2006 CCRTS

THE STATE OF THE ART AND THE STATE OF THE PRACTICE

System Modeling Approach to Network-enabled Defense

C2 Concepts and Organizations, C2 Modeling and Simulation, Social Domain Issues

Dr. Tuija Kuusisto
Defence Forces, Finland
P.O.Box 919, FIN-00131 Helsinki, Finland
Tel. +358 40 5529541, fax +358 9 181 23645
tuija.kuusisto@mil.fi

LtCol. Rauno Kuusisto, PhD
National Defence College, Finland
P.O.Box 7, FIN-00861 Helsinki, Finland
rauno.kuusisto@mil.fi

Abstract

This paper concerns the command and control of network enabled warfare from the information flow point of view. Organizational structure and more recently processes have been the typical aspects to concern when developing and modeling command and control approaches to network enabled warfare. However, it is information that connects command and control structure and activities. Information flow aspect most probably provides novel insights on network enabled warfare and its command and control. The paper uses a system modeling approach to outline the information flows in Network-enabled Defense (NED). NED is a working title for a concept that uses the principles of network enabled warfare for securing the functions vital to society in Finland. The paper defines the information flows affecting and included in the command and control of NED by applying a general model about situation awareness and managing. The model supports especially the categorising of the contents of information flows. It contains three main categories of information: action information, basic information and conclusions as well as information refining steps, i.e., information process model. Currently a prototype of a command and control system based on the model is under development.

Introduction

The shift of military command and control from a heterogeneous environment to cover divergent groups of players, information system services and information has challenged the traditional command and control practices. The players include military leaders and units, state authorities and departments, interest groups and media. Information system services cover modern field equipments and intelligence and decision support systems that provide decision-makers with an increasing amount of effective information needed in command and control. This variety both requires and enables enhancements to the ways military command and control is implemented. As Alberts et. al (2001) state the existing and tried approaches to command and control, organization and doctrine need to be re-examined. The recent popular terms such as collaboration, self-synchronization, joint, Joint, information warfare, information operations and effect-based operations express the re-examination of traditional approaches. However, theories and practices about managing a variety of players for national security protection especially in crisis situations are still under development. These theories include command and control models and methods for crisis management in a heterogeneous network society.

Organizational structure and more recently activities or processes have been the typical aspects to concern when developing and modeling command and control approaches of network centric warfare. However, it is information that connects command and control structure and activities. Information flow aspect most probably provides novel insights on network enabled warfare and its command and control. This paper uses a system modeling approach to outline the information flows in Network-enabled Defense (NED) (Figure 1). NED is a working title for a concept that uses the principles of network enabled warfare for securing the functions vital to society in Finland. It is related to the further development of the Finnish Defence Forces Territorial Defense Doctrine. NED is defined to describe how future networks with improved and integrated information and weapon systems can enable Command and Control of Joint and Territorial operations and enable Interagency Collaboration in securing vital functions of the Finnish society in Total Defence (Kaskeala 2005). This definition states that NED is a Joint activity in which Finnish Defence Forces and one or more other state authorities, enterprises or interest groups

participate. The emphasis of the definition is on the integration of information and weapon systems. This integration supports information to flow on NED.

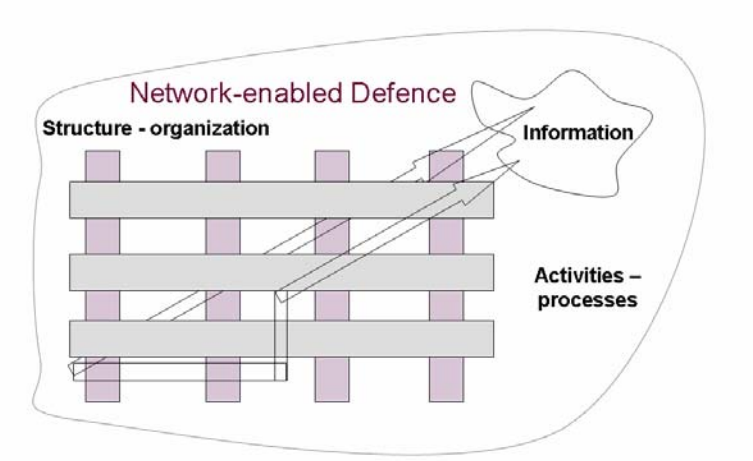

Figure 1. Structure, activities and information flows are aspects on Network-enabled Defence (NED) (based on Kuusisto et al. 2006a)

