

## **Simulation-Based Decision Support for Military Planning**

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### **ABSTRACT**

When planning a military operation, it is important to understand possibilities and 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 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 for military planning developed at FFI. The system consists of a simulation system that runs in the cloud, and a simple, intuitive web-based 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 give units basic tasks and create phase lines to coordinate units, 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 a study with 52 final-year cadets from the 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 paper, we describe SWAP and discuss the potential and requirements of such a system for operations planning based on the results of the study.

### **ABOUT THE AUTHORS**

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### **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 (Høiback, 2016). Military decision making and planning when developing a course of action (COA) must consider a large number of factors, including resources, terrain, enemy COAs etc. A standard process ensures that important aspects are considered systematically. Our objective is to study how computers can assist in this process.

We have built a research prototype of a decision support system (DSS) (Power, 2002; Hättenschwiler, 1999; Sugumaran & Degroote, 2010) for planning called SWAP, which is an acronym for “Simulation-supported Wargaming for Analysis of Plans”. It incorporates a limited set of functionality to assist planning in the land domain. The original objective for SWAP was to create a tool that can simulate a COA in order to reveal strengths and weaknesses with the plan (Hyndøy, Mevassvik, & Brathen, 2014). Wargaming is an important but time-consuming part of military planning processes today, and our proposition is that using computerized simulations to support wargaming can be efficient and provide more insights on certain aspects than the current approach of doing planning and wargaming manually. During the development of SWAP, we realized that a digital tool for sketching COAs can be beneficial in itself; especially if it incorporates analytical functionality to assist COA development prior to simulation. The current system builds on a series of earlier demonstrators (Bruvoll et al., 2015, 2016; Alstad, Løvlid, Bruvoll, & Nielsen, 2013).

In February 2019, we conducted a study, where 52 cadets from the Norwegian Military Academy (NMA) used the current functionality of SWAP. Their task was to develop and evaluate potential COAs for a battalion in a fictitious scenario. The study provided insights into the requirements and potential for a simulation-based DSS.

Our objective with this paper is to share our experiences with SWAP and to provide initial insights into the potential and requirements of a DSS for planning. The next section gives an overview of the current planning and decision making process (PDMP) in the Norwegian Army and elaborates on how a DSS might be used to support it. The subsequent section provides an overview of SWAP, before we describe the study we conducted with cadets from the Norwegian Military Academy, including results. The work is summarized and concluded in the last section.

### **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 PDMP and is interoperable with the corresponding process in NATO. Other countries have similar, but not equal processes for tactical decision making; for example the US Army’s Military Decision Making Process (MDMP).

### **The plan and decision making process in the Norwegian Army**

A standard, comprehensive plan and decision process is completed in five stages in order to develop a plan for brigade and lower-level units: 1) preparations, 2) mission analysis, 3) COA-development, 4) plan-development and 5) revision of the plan (Hærens Våpenskole, 2015). We have concentrated our efforts on how simulation and automated terrain

analysis can assist in stages 3 and 4.

The aim of Stage 3 is to develop the operational concept for the mission, i.e. describe how the mission can be solved. The stage comprises a go-trough of own forces status, enemy status and enemy COA in order to compare strengths and weaknesses. Possible own COAs are developed, and several COAs are evaluated to arrive at the best possible recommendation. Stage 4 is initiated upon approval of the operational concept. During this stage, a complete wargame is conducted to test the details and the feasibility of the plan, after which the actions of the involved units are coordinated and synchronized.

Even though a plan is at some point completed, military planning is a continuing process. 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 (Graf von Moltke, 1900) in (Hughes, 1996)). A central proposition in combat adaptivity is that planners and commanders are able to adapt to an insecure and changing environment because of their knowledge from participating in the previous planning process.

### **The Norwegian Military Academy uses simulation when teaching PDMP**

Since 2010, students at the 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 principal solutions for tactical problems.

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 Comms 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<sup>1</sup>, 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.

### **Decision support systems for planning**

Planning involves taking into account the information gathered in the various steps of the 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. In 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

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<sup>1</sup><https://www.esimgames.com/>

factors with a tight focus on explicit deliberation (Salas, Rosen, & DiazGranados, 2010), adds comprehensiveness (Forbes, 2007) and is something most of us are trained to value (the “worship of reason” (Haidt, 2001)). 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 (Kahneman & Frederick, 2004; Tversky & Kahneman, 1974).

