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Simulation-supported wargaming for assessing force structures

— methodology and best practices

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Summary

When developing and assessing future force structures, *wargaming* is a key activity for gaining deeper insight and better understanding of the strengths and weaknesses of the force structures. Today, computer-based simulation systems let us create synthetic environments that to a high degree replicate the physical properties of the real world. Furthermore, advances in artificial intelligence (AI) and behaviour modelling have given us more realistic computer-generated forces that can execute battle drills and lower-level tactics with a high degree of realism. Wargames can benefit from these advances. However, at the higher levels of the chain of command, AI cannot yet match human decision-makers, and thus, planning and conducting simulated operations in wargames requires the participation of human officers.

For more than a decade, the Norwegian Defence Research Establishment (Forsvarets forskningsinstitutt – FFI) has supported the Norwegian Army with conducting wargames for capability planning, with varying degrees of computer-based support. Throughout this period, the wargames have evolved from what can be described as computer-assisted wargames towards more realistic simulation-supported wargames. Moreover, to get a closer understanding of the deterrent effect of the force structures, which may not be observable during the actual gameplay, our emphasis has also shifted towards replicating the planning process more properly, and especially towards monitoring the planning process of the opposing force. For example, it has been important to examine to what extent specific structure elements discourage the opposing force from taking certain actions.

First in this report, we briefly describe the background for this work. Secondly, we present an introduction to wargaming in general, including definitions, key elements, types, application areas, and wargaming's relation to modelling and simulation and experimentation. We then describe our evolved methodology for simulation-supported wargaming, which includes a preparation phase; an execution phase, including a joint operational planning process; and an analysis phase. We also discuss what type of data and results we are able to extract from the wargaming sessions, the validity and credibility of wargames, and simulation systems for supporting wargames. Finally, we present a set of what we have found to be best practices for how to conduct successful simulation-supported wargames.

Sammendrag

Når framtidige styrkestrukturer skal utvikles og vurderes, er *krigsspill* viktig for å få en bedre forståelse av styrker og svakheter ved strukturene. Dagens datamaskinbaserte simuleringssystemer gjør oss i stand til å lage syntetiske miljøer som i høy grad kan gjenskape de fysiske egenskapene til den virkelige verden. Videre har framskritt innen kunstig intelligens og oppførselsmodellering gitt oss mer realistiske datagenererte styrker som kan utføre stridsdriller og taktikk på lavere nivå med en høy grad av realisme. Krigsspill kan ha nytte av disse framskrittene. Derimot kan kunstig intelligens ennå ikke matche menneskelige beslutninger i de høyere nivåene av kommandokjeden, og planlegging og gjennomføring av simulerte operasjoner i krigsspill krever at menneskelige offiserer deltar.

Forsvarets forskningsinstitutt (FFI) har i over ti år støttet Hæren med å gjennomføre krigsspill for kapabilitetsplanlegging, med varierende grad av datamaskinstøtte. I løpet av denne perioden har krigsspillene utviklet seg fra det som kan beskrives som datamaskinstøttede krigsspill, mot mer realistiske simuleringsstøttede krigsspill. For å få en bedre forståelse av avskrekkingseffekten til styrkestrukturene, som ikke kan observeres under selve spillet, har vi også lagt større vekt på å replikere planleggingsprosessen grundigere, og spesielt på å observere planleggingsprosessen til motstanderen. Det har for eksempel vært viktig å undersøke i hvilken grad spesifikke strukturelementer forhindrer motstridende styrke i å handle på bestemte måter.

Først i denne rapporten beskriver vi kort bakgrunnen for dette arbeidet. Videre gir vi en introduksjon til krigsspill, inkludert definisjoner, nøkkelelementer, typer og applikasjonsområder, samt forholdet til modellering og simulering og eksperimentering. Deretter beskriver vi vår metodikk for simuleringsstøttede krigsspill, som omfatter en forberedelsesfase, en gjennomføringsfase inkludert en felles operasjonsplanleggingsprosess, og en analysefase. Vi diskuterer også hva slags data og resultater vi kan trekke ut fra krigsspillsesjonene, gyldigheten og kredibiliteten til krigsspill, samt simuleringssystemer som kan støtte krigsspill. Til slutt presenterer vi et sett med gode tips og råd for hvordan å gjennomføre vellykkede simuleringsstøttede krigsspill.

Contents

1 Introduction

When developing and assessing future force structures, *wargaming* is a key activity for gaining deeper insight and better understanding the strengths and weaknesses of the force structures. Today, computer-based simulation systems let us create synthetic environments that to a high degree replicate the physical properties of the real world. Furthermore, advances in artificial intelligence (AI) and behaviour modelling have given us more realistic computer-generated forces (CGF) that can execute battle drills and lower-level tactics with a high degree of realism. Wargames can benefit from these advances. However, at the higher levels of the chain of command, AI cannot yet match human decision-makers, and thus, planning and conducting simulated operations in wargames requires the participation of human officers.

For more than a decade, the Norwegian Defence Research Establishment (Forsvarets forskningsinstitutt – FFI) has supported the Norwegian Army with conducting wargames for capability planning, with varying degrees of computer-based support. Throughout this period, the wargames have evolved from what can be described as computer-assisted wargames towards more realistic simulation-supported wargames. Moreover, to get a closer understanding of the deterrent effect of the force structures, which may not be observable during the actual gameplay, our emphasis has also shifted towards replicating the planning process more properly, and especially towards monitoring the planning process of the opposing force. For example, it has been important to examine to what extent specific structure elements discourage the opposing force from taking certain actions, or in other words the war-preventive, or peace preserving, effect of the concept being wargamed.

Capability planning processes and high-profile wargames will always involve or attract stakeholders with conflicting interests. In general, there is a risk that involved stakeholders may want to frame the wargame in a context that would render their interests favourably [1]. It is important to be aware of this problem and avoid that the *wargames become a battleground for stakeholder interests*. The methodology and best practices described in this report seek to reduce this problem by using simulations with computer-based adjudication, and by raising awareness of the *metagame*, or the conflict about all phases of the wargame, from preparation, through execution, and into analysis and reporting.

This report is organized as follows: First, in Chapter 2, we briefly describe the background for this work. Next, in Chapter 3, we give an introduction to wargaming in general, including definitions, key elements, types, application areas, and wargaming's relation to modelling and simulation (M&S) and experimentation. After this, in Chapter 4, we describe our evolved methodology for simulation-supported wargaming, which includes a preparation phase; an execution phase, including a joint operational planning process; and an analysis phase. In Chapter 5, we discuss what type of data and results we are able to extract from the wargaming sessions; in Chapter 6, we discuss the validity and credibility of wargames; and in Chapter 7, we discuss simulation systems for supporting wargames. Finally, in Chapter 8, we present a set of what we have found to be best practices for how to conduct successful simulation-supported wargames.

2 Background

Wargames in various forms have been conducted at FFI for decades. However, the idea of conducting simulation-supported force structure evaluations first emerged when researchers at FFI started cooperating on scenarios for individual simulation-supported system assessments [2].

The first time an interactive, brigade-level simulation system utilizing semi-automated forces (SAF) was used as basis for a wargame at FFI, was in 2010. In the project "Future Land Forces", the performance of five fundamentally different land force structures were evaluated through a series of computer-assisted wargames [3][4]. The goal was to rank these structures based on their relative performance. In addition, the wargames revealed several strengths and weaknesses of the evaluated structures. The simulation tool we used was quite simple, but it was useful for keeping track of the movement of units and calculating the results of duels and indirect fire attacks.

Figure 2.1 Simulation-supported wargaming session at FFI in 2014.

After this, FFI has supported the Norwegian Army with conducting several simulation-supported wargaming series for capability planning, both on-site and at the Norwegian Army Land Warfare Centre. The wargames have been two-sided (Blue and Red), closed (with limited available information) and run at the tactical and operational levels, and the simulated operations have included land forces sized between a battalion and a brigade on each side. The total number of players has been anywhere between ten and one hundred, and the duration of a wargame has varied from one day to two weeks. Figure 2.1 shows a picture from a simulation-supported wargaming session at FFI in 2014.

