CANADIAN FORCES COLLEGE - COLLÈGE DES FORCES CANADIENNES

AMSC 8 - CSEM 8

Wargaming with Computer Simulation during the Course of Action Analysis.

By/par Commander S.N. Cantelon

October/Octobre 2005

ABSTRACT

Operational Art is at the heart of successful Joint Operations and their doctrine. The Canadian Forces doctrine at the operational level of warfare has become more refined in the decade after the end of the cold war. With the publication of the *Canadian Forces Operations* and the *CF Operational Planning Process* the CF has documented the basic tenants of its operational level doctrine. Both the US and UK military use a similar process when conducting joint operations. All three of these processes lead to the development of an Operational Plan. The key component of these plans is the selected Course of Action which is implemented in detail through the Operational Plan. The operational commander strives to ensure that when the COA comparison is done it reflects all of the assessed factors accurately to ensure the selected plan has a very high probability of success.

Doctrine calls for the proposed COA to be wargamed prior to the comparisons process so that the commander has sufficient information to select the most successful and feasible COA. Warfare is very complex and to achieve success the COA can only be sufficiently wargamed through computer simulations. While the simulations have potential pitfalls the gain they bring to the wargaming process is significant. Both the UK and US militaries use computerized simulation during the wargaming process to ensure the COA is validated. The CF also needs to incorporate a joint operational level computer simulation into the wargaming of COA in order to maximize success when conducting COA comparison during the Operational Planning Process.

Wargaming with Computer Simulation during the Course of Action Analysis.

To master the operational art in the future, officers must be able to think in abstractions, fed by technologies of the most complex kind.

Admiral Holland[1]

INTRODUCTION

Carl von Clausewitz describes the role of commander and strategist as essentially a creative process in drafting the plan of war.[2] The focus on the "art of war" in military studies can often be to the detriment of science, which becomes the antitheses of "art." This perspective fails to see technology as the "heart of military operations."[3] Many battles have been decisively decided by superior technology (e.g. English long bow archer's verses French knights or cannons against the walls of Constantinople.) It is hard to imagine a modern military commander deliberately avoiding the use of technology, weapons or sensors, on today's battlefield.

Wargames have long been used by War Colleges to model historical battles in order to attempt to draw out lessons learned for future battles.[4] The advent of computers has allowed for the wargaming process to undergo a transformation into software simulations that replicate a wide range of modern warfare activities. The commander of today's

---

[1] William J. Holland, Jr. "What really lies behind the screen?" *United States Naval Institute. Proceedings*. (Annapolis: Apr 2003.Vol.129, Iss. 4); Available from www.il.proquest.com/proquest/; Internet; accessed 15 October 2005.
[2] William J. Holland, Jr "Technology Is Key to the Operational Art, Not an Obstacle." *United States Naval Institute. Proceedings*. (Annapolis: Apr 2004.Vol.130, Iss. 4); Available from www.il.proquest.com/proquest/; Internet; accessed 15 October 2005.
[3] Ibid
[4] Peter P. Perla, *The Art of Wargaming.* (Annapolis: United States Naval Institute, 1990), xix

forces can seize upon this technology to enable warfare operations on the battlefield. Commanders working at the joint level implement a complex operational plan though the full spectrum of warfare. The campaign plan for that warfare is manifested in the Operational Plan (OPLAN.) Campaign plans are often rehearsed and tested through exercising the wargaming process. Computer simulation can provide the visualization in campaign design to reduce the effect of warfare's inevitable "friction". Numerous suitable computer simulation models of the operational level of warfare are available for joint planning. Joint planning that includes computer wargaming imbedded in the Course of Action (COA) analysis will maximize the joint Commander's ability to select the most suitable COA.

APPROACH

This paper will examine the utility of computerized wargaming at the operational level to determine the value of using computers for COA comparison. The paper will go through the application of operational art and COA in campaign planning by reviewing the British, American, and Canadian operational planning processes. It will then review the challenges to COA comparison when conducting joint warfare at the operational level. In order to understand the value in wargaming the paper will review the basics principles of wargaming, followed by a discussion of computer-based wargaming to determine if there are any impediments to the use of computers in wargaming. Finally current British, American, Canadian, and NATO operational level computer simulations are examined to determine the value of these simulations in the development of the COA

OPERATIONAL ART

Operational art is the realm of the joint warfighter. It has been defined as "the art of campaigning"[5] or the "conduct of campaigns."[6] Campaigns involve the employment of a wide range of military forces through a series of orchestrated battles to achieve a desired end state. Success in campaigning depends on the commander being competent in joint warfighting.[7] Effective operational art requires "leaders who understand the art and *science* of operations decisions, who are students of joint and combined warfighting, and who have *technical* awareness that makes them open to promising new approaches and capable of exploiting them."[8] Operational art demands a commitment to going beyond the traditional methods and is a crucial tool for the joint warfare practitioner.

The operational level of war, which is the level between the strategic and tactical, is the domain of the joint warfare practitioner. Joint force commanders are usually assigned a geographic area of operations for which they are responsible for the design and implementation of a campaign to achieve a specific goal. In order to effectively plan the campaign the joint force commander's staff uses operational level doctrine. The Canadian Forces (CF) operational level doctrine is contained within the "Canadian Forces Operations" manual. This manual provides the overview of a planning process that has become synonymous with the operational level of war: the Operational Planning Process. The Canadian Forces Operational Planning Process is detailed in B-GJ-005-

---

[5] John English "The Operational Art: Developments in the Theories of War." in *The Operational Art: Developments in the Theories of War*, Edited by BJC McKercher and Michael A. Hennessy, (Wesport CT: Preager, 1996), 7

[6] Montogmery C. Meigs, "Operational art in the new century." *Parameters*. Carlisle Barracks: (Spring 2001.Vol.31, Iss. 1), Available from www.il.proquest.com/proquest/; Internet; accessed 15 October 2005.

[7] Ibid

[8] Ibid

500-FP-000_e *The CF Operational Planning Process* which is both the title of a publication and an actual process. For sake of simplicity this essay will refer to the actual process as the OPP and the publication by its formal title. In the CF context the OPP is used to prepare plans for operations.[9] The OPP is divided into to five phases: initiation, orientation, COA development, plans development and plan review. Mission analysis, which is a key part of the OPP,[10] is the focus of the orientation phase and the results of this phase are the building blocks used during the COA development.

The US and UK military also have joint publications that refer to the operational level of war. The *United Kingdom Doctrine for Joint and Multi-National Operations*, JWP 0-10, publication contains a joint planning process. JWP 0-10 defines the practical expression of Operational Art as the campaign plan.[11] The doctrine explains that the commander implements his campaign design though the use of campaign planning tools which are designed to guide the commander and their staff. Some of the planning concepts used are: Centre of Gravity, Decisive Point, Lines of Operation, and Culminating Point. The joint force commander applies the mission analysis and estimate process to the direction given him in concert with the campaign planning tools in order to formulate his campaign plan.[12] The UK planning process has two major parts: the Joint Estimate and the Campaign Plan. The Joint Estimate consists of 4 stages: mission analysis, evaluation of factors, consideration of COA, and the commander's decision. The Joint Estimate is the UK process of executing Operational Art.

