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DOCTRINE: PERCEPTION AND RESPONSE.(U)

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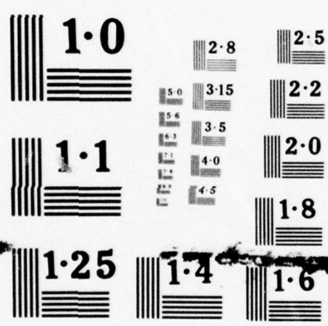

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Military resource management has reached a critical point where many of the analytic tools used in the management process have reached levels of complexity which leave most analysts and decision-makers unable to understand and employ them comfortably. A new technique for controlling the internal operation of one such tool, the Concepts Evaluation Model (CEM), the U.S. Army's primary theater-level combat simulation, promises to make the CEM operation more visible and flexible. A tactician/war game link is developed using a specialized vocabulary having precise program counterparts. The tactician develops a set of (OVER)

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contingency-like plans from which the war game evaluates, selects, and executes coordinated actions consistent with the tactician's doctrine.

DOCTRINE: PERCEPTION AND RESPONSE

BY

DAVID K. PEARCE, MAJ, USA

JUNE 1978

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EXECUTIVE SUMMARY

The past thirty years have witnessed the burgeoning of resource management techniques. The sophistication of these new techniques has created a complexity spiral. More complex questions promote the development of more complex techniques, and more complex techniques invite more complex questions. The military services are sensitive to this spiral because it threatens their ability to compete for--and control--the resources needed to accomplish their primary functions.

A subtle crisis has developed within the military studies and analysis arena and more importantly, among the decision makers for whom the analyses are done. This crisis is brought on by the growing obscurity of these analytic techniques. A declining number of analysts and decision makers understand these tools well enough to use them appropriately. Since problems are defined in terms of the analytic tools available for their solution, the increased sophistication and complexity of modern resource management techniques has increased the potential for concentrating on the wrong problems. This, in turn, leads to production of misleading results, and ultimately to ineffective resource management.

The computer-based war game is a primary example of this new technology. For the U.S. Army in particular, the computer-based war game has become an indispensible ingredient in a variety of key resource management analyses. As the complexity of the questions demanding answers has mounted, a concurrent increase in war gaming complexity has occurred.

Today, the Army is confronted with several significant problems. The extensive use of these computer-based war games makes the following types of problems of particular importance to the Army:

Complexity problems:

- Fewer people than in the past understand the war game tools used to study problems.

- Fewer people than in the past are able to define the problems to be studied because problem definition requires an understanding of the analytic tools available.

- Fewer analysts and decision makers than in the past are aware of the limitations that ought to be kept in mind if war games are to be used intelligently.

Technology problems:

- Despite the size and marked increase in sophistication when compared with earlier computer-based war games, the modern versions cannot portray a variety of combat actions that are of vital interest to Army planners.

- Existing approaches to expanding model capabilities require increases in the model size or computer running time. Many computer facilities have already reached their upper bounds in capacity, making further expansions infeasible.

- Specific problems are often forced to fit within a general model context, at the expense of ignoring unique requirements that cannot be treated directly.

Cost problems:

- Modern computer war games take millions of dollars and years to build.

- Modifications and additions to existing war gaming models can require months of design, programming, and testing effort, and are often possible only if older capabilities are excised.

- Modern computer-based war games are expensive to operate. A full-time staff of programmers, data experts, and analysts is required for larger models. Computer running times are lengthy, and especially significant when a study requires a large number of model runs.

The Concepts Evaluation Model (CEM)

In response to the growing concern for the capabilities, limitations, uses (and abuses) of these computer-based war games, the U.S. Army organized a research project to study the Army's largest and most important theater-level war gaming model, the Concepts Evaluation Model (CEM). This project was charged with incorporating specific enhancements to the CEM capabilities, improving the model's efficiency, and exploring new model technology.

During the course of this project a significant new technique was discovered for controlling the units and resources in the CEM. The control technique was a marked departure from the traditional means of control in theater-level war games, and promised to meet directly many of the

the problems for which the research project had been initiated.

Before the new control technique could be developed, however, the Army shifted resources from the CEM research group to a priority study called WARRAMP, for WARtime Requirements for Ammunition, Material, and Personnel. WARRAMP was a methodology development effort designed to provide an automated resource management system consisting of a hierarchy of interrelated models. WARRAMP was to provide, among other things, a new version of the CEM. This new version was to be at the top of the system of interrelated models. In addition, this new version was to be a much needed replacement for the version of CEM in use by a variety of other studies. Although many improvements were made, the promising new control technique was not incorporated. The new version, therefore, while an improvement in terms of such things as speed of operation and size, is not the powerful analytic tool that could have been constructed.

The Control Mechanism

The new control technique envisioned for the CEM rests on the recognition that doctrine provides its users with a framework for perceiving and responding to the combat environment. In the design presented in this paper, a special vocabulary is designed around these two major functions, and these vocabulary elements can be used to translate any doctrine into a standard form. Each element in the vocabulary has a precisely defined counterpart in the computer war game. Use of a term activates the model function. Using the vocabulary to translate his doctrinal perceptions and responses into a set of tactical concepts, the tactician is able to drive the actions in the computer war game.

In recording his doctrinal perceptions and responses the tactician would generate a set of contingency-like plans. These plans would then be selected and applied by the war game when the simulated conditions were appropriate for their application. Since the tactician would be able to communicate his ideas of when each plan was to be applied, unparalleled control would be achieved.

This control system has several attributes which make it uniquely suited to attacking the Army war gaming problems. These attributes, and the problems to which they primarily apply, are:

Flexibility. A model equipped with the system will depend on the tactician's plan for the logic to be used in coordinating the simulated forces and resources. The model can be applied to a variety of problems simply by altering the plans.

Economy. Since major revisions in model performance could be accomplished by changing the set of plans used to direct the action, the high costs of computer program redesign and alteration could be avoided. In addition, the technology employed in the system circumvents the problems of program size and computer storage requirements, thereby making it possible to increase greatly a model's capabilities without an increase in the computer facility resources.

Observability. The system is far more observable than conventional model logic. The language approach enables a large increase in the number of people able to participate in the study process because the relevant aspects of the computer model are readily available. This leads to improved analysis of problems, wider critical review, and more knowledgeable decision makers.

The tactician/war game linkage permits the tactician to tailor the model to various requirements, to explore new ways of employing forces and resources, and to evaluate the impact of his planning. The speed, accuracy, and detail made possible by the computer makes the linkage a significant improvement over conventional types of manual or automated war games. Further, the approach is simple, closely parallels the actual process of command and control, and is well within the range of modeling technology.

Abstract of

DOCTRINE: PERCEPTION AND RESPONSE

The U.S. Army uses computer-based theater-level war games extensively in studying the increasingly complex questions of resource management facing it today. Consequently these war games themselves have become increasingly complex and several current problems have resulted. The purpose of this paper is to document a new technique for controlling the theater-level war game which promises to attack directly these problems. The technique uses a special tactician/computer interface system which enables the tactician to control the units and resources according to the perceptions and responses inherent in his doctrine. While the work is primarily concerned with the U.S. Army's Concepts Evaluation Model (CEM), its largest and most important theater-level war game, the concepts and processes have application in the areas of modeling technology, training, and doctrine development. The paper explores the background issues which have led to the Army's current war games uses, develops the technique for controlling the units and resources proposed for the CEM, and explores other applications of the technique. From this work it is clear that the technique offers significant promise. The Army's extensive use of the computer-based war game is likely to continue, despite the attendent problems. New technology is needed to minimize the impact of these problems, and the system described here is a major step in the right direction.

TABLE OF CONTENTS

CHAPTER PAGE

LIST OF TABLES

LIST OF ILLUSTRATIONS

FIGURE PAGE

DOCTRINE: PERCEPTION AND RESPONSE

CHAPTER I

INTRODUCTION

Resource management is a fundamental function of modern government. Regardless of the political underpinnings, resource management is the key to prolonged success. This is also the case for the component parts that make up the government. Every agency is charged with the effective application of the resources supplied to it. Each one is concerned, therefore, with internal resource management. In addition, each of these agencies is in earnest competition with all the others for a larger share of the government's budget. Thus, each must be concerned with external resource management as well.

The two types of resource management operate together. Success in one can lead to success in the other. Effective internal management can be a key factor in an agency's competitive position. Likewise, successful competition for a larger share of the budget brings more resources for the internal structure to manage. The opposite is also true, however, and failure in either arena can lead to failure of the agency, or impairment of its primary function.

The simple truths of the resource management imperative have sired a large number of tools and techniques to assist the decision maker. This number has increased many fold since World War II. The burgeoning arts of operations research and systems analysis have revolutionized the nature and intensity of resource competition and internal management. Furthermore, the computer has had a tremendous impact by providing the requisite speed, accuracy and efficiency to make expansions of resource management techniques available for virtually any size of agency.

A natural outgrowth of the increases in the size, sophistication, and numbers of problems and the tools available to solve them has been what might be called a "complexity spiral." More complex questions foster the development of more complex problem solving techniques. Conversely, increases in the sophistication of an analytic tool can force the question poser to reformulate his questions.

The military services, both as users of resources and as competitors for them, rely on a wide variety of these new tools to provide the necessary control and insight. While the U.S. Services must effectively manage and compete for resources, they operate with the added feature that their budgets represent in the neighborhood of 58% of the total "discretionary" portion of the federal budget.[1] While this is healthy from the standpoint of supervision and scrutiny, it is clear that they must be able to justify their budgets and to use their resources wisely. Weak budget proposals and a record of indifferent management can open the way for the other competitors to claim a larger piece of this discretionary fund pool.

Unique among the various elements of the government, the services are faced with peculiar complexities and limitations. Many of the resource management tools used successfully by other elements are not well suited to the problems encountered by the military. Military experience in war is so infrequent and costly that the uncertainties and complexities must be studied vicariously. Preparing for a future conflict is a long and tenuous process.

War games have traditionally provided military planners with a means of studying the unique requirements of military resource management. The computer based war games introduced into the services in the past 20 years have been carrying on this tradition, and today they form the backbone of most major service decisionmaking process.

The acceptance of these automated war games and the essential roles they now play are the result of several factors. First of all, and unlike the majority of the new tools developed after WWII, computer-based games had roots in a traditional military activity. Many of the leaders and staff analysts who first used them had been exposed to manual war games prior to WWII. The other tools, however, possessed few such links with previous military experience. Queuing theory and linear programming, for example, had no familiar predecessors.

War games had also provided a major way for systematically examining problems that were too complex to be handled in other ways. The computer-based versions held the same promise. A second factor, then, is that substitutes for war games do not exist. This remains true despite the fact that the real world processes are complex, and that the war game at its best is still an imperfect window on reality. It continues to give the planner and analyst the only viable substitute for unaided judgment and guesswork.

Computer-based war games are a mixed blessing. On the positive side they offer a way for the services to continue to compete for and manage resources. This is significant at a time when the military staffs are shrinking, and the staffs charged with overseeing them are increasing, in both size and sophistication. Also on the positive side is the fact that the large war games made feasible by the computer can provide insights into problems which could not be comparably approached by even manual war games.

On the negative side, computer-based war games have created some new problems which were not found in their manual predecessors. Increasingly sophisticated problems have promoted a bewildering increase in the complexity of the war games used to study them. At the same time, the increasingly sophisticated war games enhanced the complexity of the problems themselves, because problems are often defined in terms of the tools available to solve them. It is this sort of spiral which prompted the theme of the 1976 Army Operations Readiness Symposium, "The Complexity Crisis, and How to Avoid It." (The participants proved to have little to say about avoidance.)

The major result of this complexity is that today's military decision maker can become unavoidably removed from the study process. In the areas of force definition and force concepts in particular, the war games have become so sophisticated that the decision maker and his staff are hard pressed to acquire the thorough knowledge needed either to task them effectively or to use their products wisely. Unfortunately, the computer-based war games are being used more than ever before with a trust borne of necessity rather than knowledge.

A second problem created by the complexity of the automated war games is that they are expensive to use. The bigger models require rather large full-time support staffs of programmers, data gatherers, model operators, and data analyzers. It is not uncommon for one of these models to require months of preparation prior to a single play. Variations on the initial play do not normally require such a long period of preparation, of course, but each new problem usually does.

The third and final problem created by this complexity concerns the credibility of the products produced with the aid of these models. Known and suspected model limitations can overshadow whatever value is gained from their use. This is aided by the tendency of many casual observers of war gaming to be most impressed by what the models cannot do. The assumption is then applied that unassisted military judgment will be superior to the "judgment" of a model. Clearly, however, effective use of the model requires that it assist military judgment and not replace it.

The various users of these war games have long recognized the impacts of these types of problems. They have been--and are--faced, however, with some realizations. The models--even with their limitations--can not be discarded without losing their responsiveness and speed. New models can not be built for each particular problem in an effort to avoid the limitations caused by making the problem because the costs are too great. Familiarity can not be forced on the decision makers unless they are willing and technically able to accept the responsibility. Finally, credibility can not be enhanced unless the models became more understandable and observable. The suspicion that something might be wrong can only be amplified when it is impossible for the doubter to test his concerns.

The U.S. Army launched a concerted effort to improve its primary theater level war game, the Concepts Evaluation Model (CEM), in June 1976. From its development in the early 1970s the model had been applied to resource management problems of force design, logistics analyses, force performance, and equipment comparisons, among others. Despite its size and sophistication, however, the CEM was suffering from many of the restrictions just discussed. A research group was organized to improve the fidelity of the model's representations, to enhance the credibility of model outputs, and to make the CEM capable of portraying new types of doctrine.

The major development of the research group was a system of coordination which promised to eliminate, or significantly reduce, the limitations found in the CEM. The concept envisioned a linking system whereby the military decision maker could communicate directly with the war game. With a highly visible means of controlling the model logic, credibility could be enhanced. The fact that the decision maker could dictate his desires about the actions represented would make the model flexible enough to be fit to the problem, and not vice versa.

Before the system could be fully designed and tested in a modified version of the CEM, a high priority study was initiated which required the shift of resources away from the research group. This study, WARtime Requirements for Ammunition, Materiel, and Personnel (WARRAMP), needed a theater-level war game as part of a new model hierarchy. It was decided to use the CEM as the starting point and to incorporate as many of the features from the system developed by the research group as possible.[2]

A major underlying reason for incorporating a number of changes, to include the new system developed by the CEM Research Project, in the WARRAMP CEM was to speed their implementation. While the WARRAMP requirements for a theater level war game were not particularly sophisticated, the time seemed ripe to consolidate resources and produce a significantly improved model. This new version was to replace the one in use in a number of annual studies and nonrecurring special analyses. Unlike the WARRAMP Study, these studies did require a model with as many enhancements as possible. Their diverse purposes, especially, made the new system of coordination a highly desirable improvement. When personnel shifts and schedule problems reduced the scope of changes actually installed in the WARRAMP CEM, the study itself was not hurt. Unfortunately, however, the other expectant users of the new model have not found it to be significantly different. A number of relatively major changes have made the model easier to work with and faster to run, but the promise of the new coordination capability has simply not been met.

This paper has three purposes. The most important of these is to document and expand the system designed by the CEM Research Project. In this author's view, this system represents the most promising solution to the vexing problems facing users of large scale computer war games. Isolated fixes and local understandings can continue to keep the models gainfully employed, of course, but the system described here transcends the limited scopes of these partial solutions by attacking the major problems directly. This purpose is especially important because the model produced by the WARRAMP Study will not encompass many of the fundamental mechanisms which make the system so promising. By developing the concepts in detail it is hoped that this paper will serve as a repository of knowledge that can be used to implement the system in the future.

The second purpose of this paper is to develop an understanding of the background which has brought about the current intensive use of computer-based war games. This situation finds the analyst having a less secure position than ever before. Extremely complex models and methodologies have acquired a dominant role in many major studies. The analyst's field of vision has been narrowed, to a great extent, to match the capabilities of these large and often poorly understood tools. This background will enable the reader to appreciate the evolution of the current computer war games in the U.S. Army, to sense the extent to which these games are used, and to understand that the dependence on them is likely to increase in the future.

The final purpose of this work is to show how the system for controlling the forces and resources could be used. The most obvious and immediate use would be in a model such as the CEM which has a major role in current studies. The system would ensure greater flexibility and visibility, two key problems with existing models of combat. In addition, there are exciting possibilities in training, model technology, and doctrine development for the system. It is hoped that this final purpose will provide the impetus for dedicated development of the system beyond its current infancy.

The paper is organized in the following way. Chapter II, Background, sketches the general threads of war gaming and leads into the modern uses. Chapter III narrows the focus to the Army's war gaming activities, and concludes with formation of the research group. Chapters IV, V, and VI are devoted to documenting the coordination system itself. Their treatment is an expansion of an unpublished working paper presented at the 39th meeting of the Military Operations Research Symposium in June 1977.[3] Chapter VII examines the possibilities for using the concepts explored in the earlier chapters in other areas. Chapter VIII, Recapitulation, reviews the major points of the paper.

Although the subject matter of this paper is of a specialized nature, it is not necessary for the reader to have a detailed background in U.S. Army computer-based war gaming. The references mentioned in the paper can provide the details about a variety of subjects. The CEM model, for example, is a complex subject in itself, despite the general lack of detail presented here. Similarly, to appreciate the depth of the Army's reliance on the CEM, a review of the various studies which use it would be required. The concepts would benefit from the perspective that such a background would afford, certainly, but every effort has been made to describe the situation to ensure that the problems are clear, the alternatives are known, and the possibilities created by the system can be appreciated.

CHAPTER II

BACKGROUND

Modern war games are vital components in many analytic efforts designed to shed light on the complex problems facing the services today. How did the services come to depend on them? Is it likely that these war games will be abandoned in the future? What hopes did the early proponents of computer assisted war gaming have when they were able to push these new tools into existence? This chapter will present background information that answers these questions. This information will provide the necessary perspective for approaching the later chapters. Starting with a brief look at the traditional roles that war games have played, the chapter then moves to modern studies and analyses in which computer-based war games have become so prominent. Many of the problems found in the computer war gaming area today have roots extending to the expectations and initial modelling attempts of the past 30 years.

War Games

War games of one variety or another have been in existence for centuries. They have afforded entertainment, training, and research for military leaders in virtually all civilizations. Chess and checkers are familiar games which can be traced to early attempts to systematically examine warfare. There is evidence, for example, that chess has been used by the Chinese for over 4,000 years.[1]

Early war games were too stylized to be of practical use in most areas in which they are employed today. In fact, the first example of a game having major characteristics found in modern ones was introduced in Prussia in 1811. Baron von Reisswitz, and later his son, developed a game which held considerable realism when compared with earlier efforts. A sophisticated system of rules, supported by detailed terrain representations and teams of players, was used to evaluate the performance of two opposing forces.

