DISCCO – A General Approach to Command and Control Support

Klas Wallenius, SaabTech Systems AB, and Royal Institute of Technology
klasw@nada.kth.se

Abstract

DISCCO (Decision Support for Command and Control) is a generic and network based set of services, including Command Support Tools helping the commanders in the human, collaborative and continuous process of evolving, evaluating, and executing solutions to their tasks. DISCCO also includes Decision Support Tools that, based on embedded AI and simulation techniques, improve the human process by integrating automatic and semi-automatic generation and evaluation of plans. These tools interact with a common information model capturing the recursive structure of the situation, including the dynamic organization and the goals of own, allied, neutral, as well as hostile resources. Using DISCCO, the commanders will be able to interact with this model to get a better understanding of the situation. They will also be able to try out different solutions to their tasks at hand, by predicting the situation using embedded simulation tools. Hence their awareness of the situation will be greatly enhanced. Since the model is generic, DISCCO will have the potential to support Command and Control throughout different command levels in civilian, as well as military, organizations.

1. Introduction

Flexibility is the keyword when preparing for the uncertain future tasks for the civilian and military defence. Support tools relying on general principles will greatly facilitate flexible co-ordination and co-operation between different civilian and military organizations, and also between different command levels. Further motivations for general solutions include reduced costs for technical development and training, as well as faster and better decision-making. Most technical systems that support military activities are however designed with specific work tasks in mind, and are consequently rather inflexible. There are, admittedly, large differences between for instance fire fighting, disaster relief, calculating missile trajectories, and navigating large battle-ships. Still, there ought to be much in common in the work of *managing* these various tasks. We use the term *C2* (Command and Control) to denote management of civilian and military, rescue and defence operations.

We propose a general approach to achieve flexible support of C2. *DISCCO* (Decision Support for Command and Control) is a set of network-based services including *Command Support Tools* helping the commanders in the human, cooperative and continuous process of evolving, evaluating, and executing solutions to their tasks. Hence, these tools provide the means to formulate and visualize tasks, plans and assessments, but also the means to visualize decisions on the dynamic design of organization regarding roles, mandates, and obligations. Also included in DISCCO are *Decision Support Tools* that, based on AI and simulation techniques, improve the human process by integrating automatic and semi-automatic generation and evaluation of plans. The tools provided by DISCCO interact with a *Common Information Model* capturing the recursive structure of the situation, including the dynamic organization and the goals of own, allied, neutral, and hostile resources. Hence, DISCCO provides a more comprehensive situation description than has previously been possible to achieve.

DISCCO shows generic features since it is designed to support a decision-making process abstracted from the actual kinds and details of the tasks that are solved. Thus it will be useful through all phases of the operation, through all command levels, and through all the different organizations and activities that are involved. Consequently the usage of DISCCO may be used both for civilian and military purposes.

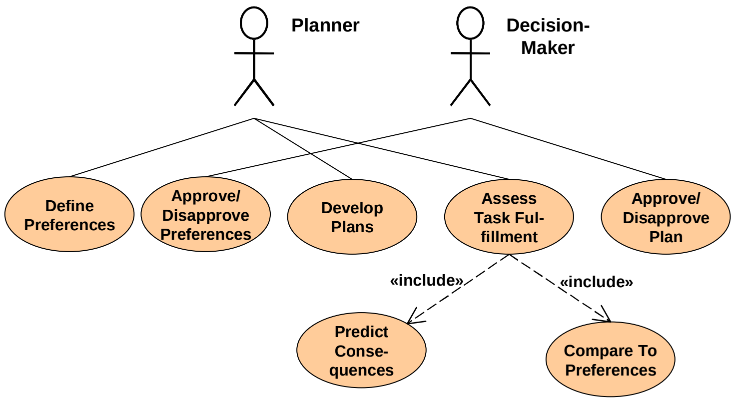

Figure 1. *Use Cases depicting the decision-making process*

2. The Generic Decision-Making Process

Military organizations have instructions on how to perform decision-making in C2. The Strategic Commanders Guidelines for Operational Planning (GOP) is one example of such prescriptive doctrines [7] for the planning phase of an operation. There is also a decision-scheme for the Swedish Armed Forces ("Bedömandemallen") [3]. Clearly these prescriptive models could be the baseline when designing DISCCO. They have, however, been criticized for not taking into account how people perform decision-making in practice. For instance there is often no time to develop and to evaluate several decision alternatives as prescribed in the decision-making doctrines. Also it has been shown that decisions are made very early in the process, based on the decision-maker recognizing the situation from previous experiences [6].