---

[9] Canada, Canadian Forces, B-GJ-005-500/FP-000 *CF Operational Planning Process,* (Ottawa : Issued on Authority of the Chief of the Defence Staff, 2003), 1-1
[10] Ibid 4-4
[11] United Kingdom, Ministry of Defence, Joint Warfare Publication 0-10 *United Kingdom Doctrine For Joint And Multinational Operations,* (Shrivenham: Joint Doctrine and Concepts Centre, 2002), 3-7.
[12] Ibid 7-1

In the US model of campaign design Operational Art is also applied through a national process. Each US service branch, Army, Navy, Air Force and Marines have their own planning doctrine, however in or

restraints. The process then directs the development of various COAs to attempt to control all the variables followed by a comparison. All three processes emphasize the role of the Commander in the selection of the desired COA. The COA is fleshed out in detail and turned into an OPLAN. One can deduce that the critical part of these processes is the COA comparison in order to provide the commander with the best information in the selection of the desired COA, as this COA will become the OPLAN.

COURSE OF ACTION

The OPLAN is the tangible manifestation of the Operational Art at the Operational Level of war. In the CF context the plan will identify the centres of gravity and decisive points, and lay out a sequence of events that reflects these factors in achieving the end state. In determining this sequence of events the planning process must answer "Which military conditions must be attained in order to achieve the strategic and the operational goals?" and "What sequence of action is most likely to produce these conditions?"[15] Initially staff analysis and interaction with the commander is focused on ensuring that these questions are answered and then developed in a Course of Action. The OPP specifically calls for the staff to conduct a comparison of the proposed COAs. The comparison results in a formal brief given to the Commander called the Decision Brief.[16] From this brief the Commander selects his/her preferred COA. The staff turns the chosen COA into a concept of operations, which in turn is further amplified and published as the detailed plan, the OPLAN.

[15] Canada, Canadian Forces, B-GJ-005-500/FP-000 *CF Operational Planning Process,* (Ottawa : Issued on Authority of the Chief of the Defence Staff, 2003), 2-7
[16] Ibid 4-11

Similarly, US military staffs using JOPES are instructed to focus on key information necessary to make the decisions in the mission analysis. No more than three COAs are developed in order to focus the staff resources on the most likely scenarios.[17] Each COA must include: what type of action is planned, when it begins, where it takes place, why the action is planned (commander's intent) and how (the method of employment.)[18] US doctrine states that COA analysis will occur through the use of wargaming, as it is an attempt "to foresee the action, reaction, and counteraction dynamics of an operation."[19] Doctrine provides guidance in Joint Publication 5-00.2 Joint Task Force (JTF) Planning Guidance and Procedures on the specifics of wargaming. It notes "Wargaming is a conscious attempt to visualize the flow of a battle, given JTF strengths and dispositions, enemy assets and possible COAs."[20] Wargaming is an integral part of the US military planning process during COA development.

The UK uses a similar approach to the Planning Process with the Joint Estimate, the Joint Force Commanders Planning Guidance, and the Campaign Plan. The Joint Estimate's final outcome is the selection of the commander's preferred COA for implementation. JWP 0-10 states that staff analysis is to produce options for the Commander on how the mission can be accomplished.[21] These COAs must contain "...forces required, the logistic concept, the deployment concept, the estimated time and space required and a

[17] Norman M. Wade, *The Joint Force & Operational Warfighting SMARTBOOK: Guide to joint doctrine, Operational Warfighting and Theater/Campaign Fighting*, (Lakeland: Lighting Press , 2003), 4-37
[18] Ibid 4-37
[19] Ibid 4-38
[20] United States, Joint Chiefs of Staff, *JP 5-00.2 Joint Task Force planning guidance and procedures.* (Washington, D.C. : Joint Chiefs of Staff, 1999), IX-45
[21] United Kingdom, Ministry of Defence, Joint Warfare Publication 0-10 *United Kingdom Doctrine For Joint And Multinational Operations,* (Shrivenham: Joint Doctrine and Concepts Centre, 2002), 7-1

concept for the reserves."[22] The joint staff is to validate each COA against the enemy's anticipated action in the defined geographic area, and be of sufficient detail to "consider the potential action of enemy forces 2 echelons down."[23] This is a complex task and UK doctrine further notes that Operational Analysis staff using computer software should be used to provide sufficient rigor to the comparison.[24] The use of appropriate computer software enables the staff to fully conceptualize the ramifications of their potential COAs to obtain maximum effectiveness. Thus the UK joint planning process embeds computer simulation into COA development.

The planning process as implemented by each nation is mix of command decision and staffing processes which involve COA development and comparison. The processes all aim to select the plan most likely to achieve the desired end state. One of the critical steps that all three countries campaign planning process use is an analysis of the proposed COA. A comparison process is then used to determine which COA best achieves the desired end state. The Commander plays a key role in that he/she must select the best COA. Once the COA is selected the process triggers further staff planning to develop detailed documentation on plan implementation.

How then does the commander select the best course of action? In wartime it will quickly become apparent if the best course of action was selected but how in peacetime or prior to hostilities does the commander know if the course of action selected was correct? The key to this is to simulate the COA through wargaming and to provide the

[22] Ibid 7-5
[23] Ibid 7-5
[24] Ibid 7-5

feedback to the commander in the form of an expected outcome. This feedback will provide the commander with a more accurate sense of the COA's feasibility and its likelihood of success. In turn this will assist the commander with the execution of OPP when deciding which of the COAs to develop into the OPLAN.

CHALLENGES TO COA ANALYSIS

Traditionally joint forces have been organized in a functional specialization, i.e. commanders such as the LCC, MCC and ACC who were the focus of the joint campaign plan. This belief stemmed from the view that the best way to conduct the planned joint operations was via the service (Army, Navy, or Air Force) that was best suited to the several parts of the problem. The USAF is the most outspoken advocate of this specialization, as implemented over Kosovo in Operation ALLIED FORCE.[25] While the historical focus on joint warfare has been oriented around component specialization there is a differing approach that seeks to realize all of the benefits associated with the functional capabilities.

> The schools of thought point logically to different operational command and control arrangements and to different resource allocations [in a joint environment]. Specialization, for example, takes advantage of inherent efficiencies in the integrated traditions, doctrines, discipline, service loyalties, and procedures of single institutions. Synergy, in contrast, blends particular service

[25] MGen John L. Barry and James Blaker, "After The Storm, The Growing Convergence of the Air Force and Navy," *Naval War College Review*. (Washington: Autumn 2001), Available from www.il.proquest.com/proquest/; Internet; accessed 15 October 2005.

> strengths on mission-by-mission basis to provide higher output than any single service could provide[26]

The alternative perspective advocates a synergistic view where the respective force components are combined to achieve a greater affect. To implement a synergistic command and control will require a great deal of understanding of the interaction of service specific capabilities. This adds a significant level of complexity to COA development. The technological enhancements in weapons and information operations combined with the growing levels of interconnection between systems in modern warfare mark a revolutionary change in warfare.[27] The greater the synergy desired the greater the complexity to the analysis. How is the Commander to know, when assessing the proposed COAs, if the synergies of warfare systems that underline a particular approach are within the realm of the possible? The answer lies in wargaming.

