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## War-gaming network-centric warfare

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**Abstract:** It is possible to design conventional war games with a reasonable degree of validity, but to explore fully the needs of network-centric gaming, war gamers must go beyond traditional methods. The only way to game network-centric warfare is to actually create a network of players with shared awareness.

**Links:** [Linking Service](#), [Find it @ UAB](#)

**Full text:** The familiar techniques of war gaming will be insufficient for scenarios involving network-centric warfare. NCW, as it is known-with its focus on speed, downstream effects, and information flow-will require of gamers more than simply additional computational power or communications bandwidth, although these will certainly be needed. Gamers will need a new framework in which to apply these tools.

In 1886, Lieutenant William McCarty Little introduced war gaming to the Naval War College. The concept found immediate acceptance; faculty and students recognized that the war game was well suited to analyzing the characteristics of naval warfare of the time. Gaming has since been applied to all manner of warfare, in a variety of ways. As warfare has become more sophisticated, multidimensional, and joint, the challenges of gaming it have increased. Even the application of computer technology has not been effective for all purposes, especially in games that involve large forces. We are now facing, in network-centric warfare, a new form of conflict that will challenge gamers even more severely. In this article we will attempt to develop a framework to help us identify techniques necessary for gaming network-centric warfare.'

A characteristic of warfare that has made it amenable in the past to simulation through gaming is its inherently structured nature. Troops operate in formations; so do ships and aircraft. Groupings of units or formations generally operate according to doctrine, in some specified relationship to one another. As a result, war-game designers have been able to govern and model the movements of forces and to project the results of combat with the enemy by relatively simple rules. A scenario that confines itself solely to surface ships, ground forces, or aircraft generates possible interactions and outcomes that are few enough in number for a "playable" game-one with rules sufficiently simple to allow it to be played in a reasonable period of time and at acceptable effort and expense. However, as the numbers and types of playing "pieces" grow and the flexibility of their employment doctrine increases, the difficulties of gaming by sets of rules swell almost exponentially. Today, despite the impressive increases in computing power, operational-level games involving the full range of forces (which includes space assets), even in traditional hierarchical command arrangements, must generally be controlled and adjudicated not by rules or algorithms but by the professional judgment of human umpires.<sup>2</sup> The current state of affairs in war gaming, then, is not totally satisfactory. Still, it is possible to design and execute games that have a reasonable degree of validity. By validity we mean a correspondence with reality sufficient to allow useful insights to be drawn from the game's results. Validity is achieved through careful design of the scenario and control techniques, and recruitment of players and umpires with appropriate credentials. Of course, computer models are critical, but they are usually employed "off-line"-that is, specialized models are used to support the judgment of the human umpires who ultimately decide the aggregated outcomes of complex and extensive engagements.

### A BASIC GAMING FRAMEWORK

War gaming can be classified in many different ways. One common distinction is between educational (or training) games and research games. In educational games, the objective is to acquaint players with warfare situations and exercise their decision-making skills. Designers of educational games may stretch the bounds of

probability somewhat in scenarios, as may control cells in move-- outcome assessments, in order to ensure that players are confronted with the decision-making situations desired by the game's sponsor-the command or entity (not necessarily the war-gaming center where it is conducted) that created the game requirement and set its objectives. Research games, in contrast, are designed to generate insights into military problems; designers and controllers attempt to inject as much realism as possible, given the inherent limitations of the medium. Network-centric warfare would be gamed primarily for research purposes; however, of course, research games frequently have instructional value, and the proposals advanced here would apply to educational and training games as well.

War games are also classified by the way they deal with time. Some proceed in stages, known as "moves." In each of these steps, players (or groups of players) privately assess a situation as they perceive it-on the basis of "intelligence" provided by the control cell, and within the scenario framework-and then report to the controllers their intentions (force movements, dispositions, and fighting orders) for the next specified period of time. The control cell's umpires, receiving inputs from all player cells, analyze their interactions to identify likely combat engagements and assess their outcomes. Generally, moves cover short periods of time for tactical-level games and much longer increments for operational and strategic-level ones. In contrast to such stepwise exercises are operational games, which involve "moving game clocks" and present players with continuously changing situations to which they must respond. The "clocks" in such games, which are almost always computer based, typically run at four or six times normal speed. Operational games tend to be limited to the tactical level, due to the necessarily limited spans of time they can accommodate.

