Use of Combat Simulations and Wargames in Analytical Studies

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ABSTRACT: DSTO has invested considerable time and money in establishing a capability to conduct the analysis of complex problems using combat simulations and wargames. This paper covers the systems CAEN, CASTFOREM and Janus, addressing their characteristics, the prerequisites (such as scenarios, force structures and specific equipment performance data) for their use and how they can contribute to a study methodology. The requirement for algorithm, data and overall performance validation is addressed as are limitations and assumptions inherent in using these complex simulation systems. The method for their use involves identifying aspects of the problem to be studied through simulation and wargames, the study itself and how the results are integrated into the overall evaluation. Methods of improving the systems to enhance their utility are also covered.

1. Introduction

Complex computer based simulations have been developed in the US and UK for analysis and training in the military environment. DSTO has acquired four of these simulations, CAEN, CASTFOREM, Janus and Thunder, and developed a capability in the analytical application of the first three. Additionally, the ADFWC has acquired and uses Joint Operations Simulation (JOS) for training. These systems have been used for many years overseas and are of proven utility to trainers and analysts alike. However there are some important preconditions that must be understood in order to optimise the outputs of the simulations. Most important is to ensure that the complex and detailed scenario that is implemented in the simulation will generate useful information in the context of the study.

This paper describes each simulation and wargame, comments on the military environment in which it may be used, describes the analytical process in which it is currently used by Land Operations Division of DSTO and comments on the role of wargames and simulations in that analytical process.

The topics covered by this paper are extremely diverse. A number of papers have been published covering the many aspects in detail, so this paper should be viewed more as a summary and user guide than a detailed investigation of any particular area.

2. Wargame or Simulation

There are a large number of diverse definitions and opinions on what constitutes a wargame and a simulation; the terminology is almost endless. It is useful therefore to discuss common definitions and to explain how the terms wargame and simulation are used in the remainder of this paper.

2.1 Simulation

A simulation is an imitation or representation of a complex system. It may be incomplete, modelling only some elements of the system in order to allow analysis. A simulation may consist of a suite of models implemented through time.

The main use of a simulation is to provide an insight into the outputs of a complex system that cannot be accurately modelled because the procedures and inputs may not be easily defined (but may be statistical distributions or approximations). The results of a simulation cannot be predetermined, but rely on the inputs and procedures and their behaviour according to the laws of probability.

In this paper, the difference between a simulation and a model is that a simulation is a fabrication of a complex real system implemented through time, whereas a model is a precis, often a mathematical description of a system.

There are three sub-categories of simulations relevant to this paper. Constructive simulations are ‘simulations that involve real people making inputs into a simulation that carries out those inputs by simulated people operating simulated systems’ [1]. A closed simulation may mean that the disposition of opposing sides is largely unknown to the players in control of a side or mean that there is no human input to the simulation. A systemic simulation is a simulation where there is no human interaction after the scenario has been coded. These are used for parametric excursions and to generate robust statistics.

2.2 Wargame

The Art of Wargaming [2] defines a wargame as ‘... a warfare model or simulation ... whose sequence of events affects and is, in turn, affected by the decisions made by players...’

Wargames are an abstraction of reality based upon a suite of models, data, rules and procedures used to represent movement, detection, firing and other aspects of the mechanics of combat. They include human decision-making and conflict, and do not produce rigorous, quantifiable or duplicable results.

The distinction used in this paper between a wargame and a simulation is that a wargame relies on
human interaction and decision making. In contrast, a simulation is pre-programmed and run independently of human interaction, and can be used to produce results that can be analysed using statistical techniques. The formal definition of a constructive simulation is at odds with this distinction.

2.3 Terms in this Paper

In this paper hereafter the word wargame means an interactive constructive simulation supported wargame and the word simulation means a systemic computer simulation.

3. Levels of Military Operations

Three levels of military operations are relevant to this paper; minor tactical, tactical and operational. A fourth, strategic, is mentioned for completeness.

Minor Tactical. Minor tactics are ‘the application of weapons and formations to ground. (This includes)...

a. Weapon handling and application of fire.
b. Field craft and appreciation of ground.
c. Selection and construction of fire positions.
d. Concealment and the use and construction of cover.’[3].