In this paper the concept of information is understood as a general term for data, information and knowledge. Data is a set of discrete and objective facts about events (Davenport & Prusak 1998). According to Thierauf (2001) information is defined as structured data that is useful for analysis. Information has a meaning to a receiver (Davenport & Prusak 1998). Information becomes to knowledge, when information is understood and interpreted. Knowledge can be defined as an ability to turn data and information into an effective action (Applehans et al. 1999). When the temporality of information is concerned, three classes of information are identified: historical information about the past, perceptions as information about the current moment and assumptions about the futures (Bergson 1911, Damasio 1999). NED activities deal with huge amounts of effective information of all these six types. The computer-based content management and search systems of NED shall provide the human users with generalized and grouped data and information so that the users are able to turn the provided data and information into effective action.

The research question of this paper is: What is the information flow aspect on the command and control of NED? First, NED as a system is outlined. Secondly, information flow aspect on NED system is described and a general model about situation awareness and managing is applied to define the contents of information flows affecting and included in the command and control of NED system.

Network-enabled Defence as a System

Network-enabled Defence (NED) is an interacting and adaptive social system in space and time (Figure 2). Information flows and technology enabled operations take place in NED system. Habermas's (1984, 1989) classification of information in social systems increases understanding about the complexity of distributing and gathering relevant information for an activity. Habermas bases his thinking about relevant information on the theories of social sciences. He combines theories about society, a human being as a part of society, and system thinking. Habermas (1989) states that four basic classes of information direct an actor's activity. Those are values, norms, goals, as well as perceived facts and information of usable means and resources (Habermas 1989). Habermas's interest is on societal aspects, which guides his thinking to a direction where

society is modeled as an integrative subsystem. In this paper, the viewpoint is different. Information and its purposeful use through availability in NED are modeled. As a result, the classification of information that Habermas adopted is not applied in a sociological context but in the information availability in NED context.

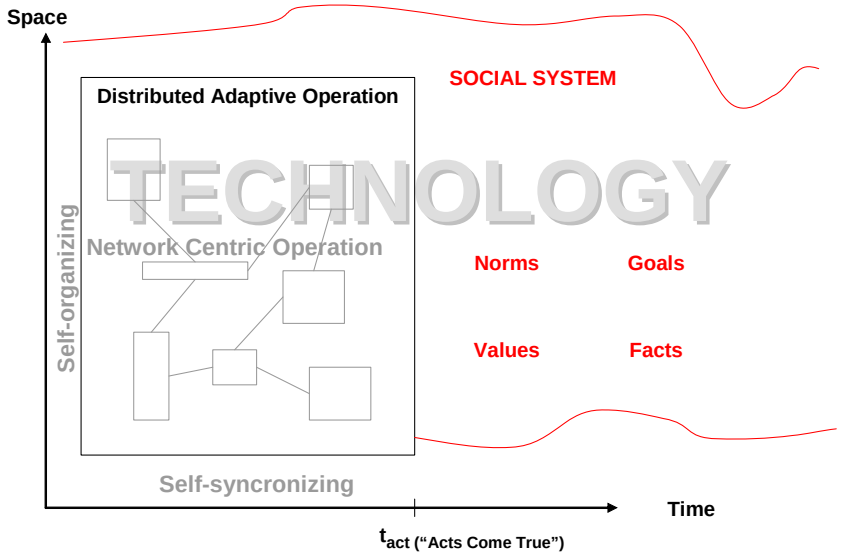

Figure 2. Network-enabled Defence (NED) as a system

Following Habermas thinking, the information flows in NED system contain norms, values, goals and facts. Information about values forms the long-lasting basis of information creation. Norms will determine mutually expected rules, among which the subjects of a community will perform their interactions. (Habermas 1989) Goals will determine the desired end-state of actions. Goals direct resources and means to achieve success as effectively as possible. Means, resources and facts are used for implementing those activities in practice that lead the actor to fulfil its goals as optimally as possible. Typical Finnish values of NED system contain patriotism, honesty and reliability. Norms include legal codes and the rules and regulations. In Finland goal is the protection of functions vital to society as stated in a strategy accepted by the Finnish Government (2003). Resources and means are utilized to reach the goal. The means consist of command and control methods and practices of NED including self-organizing and self-synchronizing.

