11th ICCRTS
COALITION COMMAND AND CONTROL IN THE NETWORKED ERA

The Pros and Cons of Network Centric Organization – An Empirical Investigation

Bjørn T. Bakken (POC)
Norwegian Defence Leadership Institute
Oslo Mil / Akershus
NO-0015 Oslo
Norway
Email: btbakken@fil.mil.no
Phone: +47 90196149
Fax: +47 230973771

Thorvald Haerem
Norwegian School of Management
Nydalsveien 37
NO-0442 Oslo
Norway

Morten Ruud
Norwegian Defence Leadership Institute
Oslo Mil / Akershus
NO-0015 Oslo
Norway

Laila Frotjold
SIKT AS
P.O. Box 246
NO-5751 Odda
Norway

Sections
C2 Concepts and Organizations – Network-Centric Metrics – Cognitive Domain Issues

Bakken, Haerem, Ruud, Frotjold: The Pros and Cons of Network Centric Organization – An Empirical Investigation

Abstract

In environments that demand a high degree of flexibility together with rapid and accurate decision-making, network centric command structures have been promoted as “the” organizational solution to meet these demands. Network centric command structures, arguably, enhance the situation awareness and the understanding of the situation. However, our results show that a network centric organization does not necessarily lead to higher perceived situation awareness or better understanding of the situation. In fact, we found evidence of the opposite.

Our results indicate that operational and tactical command levels tended to perceive the success and effectiveness of the operation significantly different, and in particular as the structure shifted from a hierarchical structure to a network structure. The cause may be the removal of the buffering and delegation principles that the hierarchical command structure holds. In addition, the self-synchronization processes required in the network structure, seemingly pose a heavy load on the information processing capacities of the tactical level decision makers.

While our preliminary findings are in contrast to contemporary writings on the organization of military operations, they still make sense in light of basic theories on information processing in organizations. A main impression from this set of experiments is that many aspects of human interaction have to be managed before a network centric structure may give a full range of benefits in operations.

The Pros and Cons of Network Centric Organization – An Empirical Investigation

INTRODUCTION

The types of threats facing defence organizations have changed radically over the last couple of decades. The change from the threats of the cold war to the threats of asymmetric warfare together with the technological changes in effectors, sensors and tools for decision support raises the question of whether the traditional hierarchical structures of the past are appropriate structures for the future.

Organizational theory agree that the specific changes in the environment combined with the changes in technology, i.e., the ways operations are run, provide good reasons to question the traditional ways to organize (e.g. Scott, 2003; Thompson, 1967). In light of these developments, the network structure of organizing has been advocated as providing several favourable opportunities and properties. In short, military strategists propose that the network organization is a more appropriate way to organize modern operations, than the hierarchical organization (e.g., Alberts et al., 2001). The fundamental question of hierarchy versus network raises several associated questions. Two such questions have been mentioned in particular: First, the role of visualization technologies and second; the role of communication technologies and amount of information.

We have developed a research model to test the relationship between organization structure (hierarchy versus network) and performance. This model also allows investigating whether the effect of the organizational structure, i.e. hierarchy versus network, is different between organizational levels, i.e. the operational and tactical. In addition to the aspect of effectiveness we have included two factors we have assumed to mediate the effect of organizational structure, namely situation awareness and perceived task complexity. More models and relationships are designed and proposed for future experiments and investigations of the interplay of human factors in a network centric defence organization. To support experimentation, the *NCW Learning Lab* was designed, implemented, tested and set in production during 2003-2005 (Bakken, Ruud & Johannessen, 2004).

METHODOLOGY

The experimental study was supported by the *NCW Learning Lab*, a simulation environment that allows the operation of an entire multi-level command system. The inclusion of more than one level introduces opportunities to investigate relationships that to our knowledge have not been studied in such semi-controlled environments that a research simulator represents. More specifically, the *NCW Learning Lab* supports the manipulation of organizational structure, for example in term of hierarchical and network structures. We were therefore able to design studies that investigate the effect of organizational structure on both an operational and tactical level. The lab also supports investigation of the influence of technological factors, such as use of different communication media and visualization tools. The *NCW Learning Lab* is described in more detail in Appendices B (gaming procedure) and C (software architecture).

The data for this first study was collected from 79 respondents, 9 % women and 91 % men. All the respondents were enrolled in military activities associated with the Norwegian Defence. To elaborate; the participants served in the Army (51.2 %), the Navy (41.9%) and the Air Force (7%). In total, the data was collected from six main runs of experiments during 2005[1].

OPERATIONALIZATION

Network and hierarchy can be distinguished by the nature of the communication structure in an organization. Thus structure can be operationalized as ways of observing the communication channels available for each unit of the structure (Hansen, 1999). The dimension of authority, as a distinguishing factor of each organizational structure, has been described in ways of assigning the nature of authority vested in each unit (Stinchcombe, 1959).

In an experimental setting these variables are possible to manipulate in order to test their respective relevance for performing tasks that requires collaboration within a group. In an experimental setting, centralized or decentralized communication channels might define the organizational type (Guetzkow & Simon, 1955).