On the other hand, there should be no conceptual difference between brief ideas and fully developed and detailed mission plans. Both represent potential solutions on how to achieve the tasks. It should thus be possible to use the same means to represent the whole continuum from an idea to a developed plan. Also, there is technically no difference between managing only one tentative plan from managing several decision alternatives. Hence the Use Case diagram in Figure 1 depicts a generic process capturing the different operational aspects of decision-making in C2 [4] [10].

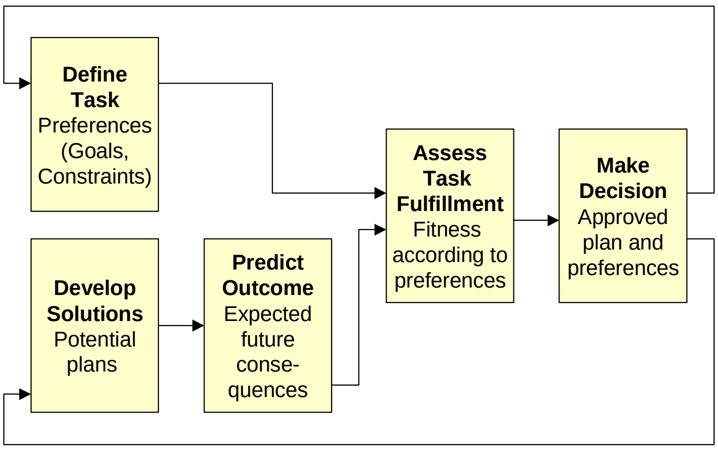

Figure 2. *The Decision-Making process is constituted by an iterative search for solutions that are expected to fulfil the task*

The suggested process assumes that the decision-making is performed as a collaborative process performed by commanders on different levels supported by their staffs. In Figure 1, these are substituted by two generic actors, the *Planner*, and the *Decision-Maker*. The model depicts the iterative search for the task ("what to achieve") and suitable solutions ("how to achieve it"). The task is represented by positive and negative *preferences*, i.e., goals and restrictions. The solutions are represented by potential *plans* that, given that they are executed, are expected to have *consequences* in accordance with the preferences. The fitness of the plans is assessed first by predicting the expected consequences of the plans, and then by comparing these to the preferences. A decision is made when the preferences or one of the plans is either approved or disapproved (the latter calling for further development).

Figure 2 further emphasizes the iterative search for a suitable solution in this process. The process is saisd do be *generic* since it depicts all forms of decision-making performed by the commanders and their staffs.

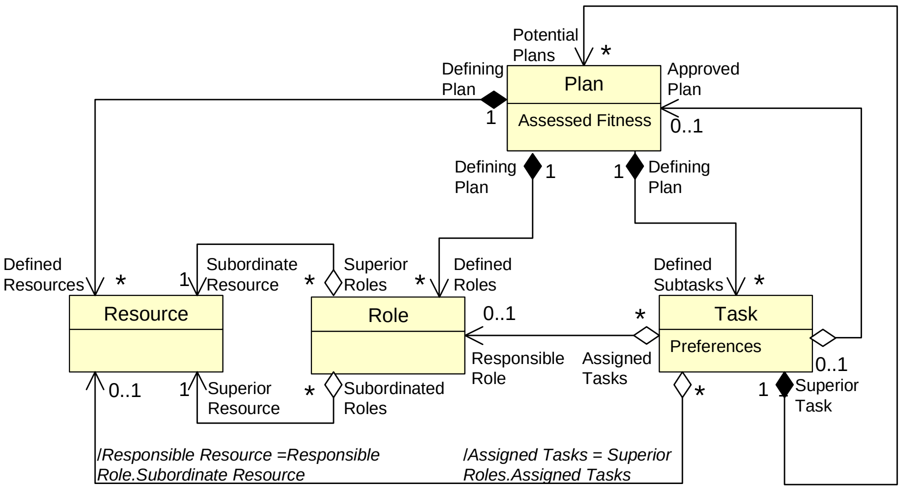

Figure 3. *The Class Diagram depicting the relations between the recursive hierarchy of tasks and plans (to the right) and the organization of resources (to the left).*