NED system depicted in Figure 2 consists of self-organizing, geographically distributed and interacting adaptive operations. The result of a distributed adaptive operation is realized at the moment of t_{act}. Kauffman (1995) argues that self-organization is order for free. Moffat (2003) defines that the self-organization of a system means that a system evolves over time to an attractor corresponding to a special state of the system, without the need for guidance from outside the system. He continues to define that for an Information Age force, self-organization is a local action, which often appears chaotic and induces long-range order. Adaptation means that combat forces continually adapt and coevolve in a changing environment. (Moffat 2003) According to these definitions, a self-organizing, adaptive operation is locally inducing long-rang order and able to adapt and change within a changing environment without the need for a guidance outside the operation.

In NED system, the self-organizing, adaptive operations contain a set of technology enabled, interacting and self-synchronizing network centric operations. To synchronize is defined as to

represent or arrange (events) to indicate coincidence or coexistence (Merriam-Webster 2003). In military environment synchronization is defined as the arrangement of military actions in time, space, and purpose to produce maximum relative combat power at a decisive place and time (DoD 2005). Alberts et al. (2001) defines that self-synchronization is decentralized command and control. The aim of self-synchronization is synchronized activities while the result of self-organization is a state of a system. Referring to the aspects on a system depicted in Figure 1, self-synchronization covers only the activity aspect on a system while self-organization covers the structure, activity and information flow aspects on a system.

According to the definitions presented in previously, a self-synchronizing, network centric operation is arranging its actions in time, space and purpose to produce maximum relative combat power at a decisive place and time. A self-synchronizing operation follows mission and synchronizes its activities with the activities of friendly, neutral and hostile network centric operations of NED. The adaptation and interaction of self-organizing, adaptive operations and self-synchronizing network centric operations lead NED system to evolve.

Information Flow Aspect on Network-enabled Defence System

Information flow aspect on the evolving NED system is presented in Figure 3. Figure 3 provides a more abstracted view to NED system than Figure 2. In Figure 3 it is depicted that interaction with outside world (W) in common space (S) makes NED system to change over time (t). Outside world includes other systems and system of systems such as organizations, groups of organisations and groups of individuals. NED system affects and is affected over time through information flows (Ii, Io and Ie), which respectively are describing the information that is coming into NED system, going out from NED system, and flowing inside NED system. Effects through information flows make NED system to change gradually by an evolution (Ce) or radically by a revolution (Re) over time.

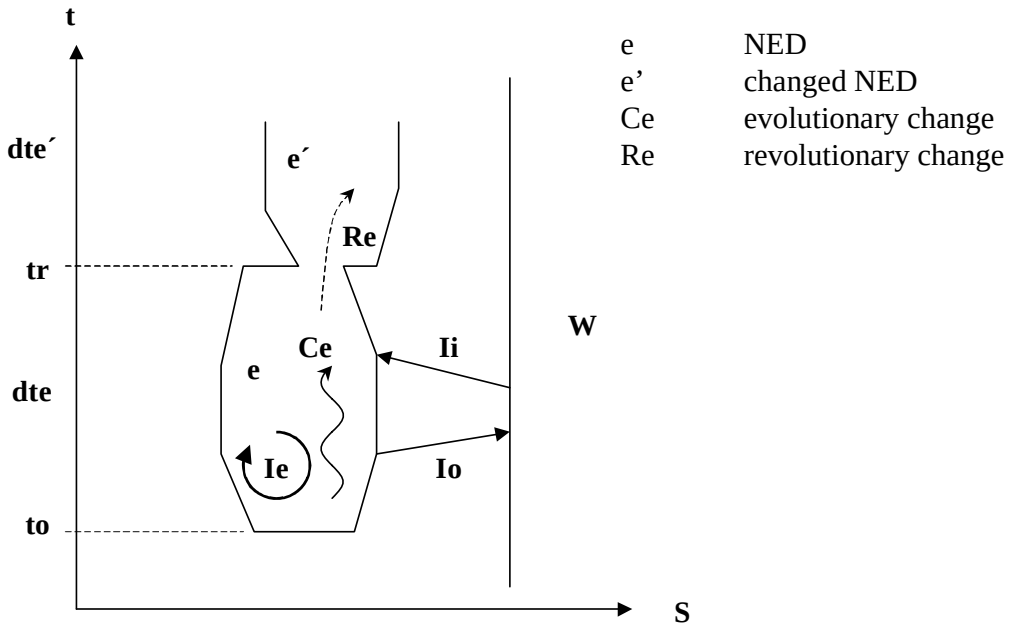

Figure 3. Interaction makes NED system to change over time (based on Kuusisto & Helokunnas 2003)

