Simulation in Support of Army Structure Analysis

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ABSTRACT

In Norway, analysis of the Army structure has previously been done through traditional wargaming in combination with a variety of computer models covering parts of the spectrum from duel situations to the operational level. Through this method, the important combined arms effects are generally a model input based on military experts.

This paper describes recent work that has been done at the Norwegian Defence Research Establishment (FFI), where we have introduced interactive simulation as an additional tool for the Army structure analysis. Our objective has been to gain a better understanding of the often complex combined effects of different types of forces. Such forces include direct and indirect fire units, engineering resources, sensor units, C2, and naval and air force units. We have used the lightweight simulation platform Mōsbē from BreakAway as a tool for computer aided wargaming. This simulation platform supports brigade level operations where the participants act as military leaders. With a user interface like a real-time strategy game, military experts have been directly involved in planning, gaming and post-evaluation.

Through a series of experiments we have been testing the performance of five fundamentally different land force structures in a set of chosen scenarios. The goal has been to rank these structures based on their performance. For each scenario we logged data and recorded video from the simulation, and the participants completed questionnaires about the performance of the tested Army structure. The experiments revealed pros and cons of the tested structures both on operational and tactical levels. Further, the data output from the simulation series has been fed into a quadratic Lanchester model. This has served both as means to validate results from the experiments, and as a model to search for an optimal Army structure.

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INTRODUCTION

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This paper describes recent work that has been carried out at the Norwegian Defence Research Establishment (FFI), where we have introduced interactive simulation as an additional tool for Army structure analysis. Our objective has been to gain a better understanding of the often complex combined effects of different types of forces. Such forces include direct and indirect fire, engineering, sensor, C2 and Naval and Air Force units. We have used the lightweight simulation platform Mōsbē from BreakAway as a tool for computer aided wargaming. This simulation platform supports brigade level operations where the participants act as military leaders. Military experts have been directly involved in planning, gaming and post-evaluation to ensure realism.

Through a series of experiments we have been testing the performance of five fundamentally different land force structures in a set of chosen scenarios. The goal has been to rank these structures based on their performance. For each scenario we logged data and recorded video from the simulation, and the participants completed questionnaires about the performance of the tested Army structure. The experiments revealed pros and cons of the tested structures both on operational and tactical levels. Furthermore, the data output from the simulation series has been fed into a quadratic Lanchester model. This has served both as a means to validate results from the experiments, and as a model to search for an optimal Army structure.

First, this paper briefly describes the background for this work. Second, our overall method is presented. Third, the simulation experiments and preparations we made prior to these experiments are described. After this we summarize some of the results from the experiments and discuss the validity of these results. Finally, we present lessons learned from this work.

BACKGROUND

FFI's first battle lab facility was finished in 2005. It offered new possibilities for experimentation with emerging technologies and concepts in collaboration with military users. The Land and Air Systems Division at FFI has previously used this facility in various projects in support of procurement of new military equipment and platforms (these projects include Air Defense, Combat Vehicles, Indirect Fire and UAV). The experiments have typically been carried out with military system operators playing through a set of scenarios both with and without the technology or platform being evaluated. The size of the experiments has been from platoon to company level, and the systems under evaluation have been modeled with a high level of detail.

Collected data from these experiments have both been quantitative measurements, and qualitative feedback from the users during after action review and through questionnaires.

Developing new technology often requires several iterations with further development and new experiments in the battle lab facility. The battle lab facility has thus become an important arena for collaboration between various projects at FFI, and between scientists and military personnel. Already in 2008 we started to consider applying many of the same methods to carry out simulations on battalion to brigade level, to support defense structure analysis (Martinussen et al., 2008).

The Analysis Division at FFI conducts analysis in support of military operations and defense planning. In 2009 the "Future Land Forces" project was initiated, with the goal to analyze future requirements for military land power in a national, allied and multinational context. The main objective was to ensure cohesion and balance between resources and requirements in the development of military structures.

With the emerging activities in modeling and simulation in the battle lab facility at FFI, it was proposed to use this expertise to support the "Future Land Forces" project with simulation experiments. Through joint work in the battle lab facility, simulation experiments have been used to conduct Army structure analysis as described in this paper. Interdisciplinary collaboration has been of key importance in this work.