Furthermore, the organization structure may be obtained through either observation, self-report or by paying attention to the perception of individuals of authority relationships. Katz and Kahn's (1978) concept of perception of authority structure might give guidelines for making an instrument and obtaining data on perceived authority. According to their theory, organizations have different degrees of hierarchy that are determined by the level of differences of perceived and objective control among people on different levels of the organization. If there is a higher difference in control, a hierarchy exists.

In the experimental settings in the *NCW Learning Lab*, organization structure is manipulated in order to test influence or organization structure on task performance. The *NCW Learning Lab* allows manipulating command systems in terms of hierarchy and network structures.
In the experiment, the operationalization of organizational structures is done through the manipulation of communication channels.

Six scenarios were conducted. Preceding the scenarios, the participants where told by the staff what kind of communication structure they were allowed to use. In three scenarios, the participants were told that the communication structure was centralized, meaning that the communication between headquarters at different levels had to follow the hierarchical communication lines. No verbal communication was allowed. Whereas in the three other scenarios, following network structures, the players where told that communication among all players were legitimated and indeed encouraged. The different communication structures used are illustrated conceptually in figures 1 and 2 below.

[1] Detailed documentation of the experiments: theory base, design, measures, procedures and results are found in Haerem, Bakken and Myrseth (eds.) 2006: Human Aspects of Decision Making in Network Centric Organization. Research Report, Norwegian School of Management (Oslo) / Norwegian Defence Leadership Institute (Oslo) / Norwegian Battle Lab and Experimentation (Stavanger / Bodoe).

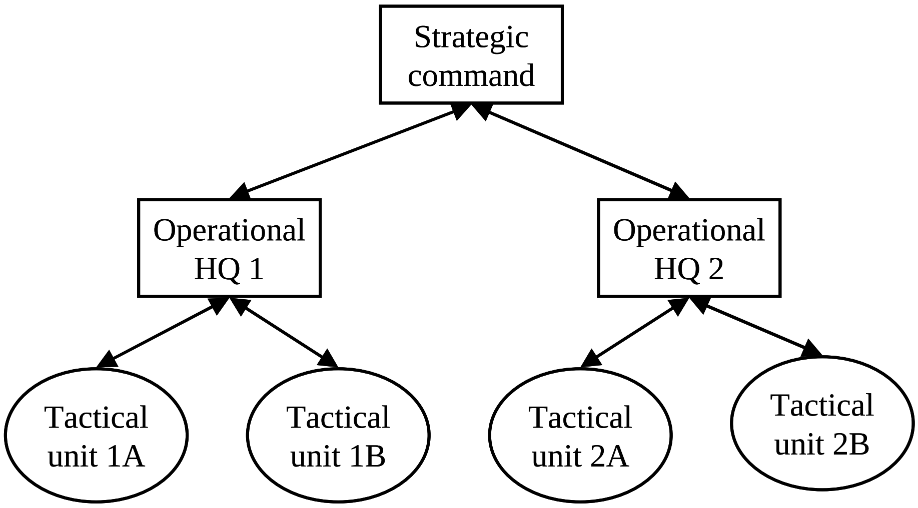


Figure 1: Hierarchical command structure (communication strictly along vertical lines)

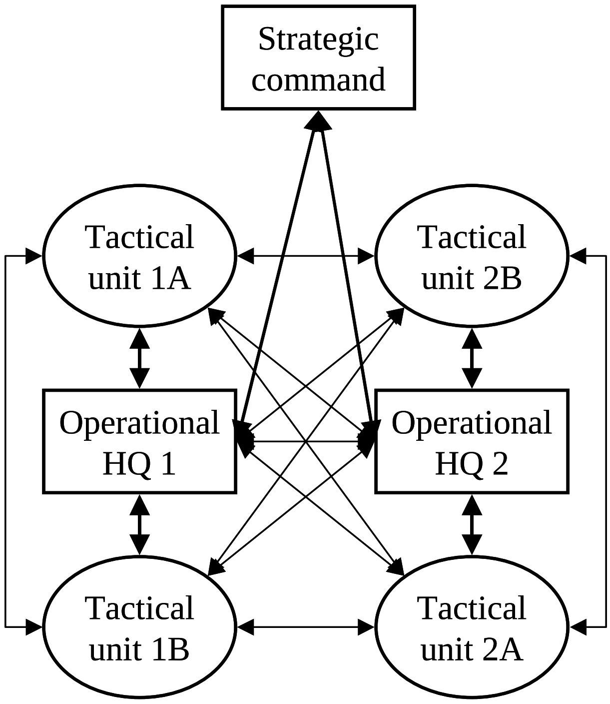


Figure 2: Command structure networked on tactical-operational levels ("all-to-all")

RESEARCH MODEL

We have developed a research model that contains relationships between organization model (hierarchy vs. network), and level in command system (operational or tactical), as independent, interacting variables. These variables affect perceived situation awareness and perceived task analyzability as intermediate variables that in turn affect operational outcome.

The outcome variable is a compound of speed in the operation, information sharing, success in the operation, and effectiveness in the operation. All the components of "outcome" are currently operationalized as perceived[2], that is, participants themselves assess them by responding to questionnaires (see Appendix A for questionnaire items relating to perceived outcome).

