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Cloud-based decision support system for planning military operations

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Summary

When planning a military operation, it is important to explore possibilities and understand consequences of the plan. To this end, wargaming can be used for assessing possible courses of action (COA) for own and enemy forces. Traditionally, this is done by humans alone, drawing tactical graphics and moving pieces representing military units on a large map. We propose that computer-assisted wargaming holds a potential to help military commanders visualize, evaluate and share different possibilities and consequences, beyond what is supported by the traditional and current methods.

"Simulation-supported Wargaming for Analysis of Plans" (SWAP) is a research prototype of a decision support system (DSS) for military, tactical planning. The system consists of a simulation system that runs in the cloud, and an intuitive web-based, graphical user interface that does not require a lot of training. The user interface has basic functionality for terrain analysis, such as route planning and identification of favorable vantage points around a target area. A user can assign basic tasks to units and create phase lines to coordinate task executions, thus specifying a COA. The user can then choose to simulate the COA to reveal possible consequences such as engagements, losses, time expenditure and resource consumption.

In February 2019, we conducted an experiment with 52 final-year cadets from the the Norwegian Military Academy. The purpose was to test using a simulation based DSS and compare it to the traditional way of wargaming for COA development and analysis. The cadets were divided into groups and asked to make simplified decision briefings for two different battalion operations, one when using SWAP and one while using the traditional method.

In this report we describe SWAP, and based on the results of the study, including feedback from the cadets, we discuss the potential and requiremets of such a system for operations planning. The objective of this report is to convey to Norwegian Armed Forces stakeholders the potential we see in using computers and simulation to assist military planning and decision making.

Sammendrag

Planlegging av militære operasjoner krever at man kan utforske og vurdere ulike muligheter og forstå konsekvenser av planen. Krigsspill er et viktig hjelpemiddel for å visualisere ulike handlemåter både for egne og fiendtlige styrker. For å utvikle og forfine handlemåter bruker man gjerne store kart som man tegner handlemåter og flytte brikker på. Vi mener det er mulig å lage digitale hjelpemidler som kan støtte plangruppa enda bedre med å visualisere, evaluere og dele ulike muligheter og konsekvenser.

Vi har laga en forskningsprototype på et beslutningsstøtteverktøyt for planlegging kalt SWAP ("Simulation-supported Wargaming for Analysis of Plans"). SWAP benytter skybaserte løsninger og et enkelt brukergrensesnitt som lastes ned i brukerens nettleser. Her har brukeren tilgang til terrenganalysetjenester som ruteplanlegging og identifisering av stillinger. Brukeren kan laste inn oppdragsorganisasjon og spesifisere handlemåter ved gi enhetene ulike oppgaver og tegne faselinjer for å synkronisere utførelsen av oppgavene. Brukeren kan deretter simulere handlemåtene mot fientlige handlemåter for å identifisere mulige konsekvenser relatert til tidsbruk, eventuelle tap og ressursbruk.

I februar 2019 gjennomførte vi et eksperiment der 52 sisteårs studenter ved Krigsskolen på Linderud prøvde å bruke SWAP til planlegging. Hensikten med eksperimentet var å utforske nytteverdien til et simuleringsbasert beslutningsstøttesystem for planlegging. Eksperimentet inngikk som en del av undervisningen i plan- og beslutningsprosessen. Studentene fikk i oppgave å utvikle beslutningsbriefer for to bataljonsoperasjoner, en ved hjelp av SWAP og en ved hjelp av et tradisjonelt papirkart. Deretter skulle de gi tilbakemelding på bruken og potensialet for et digitalt hjelpemiddel som SWAP.

I denne rapporten beskriver vi forskningsprototypen SWAP og diskuterer potensialet og forutsetningene for et slikt hjelpemiddel for militær operasjonsplanlegging basert på tilbakemeldinger fra studentene. Hensikten med rapporten er å formidle mulighetene som ligger i et slikt digitalt hjelpmiddel til interessenter i Forsvaret.

Contents

1 Introduction

Military operations are both artful and scientific but are neither art nor science alone. Achieving results in war calls for science when testing a hypothesis, such as a plan. Creating such hypotheses and using the results of war for a purpose is art [1]. We do not think that computers can substitute humans in the artful and creative aspects of military decision making, but computers are far better than humans in storing and processing data, thus contributing efficiently to the scientific processes of military planning and decision making.

Military decision making and planning must consider a large number of factors, including resources, terrain, enemy course of action (COA) etc. Military organizations often standardize their planning and decision making processes. A standard process ensures that necessary aspects of military operations are considered systematically. Our objective is to study how computers can support this process.

We have built a of a research prototype of a decision support system (DSS) [2, 3, 4] for planning. The research prototype is called SWAP, which is an acronym for "Simulation supported Wargaming for Analysis of Plans", and it incorporates a limited functionality to assist COA development and simulation for planning of land operations. The original objective with SWAP was limited to study the potential of a tool that can execute a COA in a simulation environment in order to reveal strengths and weaknesses with the disposition of forces. Wargaming is an important but time consuming part of military planning today, and our hypothesis is that using simulations, handling a great amount of data for wargaming, can be efficient and provide more insights on certain aspects than without simulation support. During the development of SWAP, we realized that a digital tool for drawing out COAs can be beneficial in itself, especially if it incorporates tools to assist the COA development before the simulation starts.

In February 2019, we conducted an experiment where 52 cadets from the Norwegian War Academy tried and provided feedback on the current functionality in SWAP. They used SWAP to develop and evaluate potential COAs for a battalion in a fictitious scenario. The study provided insights into the requirements and potential for a computer based DSS.

The objective of this report is to convey to stakeholders in the Norwegian Armed Forces the potential we see in using computers and simulation to assist military planning and decision making at a tactical level. The next chapter explains the current Norwegian army tactical planning process, and highlights some of the problems that may be reduced by using DSS. Chapter 3 provides an overview of what the prototype SWAP can do today. Chapter 4 describes the experiment conducted together with the Norwegian War Academy, and in chapter 5 we discuss how a tool like SWAP should work based on the results from the experiment and our military and technical knowledge. The last chapter summarize the possibilities with at tool like SWAP and how computers can assist in order to facilitate faster decision making in the future. Technical details of the SWAP system is described in a separate FFI-report [5].

2 Military planning and how decision support systems can support it

Military operations and tactics is an art-scientific hybrid that demands both simplicity and complexity. The factors to be considered are, in principle, unlimited. At the same time, there is a need for an understandable language and human cognition-manageable processes to efficiently analyze and convey these complexities. The Norwegian Army process, in which the analytical preparations for battle are made, is called the plan and decision making process (PDMP) and is interoperable with the corresponding process in NATO. As illustrated in table 2.1, other countries have similar, but not equal processes for tactical decision making; for example the US Army's Military Decision Making Process (MDMP).

2.1 The plan and decision making process in the Norwegian Army

A standard comprehensive plan and decision process for brigade and lower level units is completed in five stages: 1) preparations, 2) mission analysis, 3) COA-development, 4) plan-development, and 5) revision of the plan [6]. The more complex the mission, the more time it takes to complete the planning process. The PDMP could take a few hours or several weeks, depending on the difficulties encountered when merging the art and science needed to win the battle.

Stage 1 of the PDMP comprises necessary preparations for the planning process. In addition to collecting the necessary tools, the scope of the tactical mission is analyzed and guidelines for further planning is conveyed to involved personnel. In order to work efficiently and state responsibility, the commander, or second in command, gather their closest co-workers and outline the work. This stage requires some products and tools: orders and plans, maps and photos, intelligence preparations intelligence preparations of the operational environment (IPOE) and several logs.

