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PLANNING FOR THE KAMIKAZES

Toward a Theory and Practice of Repeated Operational Games

John T. Hanley Jr.

Operational gaming, which includes war gaming, in this context means a simulation that does not involve actual operations, one in which the flow of events affects and is affected by decisions made during the course of those events by players representing the roles of those involved in shaping the outcomes.¹ In 1957, operations analyst Clayton Thomas wrote that “there is no body of theory that sanctions the common use of operational gaming to seek a solution of a game through repeated plays.”² Little in operational gaming has changed since then.

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The purpose of this article is to suggest possible approaches to, and the value of, repeated operational gaming, either by one institution repeating games or by accumulating data from games played anytime, anywhere to explore what is essentially the same contingency.

Fleet Admiral Chester Nimitz in 1960 stated: “[T]he war with Japan had been re-enacted in the game rooms here [at the Naval War College] by so many people and in so many different ways that nothing that happened during the war was a surprise—absolutely nothing except the kamikaze tactics towards the end of the war; we had not visualized those.”³ Although this is an overstatement, it is true that repeated operational games, at the tactical and strategic levels, did allow Nimitz to understand developments as they happened and

to adjust his strategy for fighting in the Pacific.⁴ By the start of World War II, 99 percent of all USN flag officers were graduates of the College.⁵

This article proposes that repeated operational gaming provides an unparalleled technique for predicting factors governing battles and campaigns and anticipating actions that would be reasonable for adversaries and allies / security partners to take, thus eliminating most surprises, thereby better informing operational planning, force allocation, and force development.

Since 2003, the Naval War College has been conducting “Halsey” games with its students, similar to the way it was done at the College from shortly after 1887, when William McCarty Little introduced war gaming there, until World War II.⁶ An analysis of the Halsey games, using some elements of game theory, suggests promising ways to learn from repeated gaming.

This article addresses a version of the questions that George H. Heilmeyer, a highly respected director of the Defense Advanced Research Projects Agency (1975–77), posed when he was determining whether to approve a new project.

WHAT ARE WE TRYING TO DO?

We are trying to understand the factors governing emergent developments in the real world through mastering the complexity created by the interaction of sentient actors—represented by role players, umpires, and game control—whose behavior, with an admixture of luck and the randomness of nature, affects what happens. More specifically, we are trying to develop understandings of how U.S. courses of action (COAs) would interact with those of both allies / security partners and potential or actual adversaries to achieve U.S. security aims.

Specific cases include anticipating the strategies that potential adversaries such as the Chinese People’s Liberation Army (PLA), Russian military and paramilitary forces, Iranian Revolutionary Guards and military forces, and Islamic militants would use against U.S. forces in combat, so as to develop appropriate capabilities to deter and, if necessary, defeat them.⁷ Armed conflict in the future also will involve a greater admixture of cyber and movements comprising small groups and individuals that can wreak havoc with terror and weapons of mass destruction at a level that only states could accomplish in the past. Over the past decade, Intelligence Community (IC) Title 50 authorities have become a larger component of operations that are still dominated by Department of Defense (DoD) Title 10 authorities in U.S. counterterrorism efforts. Improvements in our ability to identify and track “persons of interest” through advances in sources of information, including biometrics, and the processing of “big data” portend an expansion of “shadow wars” beyond counterterrorism as the United States extends these new tools to missions such as counterproliferation, counterintelligence, and long-term competition with potential state adversaries. Going beyond

the war-gaming techniques of the period between the world wars, we are trying to anticipate future equivalents to the kamikazes.

This effort involves two major objectives. The first is to understand the logic of the competition under study to identify governing factors and anticipate how the key players may act. The second is to create a common vision and commitment to action among relevant policy makers and commanders. Gaming is a powerful method for simultaneously mastering complexity, enhancing communication, stimulating creativity, and contributing to consensus and a commitment to action.⁸

HOW IS THIS DONE AT PRESENT?

The major militaries of the world have used war gaming for over two centuries to simulate the logic of combat. Before the development of operations research (OR) in World War II, war gaming and field exercises were the primary techniques military organizations employed to create the synthetic experience of war. While using operational gaming to predict the outcomes of engagements is exceedingly problematic, given the number of factors not under the control of the participants, war gaming has a history of predicting accurately the factors governing battles and campaigns that actually emerged during subsequent operations.⁹ War gaming was a continuing activity at places such as the Naval War College and within German and Japanese military commands, by which participants studied operational challenges during the years between the world wars.

Following World War II, computer-based combat and campaign simulation largely replaced war gaming within the Pentagon, although the earlier practice continued in military colleges and operational commands. Repeated operational gaming within DoD is rare today. Although many institutions within DoD game elements of the same contingencies, these institutions and their supporting contractors have few incentives to share game details and outcomes.¹⁰

As noted, the role of war gaming in military decision making diminished significantly from the World War II era with DoD's adoption of OR's cousin, systems analysis. DoD largely turned to computerized combat and campaign simulations for operational, force, and procurement program planning. The models used in these simulations are direct descendants of those developed during World War II. When computerized combat simulations are used for operational planning, the forces and systems available are generally fixed, and alternative operational courses of action are explored; when these simulations are used for systems analysis, the operational concepts are fixed, and alternative systems are explored. This process does not capture the coevolution of technology and operational concepts as well as operations, gaming, and field exercises did in the past. Furthermore, when using computer simulation, it is the analyst developing the models

and analyzing the results who derives the experience rather than those directly involved in making policy or military decisions. In contrast, games provide decision makers themselves with direct experience in working through anticipated contingencies.

Recently, DoD leadership has directed a reinvigoration of war gaming.¹¹ The vast majority of games that DoD elements conduct explore a “wicked problem” for a day to a week to gain some insights. Characteristics of a wicked problem include that the problem is not understood until after the formulation of a solution, and that the solution uncovers other problems to be resolved.¹² These games explore essentially one course of action, which is principally a function of the scenario and the participants in that game.

