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# THESIS

WARGAMING IN SUPPORT OF
COMMAND, CONTROL AND COMMUNICATIONS
EXPERIMENTS

by

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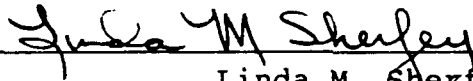M.S., Indiana University 1977

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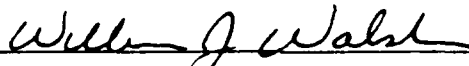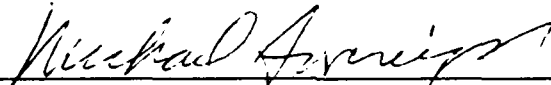NAVAL POSTGRADUATE SCHOOL
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## ABSTRACT

The purpose of this thesis is to provide information about wargaming to prospective users. An in depth discussion focusing on two primary components of wargaming is presented. The first component is wargaming in general. A description is provided of wargaming features and a discussion concerning the limitations and hazards inherent to wargames. The second component is how to design a wargame experiment to support command, control and communications (C3) hypotheses testing. A description of the steps in planning a general wargame experiment including detailed information on wargame software considerations is presented. Finally a synopsis followed by a critique of an actual C3 wargame experiment is provided as an example of the principles given in this thesis.

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# I. INTRODUCTION

## A. BACKGROUND

Peacetime operations that can be observed stimulate little of the activity that can be expected in crises or wartime, and fleet exercises that offer an opportunity to observe combat direction offer little opportunity to observe higher level command functions in a realistically stimulated environment (Ketron, Inc. 1979, p. 4). Before Desert Storm, many weapons, systems, and ideas were untested in combat. The Navy cannot rely on actual conflict for evaluating its combat capabilities. Wargaming used as a tool in research, operational planning, and training is rapidly expanding to meet these needs.

> Improvements will be needed to adapt existing systems and technology and to make limited upgrades and changes in a number of areas, including, the following:...Simulation-gaming support to assist in near real-time analysis of alternative courses of action and for peacetime training and readiness.... (Command and Control Functional Analysis and Consolidation Review Panel Report, 1991, p. 7)

Interest in improving the Navy command, control and communication (C3) systems has been encouraged by the Department of Defense in recent years for several reasons. The threat to Naval forces continues to become more complicated due to complex, multi-dimensional anti-ship missiles deployed on aircraft, ships, and submarines, and

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increasingly sophisticated electronic warfare technology. There has been an exponential growth in the amount of information available to commanders for assessing the situation and operational planning. Rapid advances in computer and communications technologies have enabled the planning and design of increasingly sophisticated systems to support tactical C3.

Modeling, simulation and gaming can effectively be used for identifying requirements and designing, developing, acquiring, training for and employing major C3 systems. Command and control of military forces and assets is ultimately a human decision process supported by C3 systems with human operators receiving imperfect information. The most effective and economical way to evaluate systems involving human processes is by using wargaming. In particular, wargaming best supports research for the following command and control functions: situation monitoring, decision making, and management of forces and intelligence support assets.

> The first step in command and control research (C2R) focuses on decisions critical to military operations, the two most important being to identify decisions that have an impact on combat outcome; and to identify the appropriate command levels where different decisions are most appropriate. Once the crucial decisions are identified, C2R then encompasses many issues, including identifying information required to make the best decisions and the effect of time on the information gathering and dissemination process. (Hogan and Might, 1988, p. 33)

Navy officers need to be aware of the benefits and hazards of using wargaming for research, operational planning and training. Decision makers, who have not been involved in wargaming, can expect to deal with games or the results of games in the course of their careers. Wargame use is as complex as the situations they attempt to address.

> The fact is that wargames and wargaming are consistently misunderstood, denigrated, even denounced, not only by gaming outsiders, but also by gaming proponents and practitioners. This unfortunate situation is a result of a failure to reconcile the fundamental ambiguities of wargaming, to understand the nature of the tool - the game - and of the process of using it - gaming. (Perla, 1990, p. 2)

In addition to limitations inherent in the games, game data users need to question and understand the process of applying a wargame to an experiment. An example of wargame abuse is the wargame that was conducted in the spring of 1942 at the War College in Tokyo. Japanese naval planners were preparing plans for the capture of Midway and the western Aleutians in early June, the seizure of strategic points in New Caledonia and the Fiji Islands in July, air strikes on southeast Australia, and operations against Johnston Island and Hawaii in August.

> During the play the Nagumo Force was attacked by land-based air while its own planes were attacking Midway. Following the rules of the game, an umpire determined that the carriers received nine hits and that two of them, the Akagi and Kaga, were sunk. Rear Admiral Ugaki, the director of the game, arbitrarily reduced the number of hits to three, and the number of sinkings to one, and then permitted the sunken carrier to participate in the next part of the play dealing

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with the New Caledonia and Fiji Island invasions. (McHugh, 1966, p. 2-19)

Wargaming and model use will continue to grow in importance as funding is reduced and the need for analysis tools increases. Wargame adaptability uniquely applies to the ever expanding and diverse third-world military scenarios, the continuous redrawing of global country boundaries, and unique combinations of our own forces.

## B. PURPOSE AND GOALS

The principal purpose of this thesis is to provide information about wargaming to prospective users. The first component is wargaming in general. The goal is to provide the reader with limitations that need to be considered and hazards that must be avoided when using conclusions derived from wargame data. The thesis contains a description of wargame features and a discussion concerning wargame limitations and hazards. The second component is how to design a wargame experiment to support C3 hypotheses testing. The goal is to enable the reader to test C3 hypotheses using a wargame experiment by providing a guide. A general description of the steps in planning a general wargame experiment is provided, including detailed information on wargame software considerations. A synopsis followed by a critique of an actual C3 wargame experiment is furnished apply the principles supported in this thesis.

## C. ORGANIZATION AND SCOPE

This thesis is an implementation guide. Chapter I provides the reader with a background on why wargaming is advantageous for research and will be even more useful in the future. It also includes the thesis purpose, goals, and organization. Chapter II goes into more detail on C3 wargame applications, types, features and basic requirements. Chapter III describes the limitations inherent to wargaming and hazards to avoid in wargame use. Chapter IV guides the reader through the steps for a general experiment design, including detailed information on the critical stage of software selection. Chapter V provides a synopsis of an actual C3 experiment that used a wargame to evaluate a decision aid. Then the example is critiqued to apply the principles given in this thesis. The final chapter is a summary.

## II. WARGAMING DESCRIPTION

Before going into the specifics of wargaming considerations and experiment design, this chapter ensures that the reader understands the author's idea of what a wargame is, some general and C3 wargame applications, the types of wargames, and common features and basic requirements of a wargame.

### A. DEFINITIONS

In order to begin with a common understanding of terms used in this thesis, the following definitions apply.

- Models are simplified approximations of reality. A model is a representation of an object or structure, or an explanation or description of a system, a process, or a series of related events (McHugh, 1966, p. 1-4). The amount of detail and variables in a model can vary to fit its use. Some models look like what they represent, some are similar and some are symbolic.

- A wargame is a theoretical representation, in accordance with predetermined rules, data, and procedures, of selected aspects of a conflict situation or military operation. A gaming exercise employs human beings acting as themselves or playing simulated roles in an environment which is either actual or simulated (PACER Systems, Inc, 1975, p. 11).

- A simulation is an operating representation of selected features of real-world or hypothetical events and processes (McHugh, 1966, p. 1-1). All-machine simulations (no human decision making) are not defined as games. All games however, are simulations.

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There is a distinct difference between a simulation and a

wargame that needs to be understood for C2 applications.

> In simulations, explicit rules and procedures within the
> simulation help define available choices and decisions.
> Conversely, in war games, players interactively make the
> pivotal decisions and choices. In this context, war games
> are simulations with participatory user interaction.
> (Airpower Research Institute, 1985, p. 3)

Use of strictly simulation is not recommended for C2

hypothesis testing experiments because human impacts and

dimensions are not easily duplicated by a computer program.

> In model building, C3I is generally recognized as one of
> the most difficult areas to portray. Within the open
> simulation (man-in-the-loop) framework, some of the burden
> is removed from the model designer when the decision is
> made to allow the player to perform the command and
> control (C2) functions directly. The remaining processes,
> intelligence and communications, are somewhat more
> mechanical and, therefore, simpler to represent in a
> rational fashion. (National Defense University, 1986,
> Volume I, p. IX-1)

In addition to understanding what wargaming is, it is also

useful to understand what wargaming is not. Wargaming is not

a technique for producing a rigorous, quantitative or logical

dissection of a problem or for defining precise measures of

effectiveness by which to compare alternative solutions

(Perla, 1990, p. 164). Wargaming is not real. The level of

abstraction depends on the model and the application. A

wargame is not duplicable. The interplay of human decisions

affects the simulated outcomes and therefore, does not allow

the researcher to expect the same sequence of decisions and

outcomes during a replay of a game. Wargame designers and

analysts involved in research need to be careful to define the

results of a wargame in terms of why and issues raised, not what happened. A game should not be used to predict outcomes. They are best used to investigate processes.

## B. GENERAL WARGAME APPLICATIONS

This section discusses why professional wargames are played in addition to its traditional use for training. Some of the added applications for wargames are to investigate not rigorously quantifiable problems, decompose complex problems, uncover new aspects of a problem, test operational plans, assist in the planning process, and focus on human behavior.

### 1. Explore Not Rigorously Quantifiable Problems

For this type problem, the choice of which variables form the basis of a problem and the relationships of the variables are not easily determined. An example of a not rigorously quantifiable problem is determining the United States strategic forces necessary to deter nuclear war. A rigorously quantifiable problem would be determining the impact point of a bomb dropped by an aircraft. Selecting an output measure, determining relevant variables, and defining the underlying model is much more difficult in solving a not rigorously quantifiable problem. Wargames represent the only formal decision aid available for this type of problem.

