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SEMINAR GAMING: AN APPROACH TO PROBLEMS TOO COMPLEX FOR ALGORITHMIC SOLUTION

Human judgment must be used to address problems too complex for algorithmic solution. Many problems faced by decision makers involved with defense work are of this type. Various techniques have been developed to organize and structure the application of judgment to such problems. One of these techniques is seminar gaming, which has been used in technology gaming and in the systems-engineering–oriented warfare analysis process employed in APL's Warfare Analysis Laboratory exercises. Past applications of seminar gaming are examined, some of its fundamentals are identified, and its current status is discussed.

INTRODUCTION

The Applied Physics Laboratory's Naval Warfare Analysis Department is involved in analyses that address warfare problems under the sea, on the surface (of both land and sea), in the air, and even in space. Typical questions addressed by the analyses include the following: What are the best jamming modulations for Air Force and Navy jamming aircraft flying over enemy territory? What is the operational impact of advances in acoustic and nonacoustic detection on U.S. submarines? What firepower would Navy air defense systems have against stealthy antiship missiles? What is the effect of changes in flight profile on a cruise missile's ability to survive enemy defenses and reach its intended target? Is a system dedicated to defense against tactical ballistic missiles needed? What is the military utility of an antisatellite system?

Analyses span the entire spectrum of a military system life cycle. Some address questions of mission need and requirements; some study effectiveness and design sensitivity trade-offs; and some support tactics development as well as planning and assessment of operations and tests at sea. The various analytic approaches employed include both closed-form mathematical techniques and computer simulations. Some problems the Naval Warfare Analysis Department studies are too complex for algorithmic solution, however, even when the algorithm is a large, intricate, computer simulation that uses artificial intelligence processes to give it great flexibility in dealing with complex issues.

Problems too complex for algorithmic solution often are not well understood. They may involve processes that are so far irreducible to specific formulas, especially such human judgment processes as military command decisions or comparison of the relative importance of such very different kinds of systems as those providing logistical support and those providing early warning surveillance. A variety of multi-objective evaluation techniques exists.[1] Some involve sophisticated methods for developing value functions and for extensive computation, but ultimately the relative weighting of radically different objectives is a matter of expert judgment.

Currently, all approaches to such complex problems involve the use of human judgment and expert opinion. That judgment is used to integrate dissimilar kinds of data, to determine the relative likelihood and importance of factors that cannot be validly weighted by quantitative methods, and to generate assumptions as needed about missing data items and relationships among various factors. In defense work, decisions cannot always be delayed until algorithmic techniques are developed that can deal with such complex problems. Decisions about funds, whether for research or for system procurement, may have to be made. Tactics will be developed and operations planned. Consequently, judgment-based decisions are essential.

In one sense, this kind of judgment is applied in every analysis as part of the problem formulation process in which the context and scope of the analysis are determined.[2] In the more restrictive sense of using judgment in the analytic process considered here, some techniques are more formal and rigorous than others in the way that judgment is employed. For example, the Delphi process, originally developed by The RAND Corporation in the 1950s as a way to obtain reliable consensus from a group of experts,[3] involves iterative sampling of expert opinion, along with feedback communication of statistics about expert opinion, and has evolved into a variety of forms with specific processes for different kinds of applications.[4]

This article discusses seminar gaming, which is a particular approach to dealing with problems that are too complex for algorithmic solution. Seminar gaming has been used in technology gaming and in the systems-engineering–oriented warfare analysis process that has been used in the Warfare Analysis Laboratory of the Naval Warfare Analysis Department.

PAST APPLICATIONS

What is seminar wargaming? In general, during a seminar game, all information ("ground truth") as well as game-specific information (i.e, only that information that would be available to a person in the game situation) is available to participants in the game. Seminar game discussions involve players representing all sides of the conflict. Sometimes seminar games are called "open games" because of player accessibility to all information during a game. The purpose of a particular game determines what level of information may be used by players during the game. Normally, seminar games are not real-time games; that is, game clock progression is not identical with normal time. Information accessibility allows seminar gaming to treat "what if" questions, but limits the ability of the technique to address questions related to the psychology of decision making and other issues that need to simulate limited information and operational pressures.