3. A Conceptual Model of C2

From the generic decision-making process illustrated in Figure 1 and Figure 2, we are able to identify two of the main entities involved in C2: *tasks* with preferences, and potential *plans* with assessed task fulfilment. As the plans should represent potential decisions made by commanders, they include (1) the organization of available resources, (2) the definition of subtasks to achieve and (3) the assignments of these tasks to the available resources.

The Class Diagram in Figure 3 illustrates the relations between these entities. In the right part of the diagram, the recursive hierarchy of plans and tasks is represented. A plan defines any number of subtasks to solve its superior task. A task may have any number of potential plans, although only one at the time could be approved.

A *resource* is a generalization of physical entities such as persons and technical artefacts (e.g. ships and tanks) on the one hand, and temporary and stationary organizations (e.g. battle groups, battalions, and fire squads) on the other hand, see Figure 4, below. To model the recursive structure of organization, a resource may consist of several subordinated resources. A resource may also be a part of more than one superior resource. To model such multiple memberships, the Role class is introduced, also depicted in Figure 4.

With different roles there may be different kinds of privileges and obligations following prevailing explicit or tacit doctrines. The meaning of “subordination” and “commanding” may be very dissimilar for different organizations. Although doctrines are not currently part of the suggested model we believe that introducing different types of roles might capture some of these issues. To be able to represent decisions on changes in the organization, we let a plan define new roles, as showed in the left part of the Class Diagram in Figure 3. Furthermore, the assignment of a task to a certain role, and hence to a certain resource, are parts of the plan.

This *conceptual model* has been described only briefly. Further explanation and motivation for the model and for the generic decision-making process is presented in [11]

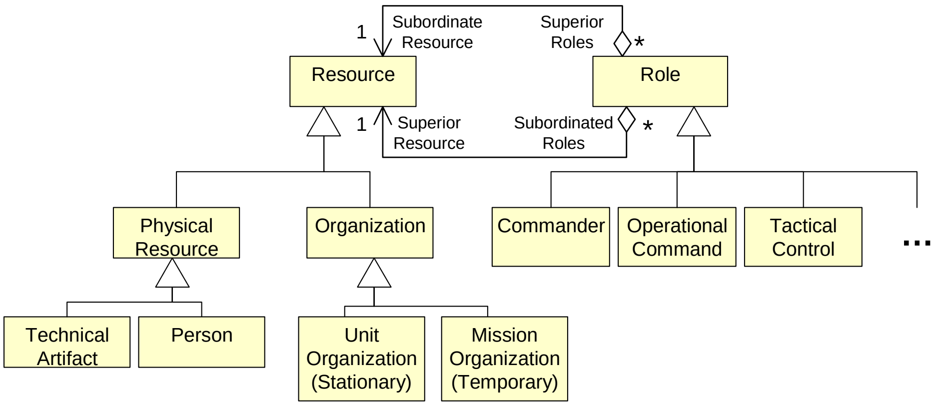

Figure 4. *An expansion of the Class Diagram in Figure 3. A resource is a generalization of physical entities such as people and battle ships, but also of organizations such as stationary and temporary battle units. A role is a generalization of different relations between superior and subordinated resources.*