Attributes of time are duration and moment, which are either subjective or objective. Subjective duration is a duration that any entity needs to complete an action. Objective duration is a

duration that the world allows for an entity to complete the action. An action, described as an entity (e) in Figure 3, starts at a certain moment (to), has a subjective duration (dte) and reaches its ending moment (tr) where the action is finished or reborn as an action e'. The new action (e') has duration (dte'). In a NED system, a lot of this kind of temporal actions, i.e., subsystems occur. They make NED system to change. They include self-organization and self-synchronization. For example, self-organization of NED starts, makes NED to evolve over time to an attractor where self-organization of NED ends. This applies to any subsystem of NED like an adaptive operation of NED and a network centric operation of an adaptive operation.

As Figure 3 depicts there is a variety of information flows in NED system and between NED system and the world. Traditionally, the structure of the information flows in military environments has been hierarchical. Alberts et al. (2001) describes that the distribution of information has been identical to the distribution of authority in traditional hierarchical military organizational structures. However, the impact of Information Age has been the decoupling of information flows from the hierarchical structure (Alberts et al. 2001). This means that information flows on NED system and its command and control cannot and do not need to follow only hierarchical structures but a systems of systems structure. For example, information flows in joint operations in which elements of two or more Military departments participate (DoD) and in Joint operations follow and shall be managed to follow a systems of systems structure consisting of human and technological networks of networks structures.

The current command and control approaches are typically grouped to cyclic, interventionist, problem-solving, problem-bounding, selective control and control-free philosophies (Alberts et al. 2003). When the three aspects on a system depicted in Figure 1 are applied to this grouping, the result is that the grouping is mostly based on the activity aspect on command and control. Besides, an attention is put on information contents conveyed by command and control. The descriptions of these command and control approaches stresses that information flows are not following the hierarchical structure in the least centralized approaches. In addition, Alberts et al. (2003) describes that the assumptions for the least centralized approach, i.e., self-synchronization, are: Clear and consistent understanding of command intent, high quality information and shared situation awareness, competence at all levels of force and trust in the information, subordinates, superiors, peers and equipments. Next the requirements and contents for shared situation awareness are studied.

Habermas (1984) argued that those who take part in interaction such as command and control in NED, should share at least one item of knowledge (Figure 4). This guarantees that the interacting parties construct a shared view on the situation coherently. The shared item of knowledge is needed for creating mutual understanding. Prerequisite is that the interacting parties believe in the shared item of knowledge. This requires that the parties have created the shared item of knowledge. The creation of shared knowledge answers to the question "why?" – why those involved want to share their valuations and knowledge. The shared knowledge is included in the shared culture of the interacting parties. The shared culture is typically developed by an education and by performing collaboration and shared actions over time.

When the three distinct views on a system depicted in Figure 1 are applied to a subsystem of NED consisting the command and control of NED and further on to its subsystem consisting of the information flows on NED system command and control, the result is information structure, information activities and information contents. Information structure is typically expressed as conceptual schema and data schema following a conceptual model such as a network or a relational model. The Multilateral Interoperability Programme (MIP 2004) and its C2

information exchange data model (C2IEDM) is an example of the development of a military specific conceptual schema. C2IEDM gives a starting point to implement a data schema of a database containing explicit information flowing on NED. Activities concerning information are presented as information management processes and use cases. Information contents include meta information about information structure and its relations to information processes as well as the actual data.

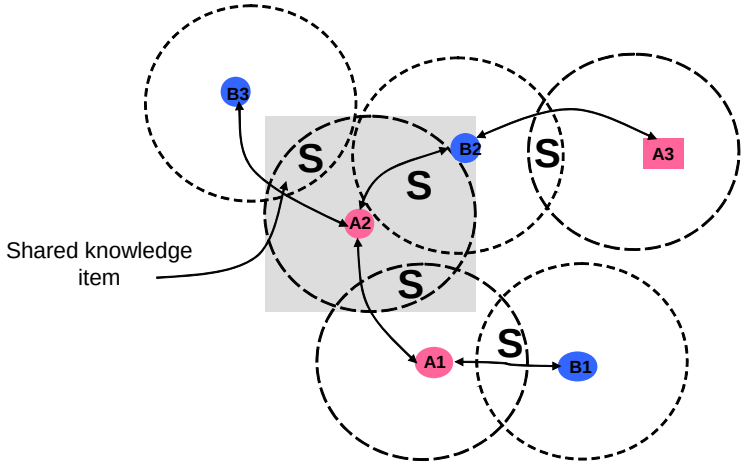

Figure 3. Shared activities in a network requires that the interacting parting share at least one item of knowledge item (based on Habermas 1984, Helokunnas & Kuusisto 2003)