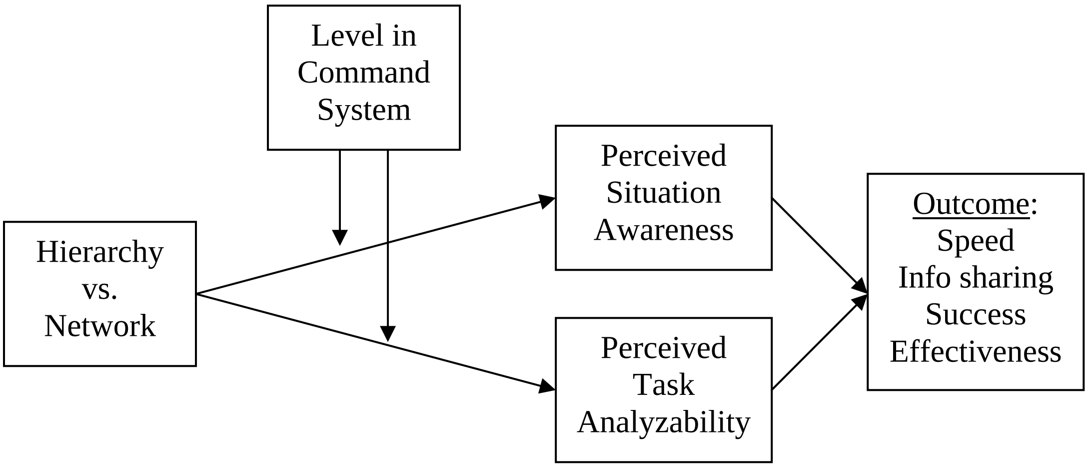


Figure 3. Research model

In accordance with reviewed literature, our hypotheses state that *network* structure contributes to better/higher:

- Situation awareness
- Analyzability of the task
- Speed in operations
- Information sharing
- Degree of success
- Degree of effectiveness

… as opposed to the *hierarchical* structure.

---

[2] For details on operationalizations, see Haerem, Bakken and Myrseth (eds.) 2006: Human Aspects of Decision Making Network Centric Organization. Research Report, Norwegian School of Management (Oslo) / Norwegian Defence Leadership Institute (Oslo) / Norwegian Battle Lab and Experimentation (Stavanger / Bodoe).

RESULTS

We have analyzed the relationship between command structure and the decision makers' perceived situation awareness, task analyzability, speed in operations, information sharing, effectiveness and success of the operation. We have also studied how this varies depending on the level (operational vs. tactical) in the command structure. When interpreting these results it is important to note that it is *perceived* measures of operation success, effectiveness, speed and quality of information sharing which is applied, and not objective measures.

Direct Effects

The results of the Multiple Analysis of Variance (MANOVA) shows that the structure of the command system influences the situation awareness and task analyzability significantly (p=.02), while the level of the command system does not seem to have any significant influence. This is illustrated in figures 4 and 5 below.

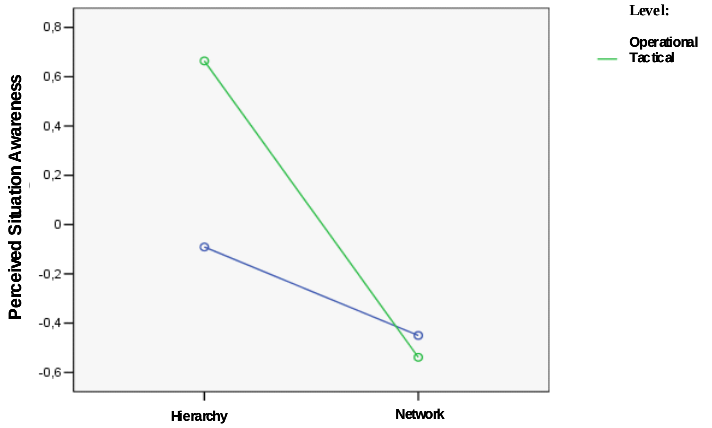


Figure 4: Perceived situation awareness as a function of command structure and level

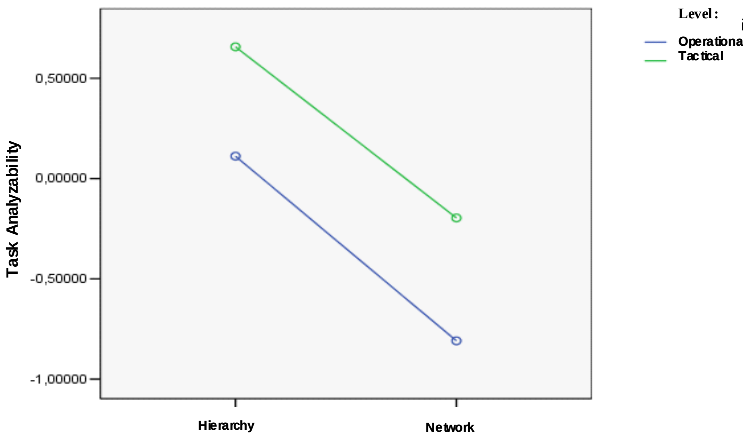


Figure 5: Task analyzability as a function of command structure and level.

