENECA to become a truly "learning" environment, it is essential that all information generated in either of the two process stages is evaluated for future reusability, and if so, is added to the ever evolving SENECA repository. It is here that the rigorous development and use of simulation conceptual models can contribute significantly to the validity and cost effectiveness of simulation based NEC concept development and evaluation.

In the following sections of this paper we start by describing our terminology regarding conceptual modelling and the role that conceptual modeling plays in the development of future Networked Enabled Capabilities. We then provide a summary of a NEC conceptual model for the description of the simulation context. We also describe a number of *design oriented* conceptual model issues that we think should be addressed at this stage.

2. The Role of Conceptual Modeling

One of the first steps in any systems engineering process, whether oriented at the development of simulation systems or some kind of operational system or equipment, is the translation of the user's needs and requirements into a design approach that will guide the actual development and building process. The development and description of a Conceptual Model is an essential step in that it provides a means to reach agreement between the user and the system developer about *what* the simulation or operational system will do. Furthermore, the system developer uses the Conceptual Model as a prescription for the description of *how* the system or simulation is going to perform the required tasks. Much has been written about what is actually meant by the term *Conceptual Model* in diverse areas such as databases, knowledge engineering, and computational science [1]. In any case, the conceptual model is used to authoritatively describe either problem domain related issues, design related issues, or both. Mapping the "what" part of a Conceptual Model to the "how" part is essentially a creative process that makes conceptual modeling such a daunting undertaking.

For our purposes, we will adhere to the definition of a conceptual model that is given in the DoD *Recommended Practice Guide (RPG) for Verification, Validation, and Accreditation (VV&A)* [2]:

> *A simulation conceptual model is a Developer's way of translating the requirements into a detailed design framework, from which the software that will make up the simulation can be built. A simulation conceptual model is the collection of information which describes a Developer's concept about the simulation and its pieces.*

This definition recognizes both the domain oriented ("What is to be represented in the simulation?") and the design oriented character ("How is the simulation going to do this?") of conceptual models, and also provides elements to support various validation activities throughout the system development process. Thus, the conceptual model should capture representational and quality requirements about the (part of the) real-world that is to be simulated. This so-called *simulation context* consists of authoritative information about all relevant elements of the domain that the simulation or system is expected to address, e.g., (military) entities, physical processes, but also, especially in the case of command & control "intensive" simulations, organizational structures, military tactics, techniques, and procedures, etc. The simulation context is the *domain-oriented* part of the conceptual model. The "raw" information that comprises the simulation context is typically provided by the user-supplied subject-matter expertise.

The other part of the conceptual model is *design oriented*. In the RPG this part of the conceptual model is referred to as the *Simulation Concept.* It describes the developer's conceptual design for the simulation application in terms of representations of entities and processes, behaviours and algorithms, data and configuration (architecture). The coherence, consistency and completeness of the mapping of simulation context onto simulation concept provides a first conceptual validation of the design approach. Figure 1, taken from reference [2], shows the relationships between the various components of the simulation conceptual model.

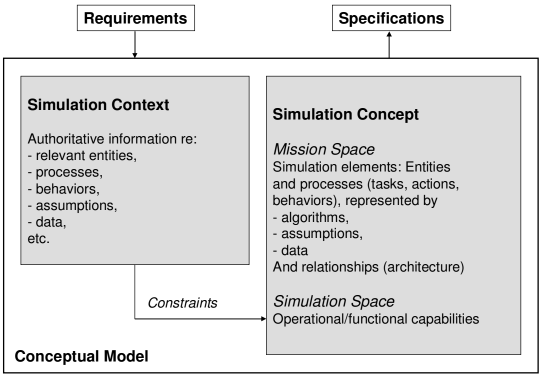

Figure 1. Conceptual Model Components.

The definition provided above is aimed at the development of *simulations*, but conceptual models also play a role in the design phase of operational systems, processes, and organizations. Thus, where appropriate, we will broaden the definition of a conceptual model to also apply to this development process. The reason is that we would like to take advantage of similarities between the nature of simulation systems and the Network Centric Operations and systems they are representing in order to be able to use (parts of) the same conceptual model for both the development of the simulations as well as the future Network Centric systems, systems-of-systems, and command and control processes. In this way, we hope to achieve explicit consistence between the simulations used to assess future Networked Enabled Capabilities and the Capabilities themselves.