In the 1870s, after some 60 years of experience with the burgeoning rules of the Reisswitz game, the Germans decided that new games were needed. The Reisswitz game had become unwieldy. Two tacks were taken. Continuing the Reisswitz tradition of pre-game specification, the Rigid Kriegsspeil tried to simplify the Reisswitz rules and to speed up the game play by using tables and other aids to computation. The Free Kriegsspeil, on the other hand, was based on the idea that, in the interest of realism, an experienced commander was needed to control the play. Rather than depending upon a set of "rigid" rules, the controller had great freedom in deciding the outcomes of events. In addition, he was uninhibited by a particular set of tactical ideas which were embodied in the rigid game rules. He could, therefore, respond to changes in thinking easily.

War games are used for a number of purposes. The U.S. Army defines a war game as "a simulation, by whatever means, of a military operation involving two or more opposing forces, conducted, using rules, data, and procedures designed to depict an actual or assumed real life situation."[2] In slightly different words, war games "are mechanisms that facilitate the orderly contemplation of the actions of imagined military forces under imagined conditions."[3] From these definitions it is clear that many military training situations are legitimately classed as war games. Likewise, the military planning process, which typically includes a commander's estimate and the generation and selection of alternative courses of action, can be seen to contain a number of war games. Finally, any attempt to examine new organizations, equipments, or concepts also involves some form of a war game, even if only a mental variety.

The most widespread use of war gaming has been in training. The goal of military training is to develop experience. Sterne lists seven sources of experience, war being the most realistic, followed by six types of war games; field maneuvers, field exercises, command post exercises, tactical rides and walks, map maneuvers, and simulations and equations. In the Army definition, "simulation" was used to describe any war game. In the narrower sense, however, the term simulation is usually confined to mathematical models. Since this last type of war game will be the central topic of this paper, it is significant to note that simulation and equations are "the least realistic and most abstract sources of military experience...."[4]

War games have also been used to evaluate the qualifications and skills of military leaders. Admiral Kidd, to provide a modern example, has encouraged his staff and subordinate commanders to become proficient at war gaming.[5] Implicitly, performance of staff and decision making tasks during the simulation are used to assess the competency of the players.

As mentioned, the commander and his staff routinely war game alternatives while executing the military planning process. This process is extended as well into generating contingency plans for future conflicts. Although the bulk of the war gaming may be done informally, scenario production and plan review each involve some gaming to some extent.

A third use of war games, especially in the modern framework, is in the production of synthetic data. "War games create synthetic history composed of imagined events."[6] This is a secondary feature of war game uses in the other areas, of course, but it has become an increasingly important purpose in itself. The important emphasis is now being placed on the interation of a family, or hierarchy, of models. Each of these models is used as the "history" which is input to the next model. One model, therefore, might provide a detailed history of ammunition usage. This history becomes an input to the next model, providing the details of the ammunition consumption in the form of aggregate values and equations.[7]

The final use of war games is for research. Explorations into new weapons systems performance is a good example of this type of use. They are also used to test new organizations, concepts, and problems. The value that war games have in this type of activity is high, primarily because they provide the only alternative, in most cases, to complete reliance on subjective assessments.

War games, in all their varieties, are limited to a greater or lesser extent. Depending on the situation these limitations may render a game useless. In other situations the model may be completely adequate. Therefore it is difficult to list all the limitations to which war games are subject. In general, however, the limitations can be traced to the "conflict of practicality versus realism."[8] The Reisswitz game, as mentioned, was limited because the users attempted to create greater realism by incorporating more and more rules. Unfortunately, the proliferation of rules soon made the game no longer practical to run. All war games represent a compromise between realism and practicality. Practically any increases in realism are paid for by increases in the cost of running the game. More detail usually means more time to run the simulation. Similarly, if more units of the force are to be included in the war game, the time and expense of running will increase. If the complexity of the rules used to control the war game increases there will be a corresponding increase in several cost areas, including preparation, play, and analysis of the game.

The development of the computer has tended to support a greater realism in war games, primarily because the rapid computational power has broadened the realm of practicality. It has not, however, eliminated the basic need to strike a compromise on realism. Furthermore, the computer assisted war game can have a unique limitation not found in the others. Sterne views the major strength of war gaming to be the post-game analysis and discussion. However, "...meaningful discussions among participants, after the close of play, can be hurt by any use of computers that impair the ability of the players to follow the course of the play and the reasons for it."[9] This is even more true today than it was when Theodore Sterne made this observation 12 years ago.

Modern War Gaming

A useful approach to understanding the present use of war games is to examine the development of military analytical capabilities over the past 60 years. War games, as a group of analytic tools, have tended to remain with the military more so than other techniques, although there is now a pronounced war gaming capability in a number of civilian organizations.

It is also important to note that the trend is likely to continue, placing an increasing percentage of war gaming expertise outside the active military. This will be discussed again later, but it should be kept in mind during the immediate discussion. This discussion draws extensively on the work of Charles Thomson.[10]

War games and gaming were the exclusive properties of military establishments until WWII. Several uses of war games by the military to plan and analyze land and sea battles are well known. The Naval War College is credited with gaming virtually all naval operations of the Second World War during the preceding two decades.[11] The Army had similar successes using gaming to anticipate and plan for many of the ground conflicts which were experienced during this century, although the training benefit tended to outweigh the forecasting abilities of these games.[12]

During the early stages of WWII, it became clear to the U.S. military and civilian leadership that an analytical ability, to include war gaming, was needed to augment the capabilities contained in the Department of War. New weapons and employment procedures were needed, and it was decided that a civilian organization, made up of the finest scientists and engineers, was the best source. The Office of Scientific Research and Development, headed by Vannevar Bush and reporting directly to the President, was created early in World War II.

At the conclusion of the war, many of the members of the OSRD wished to return to their pre-war employments. A few military and civilian leaders saw the need, however, to maintain and enhance the close military cooperation and accumulated civilian experience which had been established. Little was accomplished in this regard as other priorities tended to siphon away the talents and attention which had given the OSRD billions of research dollars in WWII. Small clusters of military and civilian researchers continued to operate within the services, but no cohesive plan for developing a civilian organization was tried. The Navy continued to support the Operations Evaluations Group and the Office of Naval Research, but these tended to commit funds to universities for small study projects rather than for independent research.

The Air Force initiated the RAND organization as Project RAND with Douglas Aircraft, the Navy created its Center for Naval Analyses (CNA), and the Army formed the Operations Research Office (ORD) shortly after WWII. These three civilian organizations, two of which remain in operation today, were organized under the Federal Contract Research Centers (FCRC) concept, where the services constructed independent civilian research groups, provided the bulk of the contracts, but permitted these non profit organizations to determine their own directions in research.

The goal of the FCRC concept was to develop a specialized research capability which was generally free from the personnel turnovers, interservice rivalries, and limited expertise found in the military research organizations.

This is an important point to remember because the goal has been achieved sufficiently to make an understanding of current research trends and capabilities in the services impossible without recognizing the impact of the FCRCs on concept definition and policy guidance. In the primary area of this paper, in particular, the early work by the Army's ORO, and its offspring, the Research Analysis Corporation (RAC), have had a profound impact on the philosophy and expectations underlying much of the Army computer war gaming today. Indeed, to appreciate the high hopes and early efforts in developing the forerunners of the modern computer based war games is to understand much of the current dependence. To understand the expectations which guided the research until the termination of RAC in 1971 is to understand the heavy burden which has come to be placed on the models and methodologies found in virtually all Army studies.

A forecast written by a RAC scientist in 1963 is perhaps the best evidence of the infant expectations which have now matured. Nicholas Smith, Chief, Methodological Research Division, was attempting to predict the scientific advances applicable to military problems analysis through 1983.[13] Since the emphasis was on military applications, and since the FCRCs were the major pioneers in these areas, his predictions can be viewed as an outline of future FCRC emphasis. In general, the forecast calls for the development of computer and model technology to the extent that most problems in military planning would be addressable by the 1980s. Simulation figures prominently in the forecast, often appearing to be the shining light of the operations research techniques. The forecast also sees the trend which led to Thompson's assessment 12 years later. "Building new systems - usually computer-assisted - bulked large in RAC's work throughout its life. Such systems were usually designed to perform large, detailed, complex, and usually recurring tasks for the client."[14] Many of these systems are still in operation.

Although the Army's FCRC was disbanded in 1971, the concepts and processes pioneered for the Army during the preceeding 25 years have found continued use, as just mentioned. Many of the people involved in the original organizations are now positioned in a variety of Army, OSD, and private concerns and organizations which participate in the Army study process. Therefore, much of the emphasis found in the FCRC work is still present because many of the same people are determining that emphasis. In addition, and perhaps the most important of the two points, is the fact that the various users of the earlier work of RAC have developed organizations, requirements, and problems which are couched in terms of RAC-type processes. In other words, consumers have come to expect certain types of analyses, have learned the types of questions to ask, and are comfortable with the familiar answers.

In conclusion, then, the services in general--and the Army in particular--have developed computer-based war games with the hope of obtaining new tools with which to tackle the growing number of problems. Coupled with the expanding capabilities gap which has come to exist between the service staffs and the staffs of the Office of the Secretary of Defense, the Congressional Budget Office, and the Office of Management and Budget, to name the major overwatchers, these early hopes have spawned a collection of models which are now inseparable from many special and routine study requirements. Since the complexity and quantity of demands for information is likely to rise,[15] there can be little doubt that these analytic tools will be essential for years to come.

CHAPTER III

THE CEM, AND THE CEM RESEARCH PROJECT

By the mid 1970s, the increasing complexity of the problems requiring solutions - and the war game tools available to provide them - was making it very difficult for anyone to understand or evaluate a study product. The situation had been reached when faith in the study methodology was easier to develop than accurate knowledge about it. In addition, the assessments offered by analysts working in many problem areas had become usable only to the extent to which their work could be supported by computer printout. An unfortunate division had developed: because the problems and computer war games had become so complex, model builders and model users had split apart, "...for soldiers often do not understand such programs [models], and the professional coders and programmers who do understand them often do not understand military matters."[1]

Despite the high hopes behind the origination of computer war games, and during a time of relative satisfaction among many model users, a number of Army planners and analysts began to question them. Had the original expectations been met, or had the models, through their sheer size and complexity, lulled their users into a false sense of security? Were the models justifying the resources needed to acquire and operate them, or had they become expensive window dressings? Worst of all, perhaps, was the fear that model outputs might be assigned a value in an analysis which was related to the cost of generating them, and not to the objective contribution that they made to achieving the study goals.

This chapter traces how these types of concerns prompted the Army to create a special group to work out improvements for the Concepts Evaluation Model. Not only was the CEM the largest and most complex model of theater level ground war in the Army inventory, it was also a key component in a number of critical Army studies. Model shortcomings in the CEM could be having a significant impact on the quality of Army decisions in a variety of areas.

The first section contains a brief description of the CEM. While the section will only brush several CEM areas lightly, it has three objectives. First, the description includes a number of program, program support, and computer requirements which should indicate that the CEM is quite large and expensive to operate. Second, the description should suggest the complexity of the model processes, even though they will receive only a brief mention. Finally, the section should provide enough information about the model structure and processes to enable the reader to understand the setting for the remainder of this paper.

The CEM Model

The CEM, originally called the CONAF Evaluation Model, (after the Conceptual Design of the Army in the Field Study for which it was designed) was developed by RAC, and its for-profit follow on, the General Research Corporation (GRC). As a theater level combat simulation, the model is capable of representing combat between two opposing air and ground forces in a non-nuclear, or conventional, war.

The CEM is a very large model. It consists of three interdependent computer programs, a pre-processor program, which translates the input data into model usable form; a main combat program, which contains the combat portrayals; and a post processor program which prepares reports from the data provided from the main program. Written entirely in the FORTRAN programming language, the three components have nearly 200 FORTRAN subroutines (separate program elements). The main combat program uses five levels of subroutines, meaning that program control is exercised from a main controlling module, down through four other subordinate levels of modules.

Computer requirements for the CEM are also relatively extensive. In its normal configuration the model uses approximately 160,000 words of computer core storage for the largest program overlay, or segment, of the main program. Use of the overlay technique enables the program to be made to fit on a particular computer by working as needed with a number of pieces of the total program. The tradeoff here is that, the smaller the computer core capability, the larger the number of these pieces. More pieces mean longer running time for the total program because as each piece is called for it must be brought into the core storage area from a peripheral storage device.

A full run of the CEM - to include all three interdependent parts - can take from eight to ten hours on a UNIVAC 1108-series computer. During this time a truly remarkable quantity of data is processed. While a good deal of the data is of a transient nature, being stored and used only temporarily, a large amount of data is retained. From this base of data, the post processing program prepares the reports and graphs which are used in the game analysis.

Within the CEM model architecture, up to 435 discrete units can be represented. These units are organized into two sides, and into four or five echelons depending on the side. The Blue side can have brigades, divisions, corps, armys, and a theater. The Red side has no capacity for representing a brigade level echelon.

Units in the CEM are defined in a number of ways. Organizationally, units are identified by side, echelon, and, in most cases, the particular parent to which each belongs. Blue divisions can have three brigades. Blue and Red corps level units consist of from two to five divisions, some artillery and cavalry assets. The Army echelon units consist of a variable number of corps units. The theater echelons can also have a variable number of army level subordinates.

Units are also described in terms of the equipment, personnel, and other items which determine their capabilities. For major weapons systems, each side can have a number of notional types. Each side can have up to 12 types of tanks, 12 of light armor, 12 of a combined category of anti-tank and mortar weapon types, and eight types of artillery tubes. The Blue side can also have up to five types of helicopters. Within certain limits, units on a side can be made up of any combination of the available weapons types.

The major weapons are defined separately. Each weapon is assigned a set of firepower scores. These are used to build a unit's ability to inflict damage on the various types of enemy weapons and personnel. Each system is also given a set of vulnerability factors which describe its susceptibility to the effects of enemy firepower. Finally, each weapon is described according to its crew size, breakdown rate, and supply requirements.

Logistics data and personnel information complete a unit's description. Ammunition requirements are identified as required either for a unit's artillery or for its other weapons. Requirements for petroleum, oil, and lubricants (POL) are specified for each of the various combat postures possible for the unit. A general category, "other supplies," is entered to reflect the other types of supplies, measured in tons, needed by the unit during various types of combat operations. The final unit description is the number of personnel assigned.

Combat forces in the CEM are arrayed along a forward edge of the battle area, or FEBA. The FEBA can consist of up to 1,000 segments which are called minisectors. Every unit on the FEBA is identified by the minisector numbers which correspond to its boundaries. The minisectors between those minisectors serving as boundary points form a subsector. The subsector is the basic unit used during the assessment of losses following an engagement.

The CEM is time-stepped, as opposed to event-stepped during operation. This means that intervals of time are used to move the model from the start of the game to its conclusion. Event stepped operation would mean that the model would progress from one event to another, regardless of the amount of time involved between the events. The basic unit of time is the division cycle, normally defined as a 12 hour period. this is the amount of time needed by a division to plan and conduct an operation. Each echelon above the division is considered to require twice as much time as the next lower level. The corps, for example, has a cycle which encompasses two division time cycles.

Two major functions are accomplished during each cycle, decision making, and assessment. The decision making function attempts to generate an approximate picture of the strength of the forces opposing the commander in a sector. The decision making function, operating in part on the estimation of enemy strength, assigns missions to subordinate units, distributes artillery resources, and determines whether to commit a reserve, if available, or to create one from an on-line unit if the situation warrants.

The second process during the cycle is the assessment. This function determines the engagement outcomes for the missions and resources committed by each side. The major factor used here is the firepower available. FEBA movements and combat losses of personnel and equipment are determined by the types and quantities of weapons and targets belonging to each side at the conclusion of the decision making process.

Decision making in the CEM is based on a key assumption: that units will always adopt a mission that is as aggressive as possible. In other words, if a unit can choose from a list of missions including attack, defend, and delay to suit the situation, it will take that mission which promises to inflict the maximum casualties on the opponent, while not jeopardizing its own survivability beyond a particular limit.

The final CEM subject to be presented here is the CEM support area. The CEM is too large and complex to be stored in a computer library and "dusted off" before using it on a new study. The model requires a fairly stable group of programmers, analysts, and model operation specialists in order to be used properly. To maintain the necessary expertise, in fact, the model must be used often.

Developing a new input data collection for the CEM is an expensive endeavor. The 15,000 or more data items needed by the model to operate can take up to 20 or 30 man-months to produce. The actual collection of data may not be too time consuming, but the translation of this raw data into a meaningful input to the CEM model requires both the most time and the most talent. The translation remains an art, requiring experience and skill.

The CEM Research Project

With the perspective gained from the section just completed, and keeping in mind the fact that the CEM has become an important analytical tool for the Army, this section turns to the details of the CEM Research Project. It is difficult to convey the urgency with which the project was initiated. The growing concerns and doubts among Army planners had created a significant amount of internal tension. It was recognized that the stakes were high, and that the current dissatisfactions could only increase unless some remedies were found.

The CEM had attained its importance to the Army in several ways. The first, and most obvious, was the fact that the model had been built originally by RAC to satisfy a particular Army problem. The CONAF Study was interested in gaining insights into the equipments, organizations, and employment techniques of forces which might be available after 10 years.[2] The second major reason for the CEM's rapid rise to importance was the fact that it had two attributes which made it useful for a variety of purposes. The series of detailed inputs made it possible to describe a wide range of forces and force structures. Also, the large number of force performance indicators produced by the assessment routines in the model made it possible to monitor a wide variety of detailed processes. In combination, these attributes soon pushed the CEM to the center stage.

Because of the large numbers of uses to which the CEM has been applied, a complete list of the potential problems and their impacts would be quite long. Each study, with its own special interests and requirements, would be extremely sensitive if the CEM were in error in a certain way. Instead of attempting to compile such a list, however, it is instructive to examine the general concerns provided by the offices of the Deputy Undersecretary of the Army for Operations Research, ODUSA-OR, and the Deputy Chief of Staff for Operations and Plans, ODCSOPS. In late 1975 and early 1976, a series of dialogues were set up to discuss the problems which were felt to exist with the CEM, and to suggest alternatives for combatting them. One memorandum from a senior analyst in ODUSA-OR is a good source here.[3] His concerns ranged from the validity of model inputs to specific model shortcomings. His general fear was that CEM employment had exceeded its abilities and those of the model users to responsibly support. His recommendations included a review of the inputs, analysis of the existing methodologies which used the CEM as a component, and the formation of a panel to direct the development of model capabilities which would be more in line with the demands being made.