The advent of more complex force utilization through the joint operations as described by Admiral Giambastiani, Commander US Joint Forces Command, requires forces "to function effectively throughout the battlespace, employ Network Centric capabilities, establish pervasive and persistent collaboration - horizontal and vertical, and to operate in a dispersed but interdependent way." [28] This level of complexity needs to be captured in the COA analysis to ensure the resultant campaign plans achieves success. The COA analysis or validation is a process where "each COA is visualized in context of the enemy's most likely or most dangerous course of action in an action-reaction-

---

[26] Ibid.
[27] Paul Bracken and Martin Shubik, "War gaming in the information age: Theory and purpose." *Naval War College Review,* (Washington: Spring 2001.Vol. 54, Iss. 2); Available from www.il.proquest.com/proquest/; Internet; accessed 15 October 2005.

counteraction methodology.'[29] Ideally this process is wargamed to determine the COA outcome. Both UK and US doctrine embed the use of wargaming, including simulation, during COA development. The concept of wargaming is part of Canadian doctrine, The CF Operational Planning Process states "a method of comparing COAs is wargaming."[30]

WARGAMING

> "The role of wargames is to help human beings investigate the process of combat"[31]

Wargames have been used by militaries for over a century.[32] A wargame is a combination of a game, history, and science. Wargames are ancient: *Chaturanga* was a chess-like wargame originally from the sixth century in India.[33] Modern wargames are no more than a representation of a particular battle or campaign. The player's pieces are not rooks and bishops but numerical representation of combat units. These numerical representations are then compared and probabilities are used to determine what damage has been done to each side. Each side can have hundreds of these combat units "pieces" in play at any given time. The board is not flat with black and white squares rather it is an accurate reflection of the geography of the expected battlefield. The player's role then

---

[28] United States, Joint Forces Command, "Delivering joint solutions today or joint problems tomorrow." http://www.jfcom.mil/newslink/storyarchive/2004/pa110404a.htm; Internet; accessed 15 October 2005.
[29] United States, U.S. Army War College Department Of Military Strategy, Planning And Operations, *Campaign Planning Primer AY 05*, Available from www.carlisle.army.mil/usawc/dmspo/Publications/Campaign%20Planning%20Primer%20AY05%20.pdf; Internet; accessed 15 October 2005.
[30] Canada, Canadian Forces, B-GJ-005-500/FP-000 *CF Operational Planning Process,* (Ottawa : Issued on Authority of the Chief of the Defence Staff, 2003), 4-11
[31] Peter P. Perla, *The Art of Wargaming.* (Annapolis: United States Naval Institute, 1990), 179
[32] Ibid, 17
[33] Ibid, 6

is to apply the correct strategy and tactics to the game pieces, in effect the orders to field units. "Wargames are chess on steroids."[34]

Dr. Peter P. Perla who wrote "The Art of Wargaming" notes that Wargaming explores: "human decision-making, exercises test human and mechanical abilities to carry out decisions."[35] Wargaming is a disciplined process with rules and steps that attempt to visualize the ebb and flow of battle. The term wargame in this paper refers to a process driven by a set of rules; when computers are involved with the process the paper will refer to these simulations as computerized wargames. Simulations will be examined later in this paper but in order to understand the value of computer wargames it is important to understand the basics of wargaming in the professional context.

Wargames can help the commander and staff officer experience decision-making under circumstances and conditions that are hard to replicate except during war.[36] There are currently three main roles for wargaming: training staffs for future operations, visualizing the COA in order to exploit opportunities or avoid pitfalls, and to generate predicted results to be used in COA comparison. Dr Perla notes that wargaming is not operational analysis, which focuses on numerical output; rather it is a human decision-making process. Wargaming excels at testing human decision-making and the consequences of those decisions. Dr. Perla defines a wargame as a "model or simulation whose action does not involve the activities of actual military forces."[37] He staunchly argues that

[34] James F. Dunnigan, Wargames, *Preemption And A Lot Of Other Curious Behavior*. Available from http://www.informs-sim.org/wsc03papers/114.pdf; Internet; accessed 15 October 2005.
[35] Peter P. Perla, *The Art of Wargaming.* (Annapolis: United States Naval Institute, 1990), 11
[36] Ibid 9
[37] Peter P. Perla, *The Art of Wargaming.* (Annapolis: United States Naval Institute, 1990),164

without human involvement in the simulation it is not a wargame. Dr Perla supports the use of wargaming at the operational level; he notes that wargames are ideally suited to focus on force levels and employment options feasibility in campaign plans.[38] Wargaming is an excellent means of replicating the conditions of war without the resource requirements of a live exercise.

The operational level wargame is best suited to the gaming concept of the closed game as it best replicates "the fog of war."[39] Closed wargaming occurs when the players are restricted to the knowledge of the enemy forces which could be achieved through their own force's sensors. Dr Perla further states that that closed games "require some sort of computer assistance."[40] The interaction of the human decision-maker and the simulation is what provides wargaming with its potency as a tool of war in the planning process.

Wargaming is a powerful tool that can give the players insight into their plan of operations. Whether it is applied at the strategic, operational, or tactical level the concepts remain the same; no matter who the participant is, wargaming forces them to "look at reality from a different angle and can lead to fundamental changes."[41] Wargame analysis is a complicated process that is "essentially the art of discerning order in the midst of chaos."[42] Done properly it will allow the participants to understand the strengths and weakness of a plan. At the operational level it can be used to examine a complete campaign through the simulation of a series of tactical encounters.[43] The players can dynamically adjust their strategy and measure the outcome. To be truly

[38] Ibid, 171
[39] Ibid, 171
[40] Ibid, 175
[41] Ibid, 181

valuable the wargame must be analysed as the process of wargaming presents an immediate form of feedback to the players that alone is not sufficient. It is through detailed analysis that the players will be able to explore the implications of their human decision-making, the resulting outcomes and then learn from the event.[44] While wargaming can be conducted manually, at the operational or campaign level, according to Dr Perla it is ideally suited to computerization.[45]

CF doctrine currently indicates that wargaming is done manually and only done by computers when time and resources permits.[46] The perception that computer wargaming is time-consuming may stem from a poor understanding of the inherent complexity of manual wargaming as described by Dr Perla or the lack of a CF operational level computer simulation model.[47] With the advent of the new challenges in joint operations as stated by Admiral Giambastiani, the question must be asked whether manual methods of wargaming suffice to provide the Commander with sufficient information in selecting the COA. The US military's JOPES process conducts a COA analysis with results from wargaming with "computer aided modeling and simulation."[48] These are compared through the use of a decision support template, or a points-based decision matrix from

---

[42] Ibid, 271
[43] Ibid, 281
[44] Ibid, 290
[45] Ibid, 304
[46] Canada, Canadian Forces, B-GJ-005-500/FP-000 *CF Operational Planning Process,* (Ottawa : Issued on Authority of the Chief of the Defence Staff, 2003), 4-11
[47] Note: There is no CF wide approved operational model for joint wargaming. Both the Army and Navy use wargaming systems through LFDTS and CFMWC respectively for component level training. The Canadian Forces College uses computer based wargaming systems and they will be examined in detail by this paper.
[48] United States, Joint Chiefs of Staff, *JP 5-00.2 Joint Task Force planning guidance and procedures.* (Washington, D.C. : Joint Chiefs of Staff, 1999), IX-49

which the Commander selects his/her COA. Computer simulations or models[49] can provide a sound base line to develop some metrics in analysing the proposed COA's through a common model.