### 2. Decompose Complex Problems

Another application is to use a wargame as a tool for decomposing complex problems. Proper game preparation forces

a consideration of the range of possibilities for any assumption. This step provides a natural method for subdividing a problem into smaller parts. With wargaming experiments, one assumption at a time can be manipulated to examine its impact on the problem. The decomposition of a complex problem into separate models, each of which can be evaluated and the results later combined, is an aid to exploring a complex problem. However, caution should be applied when making the final combination.

## 3. Uncover New Aspects

Wargaming can be a form of brainstorming to generate aspects of a situation that are not readily apparent. By role playing in a realistic game, participants involved in a complex scenario can explore alternative policies, discover unexpected alternatives, and sometimes, anticipate outcomes that differ from those originally envisioned (Airpower Research Institute, 1985, p. 44). This approach can be used in research to generate and test hypothesis concerning human interactions.

## 4. Test Operational Plans

Another use of wargaming is testing operational plans. The experiment requires a realistic model in order to apply a real-world situation that requires planning a complex sequence of actions. Insights may be gained as to how the plan will work in the real world by playing out the planned actions. If

the initial design of a game incorporates well-known critical factors into its models and procedures, the play of the game and the questions and issues it raises can lead to the discovery of other factors whose importance may have been previously unsuspected or undervalued (Perla, 1990, p. 181). The reader is reminded that insights not predictions of possible outcomes will be generated.

## 5. Assist in Planning Process

Since a wargame can be used to evaluate a plan, it can also be used to integrate plan evaluation into the planning process. First a plan is gamed and evaluated, then any deficiencies can be corrected in the next iteration. The idea is to create a planning, testing, and replanning cycle. The more complex the situation and therefore the plan, the more useful and practical is the wargaming application. The design of the game (organizing), and the play and subsequent analysis of the game (exploring) form a circular chain or feedback loop, in which the questions and issues arising from one play of the game can reshape or reorganize the game system itself to make it a more accurate representation of reality (Perla, 1990, p. 180).

## 6. Focus on Human Behavior

Wargames allow the researcher to focus on human behavior, specifically on human decision making. The models usually offer various outcomes based on a probability

distribution. Thus, the "roll of the dice" provides a wide range of possible results or snapshots of reality with which the players must deal (Perla, 1990, p. 276). The value of wargaming for decision making is in qualitative assessments of why decisions are made. The advantage of a wargame over an exercise is that in an exercise there are limits on the range of physical parameters and processes and on the range of potential decision choices participants can choose from.

## C.  C2 WARGAME APPLICATIONS

In model building, C3 is recognized as one of the most difficult areas to represent. Because wargaming uses a man-in-the-loop framework, some of the complexity in model building is reduced by allowing the player to perform the command and control (C2) functions directly. The communications function is more mechanical and can be simpler to represent in the model.

There are at least four aspects of command and control activities and processes that can be approximated in wargames because they are characteristics that can be represented realistically enough in the games to support meaningful analysis. These aspects are:

- Command roles. Decision making functions and the nature and scope of the force actions that result from the decision making responsibility are defined by doctrine and convention so there should be very little discrepancy between command roles in reality and those for a game.

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● Hypothesis formation. Any time that decisions must be made in the face of uncertainty and incomplete information, the decision maker must construct from available information hypotheses as to the nature of events, situations, etc., about which he has no knowledge and make decisions as if those hypotheses were true (Ketron, Inc., 1979, p. 26). This holds true for gaming if the decision makers are playing a similar game role as the role they hold in reality.

● Filtering and interpretation of information. The way a commander identifies items relevant to a decision by filtering the constant stream of information against his hypothesis to arrive at a decision is realistic in a wargame if the actual information that the decision maker is filtering and interpreting is realistic in format, content, and order of arrival.

● Information categories. Given that the information that is provided is tactically realistic, and that the roles and reasoning just discussed reflect those which would be encountered in the real world, the requests for information to support command decision making should also be representative of real world operations (Ketron, Inc., 1979, p. 27).

These aspects focus on the exercise of decision making along the chain of command and are more dependent on the human element of C3.

## D. TYPES OF WARGAMES

Wargames can be classified in many and multiple ways. The following gives a definition for classification by technique of rule application, wargame purpose, and geographic scope and decision making level.

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## 1. Classified by Technique

The two techniques of applying rules are rigid games and free games. A technique choice for knowledge about the opponent's forces is open or closed games.

Rigid games are conducted by following detailed, nondeviating rules. The game rules usually provide for chance events; the role and the range of chance results are not left to the judgment of an umpire or controller (Hausrath, 1971, pg. 123). All possible outcomes are predetermined and rules provide for one possible outcome for each possible result of chance. For example, if there is a 50:50 chance of either of two outcomes, the rules determine how the result will be resolved such as a coin toss. Rigid games have extensive rules and are more complex to write for computer simulation. Rules provide for identical procedures, methods, and source data in each run and therefore are believed to provide more consistent and reliable data.

A free game is conducted with fewer fixed rules and the assessments are made by an umpire or controller. The controller bases judgments on military experience. It is less tied to the mechanics of play and is therefore, less reliable than a rigid game and is usually more applicable to training use.

The open game is simple and informal. The opposing players have full knowledge of the positions and actions of

their own and their enemy's forces so there is no need for an intelligence model. The open game is most often used for training.

The closed game is more complex and formal. Each team has first hand knowledge only of their own forces and partial knowledge of the opposing team is received by an intelligence model. The closed game more closely approximates reality and is more useful in command and control hypothesis testing.

## 2. Classified by Purpose

When the primary purpose of a wargame is to provide the players with decision making experience, the game is educational. When a game is conducted in an attempt to obtain information and data that will help the responsible commander to make decisions, the game is an operational planning type. If the purpose is hypothesis testing, the game is an experiment for research.

## 3. Classified by Level

This categorization combines geographic scope and the level of decision making. The three levels are : global/strategic, theater/operational, and local/tactical.

In global/strategic games, the participants are top level decision makers, and the goal is to improve their perspective, test strategies, and identify important issues at that level. The primary output of these high-level games is qualitative, consisting typically of game narratives with some

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interpretations of events and little numerical data (Perla, 1990, p. 170).

Commanders in chief of the unified or specified commands are the primary decision makers for the theater/operational level wargame. These games are designed to explore specific issues and identify strategic, operational, and tactical problems with the theater scope. The output is usually similar to that obtained for global/strategic games however, theater/operational games more often run the game more than once with the same players to generate more numerical data.

The primary decision makers in the local/tactical category are usually battle-group commanders or below. These games focus attention on force levels and tactical deployments, weapon and sensor performance, and interrelationships among various warfare areas. The outputs are a combination of qualitative and quantitative with more numerical data than the other game categories. The number of times the game is run with the same players tends to be higher.

## E. COMMON FEATURES OF WARGAMES

The following basic characteristics are present in all wargames.

- Simulates a military operation.

- Is usually at least a two-sided representation of forces opposed to each other.

- Is conducted in accordance with data, rules, and procedures that conform to accepted military doctrine.

- Represents an actual or predicted real-life situation.

- Provides for the employment and tactical movements of units in each force.

- Uses some graphic means of identifying units, weapons, and positions of forces.

- Provide a system for taking into account the firepower and other capabilities of the forces and equipment involved and a means for assessing the effects of combat.

- Includes a clash of opposing forces in fire fights, battles, or prolonged campaigns. (Hausrath, 1971, p. 11) and (McHugh, 1966, p. 1-12)

A wargame played for logistic requirement determination would have exceptions to the above list of characteristics.

## F. BASIC REQUIREMENTS FOR WARGAMES

The following is a list of the basic requirements that are common to all wargame applications. These requirements need to be determined early and include: personnel; facilities and equipment; rules, data and procedures; and a scenario.

### 1. Personnel

Because wargaming involves humans in the decision process, an especially important requirement is knowledgeable personnel. For C3 experiments, it is critical that the players be highly qualified and be assigned to positions appropriate to their experience and training. The game

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designers and analysts should be militarily knowledgeable and have the required mathematical, statistical, and related technological knowledge and skills.

> These scientists must translate military characteristics and actions into models and data that may be recorded and tabulated. They must then compute the interactions. They must assure that chance events and results are treated in a sound mathematical and statistical manner to represent realistic probabilities. In supervising the recording and processing of game data, and in the interpretation of results, proper allowance must be made for the effect of assumptions, approximations, and change results. All elements must be managed within the limits of reliability imposed by the original input data and data-processing methods. (Hausrath, 1971, p. 84)

Most games currently in use are played on computers. Some members of the team of designers and analysts must be skilled in designing and programming, modifying, and troubleshooting the models processed in the computer; the supervision of the computer input preparation; and the interpretation of computer outputs.

### 2. Facilities and Equipment

The complexity of gaming facilities and equipment has grown with technology. In the 1800's games were played with physical pieces representing equipment and units, now games are usually played on interacting computers with display monitors. Facilities usually consist of two or three adjoining rooms, each having access to a connecting corridor.

### 3. Standard Rules, Data, and Procedures

Standard rules, data, and procedures are provided in the form of a game manual or handbook. Also a set of

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reference data such as the weapon capabilities and the quantities of each weapon available on each unit is required.

## 4. Scenario

A statement of the situation is required for the initiating and conducting of any game. It may be a briefing and/or a detailed game directive. The statement of the situation must include all the "givens" for the game.

> These "givens" include a statement of the geographic locale, the forces and weapons available to each side, the time frame in which the action is set, and the political and other constraints applicable to the game. Also, "givens" customarily include a resume of the conditions leading to and resulting in the initiation of conflict, the starting deployment of forces involved, and, above all, orders or instructions to each commander stating the purpose and objectives of the game, his special mission, and related details. (Hausrath, 1971, p. 84)

This chapter has defined the difference between a simulation and a wargame, wargame applications other than training and logistics, and some common features and basic requirements of all wargames. The next chapter addresses the limitations and hazards inherent in wargaming use and conclusion application.