ODCSOPS, the principle user of the CEM related products, was also concerned. It had become apparent that the credibility of many of the studies sponsored by ODCSOPS depended to a great extent upon the credibility of the CEM. In addition, it was recognized that the CEM could not be used in a number of problem areas which needed some attention. For example, the CEM was unable to represent the Soviet breakthrough tactic. Clearly, however, the tactic posed special problems for the combat and support elements, especially in Europe. Could the Army avoid this reality in its major studies simply because the CEM could not respond appropriately? It certainly made little sense to study the vulnerability of the lines of communication (LOC) if the model used to evaluate LOC performance could permit only a continuous forward edge of the battlefield, or FEBA. In a similar way it was recognized that tactics and forces ought to both be adjustable. In the CEM, as with virtually all theater level simulations, force description has always exceeded tactics description in terms of flexibility and richness. It has always been easier to portray diverse forces than to represent changes in the ways these forces are to behave. MGEN Meyer (now LTGEN Meyer), in his capacity as the Assistant Deputy Chief of

Staff for Operations and Plans (ADCSOPS), was particularly aware of the conceptual problem.[4] Did it make sense, for example, to design a new force, arm it with new weapons, and then employ it in the simulation in precisely the same way used for an existing force? Similarly, wasn't it possible that there might be better ways of employing existing forces? Obviously, both of these questions if they are to be examined within the context of a theater war game require a model which can have its tactics adjusted.

After considering a number of alternative approaches to the CEM problems, MGEN Meyer decided to sponsor a research project which was to conduct research into new theater war gaming areas, to accomplish sensitivity analyses on a number of key data items and model processes, and to develop ways of incorporating several specific capabilities into the CEM. The other alternatives had all involved the assignment of the responsibility to ongoing studies which were using the model. In response to a proposal to place the responsibility for CEM development in the CONAF Study, however, MGEN Meyer made it clear that the effort should be independent.

> I have reviewed your proposal...and feel that we would be better served with a separate effort, independent of CONAF. The extent to which the Army Staff relies on the CEM demands that we devote substantial research and development efforts improving its quality.[5]

As a result the CEM Research Project was organized at the U.S. Army Concepts Analysis Agency (CAA), in Bethesda, Maryland. CAA was the principal user of the CEM, and had the largest concentration of theater level modeling experience available.

The CEM Research Project had four major objectives:

1. To conduct research on and with the CEM necessary to establish the limits of present model capabilities in specified areas of concern.

2. To determine the feasibility of and methodology for developing new capabilities and to assess, through testing, the adequacy of new or extended capabilities.

3. To analyze the CEM computer program architecture and develop improvements contributing to more manageable and reliable software which will make analysis of and with the model simpler and quicker.

4. To improve the efficiency and utility of efforts required to input the model and evaluate its outout.[6]

The basic approach taken to meet these objectives was simple. To provide a base from which to work systematically, the specific areas of concern covered by the first objective were ranked according to several criteria. It was felt that a complete analysis of each area, covering the ultimate uses, existing computer programming in related activities, and the design needed to interface the new capability into the model would touch upon each of the objectives. For example, the tactical concept of penetration was of concern. It would be studied, existing computer coding for FEBA and force movements would be identified, and a plan for incorporating the needed capability into the model would precede the actual implementation and testing.

The alternative to this approach was a systematic treatment of the objectives independently. In other words, each objective would be examined in relative isolation. Clearly, however, the objectives are interrelated. Changes in the areas of interest to one objective would necessarily alter the areas of interest to all objectives. Changes developed to satisfy the third objective, for instance, might produce a program architecture which is very rapid. Unfortunately these architecture changes may negate some rather obvious ways of representing a desired capability. A third approach, and one which did not receive serious attention, was to develop a completely new model. The resources and time required were too great. The expanded model was needed as quickly as possible, and gamers could not wait the five or so years necessary to build a new one.

The list of the desired changes was quite extensive. The model had been used in such diverse study areas that the perceived needs were far ranging. Users of the model studying personnel requirements in wartime wanted to be able to identify casualties by military occupational specialty (MOS). Logisticians depended on the CEM to provide data on ammunition consumption, among other things. They wanted to be able to trace all types of ammunition from the prestock or supply points to the impact area. Studies which needed more information from the model about air operations wanted immediate improvement in the relatively weak air combat module of the model.

The majority of desired capabilities concerned tactical operations which the CEM could not represent. An initial survey of them revealed two interesting points. The first was that most of the items required the ability to coordinate units and resources over terrain and time. A breakthrough operation, for example, needs to be preceded by a massing of force and a penetration attack. It would not be possible to develop a model logic which realistically portrayed a breakthrough without including the preparatory actions. Likewise, a defensive action in response to an impending breakthrough also requires preparation. To realistically represent the defensive action, the preparation must be accomplished.

Part of the purpose of the survey was to examine the existing CEM program with an eye to adapting existing computer code to new uses. The second point of interest was that the CEM was not able to provide the necessary continuity needed by most of the desired capabilities to represent a coordinated course of action. This was apparent for two reasons. First, virtually all actions in CEM were of short duration. Beyond the obvious linkages found in the logistics, equipment, and personnel systems, where earlier actions impacted on the future supplies of these resources, very few actions extended beyond a single time period. This was especially true in the area most important to representing coordinated actions, command and control. Although the CEM command and control system had been viewed as the most complete of all the major theater-level models,[7] it still could not support operations which required spatial and temporal coordination. Secondly, the command and control procedures contained in the model actually relied on an inverted system. Despite the apparent sequence of command actions from the top down, the final decision-- within very broad command guidelines -- about the actions to take

other words, binding control of the units was not possible. This was obviously not suitable for representing tactics which might be quite costly to some subordinate units but necessary from the larger perspective of the higher commander.

The discovery of these points prompted a change in research strategy. Command and control became the center of focus. The project was to operate on the premise that if a command and control system could be developed for CEM which provided the spatial and temporal coordination afforded by the real system, then all of the desired tactical operations could be represented.

In accepting this new research philosophy, the major alternative approach was kept alive, however. In the event that a mechanism to represent all the operations could not be developed, each operation would be "wired" into the program. In other words, the sequence of events in a particular operation would be coded directly. This would pose several critical problems. The programming would be complex, especially for those operations which would be entered last in the model. The preceding entries would hamper the flexibility needed to design and build the new capability. In addition, most operations would, for the sake of realism, have to be "interruptable." Once an operation had begun, the environment might change enough to make its continuation unrealistic. To circumvent this problem each operation would require a number of decision rules to tell the model to stop an operation if certain events occurred. These rules would be difficult to construct and apply, and it would be difficult to trace the course of events. Finally, the alternative approach would produce a model which would be extremely difficult to modify. The connective linkages developed to portray the new capabilities would be fragile. In order to strengthen them, it would be necessary to increase both the model size and the running time -- probably beyond the practical limits.

CHAPTER IV

THE GENERAL COORDINATION MECHANISM

The CEM Research Project staff, in changing the research focus to the functions of command and control, was taking a bold step. Although the charter for the study gave the group considerable freedom, there were significant pressures to solve some of the CEM problems by a more direct approach. Fortunately, however, enough freedom was preserved to enable exploration into a new system for coordinating the actions in the CEM. This chapter presents several of the major concepts and steps involved in reaching this new system. Doctrine is examined first, followed by a look at the functions of the command and control process. The basic system, which will be expanded greatly in the next two chapters, is then introduced.

Doctrine

The CEM Research Project received a list of desired changes soon after the formation of the group. The items on the list represented a number of different study requirements, and a variety of different tactical procedures. To repeat the questions which intrigued the CEM Research staff when faced with this list, was it possible to develop a model which could accommodate each item? Were there elements common to all of them which could lead to a way of representing any and all doctrine in the CEM? This section presents the key points about doctrine which, when combined with other concepts, make the coordination mechanism possible. Fundamental to the analysis is the recognition that a doctrine determines two things for its users. First, it determines what particular parts of the total spectrum of environmental data is of interest. It provides, therefore, a filter through which a limited set of data can pass. Second, doctrine determines the manner in which the forces can respond to the filtered set of information.

In many respects, a doctrine can be equated to a language. Each provides a structure for organizing the environment. Each can determine how the environment is to be interpreted and how the alternative responses are to be generated and evaluated. In each case a model of reality is inherent in the structure. Data, concepts, and responses which lie beyond the realm of this structure are either ignored or not perceived at all. Finally, both a doctrine and a conventional language predispose the user to perceive, integrate and interpret, and react in a particular fashion.

Uniformity is another attribute of doctrine which makes it a language. Common experiences, requirements, and training tend to develop and perpetuate a common language. Military doctrine is based on the same ingredients. Military leaders in a military organization typically share common societal and educational backgrounds, and will share a particular military doctrine, or predisposing fashion of approaching military problems. In addition, the uniformity of the military education and training systems further tend to produce a group of individuals that will perceive and respond in a fairly uniform way.

Aaron Cirourel, attempting to summarize the work of a number of authors writing in this area, identified two features that help to preserve this uniformity.[1] The first process, reciprocity of perspectives, enables both members using a language to assume that each operates from the same perspective. Second is the "et cetera assumption," which enables both parties to a conversation to assume that any incompleteness or ambiguities will be resolved in a mutually agreeable fashion. Together these processes permit the brevity and speed found in communications between individuals sharing the same language.

Another important feature of doctrine is its ability to change. As with any language, a doctrine can change over time as experience and requirements dictate. Local variations can exist, of course, but the general framework evolves with relative uniformity. The evidence obtained from language study in this regard indicates that change will be slow, frequently resisted, and accompanied by a certain degree of confusion. The reasons for these characteristics are worth mentioning. The most pervasive reason is that a significant portion of communication is accomplished by implication. For Cicourel, "the attribution of meaning in everyday settings is by reliance upon "what everyone knows."[2] Needless to say, it takes an individual considerable time to become sufficiently adept with the underlying "common knowledge" of a language to make much sense of an abstract discussion. The same process severely limits the speed with which a change, even a conscious one, can be assimilated. The more complex the language, the more difficult to change. The greater the number of participants, the longer the time required to assure that the change has become "common knowledge."

The second reason for the characteristics of doctrine change is the communication system. Since, as just covered, implication imparts much of the meaning, the speed of change will be related directly to the efficiency of the communication system. A communication system which requires a substantial period of time to expose all of its participants to a bit of information will also require a substantial period of time in which to accomplish a change to the common knowledge. The widely dispersed locations, decentralized training procedures, and career rotation policies of the U.S. military services, for example, combine to make the process of doctrine change a protracted affair. Although more will be said about these first two reasons, it should be apparent that the real problem exists where an armed conflict is being fought by forces with divergent expectations about what "everyone knows."*

The third reason for the rather ponderous nature of doctrinal change, and one which is, once again, derived

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* General Starry's tailored employment of the 5th U.S. Corps, for example, contains a certain risk because it must rely on a set of "common knowledge" which is common only to the 5th Corps. Replacement personnel and adjacent organizations cannot rely on their own common knowledge to appreciate the operation of the 5th Corps.

from language analysis, is the fact that the sources of a change--the strategist, the military planner, the weapons employment expert or what have you--are constrained by the existing doctrine. It can take a number of occurrences of an event which demands a change to doctrine before the requirement is perceived. Doctrine determines how the environment is perceived. If the event which demands change is not recognized by the doctrine, it may be extremely difficult for an active participant to initiate a change. Quade would hold that the impetus for change will likely come from a relative outsider, one on the periphery of a doctrine who is not entirely held by the internally consistent structure.[3]

The fourth, and final, point to be covered is that technological advances are typically slow to mature to the point where modification of existing doctrine is required. This is true for two reasons. In the first place, a new sensor or weapon system produced by new technology meets resistance from advocates and proponents of existing systems which approximate the function envisioned for the new. Acceptance is predicated on overcoming these parochial blinders. The second cause of the delay is that the production of quantities of a weapon or sensor sufficient to impact on "normal modes" of combat operations takes time. The second cause is multiplied by the first, also, because development and production decisions are questioned hostily by those supporters of the current capability.

In summary it can be seen that doctrine is extremely stable over time. Instances of this stability have illuminated a number of battles in the past. The advent of the pike, armor, long bow, cross bow and machine gun are several familiar cases where new capabilities preceeded the modification of doctrine, often with telling results. Consider the emergence of the aircraft on the battlefield. Technological advancement, despite the general lack of enlightened military support, far outstripped the ability of most doctrine to accommodate the new capability offered by the aircraft. The dimensional expansion demanded by the aircraft's inclusion in modern warfare brought with it a host of new aspects of the environment that were now, by necessity, of interest.

Command and Control

The modern techniques of command and control are products of a long evolution. Their function has remained the same, however. Strategy and tactics are the overt processes of applying doctrine. Command and control systems are the working arms of these overt expressions. They are the links from the commander and his concept of operation to the forces and resources at hand.

Interestingly enough, the command and control function is independent of any particular doctrine. The component parts of the iterative process (estimation, alternative generation, course of action, selection and execution) do not in themselves imply one tactic or another. The familiar format for communicating between echelons, the five paragraph field order, is also void of any particular mode of operation. The basic requirement is the same regardless of the doctrine: to provide a set of instructions to subordinate units which embodies the coordination characteristic of the doctrine. It is this requirement which enables a force to be more than a simple summation of the capabilities of its component pieces.

Fundamental to the accomplishment of coordinated action is the ability to specify and translate into meaningful instructions three essential elements found in any coordination scheme. First, the commander must be able to assign a mission to each subordinate which is in concert with his overall plan. He must be reasonably confident that his subordinates will at least attempt to carry out their missions. (In the event that he is not reasonably confident, then it is assumed that he would have the presence to accommodate this fact by issuing appropriate instructions.)

The second basic element is location information. Each unit must know where it must be if the commander's concept is to be carried out. This information may be of a relative nature, such as "remain to left flank of the primary attack," or of a concrete one, such as "take up a blocking position at point Alpha." Additional data might also be provided so as to further clarify the concept. An instruction to assume a blocking position to the rear of the parent would imply that a penetration or a withdrawal is possible. In each of these examples the central point--the commander's ability to control the locations of his forces--is a key to higher (and lower) level operations.

Allocating supporting resources, whether of a logistic replenishment or fire support nature, is the final essential element. By differentially allocating resources, the commander is able to finalize his concept of operation by providing the means to enhance his units chances of successfully carrying out their instructions. Supporting the major attack by allocating to it most of the close air support is a good example.

The General Mechanism

The foregoing analysis of military doctrine and command and control requirements led to the isolation of the design features considered to be essential for the CEM work. In addition to the basic requirement of feasibility, the design had to:

1. Control the forces and resources in a manner consistent with the desired doctrine.

2. Generate alternatives and select a course of action which would be appropriate for the desired doctrine in response to the perceived environment.

3. Be able to perceive and interpret the environment in a manner consistent with the desired doctrine.

The technology required to attain the first design feature was straightforward if only a limited set of tactics was needed. Through the process of "hard wiring" mentioned earlier, each tactic would be individually designed, programmed, and installed in the model. Problems might be experienced as the program size and complexity increased, but the task could be done in this way. Clearly, though, the Army study demands were such that the installation of one or two sets of tactics would not be adequate. The burgeoning use of the model was making any such solution only a temporary one. What was needed, if possible, was a general mechanism which contained the flexibility and responsiveness to handle a wide variety of doctrines.

The contingency plan concept seemed to be the partial answer to the second feature. Just as military commander's attempt to anticipate future actions by preparing plans for use if certain events occur, the analysts running the CEM could provide a number of contingency plans. The potential number of these plans seemed at first to be unmanageable, a point to be discussed in a later section, but an approximation was at least possible. Unfortunately, earlier modeling attempts at providing this type of detailed guidance had faltered because of a fundamental problem. In the fully automated war game the potential for human intervention is small once the game begins. This is especially true in the case of large scale games. The time and expense associated with human analysis and direction can render the process unsuitable for a number of major uses. Without this intervention, however, the suitability of the human guidance provided at the beginning of the game was inversely related to the length of simulated time. In other words, a series of actions provided by an analyst before the start of the war game became less and less appropriate as the dynamics of the game altered the situation. It is not difficult to predict with some accuracy the conditions which might be facing a commander in the game after several days of simulated combat. Likewise, it is not difficult to install instructions to the forces dictating how they act. It is much more difficult, however, when the possible prediction errors become large, say after ten or more days.

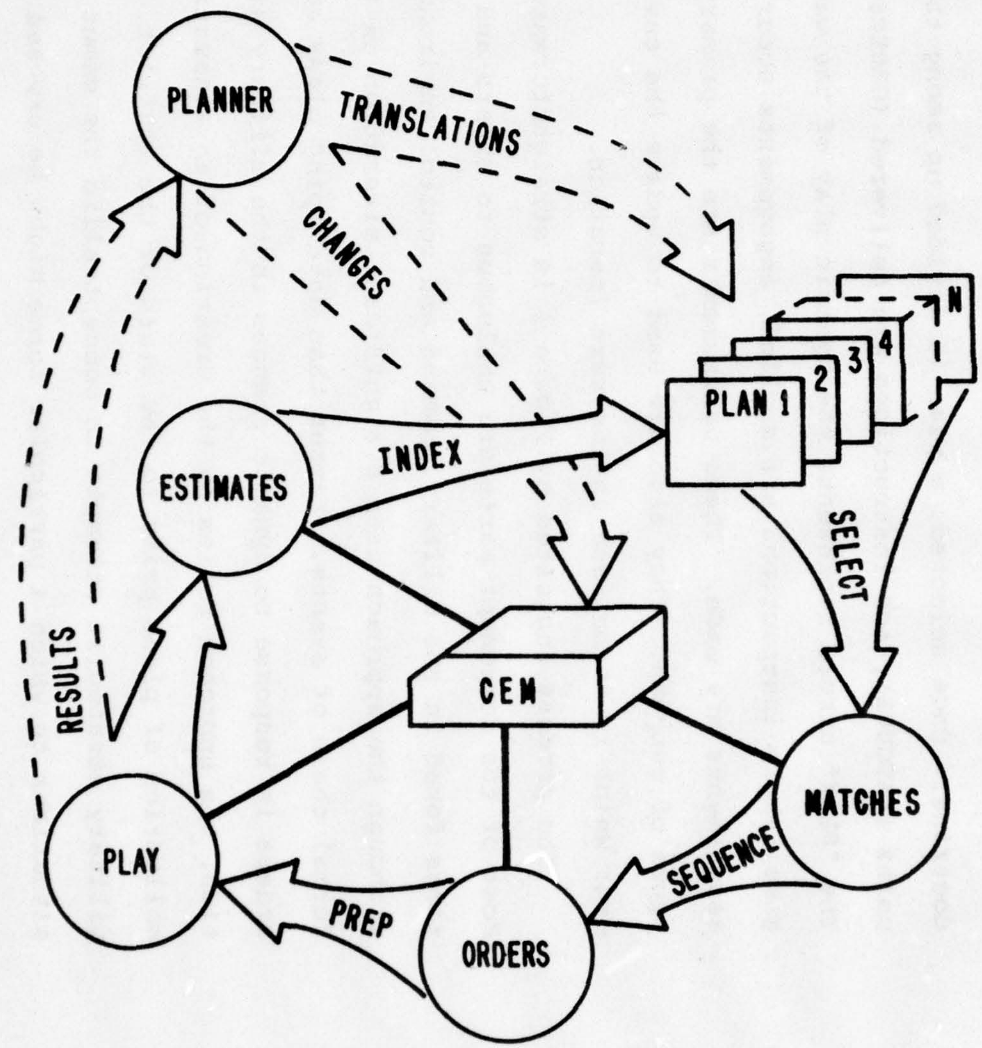
To overcome this problem a third design feature was needed. A way needed to be developed which would emulate the perception and interpretation processes inherent in doctrine. In addition, the technique had to be adjustable so that a variety of perception and interpretation characteristics could be handled. Without the ability to evaluate the dynamic changes in the war game environment, contingency plans would be driving the forces blindly. The control mechanisms developed to meet the first design requirement would, no doubt, be able to make the forces follow a predetermined sequence of action, such as massing, penetrating, and breaking through. In all likelihood, however, the majority of the time would find the forces responding inappropriately in the view of the practitioners of a doctrine.

