# Interactive Simulation to Support the Transition of Forces


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## *ABSTRACT*

*After a long period of deployments and ongoing operations, and in the wake of the financial crisis, NATO now stands before new challenges reforming its forces and maintaining interoperability in an austere economic environment. This paper suggests a methodology for using interactive simulations to support the transition of military forces through experimentation with alternative future concepts.*

*At the Norwegian Defence Research Establishment (FFI) interactive simulations have been carried out to support evaluation of alternative Army structures. Through a series of experiments we have tested 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 relative performance. This paper presents the general method, how the experiments were conducted, and how this method can be employed to evaluate the performance of alternative military structures in both a national and international context.*

*Interactive simulation experiments, where military officers plan and lead the operations, are central in our method to evaluate potential military structures in relevant scenarios. A suitable simulation platform is needed, where models of relevant military units must be implemented and calibrated. Such experiments allows for collection of relevant data, through for instance simulator log files, after-action review and questionnaires. Analysis of the collected data can reveal the strengths and weaknesses of the tested military structures, and make it possible to evaluate their relative performance. We also suggest feeding the data output from the simulation series into a quadratic Lanchester model, which then can be used for scaling purposes. In our method, military subject-matter experts play an important role through the whole process, from scenario development to analysis of the results.*

*Our experiments have given unique insight into the strengths and weaknesses of the tested structures, both on operational and tactical levels. Lessons learned from the experiments also revealed the importance of military subject-matter experts' involvement throughout the process. Simulation platforms have shortfalls, and the need to identify those is crucial for a credible outcome. The use of subject-matter experts was valuable both in identifying and overcoming the shortfalls. This collaboration has also 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.*

*We propose that a similar approach can be used to test and compare future military structures, for both national and international coalition forces. Using this type of interactive simulations it is possible to experiment with, and optimize towards, a military structure better suited for future operations.*

## 1.0 INTRODUCTION

NATO now stands before new challenges reforming its forces and maintaining interoperability in an austere economic environment. This paper suggests a method for using interactive constructive simulations to support the transition of military forces through experimentation with alternative future concepts. The method has been used to investigate both traditional and novel structure alternatives and has led to national recommendations for the Norwegian Army. In this paper we present the method as it was applied to this special case, which we believe can be used to support the transition of forces in general.

In Norway, analysis of the military 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 have typically been treated during the wargaming session, based on military subject-matter experts. The method described in this paper was developed through recent work that has been carried out at the Norwegian Defence Research Establishment (FFI). Here interactive constructive simulation has been introduced as an additional tool for evaluating the performance of alternative land-force structures, where the complex combined arms effects to considerable extent has been included in the simulation. The combined arms effect is usually interpreted as the synergy attained from the interplay between force elements such as direct and indirect fire, engineering, sensor, C2 and Naval and Air Force units. Military subject-matter experts have been directly involved in planning, execution and post-evaluation of the simulation experiments to ensure realism.

First, this paper briefly describes the background for this work. Second, the general method is presented, including a description of the experiments carried out at FFI. Finally, we present lessons learned from this work.

## 2.0 BACKGROUND

FFI's first battle-lab facility was finished in 2005. It offered new possibilities for experimentation with emerging technologies and new concepts in collaboration with military users. The general idea has been to experiment with new concepts and technologies in virtual environments.

Various projects in support of procurement and development of new military equipment and platforms (these projects include Air Defence, Combat Vehicles, Indirect Fire and UAV) have used the battle-lab facility to evaluate the operational benefit of these systems. The simulation 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 modelled with a sufficient level of detail to make an appropriate representation. The collected data from these experiments have been both quantitative measurements and qualitative feedback from the participants during after-action review sessions and through questionnaires. The battle-lab facility has become an important arena for collaboration between various projects at FFI, and between scientists and military personnel. In 2008 we started to consider applying a similar approach to carry out simulations on battalion to brigade level, to support defence structure analysis [1].

FFI conducts analysis in support of military operations and defence planning. In 2009 the "Future Land Forces" project was initiated, with the goal to analyse 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 modelling and simulation in the battle-lab facility, 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 during the autumn of 2010, simulation experiments were carried out to support evaluation of alternative land-force structures. Interdisciplinary collaboration was of key importance in this work. Through this work we have established a general method for evaluating the performance of military force structures, which is described in the next section.

## 3.0 METHOD

Human-in-the-loop simulation experiments have proven to be a good approach for evaluating tactical implications of new technologies. This concept has been further developed for testing and evaluation of entire military force structures. Instead of implementing a virtual prototype of a new technology, evaluating different military structures requires development of virtual representations of these structures. This includes modelling, configuration and calibration of all units represented in the potential force.

The performance of the military structures is evaluated through a set of simulation experiments. The structures are tested in relevant scenarios in a virtual environment. Our approach is to use interactive constructive simulations where humans are in the loop as military leaders 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 the 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. Figure 1 illustrates the concept behind this approach.