COMPUTERIZED WARGAMING

First it must be understood that the use of computers are neither a panacea nor a replacement for human decision-making. But the use of a model through computer simulation can provide a great deal of information. The use of simulation has been widely accepted at the tactical level, whether it is in an aircraft cockpit trainer or in the operations room of a bridge. No professional officer would suggest that these simulations replace reality but they do provide a remarkable indication of the performance of the actual equipment in the real environment.

In "The Art of Wargaming" Dr Perla notes that in the late 1960's into the early 1970's wargame designers began to devise computer software that could incorporate the traditional table and dice based wargames.[50] From this basis modern simulations sprang forth as computer technology became both cheaper and more powerful. In the past computer simulations of wargames have been very expensive and required specialized computers. With the advent of powerful microprocessors the cost of simulation has plummeted such that very complex simulations can be run on the standard PC. As barriers to simulation use are removed, the use of simulation-based wargaming becomes feasible as a wide spread tool for planning military operations.

---

[49] Note: the term computer simulation or model is used frequently to refer to computerized wargaming, in this paper the computer simulation or model is the software that is used. Computerized wargaming will be used to indicate a combination of the software and the wargaming process.

[50] Peter P. Perla, *The Art of Wargaming.* (Annapolis: United States Naval Institute, 1990), 130

The use of simulation-based wargaming has not been overlooked by the US military. The Defense Modeling and Simulation Office (DMSO) provides the oversight of all computer-based simulation in the US Armed Forces. Each US service branch has a wargaming center associated with their respective War College that provides service specific wargaming. The joint warfare centre of excellence in the US Armed Forces is Joint Forces Command (JFCOM). JFCOM is fully committed to the use simulation at the operational level as it provides a "realistic computer-generated battlefield models and other types of simulation support" [51] for the joint staff process.

The centre of Joint operations in the UK is the Permanent Joint Headquarters (PJHQ)[52] who are responsible for the Joint Doctrine issued in JWP 0-10. As previously discussed UK doctrine espoused the use of simulation software as part of the planning process. The United Kingdom Joint Services Command and Staff College uses a specifically designed wargame at the operational level to enhance the development of future staff officers. The Joint Operations Command and Staff Training System (JOCASTS) wargame simulation provides the computer simulation support during the operational staff planning process.[53] JOCASTS provides the staff with a realistic context to conduct staff procedures at the operational level.

[51] United States, Joint Forces Command, "Modeling And Simulations," http://www.jfcom.mil/about/fact_modsim.htm; Internet; accessed 15 October 2005.
[52]United Kingdom, Permanent Joint Headquarters, "PJHQ Organization" Available from http://www.northwood.mod.uk/org/organise.htm; Internet; accessed 15 October 2005.
[53] Newman & Spurr Consultancy Ltd., "JOCATS Overview" www.nsc.co.uk/jocasts.html; Internet accessed 15 October 2005.

The Canadian Forces lead agency in the development of simulation tools is the Department of National Defence Synthetic Environment Coordination Office (DNDSECO). DNDSECO is committed to the development of simulation for "the conduct of operations, including courses of action analysis, linking strategic, operational and tactical levels of command, mission planning and rehearsal."[54] One of the major thrusts under DNDSECO is modelling and simulation that will facilitate jointness and interoperability.[55] The use of computer simulation is divided into various types; DNDSECO identifies constructive simulations as involving "simulated people (when these are involved) in simulated situations operating simulated equipment."[56] The higher level simulations focus on major campaigns or operations involving joint forces. These simulations are able to support operational effectiveness analysis.[57] When they are combined with human intervention DNDSECO defines this type of simulation as wargaming.[58] The CF clearly sees wargaming as the combination of computer simulation and human interaction.

But how useful are these wargames? Are the results valid and are the simulations able to really reflect the conditions and considerations of a war? In their study of *Modeling for Campaign Analysis* Richard Hillestad, Bart Bennett and Louis More note: "Models of combat at the campaign level cannot predict outcomes in the strict sense of other

---

[54] Canada, National Defence Headquarters, *Modelling and Simulation: Enabling the Creation of Affordable, Effective 2020 Canadian Forces A Discussion Paper,* The Symposium Working Group/A Sub-Committee of the Strategic Capability Planning Working Group, 2003. Available from www.drdc-rddc.gc.ca/seco/documents/ Modeling_and_Simulation_Discussion_Paper_e.html; Internet; accessed 15 October 2005.
[55] Ibid
[56] Ibid
[57] Ibid
[58] Ibid

scientific experimentation."[59] But they do note that the "model can be used to identify and analyze the relative importance of various systems, operational concepts, and force structure."[60] It is the analysis of operational concepts, concepts that are the key components of the proposed COAs, which the model can provide the Joint Commander with more information on the likelihood of success. The authors note that the decisions at the operational level are "about force allocations, priorities, and timing needed to achieve operational objectives."[61] Their study continues the examination of the subcomponents of campaign level operations as fires and effects through a process of coordination; they correctly note that for the operational commander this becomes an issue of command and control. Hence any model used for simulation must capture the Commanders' command and control function. They also note that once developed the model is well suited for comparative analysis; thus a well-developed joint operational level model has the potential to be a sound tool for a comparison of COAs.

Technology in its purest form is not an impediment to this level of simulation. The issue is not whether the operational level can be simulated but whether the simulation is valid. In simulation models validity is defined as "a correspondence with reality sufficient to allow useful insights to be drawn from the game's results."[62] It then becomes the challenge of the model designer working with the various software engineers to design a simulation that meets this validity criterion.

---

[59] *Richard J. Hillestead, Bart Bennett, and Louis Moore, Modeling For Campaign Analysis: Lessons for the next generation of models.* (Santa Monica: RAND, 1996), 10
[60] Ibid, 10
[61] Ibid, 20

There are potential pitfalls to simulation modelling when being used to support decision-making.[63] The most common problem with simulation models results from the modeling of a real world system inside the software of the simulation model. This manifests itself in two ways: conflicting model results and incorrect interpretation of the simulation outcome.[64] The problem of conflicting results stems from differing statistical analysis of the subject to be modeled by the model design analyst. Simulations are ultimately a software replication of specific aspects of a real world system. Much of the initial simulation design is art rather than science. Extremely difficult data relationships (i.e. the more the model represents interaction of the complex real world factors) may be very hard to determine and replicate. It is crucial to ascertain which of these relationships must be represented in the model and which do not have a significant effect. Due to these types of decisions in model design the approach taken by different simulation designers can result in a divergence of outcomes. The key to resolving this difference in outcome is "to model the problem at the level that most efficiently and effectively represents the real system under consideration."[65] Narrowing the input data issues to a small group and applying sensitivity analysis to discover which changes of input data impact output measures the most will resolve this issue.[66] These input measures must then be carefully

---

[62] Captain Robert C. Rubel, *War-Gaming Network-Centric Warfare.* Naval War College Review Spring 2001. available from www.nwc.navy.mil/press/Review/2001/Spring/art5-sp1.htm; Internet accessed 15 October 2005

[63] Note: readers may be familiar with the computer programmer phrase "Garbage in, garbage out," for the sake of limiting the discussion of computer simulation the author has assumed that the data selected for input to the simulation is valid. The process of validation of models is a field of speciality in itself should the reader desire further information on this subject the author recommend the US DOD DMSO Validation, Verification and Accreditation web site: https://www.dmso.mil/public/transition/vva/, accessed 17 October 2005.

[64] Christopher M. Hill, and Linda C. Malone. *Caveats for Simulations Modeling In Support of Decision Making. A*vailable from www.informs-sim.org/wsc03papers/136.pdf; Internet; accessed 15 October 2005.