Whatever the usage, the purpose of a conceptual model primarily is [3]:

- To convey information;
- To promote re-use of verified domain knowledge;
- To create robustness against requirement changes.

To a lesser extent, a conceptual model enables:

- Checking the completeness of user requirements;
- Prevention against the introduction of superfluous concepts;
- Transitioning concepts into the design phase.

In summary: creation and re-use of domain knowledge come first, VV&A and other support of the follow-on development process come second.

Both domain oriented and design oriented aspects of conceptual models contain highly complex descriptions of the required information. In [4], Koopman argues that decomposition is a fundamental approach to dealing with complexity. He also points out that a suitable decomposition strategy can provide a common ground for representing both operationally driven and technically driven design decisions. It is therefore essential that a suitable decomposition strategy is chosen for the development of both operational Networked Enabled Capabilities and the supporting Modeling and Simulation infrastructure.

In our case, we would like to explore to what extent a conceptual model of net-centric principles (which is currently being developed for the conceptual description of operational Network Enabled Capabilities) can also be used to describe the simulation concept of the federations used to support the NEC development process (See fig. 2).

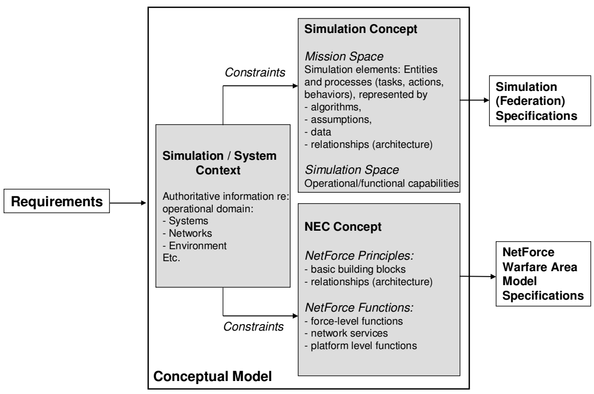

Fig. 2. A possible unified conceptual model for NEC Concept Development and Experimentation.

In the next section we describe the fundamental principles of the Netforce Reference Model (NFRM), and in section 4 some of the issues are examined that need to be addressed before the NFRM can be used as a "springboard" for simulation (federation) development.

3. The NEC Conceptual Model: the Netforce Reference Model (NFRM)

The starting point for the development of future Network Enabled Capabilities (NEC) is a well founded description of the operational environment, net-centric operations, and net-centric systems. We have started to define a reference framework for NEC concept development to help guide

- Identification of the basic concepts of NEC operations;
- Specification of the fundamental functions in a NEC environment;
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A description of basic NEC concepts in the reference framework should also help identify impacted areas (e.g., R&D, system development, doctrine development) where follow-on work is required. One such a follow-on activity is experimentation with selected NEC concepts.

In many discussions on NEC the specific net-centric concepts are just loosely defined. Terms like *synchronization, agile mission groups, real-time shared situational awareness, effects-based planning,* etc., are often ambiguously understood. This is often due to the fact that the underlying net-centric principles that construct those higher level concepts are not precisely known or defined. In discussions on how to create net-centricity, how to evaluate the effects of net-centric developments, or how to introduce NEC in organizations, the lack of fundamental understanding of the basic building blocks of NEC is felt even more.

In this section we will give a brief summary of ongoing work aimed at solving this lack of understanding. It is described in much more detail in [5]. In a bottom-up process, starting from a small set of basic assumptions, a framework of NEC concepts is built. Based on the very elementary and fundamental building blocks, higher order more complex concepts are constructed*: network services, force-level functions,* and *generic warfare models*. The framework is called the *Netforce Reference Model (NFRM)*. The purpose of the NFRM is to harmonize NEC terminology, to understand the nature and complexity of net-centric concepts, and to increase the interoperability between systems and organizations that have been designed based on these Netforce principles.