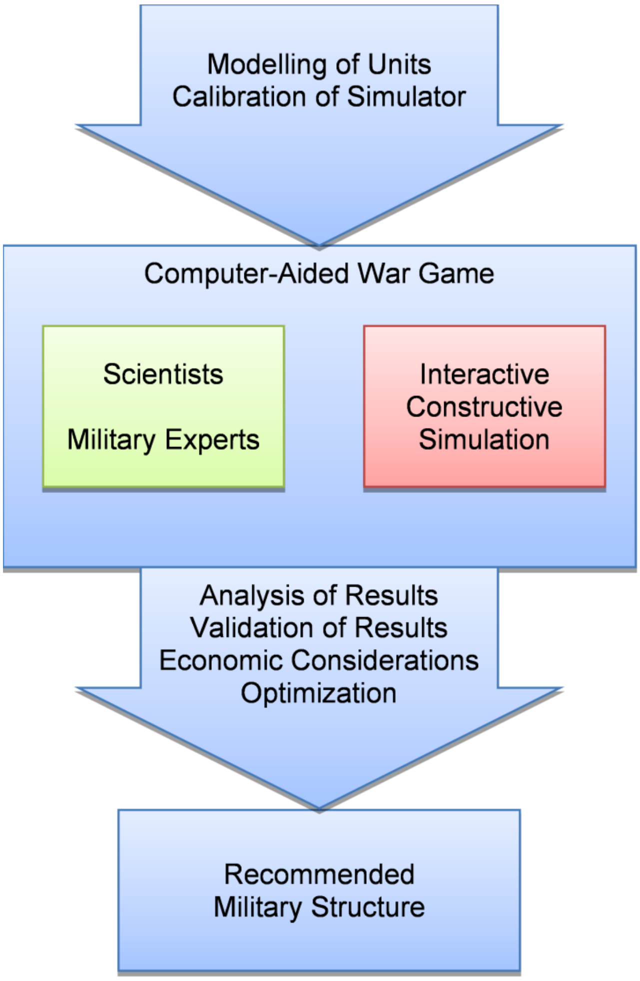


**Figure 1: Concept behind the military-structure analysis.**

It is important to collect as much data as possible from the simulation experiments. Examples of data that can be collected are log files from the simulation platform, recorded video from the simulated battle, and the participants' perceptions about the different structures' performance based on questionnaires, interviews and after-action review sessions. Prior to the experiments a review should be made to ensure relevant data are collected for possible later studies.

Finally, the results from the experiments must be analysed and validated against other sources, as subject matter experts, other models etc. The performance of the structures tested in relevant scenarios, combined with economic considerations, will make it possible to arrive at military structures that are both effective in battle and affordable.

It is important to emphasize that this method is suitable for ranking the different military structures based on their relative performance. This method does not seek to predict the exact outcome of a particular scenario. The main idea is to test the structures against a fixed adversary in a set of chosen scenarios.

## 3.1 Simulation Platform

This method is dependent on a suitable simulation platform for wargaming. The simulation platform must be able to simulate large enough operations to match the size of the military structures being tested. This could mean thousands of entities. In our case we have simulated brigade operations. The simulation platform must also support large enough terrain databases to contain the whole operational area from the scenarios. In addition the terrain must be sufficiently detailed for the forces to be able to exploit the terrain.

To make it possible to distinguish between the properties of the different structure elements in the military forces, the simulation platform must use detailed simulation models of vehicles, weapon platforms (including ammunition), and sensors. These simulation models should be well documented to facilitate the process with modelling of entities, and configuration and calibration of parameters.

The entities should have some sort of smart behaviour or artificial intelligence (AI). Ideally, each type of entities should be able to perform a set of common operational tasks realistically on their own, according to a "NATO-like" doctrine. It should be possible to give high-level orders to a battalion or a company, which then are broken down to simpler missions or tasks and distributed to the right subordinate units.

The simulation platform should have a user interface that is quick to learn and easy to use. It should also permit a high degree of interaction. We have experienced that user-interface systems used in real-time strategy games work well for wargaming. Visualisation of the simulated battlefield is also important, and the graphics engine should allow smooth navigation in the virtual environment.

To limit the resources needed to carry out simulation experiments, the number of players needs to be limited. Each player must therefore be able to control large groups of entities. In our experiments it typically took four to six players to control a brigade.

It is important that the simulation platform logs all relevant events from the simulation. Alternatively, logging can be achieved by connecting a DIS/HLA logger to the simulation. It is an advantage if the simulation platform has an integrated system for after-action review which records the simulation, otherwise video recording of the simulated battlefield can be used.

A simulation platform will always have shortfalls. For a credible outcome of the simulation, these must be identified, and workarounds must be found. Working closely together with military subject-matter experts is important in this process.

To our knowledge no simulation platforms to date fulfill all the above stated requirements. Those available at the commercial market all have some shortfalls. In the experiments conducted at FFI, we used the simulation platform Mōsbē from BreakAway. The main reason for this choice was 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. Mōsbē can be used for operational analysis, experimentation and visualisation. Each fighting entity is modelled with weapons, sensors and other parameters like speed and armour. All entities are grouped into platoons, which are the smallest controllable units in the simulation. Examples of a two-dimensional theater view (to the left), and a three-dimensional tactical view (to the right) in Mōsbē are shown in Figure 2. The development of Mōsbē has been discontinued, and the latest version was released in 2008.