[65] Ibid

[66] Ibid

managed in the simulation model and care must be taken that the decision-maker is not confused by the presentation of the data.

The second manifestation of simulation problems stems from the incorrect interpretation of the model outcomes. The best way to counter this is to conduct a large number of simulation runs to provide a level of probability to the model result. A commonly used method to achieve this is the Monte Carlo Method. By conducting numerous model runs the analyst develops a statistically significant result of the model outcome.[67] This then provides a level of confidence for the simulation model in use. Simulation pitfalls can be avoided by a careful understanding of the specific model capabilities, limitations and statistical basis.

The ability of computers to calculate the outcome of multiple events in a short time period is what makes the advantage of a computer based wargame that much more attractive. In a manual wargame combat events are often generalized into a table of data known as combat results table that the players then refer to with a die role to determine the outcome of the event.[68] Computers allow the calculation of events such as the probability of a missile hitting its target or a battalion's ability to reach a conflict site within the scope of its logistic train very quickly while providing greater fidelity in the results.[69] Computing power helps the wargame process move more efficiently.[70] The

[67] Ibid
[68] Peter P. Perla, *The Art of Wargaming.* (Annapolis: United States Naval Institute, 1990), 115
[69] James F. Dunnugan, *The Complete Wargames Handbook.* 3rd Edition 2001. Available from www.hyw.com/Books/WargamesHandbook/Contents.htm; Internet; accessed 15 October 2005.
[70] Ibid

use of computer simulation allows for the wargamer to have a very sound grasp of a future battle.

As the US military is the heaviest user of this type of technology, they have developed the most complex models of the operational level. In order to "facilitate interoperability among simulations and promote the reuse of simulations"[71] the Defense Modeling and Simulation Office created the federated models concept linked by High Level Architecture (HLA.) HLA technology combines two or more Simulation Object Models (e.g. a computer wargame simulation) together to form a Federated Object Model through the use of standardised interface specifications. For instance common representations of terrain and environment would be shared between the Simulation Object Models. [72] The individual simulation capabilities of each model are linked together in a synergistic manner that provides a much better overall representation of the real world. A federated computer structure acts in essence as one big simulation model. This type of simulation is ideally suited to microprocessor computer hardware operating in a networked environment.

OPERATIONAL LEVEL COMPUTER SIMULATION

A wide number of operational level simulations are in use by various war colleges, militaries and alliances. JOCASTS, the UK operational level simulation, functions at the joint and component level. It includes land, air and maritime subsets. Within the various environments differing levels of operations are modeled with the goal of replicating the

[71] Richard E. Nance, *Distributed Simulation With Federated Models: Expectations, Realizations And Limitations,* Available from http://www.informs-cs.org/wsc99papers/149.PDF, Internet; accessed 15 October 2005.

operational level of war. In each environment issues such as logistics, terrain impacts, weather and operational constructs such as air routes and maritime exclusion zones are simulated in order to provide the correct level of realism to the joint staff.[73] While UK joint forces are not alone in using simulation in joint staff training, the largest repository of simulation models rests with the US armed forces.

The United States Joint Forces Command (USJFCOM) currently uses modeling and simulation as part of its role as a joint force trainer. The Joint Multi-Resolution Model (JMRM) is the computer simulation model used at the Joint Task Force level. JMRM is a federated simulation consisting of two core models: the Joint Theatre Level Simulation (JTLS) and the Joint Conflict and Tactical Simulation (JCATS) operating as a software federation.[74] JTLS focuses on the operational level simulation; it employs some tactical level units in the simulation model (i.e. ships) but primarily runs the theatre level combat of air, naval and ground combat including special operations forces.[75] JCATS provides the fine level of detail in the simulation and feeds JTLS individual actions. The JCATS model includes the effect of the environment such as terrain, sea state, and ambient light. It covers unit level combat such as rifle squad verses squad and incorporates the impact of other unit's effects on the combat event (e.g. artillery). The model is highly detailed and includes human factors such as fatigue, rules of engagement and surrender. It even includes the impact of target acquisition radars and resources activities such as repair of

---

[72] Defence Modeling and Simulation Office, Web site glossary https://www.dmso.mil/public/resources/glossary/results?do=get&search_text=federation

[73] Newman & Spurr Consultancy Ltd. "JOCATS Overview" www.nsc.co.uk/jocasts.html; Internet accessed 15 October 2005.

[74] United States Joint Force Command, "Joint Multi-Resolution Model," http://www.jfcom.mil/about/fact_jmrm.htm ; Internet accessed 15 October 2005.

[75] Col M.P. Armstrong and LTC M.A. Spruill of the Modelling and Simulation Division Joint Warfighting Centre JFCOM, , telephone conversation with author, 28 September 2005

equipment.[76] Another part of the JMRM model is the Joint Deployment Logistics Model (JDLM.) JDLM provides another dimension of realism; it feeds warehouse and depot information into the JTLS model and provides in transit visibility so logisticians can then see what is on aircraft and vessels.[77] By federating JDLM as part of JMRM the logistics chain is now subject to combat attrition (e.g. supply ships can be sunk with an impact on JTLS combat sustainment.)

Both JTLS and JCATS have been used to support mission planning at the joint and component level. Simulation experts at USJFCOM emphasize that the models are not sufficiently valid to be the sole source of information when conducting COA comparison.[78] USJFCOM does not believe that manual wargaming by itself provides sufficient rigor as JTLS frequently uses 17 variables to determine one outcome. USJFCOM itself does not work with Joint Task Force commanders in COA development. Rather the focus of training is on the execution of the selected COA through the JMRM federated model architecture.[79] USJFCOM does emphasis that COA analysis requires a mix of simulation modeling and manual board gaming to maximize the validity of the comparison process.

The Joint Warfare System (JWARS) is a federated simulation model used at the operational level by US military forces. It is used by the Joint Staff, the Combatant Commanders and in various service institutions. JWARS is a campaign level model of

---

[76] Ibid
[77] United States Joint Forces Command, "Delivering joint solutions today or joint problems tomorrow." http://www.jfcom.mil/newslink/storyarchive/2004/pa110404a.htm; Internet; accessed 15 October 2005.
[78] Col M.P. Armstrong and LTC M.A. Spruill of the Modelling and Simulation Division Joint Warfighting Centre JFCOM, telephone conversation with author, 28 September 2005
[79] Ibid

military operations that includes: C4ISR systems and process, the impact of logistics both strategic and intra-theatre, and warfare at the operational level.[80] It models in a three dimensional battlespace with the full effects of terrain and weather. The forces are logistically constrained in their performance and the model implements perception based command and control (e.g. if you can not see an event you can not react to it.) Units are implemented in Battle Space Entities, which represent forces at different resolutions. Some units are at the individual level such as critical ISR systems (e.g. JSTARS) others are at the manoeuvre level such as battalions. Since JWARS is designed to be C4ISR centric the information flows between units is conducted using the Observe, Orient, Decide, Act (OODA) loop paradigm.[81] The use of the OODA loop allows the simulation to construct information in a perceived truth manner (e.g. the situation map) for the commander thus allowing for a "realistic" wargame experience. The analyst can then review the action and see the whole truth thus advising the commander why the plan, a COA, did or did not work as expected.