Network-centric games virtually demand moving game clocks because of the criticality of time dynamics. In other words, one of the primary benefits of NCW is that the side employing it can generate rates of change that are unmanageable for the other side's command and control system. Because of this, a timestep-move convention would be unsuitable. A moving game clock would be sufficient for tactical-level play. However, analysts believe that NCW will produce an intermixing, or compression, of the levels of war.<sup>3</sup> If so, it will be necessary to accommodate both short and long-term phenomena in NCW-based war games. One possibility would be composite operational and move-step games, in which "time" advances at different speeds in various portions of the game. To meet tactical-level objectives, designers would set aside periods in which players would operate against a moving game clock, alternating with move-step phases embracing much longer increments of game time. At the start of each successive operational-play session, umpires would assess the war's progress to that point and produce a new situation for players to confront. There are probably other ways of dealing with the problem of time in network-centric games, but it is clear that traditional methods will not suffice.

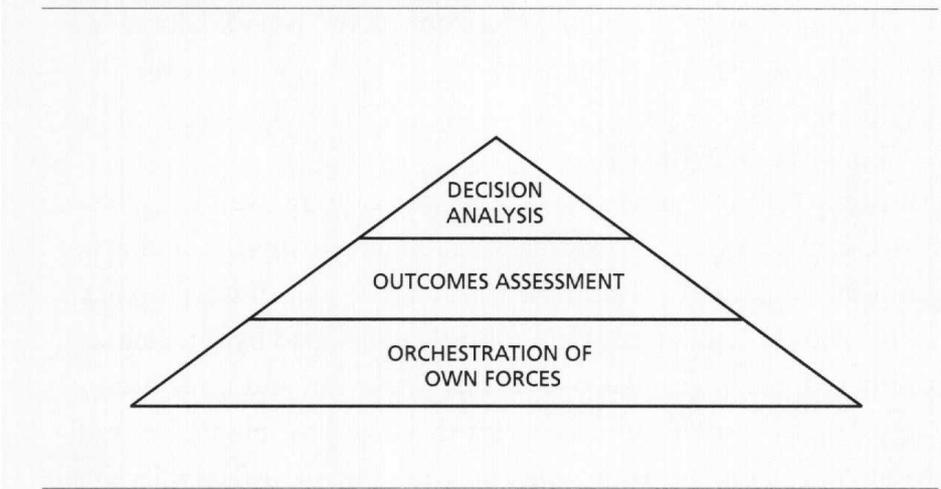
In order to explore fully the needs of network-centric war gaming, however, we must go beyond traditional classification methods. The underlying structure of war games suggests a set of categories that illuminate the way in which NCW relates to traditional gaming. All war games, whether they involve fighting sail or network-centric fleets, soldiers, and satellites, share a certain hierarchical organization. We will refer to the levels of this structure as "dimensions" (figure 1), in order to avoid confusion with the "levels of war"-tactical, operational, and strategic-which themselves form a different gaming framework.

At the bottom of the pyramid is the most fundamental dimension of gaming. If blocks representing ships are laid out, perhaps on a chart table or a grid floor, players can move them around and see directly their relationships to one another at various points. Similarly, the U.S. Army routinely conducts "rock drills," in which markers (as simple as bits of stone) representing platoons or tanks are used to orchestrate maneuvers. Even complex operations, including their logistical flows, can be simulated in essentially this way, using either physical markers or computer symbols. Many games need to go no farther. This first dimension is an extremely important aspect even of more ambitious games; the analytical or instructional usefulness of outcomes at higher dimensions of a game depends on how realistically forces are played. If tactics are used that would be