Seminar wargaming at APL goes back at least three decades. The Laboratory's Air Battle Analyzer was developed initially to investigate naval air defense issues.[5] During the past decade, APL has employed an evolving version of seminar gaming in many studies. The elements of this approach, called the warfare analysis process, are shown in Figure 1. The exercise portion is what most people consider the "game." Often, seminar games are held in the Warfare Analysis Laboratory, shown in Figure 2. As can be seen from Figure 1, the warfare analysis process is much more than the game itself. To help people appreciate that this analytic process involves much more than just the gaming portion, the endeavor is normally called a Warfare Analysis Laboratory exercise. Figure 3 is a photograph from the seminar game of a recent exercise in our facility. Table 1 lists several topics

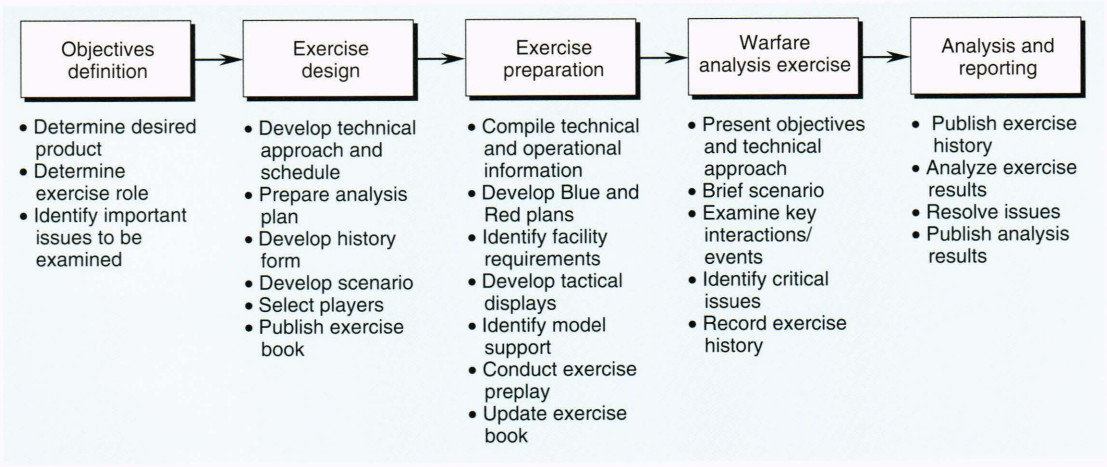

Figure 1. The warfare analysis process used in Warfare Analysis Laboratory exercises.