Minor tactics are ‘...the application of troops and weapons to ground within sub-units.’[4].

The dominant concept is fire and movement, whether fire is direct or indirect, rifle, machine gun, tank guns, mortars, artillery or ground attack aircraft. Important manoeuvre groups are rifle pairs, the machine gun, sections and individual support weapon systems. Minor tactics consist of the drills, formations and activities that form the common basis for higher level tactics, such as attacks, advances, defence and withdrawals.

Tactical Level. The tactical level of war is defined as the ‘...planning and conduct of battle’ [5] or as: ‘the ordered arrangement and manoeuvre of units in relation to each other and/or the enemy...’[4].

Tactics are the methods used to attack, advance, defend and withdraw and are unique to each phase of war. They form a framework of techniques and principles that can be modified and employed at all levels from section to brigade and beyond. For example, attack tactics emphasise a fire support element, an assault element etc, which can be applied at all levels.

Operational Level. The level at which military strategy is implemented by assigning missions, tasks and resources to tactical operations

Strategic Level. Strategy is defined as the Art and Science of employing national power. This level is not considered in this paper.

4. Scenarios

Scenarios are normally considered to be a description of the physical, enemy and friendly environments. Figure 1. For analysis conducted with wargames and simulations this is only a description of the start condition (a static description of the scenario). To employ the complex combat simulations required to represent the mechanics of military operations, a ‘dynamic’ scenario has to be developed, including relevant alternative (a ‘constrained’ decision tree). The dynamics of the scenario are a representation of the psychological aspects of the static scenario; that is the command and control, tactics employed and decisions made. For example a ‘static’ scenario of an attack will detail the terrain, enemy and friendly forces, and missions. A ‘dynamic’ scenario will include the plan, its implementation, and contingencies and options with the associated conditions for significant events.

5. Current Wargames and Simulations

Wargames and simulations attempt to cover, to varying degrees, two aspects of combat: the mechanics - moving, detecting, engaging, consumption of resources and physical communications - and the psychological - planning, decision making, execution, monitoring, suppression and morale. Across the spectrum of simulations in Australia (Figure 2), and as a general rule, the mechanics of combat are adequately modelled and these algorithms well understood. It is the treatment of the psychological aspects that is difficult and implemented, if at all, with varying degrees of success. The psychological aspects (except suppression) are generally not modelled in wargames by the constructive simulation but are represented by the command and control structure established for the wargame. In simulations, either constrained decision trees are developed or complex arrays of decision tables are used. There is a programme of research within LOD to develop intelligent agents to increase the fidelity of the psychological modelling.

Each simulation in use by LOD is discussed below.
CAEN. Close Action ENvironment (CAEN) is both a two-sided, constructive, closed wargame and a systemic simulation, and is used to assess the effectiveness of equipment and tactics in the close combat infantry battle at the tactical and minor tactical levels. The simulation can represent personnel and vehicles in close combat up to company level in rural and urban areas with up to 250 entities. CAEN provides a facility for studying the interaction between multiple opposing forces consisting of individual personnel and their vehicles.

CAEN models infantry tactics, armoured vehicles, rotary wing aircraft, small arms, indirect support weapons, wire, mines, smoke, flares, low-light and thermal sensors on highly detailed rural and urban terrains in a wide variety of weather and lighting conditions.

The model can be run in two modes. First as an interactive wargame with multiple participants (one per workstation) each creating, modifying and controlling their own forces. Second as a stand-alone systemic simulation in which the computer plays all sides and determines the outcome of the battle, recording every detail of the battle as it progresses.

Janus. Janus is an interactive, two-sided, closed, constructive, stochastic, ground combat simulation modelling the tactical level of combat. Interactive refers to the interplay between the players who decide what to do in crucial situations during simulated combat and the systems that model that combat. Two-sided refers to the two opposing forces, Blue and Red, directed simultaneously by two sets of players. Stochastic refers to the way the system determines the results of actions such as direct fire engagements: according to the laws of probability and chance. Ground combat means that the principal focus is on ground manoeuvre units, although Janus also models weather and its effects, day and night visibility, engineer support, minefield employment and breaching, rotary and fixed wing aircraft, resupply, and a chemical environment.