METHOD

Human-in-the-loop simulation experiments have previously proven to be a good tool for evaluating new technologies. This concept has been further developed for testing and evaluation of Army structures. The experiments are based on the same set of scenarios as the long term defense planning process in Norway. Prior to the experiments a number of different land force structure alternatives had been developed for evaluation purposes.

A main challenge has been to conduct interactive simulations at the brigade level with sufficient realism. The simulation platform has shortfalls, and the way around this has been through working closely together with military experts. The process has encouraged discussions as a means to cope with problems within different areas. This has resulted in robust and credible conclusions.

It is important to emphasize that our goal has been to rank the Army structures based on their relative performance. This method does not seek to predict the exact outcome of a particular combat situation. The main idea has been to test the Army structures against a fixed opposing force in a set of chosen scenarios.

The results from the simulation experiments have been analyzed, validated, and used in a larger context together with considerations about economy and force production. They have been combined with outputs from the KOSTMOD[1] (FFI, 2005) cost model and a model estimating the total force production, to arrive at cost efficient Army structures. Finally, this work has resulted in a set of recommendations for potential new structures for the Norwegian military land power. Figure 1 illustrates the concept behind this approach.

[1] KOSTMOD is the main cost model used in Norway and at FFI for long term defense planning.

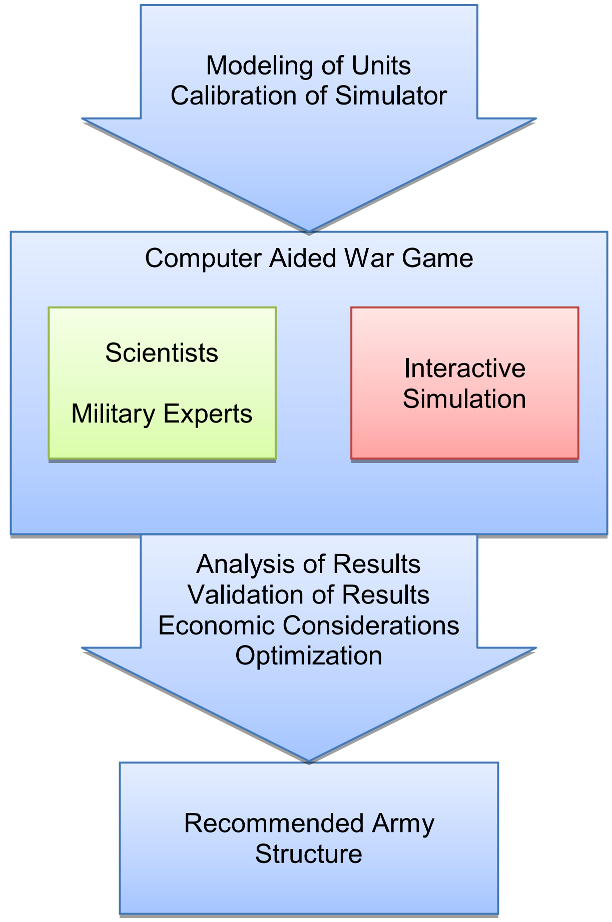

Figure 1. Concept Behind the Army Structure Analysis.

Selection of Scenarios and Tactical Vignettes

Three tactical vignettes were chosen, in which the Army structures were tested. A tactical vignette is a specific playable course of battle extracted from a larger scenario. The three selected vignettes are extracted from scenario classes designed as part of the Norwegian Chief of Defence's "Defence Study 2007".

All the tactical vignettes take place in typical Norwegian environments with canalizing terrain with few axes and limited space for maneuver. They cover delaying operations, defense and attack.

Selection of Army Structures for Evaluation

Prior to the experiment series, a number of balanced and unbalanced structures were modeled (Geiner et al, 2011), with their analytical foundations based on three warfighting concepts: maneuver theory, exchange theory and positional theory (Leonhard, 1994). The balanced structures have the ability to fight a conventional war on their own for a limited period of time, whereas the unbalanced structures do not have this ability. Only a selection of the balanced structures has been evaluated in the experiments.

