THE BATTALION DECISION AID:

A KERNEL DECISION SUPPORT SYSTEM

THESIS

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THESIS

Presented to the faculty of the School of Engineering

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Operations Research

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June 1989

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ACKNOWLEDGMENT

In accomplishing this research and the writing of this thesis, I received a great deal of help from others. I am deeply indebted to my thesis advisor Lt Col John R. Valusek for his patience, understanding, and perseverance. He provided a semi-structured environment and applied as needed the appropriate memory aids and control that kept this effort on course and on time. I would also like to thank MAJ (Ret) Dan Reyen who served as my reader and green 'sanity check'. Your reminder that 'you must be able to fly straight and level before you can do a proper turn' proved to be very good advice. I would like to thank the members of AFIT class GST 89M and the C2 contingent for their good natured approach to the experience at AFIT and their willingness to lend a helping hand to one in need. To my sons Greg and Joel, thanks for reminding me that time and life go by too quickly, and that you must go 'outside' to enjoy it. Finally, I would like to express my deepest thanks and adoration to my wife Linda, for without her self-sacrifice, tolerance, strength, and encouragement this effort would not be complete nor would my life be so wonderfully complete.

Gregory S. Miller

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ABSTRACT

The purpose of this ~~research~~ was twofold:

1) To investigate the development of a user orientated, conceptual design of a decision support system (DSS) that would aid battalion level planners in generating course of action during the military planning process.

2) To investigate the military decision making that occurs during the planning process, to identify differences if they exist between echelons of command, and the feasibility of a scaled-down version of a corps, division, or brigade decision aid in meeting the needs for a battalion decision aid.

The adaptive design methodology was used to develop a user orientated design of a kernel system which has the designed capability to 'start small and grow.' Through this design process, the second purpose was also investigated.

The use of the adaptive design tools; concept mapping, storyboarding, and feature charts; enabled the user-designer to determine the initial requirements for a battalion decision aid. Through the use of these tools, the problem space was bounded, and a key subproblem or kernel selected and descriptively modeled. Within the course of action generation subprocess of the military planning process, the

' array initial friendly forces ' process was identified as the kernel for the initial design of the battalion decision aid.

The ability of a planner to accomplish this process of arraying initial friendly forces rapidly and correctly is the cornerstone for successful planning at all command echelons. Though this similarity and the outward appearance of the decision process are identical at all command echelons, it was determined during the design of the initial system that the fundamental determination of combat power and its relationship with space and time changes due to the planner's goal structure and view of the battlefield. This suggests that a battalion decision aid cannot be a scaled-down version of a corps, division, or brigade decision aid.

This research indicates that the adaptive design process provides the proper approach and tools that enable a decision maker to gain understanding of the decision process and to directly map this understanding into a user's statement of requirements.

The Battalion Decision Aid:
A Kernel Decision Support System

I. Introduction

> *. . . The light of reason neither moves here through the same mediums nor is refracted in the same way as when it is engaged in thought. He must . . . be a man who under stress . . . does not lose the capacity of making a prompt decision.*
>
> [*Clausewitz*:48]

The Modern Battlefield and the Commander

The commander at Corps level or below must be capable of making prompt and decisive tactical decisions on the modern battlefield. The atmosphere of the modern battlefield in which the commander must make decisions still retains the same elements of past battlefields. Clausewitz describes the elements of this atmosphere as, " danger, physical effort {exertion}, uncertainty and chance " [Clausewitz:35].

These elements affect the commander's decision making process. The danger of the battle, violence, attempts to dull the intellect by stress and emotion. Physical effort, the physical manifestation of violence, affects the commander directly through fatigue, hunger, injury and indirectly through the consciousness of subordinate's suffering and death. The effects of danger and physical effort are heightened by the uncertainty of battle. "... {T}hree-fourths of the things on which action in {battle} is based lie hidden in the fog of a greater or less uncertainty " [Clausewitz:32]. To worsen the plight of the commander, the unknown is mixed with chance which reacts in unforeseen ways. These elements of the battle atmosphere are the major contributors to the friction of war.

AirLand Battle Doctrine

In contrast to the degrading effects the friction of war has on the commander's mental faculties, "the basic tenants of the AirLand Battle Doctrine: initiative, depth, agility, and synchronization" [FM 100-5:2-1] require the optimal performance of his intellect in the tactical decision making process. The commander must have agility of the intellect which will give him the "capacity - - relative to that of ... {his} ... opponent - - to acquire, analyze, and act on information" [Fastabend:31] . Agility requires of the commander: creativity, judgment, and analytical skills. The commander must seize and maintain the decision making initiative. This initiative is the commander's ability to recognize the need for immediate action, which is the result of his subjective and objective understanding of the situation. The tempo and spatial depth of the modern battlefield requires the commander to make tactical decisions in depth. "Commanders need depth of time, space, and resources to execute appropriate countermoves, to battle the forces in contact and to attack enemy rear forces" [FM 100-5:2-2]. This can only be achieved through his ability to see the battlefield and to quantify the factors of time, space and resources. Finally, the commander must have the ability to synchronize with respect to time "subunit task accomplishment, with respect to each other and to some unifying objective" [Fastabend:32]. Synchronization requires the commander to have the ability to make time estimates. These estimates forecast the massing of various combat entities which will achieve maximum combat power. In short, the AirLand Battle Doctrine requires battlefield commanders to successfully turn within the decision cycle of the enemy.