PDMP stage 2 is a comprehensive mission analysis to answer what has to be done to fulfil the military commanders' intent. It comprises determining the core mission and decomposing the mission into factors, both known and new, that can be analyzed. Based on the factor-considerations, the identified risks are estimated and mitigated if possible. The standard procedure is to give the mission analysis briefing to the commander and staff in order to decide and further develop the plan. Stage 2 is completed when the commander approves the restated mission, the suggested operational design, the risk analysis, and the Commander's Critical Information Requirements (CCIR).

The aim of stage 3 is the operational concept for the mission, ie. describing how the mission can be solved. It comprises a go-trough on own forces' status, enemy status and enemy COA in order to compare strengths and weaknesses. Furthermore, possible own COAs are developed in accordance with previous conclusions and commander's guidance. COAs are tested and compared and then presented to the commander with the planners' recommended COA in the decision briefing. An explicit commander's intent for the military operation is decided upon, including COA for further planning. Stage 4 is initiated with the approved operational concept. We believe a DSS like SWAP can be used to improve this stage by offering services to help the development of COAs and simulation based wargaming for efficient analysis of different COAs.

Table 2.1 The table illustrates interoperability between different countries' standardized planning process. The table is translated and reproduced with permission from Stabshåndbok for Hæren [6].

<table>
<tr><th></th><th>PDMP
(Norway)</th><th>MDMP
(US Army)</th><th>Tactical Estimate
(UK Army)</th><th>7Q (Combat estimate)
(UK Army)</th><th>COPD
(NATO/SHAPE)</th></tr>
<tr><td rowspan="2">Background info</td><td rowspan="2">Step 1: Initial situation analysis</td><td rowspan="2">Receipt of the mission</td><td rowspan="2">Understand the situation</td><td rowspan="2">Q1: What is the situation and why?</td><td>Situation Awareness</td></tr>
<tr><td>Operational Appreciation and assessment of options</td></tr>
<tr><td>Understanding WHAT and WHY</td><td>Step 2: Mission analysis</td><td>Mission analysis</td><td>Mission analysis</td><td>Q2: What have I been told to do and why?</td><td>Operational Orientation</td></tr>
<tr><td rowspan="2">Alternative solutions</td><td rowspan="3">Step 3: Developing COAs and consept</td><td>COA development</td><td>Formulate COAs</td><td rowspan="3">Q3: What effects do I need to achieve and what direction must I give in order to develop a plan?
Q4: Where can I best accomplish each action/effect?
Q5: What resources do I need to accomplish each action/effect?
Q6: When and where do the action/effect take place in relation to each other?</td><td rowspan="3">Operational CONOPS development</td></tr>
<tr><td>COA analysis</td><td>Develop and validate COAs</td></tr>
<tr><td>Solution proposal</td><td>COA comparison</td><td>Evaluate COAs</td></tr>
<tr><td rowspan="2">Solution Selection</td><td>Step 4: Developing the plan</td><td>COA approval</td><td rowspan="2">Commander's decision and development of the plan</td><td rowspan="2">Q7: What control measures do I need to impose?</td><td>OPLAN development</td></tr>
<tr><td>Step 5: Plan review</td><td>Orders production</td><td>Execution and OPLAN review</td></tr>
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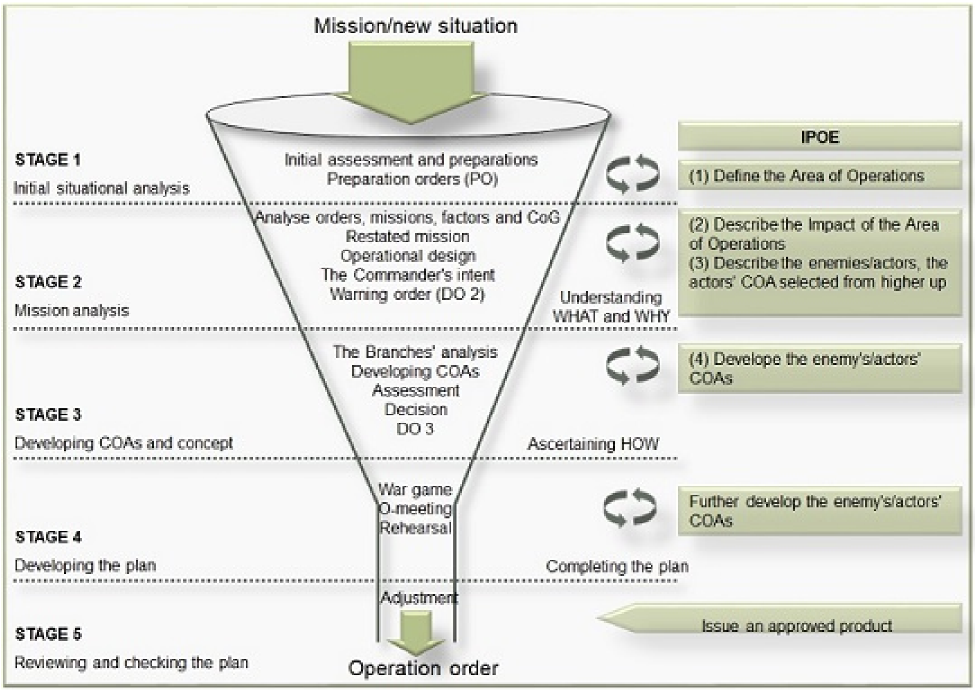

Figure 2.1 The figure shows the stages in PDMP and their main contents. Source: [6].

Stage 4 is completed with the issuing of an operation plan (OPLAN) or operation orders (OPO). During this stage, a wargame is conducted to test the details and feasibility of the plan. Afterwards, the actions of the involved units will be coordinated and synchronized. A simulation based DSS like SWAP can also be useful in this stage of refining the plan. When planning is conducted sequentially between levels, the plan will be handed over to receiving units for their own PDMP as soon as the plan has been sufficiently documented. That is, the receiving units would as much as possible participate and maintain awareness of the upcoming mission, with parallel planning as the least time-consuming.

Stage 5 comprises revisions of the plan, an activity that continues both before and during the operation. The activity of this stage depends on the situation evolving and the premises of the completed plan. Assumptions may change and call for minor adjustments or a complete revision of the plan. Depending on the necessity for change of plans, the commander orders the development of new branch plans or a complete new planning process.

Even though a plan is at some point completed, military planning is a never-ending process. Since the nature of war is a battle of human will, belligerent actions are unpredictable, and a plan may rarely be fulfilled exactly as intended. The Prussian strategist Von Moltke the Elder famously asserted that “No operation extends with any certainty beyond the first encounter with the main hostile force” (translated from [7] in [8]). This is why tactical planning must be flexible and changeable. Every new action gives rise to a new plan contingent on those actions. Working further along this line of thought, one could even say that one important purpose of the act of planning military operations is, paradoxically, to prepare for actions when the plan fails [9].

The PDMP as a process can itself be adapted when necessary. It can be overly time-consuming for the staff to go through all five stages. Tactical necessity could call for the skipping of some stages, bearing in mind that trained personnel will understand the merging risks by making shortcuts. That a trained eye is seen as necessary to adapt the PDMP is apparent in that only the respective commander or chief of staff should be allowed to decide on such changes [6].

The desirability of highest possible tempo in the planning and decision cycle is evidence based and well rooted in our military organizations. Contemporary paradigm of military doctrines calls for high tempo in order to achieve the strategic aims in a conventional war [10, 11, 12]. Operational tempo is treated axiomatic because of the potential effects it has on an adversary and its contributions to risk-reduction on own forces.

> *The joint force, supported by other instruments of National and multinational power, conducts synergistic, high-tempo actions in multiple domains to shatter the coherence of the adversary's plans and dispositions and render him unable or unwilling to militarily oppose the achievement of our strategic objectives.* [13]

As evident as the demands for the development of more efficient weapons and protective measures, the plan and decision process must be improved in order to provide better tactical and operational dispositions faster. The measures-countermeasures logic insists that weapons are improved to counter the threat they are opposing, interactively. In conventional warfare it is expected that the adversary will strive for the necessary increase in tempo compared to our current abilities, which makes our operations stagnate. This fact calls for development of methods that contribute to our own ability to increase planning speed and decision quality.