impossible to execute in the real world, assessments of interactions with the enemy will be invalid. The next dimension is assessment of outcomes, the determination of what would have happened in a confrontation of forces. Whether based upon a roll of the dice, the "crunching" of complex algorithms by a computer, or the judgment of human umpires, the outcomes form the basis for judgments of how effectively players orchestrated their forces, and for the input to be provided them for subsequent decisions. Many games stop at this dimension; such exercises are generally analytical and are meant to draw insights into the suitability of certain tactics or the efficacy of new equipment. Here again, fidelity to real-world phenomena is necessary in order to prevent distortions at the dimension of player decisions. Skewed assessments can lead to faulty analysis and to decisions that yield no useful insights.

The topmost dimension is the analysis of player decisions. Frequently the focus of educational gaming, the purpose of such analysis is to help players perceive objectively their own reactions to warfare situations. It must be emphasized, however, that many analyses focus on aspects other than player decisions. For instance, a game intended to explore the logistics of amphibious operations might require players to develop possible courses of action; the factors affecting these courses of action might well be of more concern in terms of game objectives than specific plans produced. In order to simulate the "fog of war," players in educational games are typically provided not the actual, precise, and complete outcome assessments-the "ground truth," about which more below-but only those elements (or indications of them) that might realistically be observable. Research games do not often deal with this dimension, because of its indeterminate and unpredictable nature; a notable exception is the Navy's Global War Game series.

**FIGURE 1**  
**"DIMENSIONS" OF GAMING**



**NETWORK-CENTRIC WARFARE**

Having established a baseline understanding of war gaming, we must do the same for network-centric warfare. Stripped of the jargon and mysticism that has grown up around it, NCW can be simply described as the style of warfare that is possible when individual combat units are robustly connected by information. When this is achieved, many familiar constraints disappear, and units become able to interact in many more productive ways than are possible under traditional systems of command and control. In fact, the potential flexibility is so great that centralized orchestration or management, however lightly exercised, becomes a limitation. When units know what is going on and are confident that others do as well-that is, when they have shared awareness-they can themselves avoid wasting efforts on enemy units that other friendly forces are engaging, or even shooting at each other. They can also render mutual support without higher-echelon coordination, fixed physical relationships to each other, or restrictive doctrine. The net effect of this new flexibility is a "swarming" warfare style that demands a fundamentally different approach to command and control than has been practiced up until now.'

Current U.S. practice employs layers of staffs to coordinate the efforts of command echelons below them. Plans and orders originating from a senior commander produce a series of staffing cycles in which successively junior echelons distill the orders of the next higher echelons into more focused orders for their own subordinate commanders. This cascade of planning and order writing can produce delay and confusion. In a network-centric environment, fighting organizations will be much "flatter," because the need for intermediary coordinating layers will be obviated. However, the exact nature of future command and control requirements, should new and radical policies and techniques be adopted, cannot be determined without resorting to some form of gaming and simulation.

The principal requirements for achieving network-centric warfare are a network and shared awareness. By a network we mean linkage of all units and echelons of a force with all others. But merely wiring together a collection of units does not guarantee that NCW or its benefits will result; network-centric warfare is a behavioral, tactical, bottom-up phenomenon. The network cannot be achieved either merely by tuning everyone's radios to the same frequency, because voice channels alone cannot deliver the required diversity and volume of information. Nor is e-mail sufficient. We are talking about significant bandwidth, enough for simultaneous transmission of voice, video, data, and any other necessary medium of communication. All this is necessary because shared awareness is a robust phenomenon-comprehensive, responsive, adaptable, and survivable-or it does not exist at all.'

Shared awareness entails more than the possession of large amounts of information; in fact, flooding the network with information will guarantee that shared awareness does not occur. Some undertakings require complex graphics and a sophisticated stream of diverse media; in others, only a few words are necessary. In any case, the delivery of information is not enough; it must be absorbed and interpreted by the people within the units. Shared awareness, it can be seen, is a concept still in need of refinement by the naval warfare community. For our purposes, it is a condition in which every element of a force has sufficient grasp of its own situation and that of other friendly forces to synchronize its actions with them without detailed orders from next-higher echelons, which themselves would limit their exercise of command and control to the promulgation of broad "commander's intent.'