Since 2010, our wargames have gradually evolved from what can be described as computer-assisted wargames towards more realistic simulation-supported wargames. In addition, to get a closer understanding of the deterrent effect of the force structures, which may not be observable during the actual gameplay, our emphasis has also shifted towards replicating the planning process more properly, and especially on monitoring the planning process of the Red force. Figure 2.2 illustrates the evolution of our wargames.

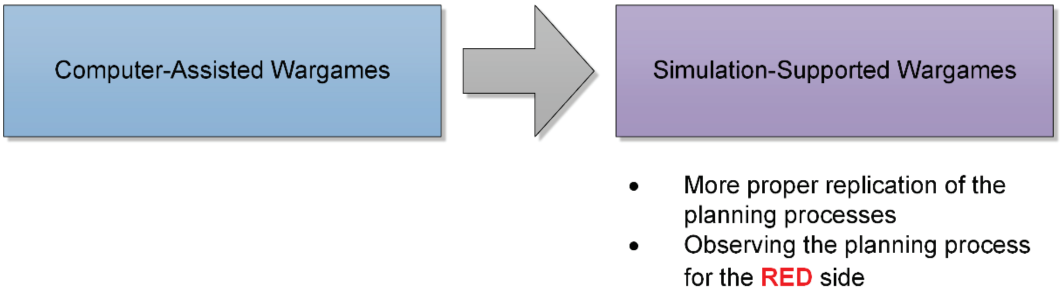

Figure 2.2 Evolution of our wargames.

3 Introduction to wargaming

We do not really know when humans first started wargaming, but the concept of using small objects to represent the manoeuvre of warriors is probably almost as old as war itself. Professional wargaming in its modern form, however, originates from a game known as the *Kriegsspiel*, developed in Prussia in the 1820's. The *Kriegsspiel* was the first wargaming system to be adopted by a military organization for professional use, like analysis and training. While the Prussians were the first to embrace wargaming, other nations soon followed. Figure 3.1 shows a re-construction the *Kriegsspiel*.

History has shown that the interest in wargaming tends to go in cycles. Presently, we are again seeing an increasing interest in wargaming, both in Norway and internationally. For the last few decades, wargames have also had the opportunity to benefit from increasingly realistic computer-based simulations. In this chapter, we present an introduction to wargaming in general. We look at definitions, key elements, the course of a wargame, types, application areas, and the relation to modelling and simulation (M&S) and experimentation.

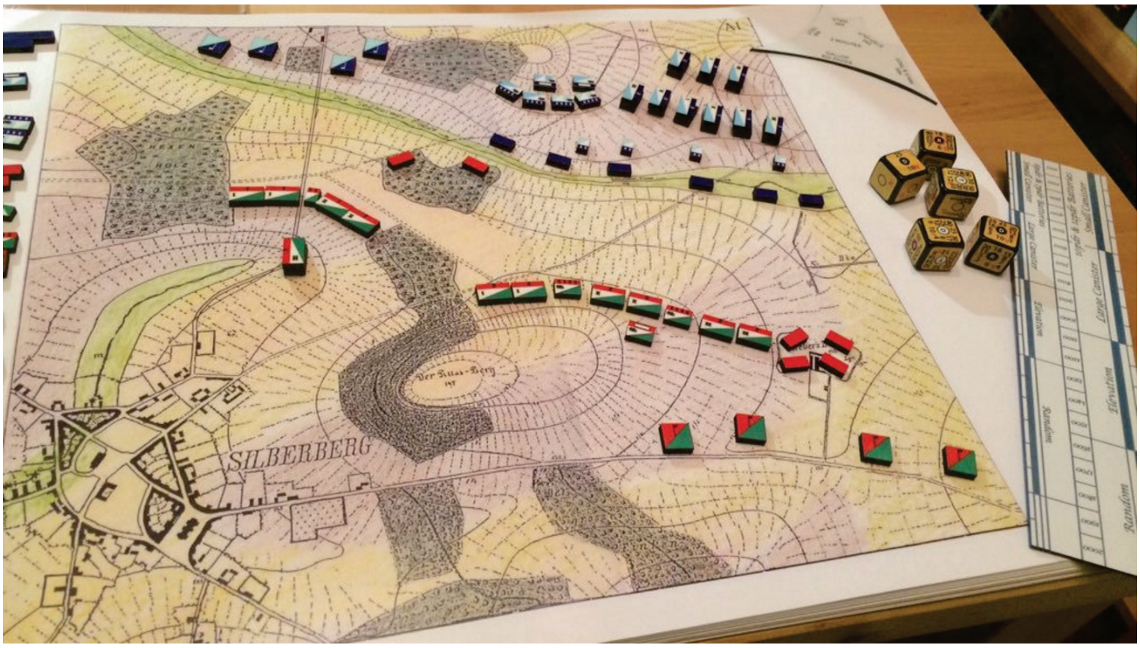

Figure 3.1 A reconstruction of the Kriegsspiel developed in Prussia by Georg Heinrich Rudolf Johann von Reiswitz in 1824 (Matthew Kirschenbaum).

Military innovation thrives during wartime. Explanations as to why this is the case may differ depending on how one perceives innovation, but for instance Hill & Allen consider this process to be evolutionary, involving an element of luck [5]. It may be that a simple mechanism of selection is at work. Only the innovators that live to tell the tale leave ideas that may be propagated to others. In peacetime, the wargame ideally replaces the war as a vessel for destruction of poor ideas. Thus, wargaming is important for military innovation. No ideas, whether old or new, should be considered sacred. Even though wargaming may not be a perfect and incorruptible tool for testing innovative ideas, it is better than the alternative. The worst innovation processes involve group thinking, organizational infighting and power struggle, and innovations may end up not even being tested before they are brought to the battlefield.

3.1 Definitions of wargame

NATO (North Atlantic Treaty Organization) defines a wargame as "a simulation of a military operation, by whatever means, using specific rules, data, methods and procedures" [6]. In his book *The Art of Wargaming: A Guide for Professionals and Hobbyists* [7], wargame expert Peter Perla defines a wargame as "a warfare model or simulation that does not involve the operations of actual forces, in which the flow of events affects and is affected by decisions made during the course of those events by players representing opposing sides". The essential parts of a wargame, emphasized in Peter Perla's definition, are the *human players representing opposing sides* and *their decision-making*. In this report, we use Peter Perla's definition.

In his book *The Human Face of War* [8], the British defence analyst and former officer in the British Army, Jim Storr stresses that "although war currently appears to be dominated by technology, warfare is fundamentally a human issue" [8]. As a representation of war, Peter Perla argues that the "active and central involvement of human beings is the characteristic that distinguishes wargames from other types of models and simulations" [7]. Furthermore, "a value unique to all [wargames] is the occurrence of previously unknown issues, insights, or decisions that arise during the conduct of a game" [9], especially when facing a determined and dynamic opponent.

3.2 Elements of a wargame

Professional wargames, which are wargames where the primary purpose is professional use like analysis or training (and not entertainment), typically consist of the following key elements [7][10][11]:

- **Objective:**
  The objective states the purpose of the wargame, i.e. what one wants to get out of the wargame. This could for example be to gain insight into the strengths and weaknesses of a new force structure, to test a plan for a specific mission, or to train officers in decision-making under pressure.

- **Scenario:**

  The scenario outlines the circumstances for the wargame. It describes the geographic area, environment, background, time frame, means and objectives for the different sides, and events related to the wargame.

- **Data:**

  A wargame includes three types of data: initiation data, feedback data and analysis data. The initiation data are the data available to the players before the wargame and the data used for configuring and calibrating the models and tools used by the wargame. Examples of such data are background information, forces available and their capabilities and intelligence information. The feedback data are the data available to the players during the wargame. Examples of such data are positions of forces and outcomes of engagements. The data available to the players before and during a wargame should mirror the data the players would have available in an actual real-life situation. The analysis data are all the data produced during the wargame that need to be collected for use in the analysis.

- **Methods, models, and tools:**

  A set of methods, models and tools constitutes the framework for the wargame execution. Typically, a wargame needs an overall method for how it should be conducted, including what wargame type (see Section 3.4) to use. Furthermore, a wargame needs a method for data collection. Models and tools used by a wargame can for example be physical models on a paper map or a computer-based simulation system.