2.2 The Norwegian Military Academy uses simulation when teaching PDMP

Since 2010, students at the Norwegian Military Academy (NMA) have used simulations as an integral part of their curriculum in tactics and military planning methods within the analytical tradition. The NMA utilizes mixed simulations, partly virtual, partly constructive, in order to focus on methodical questions and solutions for tactical problems. The evolved academy experience is that the cadets need only 2 – 4 hours of basic simulator training before starting their training in the simulator. Every hour spent in the simulator with tactical training thereafter is considered effective and makes this training highly relevant. The cadets are changing their behavior during a day, but they cannot relate it to a specific episode or teacher's instruction. The learning is emerging as a part of the activity.

As a part of a PDMP course, the students work four days on producing a COA for a battalion based on a brigade operations order. Cadets in groups of 10 take on the roles of Chief of Staff, S-2 Intelligence officer, S-3/S-5 Operations and planning officers, S-4 Logistics officer, S-6 Communication officer, Fire Support officer, Engineer staff officer, and assistant officers for S-3 and S-2. The emphasis is placed on developing a mission analysis brief and a decision briefing, meaning they are not required to fulfill a complete PDMP with a written, full five-paragraph order. The idea is to focus on their process of thinking about solving the task, not the formalities and design of the written operations order.

Currently, traditional methods are being used for the first three stages of the PDMP, but as a part of Stage 4, after a COA has been selected in Stage 3, each group get 10-12 hours to conduct a simulation-supported wargame of the selected COA. The students use the real time, entity-based simulator Steel Beasts[1], and the groups support each other to fill the necessary operator positions to conduct the wargame, including playing the enemy. Typically, the battalion operation is divided into phases that are wargamed separately, possibly up to three times. The simulation is used to visualize the consequences of the chosen COA, each phase at a time, and to tie those back to the conclusions from earlier factor analyses. The written conclusions are available to all groups and instructors on a common network, and the students have several breaks for discussions. Discussions are moderated by instructors to ensure reflections on the decomposed factors and on how the conclusions are shaping the cadets' decisions.

Simulations provide experiences for the inexperienced cadets. However, a main challenge is to make them understand that the method, within this educational context, is more important than the specific solution to a given tactical problem.

2.3 Decision support systems for planning

Planning involves taking into account the information gathered in the various steps of the planning process as well as other information available, comprehending that information, deciding what information is salient to the progress of an operation, and then to decide on courses of action. Moreover, this has to be performed rapidly in order to prevail on the battlefield. At the outset, the cognitive load of operations planning is substantial.

In the field of judgment and decision making, cognition is often modeled as two distinct sets of sub-processes: the *analytical* and the *intuitive*. The former is deliberate and strives to take into account all relevant cues. It is therefore slow. The latter relies on only a few cues, might not be fully conscious, and is regarded as rapid.

There are reasons to favor the analytical process; after all, rational thinking, taking into consideration all relevant factors with a tight focus on explicit deliberation [14], adds comprehensiveness [15] and is something most of us are trained to value (the "worship of reason" [16]). This rationale is also apparent in the PDMP. Moreover, several studies show how humans seem to fail in making correct judgments when they do not follow analytical processes, due to biases and undue heuristics [17, 18].

However, human working memory and other cognitive functions limit human ability to process all relevant factors; let alone to process them rapidly when the number of factors become large and their relationships complex [19, 20]. There is therefore substantial gain in being able to use the intuitive processes as well; as long as that intuition is good. In Hogarth's terms, intuition is expertise that is internalized [21, 22, 23]; perhaps after extended experience and deliberate practice [24]. Intuition can therefore be trained. For example, chess masters, after years of training, use pattern recognition when contemplating a chess position [25], rather than analyzing the particular position of every piece as a novice is likely to do [26]. A part of this is the process of *chunking*; where larger, and therefore fewer, cues are sampled and processed, enabling the limited working

[1]https://www.esimgames.com/

memory to process “more by less”. A large body of research has investigated how to take advantage of the quicker intuitive processes [20, 27, 28, 29].

In military decision making, it seems sensible to use both analytical and intuitive processes in concert [30]. This is what lies in the “art and science” remarks earlier. In particular, analytical processes are instrumental for training intuition. The problem in general for the complex tasks inherent in real-world decision making, is that it takes a long time to become a master. Simulations can speed up this process by facilitating both extended experience through large volumes of training and deliberate practice [9], and when integrated in a DSS, such as in SWAP, simulations can be targeted to support and train both analytical and intuitive decision processes.

A DSS can be characterized in terms of how passive or active it is regarding advise to users [3]: A *passive* DSS provides data, visualizations etc. as aids to decision making, but it is up to the user to design solutions and make the final decision. In contrast, an *active* DSS is designed to produce solutions to the user; i.e. it performs a large part of the decision process for the user. A *cooperative* DSS combines passive and active characteristics. It will provide users with possible solutions, but the user will make decisions as to which solutions to follow and can modify solutions at will [4]. Along these lines, one may use simulations as part of a DSS in a *case-driven approach* to explore critical cases (e.g., bad case, most likely case, good case) for uncovering underlying drivers in and of a situation [9]. For military planning, the intention would be to understand the salient factors in the plan to prepare for when the plan fails, instead of, or in addition to, generating the optimal plan through a statistical approach [9].

For supporting analytical processes, a DSS could compensate for limitations in working memory. By displaying a selected amount of data in various views, planners will be able to highlight the most relevant information for a certain task; for example in a time-perspective or a geographic perspective. A DSS would thus save time and add comprehensiveness, while also providing updated and relevant information so that commanders can adapt plans accordingly.

For supporting intuitive processes, a simulation-based DSS could compensate for lack of extended experience and practice. However, when planners become more experienced, a passive or interactive DSS may allow users to choose or configure what information they see as relevant and also allow users to chunk information more optimally. Computer-based tools allow rapid selection and preparation of data, otherwise not possible with manual methods.

3 SWAP is a decision support system for planning

SWAP is designed to demonstrate the concept of a DSS that is available everywhere through an easy-to-use web-based user interface, where users can develop digital, executable COAs that can be simulated without technical support personnel in the loop. In this chapter, we describe how SWAP works from the user point of view.

SWAP has limited functionality and rudimentary simulation models, but the intention is that sufficient possibilities are offered for potential stakeholders to try out the concept and identify requirements for a simulation based DSS for military, tactical planning.

3.1 SWAP facilitates digital planning

SWAP displays forces on a digital map where the user can task units and create tactical graphics and control measures. In essence, this is the same process that a user would perform on a paper map. However, drawing a plan on a digital map as opposed to freehand drawing on a paper map, opens up new possibilities for collaboration between users at different physical locations and integration with command and control (C2) systems. Also, it can enhance readability and facilitate use of standard graphical symbols, which makes the graphics easier to interpret without additional verbal explanations.

SWAP takes the the concept of digital plans one step further, into *executable*, digital COAs. The COA created in the user interface, is translated into a machine interpretable, unambiguous language, making it possible to simulate the COA without simulation operators in the loop. This is the idea behind the work on the Coalition Battle Management Language (C-BML), a machine-interpretable language for military orders [31] and more recently, C2SIM [32, 33].

Drawing a COA in SWAP must be fast and easy. If it is not sufficiently fast and easy to enter a COA into SWAP compared to drawing it out on a paper map, people may not use it, despite other benefits. Although user interface design is not our specialty, we have striven to make SWAP as easy to use as possible. In the earlier demonstrator version of SWAP, the user interface was tightly connected to the internal language used to express military orders digitally. In the new interface we have decoupled the presentation layer from the model language and looked at computer games for inspiration.