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 (Miller, 1956; Gigerenzer & Todd, 1999). 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 (R. M. Hogarth, 2001; R. Hogarth, 1981; Dreyfus & Dreyfus, 1988); perhaps after extended experience and deliberate practice (Ericsson, 2006). Intuition can therefore be trained. For example, chess masters, after years of training, use pattern recognition when contemplating a chess position (Chase & Simon, 1973), rather than analyzing the particular position of every piece as a novice is likely to do (Gobet & Charness, 2006). A part of this is the process of *chunking*; where larger, and therefore fewer, cues are sampled and processed, enabling the limited working memory to process “more by less”. A large body of research has investigated how to take advantage of the quicker intuitive processes (Gigerenzer & Todd, 1999; Klein, 1997; Lipshitz, Klein, Orasanu, & Salas, 2001; Hammond, 1996).

In military decision making, it seems sensible to use both analytical and intuitive processes in concert (Kahneman & Klein, 2009). 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 (Hannay, Brathen, & Hyndøy, 2015), 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 advice to users (Hättenschwiler, 1999): 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 (Sugumaran & Degroote, 2010). 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 (Hannay et al., 2015). 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 (Hannay et al., 2015).

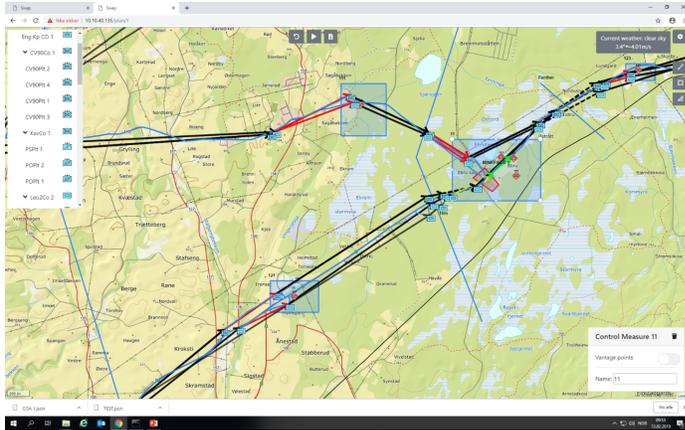
For supporting analytical processes, a DSS could compensate for limitations in working memory. By displaying a selected amount of data in various views, planners will be able to highlight the most relevant information for a certain task; for example in a time-perspective or a geographic perspective. 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 expert, 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.

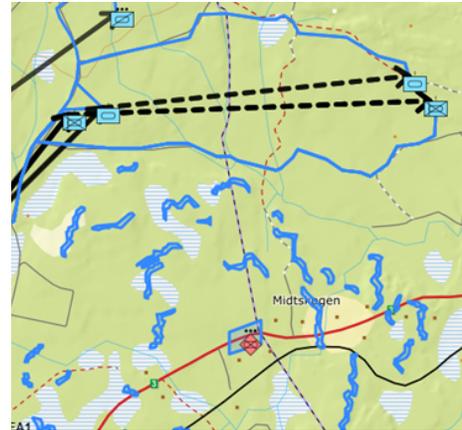
## **SWAP—A DECISION SUPPORT SYSTEM FOR PLANNING**

SWAP is designed to demonstrate the concept of a DSS that is available everywhere through an easy-to-use web-based front-end, where users can develop digital, executable COAs that can be simulated without technicians in the loop. In this section, 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



**Figure 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.**



**Figure 2: The figure shows vantage points around a selected area.**

offered for potential stakeholders to try out the concept and suggest further development.

### 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 functionality that one has on an analog map. However, drawing the plan on a digital map opens up new possibilities for exploring multiple possible plans in rapid succession. When coupled with consequential information from additional tools such as route planning and vantage point analyses (see below) as well as simulations of the plan, a reasonable proposition would be that this facilitates both analytical processes through comprehensiveness (Forbes, 2007) and intuitive processes through training the recognition of beneficial and adverse patterns in plans.