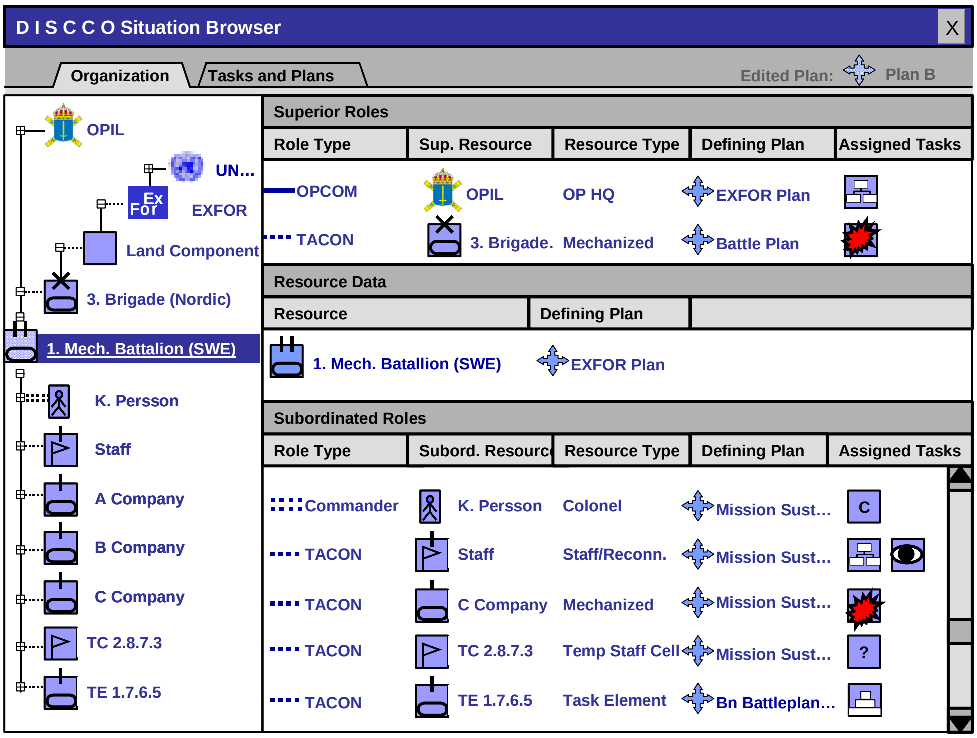

Figure 5. *An example of a hierarchically oriented browser for navigating and editing the Common Information Model from the organizational point of view. "OPIL" has the operational command over the Swedish "1. Mech. Battalion", while the tactical control has been delegated to the Nordic "3. Brigade" in the UN forces.*

4. The Common Information Model

A system based on network technology may facilitate a shift from sending explicit messages between the units into the interaction with a common set of information. The *network centric* paradigm implies that information is shared by default rather than due to explicit decisions on what pieces of information that should be sent to other units [10].

The conceptual model of C2, as presented in the previous section, depicts the relations between resources, roles, tasks, and potential plans that together provide the structure necessary to maintain this shared set of information. Building on the conceptual model, the Common Information Model in DISCCO is used to share information regarding both potential and approved decisions on how to manage own resources, but also what is suspected and known of the adversary resources. The recursive structure of the model facilitates selection of information that is suitable for the decision-problem at hand. Altogether, the Common Information Model provides a more comprehensive and adaptable description of the situation, than previously has been possible to achieve.

