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Hierarchy or Network in Military Command Organizations? Preliminary Results from Experiments with the NCW Learning Lab

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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. The NCW (Network Centric Warfare) Learning Lab was developed to allow systematic, simultaneous experimental manipulation of structural and individual varibles, in order to observe the effects on dependent variables such as actual and perceived operational effectiveness. The Learning Lab was designed to particularly stimulate the dynamic aspects of decision making. Our preliminary results show that a network centric organization does not necessarily lead to higher perceived situation awareness or better understanding of the situation. Although our findings are in contrast to contemporary writings on the organization of military operations, we find them to make sense in light of basic theories about information processing in organizations.

INTRODUCTION

The changes in threats to 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 favorable 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).

THE NCW LEARNING LAB

The NCW Learning Lab is a simulation environment that has at least two features that makes it different from other simulators used for experimental purposes. First, the lab allows the operation of an entire multi-level command system. The NCW Learning Lab can simulate and investigate decision-making on a range from one to (currently) four levels of a command system. This is different from most labs we know of, that primarily permit investigation on a single (usually tactical) level. The fact that the lab opens for simulations of organizational mechanisms that works across levels is important because such mechanisms are assumed to be a core property of organizations. Moreover, the empirical studies of such phenomena have been done by cross-sectional surveys which have often shown conflicting results. Thus, 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. This project has defined these opportunities as important to ensure the value of the experiments’ contribution to the existing knowledge base.

More specifically, NCW Learning Lab supports the manipulation of organizational structure, for example in term of hierarchical and network structures. Since the lab also supports simulation of several levels in command systems we are 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 First Experiments

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].

Figure 1. Military officers interacting with the NCW Learning Lab using the CODS[2] display.

Overview of the Gaming Environment

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.

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[1] Detailed documentation of the experimments: theory base, design, measures, procedures and results are found in Haerem, Bakken and Myrseth (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).

[2] CODS = Common Operational Decision System, by Lenco AS, Norway, and Norwegian Battle Lab and Experimentation (NOBLE).

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 2 and 3 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 two 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 (and, are the resources available at an acceptable cost)?

Military Decision-Making as a Dynamic Process

It is highly appropriate to recognize military operations and security crises as dynamic processes, continuously unfolding in time. Consequently, managing such processes is similar to handling a dynamic decision problem, with the following features (adapted from Brehmer, 2002):

- It requires a series of decisions
- The decisions are interdependent
- Decisions must be made in real time
- The state of the problem changes, both autonomously, and as a consequence of the decision-maker's actions. This implies among others:
    - Deciding to do nothing is also a decision (albeit it might be unconscious)
    - Decisions may not be reversed (at least not without a cost)
    - There may be prominent time delays, both in information and physical flows
    - The problem may be dominated by feedback and non-linear relationships

At the highest level of a military operation or a security crisis, the decisions to be made are mainly concerned with resource allocation, to be done in a way that provides for the best possible overall outcome. The most basic decision of this kind is to order a movement of forces from one location to another. It can also involve setting priorities for subordinate commanders, as well as guide the attention of sensor equipment (in a C3I system), and so on.

This conceptual idea is also implemented in practice. Consider this general description of crisis management, taken from the NATO/PfP "Generic Crisis Management Handbook" (1997 interim version): "Procedures and activities in crisis management range across; information acquisition and assessment; the analysis of the situation; the establishment of goals to be achieved; the development of options for actions and their comparison; the implementation of chosen options, to (finally, as feedback to close the loop) the analysis of the reaction of the parties involved."

Following Brehmer (2000, 2002) this kind of task can be seen as a problem of finding a way to use one process to control another process, and it is the relation between the processes that determines what strategies are possible. It also means that the time scales of the task are important. The decision maker thus has two essential tasks:

- To control the system
- To control his workload and avoid being overwhelmed by the task

That a series of interdependent decisions is required means that the decision maker must learn to allocate (in time and space) his resources in a way that provides for the best possible overall outcome. That the task changes both autonomously and as a consequence of the decision maker's action means that he must be able to distinguish between the effects of his own actions from autonomous effects.

That the decisions must be made in real time means that the decision maker must be able to find a strategy that protects him from being overwhelmed (according to Brehmer (2002) expert decision makers are recognized by their capability to adapt their work strategies to control their work load). He/she must learn not only about the task, but also about his own abilities. He/she must understand how to use a process for controlling another process, find ways to handle the delays, and possess an understanding of the time scales.

OPERATIONALIZATIONS OF HIERARCHICAL AND NETWORK STRUCTURES

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 2 and 3 below.