3.1 The Network-Node paradigm and the Basic Nodes

The NFRM regards net-centric operations from a *systems-of-systems* point of view: the net-centric system-of-systems is a collection of nodes, interacting with each other through a network, in order to carry out the net-centric operation. All components in a net-centric operation, from organizational elements, systems, combat assets (tanks, jets, ships, and soldiers), sensors and weapons or support units are regarded as nodes in a network. This we will call the *Network-Node Paradigm.*

The Network-Node Paradigm: all entities in a net-centric operation can be regarded as nodes interacting with each other through a communications network.

To establish an unambiguous terminology the following definitions are used:

Node	an entity in the NEC environment that performs one or more basic net-centric actions and is able to communicate with other nodes in the NEC
Node type	the characterization of a node according to its main basic net-centric action
Netforce	the total collection of connected nodes that work together to perform a specific NEC. This is the total net-centric system of systems (NSoS)
Network	the collection of nodes that perform communication and data distribution actions

By adopting these definitions it is unambiguous what we mean by *network*. In our definition it is restricted to the infrastructure of the whole net-centric environment while the *Netforce* stands for the total netted force.

Taking the operational point of view we can define a small set of task descriptions to characterize NEC:

1. the collection, processing, interpretation of data/information,
2. the provision through the network of quality information to all decision makers,

3. the ability of co-operative and synchronized decision making to create tailored measures,
4. the ability to execute these tailored measures in a timely, accurate and synchronized way.

This set is both information and network driven. It is our key NEC characterization. In analyzing these key characteristics we derive 6 elementary NEC actions. Five of which are operational and one arising from the necessity of a net-centric support of the operational NEC actions.The six elementary NEC actions are:

data collection the action of collecting data and information for use in net-centric operations

information processing & provision the action of data and information processing, interpretation, association, correlation, fusion, and the provision of that information in the right format to information requestors

communication the transportation of data and information using various ways of transport media

decision making the action of using the available data and information to decide on possible courses of action

taking action the action of effectuating the decisions made by the decision making processes

providing support the action(s) of providing support for the net-centric operation to be carried out and sustained. This class of elementary actions consists of a variety of different support actions.

In our Netforce approach we will apply the axiom that these elementary actions can be represented in the net-centric environment by entities or nodes capable of performing one or more of those actions. Consequently we arrive at the following set of basic net-centric nodes with which we model NEC:

Netforce Actions and Node Types	
Basic actions	*Node types*
data collection	Collector (C)
information processing & provision	Information provider (I)
decision making	Decider (D)
taking action	Effector (E)
communicating	Communicator (Com)
providing support	Supporter (S)

Table 1 The Basic Netforce Actions and Node Types

Each node in the Netforce can be characterized according to its major action it performs. Many real world objects exhibit more than one basic Netforce action. For instance a naval combatant exhibits all six basic Netforce actions. Such objects will be called *composite nodes* in the Netforce. In addition to *type,* nodes have other elementary properties as well: *identity, status, capability, structure* (e.g. composite)*, control, security, integration,* and *interaction*. For a description and discussion of these properties the reader is referred to [5].

3.2 Basic Node Related Concepts

In section 3.1 the nodes and their elementary properties were introduced and briefly described. The network-node paradigm provides us with a set of elementary node types and a set of elementary properties for nodes. These two sets are the starting point to derive and define the basic concepts from which the Netforce reference model is constructed.

This section discusses the basic concepts directly related to the nodes. In section 3.3 the basic Netforce concepts are discussed that relate to multi-node behavior arising from interacting nodes. In our discussion we will start with the most important concept: how does a node interface with the Netforce and with the network. Having defined this mechanism, many of the other properties are more or less automatically derived and subsequently discussed.

In a net-centric environment one of the most important concepts is how nodes interface with the Netforce and the network. For this, a layered model of the node structure has been defined. A distinction is made between the node core functionality (one or more basic Netforce actions) and the functionality required to function in a Netforce environment. This layered node structure is shown in figure 3.