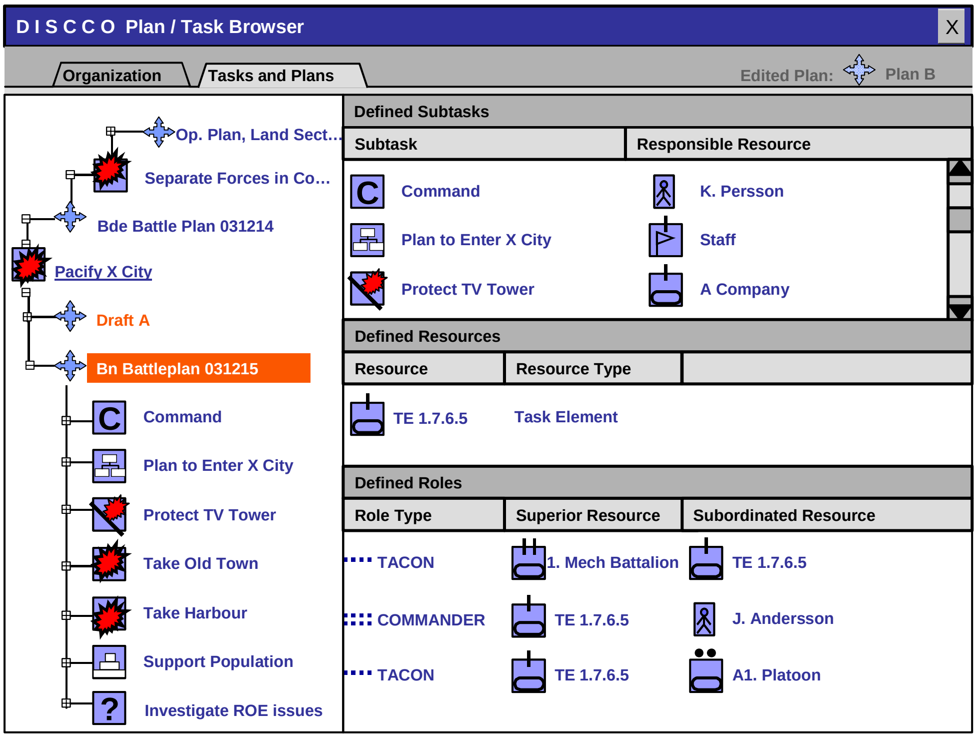

Figure 6. *An example of a hierarchically oriented browser for navigating and editing the Common Information Model from the Task/Plan point of view. The task "Pacify X City" has been assigned to the 1. Mech. Battalion. Currently there are two solutions to this task, of which "Battle plan 031215" has been approved. This plan involves the definition of a number of subtasks assigned to resources subordinated to the battalion. It also involves the definition of a temporary task element "TE 1.7.6.5".*

5. Command Support Tools

Command Support Tools aim at helping the commanders in the human, cooperative and continuous process of developing, evaluating, and executing solutions to their tasks. Hence, these tools provide the means to formulate and visualize tasks, plans and assessments, and also to formulate decisions on the dynamic design of organization, all represented in the Common Information Model. Different tools will have to be developed and evaluated in DISCCO to support the collaborative decision-making process by navigating and editing the Common Information Model from different views:

1) *Hierarchical views* reflect the recursive structure of organizations and plans. Figure 5 gives an example of a tool to browse the directed graph that represents the dynamic organization, while Figure 6 illustrates a tool to browse the corresponding graph representing the Task/Plan hierarchy.

2) *Time views* depict expected or historical events on a time line. The extension in time of tasks and assignments are typically visualized with these tools.

3) *Geographical views* illustrate the events and relations on a map. While traditional situation pictures typically emphasis the positions of different resources, it will, by means provided by the Common Information Model, be possible to depict also tasks and other relationships. In addition it will be possible to select the appropriate level of abstraction, by zooming up and down through the recursive structures.