- **Rules:**

  The rules dictate how and when the methods, models and tools are applied. For example, they control the information the players receive during the wargame and dictate how the result of the events in the wargame are adjudicated. The rules can be enforced manually by *adjudicators* or *umpires*, or they can be automatically enforced by computers.

- **Players:**

  The players typically represent two (Blue and Red) or more sides in a conflict situation or war. They are usually assigned different roles, for example Blue Army Commander or Red Air Force Commander.

- **Analysis:**

  This element is first and foremost important for wargames for research and analysis. The analysis involves observing and collecting data from the wargame. Furthermore, it typically seeks to understand what happened during the wargame and why. Analysis is often crucial for meeting the wargame objective.

Figure 3.1 illustrates the key elements of a wargame and their relationship.

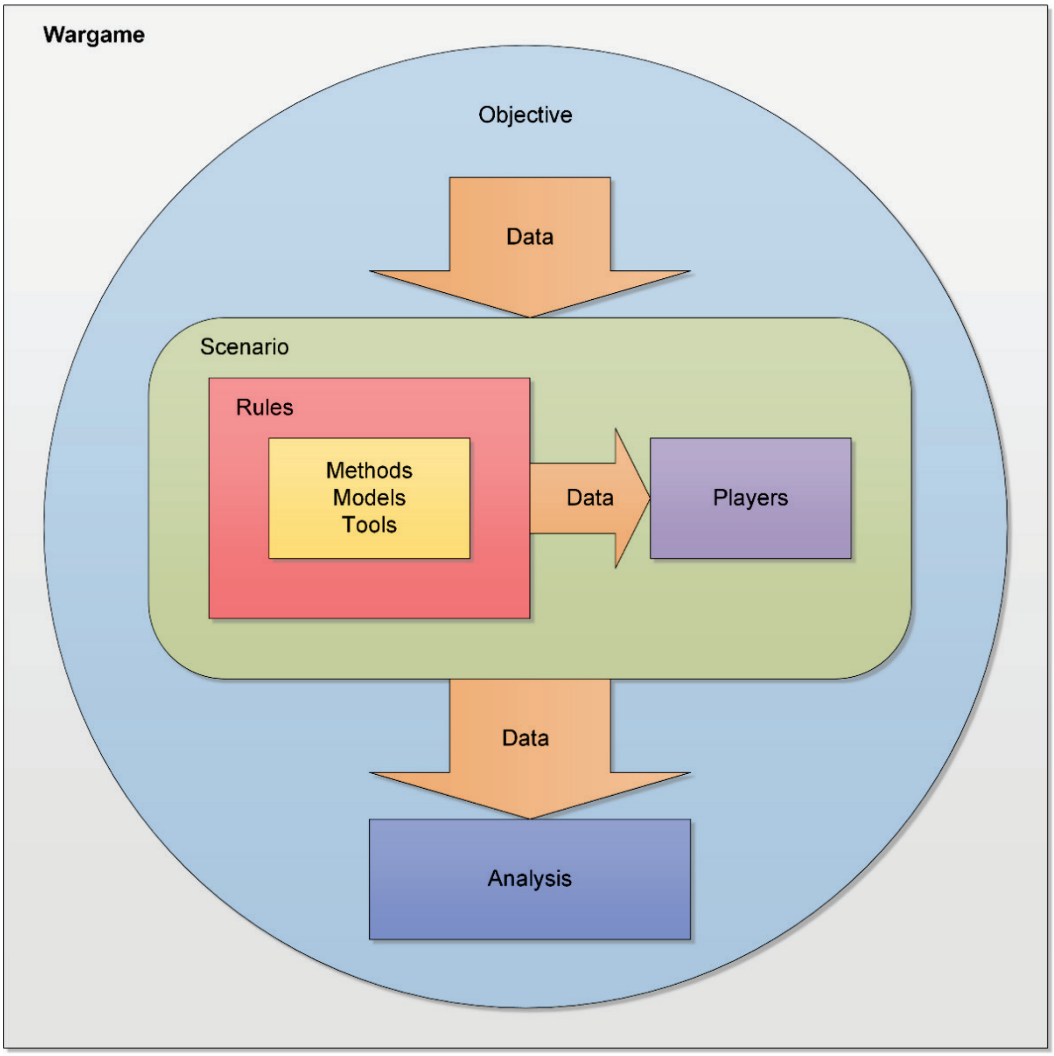

Figure 3.2   The key elements of a wargame.

3.3 The course of a wargame

Conceptually, most wargames by and large follow the same basic course from start to finish. From a set of *initial conditions*, which describe the state of the simulated world at the beginning of the wargame, the Blue and the Red side typically take actions that changes the state of the simulated world. For example, if the wargame starts with an action from the Red side, this action will typically be met by an action (as a reaction to the Red side's action) from the Blue side, which again will be followed by an action from the Red side, and so on – until the wargame finally ends. In *turn-based* wargames the sides take actions in turns, while in *continuous* wargames (like most simulation-supported wargames) there are no restrictions on when actions can be taken. Figure 3.3 illustrates the course of a turn-based wargame with alternating actions from the Red and the Blue side. Each new state of the simulated world can be manually determined by adjudicators or umpires, or calculated by computers.

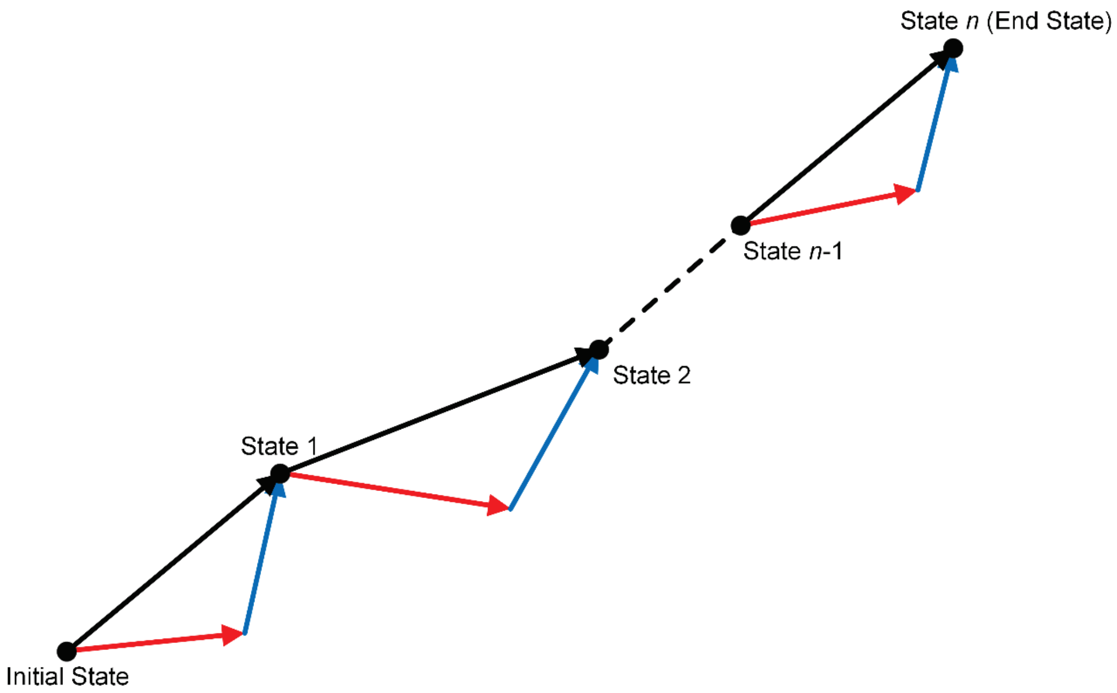

Figure 3.3 The course of a wargame with alternating actions. Red arrows show actions from the Red side, and blue arrows show the actions from the Blue side.

3.4 Types of wargames

There are several types or styles of wargames, ranging from simple seminar-type, discussion-based wargames to more detailed wargames with physical models on a paper map, and on to even more detailed wargames with computer-based simulation support. The different types of wargames have different advantages and disadvantages regarding their complexity of setup and execution, resource usage, fidelity, and credibility (see Chapter 6). Figure 3.4 illustrates the spectrum of different types or styles of wargames.