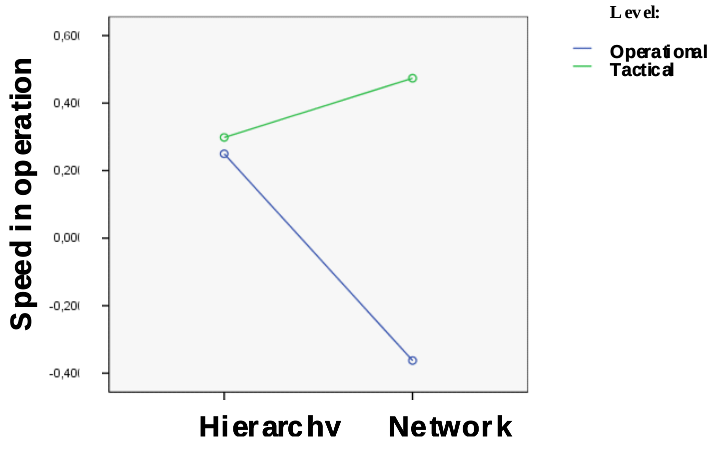
The results furthermore show that structure has a significant influence ($p=.05$) on speed, information sharing and perceived success. Level in the command structure seems, based on this analysis, not to have an effect ($p=.75$). But, as we shall see from the analysis of the interaction effects below, the effects of the tactical and operational level are opposite of each other and thereby cancel out the direct effect.

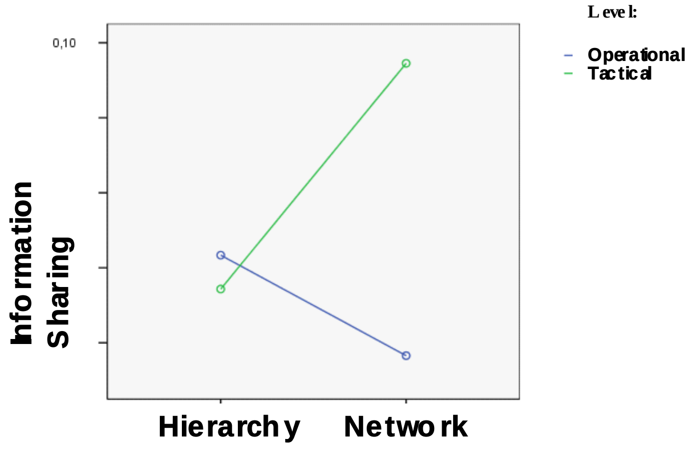
The first main result is the significant difference between the hierarchical command structure and the network centric command structure, when it comes to perceived situation awareness and perceived task analyzability. Both measures scored higher in the hierarchical structure than in the network structure both on the operational and tactical level.

These findings do find some support in the research stream viewing organizations as information processing systems, although the findings contradict some of the popular writings on the virtuosity of network centric organizations. In a hierarchical command structure the tasks and responsibilities of each unit and role within each unit is delimited and clearly defined. The communication lines between units, superiors and subordinates are equally clearly defined. This is in contrast to a network organization which stimulates task resolution processes and resource dispositions on a tactical level, between tactical units and actors, to facilitate quick response to unexpected situations. Such self-synchronization on the tactical level generates high demands for information processing and problem resolution. Together with time pressure and other stress factors these conditions are likely to produce increased perceived uncertainty. Although the perceived analyzability is significantly lower in the network centric command structure, it is interesting to note that the “objective” uncertainty is constant since the scenario is constant. This indicates that the organization structure also influences the perception of uncertainty in operations.

Interaction Effects

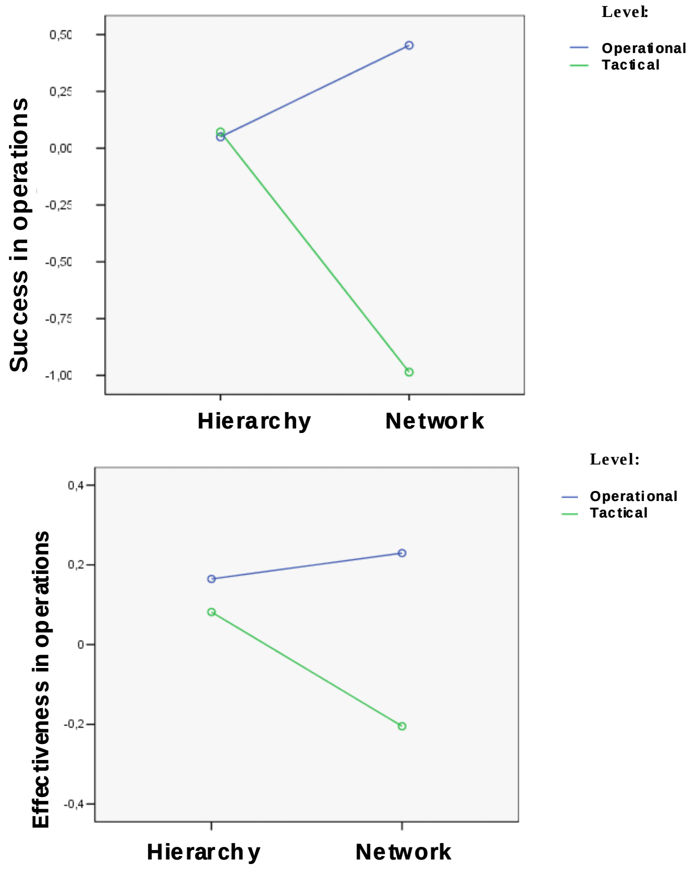
There is a difference in the perception of speed, and quality in the information sharing between the operational and tactical level under the network structure. There is no such difference under the hierarchical command structure. Tactical level perceives the speed in the operation as higher, and the information sharing as better than the operational level does. This is in line with main stream theory which argues that a network structure opens for direct communication lines between the actors and reduces the amount of bottlenecks which easily arises in a hierarchical structure. However, this difference is not statistically significant with the sample size we have.