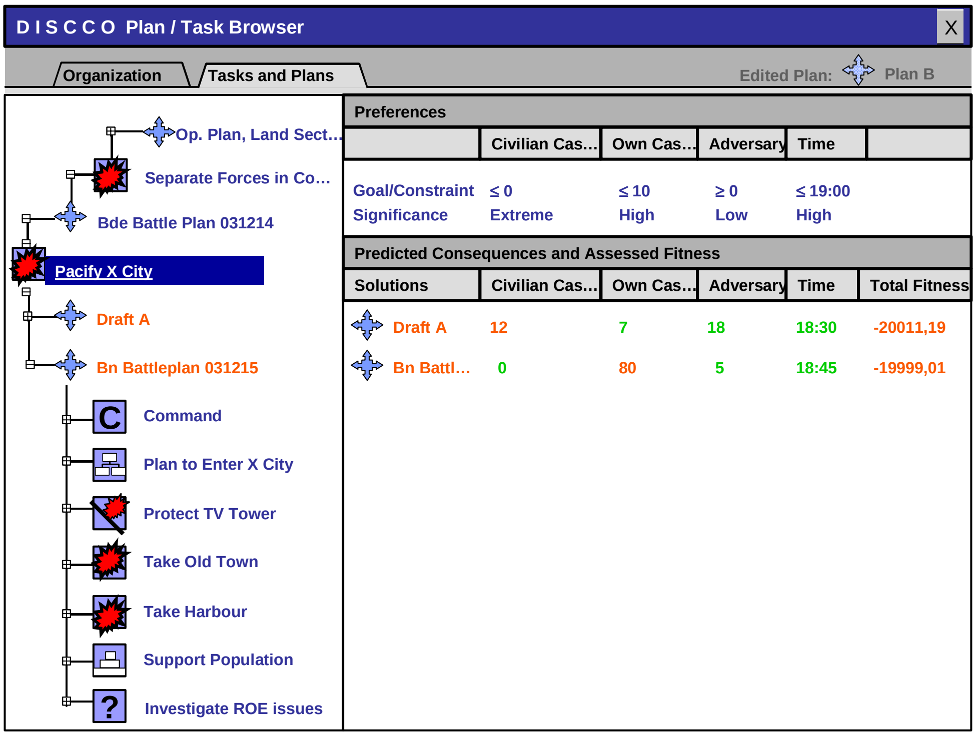

Figure 7. *An example of the assessment of potential solutions in the Task/Plan browser. Neither the approved battle plan, nor the draft alternative plan, fulfils the goals and constraints. However the consequences of the Draft A plan could be considered being worse since the absence of civilian casualties is said to be extremely important.*

6. Decision Support Tools

Decision Support Tools aim at enhancing the human decision-making process that was depicted in Figure 1 and 2. Several technical solutions could be considered to support this process [1][2][4][5]:

1) Plans could be generated by use of techniques that recognize the situation and find the most suitable plan from a set of plan templates. Besides, search techniques such as genetic algorithms could be used to successively improve a set of plans according to the preferences.

2) The prediction of consequences is naturally performed by mental simulation, i.e., within the minds of the decision-makers. By full integration of agent-based simulation in DISCCO, it will be possible to automatically predict the development of the situation. By offering this opportunity to simulate plans, as they are designed by use of the Command Support Tools, the consequences of potential decisions could immediately be tested during any phase of the operation. It is however only a subset of all aspects of the reality that can be simulated, and it is thus essential that the use of embedded simulation models can be mixed with mental judgments. DISCCO will encompass embedded simulation

functions designed to facilitate successive introduction of simulation models as they are improved by the continued technical development.

3) The tasks are constituted by their goals and constraints in different aspects that may be represented by a *multi-attributed preference function*. By using this function, the predicted consequences of different solutions could be valuated by the calculation of a total fitness value.

Figure 7 shows an example on how Decision Support Tools could be integrated with the Command Support Tools. The expected consequences in different aspects of two alternative plans are presented in the Task/Plan Browser. Some of the consequences may have been predicted by the use of embedded simulation, and some may have been manually assessed and entered by a commander or some member of the staff. Also, the consequences may be compared to the goals and constraints that represent the task.

7. Conclusions

All the techniques and concepts that have been described in this paper are tentative. As such, they have been included to indicate the possible direction for further development of general tools supporting decision-making in the context of C2. A *roadmap* has been suggested on how to implement DISCCO within the future common C2 system of the Swedish Armed Forces [8]. If accepted, this roadmap will generate a substantial effort of research and development. To achieve the necessary acceptance for this effort, the work on a prototype system has started at SaabTech Systems AB with the purpose to illustrate some of the main concepts of DISCCO. Internally funded, this effort is planned to continue during the first part of 2003.

By this development, DISCCO will facilitate common situation awareness since the Common Information Model may be visualized through suitable views and levels of abstraction. Compared to a traditional situation picture, the Common Information Model represents also intents and occupations of the units, as well as command chains and similar issues.

Planning will be supported by the possibility to edit plans representing potential decisions regarding subtasks and organization, also presented in different views. The situation awareness and the decision-making is further facilitated by the ability to predict the situation by the handy use of embedded simulation, and also in terms of increased safety by the possibility to test for deficiencies of the plan before it is executed.