In 2003, the Naval War College initiated the Halsey series of games to provide students with in-depth experience in developing campaigns against potential opponents they might face when occupying more-senior positions later in their careers.¹³ Some of these games have used a two-sided “metagame” approach for examining alternative Red (i.e., opponent) objectives. This approach gives one side foresight of the other side’s strategic concept for conducting its campaign, and then turns the tables iteratively until neither side can do better.¹⁴ Once neither side can gain by changing its strategy—known in game theory as a “Nash equilibrium”—the games move on to examine a different Red objective and campaign approach. This is a valuable technique that explores a broader strategy space than single games and leads to interesting equilibriums that suggest what would be reasonable behavior for the various traditional and nontraditional forces involved in the fight. However, the number of games a Halsey team can play is limited. The program began playing one game per trimester, which evolved to one iteration per year to allow detailed exploration of tactical and logistical details. The Halsey approach is unique to the Naval War College.¹⁵

Few gamers know or appreciate game theory and how it should inform their gaming efforts. John von Neumann initiated game theory in 1928 as a rigorous approach to games such as poker and to economic and sociological problems that “involv[e] . . . questions of parallel or opposite interest, perfect and imperfect information, free rational decision or chance influences.”¹⁶ In 1944, along with Oskar Morgenstern, he published these concepts in *Theory of Games and Economic Behavior*. Although the mathematics is relatively simple, game theory is arcane, requiring detailed study to apply, and has few military practitioners. The comprehensiveness of the concepts, the focus on game-theoretic “solutions,” and the application to economic behavior based on *Homo economicus* rather than deontic logic have deterred gamers from studying game theory, and thus the perceived value of applying game theory to gaming has been limited.¹⁷

Although several papers in the 1950s and '60s were published applying game theory to military topics, finding instances where game-theoretic analyses have influenced military decisions is rare, particularly recently.¹⁸ Whereas war games are rich (complex) in detail, the vast majority of game-theoretic results come from toy models that strip away context important to actual decision makers. "For some games, game theory will suggest a 'solution' to the game, that is a best way of playing the game for each person involved; but for most games describing real problems all it can do is rule out some types of decision and perhaps suggest which players will [have incentives] to work together."¹⁹ Careful application of game theory can illuminate structural details underlying operational gaming that assist in the formulation of strategy.

The core of OR techniques involves mathematical programming for optimization using deterministic models, stochastic models incorporating probabilities, and statistics for estimating expectations.²⁰ None of these techniques accommodate complex adaptive systems, such as human decision and learning. Approaches for dealing with complexity to understand the logic of the underlying phenomena, enabled by advances in computer simulation and biological rather than statistical and mechanical paradigms, are relatively new. Techniques such as genetic algorithms employing fitness landscapes, cellular automata, and agent-based models for understanding self-organization and emergence of new phenomena have blossomed over the past three decades, but as yet are on the margins of DoD and IC analysis.²¹ Entities such as the Santa Fe Institute and the New England Complex Systems Institute have formed to bring together scholars from a wide range of disciplines and educate a new generation of analysts in these techniques.

Commercial gaming technology has advanced. Outside DoD, computerized games have become a ten-billion-dollar industry, with 67 percent of U.S. households playing video games for an average of eight hours per week.²² An even larger fraction of the population in countries such as the Republic of Korea enjoys computer games. Within DoD, the Naval Postgraduate School and its sponsors have pursued efforts such as the Army Game Project for familiarization and recruiting and the Massive Multiplayer Online Wargame Leveraging the Internet (known as MMOWGLI) to foster innovation through crowdsourcing. The Navy originally developed a game for training and tactical development that became Harpoon Advanced Naval Warfare. Jane's Combat Simulations / Electronic Arts teamed with companies that do simulation and training for DoD to produce games such as 688-I and Fleet Command. These games contain high-quality data for expected systems performance. The PLA recently developed similar games to promote public interest and recruitment. However, a wide gulf exists between

the commercial and military gaming communities, with the former incentivized by the entertainment value of the game and the latter emphasizing the validity of combat models.²³

WHAT IS NEW AND WHY MIGHT IT BE SUCCESSFUL?

In a sense, this article's central proposal is far from new. A century ago, Rear Admiral Bradley A. Fiske recommended a similar approach in *The Navy as a Fighting Machine*:

By this scheme, a body of officers at the Navy Department would occupy their time wholly in studying war problems by devising and playing strategical and tactical games ashore and afloat. After each problem had been solved to the satisfaction of the staff, each distinctive situation in the approved solution would be photographed in as small a space as practicable, preferably on a moving-picture film. In the solution of problem 99, for instance, there might be 50 situations and therefore 50 photographs. These photographs, shown in appropriate succession, would furnish information analogous to the information imparted to a chess student by the statement of the successive moves in those games of chess that one sees sometimes in books on chess and in newspapers. Now if the film photographs were so arranged that the moves in the approved solution of, say, problem 99 could be thrown on a screen, as slowly and as quickly as desired, and if the film records of a few hundred such games could be conveniently arranged, a very wide range of situations that would probably come up in war would be portrayed; and the moves made in handling those situations would form valuable precedents for action, whenever situations approximating them should come up in war.²⁴

Now, with the Internet, war games played anywhere, or online, can contribute to portraying a wide range of situations that probably would come up in the event of war. Whereas Fiske proposed using photographs, the proposed approach for developing and applying a theory of repeated games involves capturing, in extensive form, "manual" and online operational games played either sequentially by one organization, along with their context; in different times and places by various organizations; or many times online. In manual games (which may employ computer calculation in adjudication and may be played online), players must make decisions, either simultaneously or sequentially, during each of their moves, taking into account what they know about the current situation; and procedures used to evaluate the consequences of the player's decisions must be quite clear to the players and simple enough for the players to understand.²⁵

Presentation of game data in extensive and strategic forms (see next section) allows a combination of game-theoretic and, for larger strategy spaces, complex adaptive science techniques to analyze the games. Given that this approach showed promise in analyzing the Halsey games, this type of analysis might be successful.²⁶ Tapping into games played anywhere but exploring the same

contingency would increase the space of strategies evaluated beyond what one team could do at an individual institution.