As Maddox and Moore denoted, this is impossible since both the threat's and the U.S. decision cycles are the same. To achieve the same goal, predictive planning must be utilized [Maddox:110]. "Predictive planning requires the U.S. commander to think through and plan options to counter probable enemy courses of action" [Maddox:110]. Then by focusing the intelligence assets on key indicators, the commander can determine what action the enemy has chosen. With the contingency plans already issued, the commander need only order the execution of the appropriate choice

[Maddox:110]. This will allow "the U.S. commander to seize the initiative and turn inside the cycle" [Maddox:110].

Command and Control (C2)

To meet the demands of the AirLand Battle Doctrine and "{t}o defeat the enemy and break his will to fight, Army leaders must generate and apply combat power decisively {with measured control}, and that is the function of C2" [Dacunto:63] . The process of C2 "consists of four steps: acquire information; assess that information; determine what action to take; and direct subordinates to carry out those actions" [Dacunto:63]. Recognizing the inadequacy of the manual C2 system to meet the demands of the AirLand Battle, the Army has set out to find a system or family of integrated and interoperable systems that would enable the commander "to make sound and timely decisions and rapidly direct the actions of subordinate and supporting units"[*Army Focus*:34]. The Army Tactical Command and Control System (ATCCS) is **the system** that will assist the commander at each echelon by providing the "means of command, control, and coordination for the five Battlefield Functional Areas (BFA): maneuver, fire support, air defense, intelligence/electronic warfare, and combat service support" [*Army Focus*:34]. Across the five BFA, these tasks are accomplished through the use of three types of information (technical, staff, and command).

The Maneuver BFA has presently been employing automated command and control from corps through brigade. This has been done with the Maneuver Control System (MCS). C2 at and below the battalion level is still done in the manual mode. This requires the brigade staff to enter all force level control data received from subordinate units. The slow and unresponsive information flow from subordinate units using manual procedures with its almost complete lack of information management is unable to meet the dynamic nature of the modern battlefield [CACDA(3):D-1].

Recognizing this fact, the Combined Arms Combat Development Activity (CACDA), Ft. Leavenworth, conducted a study of the problem. On 6 November 1987, the final report, Analysis of Tactical Automation Requirements For the Maneuver Functional Area was released. The findings of this report justified the expansion of automated C2 at and below the battalion level as the best way to correct the information flow problem. In addition, the "Operational and Organizational Plan Annex for the Family of Maneuver Control Systems," dated 8 August 1988, reiterated this need for automation at and below the battalion level. It also restated that the MCS must possess the operational capabilities to support commanders and their staffs in future planning, course of action assessment, and analysis of tactical decisions [CACDA:D-3].

Battlefield Planning

On the battlefield, planning is continuously and concurrently carried out at all levels of command.

> A higher level communicates to a lower level . . . a partial specification of a subproblem to be solved, a partial specification of the resources available in solving the given subproblem, and a partial specification of aspects of how the subproblem is to be solved.
> [Powell:1]

This planning may occur over several days or a few hours depending on which level of command the planning occurs. The common knowledge of doctrine and the principles of war unify each level of planning [Powell:2].

To assume that the character of the planning is the same throughout the command hierarchy would be incorrect. Though the structure of the process remains the same, the nature of the planning is influenced by the focus of each level of command [Powell:2]. This shift in focus can be described in terms of the following three factors: the level of war, organization and capabilities, and resources.

First, the difference in planning can be explained in terms of the levels of war. Corps conduct operational planning which focuses on gaining positional leverage on the battlefield which will lead to the defeat of the enemy and the achievement of strategic objectives. The primary focus of the operational level of war is the planning and conduct of campaigns and battles which are characterized by large scale maneuvers (e.g. penetrations, single and double envelopments, and airborne assaults) of large and possibly multiservice forces [US Army Combined Arms and Services Staff School (CAS3),E716:9].