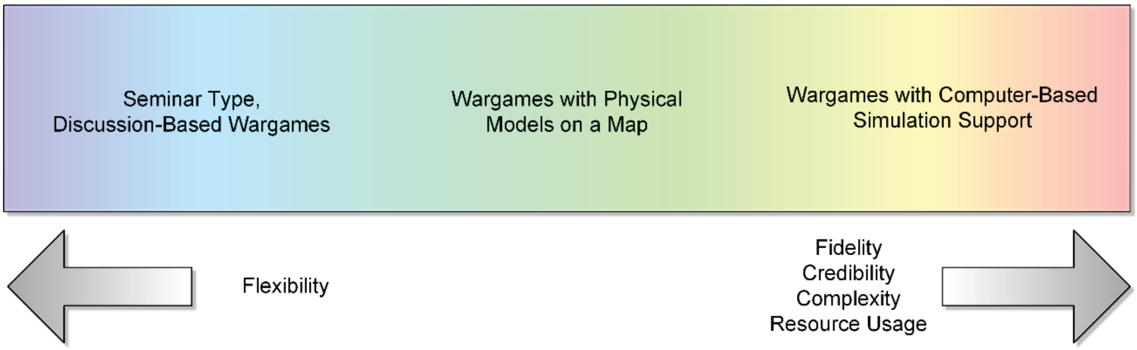

Figure 3.4 Spectrum of different types or styles of wargames and their associated flexibility, fidelity, credibility, complexity of setup and execution, and resource usage.

Seminar-type wargames are more flexible, can be relatively easy to conduct, require few resources, and are often used for exchanging, challenging, and developing new ideas, especially in the early phase of a study or capability planning process. Furthermore, strategic and political-military wargames are often conducted as seminar-type wargames. This type of wargames, however, are adjudicated by human adjudicators or consensus among the participants and can therefore more easily become too strongly influenced by the participants' opinions and assumptions. They therefore tend to elicit less credibility than wargames adjudicated by more clearly defined rules or computer-based simulations.

Manual wargames will in general have a lower fidelity than wargames with computer-based simulation support. According to Peter Perla, the classic problem with manual wargames is how to "reproduce enough of the physical reality without so overburdening the player with game artificialities that his experience of play only vaguely resembles real-life command" [7]. On the other hand, wargames with computer-based simulation support generally require more resources and usually take more time to prepare and conduct.

The value of using computer-based simulations to support wargaming lies first and foremost in having a system to automatically keep track of the forces, calculate the detections of their sensors, and evaluate the results of duel situations and indirect fire attacks. In addition, computer-based simulations are well suited for realistic representation of uncertainty and *fog of war* by adding filters on the ground truth.

Which wargaming type to use will of course depend on the actual research question or study, in addition to available time and resources. Not every study requires a simulation-supported wargame with the highest available fidelity. When selecting an approach, "[t]he key consideration, apart from resource availability, is determining what is the lowest level of cost/venue necessary to provide a valid product which meets the specific study requirement" [12].

3.5 Application areas

There are mainly two application areas for professional wargames:

1. Training and education
2. Research and analysis (e.g. capability planning or plan testing)

This is illustrated in Figure 3.5.

In this report we focus on wargames for research and analysis, also known as *analytical wargames*, and especially analytical wargames aimed at assessing force structures. The general purpose of analytical wargames is to *gain insight into complex issues related to warfare*. As former U.S. Deputy Secretary of Defense Robert Work and General Paul Selva (U.S. Air Force, retired) expressed it, "[Analytical] [w]argames provide opportunities to test new ideas and explore the art of the possible. They help us imagine alternative ways of operating and envision new capabilities that might make a difference on future battlefields" [13].

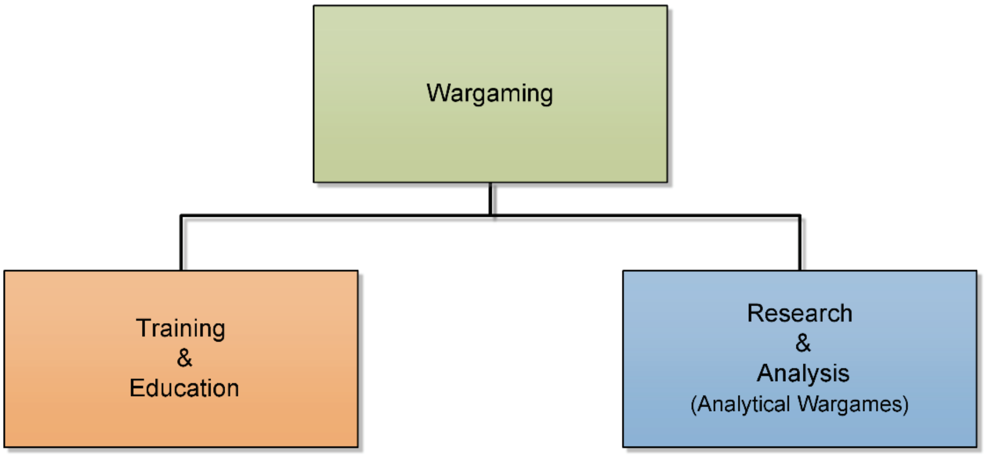

Figure 3.5 Applications areas for professional wargames.

3.6 Modelling and simulation, wargaming and experimentation

The scenario, data, rules, and players of a wargame form a model of warfare. The execution of that model over time is a simulation. When we use the term "simulation-supported wargame", we mean a wargame supported by computer-based simulations. A simulation-supported wargame can in M&S terminology be classified as a *human-in-the-loop* (HITL) simulation where the human players interact with a *constructive simulation* with *semi-automated forces* (SAF). The human players are thus a part of the simulation as a whole. A characteristic of HITL simulations is that the humans influence the outcome in such a way that it is difficult, if not impossible, to reproduce exactly [14].

M&S is essential for most defence experimentation. Analytical wargames can be categorized as a type of experimentation known as *discovery experimentation*. Discovery experimentation involves introducing novel systems, concepts, organizational structures, technologies, or other elements to a setting where their use can be observed and catalogued [15].

M&S, wargaming and experimentation are in many ways fundamentally intertwined. They all exist on a spectrum ranging from very simple to highly complex, and there are several opportunities for cross-domain solutions between these techniques [16].

4 Methodology for simulation-supported wargaming

Wargaming is an essential tool for developing, testing and analysing new force structures. Through wargaming it is possible to gain insight into how well suited a force structure is for a given scenario, and reveal the structure's strengths and weaknesses. Having a good execution plan is, however, paramount for conducting successful wargaming experiments and getting the most out of the collected data from the events. In this chapter we describe our methodology for simulation-supported wargaming, which has evolved through our experiences with planning, execution, and analysis of wargaming experiments over the past ten years.

In addition to Peter Perla's book [7], there are several guides for wargaming in general [9][11]. The methodology described in this chapter is specially tailored towards analytical wargaming for supporting the development of future force structures. Typically, we use this methodology to assess and compare the performance of different force structure alternatives, which may vary with regard to *composition of materiel and equipment*, *tactical organization*, or *operational concept*.

Our methodology for wargaming experiments consists of three major phases:

1. Preparation phase
2. Planning and execution phase
3. Analysis phase

The phases are described in detail in the sections from 4.2 to 4.4, respectively. The relationship between the different phases is illustrated in Figure 4.1, where the planning process and the war-game execution phase constitute the core of the experiments.

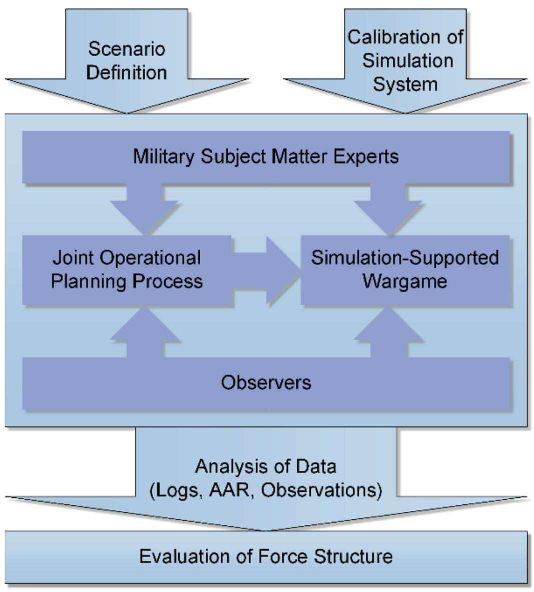

Figure 4.1 Illustration of methodology for wargaming experiments.