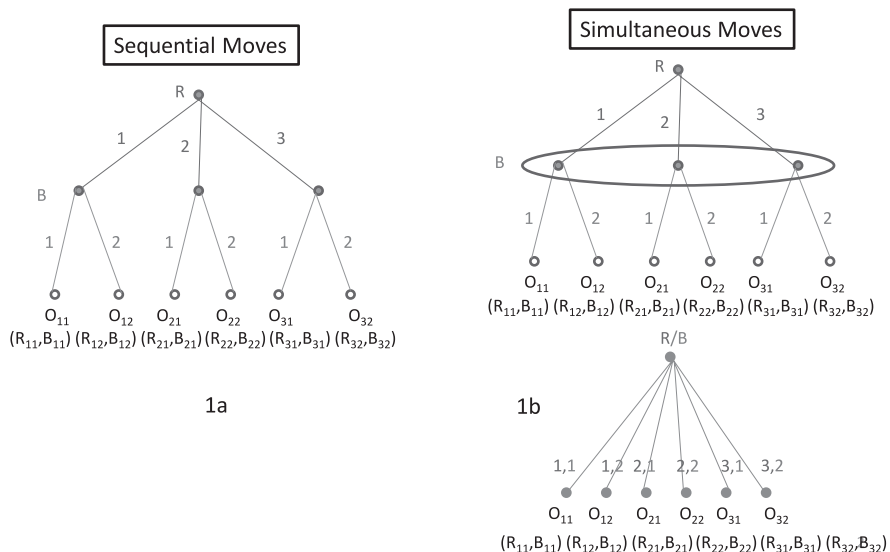
Useful Elements of Game Theory

Game theory “provides a language for the description of conscious, goal-oriented decision making processes involving more than one individual.” It furnishes a methodology to make amenable to analysis such subtle concepts as state of information, choice, move, strategy, outcome, and payoff.²⁷

Games presented in extensive form as a “tree” illustrate these concepts most clearly. Representing games in extensive form captures the timing of the players’ moves relative to relevant events and representations of what the players knew about others’ choices when they selected their moves. Figure 1 illustrates two simple, two-move games in extensive form involving players Red (R) and Blue (B). The players make sequential moves in 1a, where Blue knows Red’s choice when making its move, and “simultaneous” moves in 1b, where both sides select their moves without knowing the other’s choice.²⁸ For simplicity, these games represent Red having three and Blue having two choices, one branch representing each choice. A move involves selecting one of the possible choices—a COA. The moves are numbered and the outcomes are indicated with subscripts that relate to the players’ moves, e.g., O_{ij} indicates the outcome should Red select COA i and Blue select COA j . The payoffs to Red and Blue are indicated similarly by R_{ij} and B_{ij} , respectively. The payoffs are the value (utility) of the outcome to each player. Should the value of all outcomes be equal and opposite for Red and Blue (i.e., $R_{ij} = -B_{ij}$ for all Red COAs i and Blue COAs j), the game would be zero-sum.

Von Neumann and Morgenstern developed a method for expressing the utility of an outcome to an individual player as a specific quantity. However, this

FIGURE 1
GAMES IN EXTENSIVE (TREE) FORM



method is difficult to employ and is made conceptually and practically much more difficult when attempting to quantify a single utility for multiple players representing different organizations or groups of individuals. In general, although some situations, such as winning or losing a duel, may be modeled usefully as a zero-sum game, the more complex the description of the outcome, the less valuable modeling the game as zero-sum is likely to be. Halsey game summaries provide descriptions of the tactical outcomes resulting from player moves and the operational outcome of the game, but the payoffs (i.e., the player's evaluation of the outcome and preferences among alternative outcomes) need to be inferred from the descriptions.

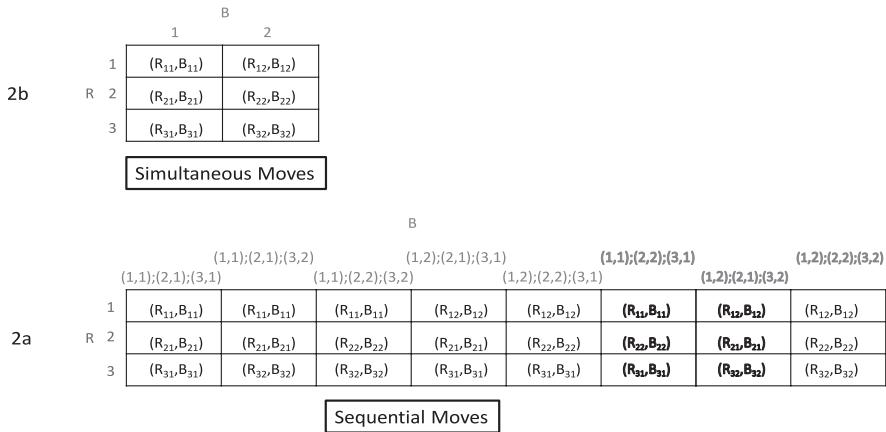
Figure 1b also illustrates two ways to represent simultaneous moves and the information available to players when they chose their next move. The bubble (ellipse) around the positions at which Blue selects its move indicates that Blue does not know which move Red has selected when it makes its choice. The lower figure is an alternative representation of the same situation.

In a game with more than two players, the sequence of player choices and moves is represented, adding to the detail above. Game controller and umpire decisions are treated similarly to a player's, representing their adjudications as moves in the game.

If the focus of the analysis is on strategy and payoffs, representing a game in strategic form may be more useful than the extensive form. A two-person game in strategic form (also called the normal form) is represented as a two-dimensional matrix. Each player represents a dimension, requiring games with three players to be drawn as cubes; games with more than three players are even more challenging to illustrate. Figure 2 illustrates the same games as in figure 1, but in strategic form.

In shifting to the strategic from the extensive form, the move sequence and information structure loses many details. However, the strategic form of these simple games shows the importance of information (intelligence). Blue has many more COAs available when acting with knowledge of Red's COA than without that knowledge.²⁹ A strategy in game theory is complete description of the play, accounting for all contingencies. Here the strategies, or COAs, available to Blue going from the simultaneous to the sequential game go from selecting either COA 1 or 2 to selecting among eight along the lines of (1,1);(2,1);(3,1), which means Blue selects 1 if Red selects 1; Blue selects 1 if Red selects 2; Blue selects 1 if Red selects 3. Blue has one COA for all combinations of the three Red moves and its two Blue moves. Although transitioning from a multimove game in extensive form to one in strategic form boils down to a matter of careful book-keeping, accounting for all combinations of possible COAs in games with many moves is daunting.