In contrast, divisions, brigades, and battalions conduct tactical planning which focuses on the massing of firepower at the critical place and time on the battlefield to destroy the enemy force or its capabilities. The commander's primary concern is the achievement of his assigned objective and the survival of his force. The primary focus of planning at the tactical level of war is maneuver which is characterized by the combination of movement and fire support in a unified and synchronized effort [CAS3,E716:9]. Divisions and brigades have the ability to unify and synchronize the efforts in both the close-in and deep battle since they possess the assets to see and shoot deep. Battalions lack the ability to see and shoot deep. Consequently, battalions concentrate on unifying and synchronizing the effort in the close-in battle. This is not to say the battalion commander is not concerned about the deep battle, but that he has little ability to influence it.

Second, corps and brigades have no fixed organization and therefore flexible capabilities (See figures 1, and 2).

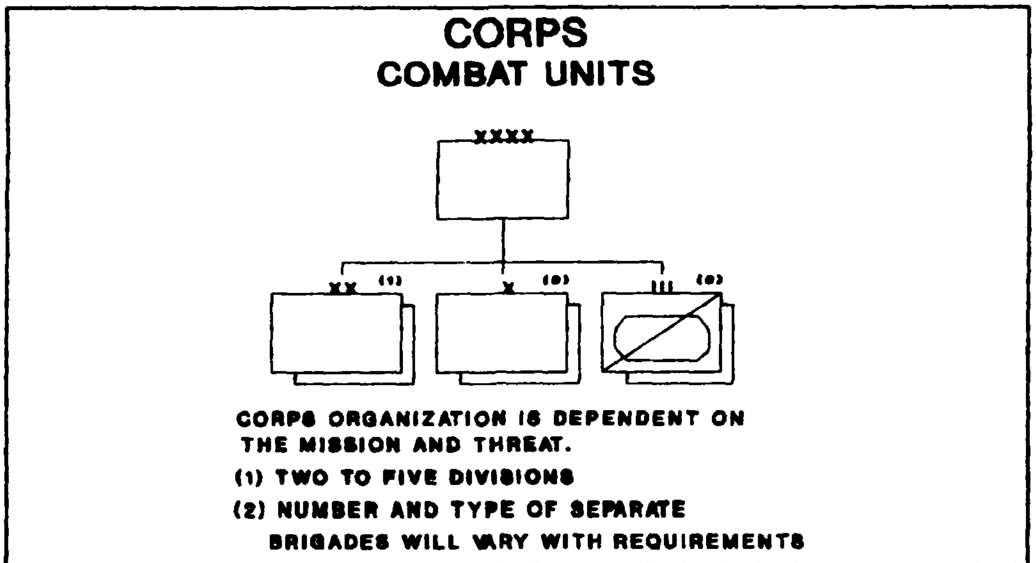


Figure 1. Corps Organization [CAS3,E709:5]

The composition and capabilities of these two organizations are determined by the operational requirements and the threat. Divisions, on the other hand, have a specific organization which give them a known capability that is derived from the number and type of maneuver battalions, infantry and armor, assigned to the division. (See figures 2,and 3.) A battalion has a specific organization on the battlefield. Its organization will be one of five possible configurations with associated capabilities and limitations. A battalion can be an infantry or armor battalion, or an armor heavy, infantry heavy, or balanced task force. (See figure 4.) In short, divisions and battalions are

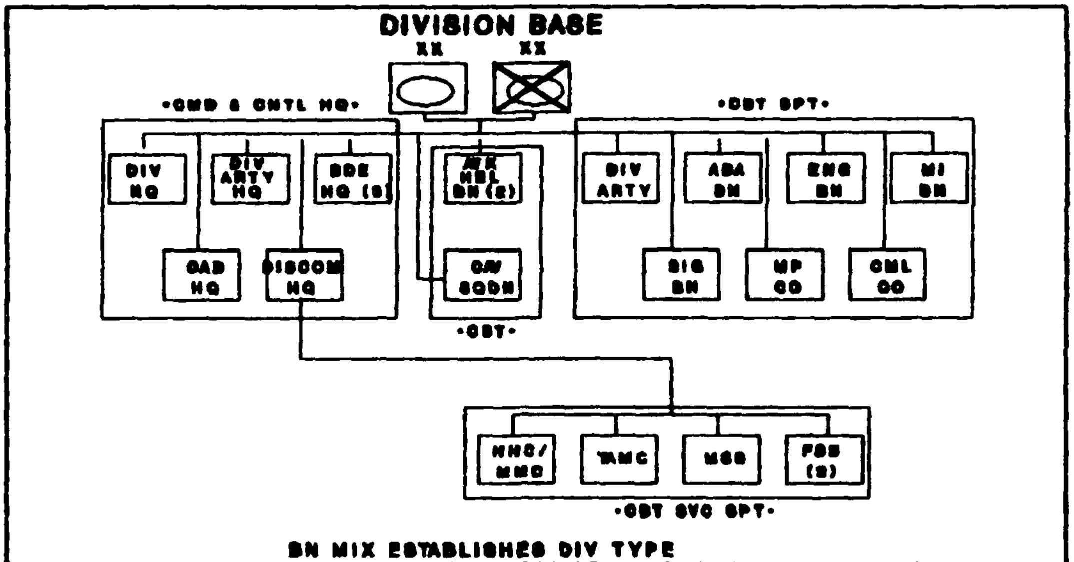


Figure 2. Division Base [CAS3,E709:19]

are organized to fight while corps and brigades are C2 elements placed over divisions and battalions respectively.