The Netforce interface comprises three distinct layers:

- *the network communications component*: this component provides the node with the means to connect to the network itself.
- *the node interface component:* the component which provides the translation of external node commands (e.g. sensor settings) to internal node commands.
- *the node specification component:* the component that specifies the node identity and its services to the Netforce.

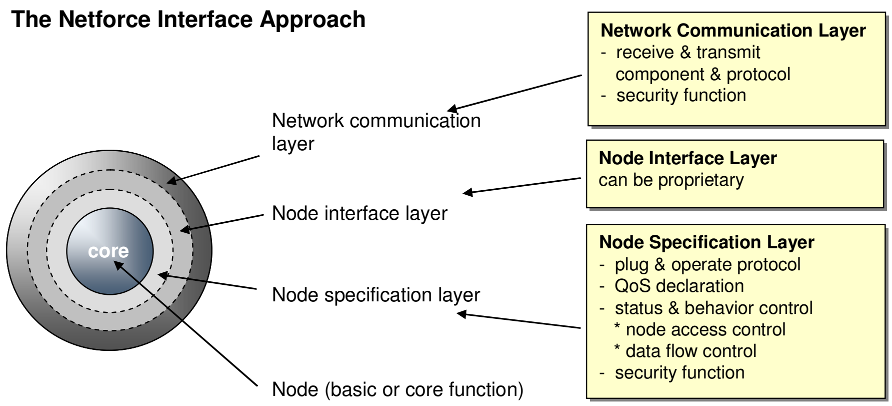

Figure 3. The Layered Node Structure

The various interface layers deal with node properties like node identity, capability, structure, and security (access control).

3.3 Nodes and Their Interactions

In this section we will extend the Netforce principles by looking at the node interactions, thereby transitioning from single node to multi-node concepts. We will start by describing simple node interactions first. The most characteristic basic node interactions can be illustrated by the real-world processes that can be associated with them:

Node Interaction	**Operational Process**
C-I	Information creation
I-I	Information processing / availability
I-D	(shared) situational awareness
D-D	Synchronized decision making
D-E	Effector assignment
E-I	Guided action, engagement
E-E	Synchronized engagement

Table 2. Basic node interactions

One of the mechanisms used in the node interactions is Quality of Service (QoS) management. The purpose of QoS management is to enable the optimal use of node capabilities by the Netforce (other nodes) in both a static and dynamic way. Suitable QoS management schemes can be used to optimize (parts of) the Netforce dependent on operational needs. In principle, QoS applies to all node properties and capabilities.

Basic interactions between nodes can be aggregated into multi-node interactions, including composite nodes, for the creation of higher level services and functions.

3.4 Network Services and Netforce Functions

The node definitions, including their properties and relationships, provide the groundwork on top of which we can now build higher level, dynamic Netforce principles that describe the behavioral aspects of NEC. These are the functions and services (F&S) that control and manage the Netforce and prevent it from becoming a chaotic behaving system. *A function or a service is the management, control of multiple node capabilities to collectively and coherently achieve a specific purpose.*

A distinction is made between *network* and *Netforce* functions and services. For the Netforce we distinguish between the *operationally oriented functions* and *support services*. Because the network is regarded as the enabler of the net-centric concept, we will use the term *services* to describe network capabilities. A (typical, not exhaustive) list of functions and services is given in table 3.

Netforce Functions and Services	
Netforce functions	*Network services*
Operational functions	Communication services
Support services	Network optimization
Node management	Security management
Data management	….
Security management	

Table 3. Force Level functions and services.

Functions and services can be described in two different ways. When we consider a function or service from the level of the participating nodes, we can talk about a *inter-node function* or *service*. In that case all interactions and interfaces with the involved nodes need to be specified. When we consider a function or service from a higher level, like a function or service occurring inside a composite node, then we can talk about an *intra-node function or service* and a black box type of specification suffices on the composite level. The difference between an *inter-node* and an *intra-node F&S* is therefore the level of abstraction and the required level of specification. When we treat a set of nodes as a composite object, then the F&S inside that set become intra-node F&S on the composite level, and a different way of specifying them can be used. An example is a CMS (combat management system) of a naval combatant. On the level of a naval task force a ship CMS is an intra-node function (also called a platform function). A so-called force level TEWA (threat evaluation and weapon assignment) function is an inter-node function. here the interface and behavior specification with each node is required. In our situation today we still have many intra-node functions for all kind of platforms (nodes), like tanks, ships, aircrafts. Although the same, these functions of similar platforms are often not connected to each other yet, or at best only in a rudimentary way. We are in a transition process where these intra-node functions become connected to each other and thereby creating an inter-node function. When dealing with F&S we therefore have to take into account existing intra-node F&S and how to interface with them or how to integrate them into an inter-node function. In our Netforce discussion here we will only address the inter-node F&S.