Commanders plan and execute their battles on digitised maps. The warfighter's view is a two-dimensional map-like display that includes grid lines and graphic control measures. To the weapon systems in the game, however, the terrain is three-dimensional, with elevation and contour affecting manoeuvrability and lines of sight.

Individual weapon systems, whether riflemen, tanks, or aircraft, automatically engage the enemy with the appropriate weapon or ammunition. A Leopard tank, for example, knows when to use armour-piercing sabot or high explosive main gun ammunition or use its machine guns. The computer makes these decisions based upon range, target type, and ammunition remaining. Units can run out of both fuel and ammunition if not resupplied.

CASTFOREM. The Combined Arms and Support Task FORce Evaluation Model (CASTFOREM) is a simulation of a combined arms conflict at battalion and brigade level (tactical). It is a high resolution, two-sided, force-on-force, stochastic, event-sequenced, systemic simulation model. CASTFOREM is a useful model for representing tactics through the use of Decision Tables (DTs) which collectively constitute an embedded expert system for battlefield control.

The implementation of DTs is the key characteristic which makes CASTFOREM different to other simulation tools and particularly the difference to a wargaming tool such as Janus. In Janus an interactor makes decisions and implements them into the model in real time. CASTFOREM, having no real time interaction executes decision tables in order to decide on an action to implement. Through the use of DTs, the military analyst can allocate resources where the need is greatest, direct forces, as would a commander in the field, and impose constraints on the effectiveness of individual soldiers. DTs can be structured for control at all levels of resolution, and provide a framework in which to place Combat Orders (COs) so that they are used at the appropriate time. COs are routines that specify, in sequence, the actions which should take place. COs place calls to Primitive Orders (POs), which are Simscript II.5 routines which implement the action or invoke the algorithm to make required calculations. The DTs, COs, and POs together, in essence, provide a simple 'artificial intelligence' to simulate the human decision making process and the actions of combat.

Databases. The databases used for the wargames and simulations describe systems extensively and in detail. Individual fighting systems have distinct properties: dimensions, weight, carrying capacity, speed, weapons, and weapons capabilities like range, type of ordnance, and ammunition basic load. Multiple databases may be available for different uses, for example day and night, or classified and unclassified.

An enormous amount of system data is required in the wargames and simulations. The data covers the systems attributes that relate to mobility, physical dimensions, thermal signature, sensors, vulnerability and lethality.

6. Evaluation Process
6.1 Logical Basis

The analysis of military operational systems is an extremely challenging undertaking because the system itself is complex, adaptive, dynamic and ill defined. The process must meet the following conditions:

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1 CAEN is developed in the UK by the Centre for Defence Analysis, Land Studies Department, DRA Fort Halstead.
The process must be able to evaluate and optimise a real, complex ‘soft’ system.

The problem has to be reduced to a manageable level whilst ensuring that the results of the evaluation/optimisation are still applicable, relevant and useful.

An appropriate mix of auditable and defendable qualitative and repeatable quantitative results, in an appropriate form, must be provided to enable decisions to be made with an acceptable level of risk.

The evaluation process is fundamentally a large-scale operational test and evaluation (OTE) problem and the following characteristics of OTE generally apply:

- OTE should be conducted in a realistic environment.
- OTE tests the entire system.
- The evaluation criteria are a hierarchy of measures including such things as mission success, \( P_{\text{des}} \), \( P_{\text{pit}} \), and \( P_{\text{fail}} \).
- Normally combat conditions are created and the results observed.
- The tests are generally not repeatable and the interactions are usually unique.

### 6.2 Battlelab Process

The problem is investigated using the Battlelab process [6]. This is a methodology for objective force development in a military environment. In essence it is the application of accepted OTE methods to complex organisation and combat effectiveness studies. The Australian Battlelab process has the following features:

- it attempts to quantify the critical areas;
- modelling fidelity matches the question;
- it includes all relevant military operating dimensions, eg doctrine;
- it involves operators and scientists; and
- it validates the representation of the system under review by Model-Test-Model.

The range of refinement and validation tools which can be utilised in the evaluation is shown in Figure 3. The Figure indicates that fidelity increases from wargames through abstract computer simulation to field trials, with increasing cost for increased fidelity. On the other hand, at the field trial end of the spectrum only relatively small amounts of very specific data can be collected, whilst wargames and computer simulation can provide large quantities of data ranging from campaign level information down to component level performance data. The nature of the critical area to be addressed and the fidelity requirements of the problem determine the selection of the appropriate tool(s).