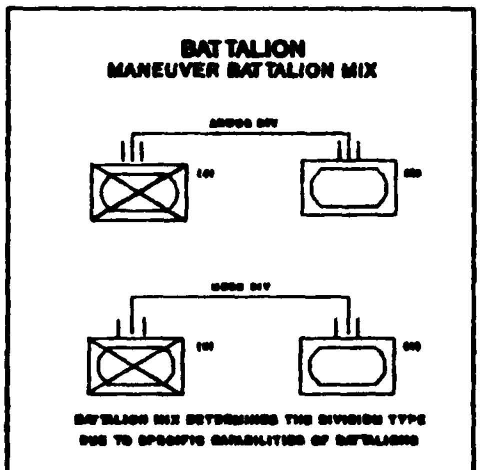


Figure 3. Battalion Mix [CAS3,E709:25]

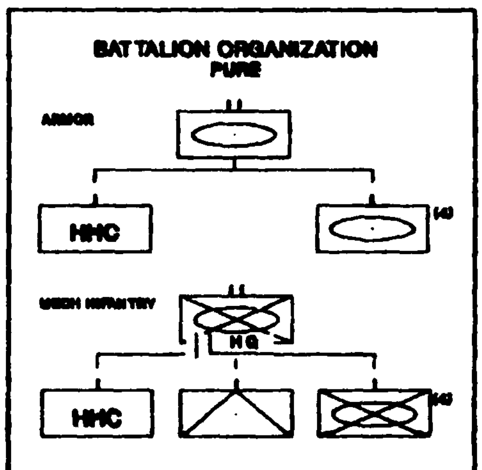


Figure 4. BN Organization [CAS3,E709:37-39]

Finally, the difference in planning can be explained in terms of resource allocation and utilization. At corps through brigade level, the focus of planning is on the allocation of resources. At battalion and below, the focus of planning is on the utilization of organic and inorganic assets; physical emplacement of units and key weapon systems on the allocated terrain, and the use of the allocated combat multipliers. Figure 5 displays this shift.

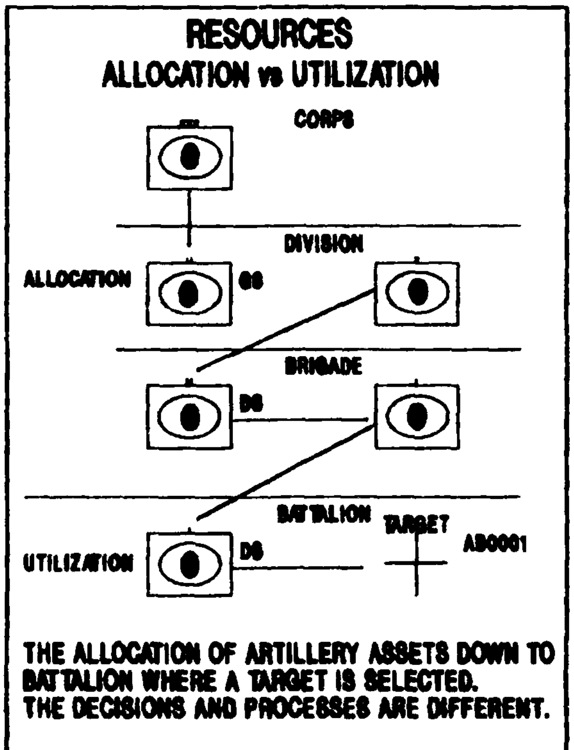


Figure 5. Resources

To date, the efforts in decision aiding, like the MCS prior to November 1987, is focused at corps through the brigade level of command. The Defense Advanced Research Projects Agency (DARPA)/ARMY AirLand Battle Management

(ALBM) program is currently developing an aid to assist planners at the corps and division command levels, through the use of a collection of cooperative expert systems [Stachnick:1]. At the brigade level, Brigade Planner is in the field and will be updated in the near future with version 2. Brigade Planner is the product of the Training and Doctrine Command, White Sands Missile Range (TRACWSMR). Currently, no research or development effort for the design and development of a battalion level decision aid exists, based on this author's research of the open literature and conversations with the proponents for close combat heavy and light, the U.S. Army Armor and Infantry Schools, respectively and the US Army Combined Arms Combat Development Activity, Ft. Leavenworth.