Figures 6/7. Interaction effects of command structure and level on speed & information sharing

On average, there is no difference in the perception of success and effectiveness under the two command structures. But, there is a surprising difference in the perception of the success between the two levels in the command structure. In the network structure, operational level perceived the degree of success as significantly higher compared to the tactical level. In the hierarchical structure there were only marginal differences: The perceptions of the effectiveness in operations follow the same overall pattern, but the differences are not significant.



Figures 8/9. Interaction effects of command structure and level on success & effectiveness in operations

One might want to explain the drop in perceived success at the tactical level with the drop in perceived situation awareness and task analyzability. However, the drop in perceived situation awareness and task analyzability is also found on the operational level, which perceives an increase in success. Equally troubling is that the tactical level, in contrast to the operational level, perceives an increase in speed and quality of information sharing, which one might assume would lead to an increased sense of control and success.

The best explanation we have for this finding is that the network structure encourages the tactical level to take responsibility for the problems that arise, not only in their own unit, but in other units as well. The hierarchical mechanisms, which buffer each individual from direct negotiation with other units about assistance and request for resources, serve to reduce uncertainty, focus attention and sets clear criteria for success or failure. In hierarchical command structures it is the operational level that is supposed to handle the uncertainty and define clear orders for the tactical level. The network centric command structure does not have this information processing property. In the network structure the tactical level receives direct requests from other tactical units about assistance and other issues that require coordination. These findings also find support in studies of command and control at the Team Effectiveness Lab at Michigan State University (Moon et al., 2003).

In this respect we may say that the network structure requires self-synchronization on the tactical level. Self-synchronization, in the sense of network coordination, introduces both complexity and uncertainty on the tactical level. One reason to lower perceived success may be that others' problems become vivid to the units and individuals on the tactical level and that these problems become every unit's responsibility. This is very different from the way responsibility is delegated in the hierarchical structure.

That the operational level perceives a higher degree of success in the network structure may be caused by the same mechanism. If it is so that the tactical level takes on responsibility to handle the situations as they emerge by self-synchronization, then the operational level may perceive fewer requests for resources to handle unexpected difficulties.

CONCLUSIONS AND FURTHER WORK

In environments which demand a high degree of flexibility together with rapid and accurate decision-making, network centric command structures have been promoted as "the" organizational solution to meet these demands. Our objective was foremost to contribute to a methodological platform for experimentation with command concepts in the years to come. The measurement instruments developed and reported above have been found valid and reliable (Harem, Bakken, & Myrseth, 2006). This set of instruments and manipulations, including the *NCW Learning Lab*, allows us to efficiently capture central aspects of human aspects of decision-making in future experiments. Hence, we have contributed to a good foundation for future experimentation.

The practical importance of this project is the indications given by the preliminary results. Our findings are in contrast to contemporary writings on the organization of military operations. But the findings make sense in light of basic theories on information processing in organizations. Network centric command structures are argued to enhance the situation awareness and the understanding of the situation. But our results show that a network centric organization does not necessarily lead to higher perceived situation awareness or better understanding of the situation. In fact, the data show the opposite relationship.

Our results indicate that operational and tactical command levels tended to perceive the success and effectiveness of the operation significantly different, and in particular as the structure shifted from a hierarchical structure to a network structure. The cause may be the removal of the buffering and delegation principles that the hierarchical command structure holds. In addition, the self-synchronization processes required in the network structure, seemingly pose a heavy load on the information processing capacities of the tactical level decision makers.

Gaining knowledge about such relationships will have great practical relevance for the development and improvements of existing concepts of operations, planning processes, command structures, in addition to the understanding of intention based management and improvements in decision-making on an individual, social and organizational level.

The results from this series of experiments indicate that Network Centric Warfare (NCW) sets different and difficult demands on the decision makers in such a command structure. A main impression from this series of experiments is that many aspects of human interaction have to be managed before a network centric structure may give benefits in operations. Further experiments are necessary to evaluate the robustness of the relationships uncovered in the experiments performed in 2005. Until stronger evidence is established we have to settle for these humble speculations.