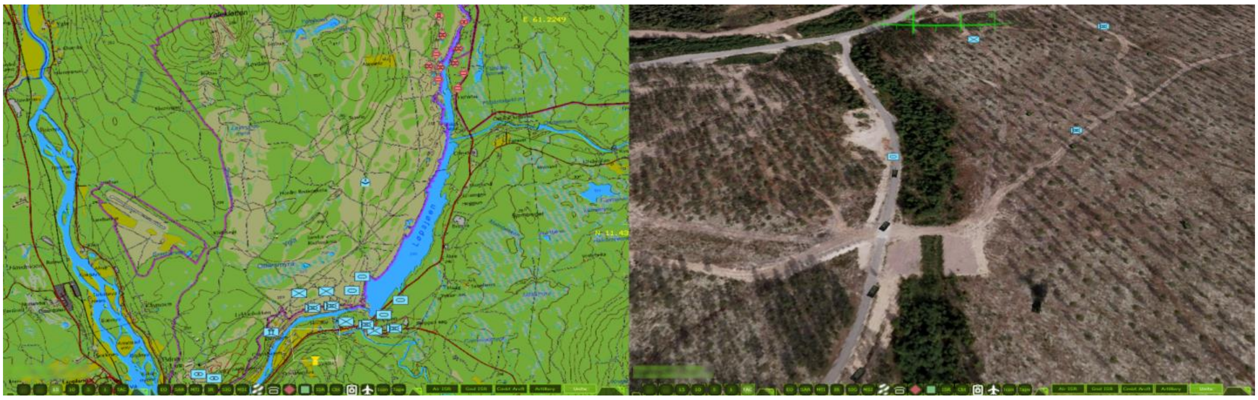

**Figure 2: Two-dimensional theater view (to the left), and three-dimensional tactical view (to the right) in Mōsbē.**

### 3.1.1 Simulation Platform Technology

Most of the technology needed to make simulation platforms that satisfies the requirements stated above is currently available. However, there is need for further research and development within AI for military simulations. A part of the problem is also that realistic AI for thousands of units is very computer intensive. In addition, there is a need for simulation platforms that support both large areas and detailed representations of micro terrain.

The simulation platforms used for interactive constructive simulation are primarily developed for command staff training. It is therefore the training requirements that drive the development of these systems. However, the requirements for using this technology for experimentation and analysis are very similar to the requirements for training. With more detailed simulation models and more realistic AI this technology could also have the potential to be employed for real-time decision support during operations, and in the future perhaps predict probable outcomes of operations.

## 1.1 Modelling and Calibration of Entities

When a simulation experiment comparing different military structures is carried out, the simulated entities must be calibrated. The simulation platform has to give a realistic simulation of the course of events in the battle. We recommend that the calibration of the simulated entities is conducted in collaboration with military subject-matter experts, to get a good representation of the military systems. For instance, the format that are used for parameters in simulator platforms do not always correspond to the format available in classified look-up tables, which typically are more detailed. Expert assessment could thus be necessary to derive representative parameter values. Important parameters to represent in the simulated entities are speed, armour, and sensor signature. The entities also need to have a good representation of sensors and weapon. If one type of military unit can detect, engage or destroy another type of military unit in the real world, this should also be possible in the simulation. The simulation platform must produce realistic outcome for duel situations for pairs of units as well as the battle as a whole.

Before the simulation experiments at FFI were carried out, scientists and military experts calibrated the entities in Mōsbē. The weapons were calibrated with a penetration parameter, and all vehicles were calibrated with an armour parameter. These parameters are used to decide whether a weapon can destroy a vehicle. The sensors were calibrated with parameters like range, strength and degradation from weather and darkness. Each vehicle was given a signature parameter. These parameters were used to control the detection distances.

To help validate the results from the experiments, detailed smaller-scale virtual simulations of typical battle situations from the experiments have been played in Virtual Battlespace 2 (VBS2).

## 1.2 Experiment Setup and Execution

After choosing a suitable simulation platform, modelling and calibrating the relevant units, and developing a set of relevant scenarios, the experiment sessions are ready to begin. Figure 3 illustrates the course of a typical experiment session for each scenario.

Each experiment begins with a separate military planning session for the participants/players on each side, where the course of action is discussed and chosen. In addition to the Blue- and Red-force players, a small group of persons is needed as “white cell”. The white cell functions as administrators and umpires, and also handles issues not represented in the simulation platform. During the planning session, the brigade commander discusses and chooses courses of action together with his/her commanders. The forces available on each side are grouped according to their chosen tactics without knowing the exact strategy or location of the opposing force. It is also important to take into consideration the experiment setup, i.e. keep the Blue players and Red players separated and make sure that the available information from the battlefield during the simulation is close to what is available in reality.

Executing the simulation may take several hours depending on the chosen scenarios. Our simulation experiments typically lasted about 4-5 wall-clock hours. The simulation was stopped when one side undoubtedly was unable to achieve its goal.