Research Problem

Considering the speed and lethality of the modern battlefield, the consequences of slow or incorrect decision making are cataclysmic. A commander must be capable of efficient application and measured control of all combat organizations under his command as dictated by the AirLand Battle Doctrine. If the MCS is to achieve its required operational capabilities, it must provide the required data to support the information requirements of higher echelons of command, and provide the commanders at battalion and below the necessary capabilities to accomplish the AirLand Battle tasks. In light of the fact that no decision aid is being designed for use at or below the battalion level, it would be useful to investigate an automated decision aid that would enable the battalion commander to rapidly, efficiently, and correctly determine resource utilization during the development of future operation plans.

Research Objectives

The objectives of this research were:

1. To develop the conceptual design of a decision support system (DSS) which will assist in generating courses of action;
2. To investigate adaptive design as a method to develop the decision support system; and
3. To investigate the differences that exist between battalion and higher echelons of command during the planning process.

Scope and Limitations

The scope of this research effort was to develop a conceptual design of a DSS to be used at the battalion level of command to determine the initial force array for a course of action. This process became the means for defining the requirements of a tactical decision aid.

The limiting assumptions that were made in the conduct of this research are;

1. The environment in which this planning takes place is conventional ground warfare in a combined arms defensive operation located in Europe. Nuclear and chemical warfare were not considered.

2. Course of action evaluation and comparison phases of tactical planning were not considered. These activities occur later in the planning process. This assumption eliminates most of the staff interaction and focuses the planning effort at the highest levels of the battalion command structure.

3. The battalion has received a new operation order over the MCS. The order was in the standard five paragraph format with appendices.

4. Mission analysis has been completed. All specified and implied tasks have been identified.

5. The battalion is organized as a balanced task force and has been allocated the standard combat support slice.

6. Intelligence preparation of the battlefield has been completed. The task force is facing a Soviet motorized rifle regiment. All avenues of approach into the task force's sector have been identified.

The remainder of this thesis is divided into the following parts. Chapter II discusses the idea of decision support systems (DSS) and its applicability to the tactical planning problem. Then Chapter II examines the adaptive design methodology for decision support systems and its application to the initial force array subproblem of the course of action development problem. Chapter III discusses the roles and influences of combat power in the planning process, approaches that attempt to quantify combat power and the differences in the factors that influence the evaluation of combat power based on the echelon of command. Chapter IV provides the conclusion and recommendations of this research effort, the value of adaptive design, and a direction for further research.

II. Literature Review and Methodology

> *The general who wins a battle makes many calculations in his temple ere the battle is fought . . . Thus do many calculations lead to victory, and few calculations to defeat . . . It is attention to this point that I can see who is likely to win or lose.*
>
> [Sun Tzu:43]

Introduction

Based upon the overwhelming importance that planning has on the outcome of battle, what capabilities must a battalion level decision aid have that would enable this aid to effectively assist the commander facing a tactical planning problem ?

To answer this question, Chapter II discusses the idea of decision support systems (DSS) and its applicability to the tactical planning problem. Then Chapter II examines the adaptive design methodology for decision support systems and its application to the initial force array subproblem of the course of action development problem.

Decision Support System

There exists no widely agreed upon definition of a decision support system. Most definitions include the terms computer, human involvement, and the importance of the link age between the two [Jarvis:4] . The definitions range on one extreme as an interactive computer system that aid decision makers in the utilization of data and models in solving unstructured problems and at the other extreme as any system that provides a contribution to decision making [House:9]. An example of each type of definition are provided below:

1. A computer based system designed to enhance the effectiveness of decision making in performing semistructured tasks [Alavi:21].

2. A system, manual or automated, that supports the cognitive processes of judgment and choice [Valusek,July 1988].

Others feel that a DSS should be defined by its characteristics in several key areas. Sprague states, "the 'characteristic' approach seems to hold more promise than definitions . . . in understanding a DSS and its potential" [Sprague:3]. Drawing from the studies of Keen, Alter, and others, Sprague outlines the characteristics of a DSS;

- they tend to be aimed at the less well structured, under specified problems that upper level managers typically face;

- they tend to combine the use of models or analytic techniques with traditional data access and retrieval functions;

- they specifically focus on features which make them easy to use by noncomputer people in an interactive mode; and

- they emphasize flexibility and adaptability to accommodate changes in the environment and the decision making approach of the user [Sprague:3].

Regardless of the approach selected, the goal of a DSS is to enable the decision maker to make better decisions in terms of efficiency, effectiveness, and (or) understanding.

As stated earlier by Alavi, DSSs are ideally suited for semistructured problems; but, what is a semistructured problem? A problem is semistructured if it does not lend itself to formulation in a manner which is analytically tractable and unequivocally captures its essence, but requires subjective analysis and judgment to formulate and resolve [GAO:9]. These problems are delineated by large information requirements, uncertainty associated with the environment, the resources, and the advantages of competing courses of action.