**FIGURE 2
GAMES IN STRATEGIC FORM (MATRICES)**



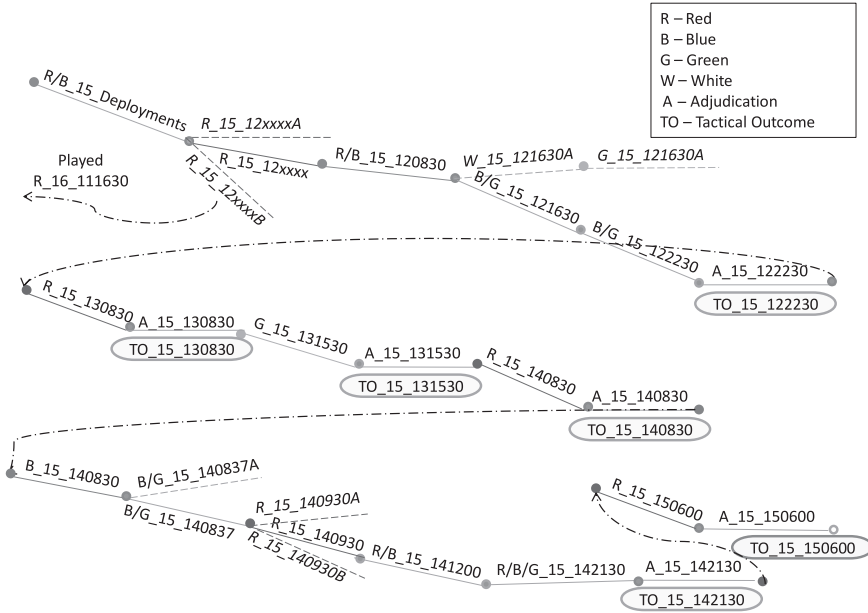
The strategic form is often easier to use than the extensive form for identifying equilibrium points and any absence of a pure strategy equilibrium point.³⁰ Formally, an equilibrium point is “a vector of strategies such that no one player, regarding the others as committed to their choices, can improve his lot.”³¹

The Halsey Games as a Case Study

The proposition presented at the beginning of this article was that capturing the Halsey game moves in extensive form would provide a comprehensive way to illustrate the decisions that Blue and Red commanders made in executing their COAs so that others could see quickly what had been attempted and follow a narrative of what worked for each side and what did not. This would allow those others to benefit from the experience of the games. Also, the games in extensive form would allow direct alignment and analysis of multiple games played over a span of time.

Figure 3 diagrams Halsey game 15 in extensive form. The game begins with Red and Blue deployments, followed by Red considering three choices and selecting one. The solid line represents the move; the dashed lines represent choices not pursued. The numbering convention illustrates which team made the move, the number of the game, and the date/time of the move. The game involved Red, Blue, Green, and White, representing different countries. One of the Red choices not selected in game 15 became the Red move in game 16, which allows adding game 16 to the game tree for analysis (while complicating the illustration). Following Red’s initial move, Red and Blue, followed by Blue and Green, made subsequent moves without any intelligence updates to the various role players on those teams, creating effectively simultaneous moves. Then the umpire and control team adjudicated a tactical outcome on the basis of the role player moves. The focus of the Halsey games is on move assessments and the exploration of

FIGURE 3
HALSEY GAME 15 IN EXTENSIVE FORM

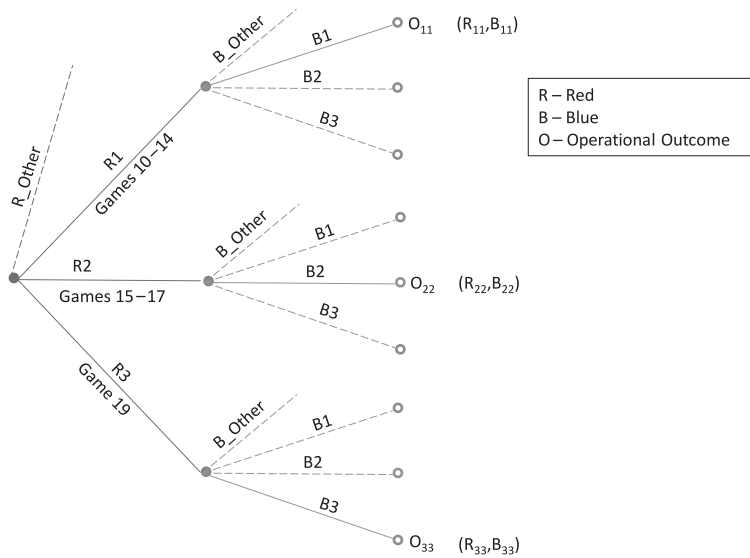


alternatives. The “meat” of the games is in the deliberation of alternatives.³² The game continued to a culminating point for the purposes of that game.³³ In this way, the moves and outcomes for a play of a game representing one Red campaign approach may be captured.

Figure 4 illustrates the set of Halsey games at an operational level. Campaign-level games began with game 10. In these games, Blue knew Red’s strategic concept, though not the tactical details. Blue then gamed one of its principal strategic concepts against Red’s, using variations over several games, as Red also varied the details of its strategic concept on the basis of what had been learned in previous games.³⁴ The variations did not affect the overall operational outcome resulting from the pair of strategic concepts, which suggests that the governing factors identified in the games are robust across the variations in the specific COAs considered. (Although Green also made moves in the games, they did not affect the game outcomes significantly beyond the initial game conditions, so are not represented in the diagram.)

Games 10–14 explored Red pursuing one campaign strategic concept, games 15–17 explored another Red campaign strategic concept, and game 19 explored a third. (Game 18 explored a completely different contingency involving Red attacking a different opponent.) The U.S. IC provided the initial Red strategic, operational, and tactical concepts. The Halsey teams then refined these estimates as they enhanced the effectiveness of Red approaches against Blue and Green.