The number of tasks supported by SWAP is currently limited. Our initial ambition was to support basic tasks for maneuver, engineer and artillery in order to present and simulate brigade or battalion-level COAs. So far, SWAP supports two types of movements, one used for transporting units as fast as possible and one for more cautious advancement. In order to relieve the user from having to specify detailed routes, SWAP suggests routes that can be adjusted by adding waypoints. The user can sketch target areas and assign tasks for maneuver units to seize or support by fire on these areas. Similarly, engineering units can be ordered to breach an obstacle described as an area. Units are synchronized by using phase lines. Today, all tasks are displayed as standard arrows with different colors. However, a system put into actual operational use would offer standard military graphics [34]. Figure 3.1 illustrates a COA sketched in SWAP.

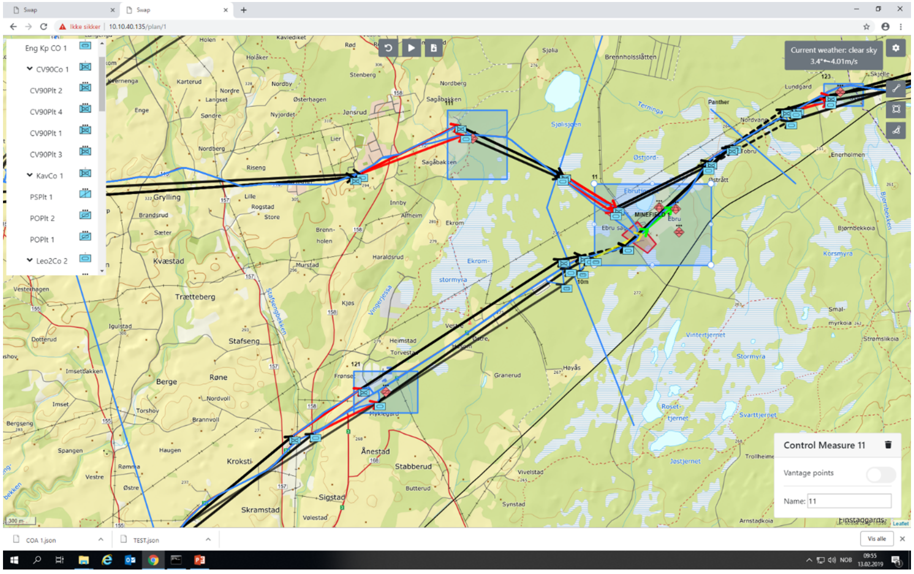

Figure 3.1 The figure illustrates how a COA looks like in SWAP today. This particular COA was made by one of the groups of cadets during the study.

In order to fully exploit the benefits of a digital plan, SWAP can be integrated with a command and control information system (C2IS). The order of battle is imported using the Military Scenario Definition Language (MSDL) [35], which can be exported from a C2IS. A connection to the Norwegian C2IS (NORCCIS) has been demonstrated with an earlier version of SWAP where the order of battle, including initial positions of forces, and a plan consisting of tactical graphics were imported into SWAP [36]. We also envision that COAs developed in SWAP could be imported directly into a C2IS; thus eliminating the need to enter the final plan manually into the C2IS afterwards. This has not yet been implemented.

3.2 SWAP facilitates terrain analysis

In addition to making it possible to create digital COAs, SWAP provides functionality to facilitate terrain analysis. Today, SWAP incorporates two terrain analysis tools, one for tactical route planning and one for identifying vantage points. These are two examples of tools for terrain analysis that can be made available in a digital map. The objective with such services is to make it faster and easier for the user to perform terrain analysis, which is a very important part of planning for land operations.

The route planner finds the best route given a set of prioritized aspects [37, 38]. Possible aspects are accessibility, cover (from direct fire), concealment, and threat. Today, priorities are predetermined for the different tasks, and the tool only presents the default routes the simulated units will follow if they are not interrupted by other instructions. By displaying routes in the user interface, the user gets the opportunity to override the computers' choice by adding waypoints. The route planner provides the estimated travel time for a given route for a single battle tank, taking soil type and inclination into consideration. The user must compensate for the extra time required to move a unit consisting of several vehicles.

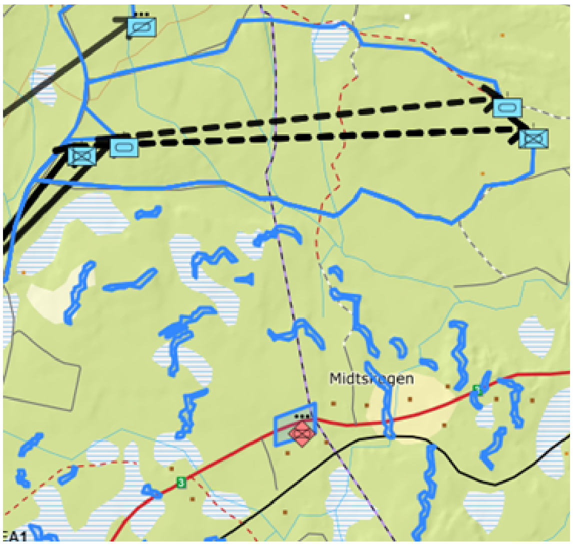

Figure 3.2 The figure shows vantage points around a selected area.

The route planner was originally developed to make simulated units in computer generated forces move more realistically. That is, make the simulated unit select an appropriate route according to its task instead of just moving in a straight line for A to B.

The vantage point service is purely a decision support tool at the moment, and is not used by the simulation. It displays all positions that have line of sight covering a given proportion of a selected target area, and that at the same time are close to cover from direct fire from the same area. Currently, the tool only considers terrain height, so the user is asked to consider vegetation when selecting among the suggested vantage points. The user can use this tool to find good positions for e.g. observation, attack, or the support of an attack. An example, showing how the cadets used the vantage point tool in the experiment, is included in figure 3.2.

3.3 SWAP can simulate a course of action

The user may choose to simulate a COA. The user will see the units moving across the map, while status information such as health, fuel and ammunition supplies is updated as the COA is simulated. This simulation can be used to discover weak elements in the COA, such as synchronization issues and show potential consequences of the decisions. At the very least, it should make it possible to compare different COAs.

For the simulation to be useful, the limitations of the simulation models must be understood by the user, and the models must be validated. In the current prototype, SWAP uses standard models for engagement and resource consumption provided with the commercial off-the-shelf (COTS) simulation system VR-Forces from MAK[2]. We have not validated these models thoroughly. The same applies to the terrain analysis tools. The current models are sufficient for making a user see

[2]https://www.mak.com/products/simulate/vr-forces

the potential of a tool like SWAP, but the models must be validated before one can use them for decision support.

We have chosen to base the simulation on statistical aggregated models, which require less detailed behavior models. This avoids the strange behaviours that may arise when simulating single entities, such as a unit positioning itself in full display of the enemy instead of hiding behind a hilltop. Theoretically, it is possible to take into account all kinds of factors like training level, fatigue, motivation etc. in statistical models used in aggregate simulation. However, it is challenging to validate such models. An important part of future work will be to obtain better knowledge of the required fidelity of these models.

3.4 SWAP is available in a browser

SWAP is built upon the concept of Modeling and Simulation as a Service (MSaaS) [39, 40, 41], meaning that SWAP consists of several loosely coupled back-end and front-end services that can be reused individually for different purposes. Figure 3.3 provides an overview of the SWAP architecture.

The SWAP graphical user interface (GUI) is a web application that can run in any browser, and it is possible to run several instances at once. It connects to external services for weather information and maps and has direct access to the terrain analysis services for route planning and vantage points. Only when a user choose to start a simulation, a connection to a simulation system is established, and an enterprise service bus (ESB) makes sure data is sent to the correct addresses.