The core concept of the evaluation process is the model-test-model method (as described in Hoivik [7]). This process provides for the iterative refinement and analysis of the system under review.

The model-test-model cycles allow for the framing of hypotheses concerning system behaviour, the validation of the model(s) using field trial observations, and the use of the model(s) for the prediction of system phenomena for situations outside of the field trial conditions. This Battlelab process should not be confused with the US Army’s BattleLabs which are physical establishments.

![Figure 3: Use of tools in the analytical process](image)

The initial modelling phase refines the model, establishes or predicts (once sufficient confidence is gained) the performance of the system and the reasons for this performance, and selects or confirms the tests to be conducted. The roles of the test phase are to measure the performance of the system to increase confidence in the modelling and validate its predictions, provide data for subsequent modelling, demonstrate the performance of the system, and measure factors which cannot be modelled. Within this methodology the validation and demonstration aspects of testing are the most important. The results of testing are either measurable data elements or defendable observations.

The final modelling phase is an analysis and review or feedback phase of information into the initial model. This phase confirms the predictions of the initial modelling in a specific environment and the reasons for that system’s performance. In addition, and when sufficient confidence is gained, it allows predictions to be made in environments that are not tested. The modelling will also provide one of the means of aggregating the performance of the activities tested.

The model-test-model cycle is repeated until there is sufficient confidence in the outcome/impact of an issue to allow an informed decision. Results can be implemented at any stage of the process.

### 6.3 Problem Definition

It is essential to accurately define a problem before applying a Battlelab process to it. The complexity of military operations systems and processes means that, due to resource constraints, only a limited number of activities can be modelled, tested and analysed. Therefore, it is essential that those activities which provide a clear indication of the performance of the overall system are selected for analysis using the Battlelab approach. The selection, or refinement, process

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\[ \text{ii The relevant definition of evaluation is ‘the review, analysis and assessment of data obtained from testing or other sources’ [5].} \]

\[ \text{iii TEWT – Tactical Exercise Without Troops} \]
is founded on the progressive use of judiciously selected elements of the tool-set in Figure 3.

A problem definition phase is conducted to understand the whole problem and to answer the ‘right’ questions. The aim is to select the most useful tasks to evaluate. The process establishes the context and environment for the evaluation and refines the trial aims and objectives.

The outputs of the problem definition phase are a clear description of what the military operations system has to achieve, its perceived weaknesses and the important questions to be answered to both validate assumptions and to optimise the system. A conceptual model is developed and the military system is typically described by a concept of operations, mission essential tasks and capability requirements; the weaknesses by critical areas and issues, and questions to be answered by objectives, Figure 4. While it is reasonable to structure an evaluation around critical issues and then build an experiment to investigate each question, this is not pursued in this evaluation methodology due to the time and resource constraints. Instead activities are identified that can be observed and measured to provide evidence for the analysis of the critical areas and issues. Conclusions are then drawn and the results reported against the trial objectives.

6.4 Role of Wargames and Simulations

Modelling and simulation has three roles in the methodology. In the problem definition and the initial modelling phases it provides early system problem identification, and focuses and highlights critical operational issues. During the predictive modelling phase it allows the system to be assessed against unavailable threats, and supplements and extends test data.

The most important characteristic of the use of modelling and simulation in this evaluation process is that they provide insights as well as absolute quantitative answers. The replay of the simulation used as an activity to drive an After Action Review (AAR) is as useful as a statistical analysis of the loss exchange ratios.

Modelling and simulation have some important requirements to be met if they are to contribute to the overall evaluation. It is important to understand the nature and interaction of the elements within the scope of the assessment definition and make ‘appropriate’ simplifications and approximations. Mathematical and quantitative statements should be used where possible or logical, conceptual (qualitative) models of organisational and other un-quantifiable aspects should be constructed. In this way the utility of the model for prediction can be appreciated.

The wargame has to be validated\(^7\) to ensure that the greatest confidence possible can be placed in the results.