REFERENCES

Alberts, S., Garstka, D., Hayes, J.J., Richard, E. & Signori, D.A. 2001. ***Understanding information age warfare.*** CCRP Publication Series.

Bakken, B.T., Ruud, M., Johannessen, S. 2004. ***The System Dynamics Approach to Network Centric Warfare and Effects Based Operations - Designing a "Learning Lab" for Tomorrow's Military Operations.*** Presented at the 22nd International Conference of the System Dynamics Society, Oxford.

Brehmer, B. 2000. **Dynamic *Decision Making in Command and Control***. In McCann & Pigeau. The Human in Command: Exploring the Modern Military Experience. Kleuwer, New York.

Brehmer, B. 2002. ***Learning to control a dynamic system***. Unpublished manuscript, Swedish National Defence College, Stockholm.

Guetzkow, H., & Simon, H. A.1955. The impact of certain communication nets upon organization and performance in task-oriented groups. ***Management Science,*** 1:233-250.

Haerem, T., Bakken, B., & Myrseth, H.P. (eds.) 2006: ***Human Aspects of Network Centric Organization***. Research Report, Norwegian School of Management (Oslo) / Norwegian Defence Leadership Institute (Oslo) / Norwegian Battle Lab and Experimentation (Stavanger / Bodoe).

Hansen, M.T. 1999. The search-transfer problem: The role of weak ties in sharing knowledge across organization subunits. ***Administrative Science Quarterly,*** 44: 82-111.

Katz, D., & Kahn, R.L. 1978. ***The social psychology of organizations.*** New York: John Wiley & Sons.

Moon, H.et al. (2004). Assymetric Adaptability: Dynamic Team Structures as One-Way Streets. ***Academy of Management Journal***, 47(4): 681-695.

Perrow, C. 1967. A framework for the comparative analysis of organizations. ***American Sociological Review,*** 32: 194-208.

Scott, R.W. 2003. ***Organization, rational natural and open systems.*** Upper Sadle River: New Jersey.

Stinchcombe, A.L. 1959. Bureaucratic and craft administration of production: A comparative study. ***Administrative Science Quarterly,*** 168-187.

Thomson, J.D. 1967. ***Organizations in action.*** New York: McGRaw-Hill.

APPENDIX A: Measures of Outcome[3]

Operational effectiveness of military operations, according to Alberts et al. (2001), is impacted by several key concepts and the relationship between them. Some of the key concepts he mentions are; awareness, shared awareness, collaborative planning, and synchronized actions.

To elaborate, it is stated that in network-centric operations, the power of the network is manifested by increased richness through increased reach, increased shared awareness and improved collaboration. Increased richness through increased reach refers to that networks enable information richness to be increased by enabling information from multiple sources to be shared, correlated and accessed. Increased shared awareness, on the other hand, point to that networks contribute to the generation of shared awareness by enabling richness to be shared. Whereas, improved collaboration indicate that network enable information sharing which transfer shared awareness into collaborative planning and synchronized actions that create a competitive advantage.

Together, these processes increase the effectiveness of a military operation. Furthermore, Alberts et al. (2001) emphasize that quality of interactions and speed in the operation are hypothesized to influence operational outcome or what they refers to as degree of operational success and force effectiveness and efficiency (Alberts et al., 2001).

Perceived Operational Effectiveness

We chose to measure perceived operational performance or effectiveness by developing several items based on the concepts in Alberts et al. (2001). An exploratory factor analysis was used in order to gather information about inter-correlations among the set of variables The validity of the scale was tested by using a principal component analysis; the results are shown in the table below. The Kaiser was sufficient, showing value beyond .7.

Items	Components		
	Success	Information sharing	Speed
Success according to targets	,93		
Success according to intention	,82		
Effectuated a successful operation	,72		
Necessary quality of sources to information and communication		,84	
Sources of information and communication have contributed to distribution of information		,82	
Minimized risk		,73	
Effectuated within time limits			,82

Table A1. Perceived Operational Performance; Success, Information Sharing and Speed. Rotated Component Matrix. Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

[3] Adapted from Haerem et al. (2006).

APPENDIX B: NCW Learning Lab – Gaming Procedure

A session with NCW Learning Lab starts with the players reading the scenario description, which is a narrative describing a fictitious or real security policy crisis situation. The scenario is usually structured as follows: A background which describes history and events leading up to the present situation, including any orders or directives issued by NATO, UNSC or other national or international supreme command authority. Then the operations area (OA) is defined, with borders of sea, land and air territories. The territory description usually names geographical areas (nations, regions etc) that are included in the OA, and/or which border on the OA. Lastly, the resources and capabilities available to resolve the crisis situation are listed along with key characteristics such as their main function or role, transportation speed, sensor coverage, combat power and the like.

Attached to the scenario is the mission and intent statements issued by the supreme command (e.g., SACEUR in the case of an international crisis, or National Strategic Command in the case of a national crisis). The intent defines (among others) the purpose and objectives of the mission; the means or methods with which the crisis can be resolved; and the desired end state. The mission and intent statements may be followed by a plan for "conduct of operations", which usually proceeds through four phases (example taken from a NATO led and UN approved crisis response operation): 1. Preparation and deployment; 2. Establish and maintain security; 3. Termination; 4. Redeployment. Success criteria for the mission may be stated as "decisive points", for example: reduced criminal activity; reduced para-military activity; neutralization of threats to democratic process.