To have an agreed set of generic Netforce functions and services with 'standardized' interfaces and architecture, would increase interoperability between different national systems considerably.
We have derived the following set of Netforce Generic Functions and Services:

- Collector Management (CM)
- Picture Compilation (PC)
- Situation Evaluation (SE)
- Effector Assignment (EA)
- Effectuation (Eff)
- Planning and Coordination (PLC)
- Resource Management (RM)
- Netforce Management (NM)

3.5 Netforce warfare Area Modelling

The set of Netforce principles described above have been formulated in a way that makes them independent from the application of net-centric concepts in a specific operational setting. Although we can at this stage not yet claim that the set is complete or consistent, we will indicate how the transition to the operational domain can be made by showing how an operational domain can be modeled using these Netforce principles. Such a domain can in principle be any warfare area, such as air defense, mine detection, amphibious operations, or crisis response, etc.

In combining the eight generic Netforce F&S and the four generic Netforce databases (a description of which has been omitted in this paper for the sake of brevity, see [5] for details) we created one overall process model, which we call the Generic Netforce Warfare Model. This Model provides insight in the overall structure of a warfare area. It is the basis for the simulation of processes that typically take place in a net-centric environment. Note that in this generic model the strategic, operational and tactical levels have been "folded together" for illustrative purposes. Also, sequencing and timing issues are not represented here for the same reason. Even with these omissions, it helps to understand the structure, or generic functional architecture, of a warfare area.

4. Design Oriented Conceptual Model Issues

In Conceptual Model terminology, certain parts of the NFRM describe NEC system *context* (the domain-oriented part), while others describe NEC system *concept* (the design oriented parts). As stated in sections 2, our aim is to determine to what extent we can develop both NEC *system* concepts as well as NEC *simulation* concepts based on the same NEC system/simulation context. This would be greatly facilitated if we could use the same "language" for the common elements in both operational context and concepts and in simulation context and systems. Three of these "language" issues are discussed here.

4.1 Decomposition strategies

Although Koopman in his paper on decomposition strategies [4] approaches the issues from a design oriented point-of-view, his taxonomy certainly also applies to the domain oriented aspects of conceptual models (particularly in the case of NEC and NCO, where we are in the process of designing a new operational context!). His objective is to relate different decomposition strategies to each other in such a way that a common ground is provided for both operationally driven and technically driven design decisions.

The overall objective of system decomposition is to reduce complexity to a manageable level. The way in which this is achieved depends to a large extent on the way the people involved think about the system context and concept, i.e., which domain and design characteristics are most relevant from their point of view. Thus, a