During the experiments, all relevant data must be collected. The collected data can for instance be log files from the simulation platform, and feedback from the participants through after-action review sessions and questionnaires. Questionnaires, before and after the execution, can help addressing how the simulation of a scenario has influenced the player’s perception of the role/importance of each element in a military force structure. Video recordings of situations of particular interest can be used when analysing the results of the experiments.

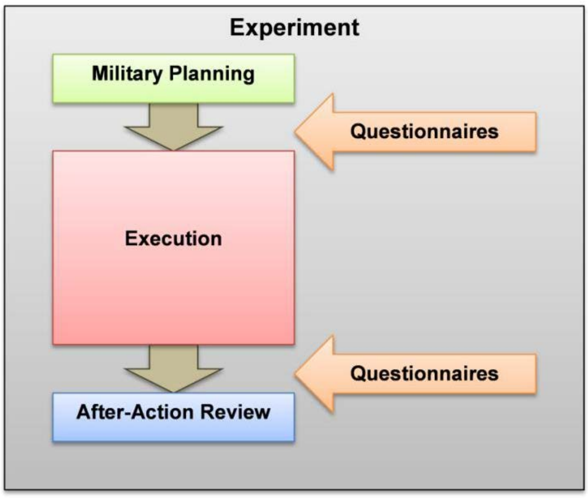


**Figure 3: Illustration of the course of an experiment.**

After each simulation session all the participants meet to have an after-action review. This includes discussions and evaluations regarding events on both tactical and operational levels. The combined-arms effects can typically be evaluated through the after-action review.

## 1.3 Land-Force Structure Analysis at FFI

As an example of a specific application of this method, we will now briefly describe the land-force structure analysis carried out at FFI in 2010. This analysis is described in more detail in [2].

Prior to the simulation experiments, a number of different land-force structures were developed [3], with their analytical foundations based on three warfighting concepts: maneuver theory, exchange theory and positional theory [4]. Most of these structures were filtered out according to a capability-based method.

Finally, we chose to evaluate the performance of five land-force structures. Three of these structures were mechanized maneuver structures, including the current Norwegian land-force structure. In addition we tested a light structure with units equipped with man-portable antitank weapons, and a distributed maneuver structure [5] largely based on network-centric warfare and long-range precision-guided fire.

The five land-force structures were tested in three chosen tactical vignettes. A tactical vignette is a specific playable course of battle extracted from a larger scenario. The three selected vignettes were extracted from scenario classes designed as part of the Norwegian Chief of Defence's "Defence Study 2007". We used a fixed opposing force for the experiments, which was based on a generic mechanized infantry brigade. This whole process is illustrated in Figure 4.

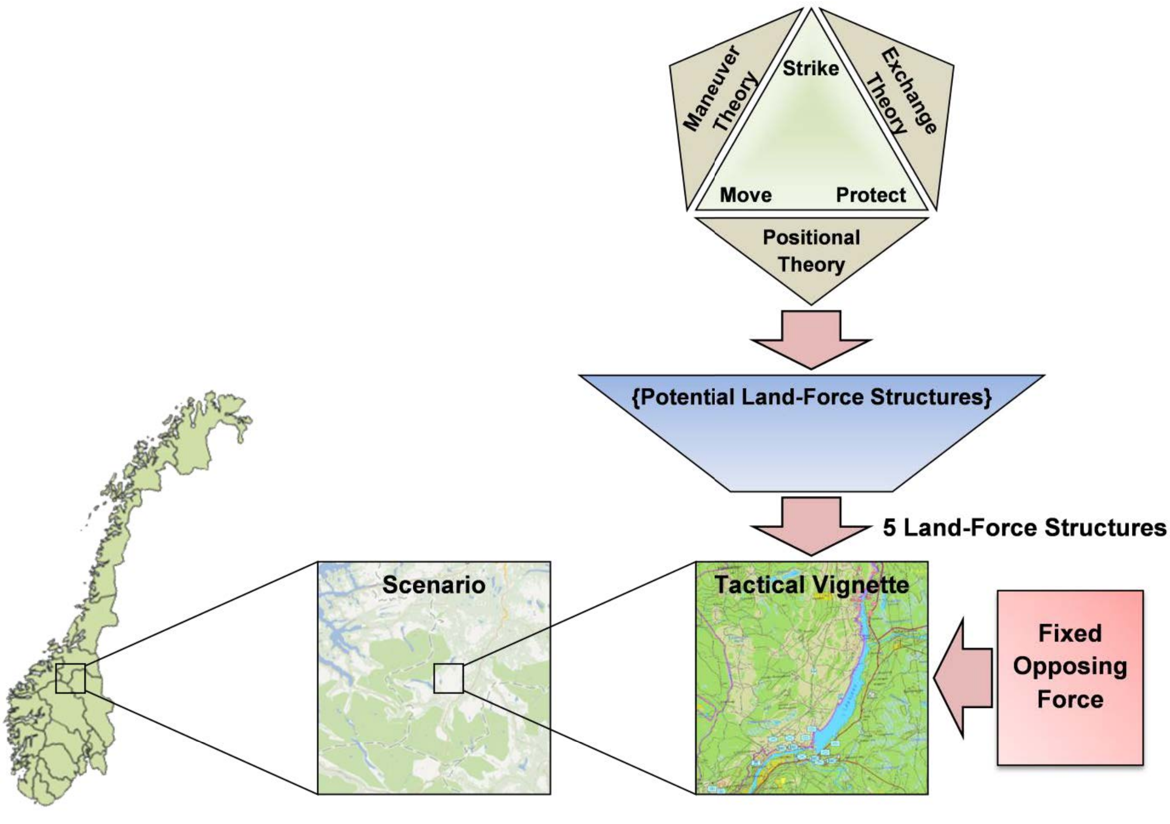


**Figure 4: Land-force structure analysis at FFI.**

The series of simulation experiments were carried out 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 defence. The experiment followed the setup and execution described in section 1.2.