Digital planning also opens up new possibilities for collaboration between users at different physical locations and integration with a command and control information system (C2IS). Traditionally, reports and returns are done orally over radios and transmitted as standardized coded messages accessible as texts on C2ISs and battle management systems. Digital planning enhances readability and facilitates the use of standard graphical symbols, which makes graphics easier to interpret without additional verbal explanations; that is, it facilitates *media synchronicity*, which is a central enabler for communication performance and, ultimately, (shared) task performance (Dennis, Fuller, & Valacich, 2008).

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 technicians 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 (Simulation Interoperability Standards Organization, 2014) and more recently, C2SIM (Carey, Kleiner, Hieb, & Brown, 2001; Pullen et al., 2012).

The number of tasks supported by SWAP, are 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 via points. The user can sketch target areas and sketch commands for maneuver units to seize or support by fire on these areas. Similarly, engineering units can be ordered to breach an obstacle sketched 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. Figure 1 illustrates a COA sketched in SWAP.

In order to fully exploit the benefits of a digital plan, SWAP can be integrated with a C2IS. Today, the order of battle is imported using the Military Scenario Definition Language (MSDL) (Simulation Interoperability Standards Organization, 2008), which can be exported from a C2IS. A connection to the Norwegian Command and Control Information System (NORCCIS) has been demonstrated with an earlier version of SWAP (Bruvold et al., 2016). Also, the final plan 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.

### **SWAP facilitates terrain analysis**

In addition to creating executable, 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. Both of these tools are designed to ease cognitive load and to chunk information quickly.

The route planner finds the best route given a set of prioritized criteria (Bruvold, 2014; Tolt, Hedström, Bruvold, & Asprusten, 2017). Possible criteria are accessibility, cover (from direct fire), concealment, and threat. Today, priorities are predetermined for the different tasks, and the tool presents the routes the simulated units will choose if they do not get any other instructions. By displaying these routes in the user interface, the user gets the opportunity to override the computers' choice by adding via points. 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. The route planner was originally developed to enable simulated units in computer generated forces to move more realistically; that is, select an appropriate route according to the unit's task rather than simply moving along the shortest possible passage from A to B. However, the route also has potential as a decision support tool.

The vantage point calculation tool is currently a pure decision support tool, in that it is not used by the simulation. It displays graphically 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 study, is included in Figure 2. The immediate and simultaneous display of all vantage points for a selected area chunks multiple cues for two different characteristics into one single cue.

### **SWAP can simulate a plan**

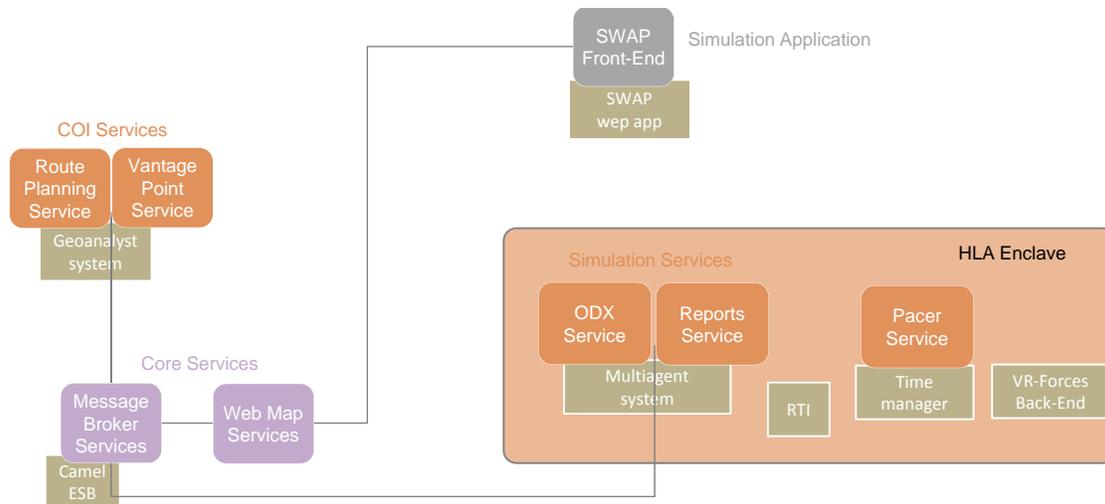
When done creating a COA in the front-end, the user can choose to simulate that plan. The user will see the units moving, while status information such as health, fuel and ammunition supplies is updated as the COA is simulated. This simulation can be used to discover weak elements in the plan, such as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

