Track: C2 Experimentation

Using Wargames for Command and Control Experimentation

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Abstract

Wargames are a staple technique of military research, but various inherent characteristics have prevented their use as rigorous analytic tools. Traditional gaming has long employed C2 among players, however, C2 has been generally regarded as a necessary adjunct to generating player moves, not as an element of independent scrutiny or play. Games that explore network-centric warfare necessarily focus precisely on player C2. Beyond their traditional exploratory function, wargames can constitute the basis for valid C2 experimentation. Harnessing wargames for C2 experimentation is possible if we conceptually divide them into two layers: the simulation layer and the command and control layer. Traditional wargames have consisted solely of the simulation layer, whose limitations with respect to experimentation are well documented. By separating out player C2 we have a different situation. C2 in a wargame can be real, not simulated, because it is what players actually do to each other and therefore is subject to valid experimental treatments. Such conceptual separation also allows the C2 experiment to ride on a relatively simple game that can be iterated more easily than traditional wargames. An example of a recent joint Naval War College / Center for Naval Analyses C2 experiment using a wargame is provided.

Introduction

The advent of the information age has spawned the concept of network-centric warfare (NCW); the harnessing of electronic information technologies to create massive efficiencies in command and control. The promise of NCW is that these efficiencies will create a new style of fighting that will make traditional forms obsolete. While there is ample reason to think that such benefits are indeed possible and will be of advantage to the United States and her allies, there is also reason to believe that the achievement of this capability will be neither quick, cheap nor easy. Simply wiring up the Armed Forces and providing them with the latest computers, cell phones and displays is not likely bring about the revolution in an acceptable manner. In the most recent series of Global wargames at the Naval War College (NWC), players consistently experienced difficulty in finding and recognizing key information embedded in nested web pages, and banks of advanced displays failed to prevent significant disconnects in shared situational understanding. Clearly, much hard work will be required to advance our NCW capabilities, and a significant element of that work will involve command and control (C2) experimentation. The purpose of this paper is to outline how wargames can be used as an effective tool to support C2 experimentation.

C2 Experimentation

While there is considerable scope for technical experimentation in the realm of NCW, much experimental activity will involve the exploration of human responses, much like that carried out in the realm of experimental psychology. Given the complexity of human response, C2 experimentation will be difficult, especially as we attempt to generate both realism and rigor in our experiments. Tradeoffs will have to be found, and one way to accommodate both imperatives is to divide the experimental effort

into phases, each of which possesses its own requirements for rigor and control but also opportunities for achieving realism and validity.

Military experimentation has taken several forms over the years, and much of it failed to attain the rigor in design and execution necessary to justify the claimed results. Recently, the Department of Defense Command and Control Research Program (CCRP) published a Code of Best Practice for Experimentation in order to improve the quality of research on NCW issues. In it, three types of experimentation, which can be roughly equated with phases in a program of experimentation are defined[1]:

- Discovery Experiments, in which the potential military benefits of a new technology or practice are explored

- Hypothesis Testing Experiments, in which theories are tested and specific hypotheses supported or refuted

- Demonstration Experiments, in which new technologies or practices are shown to have value in specific sets of circumstances.

Wargames have a role in each of these phases or experimental types. By providing them with adequate controls, games can provide a venue in which experimental activity could occur.

The Limitations of Traditional Wargames

Wargames have been around in one form or another since the advent of organized warfare. Ranging from simple and abstract two-player games such as Go to extensive simulations involving hundreds of participants, wargames have been used to test plans, educate warriors, impress congressmen, demonstrate the value of new weapons and generate familiarity with a theater of operations. Far from being a fading relic of industrial age warfare, the wargame appears to be increasing in popularity, if we are to judge by the amount of gaming activity in the U.S. military. Wargaming is indeed a useful, if not ubiquitous tool for knowledge generation; however, as an intellectual activity, it has some definite limitations. To quote Peter Perla:

> "First and foremost, wargaming is not analysis, at least not in the defense community's usual sense. It is not a technique for producing a rigorous, quantitative or logical dissection of a problem or for defining precise measures of effectiveness by which to compare alternative solutions."[2]

Moreover, wargaming is not duplicable. A true wargame, involving human players making free decisions, whether the outcomes are based on die rolls or rigid results tables, is not sufficiently controllable to be replicated in the scientific sense.