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# III. WARGAMING CONSIDERATIONS

Wargames and the conclusions derived from wargaming are often misunderstood, criticized, and even opposed. This circumstance has resulted from a misunderstanding concerning the nature of wargaming. When its limitations are understood and hazards are avoided, wargaming is a very valuable tool.

## A. LIMITATIONS

It is critical for the wargame researcher and data user to fully comprehend the limitations inherent to any wargame. These handicaps can only be mitigated and not negated. However once their effects are understood, wargaming is very useful for valid experimental testing.

### 1. Reality vs. Complexity

Wargame designers tackle a built in conflict when trying to balance realism versus playability (detail versus simplicity). The difficulty is in designing symmetry between the game system and the game player. If the game system becomes too complex when the designer attempts to accurately duplicate realism, the player's behavior may become unnatural. A complicated game system can artificially slow the players reactions to the game and make them more concerned with the mechanics of the game. However, over simplistic game systems

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do not challenge the players and will not encourage decisions more like those made in a real situation.

> The key to realistic wargaming lies in balancing the player's experience in his decision making role with as accurate a representation as possible of the physical outcomes of his own decisions, his opponents decisions, and the objective dynamics of combat. Achieving this balance is difficult because realistic decision making requires giving the player realistic information and accurately representing the realistic effects of time. (Perla, 1990, p. 303)

## 2. Artificialities

The fog of war cannot be fully duplicated; realistic information is difficult to accurately represent in a wargame. Typically the players have too much information and of too high quality. Realistic provision for chaos, unanticipated successes and failures, "someone who doesn't get the word" and a commander not knowing what is happening elsewhere in the battle are difficult to represent in a wargame.

Communication circuits as represented in a wargame usually perform too well. Message text and voice intelligibility are always good. There are no communication outages, and transmissions and delivery are much faster than in reality.

Combat results can be modified by the game controllers to continue the game. An example would be to not allow all Blue carriers and flagships to be eliminated by the first Red strike, so Blue can continue to play. If this happens, the

combat results cannot be used to assess strategy and tactics used by either side.

During the game play, the participants can become intensely involved but because the game is limited to work day hours with breaks for lunch, the combat stress is reduced. Also when the game breaks occur, the participants have an opportunity to review their situation. This assessment time would probably not be available in a similar real world situation.

Each player approaches the game with a preconceived mental model of the world and will act based on their previous experience and knowledge. This is called framing. The information presented during the game is processed by this internal model. Because it contains a set of filters and sorting and weighing factors, not all the information is accepted. When a player makes a decision, the alternatives considered fit within their mental model. Therefore, the solutions for the player to choose from have been internally limited.

Combat, fear, danger, losses and the unexpected are missing from a wargame. Morale, leadership, fatigue, and courage can be added to the list of factors that have an important effect on the outcome of a situation, but which cannot be predicted or measured. An example is whether a unit will stand and fight or break. The will to fight is not quantifiable or even understood.

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Admiral Arleigh A. Burke put his finger on the central artificiality of wargaming when he said that "nobody can actually duplicate the strain that a commander is under in making a decision during combat." In a wargame, real forces do not deploy, real weapons do not engage, and real people do not die (Perla, 1990, p. 250).

These elements are usually handled by assuming parity or equality for opposing forces.

An additional artificiality is the assumed homogeneity of similar forces such as all pilots are equally skilled and all guns and missiles of the same type work equally effectively. These simplifications are necessary for game playability.

The certainty that at some point the confrontation will escalate into warfare is a built in unnatural condition that affects the players' perception of the situation and their decisions. In a real world confrontation, the option of a diplomatic solution exists. As a result, the game commanders are less troubled by the possibility that their actions will precipitate a conflict that otherwise would have been avoidable, and tend to be more aggressive than they might be in a real world confrontation (Ketron, Inc., 1979, p. 23).

## 3. Data Validation

Data validation is a measure of how much confidence there is in the data for a given model. Many times for complex and difficult games, some of the real world data is not available. An example is a wargame concerning the benefits of using a new system in combat when it has not been

implemented or tested in the real world. Also the data can be unavailable because the system for the model has not yet been built. This is a "catch 22" predicament because a lack of real world data for complex and difficult situations can be precisely why they are wargamed.

### 4. Workable Falsehoods

To create a functioning wargame, the designer must apply some basic assumptions. In reality these assumptions are incorrect, but they are minor falsehoods that the designer and researcher can manage to deal with.

#### a. The Right Variables Have Been Selected

That the right variables have been selected is the first assumption. A close examination of the hypothesis and issues will identify a large number of variables. A good workable model will not be able to address all of the variables. It will only be able to deal with the set of variables that are high priority and only a few if any of the remaining variables.

#### b. A "Matched Set" Relationship Exists Between the Algorithm and the Data Base

The algorithm for processing data can only work as well as the quality of the data and vice versa.

> For best matching, both components should be at a comparable level of acceptable perfection....An upper bound than on the fidelity of the algorithm would that it track the variables to no greater degree of granularity than that expected in the data base. (Patton, 1990, pp. 43-44)

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*c.  The Study of War Can Approximate an Exact Science*

Technology has advanced the art of wargaming and reduced in degree many limitations.  There is one limitation, however that technology cannot impact.  A person is unable to predict how they or any other individual will react in stressful and dangerous situations of war.  This inability to predict human action and reaction is a major problem and a fundamental reason why the social sciences are generally less exact than physical sciences (Hausrath, 1971, p. 276).

*d.  The Doctrine for Tactics and Data Used for the*
    *Wargame Design is Current*

The rapid advances of technology which produces new or improved weapons and systems contributes to doctrine evolution and input data change.  Continuous revision of doctrine and data used in a wargame's design is not practical. Between periodic updates to reflect revised doctrine and data, a wargame will be out of date.

*e.  A Wargame is Repeatable*

In every human-decision game, the players learn from experience.  Therefore with each additional run of the game, the players have knowledge that they did not have in the previous game and this will affect their decisions.  It is still useful to repeat a wargame to confirm the consistency of results or the lack of consistency.  In general the reliability, validity, and applicability of the results of

reliability, validity, and applicability of the results of human-decision games are more a matter of judgment than of measurement (Hausrath, 1971, p. 287). In addition, if a stochastic method of determining the outcome of chance events is used, the same decision can result in a different outcome.

## 5. Cost

The four massive requirements of data, time, staff and computer support add up to big costs. Although a wargame is less expensive than a fleet exercise, the preparation, conduct and evaluation time for a wargame should not be underestimated. Pregame planning and postgame analysis can require several months of work. Player training and playing time takes them away from their jobs.

## 6. Stochastic vs. Deterministic

A simplistic description of the issue is whether it is more important to obtain expected results (firing 200 things each having a probability of kill of 0.5 will cause 100 kills); or whether it is more important to allow for all possible outcomes (firing 200 things as above could cause 100 kills, or 200, or zero etc.). (Patton, 1990, p. 44)

Some designers believe that a game will be more realistic if chance is portrayed stochastically so the players will be forced to consider unexpected and unusual outcomes. The opposing argument is that for a game's very finite set of encounters an outcome from the tails of the distribution could easily skew the game results.

## B. HAZARDS

The following is a list of wargaming considerations that are hazardous to the accurate results of game play. The researcher must anticipate and be vigilant to avoid these conditions when selecting a game, when the game is played and when representing conclusions.

### 1. Poor Documentation

The history of modeling shows that poor documentation creates poor results. Modeling documentation is critical when determining appropriate applications. The ongoing process of wargame revision can make the initial documentation obsolete. In addition, personnel turnovers deplete the corporate knowledge base concerning details and assumptions in models used (Airpower Research Institute, 1985, p. 35).

### 2. Uncooperative Players and Umpires

A wargame is a competitive situation. The players bring their egos to the game and don't like to lose. They have pride and some will improvise.

In order for the game to be successful, the players must play wholeheartedly and enter into the spirit of the game. There may be times in the game when a player is not busy and may become bored. Another tendency is for some players to "fight the problem" by seeing only the limitations of the game models and not the advantages. A weapon may not perform "correctly" or an outcome may not be what they expected.

Umpires sometimes have to apply subjective values judgments in determining an outcome and abuses can occur.

> Umpires can limit the information they give to players and "muddy the waters" with false or inaccurate data. Umpires can also be arbitrary and inconsistent in their handling of such factors. Similarly, there is a strong tendency for human umpires to lapse into reporting information in game terms rather than real terms. (Perla, 1990, p. 304)

### 3. Misplaced Advocacy

The results of wargaming are used to communicate and convince. The inherent ambiguity of a not rigorously quantifiable problem allows misinterpretation of wargame results. Because assumptions and data input can be manipulated, there is an opportunity to use the wargame to produce a desired outcome. The designer of a game has great power to inform or to manipulate (Perla, 1990, p. 182).

This chapter listed and described the limitations that cannot be eliminated from wargaming to enable the reader to understand the restrictions within which a wargame attempts to approximate reality. It also provided a list of elements that are dangerous to useful game results. The next chapter contains a description of the steps in a general wargame experiment plan.

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## IV.  GENERAL EXPERIMENT PLAN

This chapter's aim is to provide a broad outline of and guidelines for designing a wargame experiment to test a C3 hypothesis.  The reader should be familiar with general experimental design and analysis of variance.  A one or two-semester course in statistics would be sufficient.

Experiment credibility hinges on the approach used to plan or design the experiment.  A clearly defined approach helps to ensure that the final product is appropriate.  The statistical design of an experiment is the process of planning the experiment so that appropriate data will be collected.  The data is then analyzed by statistical methods resulting in valid and objective conclusions.  There are two considerations to any experimental problem: the design of the experiment and the statistical analysis of the data.  They are related because the method of analysis depends directly on the design.  The goal is a cost effective experiment that supports informed decisions.