DSSs focus on supporting the decision making process of decision makers faced with semistructured problems. Therefore, the design of a DSS must be able to combine human decision making with the computer's computational and data storage abilities. To do this, an understanding of the decision making process and the characteristics of decision makers is required.

Currently, there exists no single comprehensive theory on decision making, since the decision process is a function of the decision maker and the problem at hand. Consequently, there exist many paradigms of decision making. Based on the analysis of studies conducted on decision makers, Carlson is of the opinion that the paradigm of intelligence, design, and choice [Simon] would prove to be the most beneficial. This is due to the fact that the activities of decision makers can be grouped into those three categories. Intelligence or problem formulation, encompasses such functions as acquiring information, identifying objectives, and "structuring" the problem. Design activities are generating alternative courses of action. Choice includes activities that evaluate and select a course of action [Carlson:6].

In addition, four other observations have been made of decision makers. These observations are;

> 1. Decision makers have trouble describing a decision process, but they do seem to rely on {representations}, such as pictures or charts, when making or explaining a decision . . . Thus a DSS should not require that a decision maker be able to describe the decision process before the DSS is built [Carlson:6];
>
> 2. Decision makers need memory aids. These memory aids may be physical, such as paper . . . , mental rules that a decision maker applies . . . , or . . . reminders from a decision makers staff. . . DSSs should provide {memory aids that} are compatible with the needs of the decision maker [Carlson:6];
>
> 3. That there are differences in {decision makers} styles and knowledge [Carlson:6]. The DSS must possess the ability to adapt to the decision maker; and

> 4. Decision makers expect to exercise direct, personal control over their support. . . This . . . does not imply that the decision maker . . . operate the DSS. . . {but that he} understands what the DSS can do and be able to interpret its output [Carlson:6].

Based upon these observations, a DSS ,through its dialogue, model, and database components, must provide each user with the physical representations, operations necessary to support intelligence, design, and choice, and automated aids for memory and control. To support the use of operations and representations, memory aids such as databases, workspaces, views, libraries, links, triggers and profiles must be provided. Control aids include mechanical facilitators, training supporters, combined operations, and operation result changers. The design framework supposes an interactive, graphic environment, utilizing a group of representations, operations with related control and memory aids, and extensive user interaction [House:8]. Through interaction with the DSS, the decision maker gains understanding of the problem and its bounds which enables him to structure the problem and determine the appropriate techniques to attack the problem. It should complement and enhance his ability to generate alternatives and assist him in determining the best alternative.

It is important to remember that a DSS is designed to support the decision making <u>process</u>, not dictate that process. This is because a " specific decision may be of a different type in different organizations at different times or for different decision makers " [Carlson:6]. As such, a DSS should help a decision maker develop his own skills, style, and knowledge which will enhance the decision maker's ability to make informed decisions through its designed flexibility.

The question now becomes: Is a DSS appropriate for the tactical planning process at battalion level ?

Battalion Level Planning: A need for a DSS ?

Planning at battalion level is a continuous process. At any time, the commander and his staff will be planning in response to two circumstances: in reaction to changes in the tactical situation, or upon receipt of a new mission from brigade headquarters [CAS3,E104:18]. The latter circumstance is the scope of this research since it simplifies the situational factors, and better focuses the planning process.

The planning process starts upon receipt of a mission and terminates when the commander approves an operation order. What happens between these two points was the objective of the Carlisle Experiment [Andriole,July 1986]. The results of the experiment revealed that the military planning process is highly structured (sequential, procedural, doctrinal, and integrated), highly repetitive (planning, replanning, and contingency planning), mission-oriented (goal-directed), and a verbal, graphic, and non-numeric process [Andriole,July 1986:28].

The planning process that was observed is referred to as the Estimate of the Situation. This Estimate is:

> a mental problem solving process. . . It is designed to provide a systematic approach to an analysis of all factors affecting the accomplishment of a mission in order to determine the most suitable course of action to undertake [CAS3,E104:23].

The basic steps of this process are;

1. Mission (or problem)
2. The Situation and Courses of Action
    a. Considerations Affecting the Possible Courses of Action (terrain, weather, light data).

    b. Enemy Capabilities (probable courses of action).

    c. Own Courses of Action.
3. Analysis of (Friendly) Courses of Action
4. Comparison of Courses of Action
5. Decision [CAS3,E104:25].