4.1 Context around wargames

Small countries face a dilemma when developing force structures to deter enemies with a larger pool of force elements. The enemy may observe what changes are made in the defence structure and may select other, and more suited, elements from the pool when applying military power. For example, if the small country's force structure is specialized, in order to counter expected enemy courses of action (COAs), the enemy may choose something entirely different from his pool and the enemy COA may change dramatically.

Developing force structures is a slow and public process for all nations. Selecting units from an existing, large pool of force elements and creating new COAs is a fast and hidden process. It may seem like an impossible task for a small nation to achieve deterrence under such circumstances, but we have observed in several instances how low-cost changes to the force structure have had a big impact on the COAs that the enemy may consider using [17][18][19]. The changes to Soviet tactics in Afghanistan after the introduction of hand-held air defence missiles for the mujahideen in 1988 [20] is a good example of the kind of effect we have seen during the Red cell's planning process in wargames. Presence and posture were also observed to have a deterrent effect. In addition, society, landscape, and climate influenced the Red planning process. This all comes down to risk assessment on the enemy side during planning and development of COAs. In order to investigate the deterring impact of force structure changes, it is necessary to have analysts observe the planning process of the Red cell *before* a wargame, and not only during the simulated battle. Deterring the enemy from attacking is the intention of any force structure development, and the only way to observe the deterrent effect is during enemy planning.

In decision theory, risk is a necessary factor to consider to be able to make rational choices. The von Neumann-Morgenstern (vNM) decision theory is based on actors assessing choices by considering lotteries with given probabilities and outcomes [21]. The element of risk also needs to be present in planning processes. If the planning process of one side is known to any other side participating in a wargame, a part of the element of risk disappears. This would reduce the planning process to just assessing a known enemy COA, as opposed to assessing a spectrum of possible COAs and their probabilities. Therefore, it is important that the scenario definitions do not limit the enemy planning process, and that all planning processes are monitored, and especially the enemy planning process.

4.1.1 Metagame

Whereas a wargame has rules when it eventually starts, the process of choosing the type of wargame and the context around it has no clearly defined rules. As such, the process of planning and organizing a wargaming event may be viewed as a *metagame*, or a game that may be analysed within the rules of confrontation analysis [22]. For instance, a wargame at the joint level would include participants that traditionally are rivals for funding. Participants from the air force, the navy and the army may have differing interests when it comes to how scenarios should be formulated, what assumptions that should be made about future technology, how combat effects should be assessed, and so on. The same goes for branches within each of the domains. There is therefore a danger that the metagame may have more influence on the outcome of a force structure analysis than the actual wargame. The metagame is not limited to the wargaming execution. The fight about the analysis and the reporting afterwards is also subject to conflict of the same type that occurs during preparations. This is illustrated in Figure 4.2 by the metagame layer that exists outside the core methodology.

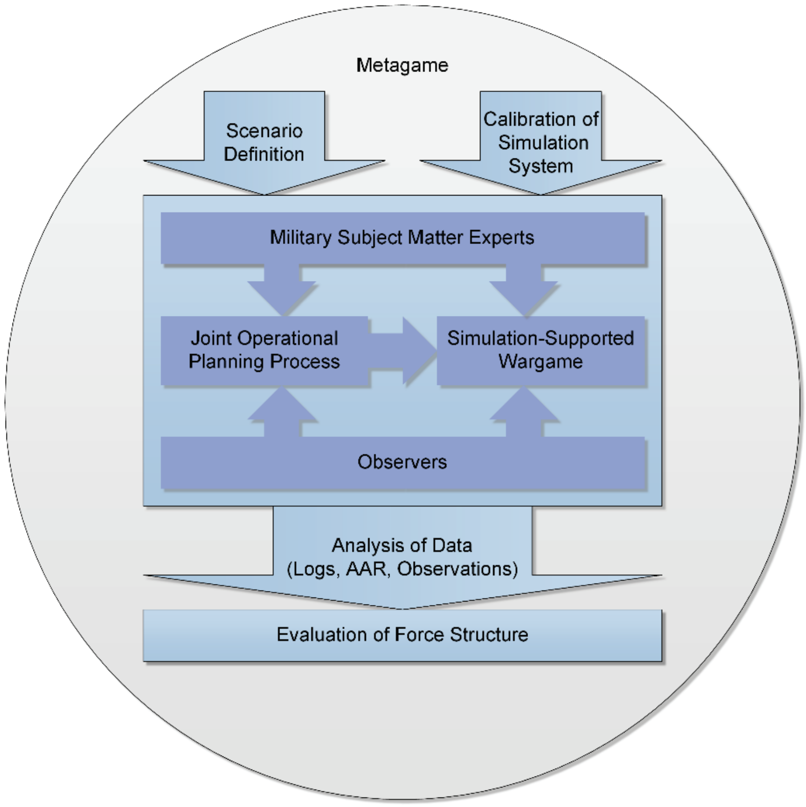

Figure 4.2 Illustration of the metagame surrounding the methodology for wargaming experiments.

Capability planning processes will always involve or attract stakeholders with conflicting interests, and the defence planning and wargaming contain many examples of stakeholders fighting for turf [1][7]. This is especially noticeable in the preparation phase of wargames. One possible way to counter this can be to properly separate the role with the power to invent changes in the force structure from the role with the power to assess and accept changes. When these roles are not separated, stakeholders will try to influence both what should be the objective of the war-game, and what method to use. In the worst case we may have a limited number of stakeholders suggesting new force structure, and then have the same stakeholders verifying that their own ideas were good simply trough *scenario-based discussions*. This is especially problematic if it is the stakeholders' cherished ideas that are at being assessed.

The Joint Requirements Oversight Council (JROC) is a good example of an institution that handles the turf war with a sound decision structure [23]. The way the U.S. military separates the inventors of ideas from the power to review their usefulness is entirely in accordance with

Montesquieu's principle of separation of powers, though on a smaller scale than the political. In Norway, the way defence planning and wargaming in many cases have been carried out, one will find actors both generating ideas for future force structures and assessing the same structures by participating in scenario-based discussions. Scenario-based discussions, which do not include a dedicated Red cell, are not wargames. Introducing Red cell players, and free and unhindered planning on the opposing side, removes some of the potential for misuse of power. A peculiar result of not wargaming proposed force structures properly has been the recommendation of force structures suboptimized to combat fixed assumed enemy COAs. By not properly wargaming such force structures, the proponents of the structural changes succeed in beating their favourite enemy COAs, but fail at challenging their own ideas.

4.2 Preparation phase

The preparation phase includes everything that needs to be done before the wargame execution phase can be started. The most important preparations are:

- Establishing a common understanding of the objective of the wargaming experiments
- Defining overall scenario, including external conditions, assumptions, and limitations
- Choosing one or more simulation systems and calibrate simulation models
- Defining order of battle (OOB) for Blue and Red side

4.3 Planning and execution phase

The planning and execution phase consists of two separate activities: (1) a joint operational planning process for both sides, and (2) the simulation-supported wargame.

4.3.1 Joint operational planning process

In this activity, the Blue and Red cell separately develop their initial plan for the operation based on the overall scenario and a controlled flow of intelligence information. The plans are preferably not a part of the overall scenario, and both sides can develop their plans freely. This also means that the plans developed by the two opposing sides remain unknown to the other side.

The joint operational planning process can in principle be done in much the same way as in reality, without any simplifications. This is an activity that should be prioritized in the same way as the simulation-supported wargame, also with regard to staffing.

During the planning process, the players must discuss different options and develop a COA that is shaped by the perceived strengths and weaknesses of the opposing force structure. Observing the planning process on both sides and revealing the underlying reasons for the decided COA can give valuable information regarding a force structure that may not be observable in the execution of the wargame itself. The deterrent effect of a force structure is an example of something that may only be observable during the planning process.