So understood, shared awareness via networks powers network-centric warfare. In turn, the "swarming" style of warfare thus enabled will generate higher operational tempos than ever before. Because of the psychological effects of shock and paralysis that such speed promises to inflict, it may become possible to produce higher-order, even strategic, effects very quickly. It is for this reason that many writers have envisioned the weakening of the boundaries between the tactical, operational, and strategic levels of war.<sup>6</sup> This compression would be furthered by information operations, which would themselves be enhanced by networking. All of this has important implications for gaming.

#### PUTTING IT ALL TOGETHER

Traditional war gaming employs markers, maps, and rules as substitutes for real warfare. What should gamers use to represent the network-centric environment? It seems clear that the only way to game network-centric warfare, as is the case for actually waging network-centric warfare, is to create a network of players with shared awareness. But what kind of network is needed? One of the principal values of gaming is that it allows its practitioners to simulate warfare "on the cheap"; field exercises using real troops and ships are prohibitively expensive, especially for educational and research purposes. How are gamers to replicate a network without generating a real one? The interrelated issues of shared awareness and robust networking confound our current attempts to game network-centric warfare. Overlaying specially designed local-area networks onto traditional command structures does not constitute a satisfactory simulation of the NCW environment. Until a tactical network of units, each of them exercising a great degree of autonomy, can be simulated, it will be impossible to game network-centric warfare adequately.

One promising line of development is agent-based models. These programs, fairly simple in concept but

demanding considerable computer power, consist of a number of individual 11 agents," virtual entities whose actions are governed by rule sets.' However, merely dictating rule sets is insufficient for exploring network-centric warfare. Units in the net must be able to generate information for headquarters, and anomalous behavior on the part of a few units will be necessary in order to create realism for the players in the command center. Absent a suitable model to simulate a network, an actual one will be required. To achieve that, distributed gaming will be necessary. The technology that distributes the gaming might be one that units would use in actual operations. If so, the control cell would need to generate "synthetic" forces, both "Blue" and "Red" (friendly and opposition), that would create a realistic combat environment in units' display systems. All of this implies a much closer relationship between war-gaming centers and operational units than currently exists. Still, a network is of no use unless players can effectively use the information it is capable of moving around. It is simply not sufficient to dump information into player cells; commanders and staffs would be quickly overwhelmed. Therefore, a prerequisite to the achievement of network-centric gaming is the development of techniques for creating shared awareness among the players. This may seem a chicken-or-egg dilemma: which should come first? However, it appears from the Navy's experience in the latest games of its Global series that shared-awareness technology can be employed and techniques "incubated" in the context of traditional command and control structures; thereafter, they can be applied to the new network paradigm. Then, and only then, can we embark on the process of effectively gaming network-centric warfare.