We have chosen to evaluate the performance of five different land force structures. Three of these structures are mechanized maneuver structures of different compositions, including the current structure. In addition we have tested a light structure where the heavy mechanized maneuver elements have been exchanged for units equipped with man-portable anti-tank weapons and additional volume. The last of the assessed structures is a distributed maneuver structure (Kelly & Brennan, 2009) largely based on network-centric warfare and long-range precision guided fire.

Opposing Force

We have used a fixed opposing force for the experiments. It is based on a generic mechanized infantry brigade, and modeled to be at the same level as the evaluated structures in both technology and training.

Interactive Simulations

Our approach has been to use interactive simulations where humans are in the loop to control the course of the battle. The main advantage of this type of simulations is utilization of human creativity, decision making and their ability to find solutions along the way.

Military leaders plan and control operations in the simulation. The simulation platform keeps track of the movement of units and calculates the results of duels and indirect fire attacks. This approach can be described as computer aided wargaming.

For each scenario we logged all important events from the simulation. In addition the participants completed questionnaires about the performance of the tested Army structure. After each simulation experiment there was an after action review session where the outcome of the battle was discussed. It has been important for us to understand the results, and the combined effects of different types of forces.

Simplifications

For each vignette, both the tested structure and the opposing force are positioned in the area of operation without any losses before the main battle. Due to time constraints, we have not simulated the course of action before the main battle, even though the various structures may have worked differently in this phase.

Furthermore, we have only included limited models for support functions like logistics and medical and engineer units in the simulations.

Assumptions

Our focus has been on the land force, hence we have not simulated air-to-air or sea battle explicitly. Instead, certain assumptions were made of the presence of air and maritime support. These units were included in the simulations for relevant periods of time.

SIMULATION EXPERIMENTS

The series of simulation experiments were conducted at the battle lab facility on site, with participants from relevant projects at FFI working together with military officers from different branches of the Norwegian defense. In order to be able to gain as much knowledge as possible from the experiments, a lot of effort has been put into preparation, methods and setup of the experiments. The simulation platform itself only makes a partial contribution to this study. In order to be able to rank the different Army structures, the participants, the experiment setup and the collected data all play an important role in producing and analyzing results of the experiments.

Preparations

Before the experiment series, we needed a suitable simulation platform. We also needed to build models of all relevant units and the terrain in that platform.

Choosing Simulation Platform

We needed a simulation platform where a few military leaders on each side could control brigade size forces and execute their plans during the course of the battle. The simulation platform thus needed to be easy to use and have an interface that permitted a high degree of interaction. Ideally the units in the simulation platform should have some sort of smart behavior that enabled them to carry out simple orders. Visualization of the simulation and the ability to log all important events were also vital requirements.

Among the simulation platforms that we considered were VR-Forces with B-HAVE from VT MÄK, Mōsbē from BreakAway, Virtual Battlespace 2 (VBS2) from Bohemia Interactive Simulations and GESI from CAE. Mōsbē from BreakAway was chosen, the main reason being that it is based on technology for real-time strategy games, and has a user interface that makes it easy to control large groups of entities.

Several platform types needed for the simulations were already implemented and it was also possible to include maps from areas in Norway. In addition, the simulator promised good opportunities for logging of simulation data.

Simulation Platform

Mōsbē can be used for operational analysis, experimentation and visualization. The Mōsbē tool kit contains three different tools. One tool is used for training and experimentation (Desktop Viewer). The second tool is used for scenario building (Scenario Editor), and the third tool is used to generate geo-specific three-dimensional worlds (World Builder).

In Desktop Viewer the player can choose between a two-dimensional theater view and a detailed three-dimensional tactical view, where the individual vehicles are shown. Examples of the theater view and the tactical view are shown in Figure 2 and Figure 3, respectively.

Each fighting entity (combat vehicle, fighter aircraft or frigate) is modeled with weapons, sensors and parameters describing attributes like armor, speed and size. Weapons and sensors are also modeled with parameters describing their capabilities. All entities are grouped into platoons, which are the smallest controllable units in the simulation.

Due to the artificial intelligence (AI) and a user interface providing good situational awareness, it takes relatively little effort for a player to control large groups of forces. However, sometimes the AI makes the forces behave unfavorably. One problem is entities taking off or engaging on their own. Another problem is the loss of too many units to mines and artillery, because a player is not notified when units are under attack.