The power of JWARS has been further enhanced with a Commander Behavior Model (CBM) which is associated with the JWARS Land Commander Models to provide a realistic appreciation of the impact of an individual commander's leadership style in the field. The CBM is programmed with rules that convert a Myers-Briggs Type Inventory score to a series of evaluations that deal with risk management.[82] The Command Model assesses the situation, determines the course of action from the list available and looks

[80] George Stone, III and Gregory A. McIntyre, *The Joint Warfare System (JWARS): A Modeling and Analysis Tool for the Defense Department.* Available from http://www.informs-sim.org/wsc01papers/091.PDF; Internet; accessed October 2005.
[81] Ibid

ahead at the potential outcome. The CBM provides a level of risk to the plan and creates a series of fuzzy logic rules[83] that are applied to the COA. This COA is then applied to a series of sub units as an order which are executed as actions; after the execution the simulation conducts a new observation and restarts the process all over again. Simultaneous to the own force moves, JWARS moves opposition and neutral forces. Opposition force commanders' traits can also be modeled through the CBM. JWARS provides the commander with a simulation that models the effect of the OODA loop and allows a commander's personality to influence the selection of a COA.[84] It provides the Joint Force planning team the ability to test a COA through logistic flows and force assessment to determine the best mix of forces for maximum mission effectiveness.[85] JWARS CBM uses the tool of wargaming to its fullest capacity.

The CF also uses wargaming, but not to the same extent. The Canadian Forces College Exercise and Simulation division uses a series of NATO simulations at the operational level.[86] The core simulation is the Land Air Maritime Battle Determination Algorithms (LAMBDA). This is an attrition-based model that conducts combat calculations at the ship, brigade, and air sortie level. While an older simulation, the LAMMDA model is easily manipulated by the analyst when conducting attrition-based wargaming and as a result the model may be adjusted to reflect specific COA factors desired by the

---

[82] Deborah Vakas, John Prince, H. Ric Blacksten, and Chuck Burdick, *Commander Behaviour and Course of Action Selection in JWARS.* Available from www.informs-sim.org/wsc01papers/092.PDF; Internet; accessed 15 October 2005

[83] Note: Fuzzy Logic is in mathematics, a form of logic based on the concept of the fuzzy set. Membership in fuzzy sets is expressed in probabilities or degrees of truth. Encyclopaedia Britannica Online http://www.search.eb.com/eb/article-9002203?query=fuzzy%20logic&ct=

[84] Deborah Vakas, John Prince, H. Ric Blacksten, and Chuck Burdick, *Commander Behaviour and Course of Action Selection in JWARS.* Available from www.informs-sim.org/wsc01papers/092.PDF; Internet; accessed 15 October 2005

commander for COA comparison. The division also uses the Transport Feasibility Estimator (TFE) to provide the planning staff with an indication whether a particular COA is possible within the constraints of logistics flow. The Global Aggregated Model for Military Assessment[87] (GAMMA) is another operational level simulation used at the Canadian Forces College (CFC). GAMMA conducts operational level simulation and is a powerful aggregation and visualization tool. In an effort to address the asymmetric side of modern operations, CFC, employs the Zoran Effects-Based Tool for Analysis (ZETA) simulation to monitor the effect of information operations on guerrilla warfare and political stability. [88] This model is specific to a NATO scenario centered on the fictional Zoran Sea. These simulations are used to replicate COAs during exercises and to provide the students with outcomes to conduct branch and sequel planning. Their most powerful employment is during exercise training when the students are developing and comparing COAs.

The Canadian Forces College focuses most of the time during operational level exercises on the implementation of the OPP. The LAMBDA, GAMMA, TFE and ZETA models are firmly integrated with the COA development. At the most basic level the TFE & LAMBDA simulations are used to derive the exercise component commanders with the force structure and flow that can be expected in the scenario. These results are used by the joint staff in COA development and validation. Once the joint staff has developed

---

[85] CACI International Inc, "Joint Warfare System (JWARS)", http://www.caci.com/business/systems/simulation/jwars.shtml; Internet; accessed 15 October 2005.
[86] Cdr R. Perks SSO Exercise & Simulation CFC, interview with author, 29 September 2005
[87] Note: Dr Peter Perla in "The Art of Wargaming" page 66, explains the aggregated method of resolution as "If two fleets meet with odds of 2 to q, the inferior will be removed; with odds of 3 to 2, the inferior loss one-half; with odds of 4 to 3 the inferior is destroyed but the superior is crippled for the remainder of the game."
[88] Capt K.W. Foster, CFC SO 2-3 Ex&Sim, interview with author, 30 September 2005

three COAs the exercise commander will select two to be wargamed. While the college uses manual wargaming with trained umpires, prior to the manual wargame the two selected COAs will be run through the various simulation models against the opposition force most likely and most dangerous COA. This provides the umpire with a finer indication of the tabletop gaming outcomes when refereeing the manual wargame. As part of the COA decision brief the operational analyst will brief the joint planning staff on the simulated outcomes. The simulation outcome of the selected COA then becomes part of the information analysis the commander uses in deciding which COA to select for implementation in the OPLAN.[89]

Key to the COA comparison process is the identification of the comparison criteria. The *Canadian Forces College Combined And Joint Staff Officer's Handbook* provides examples of what should be considered generic criteria: flexibility, economy of force, risk, simplicity, security, and effects on enemy Centre of Gravity. By using the same computer simulation software a level of standardization is provided to the COA comparison. The simulation outcomes can be measured against the criteria (e.g. Security) to provide a level of confidence in the COAs. The results from computer wargaming can then be assessed for each COA and provided to the Commander during the decision brief.

The use of simulation to assist in COA development does not have to be limited to an instructional setting (e.g. CFC exercises) or a deliberate planning environment (e.g. US Joint Planning Staff.). Operational analyst teams using computer simulation can provide

[89] Cdr R. Perks CFC SSO Exercise & Simulation, interview with author, 29 September 3005.

the joint staff with excellent input when deciding on a COA. During Exercise ALLIED EFFORT 2001 the NATO joint staff was provided with operational analyst's using the LAMBDA and GAMMA models to assist in mission analysis and COA development.[90] The operational analyst used the simulations to provide an indication of operational risk for the COA against potential opposition force actions. The planners identified over 20 criteria for the COA comparison; these criteria were ranked in order of importance as established by the planning staff. The involvement of the planning staff was key as it provided the analysts the ability to determine the weighted score for each COA outcome. These weighted results were the rationale for the recommendation made to the Commander during the decision brief.[91] The involvement of simulation did not end with the selection of COA and its promulgation in the OPLAN. Both models were used during the exercise to support what-if planning (potential branch plans.)[92]

Another example of computer simulation modeling in support of COA development was the use of an older NATO model, the Allied Deployment and Movement Systems (ADAMS) in support of COA development for force withdrawal from Bosnia-Herzegovina during Operation FIRM ENDEAVOUR.[93] In this case the model was used to assist in identifying the effects of particular events on a redeployment plan (e.g. the loss of route capacity due to bridge problem). The planning staff was able to refine the desired COA and examine the proposed remedy in a dynamic manner by using the

[90] Ms Michele Fisher, LTC Luc Debuyst, Col Mogens Anderson. and Dr Wolfgang Nonnemacher, *Operational Analysis Support to a Combined Joint Headquarters on a Crisis Response Operation*; Available from http://www.rmcs.cranfield.ac.uk/infoserv/ISMOR/ISMOR/2002/fisher.pdf; Internet; accessed 15 October 2001.
[91] Ibid
[92] Ibid

simulation.[94] The resulting improved COA could then be incorporated into the operational planning process. The use of an operational model by the staff allowed planners to make early and informed decisions during COA development, the results were briefed at the highest level and the simulation tools were routinely called upon to support HQ planning.[95] NATO joint staffs are using the using the enhanced planning ability brought by wargaming simulations to refine COA plans and to ensure the commander has a better understanding of the factors associated with COA selection.