At the battalion level, the process is not as formal as at higher echelons of command [CAS3,E104:23]. This is primarily due to the environment in which the battalion operates. The battlefield environment provides the commander with problems in the form of missions which are unique and not readily quantified. These characteristics of a mission are the result of the dynamic nature of the tactical situation and the lack of a generally accepted and validated theory on war and combat. Therefore, the commander, drawing upon his knowledge, military training ,and tactical experience is required to make subjective judgments to formulate and decide on how to accomplish the mission. Though this is required of all commanders at each echelon, commanders at battalion and below are required to be more active in the planning process due to a small or nonexistent staff. Other environmental factors that affect the tactical planning process at battalion level are "time availability, experience of the commander and his staff, and the relative urgency of the situation may necessitate variations in application of the process" [CAS3,E104:23]. This environment in which the planner - decision maker operates is an ideal environment for a DSS. The dynamic nature of the problem and uniqueness of each situation faced by the tactical planner at the battalion level indicate that the design and development of a DSS to aid in planning is warranted. A DSS will provide the commander the ability to structure the attack of the problem by selecting from the numerous analytical tools based upon his skills, experience, and understanding. This flexibility will enhance the commander's ability to explore options and make informed decisions.

To design such a decision aid using the traditional design approach would require the identification of all the requirements necessary to support the tactical planning process. But as already discussed, decision makers are not capable and should not be required to define all the requirements of the system before it is built. Therefore, a radical departure from the traditional design approach is required which will assist the user in identifying requirements for the decision aid. This approach is called 'Adaptive Design.'

Adaptive Design

The traditional design approach divides the development of a system into four processes: requirements analysis, system design, system development, and system implementation. The fundamental assumption in the "traditional 'life cycle' approach is that the requirements can be determined prior to the start of the design" [Alavi:22] . This assumption is not valid based on the observations of decision makers.

Consequently, Sprague states that:

> the traditional approaches for analysis and design have proven inadequate because there exist no single comprehensive theory of decision making, and because of the rapidity of changes in the conditions which decision makers face. Designers literally "cannot get to first base" because no one, least of all the decision maker or user, can define in advance what functional requirements of the system should be [Sprague:11].

Based upon this dynamic nature, Valusek states that;

> ... the fact ... information requirements constantly evolve with the user's receptions of the problems and opportunities. Therefore a development approach based on "freezing" requirements is not possible. The outgrowth of this (fact) is ... the concept of adaptive design [Valusek,June 1988:2].

The adaptive design approach "- start small and grow -" [Valusek,June 1988:5] condenses the four processes of the 'life cycle' approach into a single process of short duration and repeatedly iterates this process until the system adapts to the decision process. The adaptive design process requires recognition that users cannot totally define the problem or decision process, and that the user, problem, and environment are not static. Consequently, an initial system must be designed and developed to support the decision making requirements of a smaller but important subproblem selected by the user and builder [Sprague:11]. Through the use of this system, additional requirements are identified which start the evolutionary process that will ultimately enable the DSS to meet the needs of the users and the decision process. This leads to the question, how do you capture the key decision components of the tactical planning process, its information requirements, and design an interactive system which can support the numerous planners and their varied application of the process ?

Application of Adaptive Design To the Planning Problem

The tools that are being researched to enable adaptive design to "start small and grow" are concept mapping, story boarding, and feature charts. Each tool will be discussed in general terms as well as its application in a user's design of a DSS to support the tactical planning problem.

Concept Mapping

The first tool to be discussed is concept mapping. Concept mapping is:

> . . . an educational tool; it has been developed specifically to tap into a learners cognitive structure and to externalize for both the learner and the teacher to see, what the learner already knows [Novak:40].

A concept map in its simplest form is a graphical and semantical linking of two concepts which conveys the cognitive relationship between the concepts [Novak:15]. Figure 6 shows a simple concept map.