According to Habermas thinking, the interacting operations in NED command and control have to share an item of knowledge to reach mutual understanding. This item of knowledge consists of a structure, processes and contents of information flows on NED system command and control. The operations do not need to share all their information structure, processes and information contents. They need to share at least those items of information structure, processes and information contents that are required to create mutual understanding. This is depicted in Figure 4 that is an application of Figure 3.

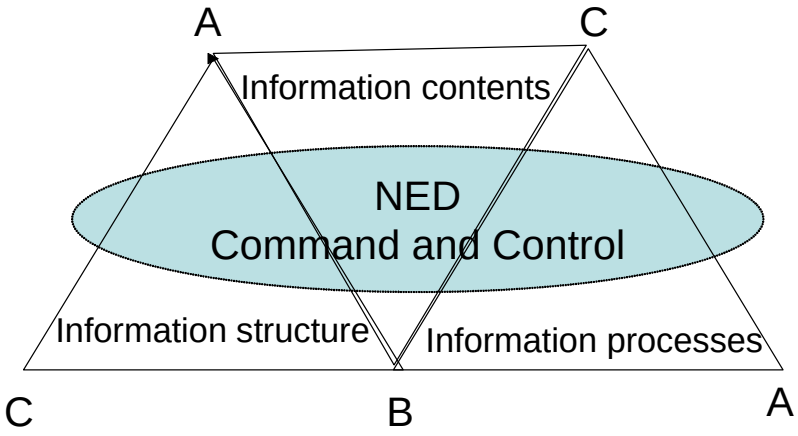

Figure 4. Interacting operations A, B and C need to share information structure, information processes and information contents in NED command and control.

Information structure, process and contents to be shared in NED command and control are presented in a general situation awareness and managing model (Figure 5). The model presented in Figure 5 contains three main categories of information: input facts, norm like information and output information as well as information refining steps, i.e., process model (Kuusisto 2006). Input facts and output information categories include frequently updated, dynamic information. Input information includes events and information about environment like changes in the conditions of the constructed environment and information about constantly updating friendly, neutral and hostile resource figures and locations. Norm like information category contains more static information including basic information about features, i.e., human and material resources and infrastructure as well as process descriptions, instructions and anticipated descriptions about futures such as futures of EU and foreseen end-states like end states of Finland in the year 2025.