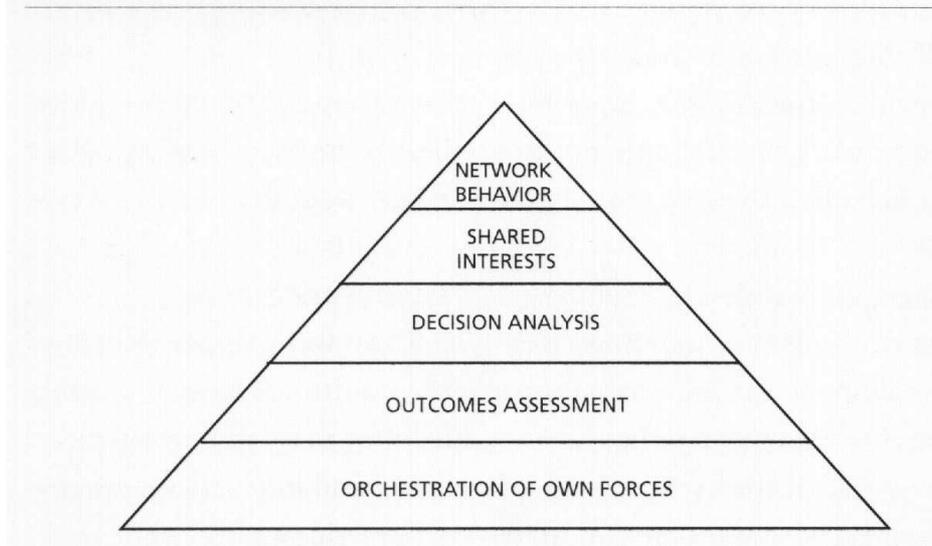
#### A Modified Gaming Framework

With the principles of NCW gaming in mind, we can alter (figure 2) the gaming structure by adding two new dimensions, producing a framework in which the higher and more challenging dimensions rely as before upon the execution of the more basic levels. This reliance has important implications as we proceed with the development of network-centric warfare gaming. First, as we have seen, gamers cannot ignore familiar skills and functions as they strive for more exotic applications. Errors or omissions in lower dimensions would call into question any insights derived or phenomena observed in the higher ones. That is not to say that absolute fidelity is required in all aspects; the attempt would probably result in a game that was unplayable or too expensive. However, it does mean that designers must pay attention to the lower dimensions and find ways to simulate properly, or fix, the variables that reside there.

The alert reader may object that the two new dimensions do not belong on top of the pyramid—that they should be considered rather as parts of the lowest dimension. This objection has considerable validity, on several counts. First, it is clear that the process of getting shared awareness and networking right is akin to orchestrating the tactical doctrine of forces. Second, one might well argue that it is the analysis of human decisions that is the most difficult and complex problem in gaming. Notwithstanding, the new dimensions are here placed atop the pyramid to highlight the extensions of gaming logic that are needed to game network-centric warfare effectively.

The dimension of player decisions becomes very interesting in networkcentric gaming. Since shared awareness is probably sensitive to competence of command, sponsors will have to be especially careful about whom they invite as players in NCW games. A reflexive application by a senior player of a traditional, centralized command style would probably end any hope of generating true shared-awareness behavior in a game. Moreover, players "taken off the street," with no training in or understanding of shared-awareness theory, techniques, and requirements will likely distort findings from games that seek to explore the various phenomena encountered.

**FIGURE 2**  
**HIGHER-LEVEL DIMENSIONS**



If all this is true, several implications emerge. First, it may be necessary to change command and control doctrine before NCW can be gamed, in order to train the officers who will be the players. In other words, game designers must work closely with command and control experts to synchronize player capabilities with game demands. Second, if NCW gaming achieves any degree of validity—that is, correspondence to a future warfare environment—the education and training needed by commanders for network-centric warfare is likely to be somewhat different than is necessary today.

Third, development of NCW gaming must proceed step by step up the framework. In other words, gamers should not begin the process by lashing together a network; they need first to game shared awareness alone, in the context of current scenarios and equipment. After collecting insights and perfecting their techniques, they can move with confidence to true network gaming.

Fourth, the development of network-centric warfare war games will bring a fundamental change to the gaming environment. Traditional games, whether played on map boards or computers, are conducted by moving playing pieces around in geographical arenas; the pieces' movements and interactions are governed by rules, perhaps quite complex. In network-centric gaming, while traditional geographic displays will be used, the most important "map board" will be the human mental picture. This is not to say that a commander's situational awareness has not always been critical—it has. But it will now be especially difficult for players to keep track of what is happening in the game, because events will orient themselves around the flows of information between networked players. While game pieces (force symbols) will continue to be necessary, the arena that counts in the network-centric game will be virtual, and there are as yet no adequate rules for the movement of information in that topography. At a minimum, gamers must recognize the fundamental shift of venue and consider how it affects design, play, and analysis. For instance, whereas previously gamers would use tactical experts as umpires and analysts, in NCW gaming they may want to involve psychologists or other social scientists, as well as perhaps physiologists and physicians.