Wargaming is a proven construct for the development of force engagement planning. In modern warfare wargaming at the operational level is an integral part of UK, US and Canadian doctrine. Computers running sophisticated simulations at the operational level are some of the many tools that planning staffs can use. The UK has embedded computerized wargaming into its application of joint planning. The US Armed Forces federated JMRM and JWARS models have the power to replicate the complicated synchronization of modern military forces. US joint force commanders use computer simulations to ensure their COA is feasible and effective across the wide spectrum of modern warfare.

The NATO experience outlined above and the exercises at the Canadian Forces College have demonstrated the value of computer simulation in COA development. The CF should apply the use of computer simulation as an integral part of joint force COA

---

[93] Mr GC MacInnes, "Computer Modeling Support to HQ ARRC during Operation Firm Endeavour," Report for NATO RTO Meeting Proceedings 22, Operational Analysis Support to NATO IFOR/SFOR Operations. (Hull: Canada Communication Group, 1999), 2-10
[94] Ibid, 2-12
[95] Ibid, 2-21

development during the OPP outside of the training exercise realm. Computerized wargaming should be integrated into the OPP process through the selection of a national operational level computer simulation. The use of computer simulations during the wargaming process provides an opportunity to study the ramifications of critical decision-making in a conflict environment. Depending on the level of technology and sophistication of the simulation used, the COA will be tested in realistic battle conditions complete with the logistics and environmental limitations. An enhanced wargaming process would allow for a more accurate measurement of the factors used in COA comparison. COA comparison factors can be more fully tested in synchronized joint warfare by conducting computer wargaming. In turn the more accurate COA data will allow the Commander to maximise his/her ability to chose the most likely to succeed COA. Computer wargaming is a proven tool in the testing of COAs whether for exercises or deployments. Computer simulations at the operational level of war can provide planning staffs an enhanced confidence factor that their chosen COA is rigorous enough to survive the “friction” and “fog of war” that affects warfare

CONCLUSION

The CF would benefit from a more integrated and technologically sophisticated approach to wargaming. Simulation wargaming can be used not only as a possible predictor of battle outcomes, but also as a valuable training tool and as an aid when considering potential branch planning. As the price of the wargaming software and hardware decreases the ability to afford a CF wide operational level simulation is more achievable. Simulations that mimic a realistic operational level battlefield are a key tool in the Commanders planning process. While wargaming cannot reliably predict the future, it

can depict a complex system of variables to ensure that the outcomes reported are statistically valid. Computer simulations are not a panacea to replace the human decision process in the COA development process; rather they enhance the operational level Commander's decision process. Computer simulation whether used to determine force flows, naval warfare or the synchronization of the air-land battle can provide the joint Commander with confidence in the accuracy of the COA analysis. When computer simulation is coupled with detailed human analysis it provides the joint force Commander an enhanced comparative template. Computerized wargames can provide great flexibility in examining the various factors used during the COA comparison stage of the OPP. Without the use of computer simulation, wargaming the COA will not have the level of fidelity to ensure all of the complex factors effecting modern warfare have been clearly understood. Computer simulation used during wargaming at the operational level will enable a much-improved COA comparison for the joint force Commander. Mastery of operational art requires a judicious use of science throughout the planning process. Computerized wargaming is part of the OPP and an integral part of operational art. The CF should acquire an operational level computer simulation for the wargaming process of the OPP.

BIBLIOGRAPHY

Barry, John L, and James Blaker. "After the storm: The growing convergence of the Air Force and Navy" *Naval War College Review*. Washington: Autumn 2001.Vol.54, Iss. 4; Available from www.il.proquest.com/proquest/; Internet; accessed 15 October 2005.

Bowers, Frances A. III and David L. Prochnow. *JTLS-JCATS Federation Support Of Emergency Response Training.* Available from www.informs-sim.org/wsc03papers/130.pdf; Internet; accessed 15 October 2005.

Braken, Paul and Martin Shubik. "War Gaming in the Information Age." *Naval War College Review.* Spring 2001. Available from www.nwc.navy.mil/press/Review/2001/Spring/art4-sp1.htm; Internet; accessed 15 October 2005.

CACI International Inc, "Joint Warfare System (JWARS)", http://www.caci.com/business/systems/simulation/jwars.shtml; Internet; accessed 15 October 2005.

Cameron, Fred. *A Century of Operational Analysis for Commanders in the Canadian Army.* Available from www.mors.org/meetings/combat_analyst/ read_aheads/Cameron-A_Century_of_Operational_Analysis.pdf; Internet; accessed 18 October 2005.

Canada. Canadian Forces. B-GJ-005-500/FP-000 *CF Operational Planning Process,* Ottawa: Issued on Authority of the Chief of the Defence Staff, 2003.

Canada. National Defence Headquarters. *Modelling and Simulation: Enabling the Creation of Affordable, Effective 2020 Canadian Forces A Discussion Paper,* The Symposium Working Group/A Sub-Committee of the Strategic Capability Planning Working Group, 2003. Available from www.drdc-rddc.gc.ca/seco/documents/ Modeling_and_Simulation_Discussion_Paper_e.html; Internet; Accessed 15 October 2005.

Canada, DND/CF Synthetic Environment Coordination Office DND/CF SECO, "SECO Fact sheet," Available from http://www.drdc-rddc.gc.ca/seco/documents/seco_fact_sheet_e.html; Internet; accessed 15 October 2005.

Canadian Forces College, "Canadian Forces College Combined And Joint Staff Officer's Handbook" (Toronto: CFC AL3-2005-03-03)

Dunnigan, James F. *The Complete Wargames Handbook.* 3rd Edition. Available from www.hyw.com/Books/WargamesHandbook/Contents.htm; Internet; accessed 15 October 2005.

Dunnigan, James F. *Wargames, Preemption And A Lot Of Other Curious Behavior.* Available from http://www.informs-sim.org/wsc03papers/114.pdf; Internet; accessed 15 October 2005.

English, John. "The Operational Art: Developments in the Theories of War," in *The Operational Art* edited by B.J.C. McKercher and Michael A. Hennesy, 7-27. Westport, CT: Preager Publishers 1996.

Fisher, Ms Michele, LTC Luc Debuyst, Col Mogens Anderson, and Dr Wolfgang Nonnemacher, *Operational Analysis Support to a Combined Joint Headquarters on a Crisis Response Operation*; Available from http://www.rmcs.cranfield.ac.uk/infoserv/ISMOR/ISMOR/2002/fisher.pdf; Internet; accessed October 2001.

Gilmour Duane A., Mr. James P. Hanna, Mr. Walter A. Koziarz, Mr. William E. McKeever, and Mr. Martin J. Walter. *High-Performance Computing for Command and Control Real-Time Decision Support.* Available from www.afrlhorizons.com/Briefs/Feb05/IF0407.html; Internet; Accessed 18 October 2005.