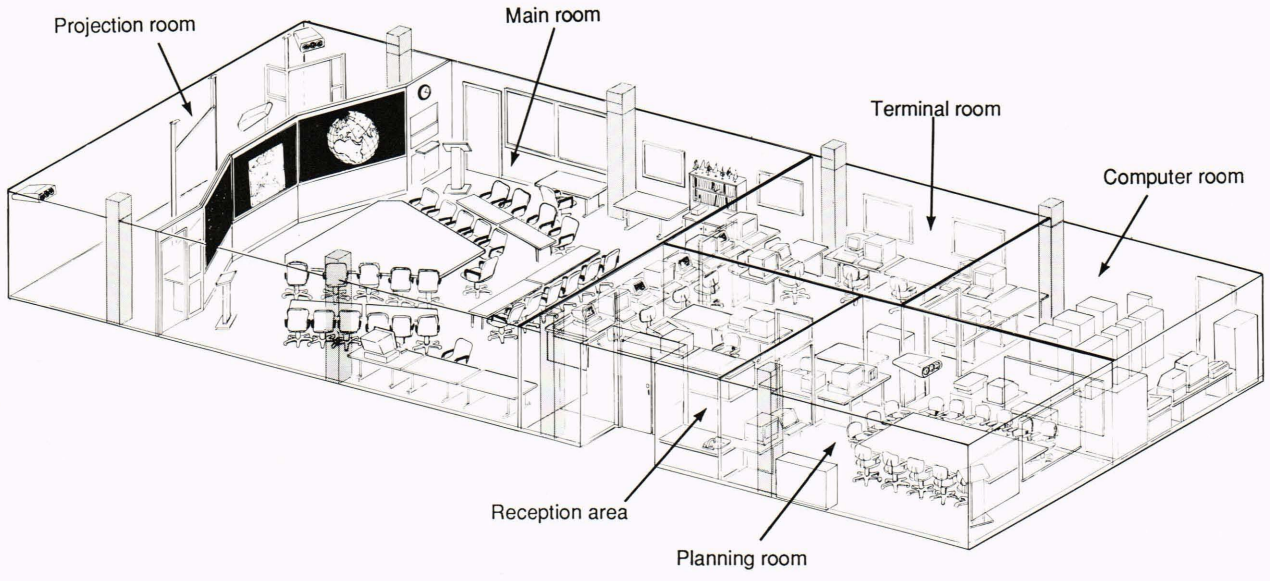

Figure 2. Diagram of the Warfare Analysis Laboratory at APL.

that have been examined using seminar gaming, revealing the broad scope of problems with which the process has been used at APL.

In 1984, the second five-year series of the Navy's annual Global War Game began. It included an Advanced Technology Cell, to improve technological considerations in the Global War Game and to stimulate participants from the Navy research and development (R&D) community to use seminar gaming techniques for strategic planning and investigation of advanced system concepts at their home organizations. Over the next several years, nearly a score of such seminar games were conducted at Navy R&D centers and a Department of Energy laboratory. The Tech Base Seminar War Games conducted by the Army Material Command in 1988 and 1990 for directors of laboratories and R&D centers in its Laboratory Command also share these roots.

In 1988, the Navy's annual Technology Initiatives Game series began, replacing the Advanced Technology Cell. This series has used seminar gaming to help R&D managers, technologists, and analysts assess the potential impact of advanced system concepts and emerging technologies. A special term was coined to describe this kind of endeavor: "technology gaming," a process that "involves knowledgeable people in structured discussions about policies, strategies, issues, technologies, systems, and military activities in an operational context."[6]

Technology gaming can be useful for the following tasks, although a particular game may not involve all of them:

1. Addressing complex problems that cannot be defined precisely and for which explicit assessment algorithms may not exist.
2. Identifying and focusing on the more important issues at the beginning of an analysis.
3. Synthesizing significant results at the end of an analysis.
4. Developing perspective about boundaries on problems, and interactions and interrelationships of elements of the problem.
5. Bridging communication gulfs between disparate elements of the R&D community.
6. Examining command and decision processes in a future context.

Table 1. Chronological listing of Warfare Analysis Laboratory applications: 1981–90.

Topic	Sponsor
Hard kill/soft kill study	Chief of Naval Operations, Analysis Directorate
Outer air battle study	Assistant Secretary of the Navy for Research, Engineering, and Systems
Aegis doctrine guidelines	Naval Sea Systems Command, Aegis Shipbuilding Project
Fleet readiness exercise preparation	Naval Sea Systems Command
Low-flyer cruise missile study	Chief of Naval Operations, Naval Warfare Directorate (National Security Industrial Association)
Tomahawk upgrade and scenario development	Joint Cruise Missile Project Office
Harpoon scenario development	Naval Air Systems Command, Anti-Ship Weapon Program
Aegis midlife upgrade study	Naval Sea Systems Command, Aegis Shipbuilding Project
Battle force system engineering	The Johns Hopkins University Applied Physics Laboratory
Autonomous underwater vehicle requirements	Defense Advanced Research Projects Agency
Soviet undersea threat study	The Johns Hopkins University Applied Physics Laboratory
Carrier battle force top-level warfare requirements	Chief of Naval Operations, Naval Warfare Directorate
Battle force connectivity 2000	Space and Naval Warfare Systems Command, Warfare System Architecture
Navy program objectives memorandum wargame	Chief of Naval Operations, Naval Warfare Directorate
Electronic warfare architecture assessment	Space and Naval Warfare Systems Command, Warfare System Architecture
Strike/antisurface warfare architecture assessment	Space and Naval Warfare Systems Command, Warfare System Architecture
Satellite laser communications requirements	Space and Naval Warfare Systems Command, Space and Sensor Systems
Sea control top-level warfare requirements	Chief of Naval Operations, Naval Warfare Directorate
Joint missile exercise preplay	Surface Warfare Development Group
Advanced submarine technology program	Defense Advanced Research Projects Agency
Aegis 2000 future Navy requirements	Naval Sea Systems Command, Aegis Shipbuilding Project
Kinetic energy anti-satellite operational assessment	Kinetic Energy Anti-Satellite Joint Program Office
Low-frequency active acoustics	Chief of Naval Operations, Undersea Warfare Attack Submarine Division
Tactical ballistic missile defense	Tactical Missile Defense Joint Program Office
Persian Gulf crisis response	Naval Sea Systems Command, Aegis Shipbuilding Project