#### Gaming Effects

Closely paralleling the development of network-centric warfare is a movement tending to shift thinking about military operations away from input-based measures (such as sorties flown, ground gained, or targets destroyed) and toward an output-oriented focus on the ultimate effects of military actions—that which, from the commander's perspective, has been caused to happen, or prevented. A classic, if limited, World War II example of this distinction arises from the cruiser-destroyer engagement near Guadalcanal on 8-9 August 1942: in "inputmeasure" terms, the result was the disaster (for the U.S. -Australian force) known as the battle of Savo

Island. But because the Japanese commander, Admiral Gunichi Mikawa, focused only on the "input" measure of allied warships sunk, the tactically victorious Japanese cruisers and destroyers departed without having attacked the vulnerable U.S. invasion shipping, which had been their ultimate objective.

The desired development of effects-based measures of effectiveness will bring with it a further fusion of the three traditional levels of war. This is characteristic of the emerging nature of warfare in the information age and has been predicted by many writers. It is a difficult idea to get hold of, and almost impossible if one remains tied to conventional intellectual frameworks. Once again, in terms of war gaming, simply superimposing effects-based planning onto the traditional gaming approach will not be sufficient; the whole approach to planning and assessment has to change.

Presently, the same rule sets that govern the movement and engagements of "pieces" determine the consequent attrition. The strategic effects of this attrition are then extrapolated—that is, if a certain percentage of an enemy force is destroyed or a particular category of targets is hit, certain repercussions upon enemy decision makers are assumed to follow. Detailed exploration of the linkages between battlefield events and political decisions has not been a regular feature of operational-level games. Combat—the use of force itself—has been the centerpiece, and its political and moral effects usually presumed. All traditional gaming models and methods are designed according to this approach.

Some work, however, has been done on effects. The Joint Warfare Analysis Center conducts detailed and sophisticated analyses of how various types of effects can be generated through bombing and other military action. To date, most of its work has focused on what may be termed "definitive effects," those whose mechanisms are physical—such as neutralizing an electrical generation grid or disrupting a rail transportation system. Such an effect can presumably be more easily predicted than can those that lie in the realm of belief and reason. The latter, whether catalytic or coercive, involve inducing enemy commanders or political leaders to make decisions one wants them to make. The complexities and difficulties of precipitating congenial decisions by hostile parties are self-evident. However, well-designed games might at least be able to generate useful insights into the problem.

To that end, a fundamental reorientation of the gaming process is required. Gamers must center their analyses, rules, and gaming contexts on the minds of the decision makers whom military actions are designed to influence. Models and methods must be capable of rationally depicting, assessing, and synthesizing the effects of a wide variety of events on these decision makers. In this context, the use of force is only one of an array of factors that must be considered if war games are to reflect in a valid way the influence of combat outcomes on an enemy's strategic decisions.

One way to shift gaming to an effects-centered approach is to focus on specific desired enemy decisions, to have players begin by analyzing the full range of factors, including (but not only) military ones, that might induce them. Such an approach would tend to keep players from ascribing a priori utility to various kinds of military actions. A sensitivity analysis might be able to identify certain types of military outcomes that would be most influential. The game proper would explore the prospects for generating those outcomes.<sup>8</sup>

#### Gaming Red

In addition to the taxonomy we have already laid out, war games can be classified as one-sided or two-sided. In one-sided games, the players are all "BLUE," or friendly; game controllers play "RED" (the enemy). One-sided games are frequently used when the sole concern is the orchestration dimension. In higher dimensions, one-sided games are most often associated with educational games; RED's actions are chosen to produce the desired decision-making situations for the players. In two-sided games, by contrast, there are both RED and BLUE players, and the opposition is free to act as it wishes; the control cell limits itself to assessing outcomes and briefing "intelligence" on them to both sides.