Situational awareness is far better than in real life, as each commander has an overview of all subordinate units. In addition, the brigade commander has a real time ISTAR picture, aggregated from forward observers and UAVs.

A weakness in the simulation is the modeling of duel situations. The outcome of a duel is based on weapon strength and target armor. There is no correction in hit probability based on range, hiding or cover. Platforms with long weapon ranges are favored in duels, and many sensors have a too high detection probability. One reason for this is that hiding is difficult due to poorly represented micro terrain and camouflage. Calculation of outcome is done at entity level, whereas the entities are controlled at platoon level. This mismatch has generally led to calibration difficulties.

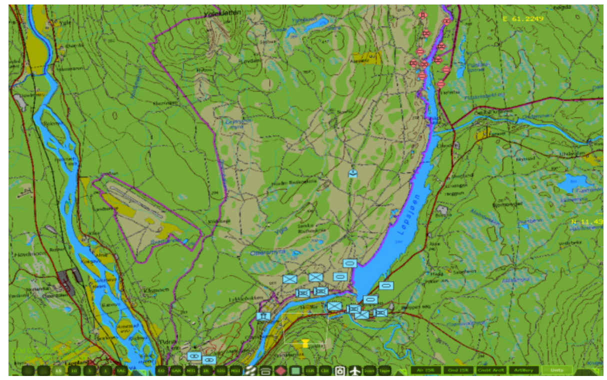

Figure 2. Two-dimensional Theater View in Mōsbē Desktop Viewer.

Figure 3. Three-dimensional Tactical View in Mōsbē Desktop Viewer.

Calibration of Simulated Units

The calibration of weapon penetration and sensor signatures of entities was conducted by scientists in collaboration with military experts. Entities are modeled with parameters like speed, armor, and sensor signature. Each entity can have up to four sensor types and three weapon types.

The weapons are calibrated with a penetration parameter, and all vehicles are calibrated with an armor parameter. These parameters are used to decide whether the weapon can destroy the vehicle or not. Artillery was the first weapon system to be calibrated. Armor parameters for light, medium and heavy armored vehicles and for infantry were also calibrated early. The other weapon types were then calibrated against these targets.

The lack of artillery parameters gives a simplistic implementation of this important capability. Most importantly, the accuracy of the artillery is not dependent on firing distance. A trade-off had to be made, which meant artillery units were calibrated according to the most important targets and shooting distances. In addition, it was not possible to implement new and more advanced ammunition.

The sensor modeling in the simulator is good, and several sensor categories are represented. The sensors are controlled by parameters like range, strength and degradation from weather and darkness. Each vehicle has a signature parameter which can be zero, low, medium or high. These parameters are used to control the detection distances. Lack of details in the sensor model made it necessary to construct new sensors specific to selected targets, which created a need for more sensors per unit than were available in the simulator. Trade-offs had to be made to prioritize the most important sensor capabilities.

A big challenge associated with sensor calibration is related to the absence of micro terrain. Without it, small units are difficult to hide once detected. The Norwegian topography, to some extent, reduces the effect of this problem but it still must be accounted for in the sensor calibration.

Terrain Building

Using the World Builder, three dimensional maps of the areas of interest were generated based on geo-specific data. A challenge often met when producing maps is choosing a balance between resolution and map size. The steep mountains in Norway create the need for high resolution to include rapid changes in terrain elevation. Another challenge was the representation of the different terrain types and water, since surface texture did not affect the mobility of the entities. The only way to restrict movement was to create boundaries, e.g. between land and water. However, the entities had a tendency to get stuck at these boundaries. We therefore ended up removing all boundaries and manually restricting movement.

Simulation Sessions

After the preparation process, the simulation experiment sessions were carried out during the autumn of 2010.

Participants

A substantial number of qualified personnel was needed to carry out this large scale experiment. Military experts played an important role through the whole process, from scenario development to analysis of the results, including the actual experiments. Some of the military officers participated in central roles during the entire experiment series, while others participated when their expertise was needed. Figure 4 shows a picture from one of the simulation sessions.

Figure 4. Scientists and Military Officers During a Simulation Session.

Planning Session

Prior to each experiment, there was a separate planning session for each side where the brigade commander discussed and chose Courses of Action (CoA) together with his commanders and issued written orders. Figure 5 shows a picture from a planning session.