The process for planning an experiment includes the following stages:  conception, design, preparation, execution, analysis and report.  A looping cycle of refinement is likely to occur when going from conception to design and from design to preparation.

The success of an experiment is measured by the degree to which the experiment results answer the requested issues and objectives, and the credibility of those results. A effective experiment requires a team of militarily knowledgeable C3 personnel (User) and statisticians that are experienced in experimental design (Analyst).

Although all of the six stages will be described, the thesis is mainly concerned with the design and preparation stages.

## A. CONCEPTION

Recognition of and a statement of the problem is the first step. This step includes going from the issues, to the objectives and then to the response variables. The importance of this stage cannot be overemphasized. The Users begin by writing a detailed statement of the issues to be investigated in the experiment. They next define a clear, unambiguous description of the specific objectives of the experiment and how they relate to the identified issues. Experiment alternatives should flow from and support the objectives. A clear statement of the assumptions is written.

Relevant measures of effectiveness (MOE) and measures of performance (MOP) are determined and designed to provide the decision-maker with either a quantitative or qualitative assessment of the objectives. The environment and the threat must be chosen because they influence software selection.

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Security considerations unique to the experiment are also determined during this stage. The Analyst can assist in helping to identify the experiment alternatives, assumptions and write the hypothesis. The Analyst makes sure that there is a clear linkage between the objective, alternative, and hypothesis.

The Analyst will also assist the User in selecting the independent variables. These factors may be either quantitative or qualitative. How these factors are to be controlled and measured is also considered. The levels of the factors must also be chosen. The dependent/response variable, how it will be measured, and the probable accuracy of those measurements are also determined. The User and the Analyst must be careful to be certain that the response to be measured really provides information about the objective.

## B. DESIGN

The focus at this step is to match the experiment objectives with available simulation models, analysis tools, data requirements, measures, hardware requirements, and security. The detailed experiment plan should have complete traceability back to the originating issues, objectives and requirements.

A key aspect is determining whether the issues and objectives lead to a specific generic experiment category. Some generic experiment types include: demonstration,

optimization, comparison, evaluation, sensitivity and prediction. Deciding the experiment type can assist in writing the mathematical model for the experiment so that a statistical analysis of the data may be performed. Also included in this step is determining the order in which the data will be collected and the method of randomization. The number of replications to support the analysis is decided. The number of subjects (player), from what population they will be obtained, and to what condition(s) each player will be exposed are planned.

This thesis concentrates on the experiment design steps that are unique to wargaming. Those steps are: designing the scenario, providing a data base, and setting up the software program.

## 1. Scenario

The game begins by placing the players in a situation that requires them to make decisions. The scenario or situation sets the scene for player decisions and provides for specific updates in the situation during the play. The updates can alter or influence the developing situation and can draw player responses to specific items of interest. By defining the setting and scope of player decisions, scenarios can direct the course of a game into either very narrow or fairly broad channels, depending on the game's goals (Perla, 1990, pg. 204). The scenario can have a major influence on

player decisions so the User needs to be sure that the scenario allows the players enough decision-making flexibility to let the game meet the objectives. In order to focus on exploring the C3 factors and reasoning that affect specific types of decisions, scenarios should allow players as much freedom as possible in making decisions by minimizing artificial restrictions.

The User needs to work closely with the scenario designer. The designer must understand the experiment objectives and how they are to be met in the game. By identifying the kinds of player activities and decision-making opportunities that are required to meet the game's objectives, the designer can ensure that those activities and opportunities can happen. The scenario writer structures the flow of game play to allow the User's needs to be met but without forcing the players to follow a rigid path. A critical node in the flow of the game, at which a player's decisions will lead inevitably down one or another of several major alternative paths (to order a battle force into a fjord or to hold it in the open ocean; to launch a strike immediately or await the enemy's attack first), may be called a decision point (Perla, 1990, pp. 208-209). These decision points need to have enough detail so that players will have a realistic range of alternatives, but the number of alternatives needs to be manageable for analysis.

A coherent scenario must be logically consistent and tie together all the elements of the experiment including the originating issues, objectives and requirements. Usually, it must also be a believable possible view of reality from the players perspective. The exception is when the objectives of the experiment are important enough that the players are willing to shelve disbelief to support exploration.

The User should review the scenario designer's documentation including reasons behind choice of assumptions, factors included or excluded from the scenario, the use of particular sources of information, and any other decision.

Control personnel, players and analysts each have their own perspective and requirements for information concerning the scenario.

> Control personnel need to understand the context of the game and the prerogatives and limitations under which they must operate. Players need the same information as control personnel, but it should be constrained to reflect their less-than-perfect knowledge of their game world. Analysts need to know not only the full story of what and why, the "ground truth," but also the story as told to players and control, so that they may interpret the effects of information constraints. Finally, the future consumers of the game's issues must know not only the context of the game, but also how to distinguish scenario input from game-play output. (Perla, 1990, p. 211)

The User also needs to plan how to distribute the scenario information to the game-control personnel, game players, game analysts and report readers.

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## 2. Data Base

In addition to understanding the situation, the players must have access to the game's data base. The data base includes all the information that the players would reasonably have access to in a real situation. The data base of the game contains information about the capabilities and number of forces, levels of logistics, and relative likelihoods of the occurrence and outcome of interactions between forces, and the physical or environmental conditions. It also is the doctrine, tactics and procedures for the use of the forces and equipments.

The data base links the scenario and the mechanics of the game. It must provide all the inputs required to allow the game's models to reproduce the qualitative scenario conditions and to generate outcomes of interactions.

The data base provided to the players should be tailored to their game role, to the types of decisions they should be making, and to the types of information they need to make those decisions (Perla, 1990, p. 212). Important data need to be easy to find or require a minimum of calculations. The players need enough information to be able to determine what possible outcomes will result from the various decisions they may make.

Some data is easily quantifiable and available such as logistics input data, weapon and equipment performance that have been experimentally field tested, and information

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available from records such as ship transit time. Some data will be unavailable such as for weapons never used in combat (tactical nuclear weapons). This data must be deducted or extrapolated from related data or assumed to be within reasonable limits.

Qualitative data for judgments of unit discipline and morale, leadership of opposing commanders can be either assumed equal for opposing teams or can be assigned quantified values that represent different levels or degrees of these qualities.

The C3 data base representation of doctrine, tactics and procedures is difficult to include. They change over time and sometimes are not well documented because they depend on the commander and his own command structure. The command and control data base should include the communication, EMCON, surveillance, EW and OPCON matrix.

### 3. Software (Wargame)

When selecting the wargame, the User and the Analyst must constantly evaluate how the experiment objectives determined during the conception stage will be applied in the game. This section lists and describes areas that the User and Analyst will examine in designing the game. These decisions form the game parameters. The software to use is the one that comes closest to these parameters.

### a. Objectives

Every wargame has objectives. The objectives determine the game's uses. For example, a game may be conducted to provide decision-making experience at one or more specified levels and types of command; another to provide information and data concerning the employment of specific forces or weapons systems, test an organization or distribution system, or evaluate a type of operation or a tactical doctrine (McHugh, 1966, p. 1-11). The game designer should have clearly identified how and in what ways the game could provide the type of experience needed to achieve its objectives. The User needs to match as closely as possible the experiment objectives with the game objectives.

### b. Scope and Level

The selection of the scope and level for an experiment follow directly from the specific experiment objectives.

> War games may range all the way from a contest between two units of a single service to a simulated global conflict involving coalitions of nations, the efforts of all services, and the impact of conventional and nuclear weapons on military forces and civilian economies. Games may be tactical, strategical, or a mixture of both. Some emphasize air operations; others, land or sea operations. Geographically, games may embrace a limited area, a single area of operations, or several areas of operations. (McHugh, 1966, p. 1-13)

Related to the scope of a game is the range of command levels. Command levels can range from individual unit commanders to

national leaders. The scope and range of command levels help to determine the basic military units that will be used in the game. If the lowest command level of naval forces is the squadron, then the smallest unit might be the division.

### c. Number of Sides

Games can be one-, two-, and n- or multi-sided. A one-sided game is played under two or more different situations. Some examples are: to find the minimum time for the simulation of a replenishment operation when there is no opposition from the enemy; and when the players are opposed by the game controllers or a pre-programmed opponent. The most common wargame is the two-sided with teams of players representing each of the two major contending parties or coalitions (Blue vs Red). A multi-sided game is less common and is most often used for diplomatic or political-military games.

### d. Amount of Intelligence

An "open" game is when all players have access to complete information on each other's plans and forces. Advantages to the open game are a reduction in personnel, space and time requirements. A "closed" game is when the players have access only to intelligence that would be available in real-world conditions. The data generated in a closed game will be more reliable if the simulated flow information is incomplete or interrupted.

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A closed game with information handling enhancements will make C3 experiments more credible. The best approach for a wargame to take in information uncertainty is to have more than one level of truth. Some information is progressively disclosed automatically as the game progresses, but more detailed and accurate information can be acquired by aggressive sensor use, additional information requests, and revealed by team members sharing their information. The fog of war can be simulated by controlling the treatment of information.

> Ideally the game should allow each player to make the following "mistakes": (1) Non-observation of entitles which are within detection range because of non-alerted operators, system failures, environment, and deception (or loss of track after initial detection); (2) Incorrect location of detected entities due to system bias, time late, lack of gridlock, etc. (multiple tracks); (3) Incorrect classification of detected entities due to noise, jamming, environment, deception, failure to correlate separate sources, delay, etc. (confusion of red, blue and neutral); (4) Failure to report events....In addition to the errors of the above type, the gaming system should introduce mistakes of the "false target" type. These include radar, sonar and visual and ECM sightings. (Sovereign, 1983, pp. 12-13)

All of the above can lead the decision maker to an incorrect assessment of the tactical situation. By allowing the mistakes to happen, C3 is more realistically represented.