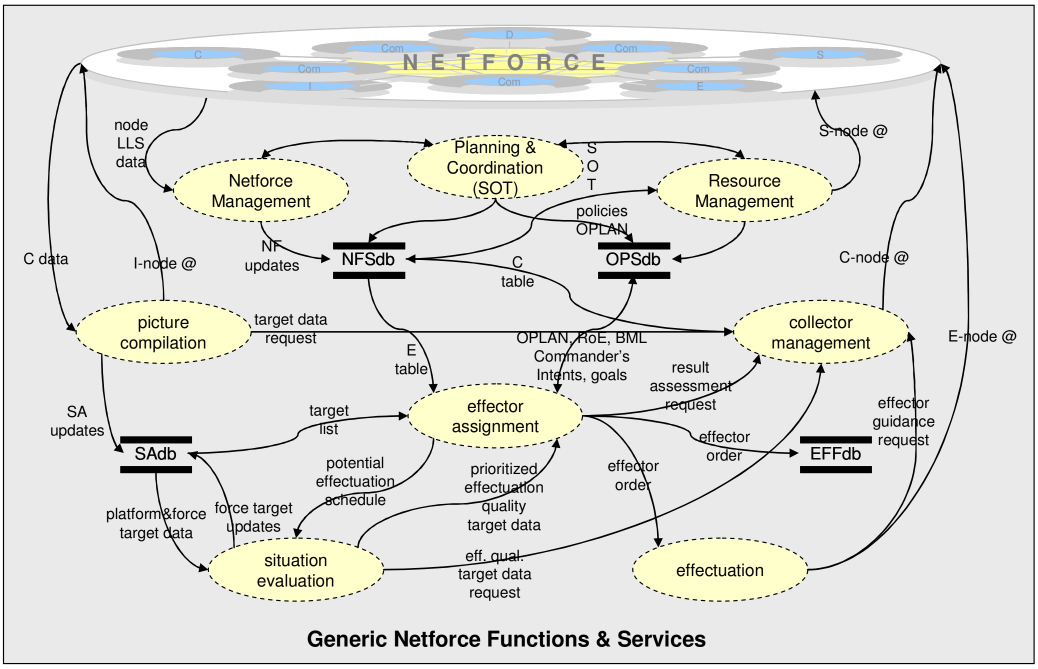

Figure 4. The Generic Netforce Warfare Model

representational framework should allow decompositions to be made according to different views. Koopman distinguishes between three fundamentally different views (or "attribute categories" as he calls it):

- *Structures* – the physical parts or components, logical objects, geometric attributes, etc. of a system. Structures represent the "what" in a system design or operational domain;
- *Behaviors* – processes, actions, control flows, etc. interacting with structures or between structures and the external environment. Behaviors represent the "how" and "when";
- *Goals* – the emergent properties of a decomposition that satisfy the needs or constraints. Goals explain "why" certain decisions w.r.t. structures or behaviors (e.g., "form" vs. "function" trade-offs) are made.

To a certain extent, these views correspond more or less to the three major views distinguished in the DoDAF [6]: systems (structures/form), operational (behaviors/function), and technical standards (at least as far as the constraints are concerned).

At this stage, the decomposition strategy for the NFRM is rather ad-hoc: at the basic node level, a structural decomposition scheme is followed, at the level of network services and Netforce functions, the decomposition more closely resembles a behavioral scheme, and at the warfare area level, elements of a goals-oriented decomposition are visible, driven by the organizational issues that play a role at this level. In general, ad-hoc decompositions lead to rather "brittle" designs, i.e., hard to modify and support. If we want to be able to validate future operational NEC concepts and verify future NEC systems designs using simulations in a manageable and tractable way, the conscious choice of a suitable decomposition strategy for the NFRM is important and therefore needs to be addressed.

4.2 Formal Conceptual Modeling Language

The NFRM has so far been mainly described in a semi-formal manner, using an ad-hoc mixture of plain text and free-format diagrams. If at one stage it is to be the foundation for the description of a set of verified conceptual models, whether for operational system development or for simulation based experimentation, a more formal approach is essential. Because of the inherent similarities between the software intensive future NEC systems and the models and simulations used in NEC experiments, a common approach to a formal conceptual model description is highly desirable. At the same time, reasonable implementation independence [1] is also essential if we want to be able to reuse conceptual models of operational systems for simulation federation design and vice versa. We are currently investigating the applicability of UML as a modeling language for the representation of both the structural behavioral aspects in the NFRM. An example of a similar approach is given in [7], where a formal Conceptual Modeling Language is used to describe abstract models of battlefield operating systems and activities for the OneSAF Objective System (OOS). By adhering to Model Driven Architecture principles, we aim for some form of "platform independence", allowing the conceptual models to be used for both operational system and doctrine development and simulation federation design.