The underlying simulation system consist of a multi-agent system and VR-Forces<sup>2</sup>, an off-the shelf simulation framework for computer generated forces (CGFs). The multi-agent system was developed to make it possible to interpret and execute a digital COA expressed with C-BML (Løvliid, Bruvold, Brathen, & Gonzalez, 2018; Løvliid et al., 2013). The multi-agent system 1) interprets higher level tasks, 2) synchronizes the execution of tasks, and 3) decomposes tasks at higher echelons to tasks for lower echelons. Interpreting higher level tasks means translating tasks such as "seize" and "support by fire" into a set of lower level tasks such as "move to location" and "set rules of engagement". Synchronizing the execution of tasks involves making certain units wait for each other on phase lines or when tasked to support or attack the same area. In the front-end, it is possible to task units at all levels in the order of battle. One can task a platoon (the lowest echelon used in the study), a company or the whole battalion (the highest echelon in the study). The multi-agent system sends tasks for the lowest echelon to VR-Forces and relays situation reports from VR-Forces back to the front-end.

SWAP is designed to facilitate the acquisition of *situation awareness* (SA) (Endsley, 2000b, 2000a), which is a factor

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<sup>2</sup><https://www.mak.com/products/simulate/vr-forces>



**Figure 3: The figure illustrates the service and application architecture of SWAP. Concrete implementations are in olive.**

in decision making. Laying out a course of action visually in some detail is intended to support SA level 1 (the status of units) and SA level 2 (the status of relationships between units in time and place). The simulation support in SWAP targets SA level 3 (unfolding of status with regards to units and relationships). Situation awareness is instrumental to both analytic and intuitive processes in selecting relevant information and chunking (Randel, Lauren Pugh, & Reed, 1996).

### SWAP technical solution

SWAP is built upon the concept of *modelling and simulation as a service* (MSaaS) (Hannay & van den Berg, 2017; Çayırıcı, 2013; van den Berg, Huiskamp, et al., 2017); meaning that SWAP consists of several loosely coupled back-end services and front-end services (applications) that can be reused individually for different purposes (Figure 3). The route planner service, for instance, is used by the SWAP front-end as well as the simulation system. Services are implemented as Docker containers (minimal virtual machines), which enables rapid deployment of multiple instances of SWAP without having to install and configure each instance (Asprusten & Hannay, 2018; van den Berg, Siegel, & Cramp, 2017). This enabled us to deploy 10 instances of SWAP for the study.

The architecture is also distributed, so service implementations can run on different computers. For example, the SWAP front-end is a web application that can be run in any web browser. It loads maps from a web map server and connects to the route planning service and the vantage point service running on some other computer. It connects on demand to an available simulation federation running in a cloud environment. An enterprise service bus (ESB) implements message broker services to handle data traffic in the SWAP system.

The simulation running in VR-Forces is exposed to the front-end via an order decomposition and execution (ODX) service and a reports service, which are both implemented by the multi-agent system mentioned above.

An important objective when implementing SWAP was to use standards for communication between the different components. The task organization and initial positions is expressed in MSDL (Simulation Interoperability Standards Organization, 2008). The front-end translates the user input into C-BML (Simulation Interoperability Standards Organization, 2014), and we closely follow the development of the new C2SIM standard<sup>3</sup>. The digital order is interpreted by the multi-agent system, which decompose the order into low level tasks that most simulation systems for CGFs can interpret. The multi-agent system communicates with the CGF over High Level Architecture (HLA) (IEEE Standards Association, 2010), and we use the Real-time Platform Reference Federation Object Model (RPR-FOM) (Simulation

<sup>3</sup><https://www.sisostds.org/StandardsActivities/DevelopmentGroups/C2SIMPDGPSG-CommandandControlSystems.aspx>

Interoperability Standards Organization, 2015) with the addition of a module to support Low Level Battle Management Language (LLBML) (Alstad, Mevassvik, et al., 2013).