Communicating the plans will be more efficient since they, by the use of networked based services, will be available to subordinated units and commanders as they are developed. As the tools are designed for collaborative use, the subordinated commanders could take part in the planning process. The background and the purpose of the task will be easier to grasp since also higher-level plans may be available to the subordinated units. Plan assessment will be supported also during the execution phase of the operation. Accordingly, it will be possible to make quick changes of the plan, facilitating dynamic decision-making.

Altogether, this general approach to C2 support will be useful to commanders and staffs on different command levels throughout both civilian and military organizations involved in managing resources to achieve tasks. The implementation will require a substantial effort of research and development. DISCCO will, however, support human decision-making that will successively improve by the introduction of new tools and simulation models, as this development proceeds.

8. Acknowledgements

This work has been sponsored by SaabTech Systems AB, and the Parallel and Scientific Computing Institute (PSCI).

A number of people have been involved in the discussions on the concepts presented. From the academic domain have Joel Brynielsson, and Professor Stefan Arnborg at the Royal Institute of Technology contributed, together with Professor Berndt Brehmer at the Swedish National Defence College. Dr. Per Svensson at the Swedish Defence Research Agency has also been available for fruitful discussions. From SaabTech Systems AB, Dr. Qi Huang, Jenny Hållmats, and Björn Bergström should be mentioned, among many others.

9. References

[1] J. Brynielsson: *A Decision–Theoretic Framework Using Rational Agency*. In Proceedings of the 11th Conference on Computer-Generated Forces and Behavior Representation, number 02–CGF–047, Orlando, FL, May 2002, pp 459–463.

[2] J. Brynielsson, K. Wallenius: *A Toolbox for Multi-Attribute Decision-Making*. Manuscript, Royal Institute of Technology, 2002.

[3] HKV: *StabsR 1 Fu* (in Swedish), Swedish National Defence, 1996.

[4] Q. Huang, J. Hållmats, K.Wallenius, J. Brynielsson: *Simulation-Based Decision Support for Command and Control in Joint Operations.* European Simulation Interoperability Workshop 2003, Stockholm Sweden. (In press).

[5] J. Hållmats: *Demonstrator för beslutsstöd i ett militärt scenario,* (in Swedish), Master's thesis, SaabTech Systems 2002.

[6] G. Klein: *Strategies of Decision Making.* Military Review, pp 56-64, May, 1989.

[7] *Strategic Commanders Guidelines for Operational Planning (GOP).* IMSTAM (OPS) – 243 – 98 SHAPE. NATO HQ, Military Committee, Brussels, 1998.

[8] L. Schylberg: *Geoinfohantering och Beslutsstöd inom LedsystT, DISCCO – En generisk plattform för lednings- och beslutsstöd,* (Management of Geographical Information, and Decision Support within LedsystT, DISCCO – A Generic Platform for Command and Decision support) LT01-DP3:503 – Bilaga 2, Swedish Defence Materiel Administration, 2002 (inSwedish).

[9] P. Thunholm: *An Attempt Toward a Prescriptive Model of Military Tactical Decision-Making.* In B. Brehmer, H. Montgomery, R. Lipschitl (eds) How Professionals Make Decisions. Mahwah, New Jersey: Earlbau (In Press).

[10] K. Wallenius: *A Network Centric Info-Structure for the Swedish Armed Forces.* Milinf 2000, Enköping, Sweden

[11] K. Wallenius: *A Generic Model of Management and Command and Contro*l, 7th International Command and Control Research and Technology Symposium, Loews Le Concorde Hotel, Quebec City, QC, Canada, September 16-20, 2002.

Klas Wallenius has been employed as a systems engineer at SaabTech Systems AB since 1993, where he has been working with data fusion and the development of a common situation picture. Challenged by these issues, he has also been a PhD student at the Royal Institute of Technology since 2000, sponsored by SaabTech Systems AB and the Parallel and Scientific Computing Institute. The research interest is in decision support for Command and Control applications. He holds a master's degree in electrical engineering from Chalmers University of Technology.