FIGURE 4
HALSEY OPERATIONAL-LEVEL GAME TREE

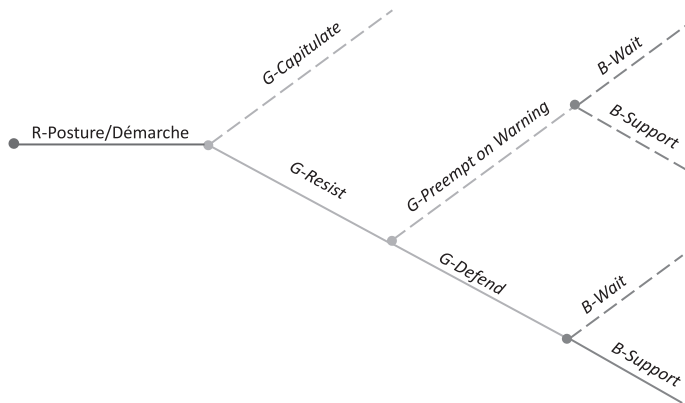


Blue responded with various COAs to each Red approach. The figure illustrates that Blue strategic concept 1 provided the best operational outcome against Red strategic concept 1, Blue strategic concept 2 provided the best operational outcome against Red strategic concept 2, and Blue strategic concept 3 (combining several possible Blue COAs) provided the best operational outcome against Red strategic concept 3, of those examined. Red and Blue “other” provide place marks for concepts not yet examined in the Halsey series as of the date the analysis was conducted. The diagram provides a concise chart for an extended narrative on the play and outcomes. It illustrates how the games proceeded over time, with games 10–14 at the top, games 15–17 in the middle, and game 19 at the bottom.

The first game of a new COA spent significant time exploring the motivations and timing of the players’ moves for establishing the initial conditions.³⁵ Figure 5 depicts a typical set of decisions that Blue and Green would address in each of these games.

Each game began with Green and Blue either observing Red posture or receiving a *démarche*. Green then had to decide whether to capitulate or resist, and, if choosing to resist, whether to preempt Red on warning or to defend following a Red attack. Blue then had to choose whether to wait or come to Green’s support immediately. Although the Halsey team explored some branches of the tree in figure 5, for the purposes of the study Green always chose to resist and defend, and Blue to support Green. This is a type of subgame for which a rich game-theoretic literature exists, and one example of where existing game-theoretic work could be used to inform the gaming.³⁶

FIGURE 5
BLUE-GREEN INITIAL SUBGAME



Gaming often is criticized for a lack of rigor and a limited ability to accumulate knowledge. A standard for rigor is whether another group could replay the game, recognizing that different player or umpire/control adjudication, including chance moves, will dictate different tactical outcomes, some of which may affect the operational outcome. The Halsey games demonstrate that, with appropriate documentation, games conducted by one organization sequentially, or by many organizations in different times and places, can be arranged to provide a detailed understanding of sets of feasible and acceptable tactical and operational COAs from Red's perspective, and feasible and acceptable Blue COAs for each Red approach.³⁷

The Halsey games demonstrated that standardized game documentation should include the following:

- Player moves, adjudication, and tactical outcomes using a consistent indexing system that identifies player, game, and time references.
- Blue should use appropriate portions of joint operations planning procedures, and other teams should use their best understanding of adversary/allied planning procedures. Benefits of using operations planning procedures include both educating officers in writing orders and improving the use of gaming in analyzing courses of action. Using the planning procedures of adversaries/allies highlights the state of understanding about how they approach the situation under study. The war-gaming “process highlights tasks that appear to be particularly important to the operation and provides a degree of familiarity with operational-level possibilities that might otherwise be difficult to achieve.”³⁸ Educating officers in writing orders was a key benefit of German war gaming between the world wars.³⁹
- The mission analysis should document COAs considered but not played.

- The geographic displays and synchronization matrices used in the games for decision making help communicate the concept of operations rapidly and should be part of the move documentation.
- Control logs should document the tactical outcomes from each individual adjudication made, providing the “true” state of the world as a consequence of the adjudication.
- The tactical outcomes (intelligence updates) provided to each side, to clarify the information conditions.
- The control team should consider carefully the trade-off between open information and contingency planning. As Quade notes (from RAND’s experience in its SIERRA Project of gaming, which had many features in common with the Halsey Alfa games), having less information about adversary moves encourages contingency planning.⁴⁰
- Routinely documenting the alternative branch points—the COAs—considered would suggest alternatives for future games, better support meshing operational games as they are played, and provide information needed for more in-depth, formal analysis of the games.
- Documentation of any paths that were replayed, if that occurred during the game.

Relevant combatant commanders have sought the results of the Halsey games to inform their planning, and the Halsey team has proposed a set of low-cost measures to enhance fleet capabilities to the Navy staff, some of which are being adopted now.

Extending the Approach to Online Gaming

Conceptually, it is also possible to capture online games in extensive form by capturing the moves of each player in the game electronically, potentially expanding the COAs examined as more players play the game more frequently. This might allow the identification of equilibriums and dominant strategies that prevail against all adversary COAs.⁴¹ Whereas manual war games such as Halsey involve a mix of free-form and semirigid adjudication (using some standard calculations), online games use rigid adjudication, dictating an outcome for each interaction as it occurs. Games such as Fleet Command allow command organizations and involve adjudicating multiple tactical interactions in a game that approaches the operational level of war.

Online games usually specify the mission or provide a choice of missions. Player setup of the scenarios in such games provides much of the information (e.g., friendly and enemy forces) contained in mission analyses and operations orders. However, the commander’s intent and concept of operations may be less clear in online gaming.

This raises the issue of act and action meaning.

[T]he data for behavioral science are not sheer movements, but actions—that is, acts performed in a perspective which gives them meaning and purpose. Plainly, it is of crucial importance that we distinguish between the meaning of the act to the actor (or to other people, including ourselves, reacting with him) and its meaning to us as scientists, taking the action as a subject-matter. I call these, respectively, *act meaning* and *action meaning*. . . . The behavioral scientist must first arrive at an act meaning, that is, construe what conduct a particular piece of behavior represents; and then he must search for the meaning of the interpreted action, its interconnections with other actions or circumstances.⁴²

In online gaming, capturing a move, such as one unit engaging another, represents an act meaning and is conceptually easy. However, without clear statements of the commander's intent and concept of operations, the action meaning must be inferred.