The mission may contain several tasks to be handled, tasks that may vary in complexity along the variability and analyzability dimensions.

Examples of tasks are:

- National force protection operation:
    - Secure and protect military bases (against terrorist attacks)
    - Prepare and execute escort operations of allied vessels
    - Protect national waters against border violation
    - Prevent resource crimes (e.g., illegal fishing)
- International crisis response operation:
    - Establish and maintain security in deployment areas
    - Contain ethnic violence
    - Collect illegal weapons
    - Arrest persons indicted for war-crimes
    - Reduce smuggling of weapons and drugs

The tasks may be presented sequentially to the players in a pre-programmed manner, or may "emerge" as a function of actions and events occurring through the course of a game. Usually, the tasks are a combination of pre-programmed and emerging. Even though the initial situation may be identical between sessions, the actual flow of events may take completely different turns, making several instances of the same scenario appear quite different.

It follows logically that the "stream" of tasks that constitute the crisis situation may occur relatively frequently (high variability) or infrequently (low variability). Likewise, the tasks may differ in the degree of analyzability, i.e., whether they may be solved with well-known procedures and methods, or whether a solution is not well known. This classification follows the framework developed by Perrow (1967).

A game with NCW Learning Lab is usually played with a group of players forming a command organization (see figures 1 and 2 in main text for example illustrations).

The lowest layer of the command chain always controls the actual resources (military forces and other objects representing capabilities) that move within the operations area to accomplish the tasks that have to be solved; whether pre-programmed or emerging. The remaining (higher-level) layers are indirectly commanding the forces by issuing plans, orders, directives and Rules of Engagement (ROE).

The surface complexity of a task is represented by its appearance to the player as presented by the user interface and the mechanisms for directing objects on the geographical “surface” to resolve the task. In addition come various indicators of status and progress, as well as a mail system containing narrative information concerning tasks. Such narrative information may be pre-programmed by the scenario designer, or ad-hoc messages written by actual co-players.

The deep complexity of a task concerns the relationships between actions that may be taken to resolve the task, and outcome as a function of how the task has been handled. The most general outcome property of a task is the degree to which its resolution contributes to achieving goals defined at superior levels of command. At the most abstract level, this is a question of escalation or de-escalation of the situation (meaning that the crisis situations worsens or improves due to actions taken, respectively). Matters are complicated when a short-term improvement in the situation may be followed by a long-term worsening, or vice versa. Thus, the player in command, when confronted with a task, must ask him/herself three questions to guide the decision-making process:

- To what degree will the resolution of this task contribute to (long-term) de-escalation of the crisis?
- What resources are needed to resolve the task?
- Are the resources available (at an acceptable cost)?

Figure B1: Military officers interact with the NCW Learning Lab using the CODS (Common Operational Decision System) flatbed high-resolution display.

APPENDIX C: NCW Learning Lab – Software Architecture[4]

The current version of *NCW Learning Lab* is built around the MindLab framework developed by SIKT AS (Odda, Norway). The MindLab architecture consists of four main components: a simulation model, a database, simulation server architecture, and the user interface. Different simulation models can be used, the only requirement is an implementation of a general interface for communication with the server. Similarly, different clients can be used, given that they adhere to the xml-based communication protocol defined by the server. The use of a database is optional, but typically provides a convenient way to initialise the model with different parameters.

This way, one can easily apply different parameter sets to different games. Figure C1 illustrates the concept. The current database also contains other data, such as logging of user activity and results obtained by the different users. The applicability of these features naturally depends on the model in question and on the interests of the model designer.

A feature recently included in the server part of the architecture is a questionnaire component that allows modellers to “pop up” questionnaires to the user at specific times of model execution. The answers provided by the user are then stored in the database, and form basis for Situation Awareness metrics.

The server currently only supports use of AnyLogic simulation models. Support for Powersim and Vensim models are planned, and such support can be implemented as the need for it arises. In order to make a simulation model adaptable to the system, it needs to implement a generic interface that the server can use for communication. As AnyLogic is Java-based, this implementation is rather straight-forward, because the model itself can implement the interface. For other simulation technologies however, a Java-based communication-layer needs to be constructed.