In our case, the typical allocation of players on Blue side is shown in Figure 5. Red side was organized similar to Blue side. Experienced military officers served as brigade commanders.

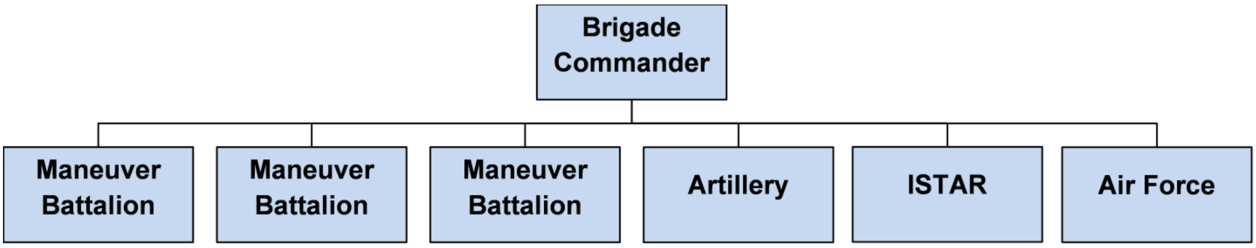


**Figure 5: Example of the distribution of players on Blue side.**

Figure 6 shows a picture from a simulation session (to the left), and a picture from a planning session (to the right).

After the experiments the results were analysed and used in a larger context together with considerations about economy and force production. They were combined with outputs from the KOSTMOD[1] [6] cost model, and a model estimating the total force production, to arrive at cost-efficient land-force structures. Finally, this work resulted in a set of recommendations for potential new structures for the Norwegian military land power.

**Figure 6: A simulation session (to the left) and a planning session (to the right) during the land-force structure analysis at FFI.**

## 1.4 Lanchester Model

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 military force structure can be averaged and used in a quadratic Lanchester model for scaling purposes.

The Lanchester quadratic model states that:

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

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

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

Rj and Bi are the numbers of Red and Blue fighting units respectively, for each type i and j. □ji and □ij are the attrition coefficients, which are assumed to be constant for the duration of the battle [7]. The rather intuitive interpretation of the model (which is readily called the Lanchesters aimed fire model) 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 can be calculated.

In our simulation experiments the simulation time was accelerated compared to a real life military operation, and the intensity varied over the course of simulation as well as between simulations. Attrition rates 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 [8] and [9].

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. 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, in this simulation.

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. This type of errors inevitably appear due to differences in the participants’ gaming skills, learning and adaptation as well as human mistakes during the simulations, among other factors.

From Figure 7, it is clear that this particular battle to a large extent follows the deterministic Lanchester model. Constant exchange rates during the entire battle indicate that the Army structures on both sides have been used in similar manner during the entire battle. There have neither been turning points nor could extraordinary events be identified.