\(^7\) Validation is the process of ensuring the model is a reasonable representation of the real world. No effort was made to verify the simulations, as this is the process of ensuring the model is designed to specification. Accreditation, a bureaucratic acceptance that the model results will be accepted, was not sought because the LOD have targeted three areas through the validation process; vegetation representation, systems data (specifically lethality and vulnerability) and the representation (at the system of systems level) of motorised company operations. The physical models of detecting, moving and engagement have not been validated in Australia because all the simulations have been validated by the developmental agencies.

An example of how wargames and simulations can be used in the validation framework is illustrated by Figure 5. This is a generalised representation of how wargames (some driven by Janus), CAEN and CASTFOREM simulations and field trials were combined to analyse motorised company operations for the RTA Task Force trials. The important characteristic is that at each level three outputs are realised. Firstly the activities of the level below, and the context for their investigation, are determined. Secondly specific questions are answered and thirdly the level below contributes to the validation of the level above.

6.5 Role of Field Trials

The credibility of results from simulations requires that performance of entities within the model is based on reliable data. Historical data and experience may be sufficient to establish baseline data, but specific field studies and trials are probably required. Such studies use live simulation and it is necessary to plan and execute data collection, preferably using quantitative techniques requiring instrumentation of entities, particularly for location, speed of movement and simulation of weapon hits. Data on aspects such as command and control and decision making may have to be qualitative to give a more reliable indication of the processes involved. [6] Traditionally, acquisition of such data has required use of instrumented ranges. New technologies, such as GPS, are leading the way for portable instrumentation systems able to provide real-time data which can be recorded for more detailed analysis. Field studies and trials are also required to validate conclusions reached through simulation. It is important to note that field studies and trials conducted to support the development and validation of simulations often consist of experiments designed to meet the needs of the analyst rather than live re-enactments of the operations modelled. Cooperation between the scientists and the military is critical to ensuring successful field exercises and the use of trained subject matter experts is considered essential.

6.6 After Action Reviews (AAR)

The AAR is the primary tool for combining the qualitative observations of the Subject Matter Experts (SME), the quantitative measurements of the analyst and the impressions of the participants, Figure 6. The observations of the SME guide the data used to reconstruct various events for subsequent discussion and analysis. In this way the qualitative work guides the quantitative. Alternatively the quantitative results may highlight some anomaly that is then explained by the context provided by the qualitative work.

wargame was part of an overall evaluation process, not the sole provider of results.
7. Conclusion

Simulations and wargames offer powerful representations of the mechanics and psychology of military operations. In the past their use has been limited to the quantitative investigation of loss exchange ratios, and system comparison. By integrating the wargames and simulations into a network of complementary analytical tools ranging from seminars to field trials it is possible to use the rich synthetic environment they offer to gain insights in the workings of military systems. The important prerequisites are to clearly identify the scenario that offers the best information and to understand the assumptions and limitations of the wargame or simulation.

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10. Author Biographies

Dean Bowley graduated from the Royal Military College Duntroon in 1984 with a BSc and received a Graduate Diploma in Fighting Vehicle Technology from the Royal Military College of Science (UK) in 1988. He has been working at DSTO since February 1995 after 13 years service in the Australian Army. He is currently Head RTA Studies.

Steven Lovaszy graduated from the Royal Military College, Duntroon in 1988. He served in regimental postings within the RAINF, followed by posting to the Army Battle Simulation Group (ABSG) on the Janus Training Team in 1994. In January 1997 he returned to the ABSG within the Analysis Section. He commenced work for DSTO in Land Operations Division in August 1997. He holds a BSc (Mathematics/C Computing), an MSc in Applied Mathematics, and an MSc in Operations Research.
Strategic Guidance → Guidance and Justification → Problem Definition → Conceptual Model → Activities and Scenarios → Critical Areas and Critical Issues → Analysis → Conclusions → Objectives Structure Manning Equipment Doctrine

Observation and Measurement

Janus Wargaming (Formation Tactics and Operations)

CASTFOREM (Simulation of Unit and Formation Tactics)

CAEN (Simulation of Sub-Unit Tactics and Minor Tactics)

Reconstruction of Field Activities (AAR) SME/OA/GPS Data

Validation

Answers to specific questions

Context

Figure 4: Evaluation Schematic

Figure 5 Proposed Janus validation process