The simulation system is a High Level Architecture (HLA) federation consisting of three federates, a multi-agent system (MAS), VR-Forces, and Maestro. Maestro controls the simulation speed in the federation. The physical movements, engagements etc. are simulated in VR-Forces, a COTS simulation framework for computer generated forces (CGFs). The multi-agent system, SWAP MAS,

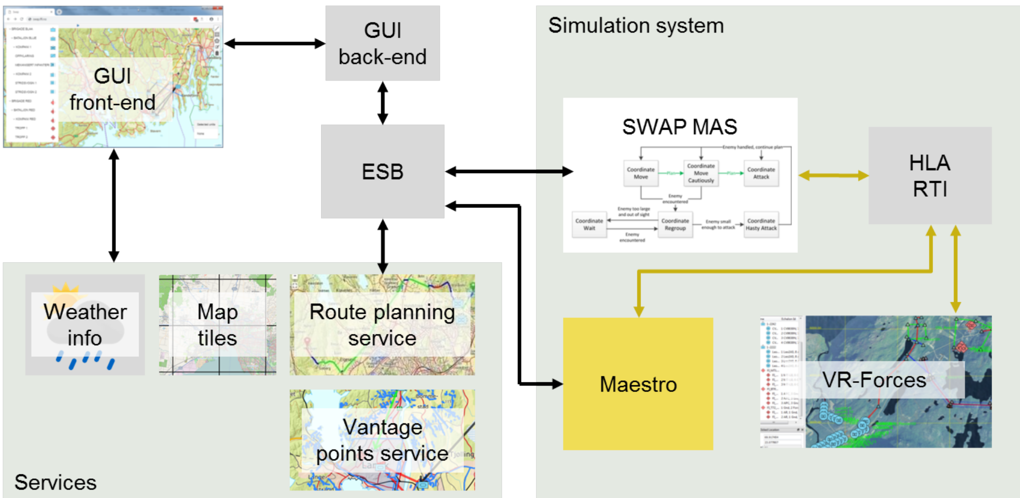

Figure 3.3 SWAP consists of several loosely coupled components.

was developed to make it possible to interpret and execute a digital COA expressed with C-BML [42]. It decomposes higher level C-BML-tasks like "seize" and "support by fire" into lower level tasks that VR-Forces is capable of performing. It also makes sure that the task execution is synchronized as specified in the COA. When a COA includes tasks for higher echelons, it decomposes these tasks into tasks for the lowest echelon in the order of battle, which is represented as units in VR-Forces. The simulation system can be used from any computer, and it is possible to start several instances. The web application will connect to the first instance that is available.

A more detailed, technical description of SWAP can be found in [5].

4 Evaluation of SWAP

Asking users up front is usually not a good way of determining what they want from new technology. New technology presents new possibilities for performing work processes differently, better or perhaps worse, that may not be obvious to users before the technology is experienced [43]. In modern development methodology, only a minimal set of functionality is initially developed and presented to users for evaluation before further functionality is added in the next increment [44, 45]. In this context, SWAP can be considered an early-stage minimal viable product [46], and its present purpose is for evaluating the potential and identify requirements for a DSS for planning.

In February 2019, we conducted an experiment with final-year cadets from the Norwegian Military Academy. The purpose was to test the basic functionality of SWAP in comparison to the traditional way of wargaming for COA analysis. The cadets were divided into groups and asked to make simplified decision briefings for two different battalion operations, one when using SWAP and one while using the traditional method. In this chapter we present a summary of the insights this experiment provided.

4.1 How the experiment was conducted

A total of 52 cadets participated in the experiment. The cadets were divided into 17 groups of 3 members (one group had 4 members). Each group was to act as an operations planning group (OPG), where each member filled one or several roles in such a group. The groups were then randomly assigned to either of two classes: ULL and YME.[3]

Two days before the experiment, the cadets were introduced to the brigade-level tactical problem to be solved, and on the day of the study they were told which one out of three battalions to plan for. For the experiment, we used a part of the fictitious scenario Bjelke as illustrated in figure 4.1. Norwegian Land Warfare Center (HVS) has used scenario Bjelke multiple times in courses for platoon-, company-, and battalion commanders. The full version of Bjelke was developed by HVS and has been used for training purposes in numerous occasions. In addition to the oral brief, the cadets received in print the brigade commander's orders with some simplifications. Because of time constraints, the cadets were asked to only consider one possible COA for enemy forces. The behavior of the enemy was scripted in the simulation system according to this most likely enemy COA.

After practical preparations, the cadets conducted stages 1 to 3 in the PDMP for two hours. They were tasked to produce a minimal decision briefing with one recommended and several alternative COAs. The study was designed as a cross-over study, where each group planned both with and without SWAP; half of the groups using SWAP first and the other half using traditional means first. After each planning session, the cadets completed an individual questionnaire on their planning experiences. Figure 4.2 illustrates the experiment design.

[3]In Norse mythology, *Ull* is a deity associated with skiing and hunting. *Yme* is the ancestor of all *jötnar* (giant, hideous, but wise, creatures).

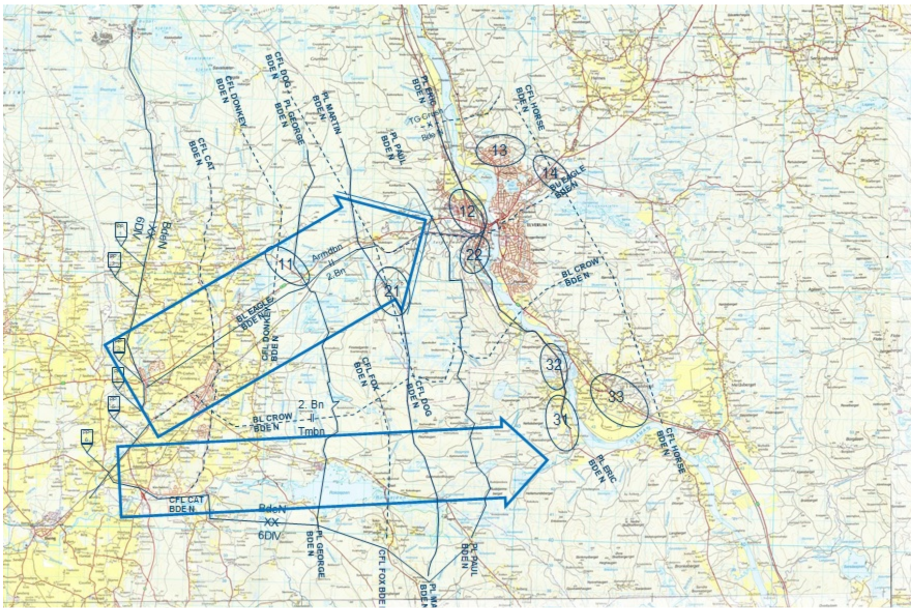

Figure 4.1 This is the shows the scheme of maneuvre (SOM) for the brigade operation used in the experiment.

The functionality in SWAP was presented to the cadets two days prior to the study, and the cadets were given only 30 minutes on the day of the study to become familiar with SWAP prior to commencing their tasks. The students received a short user manual, including known issues. The manual is included in appendix A. Each group had access to one computer where they could run SWAP. They could open several tabs in the web browser and develop multiple COAs in parallel, but we only had enough resources to let each group run one COA simulation at the time. Several research and technical staff were available for questions during the study. Figure 4.3 shows how fun it was to use SWAP.

The traditional planning mode consisted of using a large paper map of the operations area (size A0) and plastic foil sheets to draw plan overlays on top of the map (figure 4.4). Spare maps and several overlay sheets, as well as pens in various colors and wooden pieces for representing units, were available for the participants. They were told that they could use cameras and laptops to produce their decision briefs.