### e. Methods of Evaluation

One method is called "free" umpiring and is dependent on the experience, the judgment, and the objectivity of the game controllers. An umpire can select from among a broad range of realistic outcomes the one that is not only probable, but that also furthers the purpose of the game (McHugh, 1966, p. 1-18). The advantage is a quick and simple method of evaluation.

Rigid umpiring rules are based on data that reflect real-world interactions. Contacts, number of hits, and the amount of damage are determined by equations and computations performed manually or by computer.

Semirigid evaluation combines both free and rigid techniques. Some situations are evaluated by qualified officers and others are determined by equations.

### f. How Time is Represented

Time is a critical aspect of any wargame for two reasons.

> First, in reality, timing and speed of execution are often decisive in determining the success or failure of a military operation. Second, time management in a game very often determines the extent of activity that the game can explore. (Perla, 1966, p. 222)

When a game progresses by predetermined and constant intervals, it is a time-step game. Force movement is conducted during the time interval and at the end of the

interval, interactions are evaluated and the status of forces is updated. For example, a game may define a single move to represent an entire day's operations. The shorter the time interval, the longer the time required for play.

Another approach to time-increment moves is to vary the amounts of real time depending on the importance and intensity of activity expected during a given time span.

> For example, a pre-hostilities move may encompass ten to fifteen days of activity. The D-day move of the same game may represent just a single day. (Perla, 1990, p. 224)

The time interval for various moves may be predetermined in game design or may be defined by the game controllers during the game.

A critical event or event store game advances play from event to event.

Another method is continuous time. Player decisions may be made at any time and the orders and force attempts to execute those orders are continuous. Continuous time is closer to reality and is more likely to encourage dynamic interactions that occur in real operations. The game may be played faster, at the same rate, or slower than real time. However, when the game-time to real-time ratio is not one-to-one, there is a potential for distortion in the planning process. When the game is speeded up, planning time is reduced (uses too much game time) and when the game is slowed, decision time pressure is unrealistically reduced.

### g. *Method for Treating Chance Events*

Since chance events occur in real war, a wargame must be designed to deal with the probability that particular conditions will occur and to the variety of possible effects that will result from a given set of actions. Two ships may be adversaries. Which ship will fire first? Which ship will get the first hit? Will the first hit inflict little damage, cripple or sink the ship? What will happen to the opposing ship in the meantime? This example of a simple action has a whole set of probabilities or chance outcomes. For many events, the probabilities have been determined from war, exercises and test data. When the data is not available, best-estimate values are made by qualified experts. Wargames must attempt to duplicate this complex of elements and factors that may occur in almost infinite variety in real war (Hausrath, 1971, p. 285).

There are two types of game uncertainties: stochastic and deterministic. Stochastic uncertainties are often characterized as the "roll of the dice", have a probability distribution and use random numbers. Deterministic uncertainties have a known set of inputs which result in a unique set of outputs, and the probabilities of the occurrence is an average or expected value. Each model will usually require a combination of the two types of uncertainties and their correct application is critical.

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Because many assessments are based on chance factors, the Analyst should carefully evaluate the reliability of results by first performing a sensitivity analysis.

> Wide deviations may occur within the data from which average or best-estimate values are derived. The ranges of variation of these values, within which the results will remain valid, i.e., within which the values can vary without changing the nature of the result, are determined by sensitivity analysis....Sensitivity analysis does not correct the data or assumptions used; it does give the analyst some measure of the level of confidence that can or should be associated with derived findings or results. (Hausrath, 1971, p. 284)

### h. *Models*

As defined in Chapter I, a model can be a description of a system, a process, or a series of related events. The macro model of a wargame is a complex configuration of micro models and an explanation or description of their interrelationships. The most common micro models for wargames are weapons, logistics, command and control, intelligence, communications, physical environment, and sensors. During game play, the models can be programmed to calculate decision results.

> If the scenario sets the stage for the game, and the data base provides the information required for players to make decisions, the game's mechanics allow those decisions to be implemented and inform the players about their effects. Wargame mechanics may be considered as two interrelated systems: models and procedures. The models translate data and decisions into game events. Procedures define in game terms what players can and cannot do and why, sequence the game events to allow for accurate recreation of cause and effect, and manage the flow of information to and from players and control. (Perla, 1990, p. 214)

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All models should be documented so the User can understand the assumptions and algorithms contained within the model design.

A definition of the C3 model's function is to plan, direct, coordinate, and control assigned and attached forces to accomplish a mission. Many C3 models accomplish this function by using a combination of humans controlling the higher echelon decisions and computer generated decisions at lower levels. Command and control processes require the use of the communication model and often act on information from the intelligence and sensor models. Command and control processes normally include orders to subordinates, queries to superiors and subordinates for information, and an information flow to update superiors and subordinates.

Basic C3 models include the following entities with their attributes:

- C2 units: location; type of combat unit representative of this headquarters unit; lower echelon units under the direction of this unit; description of the echelon that the headquarters represents; its nationality and its vulnerability to various kinds of attack

- personnel: authorized quantity; on-hand quantity; fraction of the on-hand quantity available for duty; a factor representing a fatigue coefficient; and a capability factor

- communications: its own organic communications facilities; access to communications facilities; or have a combination of both

- facilities: size, vulnerability, mobility, level of capability (to determine response time), and capacity (National Defense University, 1987, p. II-4).

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These entities and their functions require the support of all the other models and need a direct or indirect interface.

### i. *Validation and Verification Considerations*

Validation is a measure of how much confidence there is on the output of a given model. There are two approaches for validation. The first approach evaluates the input data, the basic principles of the model and its assumptions. The second method collects real world information and compares it with the output of the wargame. One of the most important duties of the User and Analyst team is to determine the validity of the game's results and processes.

> The validity of a game's results can best be thought of as the extent to which those results reflect reality as opposed to the artificiality of the gaming environment. This validity depends on the accuracy of the mathematical evaluations of operational capabilities used in the models of the game, and on how well the quantity and quality of information available to the players of the game reflect the levels of information likely to be available to their real-life counterparts. (Perla, 1990, p. 236)

Assumptions and input data need to be carefully examined. The results can be no better than the validity of the data and the assumptions from which they are derived.

The User also needs to understand the quality or utility of both the macro and micro models. This is verification: is the model working as advertised. In the course of game play, are the experiences and insights the

players may gain from it determined primarily by the game's scenarios, assumptions, and mathematical combat models. or by the decisions that the players are capable of making. When the game is dominated by its mechanics instead of the decisions choices, misconceptions and errors in understanding can result. Player decisions cannot be driven from scenario mandates and constraints. An example of a player decision choice constrained by the scenario is assigning a mission to deter war in a crisis but mandating all the answers to the strategic questions. The key to creating accurate models and systems, then, lies in the ability of the design to incorporate as many of the elements important to actual decision makers as possible while simultaneously minimizing the number and effect of extraneous factors (Perla, 1990, p. 242).

In addition to reviewing the model developer's test plan and results, the users manual, the algorithm document including where they came from or how they were derived, the User can run tests and verify that the overall game model will work for their experiment.

### 4. Support System Capability Requirements

The capabilities of a wargaming support system should be considered. The system should have a wide range of capabilities including:

- Multiple simultaneous users

- Multiple interactive consoles

- File management for large data bases

- Security for file access.

- Graphic displays

- Recording and replay

This list should be considered as a minimum and additions will be dictated by the experiment plan.

## C. PREPARATION

### 1. Schedule

A final schedule of experiment activities should not be established until all aspects of conception and design have been determined. Time must be planned for writing the scenario, gathering and in-putting the data, player training pretesting, running the experiment and reserving facilities and hardware.

### 2. Players and Control Personnel

The number of players on a team and their decision making levels need to be adequate to meet the experiment/game objectives. The player roles need to be consistent with the geographic and operational scope and scale of the game. Each player needs to have a well-defined operational role and must understand their function within the group. Players in the roles of non-U.S. or threat roles may need special training or expertise. They must not only understand the technical

capabilities of their foreign weapons but also the tactical and strategic doctrine of the opposition.

Command levels above and below the team level may be assumed by the game controllers. At this stage, the players and control personnel are identified and matched to the functions to be performed to conduct the game.

Player and control personnel training and indoctrination are performed at this time.

### 3. Forms and Game Directives

The special data-recording forms and work sheets must be designed for the experiment and duplicated. The game directives, scenario, order-of-battle information and other materials used as preliminary information handouts to players need to be prepared and duplicated.

### 4. Playtest

Playtesting is the best way to validate the entire game system by verifying that all the micro models mesh together to form a workable macro model. As the word implies, playtesting combines playing the game by thoroughly testing its functions and its ability to meet its objectives (Perla, 1990, p. 242). To ensure that the game design is complete and that all data and procedures needed are available and correct, the Analyst thoroughly tries out the various alternatives and attempts to make the game fail.

> Especially important is the system's response to unusual, unexpected, or extreme decisions players may make. This

is especially important for system games, particularly those controlled by computer, in which the stabilizing influence of a human umpire is missing. The player that 'cracks the code' of the game may play the game very successfully, but the educational value of his experience and the operational insights to be obtained from his decision making may be nonexistent because he is only taking advantage of a loophole that exists in the game system but would not exist in reality. (Perla, 1990, p. 234)

This testing process enables the User to correct problems with the system, procedures, or data before the experiment begins. Preplaying also gives the game controllers an opportunity to familiarize themselves with the game mechanics and their responsibilities.

## D. EXECUTION

This is the actual game playing and data collection process. In a two-sided game, each team makes the decisions and perform actions appropriate to their mission. The movements, actions, and interactions are recorded by the computer. The game controllers have three functions. First is to monitor the actions of the teams and to enforce the rules of the game. Second is to evaluate the interactions following the methods and data of the game and the third function is to answer queries from the teams with the information and intelligence that are appropriate. The cycle for each team and controller interaction is: team decision - team action - controller monitor - controller evaluate -

controller inform. The game controllers need apply the rules in as uniform an experimental environment as possible for each game run.