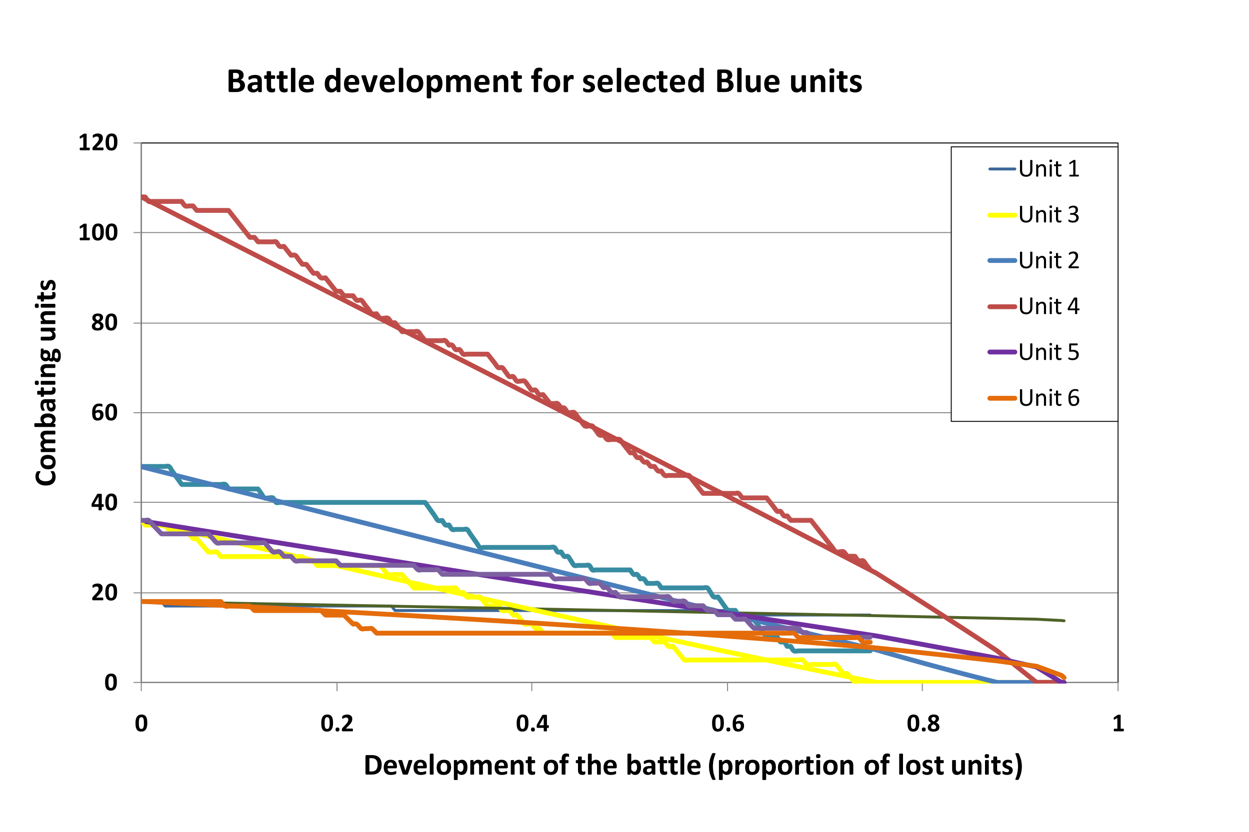


**Figure 7: Development of the battle for selected units from the simulation experiment and the deterministic Lanchester model. The jagged line shows the actual simulation, whereas the smooth line is output from Lanchester model which has been calibrated with data from the simulation.**

## 4.0 LESSONS LEARNED

The introduction of interactive constructive simulations opens possibilities to experiment with traditional force structures as well as novel and conceptual ones. Plausible scenarios created the backdrop when a range of different structures was tested against a mechanized adversary in the experiment series described in section 3.4. The method was originally intended to rank the tested Army structures purely based on their performance, but it was soon clear that simulations also revealed their operational strengths and weaknesses, which to some extent could be used to alter the composition of the structures. Conclusions from the experiment series have then been used to recommend the future directions for the Norwegian Army. We believe that this method and lessons learned are suited to investigate force structures in general and in particular to support the transition of forces.

In the following we present some lessons learned, first on the involvement of subject-matter experts in experimenting with force structures, then on the gathering and interpretation of data. Gathered data could be subdivided into the categories subjective and quantitative. The first category includes overall perceptions about the different structures' performance, and is typically based on questionnaires and tactical experiences revealed through the after-action review phase. The second category includes quantitative data gathered through a data log.

### 4.1 Subject-Matter Expert Involvement in Experimenting with Force Structures

One of the important lessons learned from our experiments have been involvement of military officers and experts through all stages of the experiment. 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 also made it easier to communicate the results with credibility.

Simulators have shortfalls in various degrees, and some were found to alter the participants' military tactics if they were awarded by success in the simulator. Thus playing on the simulator's premises would soon become the consequence if adjustments were not made. In some cases adjustments have been made solely on the basis of expert opinion, while in other cases it was found necessary to conduct separate experiments on various tactical situations in a platform for virtual simulations.

In contrast to interactive constructive simulation which is suited at tactical, operational and strategic levels, virtual simulations are often used at the procedure and lower tactical levels. This is because the latter usually has greater level of details, but with limited possibilities to construct experiments with a large number of units. On the one hand, for investigating important synergies like the combined arms effect, constructive simulations are suited, but might lack fidelity on the lower levels – bringing about false results. On the other hand, virtual simulations that are suitable for evaluating procedures might lack the framework necessary to yield valid results in a combined arms or joint environment. Due to the differences in scope between these types of simulations they are not necessarily expected to produce identical results. It is therefore our experience that participation of officers and subject-matter experts is useful in all phases of the experiments, including interpreting the results.

The involvement of military officers and experts has, however, not only increased the robustness and credibility of our results. The battle-lab experiments have proven to be an excellent arena for knowledge sharing, gathering experts from the main battle systems represented in the simulation. In a multinational context we believe similar battle-lab experiments could provide a supplemental arena to expensive live exercises for maintaining interoperability in periods between deployments. In the Norwegian experiments a general observation seems to be that commanders working closely together on military tactics and capabilities do develop mutual understanding, not only in the technical areas, but also in parts of the non-technical DOTMLPF2 spectrum. Similar arenas most likely would be beneficial in the process of bridging some of the interoperability gaps in the DOTMLPF spectrum among NATO nations.