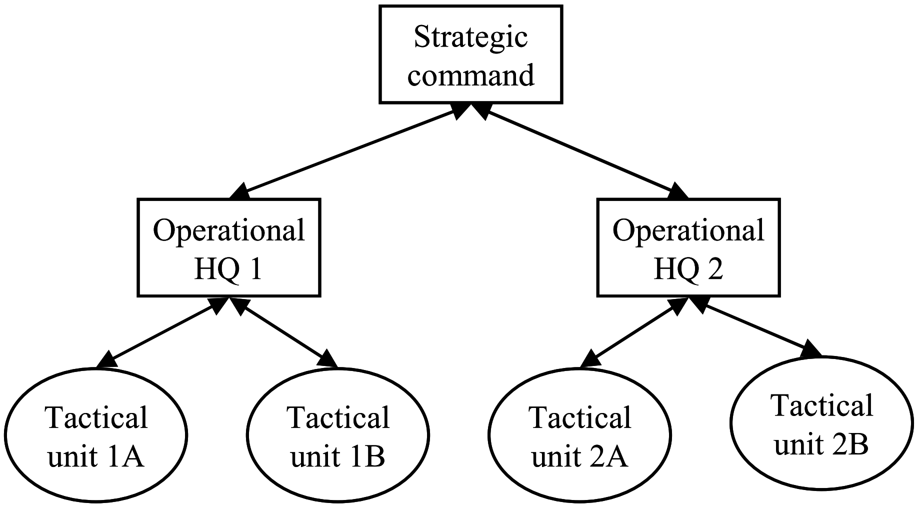


Figure 2: Hierarchical command structure (communication strictly along vertical lines)

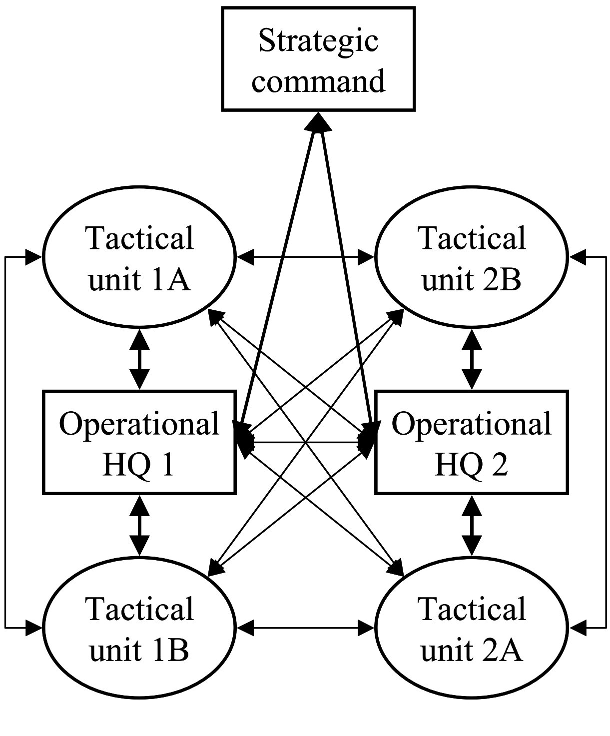


Figure 3: Command structure networked on tactical-operational levels (“all-to-all” comm.)

RESEARCH MODEL

We have developed a resarch 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 preceived task analyzability as intermediate variables, that in turn affect opertational 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 outcome components are currently operationalized as perceived[3], that is, participants themselves assess them by responding to questionnaires (see Appendix A for questionnaire items relating to perceived outcome).