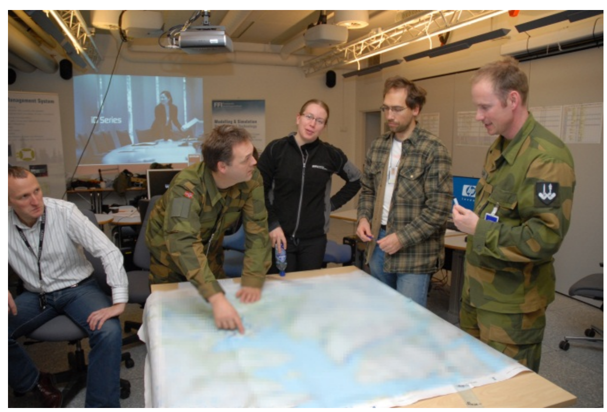

Figure 5. Scientists and Military Officers are Planning Their Strategy for the Next Scenario.

In this phase, the Army forces available on each side were grouped according to their chosen tactics without knowing the exact strategy or location of the opposing force. When the Red and Blue sides were finished placing their forces, one of the administrators merged the two sides into one complete scenario file. Both Red and Blue forces could communicate their wishes to the administrator with regard to placement of mine fields and other elements that were not sufficiently modeled in the simulation platform.

Experiment Setup and Execution

A total of 14 Mōsbē clients were available for each experiment. Four of these clients were used for controlling Red forces, while the Blue forces were distributed between five or six clients, depending on the vignette. The remaining four clients were reserved for the administrators. Figure 6 shows how the players on each side were placed during the experiment series.

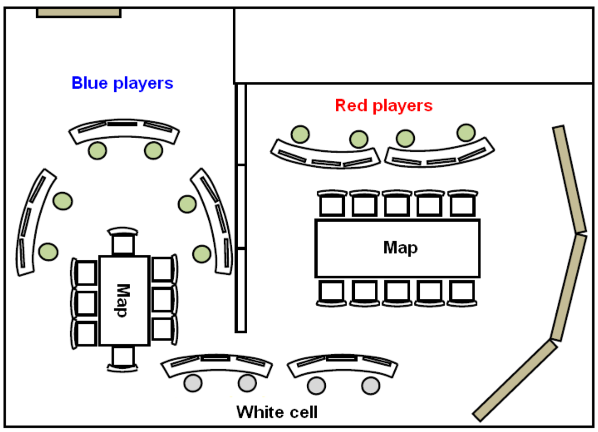

Figure 6. Experiment Configuration with Blue Players, Red Players and White Cell.

A total of 16–20 people participated in each experiment, each one with a specific role in the scenario. Although the series of experiments required a lot of time and personnel, we aspired to keep the roles of the different players as consistent as possible.

We strived to balance the player skills on both sides. Several of the players were scientists with little or no experience in practical warfare, whereas the military officers had various degrees of experience with computer gaming. In order to keep the behavior of the Blue and Red forces as realistic as possible, the presence of military experts was crucial. They played the commanders, and contributed as players and/or supporting experts.

In addition, a group of three persons played the role of "White cell". The White cell functioned as administrators and umpires, and handled issues not represented in the simulator. The people serving in the White cell kept their role throughout the entire experiment series. They were responsible for logging data, and keeping control of both sides in the battle with regards to logistics, as well as deciding which side should win in duel situations where the simulator did not adequately represent reality.

On Blue side the typical distribution of the players has been one player for each battalion, one for artillery, one for ISTAR, and one for air forces. On Red side two players controlled the maneuver battalions, one player controlled ISTAR and artillery, and one player controlled air forces. The simulator allows for sensor sharing with units controlled by other players. For each simulation the setup was therefore configured based on what type of information each player should have access to.

In order to compare experiment results, a certain stop criteria was needed. The simulation was stopped when one side undoubtedly was unable to achieve its goal. This was finally determined by the umpires. Each vignette typically lasted for 4–5 wall-clock hours.

Collected Data

The main categories of collected data were questionnaires, experiences revealed during after action reviews and the log files generated by the simulator.

Before and after each simulation experiment, players had to answer questionnaires about the Army structure being tested. The questionnaires revealed each participant's perception about the different Army structures in the vignettes, both in terms of their a priori expectations and afterwards, based on the experiment. These covered important parameters such as the structure's depth and spectrum, balance between direct and indirect fire power, armament, tactical mobility and sensor systems.