The view of doctrine as a language provided the design guidelines needed to achieve the desired perception capability. As with any language, military doctrine consists of a series of terms. The meanings and relationships implied by these terms form the framework which is common to the users of the doctrine. If an understanding of these terms would enable a leader to adopt a particular doctrine for his use, then the same understanding must be possible for the modeler. Also, if a general set of terms could be devised which was fundamental to a number of doctrines, then it should be possible, with a knowledge of the doctrine-specific meanings and relationships, to use these terms to describe any of the doctrines.

This last hypothesis formed the foundation for the design approach taken by the CEM Research Project. A hybrid lexicon of terms was to be generated which could be used by the military leader to perceive and interpret the environment. The lexicon would also contain terms for handling the other major function of doctrine, dictating how the forces respond. These terms would allow the leader to instruct his forces to behave in ways consistent with the doctrine. Interfacing the military leader with the CEM model was to be through recording devices which served much the same function as contingency plans. Finally, the terms of the lexicon were to have precise model counterparts, so that the use of the term in the recording device activated its computer counterpart.

The overall process, variously called the coordination system or the plans approach in the remainder of this paper, is shown in Figure 1. The top circle represents the military planners, analysts, and study sponsors who require interaction with the simulation. They determine the objectives for which the war game is to be used. They determine the types and values of the inputs to be used for a particular run of the model. They also determine the perceptions and responses to be used by the simulated forces, recording these instructions in a set of "plans," shown at the upper right of the figure. Finally, they receive the various outputs from the model. These data can support the study purposes, or can lead to changes in plans, model inputs, or even model logic.

The clockwise flow circling the input data and model programming, represented by the card deck symbol labelled "CEM," identifies the components and sequences of operation found in the design. Starting with the ESTIMATES circle, the environment is evaluated in a standard fashion. The plans provide the model with the perception "filters" which are to be used. The plans also provide the alternatives and the instructions which are consistent with the desired



THE GENERAL MECHANISM

Figure 1

doctrine. Once selected, a plan is divided up among the units (MATCHES), and instructions are delivered (ORDERS). The "PLAY" circle represents the dynamic play of the war game, where instructions are applied, engagements occur, and assessments are made. These assessments are the primary types of outputs. They also are used to update the environment which is to be used in the next iteration.

The process suggested by Figure 1 is straightforward. Most of the component parts are analogous to events and operations found in the military command and control environment, although the approach uses a significant alteration in the formal chain of events. Rather than developing plans and orders in response to dynamic changes in the military situation, the approach relies on the creation of an exhaustive collection of plans prior to the start of the conflict. The military strategist attempts to conceptualize the gamut of situations to which a particular force might be exposed. He then builds responses, or plans, to be used when the force encounters various conditions. Each plan is guided by his concept of operation. It is important to note that the term "plan" has a broader scope here than normal. It refers to all the elements in the instruction set, to include not only missions, locations, and resource allocations, which are found in the normal meaning, but also includes specific information about when the environment will be satisfactory for applying the coordination scheme, or concept of operation, called for. Plans are, therefore, specialized forms of coordinating instructions prepared in advance and intended for use when the situation dictates. In this sense, they are similar to traditional contingency plans.

The next two chapters concentrate on the details of the system shown in the Figure. The system developed here, once again, is based on a concept paper presented by the author to the 39th Military Operations Research Symposium in June, 1977. The lexicon, which provides the necessary building blocks for achieving the linkages, is of sufficient importance to warrant an entire chapter. The remaining elements are covered in Chapter IV.

CHAPTER V

THE MILITARY LEXICON

The most important component in the system introduced in the last several pages is the military lexicon, or vocabulary. It provides the necessary linkages which allow the military planner to communicate his ideas directly to the computer war game. To repeat the process, each term in the lexicon has a precisely defined model counterpart. When the military strategist or tactician records his tactical plan, these ideas activate the corresponding model functions when the plan is processed by the war game.

As would be expected from the previous discussion of doctrine, two major types of terms are needed in the lexicon. Doctrine dictates which aspects of the environment are relevant. The first type, therefore, consists of lexical elements which control perception. Acting as information filters, these elements enable the military strategist to concentrate only on a limited portion of the total spectrum of potential inputs. Doctrine also outlines the repertoire of actions available to a commander. Terms which control responses, then, form the second major type. Response terms are at the heart of the ability to coordinate.

These major types of terms operate together to represent a doctrine in the war game. The response terms are used to build a number of alternative courses of action. These alternatives are designed to be employed over a selected range of conditions. The perception terms provide the planner with the means of describing the range to which each alternative is to be applied.

This chapter focuses on the elements of the lexicon. Following a general discussion about the vocabulary construction process, the two major types receive the bulk of the attention, with descriptions and examples of their component terms. A third kind of term, one which enables the planner to specify the intended recipient of each component part of the plan, is introduced in between these major types. The great detail in this and the next chapter, the reader will recall, is intended to provide enough information to enable a modelling team to install the system in the CEM or other model should the decision be made to do so.

Vocabulary Construction

Constructing the various elements of the vocabulary is an evolutionary process. The process is constrained by two sets of limitations, one technical, the other conceptual. The technical set stems from the current state-of-the-art in computer and model technology. Storage and speed restrictions place fairly substantial burdens on the drive for improvements. The tradeoffs are such that model limitations caused by speed/storage concerns are often considered acceptable, primarily because corrections would make the model uneconomical as an analytical tool.

Technical problems are not restricted to the computer, of course. Model shortcomings will tend to limit the evolution of the necessary language because certain actions are not possible. Although the system for explicitly controlling forces will eventually be able to attack a number of these more severe limitations, a point to be covered later in Chapter VII, the current model capabilities do not support obviously desirable perceptions and actions. One such problem, to give an example, is that the current procedure of accounting for units negates the ability of more than one unit of the force to be occupying the same horizontal terrain strip (a minisector, in CEM terminology). Clearly, however, the planner might wish to position two units on the same strip, although separated, perhaps, by considerable distance.

Conceptual problems are also limiting the language evolution. Because the lexicon is ultimately intended to translate any doctrine into the computer simulation, it must be designed so as to be virtually "doctrine independent." Lexical elements must not, therefore, necessarily imply the hybrid language if the portrayals are to be accurate. In essence, then, the basic model must be free of any particular doctrine as well. The conceptual problems come from the fact--a fact that would be predicted from linguistics--that it is extremely difficult to demonstrate the appropriateness or efficacy of a vocabulary for describing doctrines which are alien. There appear to be certain terms which are (must be??) universal, but it is probably correct to assume that a set of lexical elements will always be more suited to specific sets of doctrine than others.

Military doctrine is not as complex as a regular language. The scope of activities is much more restricted than that which would lend itself to normal day-to-day living. Because of this relative simplicity, there is a good chance of being able to devise a lexicon that can accommodate most doctrines. This is especially true when one includes the fact that most military planners/strategists dwell on common historical data, understand to a greater or lesser degree modern battlefield dynamics, and often share common weapons and organizational structures.

Another conceptual limitation is that it is difficult to ensure that the "sterile" term in the vocabulary has been successfully translated into an equally sterile function in the computer model. The development process is aided somewhat by the fact that the specification of the interactions of the elements is being removed from the model itself, and is subject to a much wider scrutiny than possible if it were necessary to examine the computer code in order to validate the translation. The problem of function translation, however, is still present. Fortunately, structured programming techniques and the potential for subsequent external review of model operations will make the problem at least approachable.

The end result of the limitations just covered is that the language development must wait for developments in these other areas. There should be some synergism in the effort which will enhance development in all three. The limited language set to be covered in this paper represents an initial attempt, on the one hand, to provide an illustration of the system's potential, while not containing too many elements with no meaningful computer counterparts on the other. There is, for example, a lexical element which enables the planner to specify that he wants a particular unit to be on ground immediately to the rear of another unit despite the fact that, as we have seen, two units cannot be located on the same horizontal terrain strip.

Perception Terms

The perception terms in the Army implementation are called rejecters. This name stems from the way in which the procedure uses the perception data supplied by the planner. Each set of coordinating instructions contains a specification of the environment. This specification must be satisfied by the environment or the instruction set is "rejected." Since each instruction set contains mission, location, and allocation information for all the available forces and resources, a scheme for coordination will be available if the set is not rejected.

A sample of the procedure is illuminating. One of the rejecters in the lexicon pertains to the friendly-to-enemy firepower ratio. Suppose for the minute that this rejecter were the only one contained in a particular instruction set, and disregard the precise definition and manner of calculation of the ratio. If the rejecter value is specified as 3:1, the environment will be evaluated to determine the actual and the desired ratios, rejecting the instruction set if the actual ratio was less favorable to the friendly force than 3:1. In the event that the ratio was at least as favorable for the friendly force as the value specified, the coordinating string of instructions will be used to control the action.

There are eight basic types of information in the initial set. These types relate to information normally considered to be of importance to the commander. They enable the planner, once again, to specify when each alternative is to be used. As with the other portions of the original formulation, these types are bound to change as experience is gained. As the initial effort shows, the set reflects a combination of data available in the basic CEM model and new data to be produced primarily in support of a specific perception requirement.

Table I outlines the eight types of terms. The terms on the left are used throughout the remainder of this paper.

TABLE I

REJECTERS
(Response Terms)

TERM	GENERAL MEANING
Force Ratio	Ratio of friendly to enemy combat power
Frontage	Frontal distance, in kilometers, for which the unit is responsible
Endangerment	Yes/No state concerning the vulnerability of a unit's rear area
Composition	Number and type of unit's subordinates (e.g., 2 tank divisions)
Terrain	Dominant type of terrain confronting a unit (e.g., good tank terrain)
Friendly Plan History	Previous plan employed (e.g., part 1 of a 3-phase operation)
Enemy Mission	Estimate of enemy intentions
Nuclear Status	Is nuclear weapon employment likely?

Although the table provides enough general information to be used as a handy synopsis, additional details on each of the terms are provided below.

Force Ratio. This measure reflects relative combat power belonging to two opposing forces. It is always formed by dividing the actual friendly firepower by the firepower estimated for the enemy forces. Each weapons system represented in the CEM has a set of firepower values. These values are intended to reflect the relative kill capabilities of the weapon in a variety of postures, such as prepared defense or attack, when used against a variety of targets, such as personnel or tanks. The aggregate total of the firepower available to both sides is used to assess the engagement outcome. The assessment determines weapon losses, casualties, unit movements, and other key changes.

The friendly firepower is the sum of firepowers for weapons belonging to all elements of the unit, to include organic fire support, as well as a quantity of close air support estimated to be the fraction of the total available to the parent unit as specified in the order. While the friendly firepower is determined using actual quantities of weapons and organizations, the enemy firepower is an estimate, tempered by current intelligence, of the current enemy capability. The estimate is based upon historical data and modified to reflect the estimated enemy mission.

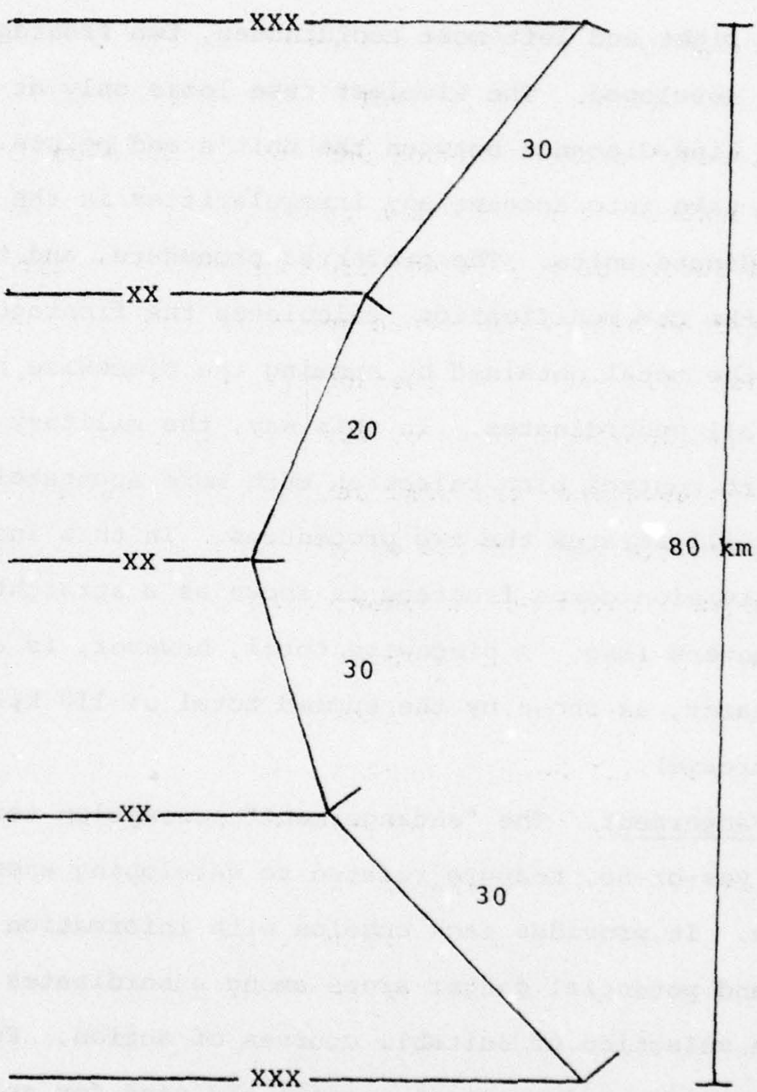
Frontage. This measure of the environment concerns a unit's responsibility for terrain occupation and/or observation. On the conventional battlefield, this measure normally refers to a portion of the forward edge of the battle area, FEBA. In general, however, the measure relates to the density of combat power a unit of a certain type and size can distribute across its exposed surfaces. In the case of a unit engaged in an "island defense," for example, where attack could come from any quadrant, the frontage would be the length of the perimeter.

In the CEM, where each unit not in reserve is assigned a set of right and left-most coordinates, two frontage lengths could be developed. The simplest case looks only at the straight line distance between the unit's end points. This does not take into account any irregularities in the locations of subordinate units. The preferred procedure, and the one used in the CEM modification, calculates the frontage for each unit as the total obtained by summing the piecewise portions held by all subordinates. In this way, the military planner is able to control plan rejection much more accurately. Figure 2 illustrates the two procedures. In this instance, a four-division corps frontage is shown as a straight line 80 kilometers long. A piecewise total, however, is appreciably greater, as shown by the summed total of 110 kilometers (38% increase).

Endangerment. The "endangerment" perception term is a binary, yes-or-no, measure related to developing enemy penetrations. It provides each echelon with information about trends and potential danger areas among subordinates, permitting the selection of suitable courses of action. For the defending side, endangerment signals the need for actions designed to preserve the integrity of the force. Endangerment

FIGURE 2

FRONTAGE CALCULATIONS



to the attacker, on the other hand, suggests actual or impending penetration and can signal continued attack.

Endangerment refers to the security of a unit's rear area. If enemy attacks are gaining ground so rapidly as to either disrupt or destroy the combat support and combat service support functions carried out in the area, the unit is considered to be endangered. As part of the data inputs to the war game, each unit is assigned a depth, in kilometers, for its average operations. This depth is from the FEBA back to the boundary between a unit's rear area and the next higher echelon. For planning purposes, as an illustration, a division might have a depth of 10 kilometers. The next higher echelon, a corps, has responsibility for the area to the rear of this 10 kilometer boundary. If the penetration is gaining ground rapidly, and the division rear area is unable to function, the division is endangered.

In the initial modification, the depth information is used in a somewhat artificial manner to determine whether or not a unit is endangered. The CEM time structure usually calls for two subordinate combat cycles during a single parent cycle. In other words, a division normally plans and executes two division time periods of operations for each corps time period. In order to permit the corps to "sense" that it is endangered, the speed of advance of a potential penetration during a division time cycle is multiplied by the number of division cycles occurring during a single upper echelon cycle. If this projected advance is greater than the depth of the unit, then it is endangered.

As previously mentioned, endangerment is a key signal for both sides. It also forms the basis for a significant enhancement in combat portrayal. The major intent of the penetrating force is to push through the forward combat forces, reach the relatively soft rear areas, and disrupt the defender's ability to support continued combat. Defenders occupying fortified positions are able to exact heavy casualties on the attacker only if they are well supported. The "pay off" for penetration, therefore, must relate to the supportability of the defender. A successful thrust into the rear area must be reflected in the defender's inability to sustain his bypassed units.

The impact of endangerment on the support capabilities available to the defender is direct. The functions of an endangered rear area are curtailed, either partially or completely, in line with the values entered for the unit under attack. In addition, all of the subordinate units of a parent are constrained, even though the developing penetration is not within a subordinate's sector. Finally, the effects of a penetration are limited to units which share a common support system. Divisions belonging to two different corps, even when they happen to be adjacent to one another, are not equally impaired unless both corps are being penetrated.

As a pay off for penetration, the attacker receives direct, although delayed, impact. The combat forces encountered in the rear area will tend to cause lower casualties to the attacker, enabling the attacker to operate longer with the same force than would otherwise be possible. In addition, the inability of the penetrated rear areas to support the forward combat elements will be reflected in the gradual reduction in combat power as resources are consumed but not replaced.

Composition. An important determining factor in a commander's decision to apply a certain course of action is the composition of forces available to him. In the CEM, the problem is simplified somewhat by the relatively stylized organizations possible. The composition rejecter, however, enables the military planner to specify the number of each type of subordinate unit required to consider a plan for action.

Units are identified by type upon entry to the model. A coding convention has been established to facilitate rapid entry of composition data, although these conventions can be easily overridden. Numbered one through five, these conventions in order are airmobile, armor, infantry, mechanized infantry, and "special."

The composition rejecter, coupled with the ability to identify unique organizations, provides a powerful means of employing forces differentially. A basic concern which has created much of the interest in changing the theater wargaming capability has been selective employment. A unit with special characteristics of weapons and organizations should be eligible for unique usage. Key here, in repeating the point made in an earlier chapter, is the idea that force designs can best be evaluated if force employment concepts can also be evaluated. Existing forces may perform better using new tactics. New force designs may require new employment concepts to reflect the design characteristics. It is unreasonable to assume that the employment concepts used to guide conventional forces will be adequate to evaluate the performance of a radically new design.