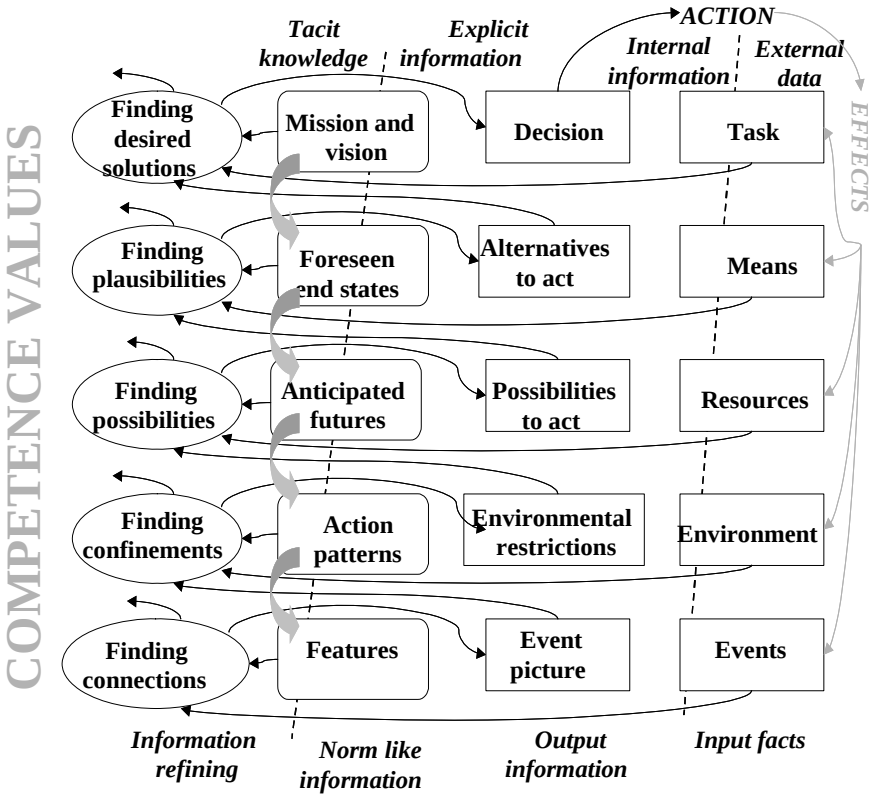

Figure 5. A general model of situation awareness and managing (Kuusisto et al. 2006b, based on Kuusisto 2004, Kuusisto 2006)

As Kuusisto (2006) describes, two kinds of information flows can be detected in Figure 5. First, from right to left, incoming facts are refined through explicitly expressed information to enrich explicit and finally tacit knowledge. The second flow goes bottom-up through all five layers. Every layer has a specialized task in the overall process. The layer that deals with event information produces the all to time updated picture of events that forms the main part of common operational situation picture. So, the explicitly expressed input information of that layer contains the ongoing information flow about the friendly, neutral and hostile activities of NED actors. The refining skill, which is needed here, is the ability to combine information and form abstractions about it. The output information product makes an input to the tacit dimension, where it enriches the internal competence to understand the activity patterns of actors.

On the next layer, the constraints are sorted out. This means the restrictions and possibilities that the environment and the action capabilities of actors have. Explicitly expressed information is the event picture and the information about environmental circumstances, like weather and terrain. Tacit knowledge of the action patterns of actors is required. The refining skills contain both the ability to combine information and abstract it, and the ability to analyze the meaning of constraining aspects in relation to the overall situation. The output information product is an abstracted analysis about restrictions and possibilities for action. The tacit dimension gets input information to develop understanding about the possibilities of the development of the overall situation. The people who are working on that layer shall have tacit knowledge about action patterns of relevant actors. When working on those levels the ability to perceive and understand the present moment is essential and enough.

The next the two layers contain information about resources and means as input facts. This includes updated information about human and material resource figures and locations. These input facts as well as information about events and environment, and knowledge about the composition and the development of the situation and possible end-states are used as basis. The possibilities to act and information about alternate ways to operate are refined. On this level, the ability to understand how the future will develop is essential.

This chain of deduction can be continued until the ultimate decision-making layer is reached. There, all output information from the lower layers shall be available in explicitly expressed form. Of course, the immediate layer output information is relatively more meaningful than information on the other layers. The whole spectrum of tacit dimension shall be available for the decision-maker. The decision-maker must be able to know the action patterns, anticipate the change of the situation, foresee the end-state of the action and deeply understand the meaning of the mission as a part of the bigger continuum of action.

The way the decision-makers are completing their judgments is based on their values. Values and competence define rather explicitly how the entire information potential is exploited. Actually, the high level decision-makers are typically able to go through the whole decision-making process in their mind before the planning session starts. They must have an ability to evaluate the process in advance to refine their task to a mission.

The referred general situation awareness and managing model extends the typical description of the contents of command and control information to the information affecting and included in command and control. The requirement depicted in Figure 4 states that interacting parties in NED system need to share information contents to that extent that mutual understanding is created. The combining of this requirement with the general situation awareness model gives the following result: It is not sufficient that the interacting operations in NED share only parts of the contents of incoming facts and output information. They have to share parts of norms like information too to understand each other.

Conclusions

This paper argues that Network-enabled Defence (NED) is an interacting and adaptive social system in space and time. NED system consists of self-organizing, geographically distributed and interacting adaptive operations that contain a set of technology enabled, interacting and self-synchronizing network centric operations. A self-organizing, adaptive operation is locally inducing long-rang order and able to adapt and change within a changing environment without the need for a guidance outside the operation. A self-synchronizing, network centric operation is arranging its actions in time, space and purpose to produce maximum relative combat power at a

decisive place and time. Self-synchronization covers only the activity aspect on an operation while self-organization covers the structure, activity and information flow aspects on an operation or NED system. The adaptation and interaction of self-organizing, adaptive operations and self-synchronizing network centric operations lead NED system to evolve gradually by an evolution or radically by a revolution

The information flows on NED system contain norms, values, goals and facts. Information flows on NED system and its command and control cannot and do not need to follow only hierarchical structures but a systems of systems structure. The interacting operations in NED command and control have to share an item of knowledge to reach mutual understanding. This item of knowledge consists of a structure, processes and contents of information flows on NED system command and control. In a general model of situation awareness and managing, the shared information and knowledge consists of parts of norm like expectations. They are features, action patterns, anticipated futures, foreseen end-states and mission and vision.