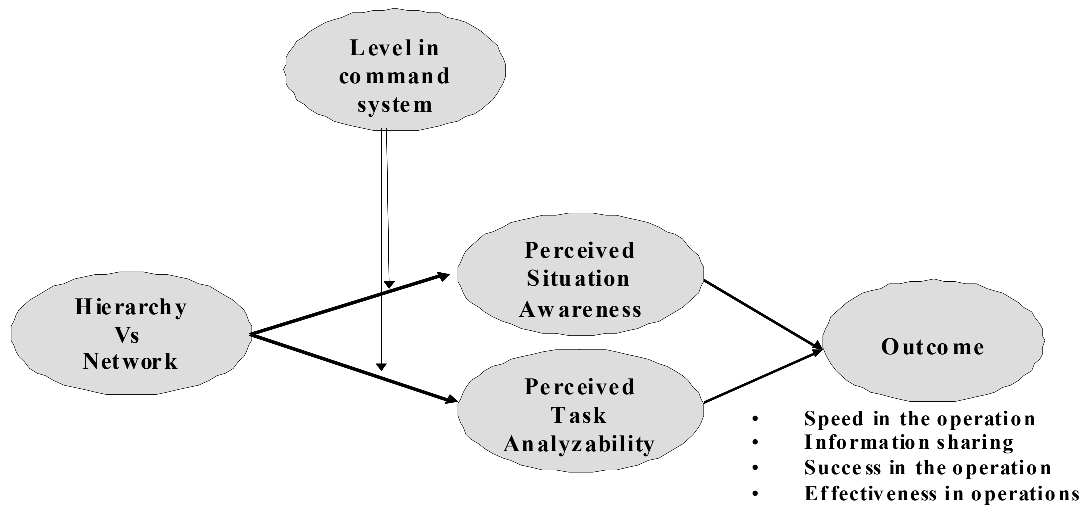


Figure 4. Resarch model.

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.

[3] For details on operationalizations, see Haerem, Bakken and Myrseth (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).

PRELIMINARY RESULTS AND ANALYSES

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 5 and 6 below.

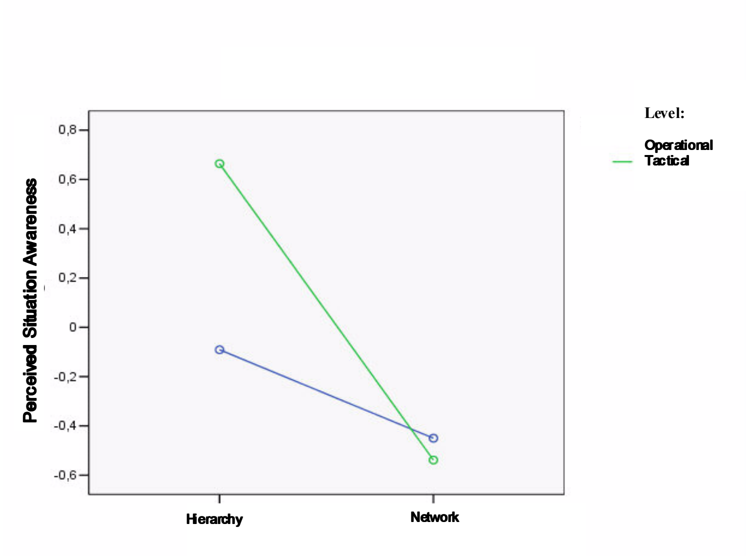


Figure 5: Perceived situation awareness as a function of command structure and level.

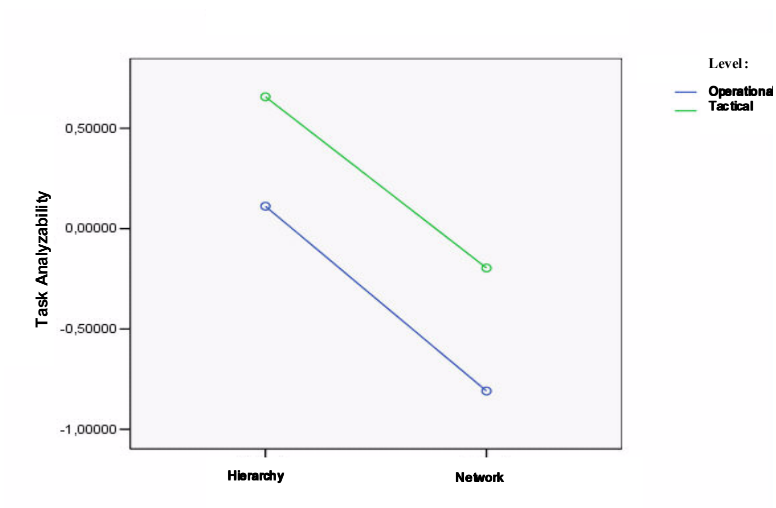


Figure 6: Task analyzability as a function of command structure and level.