It is very useful to conclude the experiment by requesting an overall assessment of the game and for specific comments about particular issues or aspects of play from the team members.

## E. ANALYSIS

Experiment data was generated in various formats, quantities and data rates. In accordance with the objectives of the game, the data generated in the play of the game will be sorted, compiled, and the results interpreted. A number of different analytical techniques may be used and were selected in the conception stage. In this step, the Analysts apply the chosen methods of data analysis to the experiment data.

## F. REPORT

There are three common report formats of which the User may request any or all. The first report is a quick look. It is written as soon as possible after the experiment and summarizes the actual conduct of the experiment as compared to the planned procedures. This report also advises as to whether the information gained will be applicable to the issues and objectives of the experiment and any possible problems anticipated in performing the data analysis.

A preliminary report can be provided no later than two weeks after experiment completion. It supplies more detail concerning the information provided in the quick look report. Benefits of the preliminary report include a preview of the format and completeness of the final report so the User can provide an opinion.

The final report includes an assessment of whether or not the objectives of the experiment were accomplished and the conclusions. It can include an appraisal of the credibility of the experiment, recommendations for follow-on analyses of the data and follow-on experiments to more fully examine the experiment and/or spin-off issues, and lessons learned concerning the experimental processes, resources used, and design and analysis techniques.

This chapter described the stages of the process for planning an experiment using wargaming. It concentrated on the experiment design steps that are unique to wargaming: designing the scenario, providing the data base, and setting up the software program. It is followed by an example of a C3 experiment which was planned to evaluate a decision aid. A description of this experiment provides an opportunity for the reader to understand the application of the principles given in this chapter.

# V. EXAMPLE EXPERIMENT

This chapter's intent is first to provide the reader with an example of an actual C3 experiment by summarizing the report into the following stages: conception, design, preparation/execution, analysis and report. Then a list of evaluation questions and answers is given for appraising the example experiment plan. Although very little information concerning the wargame is provided in the report, a list of questions for a wargame critique is also provided.

This C3 experiment investigates the effects of introducing a decision aid into a headquarters, and was conducted for the Defense Communications Agency (DCA) and the Naval Ocean Systems Center (NOSC) by ALPHATECH, Inc. The objective of the experiment was to learn how the Naval-Based Replanning System (N-KRS), a decision aid for planning Naval air strikes from aircraft carriers against land targets, can best support the strike planning process. The experiment used the tactical naval warfare simulation designated Research, Evaluation, and System Analysis (RESA) and which is located at the wargaming facility at NOSC.

The Headquarters Effectiveness Assessment Tool (HEAT) was applied in this experiment to validate defensible conclusions. The HEAT measurement tool consists of a set of variables (effectiveness measures) and a rigorous set of methods and

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procedures for applying the measures to experiments and for analyzing the results. HEAT measures fall into three broad categories; process, performance, and effectiveness. The measures are based on a theory of headquarters decision making operating in the following cycle: gathering information, assessing the situation, generating decision options, predicting the outcomes of each option, selecting a response, executing the response, monitoring its outcome and then repeating. The HEAT methodology was originally developed for DCA eight years ago to understand the headquarters planning process. The experiment described here extended the use of HEAT to examine the decision making issues associated with the introduction of a decision aid to support planning in a headquarters environment (ALPHATECH, Inc., 1989, pp. 1-2). This chapter is a summary of the experimental report prepared by ALPHATECH, Inc. The information presented is typical of the data available after an experiment.

## A. CONCEPTION

Recognition of and a statement of the problem is the first step. A detailed statement of the issues to be investigated in the experiment is written.

### 1. Navy Air Strike Planning Problem

The purpose of Navy air strike planning is to achieve a mission goal while satisfying a number of resource constraints. Tradeoffs exist between weapon effectiveness,

weapon availability, aircraft capability, aircraft availability, fuel requirements, and other factors. The air strike planner may receive guidance from higher authority on the target priorities. In the experiment, the players were given a desired probability of a kill (Pk) for the targets to indicate the priority of the target, with a higher Pk indicating a higher priority. This is an example of an aspect of the experiment design which did not follow reality.

> A typical planning process (as observed in the experiment) starts by considering the nature of the target and the desired Pk, and calculating the bombs required to achieve that Pk (weaponeering). The aircraft needed/available to transport those bombs is then considered, and fuel requirements for the bombing mission are calculated. The aircraft needed for SAM suppression, fighter escort, and jamming missions are considered, and total fuel requirements are calculated. If the total fuel needed exceeds the fuel available, then the planning process recycles, with changes being made until the plan is satisfactory. Planning is not necessarily done in this sequence, however. The planning process can start with any aspect of the strike as long as all of the relevant factors are eventually considered. (ALPHATECH, Inc., 1989, pp. 4-5).

A number of factors in the air strike planning process were not included in the experiment. Examples are weather, navigation overflight restrictions and launch sequencing.

## 2. Navy Knowledge-based Replanning System (N-KRS)

The N-KRS decision aid was produced by NOSC specifically for Naval air strikes and was based on the KRS strike planning decision aid developed by the Air Force. The

decision aid checks for consistency in air strike plans and tracks resource availability and resource use.

> N-KRS allows the planner to specify the goals of an air strike and then suggests a resource allocation to meet those goals within the constraints of the resources available. The user interface is in the form of a "template" with 9 primary "slots." The values assigned to these slots constitute the strike plan. The user may specify values for any number of the 9 slots. N-KRS can function in a fully automated mode, in which the user specifies only the target for the strike and N-KRS fills in all of the remaining slot values based on available resources and a knowledge base of planning rules. It can also function in a fully interactive mode, in which the user specifies values for all 9 slots, and the decision aid merely verifies that the plan is consistent and does not violate resource constraints. (ALPHATECH, Inc., 1989, p. 9)

N-KRS recognizes a number of different mission types. The relevant types for the experiment were Power Projection Air (PPA) missions (bombing missions), SAM Suppression missions, Air Escort missions, electronic countermeasures (ECM), and refueling. The following slots in the N-KRS user interface were used: target, Pk, ordnance, aircraft, AC number, carrier, unit (squadron), time of launch and time over target.

### 3. Experiment Objectives

The experiment had three primary objectives:

1. Evaluate the value of the N-KRS decision aid for Naval air strike planning. Specific relevant questions are:

(a) Does the N-KRS have a measurable effect on air strike outcomes?;

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(b) How does the N-KRS assist the air strike planner? - reduce workload, - reduce time, - reduce errors, - allow more option consideration, - allow more recent information incorporation.

2. Demonstrate the N-KRS decision aid to experienced air strike planners and obtain feedback on potential applications and areas for improvement.

3. Apply and improve the HEAT methodology for collecting observational data on a commander's decision making processes and linking process measures to outcome measures. Add to database of results within the HEAT framework. (ALPHATECH, Inc., 1989, p. 2)

The objectives need to directly relate to the issues of the experiment.

## B. DESIGN

### 1. Overview

The objective of the experiment was to compare air strike planning with and without the N-KRS to learn how the decision aid can best support air strike planning. In the experiment, four players prepared air strike plans with and without N-KRS, and their strike plans were simulated using the RESA wargame. Data on aircraft lost during the strike and damage to the targets were generated by RESA and provided to the subjects for use in planning subsequent strikes (ALPHATECH, Inc., 1989, p. 12).

### 2. Experiment Conditions

There were two major factors in the experiment: (1) the presence or absence of the N-KRS decision aid. Each factor had two levels: the difficulty of the scenario - easy

or hard. The design was a two-by-two factorial with four conditions; each player participated in all four conditions. In order to separate learning effects over time from the effect of using the decision aid, two of the players began the experiment in the manual condition and two began by using the decision aid (ALPHATECH, Inc., 1989, p. 12).

For the easy scenario, initial planning was based on the player's assessment of the resources needed for the mission. After the simulation was completed, the player planned a second wave and had to take into account battle damage assessment and any losses of aircraft due to an enemy counterattack before the second launch. The difficult scenario was the same; except in planning the second attack, the player had to consider that the enemy had moved a number of its aircraft away from the target base. Also, the enemy counterattack on the carrier group used more resources than in the easy scenario. Additionally, the players planned a third strike that required them to assess the aircraft available from the first strike (taking losses into account) and the battle damage from the second strike. The third strike was not played out in RESA.

Players in the experiment planned an air strike against three enemy air bases, using the resources of three Navy aircraft carriers. The mission was to destroy the enemy aircraft parked on ramps at the bases and to destroy aviation fuel stores at each base. At the beginning of each session,

the players were given background briefing materials that listed all of the assets available for the strike, the enemy order of battle at each of the targeted bases (intel), and the desired probability of kill (Pk) for each target. Their assets included five types of aircraft and three types of weapons. The briefing materials instructed the subjects to plan the strike in two waves, with the first wave hitting two specified bases, and the second wave hitting the third base together with a possible restrike of the lesser damaged base from the first wave (ALPHATECH, Inc., 1989, p. 4).

### 3. Hypotheses

The major independent variables are the presence of the decision aid and the difficulty of the planning task. The dependent variables were divided into process measures and outcome measures. The process measures are situation assessment accuracy, planning errors, information sought from intel, time to complete plan, workload, and outcome prediction accuracy. The outcome measure is the success of the air strike. The goal of the analysis was to understand the effect of the independent variables on outcomes by analyzing their effects on the processes underlying those outcomes (ALPHATECH, Inc., 1989, p. 19).

The following hypotheses were tested in the experiment:

- The decision aid will reduce the time needed to plan or replan an air strike.

- Commanders will take advantage of the reduction in the time needed to plan to seek more current information about their own or the enemy's situation.

- In the more difficult planning condition, time-to-plan will be longer, and the commander's subjective workload assessment will be higher.