Nationality and other attributes can also be used in the composition rejecter, especially if the plans are intended for corps-size units where the conventions have less meaning than at the division level. If a segment of the force shares a common doctrine, whether through national influences or some other factor, and the differences in resulting doctrinal responses are of particular interest, the composition rejecter can highlight the performance.

Terrain. Analysis of the terrain is a significant portion of the ground commander's estimate. The type of defense developed by a force, for example, depends to a great extent upon the type terrain to be defended.

To enable the planner to tailor plans to specific types of terrain, a terrain rejecter is used. Terrain type determination is made prior to considering any single plan. The evaluation is done for terrain to the front for attacking units, and to the rear for defenders. Each echelon has a depth of terrain interest which is input. This depth is used as the distance from the FEBA to the front (rear) of the unit when the evaluation is being done.

The CEM recognizes four types of terrain. These types, along with their original letter designations, new rejecter values, and general descriptions, are presented in Table II.

TABLE II

CEM TERRAIN TYPES

TYPE	REJECTER VALUE	GENERAL DESCRIPTION
A	1	Open, excellent for tanks cross-country
B	2	Marginal for tanks and wheels cross-country
C	3	Tanks and wheels are road bound
D	4	Natural/man-made barrier

The terrain evaluation consists of determining the average terrain values for selected points throughout the unit's sector. The sector is generally a straight line projection of the unit's boundaries to the front, for attack, and to the rear for defending units. The terrain rejecter entry in the plan is used as the standard against which the average value is tested.

Friendly Plan History. Most tactics used by upper echelon forces can be characterized as requiring coordination over protracted periods of time. These operations often have distinct phases during which specific tasks must be accomplished. Continuation is normally made contingent upon successful completion of these intermediate goals. The device for reflecting this type of operation in the model environment is a specific rejecter, called in Table I "friendly plan history." Through the use of this rejecter it is possible to develop plans consisting of several phases, each phase containing all the information needed to continue an operation if the situation remains favorable. By requiring that follow-on phases be considered only after successful execution of preceding ones, positive control is possible.

A simple illustration using this rejecter should suggest its versatility. The CEM structure, once again, is time-stepped, meaning that intervals of time rather than specific events are used to increment the simulation from start to finish. In most applications the smallest time step is twelve hours. Each parent unit is usually expected to require twice as much time to plan and execute an action as a subordinate. Within each parent plan, therefore, two sets of instruction must be there to control the more responsive subordinates. In multiple phase operations, however, the parent unit attempts to plan and control a major operation over several of its own time periods. Unfortunately, in a very real sense the "commander" in the model exists only in the present. Each order received from the parent unit triggers a complete evaluation. The "commander" does not possess a "memory" about the past and he does not attempt to forecast future events. The one exception to the lack of memory, of course, is the friendly plan history. This enables the "commander" to know what plan was most recently executed.

Suppose that an attempt to penetrate must be preceded by a period of force concentration or massing. Suppose further that the number of subordinate time periods required to accomplish both of these tasks is greater than the number of time periods covered by a single plan. Since the circumstances which suggest a massing attempt are capable of being specified, as are the conditions needed to attempt a penetration, the linkage between the two is the plan history. The massing activity would be in response to a certain set of conditions. The penetration effort would also be in response to a specific set of circumstances, including the fact that the massing called for in the preceding plan had been undertaken.

The system designed for the CEM is simple, efficient, and does not require significant memory storage to maintain the necessary information. Two data elements are needed. The first is the identifying plan number of the plan selected and executed during the most recent time period. Each plan has a unique number established at the beginning of the simulation. The second data element is provided by each plan. It can be a "-1," "Ø," or a "+1." A "Ø" is the default value and is interpreted to mean that the plan is indifferent to the sequence of preceding plans. A "-1" on the plan, however, specifies that the plan is an intermediate portion of a phased operation and that it can only be selected if the immediately preceding plan had an identifying plan number equal to one less than the current plan. Since multi-phase operations are sequentially arranged, the test is simple to construct and easy to plan for.

The third possibility for this rejecter is a "+1." This value signifies that the plan to which it is attached is not to be used successively. This would be the case, for example, for the first part of a multiple-phase operation. Since the sequential arrangement would hold up this first phase for consideration prior to following phases, the lack of a means to prevent successive use would make such portrayals difficult to accomplish so long as conditions remained favorable enough.

Enemy Mission. Estimating the likely actions of the enemy is an integral part of the commander's estimate. The enemy's intention may have little to do with the type of action to be conducted, but the manner in which this action is accomplished will depend upon what actions the enemy will probably take.

To provide the "commander" with this type of estimate, a numerical value is computed which incorporates the estimated enemy intentions of the forces facing the unit in its sector.

The estimates include only the enemy units which are one echelon below the unit for which the analysis is being done. A corps, therefore, receives an estimate developed from the estimated intentions of opposing divisions. The values can range from one to five, and have the following meanings: one, attack; two, defend from prepared defensive positions; three, defend from unprepared positions; four equals delay; and five indicates that the enemy forces in the sector are likely to move from the area.

Unless intelligence is provided to gain immediate knowledge of impending enemy actions, as would be the case if compositions, strengths, and positions were evaluated, it is assumed that the enemy will attempt to continue whatever action was observed in the preceding time period. Units in defense will continue to defend unless contrary information is introduced. As a last resort, if there is no information about what the enemy intends to do, the friendly commander assumes an enemy mission which is complementary to the friendly mission.

Nuclear Status. The commander's perception of the nuclear weapons status may be an important factor in his decision regarding future actions. Although the CEM is limited to representations of conventional war, the lexicon is intended to support a broader range of combat. The nuclear status rejecter is used to permit varieties of responses when approximately equivalent conditions, except for nuclear weapons possibilities, exist. A commander confronting two similar forces, one when the use of nuclear weapons is extremely remote, the other when their use is likely, will tend to distribute and coordinate his forces differently.

Three numerical values for the nuclear status rejecter are possible. A zero means that nuclear status is of no importance to the plan. A one inserted in a plan means that the plan will be rejected if the nuclear status currently maintained by the war game is equal to one or two. A value of one is interpreted to mean that nuclear weapons are likely. A value of two means that nuclear weapons have already been used. Plans containing this value are rejected if the current model status is equal to two.

The value(s) to be used for the nuclear status rejecter is (are) provided as input rather than as a calculated value. The military planner determines, prior to the start of the simulation, the nuclear status value(s) to be used, and when changes to the status, if any, are to be effective.

Match Terms

Once a plan has been selected using the rejecter terms in the lexicon, it is necessary to distribute the component parts of the plan among the subordinate units. Each subordinate must receive instructions, but which ones? The requirement led to the development of vocabulary items called "match terms." These enable the planner to record and express his desires for matching all parts of a plan with all subordinates.

The actual matching process is normally accomplished implicitly. The commander develops a concept of operation which accounts for the forces and resources he knows are available. He makes assessments of unit strengths and weaknesses continuously, so that he typically applies these assessments automatically. Modeling this match process, however, requires explicit treatment. The planner is engaged in an intellectual activity devoid of much of the information available to the real commander.

Table III gives the set of match terms. The eighteen terms, although not exhaustive, provide enough variation to give the needed flexibility to the planner.

The list of match terms can be categorized into two groups. The larger of the two groups, encompassing the first thirteen terms, contains words for expressing relationships. These terms trigger an evaluation of all eligible subordinates to determine which of them most closely meet the match word. Using code "8", for example, would instruct the model to determine which of the subordinate units occupied the largest frontage.

The five remaining terms form a group of composition-related words. These enable the planner to specify a particular type of unit for a particular part of the order. An armor unit might be desired for the main thrust of an attack, for example. Also, through the use of "special unit," code "18", the attributes of a unique unit can be selectively called for and tested.

TABLE III

MATCH TERMS

CODE	DESCRIPTION
1	Left-most unit
2	Right-most unit
3	Center unit
4	Front unit
5	Rear unit
6	Largest endangerment
7	Smallest endangerment
8	Largest frontage
9	Smallest frontage
10	Largest firepower
11	Smallest firepower
12	Largest friendly-to-enemy force ratio
13	Smallest friendly-to-enemy force ratio
14	Airmobile unit
15	Armor unit
16	Infantry unit
17	Mechanized infantry unit
18	Special unit (user-defined)

Three rules govern the employment of the match terms. The first is that a unit once matched with a part of the plan is no longer considered during other match tests contained in the plan. In other words, a unit identified as having the largest firepower would receive the part of the plan having that match term. The unit would not be looked at again until the next planning iteration. The same match term could be used again for the next segment of the plan, of course, but only "unmatched" units would be included in the comparison. The second rule simply states that the final segment of the order must go to the final unit, regardless of the match term used in the order. The third rule applies to follow-on portions of a multiple phase operation. Intermediate phases which do not contain match instructions are interpreted to mean that units will receive the same segment of the new plan. In other words, the unit that was identified through a match term to be the recipient of the third element of the initial part of a multiple phase plan can receive the third element of successive plans if the planner desires to do so.

In anticipation of possible ambiguities and other problems with the match terms, two conventions have been developed. The most important of these concerns the internal structure of the plan itself. Since the likelihood of match problems increases as the number of eligible units is reduced, and recalling that each match operation reduces the number of eligibles by one, it is important that the plan be organized in descending order of priority. The segment of the plan which is most important to the commander's concept of operation should be the first in the plan. A unit may satisfy more than one match requirement. An armor unit may possess the largest firepower <u>and</u> the largest frontage. If the plan is not ordered properly, the most important unit may be matched inappropriately with a secondary mission.

The second convention designed to overcome match problems is a part of the model. If a match term cannot be satisfied, although this is unlikely if the plan is intelligently prepared, the next match code used in the plan will be applied. This would be the case, for example, when a plan attempted to match the first of its segment with a type of unit that did not belong to the organization. This problem could be avoided, of course, by using the rejecter terms to specify that the plan is not to be used unless a particular type of unit is available. The final aspect of this automated convention, and the least desirable portion, is used when all else fails. Unmatched units are ordered in terms of firepower. The strongest of these units receives the first of the unmatched plan segments, the next strongest receives the second segment, and so on until the plan is completely issued.

Response Terms

The second major type of term in the lexicon concerns the control of the forces and resources available to the commander. These terms, categorized here as response terms, provide the means by which a doctrine can be expressed in the actions and reactions of the simulated forces.

A primary function of the operations order is to give substance to the commander's concept of operation. This order has three basic ingredients, of course, and any viable concept must be translatable into a particular combination of them. Specifically, the order must consist of mission assignments, location instructions, and resource allocations. Missions must be executable, locations must be reachable, and resource allocations must not exceed capacity. Any scheme for coordinating forces and resources must, finally, be stated in these terms. The remaining pages in this chapter cover these three essential ingredients. Although more obvious than the preceding topics, these terms are equally important.

Missions. Every unit has a general repertoire of actions it can perform. Force structure, weapons systems, transportation, and other support capabilities determine the specific types of actions which can be asked of the unit, of course, but the broad classes of action are limited. Found in this general repertoire are attack, defend, delay, and reserve actions. Once again, capabilities and doctrine dictate the details of the implementation of each of these general types of actions, but the classification is useful.

In the simplified world of the CEM, and bolstered by the focus on echelons from division level and up, the broad classifications are adequate for directing actions. A corps instructs a subordinate division to attack, usually in a particular direction and at a particular time, but the details of the attack generally remain for the division commander to develop. In the CEM modification, these "details" are precisely the contents of the plans available to the subordinate commander.

Mission capabilities in the CEM are different for the various echelons. Theater and Army echelon forces can be instructed to attack, defend, or delay. Corps and division echelons are able to receive instructions to move to a new location, or to act as a reserve, in addition to attack, defend, and delay. These categories of actions are actual mission instructions contained in the plan. They also serve an essential function in plan selection and plan set organization, two topics to be covered fully in the next chapter.

<u>Location Terms</u>. The second major portion of the "response" contained in the plan concerns the commander's scheme for force disposition. Locating forces on the battlefield is vitally important to most plans. The commander develops concepts of operation and orders which contain detailed location instructions for each element of the force. Skillful positioning is often the most significant aspect of the concept.

The CEM system for specifying this type of information consists of a number of location terms. Each term, when used in a plan, activates a particular model operation designed to implement the desired positioning. The preliminary set of these location terms is found in Table IV. The first and second columns show the name and the computer code number of each term. The third column describes the parameters associated with seven of the eleven codes. To activate each term simply requires the use of the code in the appropriate position of the plan. The four terms without parameter requirements are complete by themselves. The remaining terms, however, must be accompanied by more data in order for the term to be applied. The term "specific quantity," for instance, says that a unit receiving the instruction is to accept responsibility for an amount of the FEBA equal to the number provided as a parameter value in the plan. Likewise, the term "percent of parent frontage" must be accompanied by a value for the "percent" to be used.

Although the meanings of most of the terms listed in the table are obvious, a few words are presented below to clarify and expand each one. Two points should be kept in mind while examining them. The first point is that they were designed to be used in a variety of doctrines, real and imagined. The second point is that the terms have little meaning when taken out of context. That which seems implausible to one doctrine may be at the heart of another.

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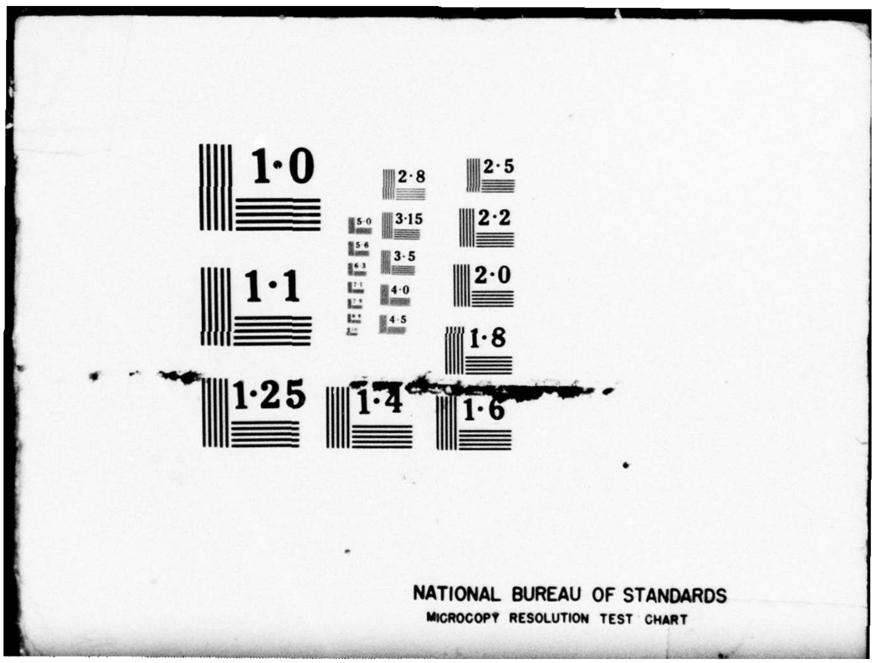

NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

TABLE IV

LOCATION TERMS

TERM	CODE	PARAMETER MEANING
Equalize Firepower*	1	N/A
Equalize Force Ratio*	2	N/A
Specific Quantity	3	Number of kilometers of FEBA to be occupied
Opposite Strength	4	Number of kilometers to right and left of center of estimated enemy strength
Opposite Weakness	5	Number of kilometers to right and left of center of estimated enemy weakness
Center of Sector	6	Number of kilometers to right and left of the sector center
Rear of Parent	7	N/A
Terrain	8	Center on terrain of type 1, 2, 3 or 4 (see rejecter discussion of terrain)
No Change*	9	N/A
Percent of Parent	10	Percentage of total parent forces to be occupied by the unit
Center on Maximum Endangerment	11	Number of kilometers to right and left of the center of the maximum endnagerment

* By convention these codes must be used for all units with the exception of units entering, in, or leaving reserve positions.

Equalize firepower. Use of this term causes an evaluation of the friendly unit firepowers, and the distribution of the units according to their ability to occupy the FEBA. A unit which has 30% of the total firepower held by the subordinates would be required, therefore, to occupy 30% of the FEBA responsibility assigned to the parent. This term is designed for use when intelligence is poor, enemy intentions are unknown, and defensive positions are being taken.

Equalize force ratio. This term assumes that some intelligence is available to make estimates about enemy firepower possible. These estimates are combined with the friendly firepower to adjust unit boundaries so that an approximately equivalent ratio is established across the length of the FEBA. This term is also intended for preparing defensive positions, although additional intelligence is required.

Specify quantity. Some tactics are developed around the ability to concentrate forces at key points. The massing-penetration-breakthrough technique is a current example. The purpose of this term is to permit the specification of the desired frontage to be held for a particular operation. In this way, for instance, the lead division in the attack can be placed along a four or five kilometer front.

Opposite strength (weakness). These two terms trigger an evaluation of the opposing forces to determine the strongest (weakest) enemy position. Once this segment is found the friendly unit is distributed against it. Although numerous contexts are possible, the primary use for the strength determination will be for defensive orientations, while the weakness information probably will be used to orient offensive forces. To avoid unrealistic shifts in units and their boundaries, of course, these terms should generally be used for units which are being deployed from a reserve position.

Center of sector. This term causes the unit receiving this instruction to be distributed along the parent FEBA at the center of the parent sector. Once again this term is probably most useful for re-engaging a reserve unit.

Rear of parent. This term is intended for use in withdrawing a subordinate from the FEBA. The term causes the vacated position to be occupied by the adjacent unit, or units, as the case may be, belonging to the same parent. The boundary adjustments applied to these units are subject to change if other location terms are used in the same order. The actual adjustments when two adjacent units are involved are based on a comparison of unit firepower, each unit being assigned a portion of the vacated position commensurate with its relative strength.

Terrain. To enable the planner to position forces on specific types of terrain, this term calls for an analysis of the area immediately along the FEBA. As discussed earlier the CEM uses four types of terrain to determine unit movement speeds, barrier effects, and other terrain related aspects. This term determines the terrain in the sector which most nearly satisfies the requirement and places the unit on it. Once again, to avoid turbulence this would be used most often when bringing a unit from reserve.

No Change. This term preserves the same relative positions of the subordinate units throughout the parent unit sector established during the preceding time period. No boundary changes are made, regardless of the force disposition resulting from the battle engagement assessments during the previous period. The term will probably prove useful for certain types of operations which have a number of related phases.