Several factors have been pointed to in building interoperability, including the non-material DOTMLPF [10]. For instance Darnis et al. [11] point to the importance of convergence of elements of nations' military doctrine as key to successful cooperation. Likewise it has been suggested that pooled forces is an important driver of interoperability, common doctrine and equipment [12]. It seems obvious that building interoperability is a complex matter, involving both material and non-material elements. Based on the positive experiences with knowledge sharing between military experts in the battle-lab experiments, we are convinced that similar experiments in a multinational context could be used to build interoperability through common understanding of for instance training and doctrines. Further, interactive constructive simulations in a multinational context could be used to experiment with traditional and novel structures to support NATO capability planning.

Human creativity often finds new solutions to problems when the rules are changed, as with introduction of new capabilities. Human-in-the-loop simulations benefits from this creativity, leading tactics to change in response to the development of the battle. When new force structures are tested in simulators, their tactics

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should be optimized and the chosen course of action be selected according to the new structure's advantages. Human-in-the-loop simulations are well suited for this purpose, in contrast to scripted simulations where novel structures often ends up being tested on the premises of the traditional way of war fighting. One of the tested Army structures in the Norwegian experiments was a distributed maneuver concept based on Kelly et al. [5]. Even though one lesson learned was that more experimentation is needed on these types of novel Army structures, it was similarly clear that interactive simulation is a good arena for such experiments. We therefore find it safe to assume similar experiments are a good starting point in developing and reforming NATO forces, both nationally and multinationally.

## 1.5 Subjective Observations

Subjective observations from simulation with force structures typically reveal strengths and weaknesses in the tested structures. This type of knowledge could be used to develop tactics, optimize the structure's mix of force elements, and could even be used to test and develop new capabilities. Operational insight gained for a particular structure could also be utilized to maximize synergies, similar to the combined-arms effect. Subjective observations have been gathered through questionnaires and after-action review as described in section 1.2.

Questionnaires can be used to elucidate attributes such as firepower, maneuverability, survivability, protection, etc., as well as overall performance for a tested structure. Semi-quantitative data from questionnaires usually are important supplements to statements about a structure's attributes put forward during the after-action review phase.

The questionnaires have also been used as a means to measure learning in open-ended simulations without defined learning objectives [13]. If questionnaires are collected both before and after the simulation, the changes in answers could also be used as a measurement of learning. The more the participants' perception of the tested structures has changed before and after simulation, the more learning has been achieved. As the participants accumulate experience with one structure, it is expected that number of changes come down – as one becomes familiar with the strength and weaknesses of a force structure.

Subjective observations, and especially those made by military subject-matter experts, have played a key role in interpretation of outcomes of skirmishes in the simulator during our experiment series. They have been the key to adjust tactics, course of action and procedures for novel structures in the simulator. The after-action review phase has proven to be a fruitful arena for bringing forth these observations, when the battle is still fresh in memory. Exchange of experiences between Red and Blue side, as well as with the umpires, contribute to balance the discussions. The participants' situational awareness during after-action review has further been enhanced through the possibility to play back sequences or show maps depicting the tactical situation.

## 1.6 Quantitative Observations

Quantitative results from the simulator log files typically include unit kill matrices, engagement distances and sensor observations. These can be used as important supplements to the subjective observations. If for instance weapon range is perceived to be a decisive factor in some skirmishes, then the engagement ranges in the log files could be used to support the perception. Records of unit kills can also be fed into a Lanchester model, as described in section 3.5. This has shown to be a useful tool not only for averaging out variance from game to game, but also for extrapolating results for similar force structures of different size.

Figure 8 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 and course of action. The fit is remarkably good, and demonstrates that the Lanchester model in some cases is well suited for extrapolating simulation results to similar but different sized structures. This property has been used in combination with cost data to search for optimal Army structures for the Norwegian Armed Forces.