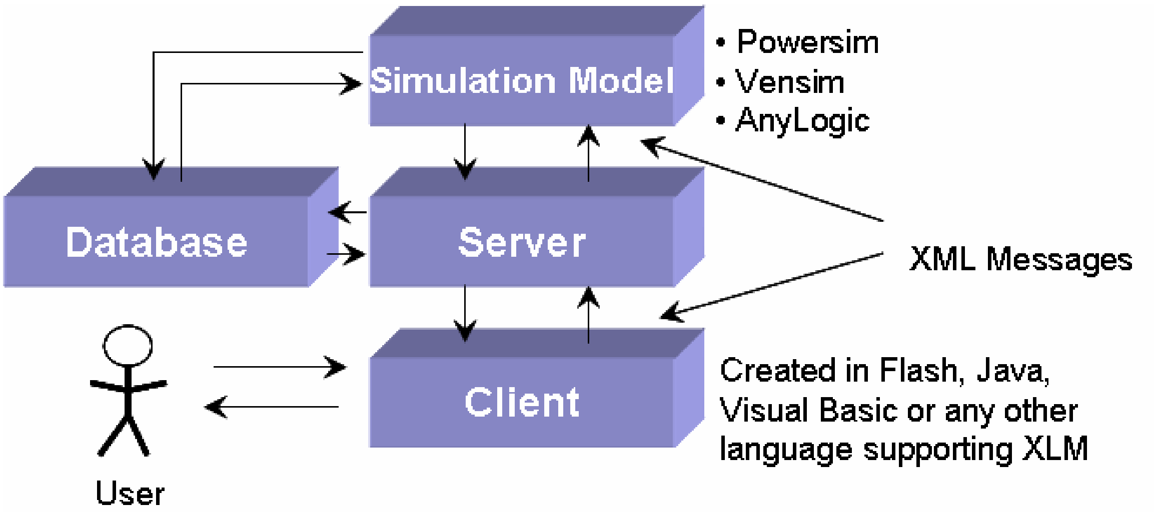


Figure C1: The MindLab architecture

[4] Text and illustrations provided by SIKT AS.

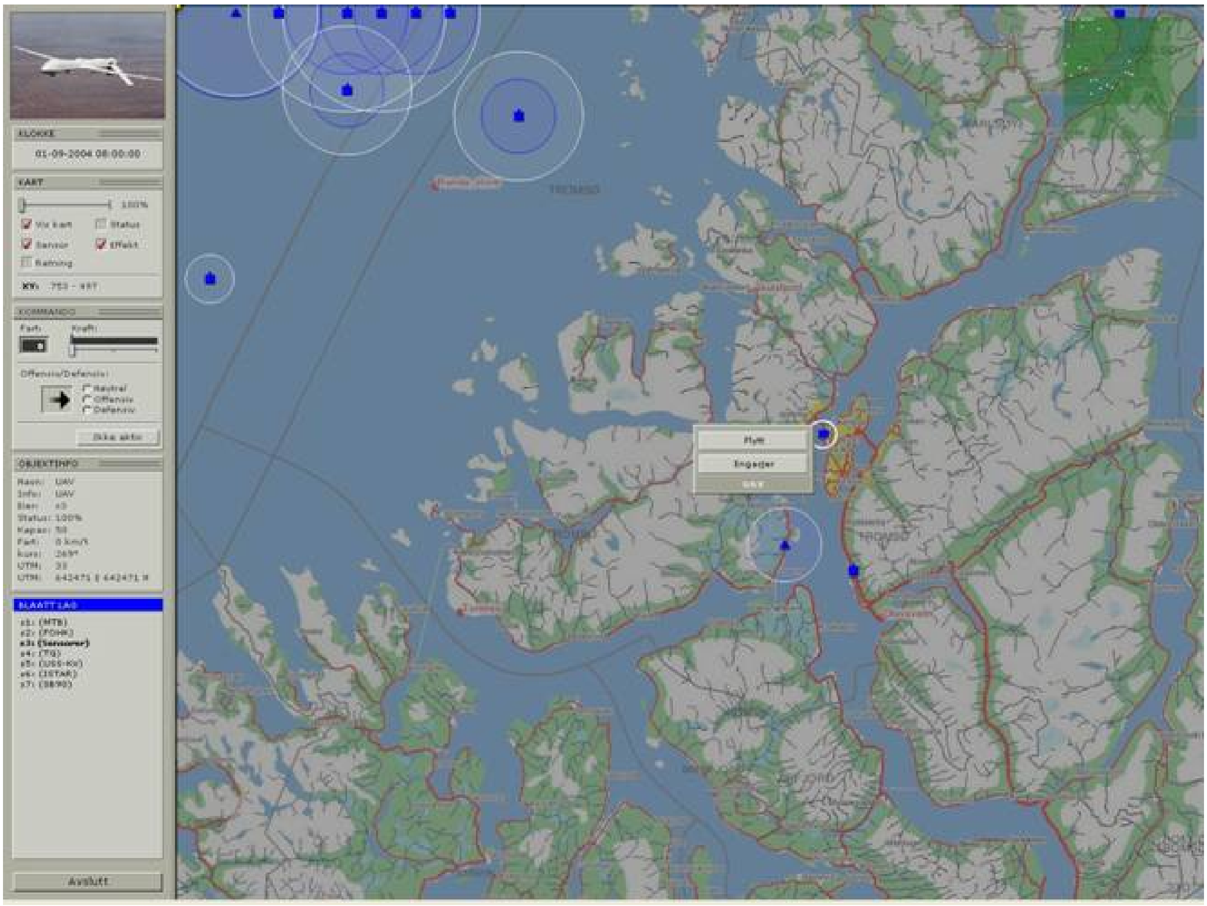


Figure C2: Sample screen-shot of user interface