- The decision aid will reduce the commander's subjective workload during planning.

- Commanders will show more proactive information seeking under conditions of lower subjective workload.

- Proactive information seeking will lead to more accurate enemy situation assessment.

- More accurate enemy situation assessment will lead to more accurate evaluation of the expected effectiveness of the plan (option) selected. The accuracy of situation assessment and effectiveness evaluation will contribute to achievement of the strike goal.

- The use of the decision aid will result in a plan with greater internal consistency (fewer errors made during planning).

- Fewer planning errors will result in better strike outcomes (achievement of strike goal).

- The effect of the decision aid will be greater in the difficult planning condition. (ALPHATECH, Inc., 1989, pp. 19-20.

## 4. Scenarios

In the experiment, all of the scenarios involved a two-wave air strike against three enemy bases. The overall goal of the strikes was to neutralize the air threat at these bases. The mission was the same for all four sessions, and was provided to each player before each session in written

briefs. Three available Navy aircraft carriers were located approximately 600 miles from the enemy bases. The enemy bases had air defenses in all scenarios, and Blue usually lost some aircraft in each wave. The wargame did not support Blue maneuvering to avoid the enemy air defenses, but Blue could send a SAM suppression mission as a part of each strike.

### 5. Amount of Intelligence

Initial intelligence information provided the enemy order of battle at each of the targeted bases. Intelligence reports gave battle damage assessment information within 15 minutes after each strike (another falsehood). The subjects could request additional intelligence reports from "national sensors" and did get them. The HEAT observer noted the time the commander made the request and instructed the RESA controller to provide the information after a delay of 10-15 minutes (another falsehood). The requested reports provided additional battle damage assessments and estimates of enemy aircraft remaining at each base. The intelligence reports were based on ground truth but were not totally accurate.

### 6. How Time is Represented

Each experiment sessions lasted approximately three hours and twenty minutes. First, the player was given an opportunity to develop or change an initial plan at a time rate of 1-to-1. The strike was launched when the plan was completed, and RESA was accelerated to run at 6-to-1 rate.

After the launch, the planes took about 30 minutes (clock time) to reach their targets. Battle damage and attrition information was available in 15 minutes. The player was given an opportunity to replan based on the new information, and RESA was slowed to run at 1-to-1. After the second launch, the game resumed a 6-to-1 rate, and RESA played the air strike to produce a final set of outcome data.

## C.   PREPARATION\EXECUTION

### 1.   Players and Control Personnel

Four experienced air strike planners participated as players. Two of the players came from the carrier Carl Vinson and had been active in air strike planning. The other two players were experienced but not currently assigned to air strike planning duties. The following describes the personnel set for the decision aid condition followed by the non-decision aid condition.

The Blue RESA operator and the Controller/enemy commander were RESA lab staff. The N-KRS operator was a NOSC staff member involved in developing the decision aid. As replanning occurred, a strike file was created off-line for entry into RESA (this allowed an interface between N-KRS and RESA to occur with a negligible time delay); the operator handling this function was provided by NOSC. The Blue player was positioned so that he could see the RESA displays and talk with both the RESA operator and the N-KRS operator. The HEAT observer was able to record the interactions that occurred and to see the RESA and N-KRS displays.

In the non-decision aid condition, the player provided instructions for the creation of the off-line RESA strike file. In this condition, the player was assisted by an individual who did weaponeering calculations to compute

probabilities of kill, and kept tallies of resources available (ALPHATECH, Inc., 1989, p. 15).

## 2. Data Collection

Three types of data were collected during the experiment:

- data collected by the HEAT observer recording the interaction of the strike commander with the N-KRS operator in the decision aid condition and the planning assistant in the manual condition;

- questionnaires completed by the players;

- and strike outcome data from the RESA simulation.

Data collected by the HEAT observer included:

- time that any information was received;

- all actions taken to obtain additional information, including the time of the action, the type of information requested and received, and the time of arrival of the requested information;

- all comments by the player about the certainty of incoming information;

- for each piece of new information received, the time replanning was initiated (if ever) in order to adjust the plan for new information, and the time that replanning was completed;

- the time and nature of all interactions regarding changes to be made to the plan between the player and the N-KRS operator or the planning assistant;

- all options for the air strike plan discussed by the player;

- all verbal instructions given by the player to the RESA interface operator;

- all comments by the player about the possible outcomes of any air strike planning options being considered;

- all comments by the player about the plan's likelihood of success;

- all comments by the player about best/worst case scenarios for the plan's outcomes;

- planning errors noted and corrected (or not corrected), including the time the error was noted, the type of error, and the time the correction was initiated and completed;

- and all comments concerning the decision aid, including ease or difficulty of use, features asked for that were not provided, and errors or confusion on the players part about the capabilities of the decision aid (ALPHATECH, Inc., 1989, p. 17).

The players completed a set of questionnaires following the launch of each strike. The first was a workload questionnaire. The second was to assess situation assessment accuracy including estimates of the expected number of targets at each base (aircraft) and the confidence levels in those estimates. The third questionnaire assessed option evaluation accuracy and included estimates of the number or percentage of targets expected to be destroyed at each base by the strike, estimates of the number of Blue assets (planes) expected to be lost and confidence levels for both estimates.

The data available from RESA was the outcome of each air strike and on the enemy and friendly aircraft lost during the strike. Data also included the movement of enemy aircraft during the difficult scenarios which was used to calculate the number of enemy aircraft remaining at the bases at the time of the strike.

## D. ANALYSIS

The following will serve as examples of the analysis. The report also included analysis of the accuracy of estimated strike effectiveness, planning errors, strike effectiveness and situation assessment accuracy.

### 1. Time Needed to Prepare Strike Plan

One of the primary hypothesis is that the decision aid will save time for the air strike planner. The mean time taken to prepare strike plans (in minutes) with and without N-KRS for the easy and difficult experiment conditions were computed. The planning times did not include time spent adjusting available aircraft counts for aircraft lost in strikes or destroyed when carriers were attacked. An Analysis of Variance (ANOVA) was also determined for the planning time.

> Overall, N-KRS did reduce the time needed to produce a strike plan; in the Analysis of Variance (ANOVA) for planning time, the main effect of the decision aid was significant at the .10 level. However, the effect of the decision aid on planning time was concentrated in the first wave of the strike. There was a significant difference in the time taken to plan the first wave of the strike with and without the decision aid ($p<.10$). In contrast, the time taken to plan the second wave of the strike was similar with and without the decision aid in both the easy and difficult conditions. (ALPHATECH, Inc., 1989, p. 21)

The analysis included studying whether the players allocated their planning time to different activities when using N-KRS. The HEAT decision making process provided a framework for analyzing the planning and decision making

activities affected by using N-KRS. In the experiment, the functions most relevant to air strike planning are monitoring, situation assessment, option generation and evaluation. For the monitoring function, the analysts studied the frequency of requests for additional intelligence information. All of the interactions between the player and the N-KRS operator or the planning assistant were recorded by the HEAT observer. For the functions of situation assessment and option generation, the recorded interactions were grouped into four decision making activities. These activities were: enemy situation assessment, option exploration, option evaluation, and commands (option selection). A table showing the distribution was generated to show the mean percentages (the percentages of interactions falling into each of the four categories for each experiment session and these percentages were averaged across subjects and across the easy/difficult conditions). An example of the results was the total number of interactions observed in the manual planning condition was much greater (611) than in the decision aid condition (360), indicating that more time was spent planning in the manual condition.

## 2. Accuracy of Enemy Situation Assessment

Before each wave of the strike was launched, the players were asked to estimate how many aircraft they believed would be at the enemy bases when the strike occurred. The accuracy of enemy situation assessment was measured by the absolute value of deviation between the estimates

given by the subjects and the ground truth about the number of enemy aircraft at each base, where a smaller deviation indicates a more accurate estimate....The mean deviation was slightly smaller without the decision aid (a mean error of 38.4 aircraft without the aid versus 51.8 aircraft with the aid) and the difference is not statistically significant. The only significant difference in enemy situation assessment accuracy was between the easy and difficult conditions. (ALPHATECH, Inc., 1989, p. 29)

## E. REPORT

### 1. Organization

The experiment report contained six chapters titled: Introduction, Navy Air Strike Planning, The N-KRS Decision Aid, Experiment Concept and Design, Experiment Results, Implications for Improving N-KRS and HEAT and Conclusions. It contained charts, figures, tables and diagrams. The appendix included subject briefing materials, questionnaires and data collection forms and a correlation matrix. The Experiment Concept and Design chapter was further organized into the following subchapters:

- Experiment Overview;

- Experiment Conditions;

- Scenarios;

- Intel Information;

- Experiment Set-up and Personnel;

- Subjects;

- and Data Collection.

## 2. Results

The report overview of the results is summarized as follows:

> The experiment results suggest that the strike planners in the experiment were able to develop equally effective plans with and without the N-KRS aid. The major advantage of the aid was that it saved time and prevented errors....As expected, the use of the N-KRS decision aid was negatively related to planning time, subjective workload, and planning time, subjective workload, and planning errors. Contrary to expectation, it had little effect on information seeking, and little effect on the accuracy of planner's assessment of the enemy situation....Few of the process measures in the experiment had any relationship to the overall effectiveness of the strike, as measured by the number of enemy aircraft destroyed. (ALPHATECH, Inc., 1989, pp. 37-38)

The report provided a figure which summarized the correlations that were found between the variables in the experiment. The figure used solid lines to indicate Pearson correlations with a significance level (two-sided) of at least $p<.15$. Dotted lines were used to show expected relationships that the data did not support. A full correlation matrix was available in the report appendix.

## 3. Conclusions

The following paragraph contains excerpts from the report's summary of conclusions.