It might seem that if a network-centric game focused upon effects is preceded, as described above, by an analysis of factors bearing upon enemy decisions, the game itself could be one-sided, in effect a high-tech

orchestration exercise. This is not the case. Network-centric warfare theory envisions that rapid operations (rapid, that is, in comparison with the enemy's ability to react) will preclude ("lock out") certain RED military options and cause the kind of decisionmaking paralysis that French commanders displayed in 1940 in the face of the German blitzkrieg. One-sided gaming could not determine if BLUE network-centric operations induced such effects. Therefore, much network-centric gaming will have to be two-sided.

In present two-sided games, RED cells typically "play" orders of battle that reflect fairly accurately those of actual states being simulated. Organizations specializing in acting as the opposition in war games (like the Office of Naval Intelligence Detachment at the Naval War College) even employ enemy doctrine, insofar as it is understood. In network-centric gaming, however, the real key will be the accurate simulation of the enemy's command and control. Whether one-sided or two-sided, war games in which RED either is given artificially good situational awareness or is allowed face-to-face communication between all its command echelons will generate distorted outcomes. NCW game designers must ascribe networked capabilities only to player cells that would actually possess them; the RED side must be designed with realistic command and control mechanisms. Only then will players and sponsor be able to perceive the effects of rapid, network-centric operations on enemy decision making.

#### Ground Truth

Virtually all war games require some mechanism for keeping track of what forces actually exist (friendly, enemy, allied, and neutral), what their condition and capabilities are, where they are, what they are doing, and what they intend to do. Ground truth is, in effect, the sum of the scenario and the moves as privately submitted to controllers and mediated by umpires. Players usually are not allowed perfect knowledge and must rely on their own interpretations of the "11 observables" supplied to them; controllers or umpires, however, need ground truth so that they can accurately adjudicate combat results. In war games that deal solely with forces and physical geography, maintaining ground truth is a relatively simple matter; the control cells know both sides' strategies and orders, decide themselves the outcomes of engagements, and maintain a master map and status board with the true positions, movements, etc., of all forces.

In network-centric gaming, however, the focus shifts from geographic to mental terrain, and from ground, sea, and air maneuver to communications and psychology. In such a realm the very concept of ground truth, let alone plotting it, becomes problematic. It might be possible to play an NCW operational game (against a running clock) without keeping ground truth, but it would be almost impossible to analyze the play after the fact. At the very least it will be necessary, therefore, to find ways to capture each side's relative awareness and knowledge at key points. Observers might take notes in command centers, or software solutions may be found. In any case, the whole concept of ground truth will have to be reevaluated.

It is not going to be possible to game network-centric warfare by simply superimposing information technology onto traditional gaming techniques. Network-centric warfare represents in war gaming, as it does in warfare itself, a new frontier, one that will require new theory, new techniques, and new technology. It will also require new kinds of training for players, controllers, and designers.

This is not to say that traditional gaming techniques are made obsolete by the new warfare paradigm. The basic principles of game design remain largely intact. Games will still consist of players, pieces, and rules, and they must, as before, be playable at acceptable outlays of effort, time, and money. Nonetheless, game designers will not be successful in gaming network-centric warfare without adopting new approaches. It is of critical importance that they do succeed, because gaming will be vital to the adoption of this new warfare style among commanders. It will be in war games that they best learn to wage networkcentric warfare and to abandon certain ingrained elements of operational and tactical art, such as fixed formations and cascading staff cycles. War gaming will be fundamental in so developing future commanders' confidence that they do not retain old methods past their usefulness, simply out of lack of trust in the new.

#### Sidebar

Until a tactical network of units, each of them exercising a great degree of autonomy, can be simulated, it will be impossible to game network-centric war adequately.

#### **Sidebar**

The arena that counts in the networkcentric game will be virtual, and there are as yet no adequate rules for the movement of information in that topography.

#### **Sidebar**

It seems clear that the only way to game network-centric warfare... is to create a network of players with shared awareness. But what kind of network is needed?