4.3.2 Simulation-supported wargame

The wargame itself is conducted as a simulation-supported, two-sided (Blue and Red) wargame, where the operation is simulated in a constructive simulation system with SAF. Within game theory, this type of wargame can be categorized as a *non-cooperative, asymmetric, sequential game of imperfect information*.

The actors in the wargame are the players on both sides and a cell of umpires or adjudicators. It is important to remember that a wargame is only as good as its players. The players are military subject matter experts (SMEs) and officers. To have a balanced wargame, it is crucial not to neglect the Red cell. Done right, this type of wargame, led by adaptive and largely unrestricted thinking opponents, tends to become highly dynamic, adversarial, and competitive.

For analytical wargames, realistic simulations are important to strengthen the validity and credibility of the results (see Chapter 6). Military operations, and especially land force operations, are complex in nature, and simulations of such operations, with sufficient realism, is very challenging [14]. Moreover, simulation systems can contain errors, and human operators can make mistakes that they would not have made in real life. It is therefore important to have experienced umpires that monitor the simulation and, if necessary, make appropriate manual adjustments to the outcomes.

The metagame to some degree also comes into play during the simulation-supported wargame. There have been examples of stakeholders withdrawing competent officers from wargames, only to replace them with less skilled personnel, most probably to reduce the credibility of a wargame that the stakeholder did not want to be successful. Other examples are umpires struggling against interventions from higher-ranking stakeholders visiting the wargame. History is full of similar examples [7] and Norway is no exception [1]. The clear methodological approach described in this report intends to counter some of the shortcomings of previous wargaming experiments.

4.4 Analysis phase

The analysis is based on observations and data from the planning process, in addition to the observations and data collected from the execution of the simulation-supported wargame itself.

During the planning process, it is important to monitor and document the discussions closely. The primary purpose of a defence force, at least in Norway, is to prevent war; therefore, the considerations made in the planning process are perhaps the most important results from the entire wargame. The preventive properties of a force structure and a posture can only be observed when the enemy considers them before a wargame starts. Several alternative COAs and manoeuvres are usually considered during the planning phase. Many of these are discarded, and some are retained, for various reasons. These reasons must be recorded. Why Red decides that a certain COA is not viable may be due to certain structure elements or expected strategy from Blue. If Red has to abandon a plan due to elements in the Blue OOB, then these elements have already proven valuable to Blue – even if these elements end up not inflicting any direct damage to Red forces during the following simulated operation.

During the actual simulation-supported wargame, a large amount of data may be recorded. It is tempting to put a lot of importance on data such as the loss exchange ratios of various structure elements. What is perhaps more important to pay attention to during the actual wargame, are the decisions made by the commanders on both sides. If a window of opportunity arises for one of the sides, why is that? How is that side able to exploit such an opportunity? Are there any ways in which they consider exploiting the opportunity, but somehow are unable to exploit or carry through? If so, why? To collect such information, it is important that the commanders openly discuss their options. It is not only why they make the choices they do that is important, it may often be equally important why other choices are *not* made.

Identifying major strengths and weaknesses of a force structure and its utilization is an important part of the analysis phase. Examining the considerations made by both sides, both during the planning phase and the wargaming phase, is the best way to do this. This is not an exact science as such data are qualitative in nature. Key elements that made it possible to use a certain COA, or perhaps a missing capability which allowed the enemy better options, are better identified by observing the considerations and decisions made by the players than looking solely at what weapon systems destroyed which enemy systems.

The analysis phase may also be subject to fights outside the context of the agreed-upon wargame methodology. Even the report writing after the event may be influenced, when roles are not well separated, and stakeholders are allowed to disproportionately influence the process.

5 Output data and results from wargames

In general, we strive to capture as much data as possible from the wargaming sessions. Depending on the simulation system used to support the wargame, a variety of output data can be recorded. It is for instance usually possible to record how far various units have moved, how much ammunition and fuel they have used, and other logistical data. *Kill matrices* are also usually recorded. This is essentially a matrix showing which units on one side killed which units on the other side. A lot of other quantitative data can also be recorded. In addition to this comes all the qualitative data. This includes, as noted earlier, observation of the planning process, and discussions with the players involved in the planning process. Moreover, it includes observations of decisions made during the wargame, and discussions with the players during or after the wargame.

It is often tempting to put a lot of weight on quantitative data, such as the kill matrices, and perhaps less weight on qualitative data. Quantitative data are easier to analyse and are often considered more objective than qualitative data like the decisions and considerations of the players. However, it is important to remember that the quantitative data are dependent on the decisions of the players on both sides, as well as input data to the model. How the players believe various units should be employed, has a considerable impact on the kill matrix. Thus, although such data are quantitative, they are not more objective than the qualitative data.

Data such as the kill matrices also omit important information. One can see which units killed which opposing units, but the reasons are lost. Other units, which did not directly destroy enemy units, may have been vital in creating the conditions for other units to be effective. Although certain units may have destroyed very few enemies, their presence on the battlefield may have been vital in preventing the enemy from conducting certain operations. For instance, the presence of close air defence may not cause said air defence to kill more enemy helicopters but may have prevented the enemy from using helicopters as aggressively as he might otherwise have. Thus, when analysing a wargame, one should be cautious about looking solely at quantitative data like the kill matrix. The whole picture must be taken into consideration.

Ideally, when comparing different force structures, several wargames should be conducted with each force structure, and the enemy should be allowed to alter his conduct in each wargame. Own forces should find the “best” way to utilize their structure in the given scenario, and the enemy should find the “best” way to counter this strategy. Only then, can one truly compare the outcome of the wargames with different force structures and conclude as to which force structure was most suitable for the given scenario. And then, of course, there is truly a wide range of possible scenarios to consider. So, while this is perhaps how comparisons of force structures should be done, time and resources will usually be insufficient for the vast number of wargames needed in order to do so.

All models have limitations. They may be designed for a specific purpose, and be appropriate for that, but less suitable for other things. This is important to remember when considering which questions can be answered through wargames, and which questions should be investigated with other tools. Exactly what can be deduced from a wargame will depend on the model being used, but generally one should focus on those questions that the experiment was designed to answer. If other results seem to emerge from the experiment, their validity should be examined, and the results often need to be evaluated in an experiment specifically designed to investigate these emerging questions.

Wargaming, as discussed in this report, is an essential tool for comparing the performance of two (or more) force structures in a given scenario. Wargames do not, however, give any precise measure of the effectiveness of any given force structure, but are suitable for identifying major strengths and weaknesses. The effect of parameters related to specific units, like their firepower and armour, should be further examined in separate studies. Such factors, although they are important, are at a level too detailed for their impact on the outcome to be studied through the types of wargames we discuss in this report. Peter Perla emphasizes that "[w]argaming is only one of the tools needed to study and learn about defence issues" [7]. Other tools should be used to supplement the wargames and study the importance of such factors.

Wargames are often substantial events, involving a large number of people and taking a lot of time. Thus, we are usually restricted to a limited number of wargames – often only one for each force structure we are analysing. It is important to remember that the outcome of one single wargame is just that: one possible outcome of the given situation. Things could have been done differently by players on both sides, and events might have played out differently. Slight changes could have affected the outcome of an event that was vital to the overall outcome.

6 The validity and credibility of wargames

Wargames can of course not be used to predict the outcome of a battle or a war, but they can produce plausible outcomes. The term “indication” has been suggested to describe any insights drawn from the outcome of a wargame [24][25]. “At its best [knowledge produced by wargames] can indicate the possibilities of a projected warfare situation and certain potential cause-and-effect linkages” [24]. Wargames can typically indicate that “if situation A occurs and if Red does B and if Blue does C, it is more likely than not that D will be the outcome” [25].