When using SWAP, cadets were told that trying out and providing feedback on SWAP was the main objective, possibly at the expense of delivering a satisfying decision briefing. This makes the comparison of the results from the two methods somewhat unfair, but due to the very tight time constraint we found it necessary to make our priorities clear. Our primary motivation for the experiment was to gain feedback on SWAP and discuss the potential of such a system with the cadets. The second incentive was to evaluate whether SWAP in its current form could aid planning.

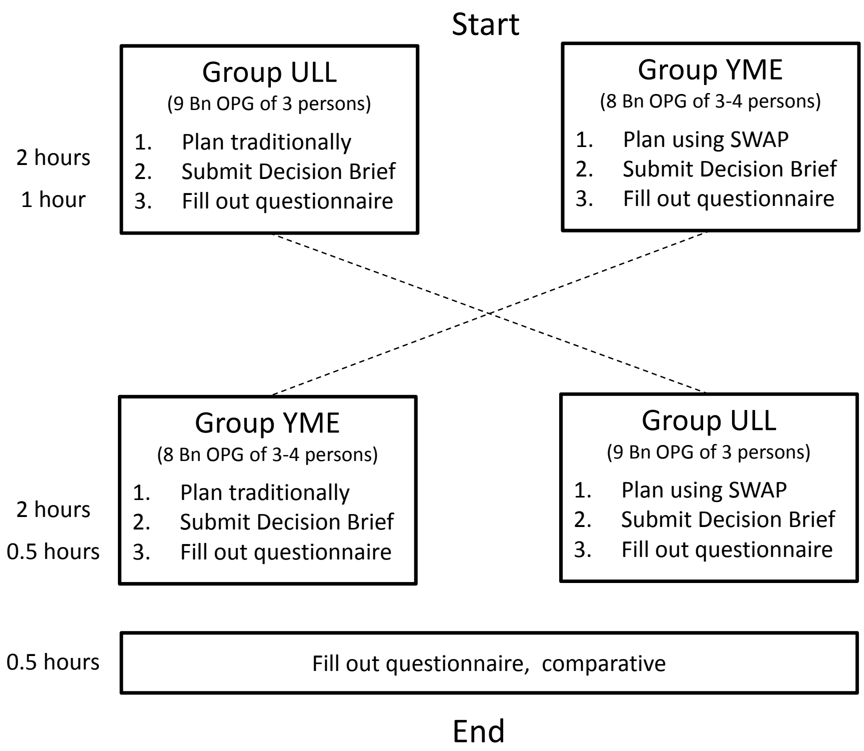

Figure 4.2 The experiment design.

4.2 Results

The experiment was designed to test several hypotheses concerning drivers of analytical and intuitive processes in decision making. Analyses of these tests are not ready and left for a later occasion. Of immediate interest here, is the user feedback that was gathered as a part of the questionnaire and provided orally during the experiment. Generally, the feedback from the cadets was positive, and they seemed able to envision how a system like this should work in a real setting. Suggestions for improvement are described below. Note that these are suggestions from novise planners. Experienced planners might have different opinions.

The cadets were able to take advantage of the functionality in SWAP when preparing their decision briefings. Figure 4.5 illustrates how they used screenshots from the front-end with added text when presenting a COA. The cadets used the route planner and vantage points tools, and the description of the COAs in the decision briefings showed how cadets had used results from the simulations when comparing their COAs and discussing possible losses and logistic issues.

4.2.1 Digital planning

Despite the very short time available to learn the tool, the cadets were able to use all the functionality fairly easily. The following are some issues and suggestions reported regarding entering a COA into SWAP:

Figure 4.3 These cadets use SWAP

- A COA containing many tasks can quickly clutter the screen. The cadets asked for better visualization of who does what, where and when.
- Standardized symbols are necessary in order to make efficient use of the planning tool.
- The cadets were able to develop COAs with the limited number of tasks available, but they missed the possibility for indirect fire, missiles, close air support (CAS), etc.
- The use of phase lines was the only means to synchronize tasks and units. This resulted in many additional phase lines. The cadets suggested the possibility to set more general conditions for when a task should start and add a synchronization matrix.
- It should be possible to change the task organization.

The points above illustrate a need for better media synchronicity in terms of standard symbols and also in terms of greater expressiveness. Some of the above points also relate to better realism by including more features. However, this must be balanced against clutter due to too many features. Hiding less commonly used functionality or making it possible to configure the user interface to only show features that are useful for a particular role, might be a way forward. How to optimize a front-end with respect to media synchronicity while retaining legibility is an important research question for further investigation.

4.2.2 Terrain analysis

Generally, the terrain analysis services were well received, and the cadets could see the potential of having such tools to help analyze the terrain, especially when the terrain is unfamiliar, and the map is all they have to go by. However, the cadets had some suggestions for improvements:

- The cadets suggested making it possible to draw a box to set boundaries for where the route planner should look for a route. (The route planner already supports this, but the functionality is not implemented in the user interface.)

Figure 4.4 These cadets conduct planning with traditional paper maps.

- Some of the cadets wanted the possibility to draw a detailed route, omitting the route planner altogether.
- The cadets thought the route planner could be a valuable decision support tool if they could have more control over how the aspects of time, accessibility, concealment, cover, and threat are prioritized.
- The cadets suggested further tools, such as a distance tool.
- The cadets suggested the possibility to switch between map view and satellite view.

The points above illustrate a wish for further analytical functionality that can be adapted in various ways. This seems to indicate a desire to explore different ways to use analytics, and providing

COA 1
This COA is simulated only until objective 12. It encompasses main attack direction along Rv 25 with supporting attacks along roads to the NORTH before assembly by objective 11.

Weaknesses: Based on simulation this COA will lead to the highest losses of engineers (ENG).
Strengths: Mutual support in designated objectives along Rv 25.
Conclusion/recommendation ENG should follow and support SQN 3 until minefields before they conduct breach.

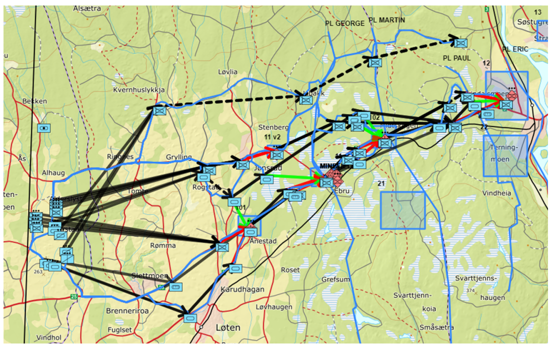

Figure 4.5 The figure shows an example of a COA from a decision brief made by one of the groups of cadets during the experiment. The text has been translated from Norwegian by the authors.

functionality that enables this would benefit this exploration. In future versions, the user will be able to set the priorities for the route planner using heuristics. These heuristics would be on the level of behaviours (e.g., "move with haste, while minimizing detection") providing an abstraction of the level of parameters, and would be developed and validated over time. A further proposition would be that this stimulates the use of analytical processes for chunking route planning parameters into heuristics, which then also aids intuitive processes.

4.2.3 Simulations

In order to fully exploit the possibilities with a DSS like SWAP, it must be possible to run the simulations much faster than real-time. In the current version, we were able to run the simulation at about seven times faster than real-time, which turned out to be too slow. Because of this, the cadets were not able to simulate multiple COAs and complete a decision briefing in the short time available.

Other issues and suggestions regarding simulation were:

- It became apparent that the most sensible way to use the tool is not to simulate a whole COA in one go, but to do so in steps. It should be possible to sketch the first tasks, simulate them and use the results to decide how to proceed. Currently, when going back to planning mode in the front-end, the units are restarted in their initial state (position, health, resources), whereas it should be possible to retain the current state and move on from there.
- A simulation continues until the tasks have been performed. For simulations to be more realistic, the cadets suggested functionality to flag measurable end-states on which the simulator would stop and signal the user. Apart from elimination of forces, a desired end-state may also be the fulfillment of other events, such as a territorial claim or a functional delineation.
- When the simulation is done, a summary of the results of the simulation is provided. The cadets wanted the possibility to end the simulation and get this information at any time.
- It should be possible to fast-forward to critical points in the COA.
- The cadets missed the possibility to alter the COA during simulation. However, with much faster simulation and the possibility to simulate the COA in multiple steps, this might not be necessary.
- The cadets liked that SWAP uses aggregate level simulation as they have experience with poor automated behavior in entity based simulations.