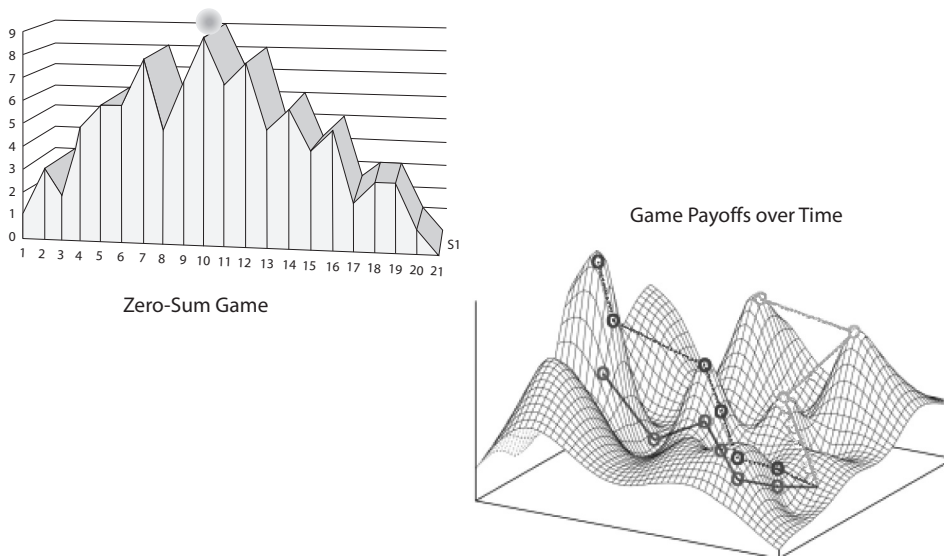
If the objective of an analysis is merely to assess which COAs provide better combat outcomes, the act meaning may be sufficient, given a very large number of COAs being explored. No matter the intent, the moves that provide better outcomes may be clear. Current large-scale, computer-based campaign analyses use this approach. However, if the game involves any forms of signaling, deterrence, or uses of force for influence rather than simply defeating enemy forces, capturing the action meaning is essential.

Employing Game-Theoretic and Complex Systems Analyses

Since translating games in extensive form into games in strategic form is a matter of detailed bookkeeping, once games are captured in extensive form, creating computer programs to represent them in strategic form is feasible. Once the games are represented in strategic form, finding dominant strategies and equilibriums is conceptually straightforward. With close attention to information conditions, these data also could support more-sophisticated game-theoretic solution concepts.

The major complication is in evaluating payoffs, using the description of outcomes. Where those contemplating an operation can review and rank outcomes quickly from a limited number of player-strategy pairings (or vectors, for more than two players), doing so for a large number of outcomes created by online gaming would require scoring criteria. Conceptually, the subjective judgment involved in selecting scoring criteria is little different from that employed in quantitative adjudication. Different participants will have different ideas about the value of a specific outcome, depending on their sophistication and ability to think through actions beyond the time frame and scope of the game. The commander's intent should provide the basis for evaluating outcomes, although this too should be evaluated for how the intent supports national security aims. For

FIGURE 6
FITNESS LANDSCAPES



the process to be objective, the adjudication and scoring should be apparent to the players and analysts involved and allow for *reclama* and adjustment, if disagreements occur.

Beyond game-theoretic solution concepts, these data may be used to develop fitness landscapes in which the height of a point on the landscape represents the value of the courses of action.⁴³ The outcomes of a two-person, zero-sum game (where the value to one player is the negative of the value to the opponent) may be envisioned as a mountain range where the height of each mountain is the value resulting from the outcome of paired courses of action of the players. A player trying to minimize the maximum is akin to someone looking for the lowest passage through the mountain range. This analogy suggests a way to capture, depict, and analyze the implication of the values to each player of a set of actions (moves). Figure 6 depicts fitness landscapes for what payoffs might be involved in a two-person, zero-sum game and the payoffs to two players in a multiple-move, non-zero-sum game, showing the payoffs over time for the COAs each side selects on each move.

The intuition is that, just as armies in Europe used the same routes over the centuries on physical landscapes to attack and retreat, fitness landscapes may anticipate logical paths that a conflict could follow. The analogy of physical terrain to fitness landscapes could be particularly useful in understanding cyber operations, leading to traditional mission, enemy, troops, terrain, timing, and civilian effect analysis (referred to as METT-TC) in what is otherwise a conceptually challenging space to depict. More broadly, fitness landscapes may allow application of developments in complexity sciences.

IF YOU'RE SUCCESSFUL, WHAT DIFFERENCE WILL IT MAKE? WHAT IMPACT WILL SUCCESS HAVE? HOW WILL IT BE MEASURED?

The first level of success would be to involve a much broader range of national security professionals, particularly members of the military, in synthetic experiences that would inform their preparations for operations, both in operational planning and force allocation and development. The second level of success would be to provide decision makers with deeper and more-accurate appreciations of the challenges and opportunities at hand, resulting in wiser policies and strategies. The third level of success would be a phase change in DoD's and the IC's analytical cultures, weaning them off methods and tools inappropriate for the complexity of the age.

The thresholds for the first level of success would be the extent of adoption of the manual operational gaming process by military colleges, then by the broader officer corps, and then by the Pentagon for force-development analysis. The threshold for the second level would be the time that senior decision makers devote to gaining synthetic experience, rather than taking briefs, and the effects of this on security and defense policy and strategy. The threshold for the third level would be the extent to which this approach replaces the reliance on inappropriate computer combat and campaign models in DoD and supplements international relations / political science techniques in the IC. Using operational gaming, in conjunction with fleet/field exercises and complementary forms of analyses, we would not expect to create Hari Seldon's psychohistory (from Isaac Asimov's *Foundation* series), but would expect to take significant steps in understanding many of the factors that govern the logic of competition and cooperation.

WHAT ARE THE RISKS AND THE PAYOFFS?

The proposed approach requires multidisciplinary teams, involves both technical and methodological challenges, and faces headwinds from the current culture of and incentives enjoyed by the military modeling and simulation community and industry. Adoption of the approach would require military and commercial gamers to work with game theorists and scholars of complex adaptive systems—each of whom is not fully familiar with the others' disciplines. Currently, need-to-know and proprietary restrictions bar the sharing of detailed game data within DoD and the IC.⁴⁴ This prevents accumulation of knowledge from games within these communities except in superficial ways. The first experiment with representing the Halsey set of games as a game in extensive form demonstrated challenges in representing actions at different echelons of command as game moves and attaching values to the outcomes.⁴⁵ Capturing moves and outcomes from online games is apparently unprecedented (although commercial games are tuned routinely as

players discover dominant strategies).⁴⁶ Analysis of fitness landscapes is at the early stage of development and has relatively few practitioners.