Percent of parent. This term is designed to allow the planner to place a unit along a certain percentage of the parent frontage. It is to be used primarily to adjust the boundaries of units already occupying FEBA positions. Used in conjunction with resource allocation instructions, this term should provide the ability to concentrate a force along a certain segment of the sector. Also the term can perform a function similar to the "specific quantity" term, but in a more flexible fashion because the system will always be able to determine a percentage without ambiguity or conflicts. Using "specific quantity," for example, it is possible that areas will become overly weak in situations where the parent has a large FEBA responsibility. It is also possible that the number of kilometers called for might not be available if the total parent responsibility is quite small. These problems are avoided by the use of the "percent of parent" term.

Center of maximum endangerment. As mentioned earlier during the discussion of the rejecter terms, endangerment is a means by which units are able to detect and communicate an impending disruption of a rear area of operation. Based on the speed of FEBA movement during the most recent period of time, the information is available to both the attacker and defender. The attacker can use the information to heighten the attack by selecting a plan which is designed to exploit the earlier success. The defender can use the information to trigger increased defensive activities, with the possible use of counterattacks, blocking positions, and so on, in order to preserve the integrity of the unit.

To take advantage of this endangerment information through appropriate responses, the location term is used to orient the units on the center of the principal endangerment area. The term determines the maximum endangerment existing in the sector by comparing the recorded speeds of advance. The portion of the sector which has experienced the fastest movement becomes the focus of attention.

Before leaving the location terms, a brief look at Table IV will expose the possibility of ambiguous and contradictory location instructions. A unit, for example, may be instructed to occupy thirty kilometers of the FEBA although the parent unit may have only 20 kilometers of unassigned FEBA available. To ensure that the impact of this type of problem is kept to a minimum, a combination of procedural conventions and model functions should resolve any conflicts. Principal among these techniques is the avoidance of concurrent use of selected terms, as noted in the table. Also, and for the same reasons found important to avoiding match term conflicts, the plan must be arranged in order of importance to the commander's concept. In this way, the first unit is treated first with respect to location assignment. Successive unit location instructions may be in conflict with the first unit, but conflicts will be resolved in its favor.

Resource Allocation. A significant feature of the coordinated plan is the allocation scheme for supporting resources. In the CEM context, the resources available to the commander include cavalry, close air support, and artillery. Each of these can be made available to one or more subordinates in order to support the commander's concept of operation. (Note: There remains the possibility for later work on the CEM to widen the allocation control to include other areas, such as logistics support.)

The initial approach used to allocate the resources is very simple. The plans contain positions for the planner to specify, as a percentage of total available, the desired support scheme. The use of percentages accomplishes two things. In the first place, since the actual resource situation cannot be predicted accurately, the planner's entries reflect his desired weighting in support of his concept. Second, the percentage approach enables the model to process the plan regardless of the availability of support. This would not be the case, of course, if the planner could specify precisely how much fire support would be required. A related advantage is that the planner, in anticipation of greater resource demands in the future, can withhold additional support. In other words, the plan can contain allocation percentages which do not total 100%. In this way, the planner is able to practice resource conservation. A final point to be made concerning this allocation approach is that, despite the fact that the planner is operating in the dark about the actual quantity of support available at the time of plan employment, he can, through the use of rejecters, ensure that some minimum level of these resources is available. Specifically, by using the force ratio rejecter, which takes into account the availability of ammunition and other support-related factors, the availability is implicitly treated.

This chapter has presented an initial vocabulary intended for use with the Concepts Evaluation Model. As a group, the vocabulary terms will permit relatively refined analysis and specification of strategies and tactics for units above the division level. When coupled to the war game via a number of connecting links, to be covered in the next chapter, the vocabulary will drive the dynamic simulation.

As with most aspects of the design work presented in this paper, the lexical elements are somewhat primitive. A mixture of existing and envisioned model capabilities has been used as a guideline, which accounts for some of the artificialities and limitations. The theater level simulation is, for many neophytes, a primitive affair. The most remarkable features about this level of war game are often those which are absent. The problem is compounded as well by the experimental nature of the approach itself. In the end, however, the approach promises to bring many of the previously exempted aspects of combat within the computer-based war gaming framework.

CHAPTER VI

PLANS

The military lexicon introduced in the preceding chapter is intended to serve as a hybrid vocabulary for the planner and strategist. Taken by itself, this lexicon may have properties which make it useful in a number of situations, the topic of the next chapter. The primary purpose for its creation, however, was to enable the planner to interact directly and flexibly with the CEM war game. This chapter deals with the various components of the interface system designed to link the planner, using his specialized language, and the simulation. Starting from the planner's position and working inward, the first of these components is the plan. The plan is simply a recording device, much like a contingency plan, for a preplanned response to a hypothetical situation. As discussed earlier, of course, the plan in this context contains more information than the plan of normal usage. Once again, it must contain information about when it is to be applied in addition to what actions are to be taken. The plan also must have several desirable attributes, including ease of understanding, simplicity of transformation from one form to another, and a format which is readily transportable.

Crossing the line now between the planner and the model, the next major component required is an orderly and rapid storage and retrieval system for the set of plans. This component consists of some simple conventions and a direct access data processing device. This latter feature enables the model to rapidly recall one or more particular plans from among the entire set.

The final major component needed in this interface is a system which enables the model to interpret, compare, and select a plan from among the various alternatives. The role of the rejecter terms here has already been covered. The complete selection algorithm, however, deserves closer attention because it is in this component where all the various parts of the command and control system come together. It is here, finally, that the simulated environment is interpreted, a plan is selected, and the fundamental building blocks of missions, locations, and resources are meted out to each and every unit.

Plans Worksheet

A good deal has been said about the nature and role of the plan in the command and control system. The concept takes on additional weight, however, when brought into the realm of practical application. The plan worksheet is the primary medium here. It is the basic unit of the system, containing all the elements needed to portray some scheme of coordination. Figure 3 shows the make-up of this worksheet. Using a minimum of information beyond the special lexicon, the planner can use the worksheet to record and enter his concepts.

FIGURE 3

PLAN WORKSHEET

COMMAND AND CONTROL PLAN WORKSHEET

PLANNER: DATE: PLAN ID:

5 10 15 20 25 30 35 40 45 50 55 60 65 70

INDEX CARD 1	SIDE	ECHELON	MISSION	RESERVE	NO. OF SUBS	VERSION									
REJECTERS CARD 2	IFP RATIO	FRONTAGE	ENDANGER	AIRMOBILE	ARMOR	INFANTRY	MECH	SPECIAL	TERRAIN - F	TERRAIN - R	PREVIOUS PL	ENEMY MSN	NUC STATUS		
MATCH CARD 3	SEG 1	SEG 2	SEG 3	SEG 4	SEG 5	SEG 6	SEG 7	SEG 8	SEG 9	SEG 10	SEG 11	SEG 12			
CARDS NUMBERED 4 TO 16	SEGMENT NUMBER	MISSION CYCLE 1	LOCATION CODE	LOCATION PARAMETER	ARTILLERY PERCENT	CAVALRY PERCENT	CAS PERCENT	MISSION CYCLE 2	LOCATION CODE	LOCATION PARAMETER	ARTILLERY PERCENT	CAVALRY PERCENT	CAS PERCENT		
	1														
	2														
	3														
	4														
	5														
	6														
	7														
	8														
	9														
	10														
	11														
	12														

5 10 15 20 25 30 35 40 45 50 55 60 65 70

FIGURE 3

The form itself is a simple compromise of human and machine requirements. From the human standpoint, the general organization parallels the course of action taken by the commander. He estimates the situation, selects his concept of operation, and issues his orders. The form offers a menu of vocabulary options available to the planner to speed his planning process. Finally, the form is easy to understand with a little practice, making review and discussion of the recorded concepts feasible.

On the machine side, several design features are found in the worksheet primarily to facilitate rapid and unambiguous translation into a form that can be used by the model. Each line of data on the worksheet represents a single 80-column computer card. The first card contains indexing data, for example. The second design feature to support the translation is the uniform column composition of each card design. Each data item is entered in a five column cell. This makes for rapid key punch data entry, of course.

Turning now to a detailed look at the worksheet, we begin at the top of the form. Here the planner and date of preparation are recorded. In addition, a unique plan identification number can be assigned to the plan for external reference. Although the actual index number assigned to the plan is determined dynamically by a processor prior to the use of a set of plans, this external reference number is useful for maintaining a master list of plans regardless of the set(s) in which used. The remaining area at the top can be used to record other information, such as review and revision dates, or a description of the coordination scheme implied in the plan.

Moving to the next line of data, labelled INDEX, six items of information are indicated. The first five items, when completed, determine a unique address within the plan storage structure. The planner systematically develops at least one plan for each of these feasible addresses. In the event that more than one plan is developed for a particular combination of side, echelon, mission, reserve status, and number of subordinates, the version number entry indicates the relative position of these various plans found at the same address. The indexing system will be discussed at greater length in a later section. From the worksheet viewpoint, however, this line is simply a way of providing internal and external sequencing and control information.

Perception inputs to the plan are recorded on the next line, labelled REJECTERS. The form has 13 data blanks keyed to the rejecter terms discussed in Chapter V. It is on this line that the planner records the test value for each rejecter to be used in the plan selection process. The actual test procedures for each of these rejecters will be covered in detail under the section entitled "Plan Selection."

The next line on the plan worksheet, labelled MATCH, is used to record the matching instructions to be used in parceling out the component segments of the plan. Up to 12 units can be matched with 12 segments. The match code entered in the first cell is used to specify which of the subordinates receives the first segment, the next is used to determine the recipient of the next segment, and so on.

The remaining lines of the worksheet all have the same format. The number of these lines is equal to the number of subordinates indicated on the INDEX line. These lines contain the "bottom line" of the entire process, of course. The coordination concept, no matter how sophisticated, must be expressable. Expressable here means a mission, location, and a portion of the supporting resources given to each and every subordinate.

Within each of these instructions to subordinates, two consecutive time periods of data are provided. This is not intended to suggest that a parent unit will always require twice as long as its subordinates to complete an iteration of the planning cycle. It is not intended to suggest, either, that subordinates will necessarily conduct two operations for each set of instructions received. The system is variable, allowing the subordinate/parent time relationships to be altered. The time division suggested by the worksheet is, however, a convenient one for most types of situations. The structure enables the strategist to control two periods of subordinate actions by providing discrete mission assignments, location instructions, and resource allocations for each unit.

Plan Set Organization and Storage

The plans must be organized in special ways in order to store and use them. Each set of plans must contain at least one plan for each possible combination, or state, of model conditions used in the indexing system. Also, the versions within each of these combinations must be organized in a particular manner in order to reflect the desires of the strategist. As will be seen, the plan selection procedure depends upon a sequential examination of the versions within a particular combination. This "internal" order of the plans is important, therefore, in determining which responses are considered first.

The structure described here is designed around the CEM context, of course. The model content determines the numbers and types of feasible combinations which must be accommodated. In describing the plan set organization in the CEM context two additional functions are served. First, an overview of the organization will provide insights into the volume of plans needed. A context which called for fewer feasible combinations would require fewer plans. A model which portrayed another side, an additional echelon, or some other increase would naturally demand a larger structure. Second, the structure presented here will suggest once again the stylized organization of the CEM context.

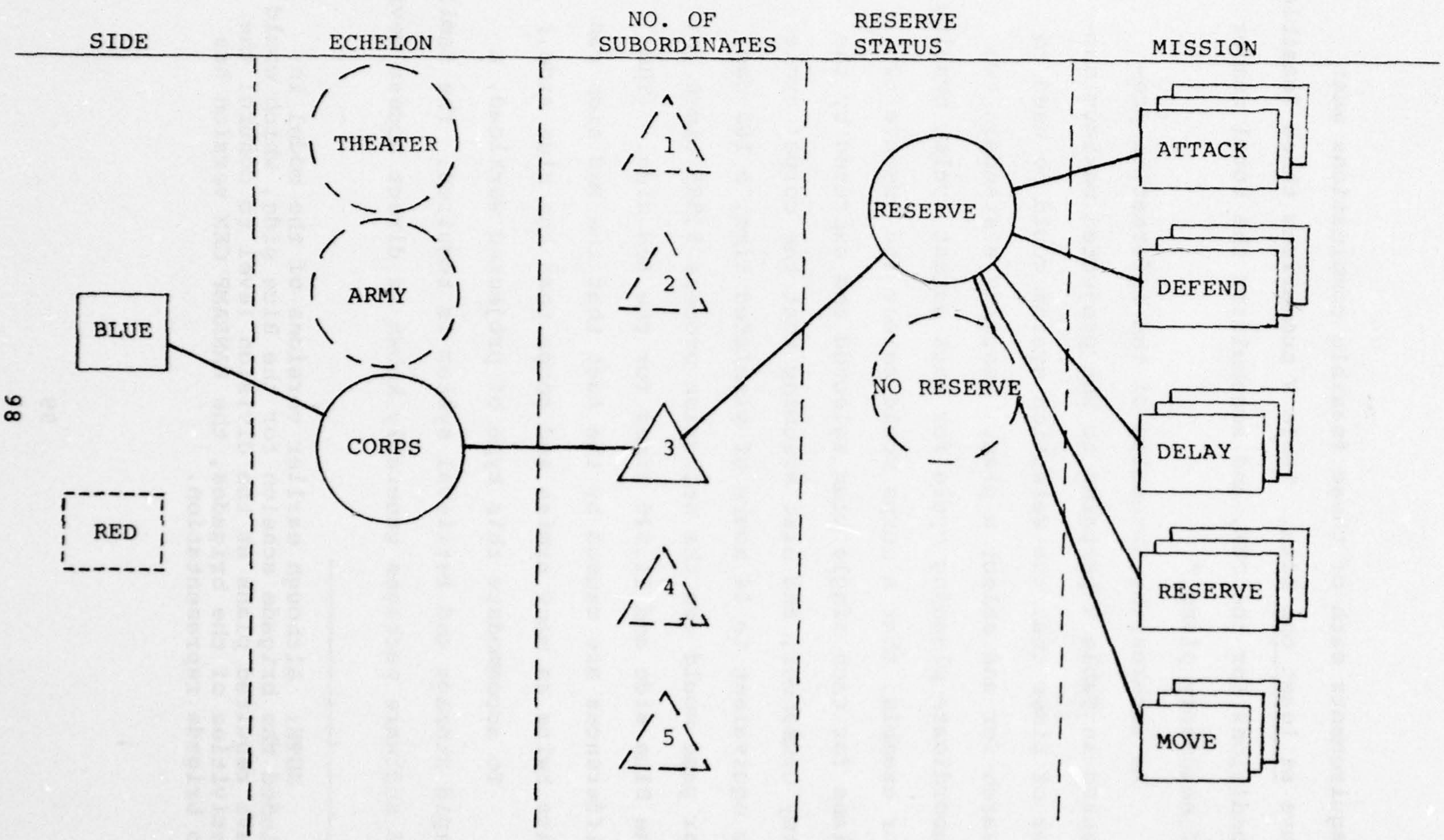
Within this organization, many real world combinations of forces and resources and refinements in the command and control process are simply not represented.

Figure 4 suggests the general structure. Although the figure displays only a part of the total, the basic components are all represented. From each symbol in a particular column, such as SIDE, a line is drawn to each symbol in the column to the right. The end result of this expansion is a large number of plan combinations in the right-most column. In the figure, this column contains only the feasible combinations and missions for a blue (side) corps (echelon) having three subordinates, at least one of which is in reserve. Specifically, this type of unit can receive five types of missions. The multiple rectangles in the MISSION column represent the fact that each of these missions may also have any number of plans, each tailored to some particular situation under the general mission.

From the figure it can be seen that CEM portrays two sides (Red and Blue), three echelons (theater, army and corps), two reserve conditions (none and at least one subordinate unit in reserve), a variety of possible subordinate unit counts, and up to five missions. The last two aspects are determined by the particular side and echelon, the differences attributable to slight asymmetries existing in the original design of the CEM. To satisfy the minimum operating

FIGURE 4

PLAN SET STRUCTURE



requirements each of these feasible combinations must have at least one plan. Table V summarizes these feasible conditions for the CEM, and accumulates the total number of necessary plans.*

An interesting extension of the information presented in Table V pertains to the projected maximum number of times that the selection system could be used to search for and select a plan. Assuming a standard two subordinate planning cycle for each parent cycle, meaning, for example, that a corps would select and execute two plans for each single plan selected and executed by the Army Commander, and also assuming that the corps' cycle is equivalent to 24 hours of simulated time, a 180-day war game would use the selection process 5,985 times for the Blue side and 11,925 times for the Red side. (The differences are caused by the fact that the Red side can have twice as many armies and corps than the Blue side.)

To accommodate this type of projected workload, a rapid storage and retrieval system is required. The family of software packages generally known as direct access devices

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NOTE: Although earlier versions of the model included the brigade echelon for the Blue side, which would have required plans at the division level to control the activities of the brigades, the WARRAMP CEM version has no brigade representation.

TABLE V

NUMBER OF PLANS*

ECHELON**	SIDE BLUE			
	Corps	Army	Theater	
Possible Missions	5	3	3	
Possible Counts of Subordinates	x4	x4	x5	
SUBTOTAL	20	12	15	
Reserve States (yes or no)	x2	x2	x1	
Echelon TOTALS	40	24	15	
SIDE TOTAL				79

	SIDE RED			
ECHELON**	Corps	Army	Theater	
Possible Missions	5	3	3	
Possible Counts of Subordinates	x4	x4	x11	
SUBTOTAL	20	12	33	
Reserve States (yes or no)	x2	x2	x1	
Echelon TOTALS	40	24	33	
SIDE TOTAL				97

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* Actually, only the number of feasible combinations is reflected here since each feasible combination can have any number of variations.

** Echelon titles are selected to convey relative sizes only. Detailed force definition is provided as input.

are ideally suited for the task. Although varying in detail, these devices all enable the programmer to go directly to an individual record within a very large file. The plan set, in this case, is the "very large file." The individual plan is associated with one record. These devices also have an important attribute beyond their speed, and this is the fact that the storage space and retrieval operations add very little to the program requirements for computer core. Since the size of CEM and similar models is a constant concern (and is often the primary reason for not adding new capabilities because of the danger of exceeding the core storage capacity of the computer) the direct access system is a welcome addition. Because the size of the direct access file can be expanded to incorporate any number of plans with virtually no addition in program overhead, the approach also provides the growth room which will undoubtedly be needed in the future.

At the beginning of this section it was stated that the one or more plan versions found under a particular index combination must also be organized in a special way. The selection process conducts a sequential evaluation of these versions, terminating the search upon finding the first non-rejectable one. Sequencing of the versions becomes, therefore, an important task. Several approaches to this problem have been examined, although operational experience is probably essential for determining the best among them.

A reasonable approach, at least initially, appears to be to sequentially arrange the plan versions into two groups, a "survival" group and a "normal" group. The survival group contains instructions for interpreting and reacting to situations which threaten the continued existence of the unit. Here, for example, would be found one or more schemes for detecting and responding to an impending enemy penetration. If the unit fails to react appropriately, it may very well be destroyed. The normal group of plans, in contrast, holds perceptions and responses designed for situations of a more routine nature. Normal defensive or offensive operations would be represented here. The goal of these two groupings is to provide a systematic way of preparing and presenting the plans to the selection process. Unit survival would be of added significance (if the doctrine dictates this) by the fact that survival responses would have the first chance of being selected.