The points above illustrate a desire to be able to sample information and experiences from simulations more freely and according to specific themes. Providing functionality to accommodate this could benefit chunking according to such themes, and a proposition would be that planners might then be able to explore and develop efficient heuristics for rapid planning.

5 Discussion and Conclusion

We have presented a research prototype (SWAP) for a decision support system for military planning. We have also presented the results from an experiment where 52 cadets from the Norwegian Military Academy tested SWAP. The prototype was sufficient to show the students the potential of a DSS for planning, and they were able to make use of the limited functionality as a part of a planning process. From the experiment, we gathered valuable feedback on the requirements of such a system for it to be of value to a military planning process. The prototype was made for planning and simulating land operations, but the idea is also relevant for other military branches and joint operations.

There are other prototype DSSs for military planning. Kott et al. describe a DSS called the Course of Action Development and Evaluation Tool (CADET) that can automatically decompose a high level COA into a detailed battle plan represented as a synchronization matrix [47]. Schubert et al. have made a DSS that simulates a large variation of COAs and provides sophisticated analyses to identify critical factors to suggest the best COA [48, 49]. Both of these are examples of more active DSSs that suggests solutions, whereas SWAP is considered a more passive DSS that provide data, visualizations etc. to aid decision making, but does not make suggestions for COAs. However, SWAP also has active elements, in that it suggests routes and vantage points.

The main purpose of a DSS is to facilitate the fast development of better plans. An important requirement is thus that it must be fast and simple to use. User interface design is an important part of this, and it is interesting to look into efforts such as Sketch-Thru-Plan, which translates speech and hand written symbols into digital plans with military symbols [50]. It is reasonable to expect that too much functionality can have a negative effect on usability and that functionality should be limited to that which is strictly needed. The user evaluation of SWAP provided specific suggestions for functionality that were perceived as needed. These suggestions should be prioritized and added incrementally, and the benefit of each should be evaluated.

Accessibility is also an important aspect of the development of a user-friendly simulation system. The system should have easy accessible tools, so that it could be used with the least possible technical preparation and support. This means for example the opportunity to use your every day computer in the office or the tactical C2IS in use in the field. If usage demands a lot of additional technical preparation and support, the cost of use could become too high, meaning users would lose skills and knowledge through infrequency of use. When a system is is attractive because of it's functionality and easy accessible, the training could probably increase tactical decision makers' pre-deployment knowledge and heuristics for improved effectiveness in combat leadership of military units.

The experiment clearly suggests that if simulations are to be used to compare different COAs when time is limited, simulations must be fast and automated. Today, the NMA uses simulations to finalize a chosen COA. They use an entity-based, real-time simulator that requires a lot of time and personnel to simulate a single COA. This is useful for education purposes, but will likely not suffice in real operations. SWAP is based on aggregate-level simulations that can run much faster than real time. However, more research is required into how to make the whole simulation system run fast enough to be an efficient planning tool. Also, statistical aggregated models require less detailed behavior models than individual entity models, reducing the need for technical personnel.

The majority of user feedback made it clear to us that for the simulation to be useful, the user must know the limitations of the simulation models. Only then can a user of a DSS know where the boundary should be between human decision making and advice from a DSS. Subsidiary to this is the importance of validated models and utilization of current data sets. In the current prototype, SWAP uses default models for engagement and resource consumption provided by a commercial simulation system. As models never can be the same as reality the user must be well aware of discrepancies, blatantly unrealistic models will likely not motivate usage of a simulation-based DSS. Studying models and their limitations is probably an important competence needed for officers in the future.

It is, however, an open question as to what degree of realism is required. This is especially pertinent for simulations that are targeted at decision-making skills, rather than, say, flight simulators for pilot training that must have near exact behavior. Theoretically, it is possible to take into account all kinds of factors, such as training level, fatigue, motivation, etc. in statistical models used in aggregate simulation. An important part of future academic work will be to provide sufficiently validated simulation models. The level of detail needed is yet to be determined.

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Acronyms

C2IS	command and control information system
CAS	close air support
C-BML	Coalition Battle Management Language
C2	command and control
CCIR	Commander's Critical Information Requirements
CGF	computer generated force
COA	course of action
COTS	commercial off-the-shelf
DSS	decision support system
ESB	enterprise service bus
GUI	graphical user interface
HLA	High Level Architecture
HVS	Norwegian Land Warfare Center
IPOE	intelligence preparations of the operational environment
MAS	multi-agent system
MSaaS	Modeling and Simulation as a Service
MSDL	Military Scenario Definition Language
NMA	Norwegian Military Academy
NORCCIS	Norwegian C2IS
OPG	operations planning group
OPLAN	operation plan
OPO	operation orders
PDMP	plan and decision making process
SWAP	Simulation supported Wargaming for Analysis of Plans

A User manual SWAP

This is a copy of the user manual the cadets recieived for the experiment. Known issues and errors were marked in red. The user manual is in Norwegian.

Planlegging

SWAP inneholder noen utvalgte oppgaver. Vi ønsker at dere bruker fantasien og utnytte disse som best dere kan for å få simulert mest mulig. Her følger en beskrivelse av hver oppgave.

Forflytning

- **Ruteplanlegger**
  - Når du velger en forflytningsoppgave, vil SWAP spørre en ruteplanlegger med ulike vekter.
  - Fem faktorer brukes til å finne ruter. Disse er: tid (raskest mulig fremrykning), fremkommelighet (bra underlag å kjøre på), skjul (vegetasjon), dekning (høydeforskjeller i terrenget) og trussel (avstand fra fienden).
  - Ruteplanleggeren sender tilbake en rute med distanse og estimert tid. Estimert tid er basert på en hastighet på 40 km/h på vei, saktere i terreng.
  - Per i dag antar ruteplanleggeren at alle spørringer gjelder én stridsvogn.
  - Skogen er modellert til å være 7 meter høy.

To typer forflytninger er lagt inn i SWAP i dag:

- **Move (svart, heltrukket pil):**
  - Formasjon for rask fremrykning, velger typisk vei.
  - Prioritet ruteplanlegger: tid: 3 fremkommelighet: 2 , skjul: 0 dekning: 0 trussel: 0
  - Makshastighet er satt til 40 km/h
- **Move cautiously (svart, stipla pil):**
  - Prioriterer ruter i skjul, mer spredning i formasjonen
  - Prioritet ruteplanlegger: tid: 1 fremkommelighet: 3 , skjul: 3 dekning: 2 trussel: 0
  - Skjul og dekning tar hensyn til plassering av fiendene.
  - Makshastighet reduseres til 40
- **Redigere rute:**
  - Klikk på pila for å få opp viapunkter som kan flyttes rundt.
  - Enheten på enden av pila kan dras rundt for å endre sluttpunkt.

- Simuleringsystemet takler bare ruter med 250 punkter. Det betyr at vi må ta vekk en del punkter sammenligna med hva som vises i brukergrensesnittet. For å unngå at dette blir et problem, kan det være lurt å heller lage flere Move-oppgaver etter hverandre enn noen med veldig lange ruter.