Employing institutions that are dedicated to education and research and have long experience in manual and online war gaming (such as the military colleges) and complexity sciences (such as the New England Complex Systems Institute) would mitigate the risks of experimenting and demonstrating the conceptual approach.⁴⁷ In March 2016, the Chief of Naval Operations and the Commandant of the Marine Corps established a virtual community of practice, or vCOP, for a limited group of sailors, Marines, and civilians with an interest in war gaming and provided funding to the Naval War College to provide web-based war-gaming/experimentation repositories.⁴⁸ This effort could serve to share the data needed to construct and analyze games in extensive form.

The major obstacle is the analytical culture in DoD and the IC, as amplified by the large contract base employed in conducting analyses for these communities. The major payoff would lie in changing this culture and producing more-insightful analysis that affects senior policy-maker and military decisions more frequently. Hopefully, part of DoD's reinvigoration of gaming will result in senior officials taking the time to participate in games rather than just receiving briefings on them.

HOW MUCH WILL IT COST?

The answer depends on the scale of the effort. The principal costs are in creating interdisciplinary teams, some of whose members may be part-time consultants. A team should consist of leads from military planning and gaming, a lead who has experience working with the commercial gaming industry, a game theorist, and a complex adaptive systems lead with experience in fitness landscapes. Consultants should include those familiar with combat/campaign models, statistics, behavioral economics, history, and political science (preferably with experience in agent-based models). Software licenses likely would be required for commercial gaming technology. Establishing standards and training war-gamers for data collection would entail additional costs. Several million dollars per year should be sufficient to develop the practice and exploitation of repeated gaming.

HOW LONG WILL IT TAKE?

This program should use rapid spiral development. Four years should be sufficient to make or break the concept, although early failures can be anticipated. The aim for the first year should be to establish game documentation and sharing standards, while using commercial games to demonstrate the techniques required for online gaming. Military college and other DoD/IC game data should be available in the second year to learn what works and to transition the

theoretical approach into early practice. A focus on cyber warfare, with the aim of developing and analyzing cyber fitness landscapes, would test the limits of the concept.

WHAT ARE THE MIDTERM AND FINAL “EXAMS” TO CHECK FOR SUCCESS? HOW WILL PROGRESS BE MEASURED?

Early elements required for success are the ability to document and share manual games, and to track online game moves and outcomes and represent them as games in extensive and strategic forms and as fitness landscapes. The next exam would be the ability to derive the logic of the competition from game-theoretic analyses and these landscapes. Then the measures of adoption discussed above will come into play.

NOTES

The author would like to acknowledge contributions from Wayne P. Hughes, John B. Hattendorf, James R. FitzSimonds, Thomas L. Allen, Stephen Downes-Martin, and Robert C. Rubel.

1. Paraphrasing Peter P. Perla, *The Art of Wargaming: A Guide for Professionals and Hobbyists* (Annapolis, MD: Naval Institute Press, 1990), chap. 4. Note that operational gaming applies to situations other than warfare. Richard D. Duke and Jac L. A. Geurts, *Policy Games for Strategic Management: Pathways into the Unknown* (West Lafayette, IN: Purdue Univ. Press, 2004) provides excellent examples.
2. Gerald R. McNichols, *An Objective Appraisal of War Gaming* (Washington, DC: Headquarters, U.S. Air Force, Operations Analysis, 1970), p. 35.
3. Chester W. Nimitz [FAdm., USN (Ret.)], address to the Naval War College, October 10, 1960, Naval War College Archives, courtesy of Prof. John B. Hattendorf, Naval War College, e-mail to author, March 29, 2016.
4. Prof. Wayne Hughes points out that this statement is not quite accurate: “The games did not predict the Solomons campaign and the dual drive up New Guinea and through the Central Pacific. The games did not predict the replacement of battleships with aircraft carriers, nor the buildup of the combat logistics force. Nor did the games predict that extent to which we would be qualitatively and quantitatively inferior through most of 1942. Nimitz was thinking in macro terms and about his own command, but he is grossly inaccurate to say ‘absolutely nothing was a surprise except the kamikaze attacks.’” Wayne P. Hughes [Capt., USN (Ret.)], e-mail to author, March 1, 2016.
5. James O. Richardson, *On the Treadmill to Pearl Harbor: The Memoirs of Admiral James O. Richardson (USN Retired), as Told to Vice Admiral George C. Dyer (USN Retired)* (Washington, DC: U.S. Navy Dept., Naval History Div., 1973), p. 109. From John M. Lillard, “Playing War: Wargaming and U.S. Navy Preparations for World War II” (PhD dissertation, George Mason Univ., Fall 2013), p. 11.
6. “Research & Gaming—McCarty Little,” *U.S. Naval War College*, www.usnwc.edu/.
7. The gaming technique applies equally well to understanding governing factors shaping the competition and cooperation in noncombat situations. But the emphasis here will be on understanding combat.
8. Duke and Geurts, *Policy Games for Strategic Management*, p. 23.
9. John T. Hanley Jr., *On Wargaming: A Critique of Strategic Operational Gaming* (Ann Arbor, MI: Univ. Microfilms International, 1991), pp. 184–227.