In [24], Robert C. Rubel writes that “the gaining of knowledge is inherent and unavoidable, whatever a [war]game’s object. The real question is whether such knowledge is valid and useful”. The validity of knowledge in general can be said to be a measure of how accurately it corresponds to the real world from the perspective of being useful for problem solving [24]. More specifically, the validity of a model or simulation is a measure of how accurately it represents the real world, from the perspective of its intended use. In [7], Peter Perla defines the validity of a wargame as “the extent to which its processes and results represent real problems and issues as opposed to artificial ones generated only by the gaming environment”. In this chapter, we discuss the factors that can affect the validity and credibility of wargames.

Wargames are human-in-the-loop (HITL) simulations. The simulation as a whole consists of the human players and the simulation of the world around the human players in which the wargame takes place. This is illustrated in Figure 6.1. The validity of a wargame thus depends on the validity of the decisions of the human players and the validity of simulation of the world around them. We can therefore say that the *validity* of a wargame is *a measure of how accurately the simulation of the world around the human players represents the real world and the decisions of the players match the decisions that would have been made in the real situation*. Models are of course always simplifications of the real world and can never be absolutely valid. The validity of a wargame must therefore always be considered from the perspective of its objective.

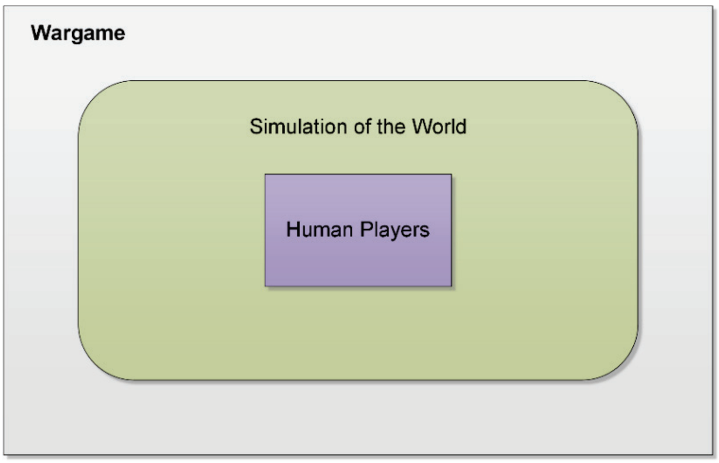

Figure 6.1 Wargames consist of human players and a simulation of the world around the human players.

Fidelity is a term that is used to describe *how closely a model or simulation matches the reality*. Generally, a higher fidelity of the simulation of the world around the human players will increase the overall validity of the wargame. Today, it is possible to create synthetic environments that to a high degree replicate the physical properties of the real world. Modelling realistic human behaviour and cognition, on the other hand, is recognized as the hardest and most complex challenge in combat simulation [26]. Anyway, in practice, available time and resources are usually the limiting factors for the fidelity of the simulation of the world around the human players.

A wargame is only as good as its players. Examples of factors that can affect the validity of the decisions made by the human players are:

- How closely the players' jobs in the real world match their roles in the wargame. In a wargame, the players tend to make decisions one, two or three grades above their own [23].
- Sufficient knowledge among the players, for example regarding a new system or concept being tested [24].
- For the players representing the Red side it can be difficult to make the same decisions as the real Red decision-makers would make [23].
- Players tend to make more aggressive decisions in a wargame than they would in a real situation, since no real lives are at stake [24][25].
- The fidelity of the simulation of the world around the human players will typically affect how realistic they perceive the situation and how they act, but it is in any case not possible to replicate the pressure and stress that commanders experience in real combat.

It is, of course, also a fundamental assumption of any analytical wargame that the players will do their best to try to win, at least within the limitations of their side's doctrine, and make the best decisions that they can [24]. The main challenge with validating wargames (and combat simulations in general) is that it is most often not possible to compare the outcomes and results to real-world situations (which by all means is not a bad thing).

The *credibility* of a wargame can be understood as *a measure of how likely its outcomes and results are to be considered as sufficiently valid, and thus acceptable, for a specific purpose*. In more simple terms, we can say that the credibility of a wargame is a *measure of how much confidence it is reasonable to have in its outcomes and results*.

It is important to note that a wargame with high validity not necessarily will elicit high credibility. For example, a wargame with high validity can have an outcome that is considered too unlikely, or even too uncomfortable and somewhat threatening, by stakeholders, and one that therefore will not be accepted. Similarly, a wargame that elicits high credibility will not necessarily have high validity. A wargame with high validity, however, deserves high credibility, and a wargame with low validity deserves low credibility. To be useful and widely accepted, a wargame needs to have both high validity and high credibility.

In his book *On Wargaming: How Wargames Have Shaped History and How They May Shape the Future* [25], Matthew B. Caffrey Jr. points out two principal factors that can affect the credibility of, or the confidence we should have in, a wargame:

1. The difficulty of what is being wargamed.
2. The quality of the wargame execution.

For assessing the difficulty of what is being wargamed, the following factors can be useful to consider:

- **Level of war:**
  Wargames at the tactical level are typically easier to adjudicate than wargames at the strategic level. It is therefore reasonable that outcomes of wargames at the tactical level have relatively higher credibility than outcomes of wargames at the strategic level [25].

- **Physics vs. human factors:**
  Wargames that involve physical effects, such as ballistics and weapons effects, are easier to simulate and therefore tend to have higher credibility than wargames that involve human effects, such as winning hearts and minds. Similarly, wargames that involve kinetic effects tend to have higher credibility than wargames that involve non-kinetic effects, such as morale, training and "second-order-and-higher" effects [25].

- **Culture of Red side:**
  It is easier to play the Red side more accurately in wargames where the Red side has a culture that is similar to our own than in wargames where the Red side has a culture that is substantially different from ours (for example regarding willingness to take losses). Wargames where the Red side has a similar culture therefore tend to have a higher credibility [25].

- **Time frame:**
  The shorter the time frame a wargame covers, the higher the credibility it tends to have. This is simply because there are fewer opportunities for the wargame to go off in the wrong direction [25].

- **Attrition vs. effects:**
  Aggregate-level, attrition-based models tend to match historical data more closely than current entity-level, effect-based models [27][28]. Wargames that use attrition-based models therefore tend to have a higher credibility than wargames that use effect-based models [25].

It is generally also more difficult to adjudicate wargames that involve new areas within warfare that are not yet well understood. Examples of such areas can be cyberwarfare, hybrid warfare, and multi-domain operations.

The quality of the wargame execution depends on the quality of the preparations, the quality of the human players, and the quality of the simulation of the world around the human players. We have already discussed important factors that can affect the validity of the decisions made by the human players and the validity of the simulation of the world around them. Many of the same factors can affect the credibility.

Other factors that may affect the credibility of a wargame are:

- Involvement of stakeholders and decision-makers.
- History and reputation of the organization facilitating the wargame.
- Reputation of the wargaming type or style being used.
- Reputation of the methods, models and tools being used (for example the software used in a simulation-supported wargame).

A final factor that tends to increase the credibility of the outcome of wargames is the number of times a wargame is repeated. If a wargame is executed only once, there is no way of knowing whether the outcome is among the most likely ones or one of the outliers. The more times a wargame is executed the clearer the pattern of which outcomes are relatively more and less likely will be [25]. It is, however, important to note that a wargame can never truly be repeated since the initial conditions can never be precisely the same. Even if the players are the same persons, they will not truly be identical, since they would have experienced and learned something during the previous play [7].

The number of times a wargame is repeated will often also increase the validity. However, this does not guarantee increased validity. "Multiple wargames all using the same faulty assumptions can produce the same misleading insights" [25].

7 Simulation systems for wargaming

According to Peter Perla "[t]he key to realistic wargaming lies in balancing the player's experience in his decision-making role with as accurate a representation as possible of the physical outcomes of his own decisions, his opponent's decisions, and the objective dynamics of combat" [7]. Modern computer-based simulation systems include synthetic environments that replicate the physical properties of the real world and CGF that can autonomously execute battle drills and lower-level tactics. Wargames have the potential to exploit these increasingly realistic interactive simulation systems, but the simulation systems must be easy to operate for the players and require relatively few operators.

The simulation system we used when we first started with simulation-supported wargaming at FFI in 2010 was quite simple and suffered from several significant weaknesses. This often resulted in questionable simulation results. For example, the simulation systems did not support representation of micro-terrain features, and this led to a systematic favourization of long-range, direct fire weapon systems. Additionally, the human behaviour models for the SAF were very simple, and this required a lot of micromanaging from the players [29][30][31].