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[1] David S. Alberts and Richard E. Hayes, *Code of Best Practices for Experimentation*, (Washington D.C.: DoD Command and Control Research Program, 2002), 19-24.

[2] Peter Perla, *The Art of Wargaming*, (Annapolis, MD: The Naval Institute Press, 1990) 164.

Beyond the basic intellectual limitations outlined above, there are practical difficulties. Most DoD-style wargames require the presence of numerous players, frequently a blend of operators, headquarters staffers and civilian contractors and consultants. Their time is limited and expensive, and therefore games are confined to a single pass through the scenario. Control is almost always either purely free assessment, or some combination of rigid and free assessment, due to the severe playability limitations posed by existing computer models. Reset and replay of the game is rarely, if ever accomplished. The free assessment of games also poses a problem. While individual umpires might be able to backtrack and divulge their assessment logic to an analyst for simple, short games, the ability to either capture or reconstruct assessments by multiple umpires in fast-moving, large games is highly problematic, to say the least. And umpires frequently bring various kinds of doctrinal and experiential baggage with them, much of the time tacit or unacknowledged, that further confounds analysts as they attempt to backtrack game outcomes to their causes.

This state of affairs has been further exacerbated by the conflation of wargames, field exercises and experimentation. In its quest to develop NCW, the Navy has undertaken a series of high profile Fleet Battle Experiments in which various elements have been tested in a fleet operational environment. The perceived success of these "experiments" has prompted other services and the joint community to follow suit. However, the scale of some of these efforts has grown to the point that they must encompass service training exercises to be anywhere near cost-effective. Moreover, in an effort to both enhance the experiment and the realism of the exercises, synthetic forces produced by computer models have been inserted, along with various command cells, assessment cells and other trappings of wargames, including free play Red cells. Such a conflation tends to be unmanageable and what's worse, compromises the intellectual rigor and integrity of the experiment. An example of such conflation can be seen in a Defense News report of an upcoming Marine Corps field exercise called Olympic Dragon 04. In the first paragraph, it is termed a wargame, an experiment and uses live forces in the field.[3]

This collection of difficulties does not negate the utility of games, but it does limit their suitability as vehicles for military experimentation. A wargame can be indicative and suggestive, and is eminently useful as an educational tool. Notwithstanding their inherent limitations, games can also be squeezed for some analytical products, especially if their play is rigidly governed by a set of explicit rules or adjudicated by means of a computer model, and then allowed to go where the rules, models and player decisions take them. In these cases, the assessments can be backtracked rigorously, and the effects of player decisions can be ascertained with some clarity. Such games do not "prove" anything in the scientific sense, but they can withstand closer scrutiny, and within the context of game rules, conclusions can be drawn.

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[3] Sandra I Erwin, "Marines to Bridge Info Gaps in '04 Wargame," *National Defense*, (Arlington, Va. National Defense Industrial Association, December 2002)

Regardless of the rigor with which a wargame is designed, executed, assessed, analyzed and reported it still does not achieve the highly structured environment required to produce reliably reproducible results. But it is precisely this rigor that an exceedingly complex phenomenon such as NCW demands in order to become understandable, and ultimately achievable. This does not mean that wargaming does not have a role in the development of NCW however, even in the realm of experimentation. In order to understand how this is possible we must first consider the nature of NCW gaming.

NCW Wargaming

To understand how NCW relates to traditional wargaming, let's first establish a set of wargaming dimensions as follows:[4]