A prototype based on the general model of situation awareness and managing is under development. The prototype is a flexible portal supported by content management services and access to a data warehouse. The prototype visualizes the contents of situation awareness model categories to the user with texts, graphics and maps. An advanced user is able to both edit the contents of the categories and publish presentations about situation to senior management.

Literature, published

Alberts, D.S., Garstka, J.J, Hayes, R.E., Signori, D.A. (2001) *Understanding Information Age Warfare*, CCRP, USA. 312p.

Alberts, D.S., Hayes, R. E. (2003) *Power to the Edge: Command and Control in the Information Age*, CCRP, USA.

Applehans, W., Globe, A., Laugero, G. 1999. *Managing Knowledge*, Boston MA, Addison-Wesley. 115p.

Bergson, H. (1911) *Creative Evolution*, University Press of America.

Damasio, A. (1999) *The Feeling of What Happens: Body and Emotion in the Making of Consciousness*, Harvest Books.

Davenport, T. & Prusak, L. (1998) *Working Knowledge. How Organizations Manage What They know*, Boston, Massachusetts, Harvard Business School Press, 199 p.

The Finnish Government (2003) *Strategy for Securing the Functions Vital to Society*, Helsinki, Edita Prima Oy.

Habermas, J. (1984) The *Theory of Communicative Action, Volume 1: Reason and the Rationalization of Society*, translated by Thomas McCarthy, Beacon Press, Boston.

Habermas, J. (1989) The *Theory of Communicative Action, Volume 2: Lifeworld and System: A Critique of Functionalist Reason*, translated by Thomas McCarthy, Beacon Press, Boston.

Helokunnas, T.,Kuusisto, R. (2003) “Strengthening Leading Situations via Time-divergent Communication Conducted in Ba”. *Journal of eBusiness Review*. Volume III. Melbourne, Australia, pp. 78-81

Kauffman, S. (1995) *At Home in the Universe*, Oxford University Press, USA. 321p.

Kuusisto, R. (2004) *Aspects on Availability, A Teleological adventure of information in the lifeworld*, Edita Prima Oy, Helsinki. 124p.

Kuusisto, R. (2006) “Flowing of Information in Decision Systems”, *Proc of HICSS-39*, USA

Kuusisto, R., Helokunnas, T. (2003) “Experiencing Time in Leading Systems”, *Proc. of the 2003 IEEE International Engineering Management Conference*, USA.. pp. 415-419

Kuusisto, T., Kuusisto, R., Armistead, L., (2004) “System Approach to Information Operations”, *Proc. of the 3rd European Conference on Information Warfare and Security*. London, UK. pp. 231-239

Kuusisto, T., Kuusisto, R., Lund, O.-P., Mikkola, T. (2006a) ”Information Flow Aspects of High Level Tactical Management”, *Proc. of The International Conference on i-Warfare and Security conference*, USA, 2006, pp. 131-136.

Kuusisto, T., Kuusisto, R., Seppänen, H. (2006b) ”Geographic Information Management in Brigade Level Decision-Making”, *Proc. of the 5th European Conference on Information Warfare and Security*, Helsinki, Finland, to be published.

Merriam-Webster (2003) *Merriam Webster’s Collegiate Dictionary*, Eleventh Edition, Springfield, Massachusetts, USA. 1623p.

Moffat, J. (2003) *Complexity Theory and Network Centric Warfare*, CCRP, USA. 160p.

Literature, unpublished

DoD (2005) Department of Defence Dictionary of Military Terms, *http://www.dtic.mil/doctrine/jel/doddict/*, visited September 15, 2005

Kaskeala, J, (2005) *The Finnish RoadMap to Network Enabled Defence*, presentation at Royal United Services Institute (RUSI) conference, September 21, 2005.

MIP (2004) Multilateral Interoperability Programme, see URL *http://www.mip-site.org*, visited February 23, 2005.