The plans within each group would also be sequenced. The approach here is to place the most restrictive plan first, followed by the next most restrictive, and so on, until the final plan in the group is the most general. By restrictive is meant the restrictiveness of the set of rejecters associated with a plan. The most restrictive plan would be the plan which is rarely used because the conditions described by its rejecters are not often satisfied. For example, a number of attack plans might be designed around the perceived strength of the enemy. The most restrictive plan, presumably, would be that plan requiring the most favorable force ratio. The least restrictive plan would be used for the least desirable force ratio. Associated with these restrictiveness assessments would also be found related attributes. The most restrictive plan would adhere most closely to the principles of war, providing, perhaps, greater economy of force, surprise, or some other aspects not found in following plans. The least restrictive course of action, however, would require the least adherence to these principles, would provide the most general response, and require the least amount of intelligence support.

Plan Selection

The third major component in the linkage from the strategist to the model is the plan selection process. Since many details of this process have been described while presenting the previous components, its general nature should be apparent. This section will expand on this nature, and should also answer questions about earlier components because the plan selection concept guided much of their design.

Two design goals were used in developing the plan selection process. The first goal was to develop a feasible system which would guarantee the selection of a plan. A number of other approaches for evaluating the plans are imaginable, of course, but they tend to cease being feasible because they all rely on complicated programming and iterative examinations. The end result is a slow--perhaps infinitely so--procedure whereby a changing set of criteria is applied to a set of plan versions. The chosen procedure, however, examines each plan only once for each planning cycle. It depends on careful sequencing rather than clever computer programming.

The second design goal was to fashion the model structure after the real process. Two advantages were to be gained here. From a design standpoint, the existence of a well-understood model, in this case the command and control process, would make the job of specifying and evaluating a simulation system much easier. The second advantage was to have a system which was explainable to a wide military audience without special experience in modeling. Because the modeled process was to be so close to the real one, rapid acceptance and use was expected.

The general process is outlined in Figure 5. Working down from the top, and recalling the design goals, the system interprets the environment, completes estimates, selects from among alternatives, and issues to each subordinate missions, locations, and resources. The explanations to the right of the figure correspond to the activities being conducted by each adjacent component.

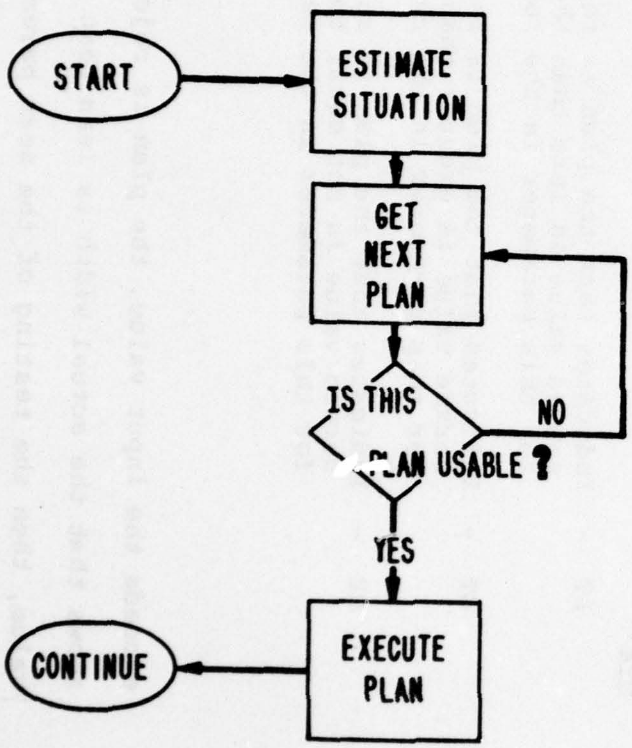
The procedure is simple. Prior to examining the first plan in the set, the environment is evaluated along a number of dimensions. The values entered in the rejection section represent limits beyond which the environment would not be conducive to successful application of the response section. Permissible value ranges are defined for each variable and the 'sense' of the individual tests comparing the specified and the computed values is predetermined. Table VI shows these test senses.

Some of the tests are 'binary,' or yes-or-no, while others are less-than or greater-than conditions. For example, a unit's total assigned frontage is an important aspect for the commander to consider. The test for frontage width compares the actual assigned width with the value specified in the perception section. If the actual width

FIGURE 5

PLAN SELECTION PROCESS

FLOW DIAGRAM



GENERAL OPERATIONS

SITUATION DESCRIPTION
INDEX DETERMINATION

GET THE FIRST UNTESTED PLAN

TEST IF PLAN IS USABLE, USABLE IF:

1. NOT REJECTABLE
2. LAST PLAN

EXECUTE THE PLAN

1. MATCH UP UNITS WITH PLAN SEGMENTS
2. ISSUE MISSIONS, LOCATIONS, AND RESOURCES

Figure 5

TABLE 6

REJECTER TEST SENSES

ENVIRONMENT	SENSE	REJECTER
FORCE RATIO (F:E)	LT	INPUT
FRONTAGE	GT	INPUT
ENDANGERMENT	LT	INPUT
COMPOSITION (EACH)	LT	INPUT
TERRAIN (EACH)	LT	INPUT
PREVIOUS MISSION	NE	INPUT
ENEMY MISSION	NE	INPUT
NUCLEAR STATUS	NE	INPUT

Key:

LT - Indicates that the plan is rejected if the observed value is less than the value specified for this parameter in the rejecter space.

GT - Indicates that the plan is rejected if the observed value is greater than the value specified for this parameter in the rejecter space.

NE - Indicates that the plan is rejected if the observed value is not equal to the value specified for this parameter in the rejecter space.

exceeds the input value, the plan is rejected. If the test shows that the actual width is less than or equal to the input value, then the testing of the next parameter is done. Once all of the parameters are tested, and none of them has caused rejection, the plan is applied to the force.

As indicated by the diamond-shaped test node in the figure of the process, and responding to the desire to have a guaranteed termination for the search procedure, if the system rejects all the versions tested prior to reaching the last one, the last plan is used. In other words, if the environment is either uncertain, possibly from a lack of intelligence, or unfavorable, according to one or more parameters, the final plan is selected. The end result is a single plan, regardless of how selected, which can be used to direct the force.

Selecting the most appropriate plan in the manner just described is analogous to the actual process, although the real commander would hardly be as systematic. Immersion in the ongoing situation makes the planning and contingency development a continuous, as opposed to a step-wise, operation. In effect, however, the background training, experience, and other aspects that make up an operating doctrine predispose the commander to confine his planning to a restricted repertoire. Despite the continuous nature of actual military planning, the existence of the predisposing modes of operation is necessary if the commander is to respond appropriately and in ways which contain a degree of predictability to assure rapid understanding and compliance. Failing to provide this predictability can effectively negate the expectations held by the participants at all echelons, and makes the requirement for direct communication much greater.

The final major component of the selection process is the distribution of the instructions contained in the selected plan. Labelled "Execute Plan" in the figure, this block accomplishes the tasks shown beside it. The function of the match terms should now become clear if it was not during earlier descriptions. The final operations in the process are concerned with issuance of the instruction strings to the subordinates.

Plan Production

This final section presents several aspects of plan production which have not been covered earlier. Each of them is significant individually and taken together, they help to place the entire concept into perspective. The first of them is the evolutionary nature of a set of plans. A set will change over time in response to a variety of forces. The second concerns the actual numbers of plans which will be needed in a mature set. Is this a limiting factor, or are the numbers manageable? The final aspect is the broad critical base which is possible with the plan set approach. More people will be able to participate in the operation and analysis of the war game than ever before.

Three processes will contribute to the evolutionary nature of the plan set: language development, operation of the model, and plan set maturation. Turning first to the language, it is obvious that the initial vocabulary is primitive. It reflects a blend of existing and desired capabilities. It attempts to afford enough flexibility so that the major characteristics of several doctrines might be portrayed. There can be no question, however, that it will receive a number of modifications in the future if the system is developed. Partly in response to vocabulary enrichments, and partly because of improved model functions corresponding to them, the language will grow.

Operational experience will also help to keep the approach in an evolutionary posture. At this time, without an operating version of the approach to observe, it is difficult to predict the types of changes which will be recommended. It is clear, however, that as the relationships of the various components come under scrutiny in the operational context, numerous changes will be necessary.

The final major cause of the evolutionary nature of the approach, plan-set maturation, centers on the fact that sets of plans are entities which are separate from the computer simulation. They are subject to review and analysis apart from model operation, can be used for a number of studies requiring the same model and doctrine, and can be added to easily. A set of plans can be seen as "community property' for an analytical agency. As such, updates and expansions can be expected. In addition, because of the rapid search procedure and the minimal overhead associated with plans storage, the plan set can be expanded to be as diversified as desired. A significant amount of time and talent is required to produce a set of plans. This and other reasons make a plans set a repository of resources and knowledge. And, considering the relative stability of doctrine, only relatively minor changes will be needed to keep the plans set in tune with current doctrine.

The second plan production feature centers on the number of plans needed to provide an adequate representation of a doctrine. At first glance, the number of plans included in a mature set would seem to be unwieldy. After all, consider the unlimited variety of environmental conditions. How will it be possible to generate, store, and recall the best plan for a particular situation when there is a vast number of situations possible? Fortunately, three facts will tend to limit the actual number of plans. The first of these facts concerns the variability of the environment. It is true that the environment is infinitely variable. This does not mean, however, that the perceptions of the environment will be equally variable. Language, it will be noted, acts as a filter, admitting only certain aspects of the total possible inputs. In addition, since language provides the structure into which the perceptions are to be entered, the perceived environment will only vary to the extent that this structure permits. The structure will recognize discrete gradations rather than a continuum. The end result of this first fact, then, is that the commander receives and responds to the limited set of variations specified by his language. The number of graded responses is limited.

The second fact which tends to reduce the number of plans is that expectation plays an essential role in most military operations. As the number of possible plans increases, the ability to rely on expectation decreases. Expectation often provides the major amount of information needed to carry out an operation. Parent, peer, and subordinate commanders all have a background of experience and training which leads them to expect the commander to operate within a fairly narrow envelope. Deviations from the expected modes of operation can make unsatisfiable demands upon the communication system by forcing the commander to rely more on direct communication than the more established actions would require. Here, once again, the end result is that the total number of plans is constrained.

The third fact which acts to restrict the number of plans is that the number of building blocks from which the plans are made is limited. In other words, the relatively few rejecter, match, and response terms can only be combined in a relatively few ways. This is not to say that the limited number of plans is restricted only to the modeling sphere, although the CEM simplifications do contribute. It is to say that the organizational and equipment characteristics of the forces to be coordinated define the general range of possible actions.

Although the reasons just covered do make the system manageable from a storage and retrieval standpoint, they do not preclude the development of sophisticated sets of plans. Over time, it is reasonable to expect that many of the combinations within the plan set will have a wide variety of versions. The point remains, however, that this richness will rest upon a base of a relatively few plans. This simple base will be a significant advancement over existing means for controlling simulated forces.

The final plan production feature, and an important one, is that the plans can be generated without regard to the computer model. Although certain guidelines need to be established so that model limitations can be considered and their impact reduced, plans can, for the most part, be produced without a sophisticated knowledge of the model context. This feature makes it possible for a set of plans to be produced by one organization, reviewed and analyzed by a second, and used by a third to drive the internal operation of the war game. Rarely before has a simulation mechanism been so observable. The typical situation, unfortunately, is that the model user or agency has a virtual monopoly on model understanding. Despite the availability of model documentation, usually provided by the model vendor, the intimate familiarity needed to appreciate the significant interactions and relationships within the model is gained only from practical experience running the model. Since the plans approach leaves many of these interactions and relationships outside the model, a wider critical appreciation is possible.

War Game Technology

General Technology Problems. War game technology is the area in which the concepts covered in this paper will have the most immediate impact. There are several key problems which are perennial concerns. Some of the problems are CEM-model specific, while others are of a more general nature. This section looks first at the general problems.

By far the most significant of these general problems are model size and model cost. Model size can be expressed in a number of ways, including numbers of operative lines of computer code, computer core storage requirements, program overlay structure, and run time. The size is important because it determines how a model is structured, what facilities can use it, and how long it takes to run. It determines, when considered in conjunction with the computer facility capabilities, how much leeway, if any, exists for future model revisions and expansions. Specific problems recognized in a model could often be solved if there was enough room remaining in the computer. Almost inevitably, however, the program size in a large war gaming model is rapidly elevated to the point where new capabilities can be gained only by eliminating older ones. What is more, the costs associated with only adding a capability are usually much lower than both adding a new capability and removing an old one. This is the case because most models have not been developed in a modular fashion. Elimination of a function may involve extensive searching for insidious connections between related elements. In addition, a well-planned elimination must contain benchmark testing to ensure that the elimination is restricted to the desired function.

The major advantage of the plans approach to the size problem is that it enables the model to acquire new capabilities in the command and control area without increasing its size. Each addition to a maturing set of plans is an increase in sophistication for the model. Also, by intelligent use of the plans, eliminations of selected functions can be accomplished without requiring eliminations of program code.

Returning to the cost problem, the system promises to make a significant contribution. The general cost problem stems from the fact that large computer based war gaming models are very expensive. In addition to the high initial dollar costs, they often require years of intensive effort to produce. Also, life cycle costs of a model can be much greater than the initial development costs. The point to be made here is that designing and building a model can not be done for each particular study need. Not only do most study budgets fall far short of the many millions of dollars needed, but their timeframes and problems would expire and change before a new model could start to operate. This is the primary reason, of course, that the large models are very general. They must be able to support a number of requirements.

Once again, the plans system has a clear contribution to make. Properly done, a new plans set can effectively tailor the model to the particular needs of a study. If, for example, new organizations and doctrine are of interest to long-range planners, a set of plans which accommodates these interests can drive the model. Similarly, if a study is concerned with the warfighting capabilities of the current forces using current doctrine, the same model driven by a specific set of plans could be used. The end result is a model which has a much wider applicability. It becomes in effect a family of models.

Participation is a third general problem in war game technology. As discussed earlier, models have become so complex that only a few operators understand the underlying rules and processes which produce results. This fact is making it very difficult for the decision-maker to place his trust and confidence in the studies which use these models. Since such studies are done to support decision-makers, any reduction in model obscuration will be a benefit.

The system of controlling the CEM through a set of plans could impact on the participation problem in several ways. The most obvious way is that it would reduce model obscuration by exposing more of the model operations to more people. This is not to say that the decision-maker would necessarily have to become familiar with a set of plans in order to feel more confident. He could, however, base his confidence on the perceptions and analyses of a much broader group of people than is currently possible. Whereas now, five or so player-analysts on a study may understand the "innards" of a model, a plans set could be understood by a variety of players, analysts, and others, many of whom might not have the requisite backgrounds to understand a computer program. The chance of myopic focus, so often found among specialists, could be reduced.

A second way in which the plans set concept would impact on participation is in plans generation. It is reasonable to expect that sets of plans would be produced cooperatively, and would involve analysts, strategists, and other groups of interested people, to include logisticians. Plans production would become a common meeting ground for isolating differences, resolving conflicts, and involving this aggregation of talents more heavily in the study process. The result should be wider acceptance of study results because of the wider participation.

Specific Technology Problems. A number of specific problems also confront war game technology. While they do have unique characteristics which also require attention, their general source can be identified as size restriction more than any other. Certain solutions are infeasible, not for lack of a design, but for lack of computer space. If the computer size could be expanded, the problems could be handled directly. This section looks at three of these specific problems, integration of multiple factors in decision-making and assessment, intelligence data introduction, and battlefield representation. While other problems could be treated also, these three should outline the important points which would be applied to most of them.

Most models depend on one or two key variables for most decision-making and assessment rules. Because these variables are of central importance they tend to take on an unrealistic weight. The most heavily weighted variable is often said to drive the model. It becomes the focal point for input specification because the impacts of the other data are relatively minor. In the CEM model, firepower is the "driver." Most of the decision rules, resource allocation rules, and assessment processes are governed by this powerful variable. While firepower is an obvious first choice if one must select a single variable to act as a model driver, criticism is often heard. The source of this criticism appears not to be firepower itself. The real source is the fact that firepower is used to the exclusion of other variables which critics know to be important.

Within the plans approach is a simple way of insuring that a number of variables are included in the decision process. While the approach does not extend to the assessment process, where firepower scores will continue to dominate the attrition algorithms, the rejecter terms will allow the model to consider a tailored set of variables when determining the appropriate course of action.

Another chronic problem in war gaming concerns intelligence data introduction. How can these data be made to impact on the actions taking place in the model? Since the traditional systems for determining model actions are quite different than their real world counterparts, it is difficult to know just how to admit new data, curtail other information, and get the impact of such manipulations to reflect in some meaningful way in the outcome. The problem is compounded by the fact that, as just covered, most models rely on one or two key variables. Whatever intelligence there is must be applied in some way to these variables if an impact is to be produced.

Here again the plans approach offers a partial solution. Since a variety of variables can be used to determine the course of events, the number of possible input channels for intelligence is increased. Rather than being forced to alter the estimated enemy firepower to represent poor intelligence, the procedure in the current CEM model, the fact of poor intelligence could be seen in faulty assessments of enemy positions, strong points, and intentions, just to name several key channels. In addition, the plans system is patterned after the actual process. This makes it much clearer to the programmer and system designer how and where the intelligence links need to be established.

The final specific problem is battlefield representation. By this is meant the way a model portrays terrain, unit positions and boundaries, battlefield depth, and any other aspects which relate to the translation of physical features into the model. This problem more than the others is a result of the limits imposed by the size of the computer.

A major tradeoff exists between resolution, which refers to the fineness of detail, and overall war game area, which refers to the depth and breadth of the area being simulated. The finer the resolution, i.e., the smaller the areas which can be discretely addressed, the smaller the overall area to be simulated. The degree of detail is important because it relates, among other things, to the level of organization which can be represented. If a model has discrete reasolutions of ten kilometer squares, for example, it would not be possible to keep track, say, of an infantry squad. The reason for this tradeoff is the fact that in order to keep track of the activities within an area, it is necessary to know where the area is. This requires a coordinate system of some kind, and each point will have as a minimum an x and y coordinate. If the resolution is down to 10 kilometers, this amounts to 10,000 individual areas. If the resolution is stepped up to one-kilometer blocks, the number of blocks in the same area jumps to 1,000,000. If data is being maintained for each of these blocks, let's say terrain type, coordinates, and units within each block, the capacity of the computer memory is rapidly exceeded.

Two general approaches have been taken to enhance resolution, increasing storage capacity, and providing for some form of local high resolution. The approach that buys higher resolution through expanded storage is the most direct, of course, because a high resolution representation is maintained throughout the entire area. Unfortunately, however, the extensive use of tape, disk, or drum storage devices can greatly increase the time required for each simulation run.