10. Garry D. Brewer and Martin Shubik, *The War Game: A Critique of Military Problem Solving* (Cambridge, MA: Harvard Univ. Press, 1979), pp. 58–74 provides a history of the development of war gaming from the 1950s to the '70s. A few games, such as RAND's SIERRA, which investigated limited war and tactical airpower, lasted a few years. The Naval War College conducted repeated Global War Games in the 1980s, first to explore the maritime strategy of the day, then to explore the implications of prolonged conventional conflict. Current Global games explore different topics each year. Although DoD occasionally has attempted to catalog games and gaming systems, few DoD institutions and supporting contractors share game details, citing proprietary and security (need-to-know) concerns, while fearing what others might do with the information they have developed.
11. Secretary of Defense to Deputy Secretary of Defense et al., memorandum, "The Defense Innovation Initiative," November 15, 2014; Deputy Secretary of Defense to Secretaries of the Military Departments et al., memorandum, "Wargaming and Innovation," February 9, 2015, available at news.usni.org/.
12. Horst W. J. Rittel and Melvin M. Webber, "Dilemmas in a General Theory of Planning," *Policy Sciences* 4 (1973), pp. 155–69 discusses the attributes of "wicked" problems.
13. John T. Hanley Jr., *The Halsey Games: An Assessment of Continuous Gaming* (Alexandria, VA: Institute for Defense Analyses, 2010). SECRET classification.
14. Martin Shubik, *Game Theory in the Social Sciences: Concepts and Solutions* (Cambridge, MA: MIT Press, 1982), pp. 328–31 describes metagames as used in this context.
15. The Halsey games began as tactical games and evolved to this approach. The Naval War College Halsey staffs also experiment with other approaches.
16. John von Neumann and Oskar Morgenstern, *Theory of Games and Economic Behavior* (Princeton, NJ: Princeton Univ. Press, 1944), p. xxix.
17. "Homo economicus" refers to people making rational choices using cost-benefit logic, where the benefit is in material gain. In deontic logic, rational choice is based on obligation (e.g., duty to family, tribe, or religion) and permission.
18. O. G. Haywood Jr., "Military Decision and Game Theory," *Journal of the Operations Research Society of America* 2, no. 4 (November 1954), pp. 375–85; Robert P. Beebe, *Military Decision from the Viewpoint of Game Theory* (Newport, RI: U.S. Naval War College, Advanced Study Group, 1957); John E. Nolan Jr., "Tactics and the Theory of Games: The Theory of Games Applied to the Battle of Guadalcanal," *Army* 11 (August 1960), pp. 77–81.
19. L. C. Thomas, *Games, Theory and Applications* (London: Ellis Horwood / John Wiley, 1984), p. 15.
20. Gaussian distributions underlie essentially all combat models, either explicitly or in the form of expected values. New appreciations of the ubiquity and implications of power-law distributions, which anticipate "black swans," have yet to be explored and incorporated in combat models. Network sciences are developing ways to expose power-law behavior.
21. The literature is too comprehensive to address here. Highlights would include John H. Holland, *Hidden Order: How Adaptation Builds Complexity* (Reading, MA: Helix Books, 1995); Stuart A. Kauffman, *The Origins of Order: Self-Organization and Selection in Evolution* (Oxford, U.K.: Oxford Univ. Press, 1993); and Stephen Wolfram, *A New Kind of Science* (Champaign, IL: Wolfram Media, 2002).
22. "Video Gaming Statistics," *ESRB Ratings*, www.esrb.org/.
23. An annual series of conferences called Connections brings together international military and commercial gamers to reduce the gulfs among various gaming communities. Stephen Downes-Martin, e-mail to author, March 25, 2016.
24. Bradley A. Fiske, *The Navy as a Fighting Machine* (New York: Scribner's, 1916), pp. 256–57.
25. Thomas A. Brown, *Potential Applications of Manual Games* (Santa Monica, CA: RAND, 1984).
26. Hanley, *The Halsey Games*.
27. Martin Shubik, "On Gaming and Game Theory," *Management Science* 18, no. 5 (January 1972), pp. 37–53.

28. Game theory generally assumes that each player knows the other players' possible courses of action and evaluation of outcomes—which rarely occurs in actual circumstances. Some work has been done on evaluating games with misperceptions. The analysis is challenging enough, and may be sufficient for the purposes of the model without going to this level. The purpose of the analysis determines the level of complexity required.
29. In this analysis, as in most game-theoretic analysis, no distinction exists in the model between decision and action. Therefore the terms *decision* and *action* are used interchangeably. A more detailed model of subordinate actions following commander decisions could be made if useful for the purposes of the analysis.
30. The absence of a pure strategy equilibrium point indicates a situation with high potential for deception. However, this requires a lengthy explanation.
31. Shubik, *Game Theory in the Social Sciences*, p. 240.
32. Jim FitzSimonds, e-mail to author, March 24, 2016.
33. Operational games conducted over short periods require careful design to reach a culminating point.
34. Strategic concepts are on the level of forward offensive operations, versus standoff strikes, versus blockades as the main effort to achieve campaign objectives.
35. Moves included other than force-on-force actions, such as diplomacy or information operations. Since the focus of the games is on force-on-force interactions, the Halsey Group queries area experts on nonmilitary factors affecting the scenario and either uses best judgments or randomizes the political play. Control makes plausible arguments for why a player team should pursue a particular policy. FitzSimonds e-mail. Halsey control used versions of the “principle of relevancy” that select the branch most useful for the game objectives when at a branch point (rather than assessing the most plausible among plausible paths), and the “principle of the lesser included event,” which forces the players to deal with a more complex or challenging situation under the premise that the solution would work in simpler situations. RAND developed these principles for its SI-ERRA series of games in the 1960s; the methodology was very similar to that developed independently by the Halsey Alfa Group. E. S. Quade, “Gaming” (unpublished handout material accompanying lectures on gaming at the Univ. of Michigan summer course, 1962), pp. 55–117.
36. See R. Harrison Wagner, “Deterrence and Bargaining,” *Journal of Conflict Resolution* 26, no. 2 (June 1982), pp. 329–58, for example.
37. *Feasible* and *acceptable* are terms of art used in joint operational planning. U.S. Defense Dept., *Joint Operation Planning*, JP 5-0 (Washington, DC: Joint Staff, 2011), p. IV-27.
38. *Ibid.*, p. IV-28.
39. Rudolf Hofmann, *War Games*, MS P-094 (Washington, DC: U.S. Army Dept., 1952).
40. Quade, “Gaming,” p. 83.
41. Downes-Martin e-mail alerted the author to Gambit, a library of game theory software for analyzing finite games. *Gambit: Software Tools for Game Theory*, gambit-project.org/. The author has not yet used these software tools.
42. Abraham Kaplan, *The Conduct of Inquiry: Methodology for Behavioral Science* (Scranton, PA: Chandler, 1964), p. 32.
43. Kauffman, *The Origins of Order*.
44. Sponsors who conduct games at the Naval War College control all game-related materials and require permission for the College to share the data. Tom Culora, Dean, Center for Naval Warfare Studies and former Director, NWC War Gaming Department, e-mail to author, February 29, 2016.
45. Hanley, *The Halsey Games*.
46. J. C. Herz, “Harnessing the Hive: How Online Games Drive Networked Innovation,” *Release 1.0: Esther Dyson's Monthly Report*, October 18, 2002, www.oss.net/.
47. The Santa Fe Institute did not indicate any interest in such a project when approached by the author.
48. DON Innovation, “SECNAV Establishes Wargaming Virtual Community of Practice,” *CHIPS*, April 1, 2016, www.doncio.navy.mil/.