> Subjects in the experiment were able to prepare equally feasible and effective air strike plans with and without the N-KRS decision aid, but they prepared these plans more quickly and with fewer errors when N-KRS was used....Use of the N-KRS aid altered the process by which the subjects produced their strike plans....In interpreting these results, it is important to note that the planners in the

experiment were probably not yet as thoroughly familiar
with the N-KRS as they would be after weeks or months of
experience in using it....Subjects' estimates of the
expected effectiveness of the strike were less accurate
when they used N-KRS....Subjects in the experiment often
commented that they would have liked N-KRS to show then in
a compact, summary format what weapons and aircraft were
available for the entire task force. (AlPHATECH, 1989,
pp. 45-46)

## F. CRITIQUE

There must be a clear connection between the objective,

alternative, and hypotheses. The experiment design and

analytical plan continue this link. Finally, the conclusions

should be about the alternatives and be based on the positive

or negative analysis results concerning the hypothesis. The

experiment report needs to make all these linkages apparent.

The experiment report prepared by ALPHATECH, Inc. is a good

example. The following questions can be used effectively to

evaluate C3 experiments. The author has included a response

pertaining to the N-KRS experiment.

The objectives need to be clear and relevant, the

assumptions reasonable, and the hypotheses germane.

- Was a decision identified which requires answering now?
  Yes. The N-KRS is a working decision aid.

- Was the real issue directly addressed? Yes. The real
  issue was how the N-KRS could best support the strike
  planning process.

- What question was the analysis designed to answer? The
  primary question was: Does the N-KRS have a measurable
  effect on the air strike outcomes? The secondary question
  was: How does the N-KRS assist the air strike planner?

- Could the issue be settled by an answer to the question? Yes if both questions are answered because the second question concerns the process.

The experimental design should find a balance between being comprehensive and executable. The measures need to be discriminatory and quantifiable; and the data replicable.

- Were all major factors effecting the question included? Yes, the factors were the presence or absence of the N-KRS decision aid.

- Were sufficient levels of the factors identified? Yes, there were two levels for the difficulty of the scenario: easy and hard.

- Do the scenarios match the issue and the question? Yes.

- Is the scope of the system being considered adequate? Yes.

- Were forces and weapons correctly included? Yes.

- Does the operational concept reflect real doctrine and tactics? Yes, except for using the Pk factor in strike planning to indicate target priority and the intel availability.

- Are standard operating procedures followed? The report did not contain this information.

- Was the experiment adequately trained and staffed? The background and experience level was appropriate for the participants. The report only says that player training in the use of the decision aid was limited.

- Were the supporting models matched in level with the issue? No information given.

- Were supporting models credible? The only model described in the report was the intel model and it was not credible.

- Were high level measures used (MOFE and MOE rather than MOP)? No.

- Do the measures succinctly answer the question? Yes.

- Were both performance and vulnerability considered? Vulnerability was not considered.

- Was a trial run performed? Information not given.

- Were extraneous factors like learning controlled? **Yes,** two players began the experiment in the manual condition and two began by using the decision aid.

- Were instruments adequate to measure variables? Yes and a variety of data was collected.

The analysis must be correct and unbiased. The conclusions supportable.

- Was the significance of each factor established? Yes.

- Did the analysis use standard procedures such as ANOVA? Yes.

- Were the conclusions based on the results? Yes.

The experiment report does not provide information concerning RESA, the wargame. The report does not contain any information on the game data base, the method of gaming evaluation, the method for treating chance events and RESA validation considerations.

In addition to evaluating the experiment plan and execution, the wargame itself needs to be examined. Appropriate questions for wargame analysis include the following list drawn from the appendix of The Art of Wargaming by Perla.

These questions concern player preparation for participation in the wargame.

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- What information was provided to participants prior to their arrival?

- How are game objectives defined in preliminary briefings?

- What information is briefed to participants before play begins?

- How and to what level of detail is the scenario described? What is it?

It is important to have a widespread view and understanding of the structure and style of the wargame.

- What is the overall game structure and style?

- Who are the players? Is there a team structure? From what commands to team members and leaders come? What are the names and real-world jobs of the principal players? How many sides are there in the game (one, two, or many)? What are the decision levels of the players, and how do they communicate? What are the responsibilities and limitations of the players, and how do these correspond to their roles?

- What are the roles of control? How are command levels above and below the players represented? How do players and controllers/umpires communicate? What are controller/umpire responsibilities, powers, limitations?

- What is the formal analysis plan?

Knowledge concerning the game execution is important in critiquing a wargame.

- What data and displays are available to the players?

- During the course of play, what decisions are made by the players, and which are left up to others (control, umpires)? Are players' questions focused on what they should do, what they can do, what they must do, what they will do, or how can they do?

- How are game events defined? What do control and the umpires not tell the players?

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- How are events sequenced? What defines an activity? How is game time controlled relative to real time?

- How does battle-damage assessment (BDA) or event resolution work? Who does BDA? What techniques, models, data do they use and how?

As mentioned in Chapter III, the human element can be a benefit or weakness of the wargame.

- What are player's feelings about their roles and ability to influence events? What do the players see as the good points and the problems of the process? What special insights and ideas did the players bring to the game, and how has the play of the game affected them?

- What are the attitudes of the controllers and umpires? How do they feel about their role, and how well are they carrying it out? Is there any source of disagreement?

This list is not comprehensive but will give the reader a foundation for forming questions unique to an experiment.

This chapter summarizes a real C3 experiment that applied wargaming to test the hypotheses and uses the principles from the previous chapters to critique the example.

## VI. SUMMARY

Naval military professionals need to be able to understand not only what wargaming <u>can</u> do, but also what it <u>cannot</u> do. This thesis provides information about wargaming to users who will apply conclusions derived from wargaming data in decision making and users of wargaming as a research tool for hypotheses testing. Game users need to understand and be able to ask appropriate questions concerning the process of using a wargame as an experiment tool.

The first chapter explains that wargame use in general is rising due its ability to assist in evaluating combat capabilities, system improvements and new technology that add to the increasing complexity of warfare. Wargaming can effectively be used for identifying requirements and designing, developing, acquiring, training for and using major C3 systems. Wargaming is particularly suited to exploring C3 issues because the game includes humans in decision making. However, wargaming is not a perfect image of reality and is as complex as the issues explored with it. Game data users need to be aware of wargame limitations and hazardous wargame issues. The goals of this thesis were (1) to enable the reader to ask intelligent questions concerning a wargame experiment before applying conclusions generated from wargame

data, and (2) to enable anyone desiring to use a wargame as an experimental tool to have a guide for the experiment plan.

The second chapter ensures that the reader understands that a wargame employs human beings as decision makers and a simulation uses programmed rules to generate machine decisions. A wargame is not real, not duplicable and not useful for predicting future outcomes. The best use of a game is to investigate processes. Some general wargame applications include: to explore not rigorously quantifiable problems, to decompose complex problems, to uncover new aspects of a problem, to test operational plans, to assist in the planning process and to focus on human behavior. Applications exploring aspects specific to C3 are command roles, decision hypothesis formation, filtering and interpretation of information and information categories used in making requests. Types of wargames are defined by: technique choice for applying rules (rigid or free) and opponent force knowledge (open or closed), the purpose of the game (educational, operational planning or research), and geographic scope combined with the level of decision making (global/strategic, theater/operational or local/tactical). A list of common features unique to wargames includes: a wargame simulates an actual or predicted real-life military operation involving a clash of opposing forces; usually represents at least two forces and provides a means for their employment; follows accepted military rules and procedures;

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and provides a means for identifying and applying the firepower of units and weapons. The basic requirements for any wargame are qualified personnel, appropriate facilities and equipment, a game manual which provides the rules, data and procedures to be applied during the game, and a scenario statement of the situation.

To avoid a reader misapplication of wargame data, the nature of wargaming, its limitations and potential hazards were discussed. The conflict between balancing reality and complexity, and the artificialities such as too much high quality information provided by communication circuits that work too well, and data validation problems contribute to wargame limitations. To facilitate game playability, the following falsehoods are acceptable: assume that the right variables have been selected for the experiment, that a "matched set" relationship exists between the algorithm and data base for the game, that the study of war can approximate an exact science, that the game uses current tactics and doctrine, and that a wargame is repeatable. Wargaming considerations that are hazardous to the accurate results of game play are poor documentation, uncooperative human players and misplaced advocacy.

Chapter IV described a broad outline of and guidelines for designing a wargame experiment. Experiment credibility hinges on the approach used to plan the experiment. A clearly defined approach is critical to ensure that the final product

is appropriate for the accurate analysis of the experiment results. The first step of the conception stage includes the clear statement of the problem issues, objectives and response variables. Identifying the experiment alternatives and assumptions, writing the hypothesis, and selecting the independent and dependent variables are also included in the first step. The design stage matches the experiment objectives with available simulation models, analysis tools, data requirements, measures, hardware requirements and security considerations. The detailed experiment plan should have complete traceability to the originating problem and issues. The design steps unique to wargaming are: composing the scenario to allow player decision flexibility, tailoring the data base to the game objectives and selecting the software. When selecting the game, the game objectives, scope and level, number of sides, amount of intelligence, methods of evaluation, representation of time, method of treating chance events, available models, game validation and verification, and support system requirements all need to be evaluated so the best possible matching of the game capabilities and experiment requirements occurs. Experiment preparation consists of establishing a schedule, selecting players and control personnel, creating forms and game directives and playtesting to validate the game system. During execution, the game is played and data collected. Analysis of the data precedes writing the report.

The last chapter applies the principles from the previous chapters to critique an example of an actual C3 experiment. It summarized the N-KRS experiment report into the stages of conception, design, preparation/execution, analysis and report. An appraisal of the example experiment design, based on the information contained in the report, was provided by listing evaluation questions and answers. Very little information about the wargame was given in the report so only questions for a wargame critique was provided.

The author has provided a summary on wargaming and an implementation guide for experimental wargaming. Although wargaming is an art, the reader is now better prepared to identify and avoid circumstances of wargame abuse and data misinterpretation.

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