At the end of the day, the participants from both sides met to have an after action review. The after action review included discussions and evaluations among participants regarding events on both tactical and operational levels. The important interplay between indirect fire units, engineering troops and maneuver forces – the so called combined arms effect – has typically been evaluated through the after action review process.

Log files containing data of events are generated by the simulator. Examples of events are detections, engagements and destruction of units. A tool has been developed for extracting data from the log file, such as killed unit ID, killer ID and time of event. All logged data has been organized into a database enabling detailed analysis.

The administrators also recorded videos, took screenshots and documented relevant events from parts of the simulation session, as they were the ones with full situational awareness.

Shortly after completing the experiment series, the majority of the participants came together and evaluated the whole experiment and discussed results in smaller groups and in plenary sessions.

All data collected throughout the experiment series and the post-evaluation formed a solid foundation for analyzing the performance of the tested Army structures.

Validation

To assess the validity of the simulation results, the sources of error have been considered and some validation tests have been performed.

Sources of error

As previously mentioned, there are several sources of error, including the modeling of duel situations. In addition, the simulation runs free of normal battle friction, which means that simulation time is accelerated compared to reality. Occasionally the advancing velocity of the forces could be just below their maximum velocity, with a minimum time required to clear axes after encounters. In addition, one of the major sources of error, differences in player skills, is also the most difficult source to assess.

Validation Tests

Detailed, smaller scale simulations of typical battle situations from the experiments have later been played in VBS2. VBS2 is a simulation tool with a better representation of micro terrain. The main conclusions from the Mōsbē simulations seem to correlate with the results from these simulations. However, there are differences in the loss exchange ratio between the two experimental setups, which imply that great care must be taken when analyzing quantitative results from the simulations.

When using this kind of simulation, the repeatability of each scenario would typically be lower than for traditional stochastic simulations. To even out the vagaries from scenario to scenario, the resulting data for each Army structure are averaged and used in a quadratic Lanchester model, as described later. In addition, the first simulation that we conducted was repeated at the end of the experiment series, with the same overall outcome. However, the kill rates were different; emphasizing that this method is valid for ranking different army structures, not for predicting outcome.

RESULTS

The results from the experiments could be subdivided into three categories. The first category includes overall perceptions about the different structures' performance based on questionnaires. The second category includes tactical experiences and results revealed during the after action review phase. The third and final category includes quantitative data evaluated through a Lanchester model.

Questionnaires

Aggregated results from the post experiment questionnaires could be used to produce a ranking of the different Army structures. However, as we discuss later, we have found a quantitative measure for this. The main results from the questionnaires reveal participant preferences with regard to structure balance and mix of force elements. These could then be used qualitatively to assess in which direction a trade-off between elements should be undertaken in order to achieve a balanced force mix.

The questionnaires have also been used as a means to measure learning in open ended simulations without defined learning objectives (Martinussen, 2011).

After Action Review

Operational insight gained for each Army structure covers how the force elements could best be utilized to maximize synergies, similar to the combined arms effect. One example of such insight is the deployment of sensors and the building of situational awareness on the operational level, as a condition for optimal allocation of resources in the theater. Another example is how freedom of movement in maneuver warfare is affected by the level of coverage. For instance, air defense in the presence of capable air threats or armor in the presence of ground threats, could be a necessity for freedom of maneuver. Thus limiting success to instances where proper coverage is achieved.

On the tactical level, the insight gathered through after action review included the balance between structure depth and capability spectrum, indirect versus direct fire power, and the effect of weapon range. For instance, it is found that in certain tactical situations longer firing range could be used to shape the enemy. This leads to a requirement for a small number of more expensive systems, whereas the volume of firepower could be provided with cheaper, shorter range systems.

Lanchester Calculations

The Lanchester quadratic model states that:

$$\frac{dB_i}{dt} = -\sum_j \alpha_{ji} R_j(t) \quad (1)$$

$$\frac{dR_j}{dt} = -\sum_i \alpha_{ij} B_i(t) \quad (2)$$

R_j and B_i are the numbers of Red and Blue fighting units respectively, for each type i and j. α_{ji} and α_{ij} are the attrition coefficients, which are assumed to be constant for the duration of the battle (Lanchester, 1916). The rather intuitive interpretation of the model (which is readily called the Lanchesters aimed fire mode) is that the outcome for each side is determined by the numbers of opponent forces aiming their fire, multiplied by the attrition coefficients or fighting effectiveness. Based on experimental data, these attrition rates and coefficients have been calculated.