Local scope procedures attempt to maintain two levels of resolution. The entire area is represented in a macro way with very low resolution. Areas of interest, however, are represented with high resolution. In the CEM, for example, the local scope includes only those segments of the overall area which are coincident with the FEBA. In this way the specification of unit locations requires only two items, a left and right boundary number on the FEBA. The penalties for such approaches are significant. Notice that there is no depth to the CEM portrayal. Also, the FEBA must be continuous.

Other approaches use a local scope which has depth and fairly high resolution by configuring forces in zones. These zones are actually processed almost as if each were a separate game. The model recalls the applicable data for each zone from a storage device, executes the necessary operations, and records the new set of zone data in storage. It then moves to the next zone, repeats the process, and continues. Once again, however, this technique has penalties associated with it. It is difficult to capture the synergistic effects of operations occurring in adjacent zones. Rules must be applied so that FEBA positions and boundaries are adjusted properly. In addition, the technique is relatively costly to run because each zone is like a new game. Add to this the increase in input-output time required to move data into and out of storage, and the true price of high resolution can be great.

The system of coordination described in this paper can make a direct assault on the problem of unit locations and dispositions. Although the system does not combat the resolution problem directly, it does suggest another way of having local scope. In particular, the local scope can be focused on the activity which most requires resolution, the combat engagement. The approach is simple. The most important procedures for controlling the units in the CEM revolve around the location of units along the FEBA. Unit boundaries are adjusted, reserve units are brought on line, and so on, within the general organizational framework established by the command and control system. Accounting for the units, however, is linked to the FEBA coordinate system. In contrast, the plans approach is oriented toward the organizational structure. Units are controlled because of their oganizational position rather than their geographical location.

Several procedures for recording unit positions could be presented which would enhance the fidelity of the battlefield representation once the positive organizational control was established. The simplest of these would describe a unit as an ellipse, storing (x,y) coordinates, lengths of the two axes, and the orientation angle of the major axis. With this small amount of information it would be possible to orient and engage forces anywhere in the overall area. Using such a procedure, in conjunction with the plans for guiding the units, would enable the model to maintain an economical global representation while simultaneously allowing high resolution at the critical points of contact.

Unit proximities and orientations could be controlled by simple calculations. The importance of these factors can be suggested by an example. The current procedure for portraying flank security in the CEM is to reduce the firepower available to a unit in the head-to-head contact. Reinforcements can only bolster the firepower of the head-to-head contact, and can not be brought to bear to the flank or rear of a unit. This is caused by the fact that the CEM has no depth. Clearly, it is often desirable to be able to conduct flank and rear area attacks. The simple approach can accommodate these desired actions because units can be "aware" of their relation to enemy positions.

Training

The primary problem facing the military training system is how to build military experience in the absence of war. War games have had a traditional role in attempting to overcome this problem. The approach outlined in this paper would produce a model which could be used successfully in this traditional role, of course, but its unique attributes will make its effectiveness greater than other forms of games. Furthermore, the language concept could have direct application to the ways in which military subjects are presented.

Any model, including the CEM, becomes a more effective training device when its functions are made easier to understand. The lessons to be gained are more readily identified when the intervening processes can be observed. Also the applicability of the training offered by a device is directly related to its accuracy in representing the real process. Each model limitation, in other words, makes the model less like reality and less effective as a training system. The proposed system of control offers notable fidelity.

Perhaps the most exciting use of the system will be in training a commander and his staff. With the military lexicon the leader will be able to formulate and test a wide range of alternatives. In a real sense, once again, what the leader can express, he can see in the simulation. Although many manual war games are designed with the objective of portraying a specific course of action, the time and resource constraints make the process incapable of handling more than one or two alternatives. An automated game with the plans set linkage, however, could provide a large number of outcomes produced by a variety of alternatives in a relatively short period. Also, the plans preparation process could be carried out beyond the confines of a particular agency. In other words, a much wider participation is possible in generating--and understanding--a set of plans which will drive the CEM.

The general effect of this model would be to provide immediate feedback to a commander and his staff while still preserving a high level of sophistication and detail. It would be possible with such a model to engage sections of students in competitions designed to explore the underlying approaches taken by several sets of plans, for example. The speed of the automated game, coupled with the detailed outputs to aid post-game analyses, would make the model a formidable training tool.

There is also a potential training use of the language concept found in the system. Viewing military training as an attempt to teach a language could provide a new lens for focusing training efforts. The traditional approach to teaching the military patterns of thought includes a mixture of historical examples, hypothetical situations, and explanations about certain principles. The subject is taught rather indirectly. The problem is that the student must be able to translate the implied messages about the ways he should think into an existing frame of reference. This is a difficult task in itself. The indirect nature of the training only adds to the difficulty. The student is faced with a trial-and-error procedure for reproducing the desired, or school solution.

Since the trial-and-error approach can require a large number of repetitions, military training in the traditional way can be time-consuming and expensive. The language approach, on the other hand, provides a systematic way of building the desired patterns because it explicitly treats the relationships between the environment and the desired reactions.

This type of thinking has been receiving some attention in Europe. The West Germans make a distinction between mission-type and order-type tactics. Mission-type tactics, or Auftragstaktik, are preferred because they afford the greatest flexibility and chance for initiative. Auftragstaktik has the following characteristics:

> "The mission must unmistakably express the will of the commander.
>
> The objective, course of action and mission constraints, such as time, must be clear and definite without restricting freedom of action more than necessary in order to make use of the initiative of individuals charged with the tasks to be accomplished.
>
> Limits as to the method of execution, within the framework of the higher commander's will, are imposed only where essential for coordination with other commands."[1]

Before a force can hope to use Auftragstaktik, however, several conditions must be satisfied, and it is these conditions which are of particular interest because they tend to recognize military thought as a language. First, the concept requires "uniformity of thinking." Commanders must be able to anticipate how their mission-type orders will be received. Second, there must be "reliability of action." Actions must be as predictable as the thoughts. "Implementation of the Auftragstaktik concept will be most possible when a tactical commander and operations doctrine has become common knowledge and when tactical principles are translated into reality."[2]

The Soviets are also interested in similar ideas. To them "command language" leads the commander to "assign missions to subordinates precisely, to report correct information to mutually supporting units."[3] While much of the attention is on precision and reduction of ambiguities, it is also clear that it is understood that the command language serves more than for communication. Using the words of Aleksei Tolstoi to clarify his position, one Soviet military writer quotes, "Language is the tool of thought. To handle language haphazardly means to think haphazardly - roughly, without precision or clarity...."[4]

A final training use of the system and the language concept centers on the areas of interoperability and standardization. A doctrine which has been explicitly stated using a standardized vocabulary would assist in clear and concise communications between allied forces. This possibility of a military language for multinational operations was forecast by the RAC analyst, Nicholas Smith, in 1963.[5] Interestingly enough, this reference constitutes the only clear anticipation of an approach such as the system described for the CEM encountered during this research effort. Many writers have discussed computer languages and the impact of improved computer languages, on model processes, but none save Smith saw a language which would link the military planner with the automated war game.

Doctrine Development

The new war gaming models which use the concepts presented here will have significant advantages over their predecessors for exploring doctrine. Their ability to execute a set of plans which reflects a change in thinking will make it possible to evaluate and compare a number of outcomes produced by the change. Tactical and strategic variations can be designed and tested in a matter of days, instead of the weeks or months needed to accomplish them through changes in the computer program.

The language approach to military thought has other uses beyond the computer war game. Expanding a point made earlier, languages are models used by their speakers to provide a framework for operating in a complex environment. They create the filters that keep the volume of inputs at a manageable level. They act to enforce systematic patterns of thinking, and they define the conclusions and responses which their users will be predisposed to consider.

These topics have received considerable philosophical attention, of course, and a growing body of empirical data has been accumulated over the past 70 years to shed some light on the classic issues. Conducted under several disciplines, these researchers can be found in psychology, linguistics, and psycholinguistics, to name the major ones. In general, these studies are concerned with one or another aspect of language as a model. How does the model impact on perceptions, thought, and behavior?

Models can be either implicit or explicit. Implicit ones, by far the most common, often operate without being consciously noticed. Language and custom dictate many of them. Explicit models, on the other hand, are formalized constructs which are easier to observe than implicit ones. Explicit models always are preceded by an implicit version. Regardless of type, model users continually test them. Changes are usually slow to happen, but testing is at the heart of adaptability. Models also serve a role in predicting the actions and reactions of others. Explicit models tend to be most common in this capacity. Unfortunately, the inadequacies of the explicit model often make it impossible to explain the differences between the predicted and observed behaviors. Obviously, the explicit model has failed to reflect the implicit one, either because the implicit model was incimpletely defined, or changed have occurred since the explicit version was developed. What is more, the explicit model used by the observer may coincide exactly with the explicit model reported by the actor. In this case, the implicit model guiding behavior is invisible to all.

The fact that explicit models may produce imperfect predictions does not, of course, negate their usefulness. In actuality, constructing and using such models is essential to success in a host of activities. In the military arena, know-your-enemy has been a tacit recognition of the idea that you will enhance your ability to wage war if you can predict your opponent's behavior.

The vocabulary concept applied in the approach is a way of making a doctrine explicit. It acts as a menu of terms which can be used to translate a particular doctrine, perhaps more clearly than in the past, into an explicit model. It forces the military planner to examine his thinking away from the comforting assumption that "everyone knows" what is meant. In so doing, issues become clearer and more observable and problem areas are discovered more readily than when the model remains implicit.

Having access to two or more models of behavior concerned with the same general function can provide a significant competitive edge. The familiar models developed by Graham Allison are useful here.[6] He attempted to describe a particular event, the Cuban missile crisis, through the perspectives of three different models of governmental behavior. Without going into detail, each model was useful for understanding certain types of behaviors exhibited by individuals and organizations. The most sophisticated of these, the Bureaucratic Politics model, gained its primary usefulness from an ability to predict behavior produced by the other models. Since the other models tended only to project their own modes of behavior on all situations, the competitive edge was obvious.

While the availability of several models of military doctrine may not give the same striking advantage, primarily because they are of similar sophistication, insights will be gained. The function of the standardized lexicon will be to make comparisons, predictions, and documentations more systematic and easier to do. In addition, the perspective gained from such a position could produce new models of behavior which would not be expected from knowledge of a single one. The language capability would be permitting the military strategist to be thinking more concretely and concisely than possible without it.

This use of a hybrid vocabulary and language to understand the shortcomings of traditional modes of thought and to suggest new ways of solving problems is similar to a view expressed by Richard D. Duke. In his book, Simulation: The Future's Language, he sees simulation/gaming to be a natural evolution in communications which will enable man to regain the gestalt perspective that once was possible with traditional languages.[7] He feels that modern societies are too complex to be handled in familiar ways. Planners of modern societies, as well as the bulk of the participants in them, must be able to integrate the diverse demands which now cause unresolvable tensions and a lack of rapport within and between social factions. The role of gaming/simulation envisioned by Duke is similar to its role in this section, although on a much larger scale. It will enable perspectives to be developed which could not come from knowledge and use of only a single mode of thinking.

CHAPTER VIII

RECAPITULATION

Complexity is the key word to understanding the modern problems which face the Services today. It also is appropriate for understanding the analytic tools which are used to solve these difficult problems. Without such tools, however, the Services would not be able to manage as efficiently, or compete for resources more effectively, than they are now. Simple problems with simple solutions are rare indeed, and they will become even more so in the future. This chapter will review the major issues in this paper and will show *how the technology* outlined can assist in reducing the significance of these issues.

Problems Revisited

This paper has discussed a number of problems. They have ranged from very general ones, such as the question of whether computer-based war games should be used to analyze modern defense problems, to rather specific items, such as the limitations imposed by the requirement to maintain a continuous FEBA. This section summarizes the most important of these problems for the purpose of providing a backdrop against which to review how the new system of coordinating actions in the computer war game could reduce their impact.

Complexity is the most general of the problems. Modern military resource questions, employment options, and the extent of uncertainty about the future make demands on the military decision makers that are more complex than ever before. Add to this the introduction and proliferation of new analytical techniques, each seemingly more complex than any preceding ones, and the complexity spiral results. More complex questions can be asked of more complex problem solvers, and more sophisticated analytical tools can demand more sophisticated questions.

This complexity spiral would not be disturbing if it could be properly managed. Unfortunately, however, improvements in the management of the questions and the techniques for providing answers has lagged behind the increases in sophistication found in either the questions being asked or the techniques expected to solve them. This lag has manifested itself in several ways. The most important result has been a centralization and specialization of the people responsible for asking the questions and generating answers. The analytical tools, with computer war games in the lead, have reached the point where there are few individuals involved who are knowledgeable about the capabilities and the limitations of the techniques available. This is not a problem as long as the proper caveats are attached to the various phases of analysis. The trend in the complexity spiral is away from these warnings, however.

As the tools and questions become more complex, the tendency is to accept techniques, problem formulations, and results provided by the study process with a good deal more faith than could be warranted if the complete baggage of caveats was included.

With the greater specialization in military analyses have come several other irksome issues. How does an organization responsible for studying certain types of problems acquire and maintain the necessary expertise? Fewer and fewer people are able to remain with a study process or a particular analytic tool long enough to learn the strengths and weaknesses. This kind of knowledge is needed, however, to properly advise the decision-makers for which the work is done. Furthermore, as the complexity increases, the time required to comprehend the study methodology or the component analytic tools also increases. The day cannot be too far off when military analysts will be unable to gain an appreciation adequate to manage such systems during a three-year tour.

Turning to a more quantifiable aspect of the complexity spiral, one needs only to consider the situation for a moment to realize that costs must rise with the spiral. Neither the complexity nor the cost of the analytic tools designed to attack it is linear. In the case of computer war games, in particular, costs have skyrocketed. This is so despite the fact that new computer systems are vastly superior to their predecessors of ten years ago, and are able to handle the same workload far more cheaply. The reason, simply stated, is that models capable of shedding light on the complex problems of today must be far more sophisticated than ever before.

A less quantifiable, but equally important cost which must be considered is the opportunity cost of a decision. Every choice between alternatives can be assigned a cost which is defined as the value of the next most valuable alternative. In the military arena, where data from the last war are difficult to project on the next, the values of the alternatives are extremely hard to quantify. It is clear, nevertheless, that a decision not to buy 2,000 more XM1 tanks in favor of spending the "saved" resources on prepositioned war reserves could be a decisive factor in the successful conduct of this future war. What is not clear is just which alternative is better, and by how much. The real costs (or the real values) of the analytical tools used to attack this type of question can be determined by judging their ability to assist the decision-maker in gaining confidence in his decisions.

The costs associated with changing a model to make it more useful for studying a particular problem have also increased. Since increases in complexity have generally produced larger and more elaborate war games, the job of modifying an existing one can be extremely expensive. As a result, a normal procedure is to adjust or redefine the problem in such a way that the tools at hand can be used to study it. While this may not be a serious distortion for some problems, it could be disastrous for others.

Model limitations have also been discussed in this paper. Specifically, the most sophisticated war gaming models of high level forces are in many ways rather primitive. Without addressing the details of these limitations, however, it is possible to list their major impact areas; first, fidelity, which relates to the ability of the model to portray a particular combat action realistically; second credibility, which concerns the acceptability of a model product to the analysts or decision-makers involved; and finally, flexibility, which refers to the ability of a particular model to be adapted to a variety of study demands. These three interrelated areas are very sensitive to model limitations.

Solutions Revisited

The general mechanism developed in this paper does have the potential to remedy many of the general and specific problems presented. Throughout has been the assertion that the proposed system would greatly enhance the theater level combat simulations. Rather than relying on a set of rigid rules, unilateral threshhold values for decisions, and embedded doctrine, the plans approach would afford flexible responses, the consideration of a variety of factors during decision making in the simulation, and would render the model virtually free from any unspecifiable operations. The approach offers possible solutions for other problems as well. The next few paragraphs will reiterate the points made about these solutions earlier.

Since the major problem identified here has been the complexity spiral, what could the new system do to lessen the adverse effects? The primary answer concerns management, just as management was identified as the primary cause of the problem. The plans approach would make the workings of the model immediately more visible to a host of people currently excluded from the modern computer war gaming arena. This would act to counter several of the problems which are now intensifying the undesirable impact of the spiral. In the first place, the plans approach parallels the actual processes of command and control which are familiar to most military leaders. Comprehension of the model operations will be directly related to an appreciation of the real process.

This broadened base will have a second effect. It will be possible to have far more people involved in the guidance and post-run analysis of the war game than ever before. With this broader base comes greater credibility. With the inherent flexibility of the plans approach comes a more flexible model. Finally, with the plans system capable of portraying a diverse set of tactics, it will be possible to have far greater fidelity than with previous systems. The model can be tailored to the particular needs of the study.

The plans approach also has some significant advantages for attacking the cost problems. As just mentioned, a model equipped with the plans system is tailorable. This means that a single model can serve a number of requirements concurrently, needing only a change in plans to change its operations.

A second aspect of cost, and the one which is most difficult to measure, is the effect of assisting a decision maker. The plans approach, because it does promise to provide great flexibility, fidelity, and credibility, will be applied to a much broader range of problems. In the areas of doctrine development especially, the ability to tailor tactics to specific forces will enable the decision maker to examine options of force design and force employment which are now beyond the legitimate range of the computer war game. Once again, it is hard to quantify just what the benefits of this capability will be when used in this capacity. It seems certain, nevertheless, that the basic assumption made by LTGEN Meyer is valid: new forces need new tactics. It is unreasonable to think that they can be properly evaluated if they must be made to respond in completely conventional ways.

Training and doctrine development, two subjects touched on in Chapter VII, could also be fertile places for the coordination system outlined. The literature in these areas which suggest this type of approach is very limited. The idea of using a vocabulary of military terms to construct a hybrid language representation of a doctrine does appear to be a fruitful approach. In addition, the language concept does seem to offer a new approach to doctrine conception, comparison, and examination.

Conclusion

The technology presented in this paper, while not a panecea for all the problems facing the modern military decision maker, is a powerful system. At first glance it seems to be so specific, and of such limited application, that its usefulness is difficult to fathom. While it is true that very few organizations and people are interested directly in the application of large scale computer-based war games, it is not true that the impact of the decisions produced by these few is of a limited nature. On the contrary, as may be surmised by the types of questions addressed and the magnitude of the resources involved, the impact is both pervasive and long lived.

In many respects, this paper has gone beyond the bounds which could be drawn strictly around the users of theater level war games. It has attempted to explain a number of recurring problems facing military resource managers. There have been, therefore, discussions of problems which cannot be resolved simply by initiating the approach advocated here. In the final analysis, however, the greater the awareness of these problems, the higher the quality of the debates about them. The general mechanism for controlling the actions in the theater level war game is a solid step in the direction of greater understanding.

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