Figure 3. Photograph from the seminar gaming portion of the September 1990 Warfare Analysis Laboratory exercise on defense requirements to counter tactical ballistic missiles.

7. Bringing operational context and constraints to discussions about the effects of technology and improvements on system capabilities.

Technology gaming is not very useful for quantitative analyses, although it may provide structure and emphasis for such analyses. In addition, it is not magic—appropriate resources are required: knowledgeable participants; an adequate analysis plan; and reasonable funding, time, and scope.

Wargaming's value in training and operational planning has long been recognized. Recently, defense analysts have shown increased interest in applying wargaming, especially seminar gaming, to technology, acquisition, and test and evaluation domains.[7] Such interest reflects a growing recognition of the complexity of the problems that must be addressed and the need for more structure and discipline in applying judgment to those problems.

FUNDAMENTALS OF SEMINAR GAMING

This article does not purport to be a handbook of how to conduct seminar gaming. Its goal is more limited: to increase awareness of seminar gaming as an analytic technique for dealing with complex issues. In addition to reviewing past applications of seminar gaming and its current status, this article also discusses four fundamental aspects of seminar gaming: (1) purpose, (2) preparation, (3) participants, and (4) process.

Within the defense establishment, seminar gaming usually has at least one of the following purposes: Its purpose may be analysis: to determine critical parameters, to test hypotheses, and to identify issues. Or it may be to educate participants and build consensus among them about the topic at issue, including establishing and improving communication bridges between disparate parts of the community. Programmatic action may also be the seminar's purpose. Key people may be helped to make particular decisions by improved understanding of the issues. Relationships developed between participants in a seminar may enable them collectively to make much more progress in some areas than otherwise would have been possible. For example, an unmanned-vehicle program manager and a cruise missile program manager met for the first time during a technology game. Improved understanding of their mutual interests, gained during the game, enabled them to make better decisions about their programs after the game.

Preparation for a seminar game is crucial. Once the game's purpose has been established, data must be collected and organized. When that is done properly, discussions during the game can concentrate on the more important subjects, questions and disputes can be dealt with factually, and needed information can be assimilated in a timely manner by participants. Often, seminar preparation involves running various computer simulations to generate data for the game. Preplay of the game improves understanding of good ways to organize and present the data.

A serious preparation problem for many past seminar games has been inadequate system descriptions. The way systems (e.g., radars, missiles, ships, communication links) are played by participants has a major influence on insights from a game. Participant familiarity with a system, its capabilities, and concepts for its employment is often dictated by the materials prepared for the game, especially for games involving future systems. If game materials describe some systems more extensively or ascribe more optimistic capabilities to them than to others, it should not be surprising that such systems appear better than other systems regardless of their real relative merits. Therefore, it becomes important for game materials to be comparable for all systems; that means similar levels of technical details about all systems, similarly realistic predictions of capabilities, and so on. Obtaining comparable game materials for all systems requires disciplined preparation and more preparation resources (time and funds), but when the game is complete, more significant insights will have been gained.

Participants in a seminar game need the right set of skills and expertise. Collectively, they need the technical, operational, institutional, and programmatic knowledge to address all aspects of the topic under consideration. Further, they need the discipline to focus their discussions on pertinent issues, the candor to deal with issues realistically, and the professional courtesy to discuss issues without rancor or pettiness. In addition, the participants need appropriate organizational associations so that all with vested interest in the topic become party to dealing with it in the game. Normally, the diverse mix-

ture of participants in a seminar game produces numerous creative insights that could easily have been missed in a more homogeneous group.