4.3 Battle Management Language for C2 information

Future Net Centric operations will inherently be highly data and information intensive. The recent drive to develop an unambiguous language for the command and control of forces and systems, and for creating situational awareness and a shared common operational picture has resulted in prototype implementations of Battle Management Language (BML) [8]. Based on underlying data models such as the NATO C2 Information Exchange Data Model (C2IEDM), and taking advantage of open web standards and technology for data transport, various BML "dialects" are expected to be a major enabler of (coalition) net-centric operations. Moreover, BML is a key-enabler to achieve C2-simulation integration, i.e., the interoperability between live (C2) systems and simulations. For NEC Concept Development we plan to develop a series of experiments, starting with completely virtual en constructive simulations, via a mix of live and simulated systems, through to live experiments. The need to be able to "plug and play" alternately with live and simulated systems requires a form of semantic interoperability. A formalization of the C2 message exchange processes in the Netforce generic functions and services in terms of BML is expected to help enable this interoperability.

5. Conclusions and Further Work

The paper has presented some ideas on the role of conceptual modeling in both the development process of operational Networked Enabled Capabilities and models and simulations used in NEC Concept Development and Experimentation. We have described a reference framework for net-centric principles, how the basic building blocks are defined in terms of types, capabilities, and interfaces, how net-centric force level functions are described in the framework, and how net-centric warfare areas are modeled. Interoperability issues ensuing from conceptual NEC architectures are typical for the problems that can be tackled through a simulation based approach. The development of synthetic environments for networked enabled capabilities, currently underway, has also been described. We have described our approach to unify these processes as much as possible where this is useful or essential. The starting point for this approach is a rigorous conceptual description of relevant elements of the application domain and issues in the design domain.

The initial approach presented in this paper needs much more work in order to become usable. Topics that we plan to tackle include:

- Better structuring of the NFRM into a more cleanly layered or hierarchical decomposition;
- Developing a more formal description of suitable elements in the NFRM based on formalisms such as UML;
- Identifying opportunities for the use of Battle Management Language in a common description of operational interoperability issues and C2-simulation interoperability issues;
- Applying the methodology in a suitable M&S case study in order to acquire early lessons learned.

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Author biographies

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Dr. Hans E. Keus is a senior program manager and advisor at TNO Defense, Security & Safety in The Hague, The Netherlands. He has an extensive background in maritime command and control and C4I.
He has worked for 8 years as Head of the Maritime Command & Control Group at TNO and was involved in combat management projects and modeling & simulation initiatives. As such he was the originator of the maritime CIC XXI experimental command facility at TNO. Currently Dr. Keus is international program manager and a senior advisor to the Royal Netherlands Navy for C2 and C4I.

He is active in the International Maritime Theater Missile Defense Forum (MTMD). In this 8 nation initiative he is a member of the BMC4I Working Group and co-leading the Technical Direction Agent for the multinational BMC4I Architecture Definition Project. He is also a member of the European Multi Platform Engagement Capability Working Group, in which European nations work together to develop a coordinated engagement capability for air defense. He is the TNO representative in the management team of the DECIS-LAB (Delft Co-operation on Intelligent Systems) and the ICIS project on collaborative decision making.

His current work involves architectural modeling of coalition missile defense architectures, collaborative decision making and concept development on NEC. Dr. Keus is a regular speaker on missile defense conference and command & control conferences.

Dr. HANS JENSE
Dr. Hans Jense is Chief Scientist, Modeling and Simulation, at TNO Defense, Security & Safety. He graduated from Utrecht University in 1984 with a degree in Astronomy. In 1991 he received a Ph.D. from Leiden University in Computer Science. He’s been active in the M&S area since he joined TNO in 1991, initially as a scientist in the High Performance Computing and Networking group, later as a senior scientist in the Simulators group. From 1997-2005 he was head of the Simulators group.

In the international M&S community Dr. Jense has been active as a member of the NATO Modeling and Simulation Group (NMSG) since its inception. From 2002-2004 he was chairman of the NMSG. He has also been a member of the conference committee of the International Training and Education Conference (ITEC) since 1997, and is currently a board member of the European Training and Simulation Association (ETSA).

His current research interests are in C2-simulation interoperability, simulation reuse, system development methodology, information visualization, and “serious games”.