Simulation time is accelerated compared to a real life military operation. In addition, the intensity varies over the course of simulation as well as between simulations. In some simulations the whole operation is conducted within a few hours, whereas in another, troops spend that amount of time just moving into position. Attrition rates therefore must be normalized to take this effect into account.

Normalizing attrition rates is done by measuring attrition against the total volume of units in the battle, instead of time. As each unit contributes differently to the outcome of the battle, their value must be weighted accordingly in the total volume. For instance, a fighter aircraft must have a higher weight than an infantry squad. The weight for each unit is derived from the eigenvalues of the kill matrices. For further information on the eigenvalue method for evaluation of weapon system weight in combat, see (Denzer, 1983) and (Howes & Thrall, 1973).

Figure 7 shows the development of an actual simulation for selected units together with the deterministic Lanchester model, calibrated with data from the same simulation against total volume. From the figure it is clear that the purely deterministic Lanchester model closely predicts the outcome. This means that the exchange ratios between units do not change much during the course of the battle.

By averaging the attrition coefficients over several simulations with similar Army structures in the same type of vignette, different simulations can act as replications, reducing the effect of random errors. The Lanchester calculations developed by this method have then been used as a means to rapidly evaluate a whole series of mechanized Army structures, varying both in volume and cost, against a fixed opposition.

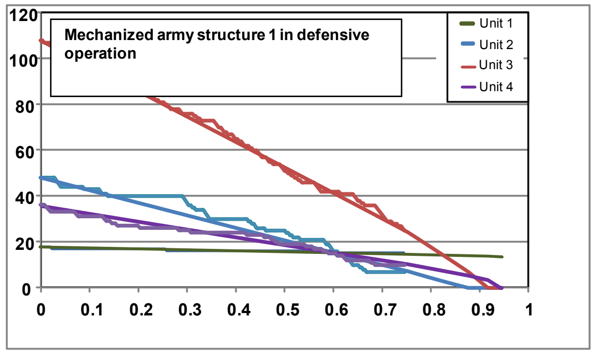

Figure 7. Development of the Battle for Selected Units. The jagged line is the actual simulation, whereas the smooth line shows the Lanchester model.

VALIDITY & DISCUSSION

The simulation series has been an open and dynamic process and, as with any interactive simulation process, the humans in the loop represent opportunities as well as challenges. Factors such as differences in the participants' gaming skills, learning and adaptation as well as perceived human mistakes during the simulations, give rise to questions concerning reproducibility and validity.

However, from Figure 7 above, it is clear that the battle, to a large extent, follows the deterministic Lanchester model. This indicates not only that the impact of singular perceived mistakes by the players in general have a minor impact on the battle as a whole, but that the Army structures on both sides have been used in similar manner during the entire battle. Constant exchange rates during the entire battle indicate that no turning points or extraordinary events could be identified. [2]

Figure 8 below shows the results from the simulation of a mechanized Army structure together with a Lanchester model calibrated on the basis of a structure of considerably different size, but with similar units.

[2] It should be noted that by presenting attrition as a function of structure volume, rather than time, there will be a strong correlation between the Lanchester model and the simulation, for major structure elements. This is because the major weapon systems contribute strongly to the structure volume.

Knowing that the two structures were perceived to perform quite differently, the fit is remarkably good. We conclude that although human factors strongly influence the outcome of interactive simulations, in this case the combined fighting effectiveness of the units dominates the outcome in these simulated battles.