Oppgaver på områder

- Området tegnes først, kan få navn.
- **Tjeneste for stillinger**
  - Når du klikker på et område, kan du velge å vise «vantage point». Da fargelegges posisjoner rundt det valgte området hvor det er god sikt til mest mulig av området og samtidig kort vei til dekning.
  - Stillingstjenesten tar foreløpig ikke hensyn til vegetasjon, kun terrenghøyder.
  - Tjenesten er ment å brukes for å finne gode posisjoner for angrep eller observasjon.
- **Seize (rød pil):**
  - Angrep med forflytning fra der «Seize» begynner og inn til midten av området, angrepsformasjon.
  - Prioritet ruteplanlegger: tid: 0 fremkommelighet: 0 , skjul: 0 dekning: 0 trussel: 0, dvs. velger kortes mulig framkommelig rute (går stort sett rett på fra der du har valgt at seize skal starte).
  - Der er ikke mulig å legge til viapunkter/endre ruta.
  - Seize er ferdig når alle enheter i området er tatt ut.
  - Når enheter har denne oppgaven, vil de også engasjere eventuelle fiendtlige enheter utenfor området.
  - Merk: Rute for forflytning i og etter Seize blir ofte annerledes i simuleringa enn i GUI. Dette forde i GUI regnes ruter til/fra endepunktet i seize-pila, mens simuleringa bruker midtpunktet i området.
  - Hvis en annen enhet er satt til å supportere, vil simuleringa automatisk synkronisere den som har seize og den som har support
- **Support by fire (grønn pil):**
  - Angrepsformasjon
  - Ingen forflytning, angriper fra der pila starter
  - Må ha en annen enhet å støtte. De venter automatisk på hverandre, og starter angrepet når begge er klare.
- **Breach (gul pil):**
  - Bare ingeniørenheter kan gjøre denne.
  - Per i dag er breach en veldig forenkla simulering av å komme gjennom et minefelt eller andre hindringer. Enheten står bare å venter i 1 time før den kan bevege seg videre.
  - I simuleringa er det mulig å bevege seg rett gjennom f.eks. minefelt. Ikke gjør det☺
  - Ingen andre enheter vil vente på breach av seg selv, så her må dere eventuelt være litt kreative med faselinjer.
  - Hvis dere anser at breach vil ta lengre eller kortere tid enn en time, kan dere like gjerne bruke en «wait» med valgfri tid.
- **Wait:**
  - Vente der den er i et gitt antall minutter

- Oppgaver kan gis ved å klikke på enheter i kartet eller i ORBAT. Oppgaver kan gis på alle nivåer, men ikke prøv å gi en oppgave til hele bataljonen, da krasjer systemet.

- Dere kan når som helst endre på en oppgave ved å klikke på tilhørende pil og manipulere denne.
- Påfølgende oppgaver gis ved å trykke på enheten i enden av pila fra forrige oppgave. Oppgavene vil automatisk simuleres i den rekkefølgen de blir lagt inn.
- En oppgave slettes ved å velge tilhørende pil og trykke på søppelkassesymbolet nederst til høyre. Alle påfølgende oppgaver slettes automatisk.

Synkronisering av enheter

- **Faselinjer**
  - Under forflytningsoppgavene move og move cautiously kan faselinjer brukes til å synkronisere enheter. (Faselinjer virker altså ikke på f.eks. seize, men må settes på move-oppgavene før seize.)
  - En faselinje kan lages før eller etter oppgavene.
  - Når man velger faselinja, kan man velge hvilke oppgaver faselinja gjelder for. Alle forflytnings-oppgaver som faselinja krysser kommer automatisk opp som forslag.
  - Faselinjene må settes mer enn 50 meter fra sluttpunktet på ei rute.
- **Seize og Support** på samme område synkroniseres automatisk.

Lagre og laste plan

- Lagre planen ved å trykke på lagreknappen til høyre for play-knappen. Planen lagres automatisk i download-mappa. Dere må selv flytte den til gruppe-mappa deres.
- En plan kan lastes opp ved å trykke på «fetch COA» øverst til venstre.

Simulering

- Status på enhetene vises i ORBAT
- Enhetene flytter seg
- Hastighet på simuleringa kan reguleres. Maks hastighet er default. Tid simulert vises øverst.
- Grafikk fra planlegginga skal kunne slåes av og på i boksen oppe til høyre, men her er det en kjent feil som kan føre til at GUI krasjer.
- Artilleri virker dessverre ikke, dvs. vil ikke ha noen effekt i simuleringa.
- Når alle oppgaver er ferdig simulert, dukker det opp en oppsummering. Kom gjerne med forslag til hva som bør inn her.

Kommentarer

- Selv om du kan komme fram i simuleringa, betyr ikke det at du kan komme fram i virkeligheten – men du har mulighet til å simulere hvordan det går hvis du gjør det, og hvis du ikke gjør det.

- Du vil planlegge mot en gitt fiende, ingen overraskelser underveis i simuleringa.
- Du kan åpne så mange brukergrensesnitt du vil, bare start nye tab-er i nettleseren. Men vi har kun lisenser til at hver gruppe kan kjøre en simulering om gangen.

About FFI

The Norwegian Defence Research Establishment (FFI) was founded 11th of April 1946. It is organised as an administrative agency subordinate to the Ministry of Defence.

FFI's MISSION

FFI is the prime institution responsible for defence related research in Norway. Its principal mission is to carry out research and development to meet the requirements of the Armed Forces. FFI has the role of chief adviser to the political and military leadership. In particular, the institute shall focus on aspects of the development in science and technology that can influence our security policy or defence planning.

FFI's VISION

FFI turns knowledge and ideas into an efficient defence.

FFI's CHARACTERISTICS

Creative, daring, broad-minded and responsible.

Om FFI

Forsvarets forskningsinstitutt ble etablert 11. april 1946. Instituttet er organisert som et forvaltningsorgan med særskilte fullmakter underlagt Forsvarsdepartementet.

FFIs FORMÅL

Forsvarets forskningsinstitutt er Forsvarets sentrale forskningsinstitusjon og har som formål å drive forskning og utvikling for Forsvarets behov. Videre er FFI rådgiver overfor Forsvarets strategiske ledelse. Spesielt skal instituttet følge opp trekk ved vitenskapelig og militærteknisk utvikling som kan påvirke forutsetningene for sikkerhetspolitikken eller forsvarsplanleggingen.

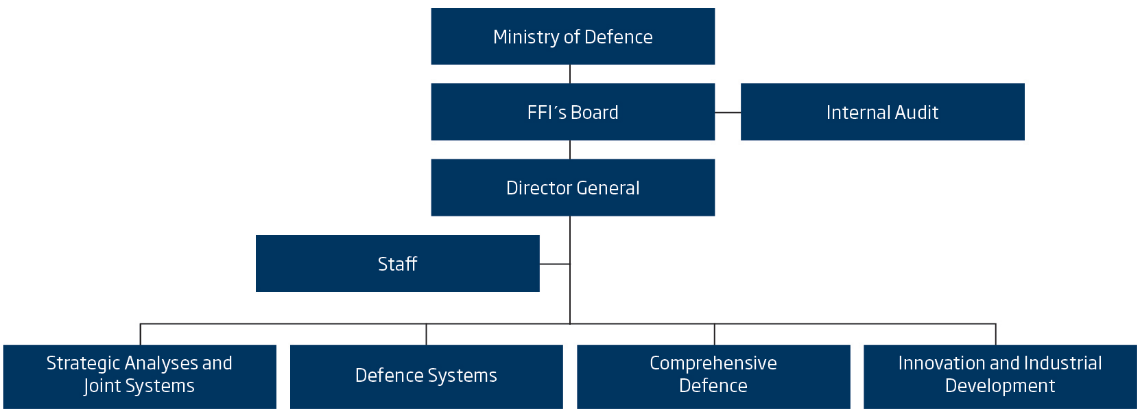
FFIs VISJON

FFI gjør kunnskap og ideer til et effektivt forsvar.

FFIs VERDIER

Skapende, drivende, vidsynt og ansvarlig.

FFI's organisation



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