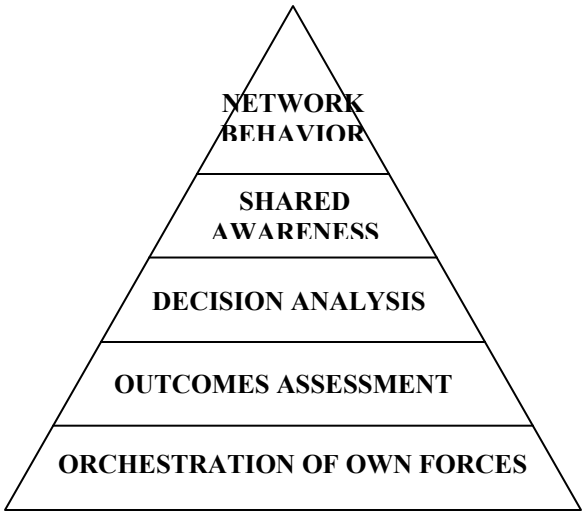

Figure 1: Gaming Dimensions

The bottom three dimensions constitute the universe of traditional wargaming. There are legitimate activities at these levels, ranging from simple "rock drills" to the large Title X games. In order to achieve validity (correspondence to the real world) in a certain dimension, game components at lower dimensions must be valid. We would not put much weight, for instance, in game findings based on player decisions in a game that suffered from a defective assessment process or in which players used unfeasible tactics. Traditional gaming has long employed command and control among players, via telephones, teletypes or other means, including the ever-popular "sneaker net." **However, C2 was generally regarded as a necessary adjunct to generating player moves, not as an element of independent scrutiny or play**. NCW raises C2 to the

[4] Robert Rubel, "Wargaming Network Centric Warfare," *Naval War College Review*, (Newport, RI: Naval War College Press, Spring 2001), 61-74.

prominence of an order of battle element and bits of information have become the new, most important playing pieces. Ground truth moves from the umpires' map boards and into the minds of the players. Who knew what, when (situational and shared awareness) is the new currency of NCW gaming as it focuses on human decision making in a networked environment.

To date, very few, if any, true NCW games have been played. That is not to say that there haven't been a multitude of games anointed with that title, but actual practice tends to belie the advertising. Some of the best-known efforts have been the Navy's Global wargames from 1999-2001. Focusing on generating a true collaborative information environment within the context of a moving clock / moving common operational picture (COP), these Global games featured an internal LAN over which players attempted to coordinate their efforts. These games were designed and executed not as experiments per se, but as demonstrations. In this role they were highly successful, generating not only insights for the players and catalytic reports for the Navy Staff and systems commands, they also stimulated one flag officer to take the game's C2 system to sea, with significant advances in C2 efficiency for his battle group.[5] But even these games did not quite reach the level of true network-centric warfare simulation. Among the reasons for this is that they were conducted on a gigabit LAN, so there were no effective bandwidth limitations or other "real world" network effects. However, they can be considered exercises in exploring shared awareness between simulated operational level staffs, albeit in a somewhat chaotic manner.

One way to achieve NCW gaming is to simulate a wide area network, with all of its congestion, bandwidth limitations, broadcast storms and other characteristics. But this is not enough. Both players and umpires must be able to observe and understand what is happening to the network, including attacks, and be able to make decisions based on that knowledge, because after all, wargaming is about player decisions. The current solution is to utilize "quality of service" software and hardware. The Naval War College is now embarked on a project to reconfigure its gaming center to do just this. However, even this is insufficient in the long run. Ultimately, we will have to somehow simulate populous, heterogeneous and dynamic tactical networks, for therein, theorists claim, lies the real potential power of NCW. But even if we succeed in perfecting the simulation of NCW for the purpose of wargaming, the difficulties inherent to wargames still intrude, and keep us from harnessing their power unless we approach the issue a new way.

A New Way to Look at Wargames

The literature on wargaming categorizes games any number of ways, including assessment technique, number of sides, level of war, etc. Games are also dissected into their constituent parts: cells, scenarios, rules, orders of battle, etc. For the purposes of this paper, wargames can be usefully thought of as consisting of two basic layers:

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[5] For an excellent discussion of how the COMCARGRU THREE staff leveraged the lessons learned and technologies they learned to use during the game, see Captain Eileen F. MacKrell, "Net-Centric Intelligence Works!", article accepted for publication in the Naval Institute *Proceedings*.