## **SWAP EVALUATED BY 52 CADETS**

Asking upfront what users want from new technology often does not give sustainable answers. 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 (Rogers, 2003). 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 (Pressman, 2010; Sliger & Broderick, 2008). In this context, SWAP can be considered an early-stage minimal viable product (Lenarduzzi & Taibi, 2016), and its present purpose is for evaluating the potential, and identify requirements, for a DSS for planning. In this section we present an evaluation of SWAP with cadets from the Norwegian War Academy and a summary of the insights this study provided.

### **How the study was conducted**

A total of 52 cadets participated in a comparative study, where traditional planning was used as a reference to evaluate planning using SWAP. The cadets were divided into 17 groups of approximately three persons for a standardized battalion staff planning process against a pre-scripted enemy COA. Two days before the study, 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. After practical preparations, the cadets conducted Stages 1 to 3 in PDMP for two hours and were tasked to produce a minimal decision briefing with several alternative COAs and one recommended. 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.

The functionality in SWAP was presented to the cadets two days prior to the study, and the cadets were given 30 minutes on the day of the study to become familiar with SWAP prior to commencing their tasks. Several research and technical staff were available for questions during the study. 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.

### **Results**

The cadets were able to take advantage of the functionality in SWAP when preparing their decision briefings. Figure 4 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.

The study was designed to test several hypotheses concerning drivers of analytical and intuitive processes in decision making. Analyses of these tests are 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 study. 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. The most prominent suggestions for improvement are described below.

#### **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 plan into SWAP:

- A plan containing many tasks can quickly clutter the screen. The cadets asked for better visualization of who does what, where and when.
- International standard 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

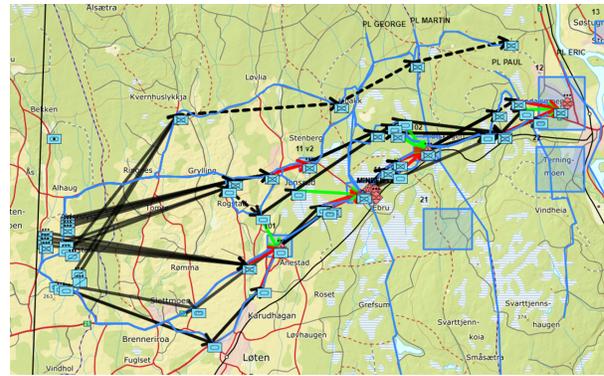
### COA 1

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 contemplate 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: The figure shows an example of a COA from a decision brief made by one of the groups of cadets during the study. The text has been translated from Norwegian by the authors.**

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.

### 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 front-end.)
- 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 functionality that enables this would benefit this exploration. A reasonable proposition would be that planners might use this to develop more efficient patterns of analysis. 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") abstracting away from 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.

### 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 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 obvious tasks have been solved. 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 fulfilment of other events, such as a territorial claim or a functional delineation.
- When the simulation is done, a summary of the results on 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 plan. (This would require much faster simulation speed.)
- The cadets missed the possibility to alter the plan during simulation. However, with much faster simulation and the possibility to simulate the plan 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.

## **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 a study 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 study, 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 operation, 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 (Kott, Ground, Budd, & Langston, 2002). 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 (Schubert et al., 2017; Schubert, Moradi, Asadi, Hörling, & Sjöberg, 2010). 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 development of better plans faster. An important requirement is thus that it must be fast and easy 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 (Cohen et al., 2015). 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 least possible administrative work, such as 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 administrative work or computer setup, the cost of using could become too high and thus user frequency insufficient for the maintenance of the skill and knowledge needed for effective use. When it is attractive because of it's functionality and easy accessible, the training could probably increase tactical decision makers' pre-deployment knowledge and heuristics for effective leadership of military units.

The study 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 which can run 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 do a host of individual entity models, making it possible to reduce the need for simulation personnel.

The majority of user feedback also made it clear to us that for the simulation to be useful, the limitations of the simulation models must be explicit to the user. 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 up to date data. In the current prototype, SWAP uses standard models for engagement and resource consumption provided by a commercial simulation system. Although a user may be aware of discrepancies between the models and real behavior, blatantly unrealistic models will likely not motivate usage of a simulation-based DSS. 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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