Herz, J.C., and Michael R. Macedonia, *Computer Games and the Military: Two Views.* Washington, DC : NDU Press, 2002.

Hill, Christopher M. and Linda C. Malone. *Caveats for Simulations Modeling In Support of Decision Making. A*vailable from www.informs-sim.org/wsc03papers/136.pdf; Internet; accessed 15 October 2005.

Hillestead, Richard J., Bart Bennett, and Louis Moore. *Modeling For Campaign Analysis: Lessons for the next generation of models.* Santa Monica: RAND, 1996.

Holland, William J. Jr. "What really lies behind the screen?" *United States Naval Institute Proceedings*. Annapolis: Apr 2003.Vol.129, Iss. 4; Available from www.il.proquest.com/proquest/; Internet; accessed 15 October 2005.

Holland, William J. Jr "Technology Is Key to the Operational Art, Not an Obstacle." *United States Naval Institute Proceedings*. Annapolis: Apr 2004.Vol.130, Iss. 4; Available from www.il.proquest.com/proquest/; Internet; accessed 15 October 2005

Kline, Captain Jeff. *Born of War, Operations Analysis is the Science of Decisions and Command.* Available from www.nps.navy.mil/orfacpag/resumePages/papers/ Kline-OA-Born%20of%20War_files/Kline-OA-%20Born%20of%20War.pdf; Internet; accessed 18 October 2005.

McKenna Ted., "This Means War" *Journal of Electronic Defense*. Norwood: Dec 2003.Vol.26, Iss. 12; Available from www.il.proquest.com/proquest/; Internet; accessed 15 October 2005.

MacInnes, GC. "Computer Modeling Support to HQ ARRC during Operation Firm Endeavour" *Operational Analysis Support to NATO IFOR/SFOR Operations*. Report for NATO RTO Meeting Proceedings 22. Hull: Canada Communication Group, 1999

Maxwell, Daniel T. *An Overview of The Joint Warfare System (JWARS). A*vailable from www.mitre.org/work/tech_papers/tech_papers_00/maxwell_jwars/maxwell_jwars.pdf; Internet accessed 15 October 2005.

Meigs, Montogmery C. "Operational art in the new century" *Parameters*. Carlisle Barracks: Spring 2001.Vol.31, Iss. 1; Available from www.il.proquest.com/proquest/; Internet; accessed 15 October 2005.

Nance, Richard E. *Distributed Simulation With Federated Models: Expectations, Realizations And Limitations,* Available from http://www.informs-cs.org/wsc99papers/149.PDF, Internet; accessed 15 October 2005.

Newman & Spurr Consultancy Ltd. "JOCATS Overview" www.nsc.co.uk/jocasts.html; Internet accessed 15 October 2005.

Newman & Spurr Consultancy Ltd, "Computer-based training for Joint Operations," *JOCASTS White Paper V2.pdf*, via email Anne Conduit JOCASTS Project Manager 21 October 2005.

Perla, Peter P. *The Art of Wargaming.* Annapolis: United States Naval Institute, 1990

Robel, Mike. *The Influence of Wargaming on History.* Available from www.strategypage.com/dls/articles/200481122.asp; Internet; accessed 18 October 2005.

Rubel, Captain Robert C. "War-Gaming Network-Centric Warfare." *Naval War College Review* Spring 2001. available from www.nwc.navy.mil/press/Review/2001/Spring/art5-sp1.htm; Internet accessed 15 October 2005.

Stone, George III and Gregory A. McIntyre. *The Joint Warfare System (JWARS): A Modeling and Analysis Tool for the Defense Department.* Available from http://www.informs-sim.org/wsc01papers/091.PDF; Internet; accessed October 2005.

Starr, Stuart H. "Good Games: Challenges for the War-Gaming Community." *Naval War College Review* Spring 2001. Available from www.nwc.navy.mil/press/Review/2001/Spring/art7-sp1.htm; Internet; accessed 15 October 2005.

Sweden. Swedish Armed Forces. "Swedish Defence War Gaming Centre" www.fksc.mil.se/?lang=eng; Internet; accessed October 2005.

United Kingdom. Ministry of Defence. Joint Warfare Publication 0-10 *United Kingdom Doctrine For Joint And Multinational Operations,* Shrivenham: Joint Doctrine and Concepts Centre, 2002.

United Kingdom. Permanent Joint Headquarters. "PJHQ Organization" Available from http://www.northwood.mod.uk/org/organise.htm; Internet; accessed 15 October 2005.

United States. Department of Defense. *Doctrine for Planning Joint Operations JP5-.0* April 1995. Available from www.dtic.mil/doctrine/jel/new_pubs/**jp5**_0.pd; Internet accessed 15 October 2005.

United States. Department of Defense. "Modeling and Simulation Information Analysis Center," www.msiac.dmso.mil/; Internet; accessed 15 October 2005.

United States. Department of Defense. DMSO, "Technology Thrusts: C4I to Sim" https://www.dmso.mil/public/thrust/c4isim/; Internet; accessed 14 October 2005.

United States. United States Marine Corps. "An Introduction to Wargaming," www.wargaming.quantico.usmc.mil/intro.asp; Internet; accessed 15 October 2005.

United States. Joint Chiefs of Staff.. *Joint Task Force Planning Guidance and Procedures JP 5-002*. January 1999. Available from www.dtic.mil/doctrine/jel/new_pubs/jp5_00_2.pdf; Internet accessed 15 October 2005.

United States. Joint Chiefs of Staff. *JP 5-00.1 Joint doctrine for campaign planning* Washington, D.C.: Joint Chiefs of Staff, 2002

United States. Joint Chiefs of Staff. *JP 5-00.2 Joint Task Force planning guidance and procedures.* Washington, D.C.: Joint Chiefs of Staff, 1999

United States Joint Force Command. "Joint Conflict and Tactical Simulation (JCATS)," www.jfcom.mil/about/fact_jcats.htm; Internet accessed 15 October 2005.

United States Joint Force Command. "Joint Theater Level Simulation," www.jfcom.mil/about/fact_jtls.htm; Internet accessed 15 October 2005.

United States Joint Force Command. "Joint Multi-Resolution Model," http://www.jfcom.mil/about/fact_jmrm.htm ; Internet accessed 15 October 2005.

United States Joint Forces Command. "Delivering joint solutions today or joint problems tomorrow." http://www.jfcom.mil/newslink/storyarchive/2004/pa110404a.htm; Internet; accessed 15 October 2005.

United States. U.S. Army War College. Department Of Military Strategy, Planning And Operations, *Campaign Planning Primer AY 05*, Available from www.carlisle.army.mil/usawc/dmspo/ Publications/Campaign%20Planning%20Primer%20AY05%20.pdf; Internet; accessed 15 October 2005.

United States Joint Forces Command. "Modeling And Simulations," http://www.jfcom.mil/about/fact_modsim.htm; Internet; accessed 15 October 2005.

Vakas, Deborah, John Prince, H. Ric Blacksten, and Chuck Burdick. *Commander Behaviour and Course of Action Selection in JWARS.* Available from www.informs-sim.org/wsc01papers/092.PDF; Internet; accessed 15 October 2005

Wade, Norman N. *The Joint Force & Operational Warfighting SMARTBOOK: Guide to joint doctrine*, *Operational Warfighting and Theater/Campaign Fighting*, Lakeland: Lighting Press, 2003