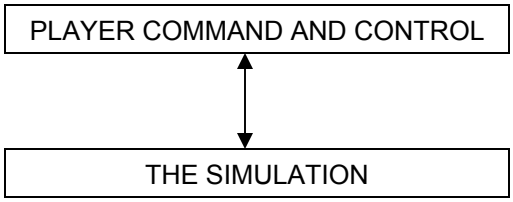

Figure 2: Wargame Structure

Player command and control consists of those means of communication as well as doctrine, business rules and organization that allow players to coordinate their inputs to the umpires. The simulation consists of almost everything else needed to make the game work, including umpires, the scenario, orders of battle, models, etc.

The significance of this breakdown is that it allows us to create some intellectual space within the context of wargaming where legitimate experimentation can occur. Another way to express why wargames are inadequate for experimentation purposes is to say that they are not real, or to put it yet another way, they are simulations and therefore, inevitably, are partial representations of reality. Their link to the real world is tenuous: governed by the "validity" of the simulation. Given the difficulties attendant to creating a valid simulation of a world that does not yet exist (the NCW world), this inadequacy is of decisive significance. This is not to say that the Global games have not been impressively indicative of the emerging military information operations environment, but they were nonetheless simulations, and no robust link to reality could be established (other than their catalytic effect: i.e., the flag officer who subsequently commanded his battle group based on his gaming experience; but we must clearly distinguish between a game influencing reality and a game reflecting reality).

However, if we rope off player command and control, we have a different situation. **Command and control in a wargame can be real, not simulated, because it is what players actually do to each other.** The link to reality is iron clad because it is reality. Admittedly, there are limits to this notion. Almost always, in wargames, Red C2 is non-existent, or rather perfect, because Red mostly consists of a single group of co-located players. To the extent that Blue players "helo" between cells, their command and control is based on a defective simulation. However, if player C2 conditions are rigorously controlled, then wargaming can be used to conduct valid C2/NCW experimentation.

C2 Experimentation Using Wargames

One approach to wargame C2 experimentation involves the application of robust observation of a single game. In this approach various elements of player performance and awareness are recorded and analyzed.[6] Subject to the inherent limitations of such an

[6] See for example Han Tin French and Amanda Hutchinson, of the Land Operations Division, Austrailian Defense Science and Technology Organisation, "Measurement Of Situation Awareness In A C4ISR

approach, which are the same as any research involving observation of natural events, results can be obtained which can be extrapolated to the real world. Notwithstanding the opportunities involved in such C2 research, this paper does not argue that the huge Newport Global games were, or even could be, valid C2 experiments; the practical logistics difficulties mentioned at the start of the paper make such games highly problematic venues because of the difficulties in achieving validity at the orchestration and assessment levels.

The CCRP Code of Best Practice for Experimentation regards wargames as weakly structured environments that are not suitable for rigorous experimentation. [7] However, the use of small, simple games have been used as a basis for experimentation for some time. One of the most notable projects is the Advanced Architectures for Command and Control (A2C2), carried out by a consortium of organizations, including the Naval Postgraduate School and Aptima, Inc. Using a relatively simple computer simulation, this project examined the ability of C2 organizations to dynamically adapt to a changing mission environment.[8] This type of experimentation reflects a rigorous and supportable approach to using gaming as espoused in this paper.

However, it is easy to sail into shoal waters when conducting research using gaming. An experiment at the Naval Postgraduate School undertook to examine the effects of information completeness, work load and fast patrol boat tactics on Navy surface action groups.[9] The experiment involved single player interaction with a computerized simulation of littoral naval combat. Players executed eight experimental runs each and their responses were analyzed to determine the effect of experimental treatments on surface action group performance. The difficulty with this type of experimental wargaming is that despite the application of suitable and rigorous procedure (as was the case in this experiment), the results were derived from the simulation layer, whose connection to the real world is inherently indirect. The dangers of investing unwarranted weight to the results are exacerbated because command and control was an implicit element of the experiment.