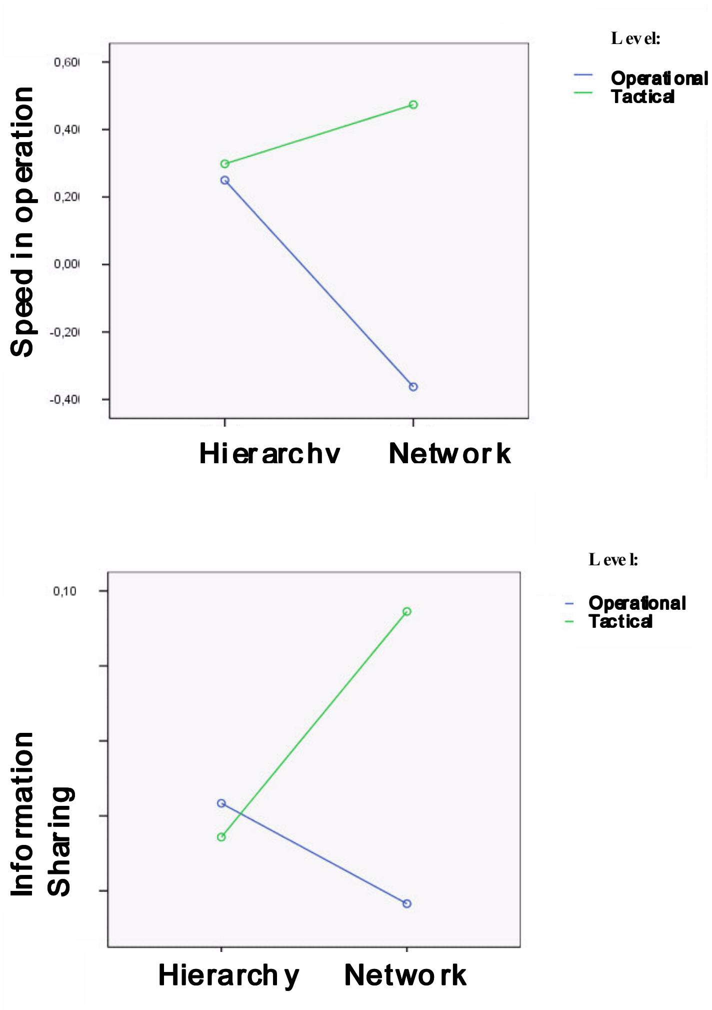
The results furthermore show that structure has a significant influence (p=.05) on speed, information sharing and perceived success. Level in the command structure seems, based on this analysis, not to have an effect (p=.75). But, as we shall see from the analysis of the interaction effects below, the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

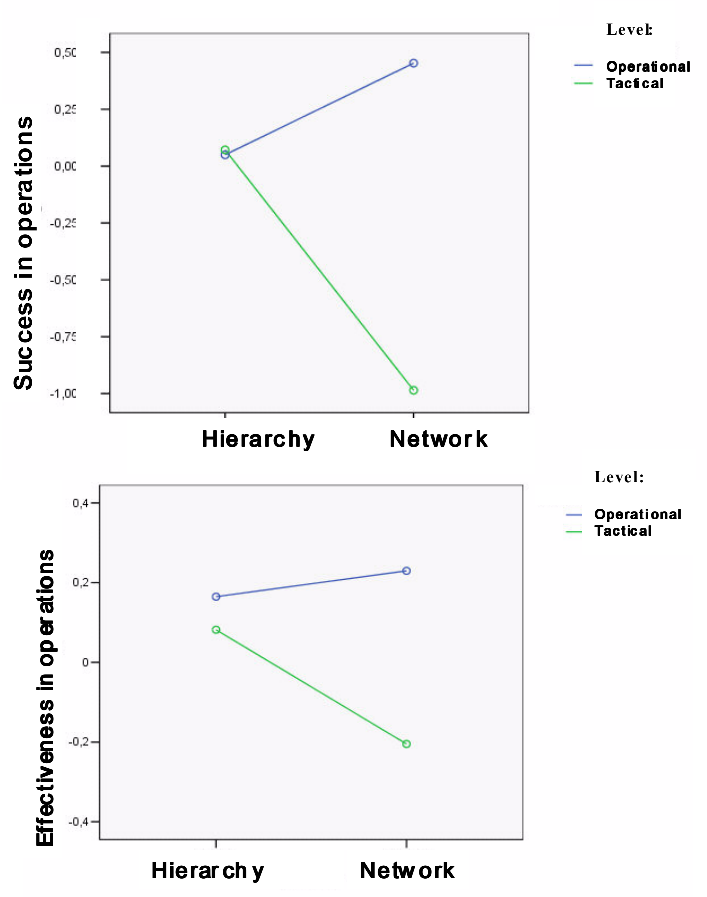
Interaction effects

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 7/8. 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 9/10. Interaction effects of command structure and level on speed & information sharing.

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 NCE 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.

The results show that the perception of success and effectiveness of the operations was significantly different between the operational and tactical level, as the structure shifted from a hierarchical structure to a network structure. As explained above, this is not an entirely surprising result. The cause may be the removal of the buffering and delegation principles that the hierarchical command structure holds. In addition, the self-synchronization, required in the network structure, was argued to pose a heavy load on the information processing capacities of the decision makers on the tactical level.

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.

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APPENDIX A: Measures of outcome (extract from Haerem et al., 2006)

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.