The exact way a seminar game is conducted, its "process," varies with game purpose, structure, host facility capabilities, and participants. Some seminar games involve a single seminar group; others have several groups meeting simultaneously. A seminar game concerned with defining characteristics needed for one new system is likely to be very different from a seminar game oriented toward a much broader subject, such as understanding the dominant factors in future undersea warfare and their interactions. The two games may employ different structures and need different kinds of supporting data. A major challenge for all seminar games is to enable all participants to use the same context in discussions. A facility able to present dynamic operational situations graphically helps participants attain a common context for their discussions, thereby allowing more rapid resolution of disputes than would be possible without such aids.

A successful seminar game requires the exercise of analytic discipline in game design, data collection, and game execution. Game leadership must ensure that critical questions are probed until their essence has been distilled, so that technical and operational thresholds may be determined where changes in parameter values make significant differences. It is easy for seminar games to become little more than simple brainstorming sessions, which, though stimulating and often valuable, will usually fail to come to closure on critical issues. A well-run seminar game, however, forces participants to address critical issues and captures rationale explicitly for conclusions. It clearly identifies what technical, operational, programmatic, organizational, political, or social facts lead to conclusions and insights.

Assigning particular roles to some participants is valuable. Those responsible for decisions about friendly forces may be designated the Blue Team. Others may be assigned to the Red Team to play the adversary. Competitive instincts help to ensure that ideas, claims, and insights do not go uncontested. Such interactive challenges give robustness to insights gained during the game.

The following list summarizes distinctive characteristics of seminar gaming conducted properly as a technique of employing human judgment to analyze problems too complex for algorithmic solution.

1. Establishment of an operational situation (or set of situations) for the problem, so that dynamic/time-critical considerations and relationships of other aspects of the problem may be evident.

2. Use of scenarios, game materials, and displays to create a common context, so that discussions of the problem by all participants in the game can be based on the same perception of reality.

3. Adroit selection of participants to ensure that various perspectives and organizations, as well as needed expertise, are represented during the discussions.

4. Application of procedural discipline so that adequate data are collected, areas requiring subsequent analyses (especially quantitative analyses) are identified, and logical and factual bases for insights and conclusions are clearly identified with an explicit statement of caveats.

CURRENT STATUS

Seminar games work. As illustrated by the following examples, they can stimulate new ideas, create consensus, and provide a structure for addressing complicated problems. The Distributed, Dispersed, and Disguised (D^3) concept for future naval operations had its genesis in technology gaming. This concept originated in the Naval War College's 1988 Technology Initiatives Game. It was then developed more completely at the David Taylor Research Center into D^3 + S (for Sustain) and later presented publicly to naval engineers.[8] Cost and operational effectiveness analysis for the kinetic energy antisatellite system concept employed seminar gaming at APL's Warfare Analysis Laboratory as its primary analytic method. This analysis played a central role in establishing the potential effectiveness of antisatellite system candidates and in building a consensus as to program need.[9] At a different level, seminar gaming in APL's Warfare Analysis Laboratory was used to develop principles that would enable commanders to set up the Aegis Doctrine Management System "if–then" logic so that their operational objectives could be accomplished under various circumstances involving one or more Aegis ships.

Seminar gaming methodology is still embryonic. Seminar wargames have been used to analyze advanced military systems for at least three decades, but little has been written about seminar gaming methodology, despite an abundance of literature on game theory and other decision-making processes.[10] The rational behavior assumed by many of the processes described in the literature has a fundamental empirical defect. Even when simple utility functions are replaced by more sophisticated and subjective expected utility functions, the behavior of human subjects in laboratory or real-world tests departs widely from predictions in both simple and complex situations. Likewise, the von Neumann–Morgenstern theory of games has not led to unique and universally accepted criteria of rationality for application to a broad range of problems.[11]