The use of small, simple wargames to examine the basic phenomenology of command and control is both practical and intellectually supportable. What follows is a brief description of one such experiment carried out by the Naval War College

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Experiment," a paper submitted to the 7th ICCRTS
http://www.dodccrp.org/Activities/Symposia/7thICCRTS/Tracks/pdf/120.PDF

[7] Alberts and Hayes, 54

[8] Friedrich J. Diedrich, et. al., "Adaptive Architectures for Command and Control: Toward An Empirical Evaluation of Organizational Congruence and Adaptation," a paper submitted to the 7th ICCRTS, September, 2002.
http://www.dodccrp.org/Activities/Symposia/2002CCRTS/Proceedings/Tracks/pdf/035.PDF

[9] Nicholas K. Vodantis, "A Two-Cubed Experiment to Examine the Effects of Information Completeness, Work Load, and Fast Patrol Boat Command and Control in the Littorals Utilizing the Wargame Simulation: Batman and Robin," a masters thesis submitted to the faculty of the Naval Postgraduate School, Monterey, CA. June 1996.

In an effort to both hone its experimental capabilities and understand some basic shared awareness phenomenology, the Research and Analysis Division (RAD) of the NWC Wargaming Department undertook an experiment to determine the effect of command style on shared awareness. To do this, it employed a simple computer-based wargame called Scud Hunt, to provide a venue for player command and control efforts. The game was a simple five-by-five matrix in which three Scud missile launchers were hidden. Teams of four players were given various ISR assets to manage, including satellites, several types of recon aircraft, special operations forces, spies and signal intelligence. Each player was put in charge of a particular type of ISR asset. Players had to coordinate their ISR efforts to maximize their chances of correctly identifying the Scud locations in five moves.

The experiment used six player teams, each of whom played the game six times in a Latin Square sequence of treatments. The treatments included command by direction (one player in charge), command by plan (players explicitly followed a provided search plan), and command by influence (self synchronization). Superimposed on this series of treatments were two others, an objective "COP" that displayed the true outputs of the various ISR assets (false positives and negatives were possible), and a "push visualization" in which players populated the operational picture with what they thought was the true case. This procedure allowed us to apply statistical tools to distill out training effects (and there were some). The dependent variable was player team accuracy in locating the Scuds. While the particular results of this experiment are not relevant to this discussion, we were able to use a simple wargame as a venue for valid C2 experimentation, producing a report that would withstand the scrutiny of a skeptical reader[10]. The experiment was valid because it included sufficient repetitions to generate valid statistical results, and it was structured such that it could be repeated by an independent researcher, with a reasonable expectation that similar results would ensue.

This experiment is an elemental example of using wargaming as a vehicle for NCW experimentation. While there are clear limits on using gaming in this manner, it appears that there is ample room for further exploration. The NWC RAD is contemplating follow-on experiments using more complex gaming systems in order to study higher order phenomena, such as common operational pictures and the effect of the accuracy and order of arrival of information on the formation of shared situational awareness. Understanding fundamental phenomenology such as this is both critical to further progress in harnessing information age technology for military use in C2, and is eminently susceptible to valid examination by wargaming centers.

We are currently proceeding on an empirical basis. It is not completely clear at what point the complexity of a game renders it unsuitable as an experimental venue. We can make some preliminary observations:

- The mechanics of the game must not constitute an intervening variable in the experiment

[10] Peter Perla, Michael Markowitz and Christopher Weuve, *Game-Based Experimentation for Research in Command and Control and Shared Situational Awareness*, (Alexandria, Va: The CNA Corporation, 2002.)

- The game must allow sufficient repetitions to derive valid statistics
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- The "realism" of the game need be no more than the nature of the hypothesis and the phenomenon under study demands
- The game must be sufficiently playable and interesting to generate player involvement and effort
- There must be a quantifiable dependent variable
- Training effects must be taken seriously

This is not to say that single-run wargames cannot be used for experimentation. Indeed, games adhering to some basic rigor in their design and execution might constitute valid exploration or demonstration experiments. This is especially true if the line between player C2 and the rest of the simulation is kept distinct. If large, one-run wargames such as Global or exercises such as Millenium Challenge 02 are leveraged for C2 research, sufficient observations over the course of multiple games using similar C2 simulation methods must be accumulated to support the derivation of insights.

Conclusion

At this stage of NCW development, much of the basic phenomenology connected with advanced forms of command and control is not completely described nor well understood. Progress will be predicated on a broad base of experimentation, some of which can be conducted via wargames if they are designed and executed in a way that provides confidence in the observations and conclusions drawn.