#### **Footnote**

#### **NOTES**

#### **Footnote**

1. For background on war gaming, see Peter Perla's excellent *The Art of Wargaming* (Annapolis, Md.: Naval Institute Press, 1990). For the purposes of this article, we can define a war game as a simulation of real warfare events based on: a scenario, or story, that provides the context for game moves; a playing board (either physical or electronic) that provides an environment in which the pieces can move; playing pieces (again, either physical or electronic) that represent forces; a set of rules that govern how the pieces move and interact with each other; a procedure for determining the outcome of battles; and finally (and most importantly), players.

#### **Footnote**

2. The operational level is one of three levels of war commonly acknowledged by military officers. The lowest level, involving individual units up to divisions and battle groups, is tactical; tactics are mostly concerned with the actions of forces in contact with the enemy. The highest level is strategy, where the plan of war is linked to national political objectives. The operational level exists between the two. There, theater and joint task force commanders devise campaign and operations plans that maneuver forces so as to engage under the most advantageous circumstances, and to link the effects of their tactical actions to the attainment of strategic objectives.

3. David S. Alberts, John J. Garstka, and Frederick P. Stein, *Network Centric Warfare*:

#### **Footnote**

*Developing and Leveraging Information Superiority* (Washington, D.C.: C4ISR Cooperative Research Program, Department of Defense, 1999), p. 69; see the program site on the World Wide Web: <http://www.dodccrp.org>.

4. For more depth on the "swarming" style of warfare, see John Arquilla and David Ronfeldt, *Swarming and the Future of Conflict* (Santa Monica, Calif.: RAND, 2000). This publication is available on the World Wide Web: <http://www.rand.org/publications/DB/DB31> 1.

#### **Footnote**

5. "Shared battlespace awareness emerges when all relevant elements of the warfighting ecosystem are provided with access to the COP [common operational picture]." Alberts, Garstka, and Stein, *Network Centric Warfare*. This is the seminal book on the subject.

6. The phenomenon of compression of the levels of war has been widely discussed in the literature. For one of the first examinations of it, see Douglas A. MacGregor, "Future Battle: The Merging Levels of War," *Parameters*, Winter 1992-93, pp. 33-47.

7. An example of an agent-based model is SWARM, developed by researchers at the Santa Fe Institute. Agent-based models have been found useful in researching complex phenomena. See the Santa Fe Institute Website, <http://www.santafe.edu>, and the SWARM Website, <http://www.swarm.org>.

#### **Footnote**

8. One computer-based tool that shows promise in facilitating this type of analysis is the "Influence Net." It is based on Bayesian inference, a mathematical technique that calculates the relative influence of one set of factors upon another. The model is applied to particular decisions to be gamed (for instance, an Iraqi decision

on whether or not to use chemical weapons). Game designers would, with the help of a virtual web of outside experts, populate the model with the encyclopedic data necessary for its proper functioning.

**Footnote**

During the game, certain cells would play combat events in a traditional manner; the outcomes would be supplied to a wider net of players who are each responding to the others' inputs. The output of the model would indicate the proclivities of the targeted decision maker at the end of the move. For a basic description of influence nets see <http://www.inet.saic.com/inet-public/>.

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Captain Rubel is a naval aviator who flew A-7s and F/A-18s from 1973 to 1991. He made seven carrier deployments and participated in operations in support of U.S. policy in the 1973 Yom Kippur War, the 1974 Cyprus crisis, the 1980 Iranian hostage crisis, the TWA Flight 847 crisis, and DESERT SHIELD. He commanded Fighter Attack Squadron (VFA) 131 and served as the inspector general of U.S. Southern Command. He attended the Spanish Naval War College and the U.S. Naval War College, where he also served on the faculty. He has a bachelor of science degree in psychology from the University of Illinois, a master of science in management from Salve Regina University in Newport, Rhode Island, and a master of arts in national security and strategic studies from the U.S. Naval War College. He is currently the deputy dean of the College's Center for Naval Warfare Studies.

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