Some attention is now being paid to seminar gaming methodology. The Navy's 1989 and 1990 Technology Initiatives Games included Methodology Cells charged with addressing technology gaming so that its methodology could be improved. The 1989 Methodology Cell was charged with examining how Technology Initiatives Games should fit in the Navy's R&D planning process.[12] The 1990 Methodology Cell was tasked specifically to examine how quantitative analyses can be incorporated into technology gaming. It concluded that quantitative analyses were more useful in pregame preparation of game materials and in postgame analyses than in providing on-line access to quantitative analytic tools during the games themselves.[10] The Military Operations Research Society sponsored a workshop on future wargaming developments in December 1989 that focused on the application of wargaming to technology, acquisition, and test and evaluation decisions, and especially emphasized

clarifying the capabilities and limitations of gaming in these arenas.[7]

The lack of real theory for wargaming inhibits progress in developing seminar gaming methodology. Even the most recent publications in the literature about wargaming are heuristic.[13] They only identify processes that have been observed to make successful gaming more likely. Gaming and the conduct of seminar games remain art forms, even more than other areas of modeling and simulation.

The technology supporting wargames is advancing rapidly, including computational abilities and software, communication networking, and display capabilities. The advances will allow future seminar games greater flexibility than they presently have. Some of these new features and examples of their use include the following:

1. Participants in a seminar may be geographically dispersed. Interactive Simulation Networking (SIMNET)[14] already provides for distributed gaming. Likewise, the Defense Advanced Research Projects Agency's Distributed Wargaming System that supported Exercise ACE 89 was played with participants at eighteen locations in seven countries.

2. Artificial intelligence techniques will be incorporated into simulations supporting games, as has already been done in the RAND Strategic Assessment System and in other knowledge-based simulations[15] to reduce the manpower required for games and to reach beyond simple "what if" capabilities for simulations.[16]

3. Sophisticated graphics will help seminar game participants understand complex situations and integrate various data. For example, RAND's Cartographic Analysis and Geographic Information System can combine terrain data from the Defense Mapping Agency with both satellite imagery and simulation graphics.[17]

4. Future simulations may be developed and operated in integrated environments, such as the RAND Integrated Simulation Environment,[18] to reduce some of the prevailing past simulation problems, such as limited portability, restricted reusability of programs, and the large effort required to develop or modify simulations.

5. More flexible human–machine interfaces, including physiological–kinematic and voice recognition ones, will make possible many new wargaming capabilities.

Department of Defense (DoD) simulation credibility problems have received significant attention for some time. Several years ago, a major study examined how large DoD simulations, models, and games were developed and used. The study found few developments that had undergone adequate review.[19] A few years ago, a General Accounting Office study found serious deficiencies in DoD simulation credibility that could be ameliorated by DoD simulation policy.[20] The finding stimulated promulgation of a simulation policy for operational testing and evaluation.[21] A recent study examined management plans, policies, and procedures for the oversight of wargames, models, and simulations used for DoD training and acquisition.[22] The study focused on simulations, including computerized wargames. Similar work in validating wargames in general, and seminar games in particular, has been very limited. Because of the lack of wargaming theory, validation approaches for wargaming involving people must emphasize the processes of game design, preparation, selection of game participants, and game control. Widely accepted approaches to the validation of gaming systems do not yet exist.

CONCLUSIONS

Many of the most significant problems within DoD are too complex for algorithmic solution. Issues must often be decided before more quantitative methods of science and engineering can be applied. In many situations, issues are resolved by doctrinaire or simple arguments, which can produce a skewed view. When done well, seminar gaming brings important discipline to the application of judgment to such problems by ensuring (1) that the operational context for future systems and their use is considered appropriately, (2) that varied vested interests are represented in the give-and-take of the gaming process, and (3) that critical evidence (facts) and rationale for insights and conclusions are made explicit.

Seminar gaming is an evolving art. Much research remains to be done before seminar gaming can become a more rigorous analytic procedure, but even without analytic rigor, seminar gaming has proven itself valuable in many applications. Seminar games have stimulated numerous creative insights that might not have been obtained by other analytic methods.

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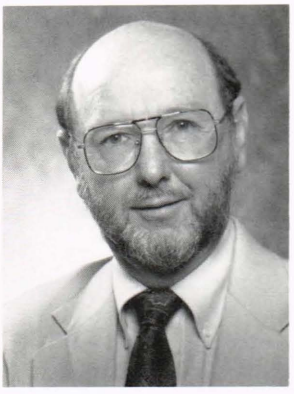

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