A few years later, when we saw the need to establish a new capability for conducting more detailed, entity-level, constructive simulations to support wargaming at FFI, we could not find any single simulation tool that was satisfactory for our use. We found that traditional constructive simulation systems often were too complex and cumbersome to use, did not have the required level of fidelity, or were not flexible enough with respect to representation of new technologies, for example new sensor systems, weapon systems, or protection systems.

To satisfy our requirements, we started to develop *webSAF*, an easy-to-use, web-based graphical user interface (GUI) for controlling semi-automated entities in constructive simulations [29][30][31]. The system was named webSAF to reflect that it is a web-based system for controlling semi-automated forces (SAF). webSAF is tailored for simulation-supported, two-sided wargaming and requires only a minimum number of operators on each side. Currently, webSAF has functionality for controlling indirect fire and manoeuvre entities simulated in Virtual Battlespace (VBS) from Bohemia Interactive Simulations (BISim) and air defence entities simulated in VR-Forces from VT MAK. The FFI report *webSAF - an easy-to-use, web-based graphical user interface for controlling semi-automated forces* [31] describes webSAF in detail. Figure 7.1 shows the webSAF user interface.

Figure 7.1 The webSAF user interface.

8 Best practices for successful simulation-supported wargames

In this chapter, we provide a list what of we have found to be best practices for conducting simulation-supported analytical wargames aimed at assessing force structures. Some of the best practices we have found are related to the need to handle the metagame, or the fight about the wargame. The usefulness of such best practices may be limited to other small nations that have not separated the power to invent from the power to test force structures. The other best practices stem from the need to provide simulation support and to replace scenario-based discussions for defence structure development:

- **Define a clear objective:**
  A clear purpose for the wargaming experiments must be specified early in the preparation phase and will be the basis for the design of the experiments.

- **Use a simulation system customized for wargaming:**
  Having an interactive simulation system with SAF that is easy to operate for the players and requires relatively few operators, reduces the resources needed for, and thereby also lowers the threshold for, conducting simulation-supported wargames.

- **Assemble a good Red cell:**
  A good Red cell is the key to discover weaknesses in own force structures, plans and procedures. The players on the Red cell should also have good knowledge of the doctrine of expected opponents. We have observed that a good Red cell quickly cured the tendency our own planners may have had to groupthink possible enemy actions.

- **Allow the opposing force to adapt:**
  Change in the structure of own force must also allow change in structure of the opposing force. Change in force structures is a slow public process and will certainly be observed by expected opponents.

- **Replicate the planning process:**
  Replicate the real-life planning process as closely as possible.

- **Observe the planning process:**
  Monitor the planning process to get a more complete picture of the strengths and weaknesses of a force structure. To document the deterrent effects of a Blue force structure, it is especially important to observe the planning process for the opposing force. Several elements in own force structures have been observed to have a deterrent effect on the operation of the opposing force. Presence and posture have also been observed to have a deterrent effect. Furthermore, we have observed that society, terrain and climate also influenced the planning of the opposing force.

- **Provide space and time:**

  Starting a wargame with forces in close proximity of each other may reduce it to a simple wargame of attrition. Well-developed wargames, where space and time have been provided, flow like martial arts opponents manoeuvring around each other, assessing each other's weaknesses, and looking for opportunities to strike. Assessing the ability to avoid an encounter may be just as important as assessing the ability to fight.

- **Allow uncertainty:**

  Building a picture of what is happening takes time and is a natural part of leading military operations. The true value of certain elements in a force structure only appears when uncertainty is properly represented. The force-in-being effect can for example be significant. Uncertainty is best represented when the tactical situation is not visible for all and the outcomes of the battle are perceived as non-deterministic to the extent that reality is stochastic.

- **Exercise vs. experimentation:**

  Prepare the participants for the purpose of the wargame. When using command and staff trainers as the simulation system for supporting the wargame, some players tend to follow procedures as if it were an exercise. If the purpose of the wargame is to explore new force structure elements, COAs or tactics, techniques, and procedures (TTPs), the players need to be encouraged to be creative when executing their tasks.

- **Keep high-ranking officers not participating in the wargame away:**

  Keeping irrelevant personnel, especially high-ranking officers, not participating in the wargame, away from the wargame itself, is important. In HITL-simulations, the human players are part of the simulation as a whole, and visiting high-ranking officers (or others) will have an effect on the way the human players interact and how they conduct their plans. Limiting visiting personnel also reduces the chance of external influence on the results [32].

9 Summary and conclusion

The Norwegian Defence Research Establishment (Forsvarets forskningsinstitutt – FFI) has supported the Norwegian Army with conducting simulation-supported wargames for capability planning for more than a decade. This report has given an introduction to wargaming in general, presented our methodology for simulation-supported wargaming, and provided a set of best practices for conducting simulation-supported wargames. The methodology and best practices are especially aimed towards analytical wargaming to support capability planning.

The methodology consists of a preparation phase, a planning and execution phase, and an analysis phase. The methodology has gradually evolved over the last ten years by using more realistic simulation systems and by replicating and monitoring the planning process before the simulated operation to gain more insight into the deterrent effect of the tested force structures.

Our best practices for conducting simulation-supported wargames include defining a clear objective for the wargaming experiments, using a simulation system that is easy to operate for the players, having a good Red cell that is not too restricted, providing space and time so that the war does not start immediately, and providing realistic representation of uncertainty and information gathering. Finally, to get a more complete picture of strengths and weaknesses of a force structure, it is important for the analysis group to observe the planning process in addition to the wargame itself.

Formalizing the separation of the power to suggest force structure changes from the power to test, evaluate and accept such changes would solve many of the problems we have seen in the defence planning. We have identified that the process of organizing a wargaming event may be viewed as a metagame. When supporting wargames with modelling, simulation, and analysis, the metagame is seen as something that happens at every level, some of which we may not have any influence over. Hopefully, this report can contribute to raised awareness about these challenges and provide some adjustments to the part of the metagame that we can influence.

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Abbreviations

AI	Artificial Intelligence
BISim	Bohemia Interactive Simulations
CGF	Computer-Generated Forces
COA	Course of Action
GUI	Graphical User Interface
HITL	Human-in-the-Loop
JROC	Joint Requirements Oversight Council
M&S	Modelling and Simulation
NATO	North Atlantic Treaty Organization
OOB	Order of Battle
SAF	Semi-Automated Forces
SME	Subject Matter Expert
TTP	Tactics, Techniques, and Procedures
VBS	Virtual Battlespace
vNM	von Neumann-Morgenstern

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

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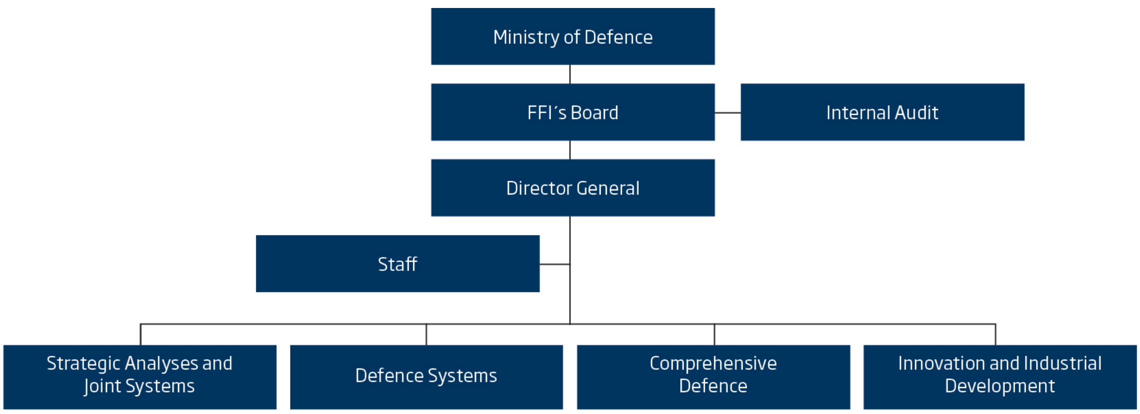

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