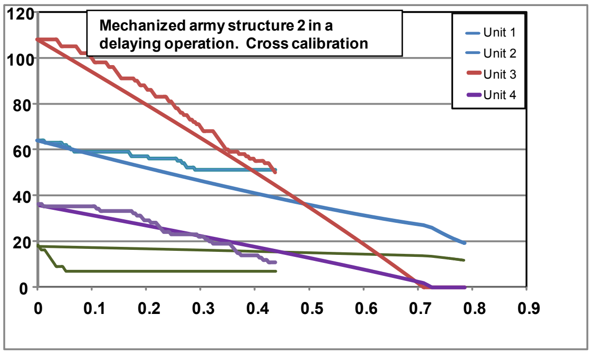

Figure 8. Development of the Battle for Selected Units. The jagged line is the actual simulation, whereas the smooth line shows the Lanchester model calibrated with data from the simulation with mechanized Army structure 1 in delaying operations.

By doing similar tests as in Figure 8, we have tested whether larger structures composed from a broader capability spectrum perform comparatively better than expected, compared to smaller structures composed from a smaller capability spectrum. This would be expected, as an increased system spectrum increases possible synergies through the ability to vary the means. However, such effects are not significant in our observations, probably due to variance between the experiments. This means that the simulations are not precise enough to discriminate Army structures with minor to moderate variations in the capability spectrum.

Our validation experiments have identified several shortfalls in the simulator. For instance, the lack of micro terrain favors platforms with longer ranges, and some typical duel situations are known to have other exchange ratios in other simulation tools used at FFI. As a tool to examine optimal force balance, the simulator is therefore not well suited.

However, the simulation series has made it possible to evaluate the need for fire support from artillery and fighter aircraft, engineering support and tactical air defense in the different vignettes. In addition, the simulation series has provided a basis for an excellent tool for scaling the overall firepower of possible future Army structures.

LESSONS LEARNED

The experiments have given unique insight into the strengths and weaknesses of the tested Army structures against a mechanized adversary in the given operational vignettes.

The experiment series led to the involvement of a large number of experts, both analysts and military. This has been critical to the successful outcome of the experiments.

Early involvement of experts, starting with the preparations before the experiment series, gave transparency to stakeholders. By participating in the calibration of the simulation platform and the planning of the experiments, they have gained insight into how the simulation platform works, including its strengths and weaknesses. At the same time the supporting experts gave valuable input into the process of making the simulations as realistic as possible. The deep involvement of stakeholders through the process has made it easier to communicate the results with credibility.

Simulators have shortfalls, and the need to identify those is crucial for a credible outcome. The use of experts was valuable both in identifying and overcoming the shortfalls. This collaboration has led to confidence in the results among all the participants.

A big advantage of using interactive simulations compared to traditional wargaming at FFI has been that the analysis has become more robust and traceable.

A side effect of the experiment series has been increased knowledge about land force operations in general, both for the participating scientists and military officers.

It is also worth mentioning that this method has been very time and resource consuming.

SUMMARY & CONCLUSION

This paper has presented a new approach for conducting Army structure analysis, where interactive simulation has been utilized as an additional tool. Through a series of experiments we have been able to rank the performance of five different land force structures. The structures have been tested in a set of chosen tactical vignettes. For each simulation session we logged data and recorded video from the simulation, and the participants completed questionnaires about the performance of the tested Army structure.

The experiments have given unique insight into the strengths and weaknesses of the tested structures both on operational and tactical levels. The battle lab, facilitating interaction between the interactive simulation, analysts and military officers, has been an excellent arena for evaluating the combined arms effect for the different structures.

The data output from the simulation series has been fed into a quadratic Lanchester model. This has served both as means to validate results from the experiments, and as a model to search for an optimal Army structure.

We have been working closely together with military experts within different areas in all phases of the experiment series, from the preparations to the post analysis. Their involvement has improved the realism of the simulations, and hence made the results more credible.

This whole concept has made the results and conclusions from the analysis more detailed, robust and traceable. Finally, this work has resulted in a set of recommendations for potential new structures for the Norwegian military land power.

FUTURE WORK

Several tactical episodes gave different outcomes in the simulation tool compared to previous tactical simulations with other simulation tools at FFI. To some extent, questionable results have been verified by tactical simulations in other simulation tools. Further investigations could, however, be of interest.

At the operational level, it was somewhat surprising that minor increases in system spectrum did not result in a better overall performance. Further experimentation would be required to investigate whether this should be expected to be the case also in a real life scenario.

Further analysis should be conducted, investigating in more detail the performance of the recommended Army structures in tactical and operational scenarios. Other interesting aspects could be to investigate emerging technologies and new operational concepts.

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