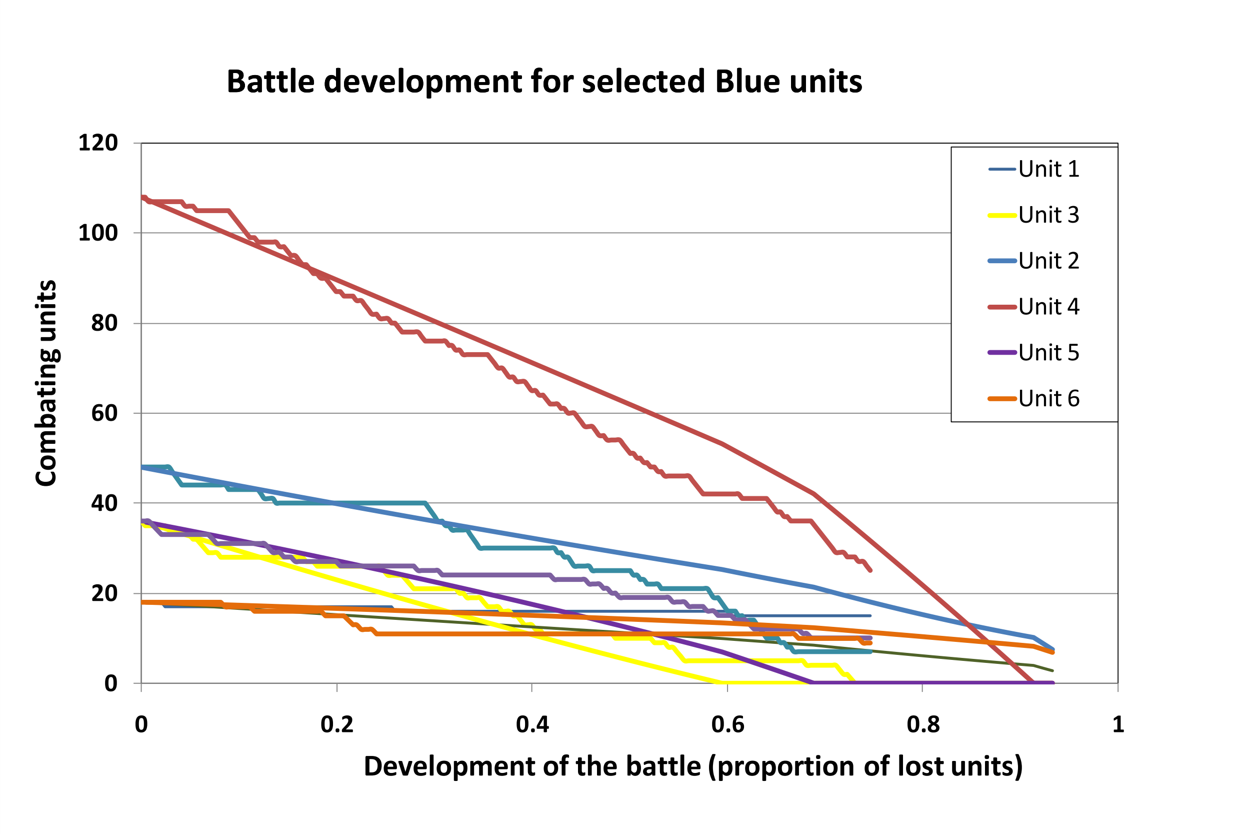


**Figure 8: Development of the battle for selected units from the simulation experiment and the deterministic Lanchester model. The jagged line is the actual simulation, whereas the smooth line shows the Lanchester model calibrated with data from simulation with a larger structure against the same adversary in the same tactical vignette.**

A note of caution should be made about using simulator experiments in predicting outcomes. Our experiments have revealed that simulators are likely to have a series of shortfalls stemming from for instance accelerated time, unrealistic representation of hit probability and survival rate, simplified sensor and terrain modelling, etc. First of all simulator experiments are therefore useful for comparing the performance of different structures, rather than predicting outcome. For instance 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. Nevertheless, for testing and experimentation with fundamentally different structures, including novel, interactive constructive simulation gives valuable insight and seems to be a natural choice.

Once credible results from simulation experiments have been achieved for a particular structure in scenarios that are representative of future challenges, data can later be used for detailed analysis in capability planning. Data from the simulation experiments carried out at FFI has later been used by the Norwegian armed forces as input for more detailed studies on mines, obstacles, and other engineering resources. Shortfalls in the simulation platforms, such as imprecise duel modelling then must be accounted for and could limit usefulness of data.

## 5.0 SUMMARY & CONCLUSION

This paper has presented a new approach for conducting military force structure analysis, where interactive constructive simulation has been utilized as an additional tool. Through a series of experiments we have tested and been able to rank the performance of five different land-force structures. Our experiments have given unique insight into the strengths and weaknesses of the tested structures, both on operational and tactical levels. The method we have presented has been used for the Norwegian Army and has led to recommendations about its future directions. However, we believe a similar approach also is suited for evaluating alternative military force structures both on joint operations and in multinational NATO operations.

Lessons learned from the experiments also revealed the importance of military subject-matter experts' involvement throughout the process. Simulation platforms have shortfalls, and the need to identify those is crucial for a credible outcome. The use of subject-matter experts was valuable both in identifying and overcoming the shortfalls. The battle lab, facilitating interaction between the interactive constructive simulation, analysts and military officers, has been an excellent arena for evaluating the combined-arms effect for the different structures. Knowledge sharing seems to have been the key behind this evaluation process, and we therefore find it likely that similar processes could be useful in enhancing interoperability in NATO, particularly in the DOTMLPF domain.

The introduction of human creativity through human-in-the-loop simulations also has shown promising results in evaluating novel structures, as those can be evaluated on their own premises with appropriate adjustments made to tactics. The method and experimental setup described in this paper thus seems promising in reforming and experimenting with transition of NATO forces.

## 6.0 FUTURE WORK

The work described in this paper has focus on Army operations. A possible next step in a Norwegian national context could be interactive constructive simulations for Navy and Joint operations. Interactive constructive simulation has also been proven useful for investigating novel concepts. The method therefore should be suited to investigate and develop future concepts like Distributed Maneuver, Air- Sea Battle3 and distributed ISTAR (see for instance [14][15]).

Experiences from the experiments in FFI's battle lab implies that interactive constructive simulations can be a useful tool in supporting transition of forces and bridging the interoperability gaps in NATO. We suggest that similar approaches can be used by NATO nations in transitioning their forces. Especially the use of simulation experiments at the multinational level could act as a facilitating arena to improve interoperability both in parts of the non-material DOTMLPF domain and for common capability planning.

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