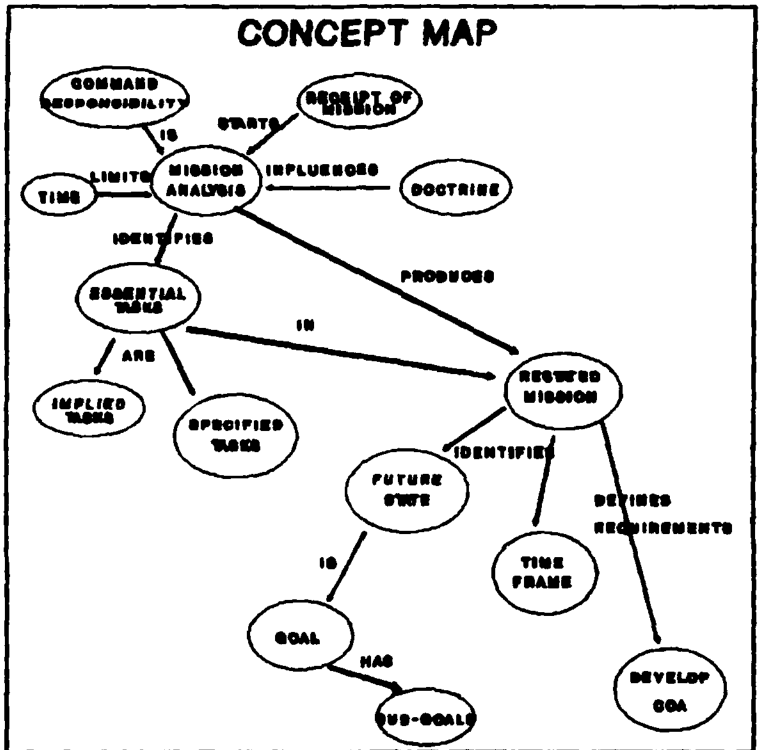


Figure 6. A Concept Map

McFarren expanded the use of concept mapping from an educational tool to a design tool that bounds the problem space and therefore the information requirements in the adaptive design process. McFarren states:

> Concept mapping is designed to meet the requirements for capturing the problem space. By identifying the key factors and ideas of a problem space and representing their relationships to each other, the problem will be identified and described by a map of concepts [McFarren:40].

Through concept mapping, the user and designer are able to gain understanding of the problem by identifying the key decision elements, kernels, within the decision process. From these kernels, one kernel will be selected for use during the storyboarding process which will provide a descriptive model of the decision process that the initial prototype will be designed and developed to support. This selection is based upon the kernel's relationship with the other kernels and the agreement between the user and builder.

The selection of the kernel for the tactical planning problem was accomplished through the use of concept mapping and a literature review. This required several iterations of this process to identify the initial array of friendly forces as the kernel.

The first concept map, Appendix A, and the literature review indicated that course of action development is the key subproblem of the tactical planning problem. All other subproblems which lead to a concept of operation are dependent on the ability of the commander to quickly develop feasible courses of action. This process requires the commander to conceptualize the influencing factors of the battlefield and design a means to counter selected enemy capabilities.

A feasible course of action must;

1) be within the capabilities of the battalion to execute,

2) accomplish the battalion's mission, and

3) be different enough from other courses of action to permit later analysis [CAS3,E104:67].

At battalion level, course of action development is usually limited to countering one enemy capability due to time and limited tactical latitude, as compared to higher echelons of command which usually consider more capabilities. Concept mapping again was used to identify the key decision elements of the course of action development problem.

The second concept map, Appendix A, indicates that determining the initial friendly force array is the key decision element for course of action development. This was chosen as the kernel that the initial system will be designed to support. This selection was based on the following reasons. First, the initial friendly force array is the first decision faced by the planner in the development of a course of action. The other concepts are either information elements or decisions made after the initial force array. Second, it is imperative that this decision be made quickly and correctly. Finally, the initial force array must accomplish the battalion's mission. It is highly possible that the number of arrayed forces required to accomplish the mission will exceed the number of available maneuver platoons in the battalion's organization. In this situation, the use of economy of force measures (e.g. scout platoon screens a flank), fire support assets (e.g. TOWs, mortars, and artillery), or both may be required.

The last concept map, Appendix A, was used to explore the factors that influenced the initial force array determination process. These factors were a function of the Mission, Enemy, Troops available, Terrain, and Time or the military acronym METT-T. Therefore, a DSS that is to aid in the determination of the initial force array must be able to access the required information, manipulate that information if required, and present the information in a manner that supports the goal structure and cognitive characteristics of the decision maker [Noah:909]. To insure that the DSS has those stated capabilities, the requirements for this system must be further defined by the user and designer. This was accomplished through the use of the second tool of the adaptive design process: Storyboarding.

Storyboarding

The second tool in the adaptive design process is storyboarding. A storyboard is, " nothing more than screen displays of the functions and tasks that the aid might perform when activated by the user " [Andriole,November 1986:855]. The approach, used to develop storyboards is the Representations, Operations, Memory aids and Control mechanisms (ROMC) approach [Sprague and Carlson]. This approach to storyboarding produces storyboards that provide the user with familiar representations that support the user's conceptualization, operation to manipulate and analyze the representations, memory aids that assist in joining the representations and operations, and control mechanisms that enable the user to manipulate the entire system to meet his style, knowledge, and skill level. Storyboarding is an,"extremely powerful vehicle {for} requirement {generation and} validation " [Andriole,November 1986:855]. It also identifies," the analytical methods most likely to help to drive the aid," and assist in the " man-machine interface development " [Andriole,November 1986:855]. In short, user approved storyboards are the user's statement of requirements to the builder [Valusek,July 1988].

The storyboarding process as applied to the design of a battalion level planning aid was guided by the concept maps and research in the military planning process. The initial storyboard, Figure 7, provides the major categories of information required in the planning process which was identified by the concept maps and research. These information requirements; mission, enemy, troops available, and terrain (METT) ; are provided to the commander in the

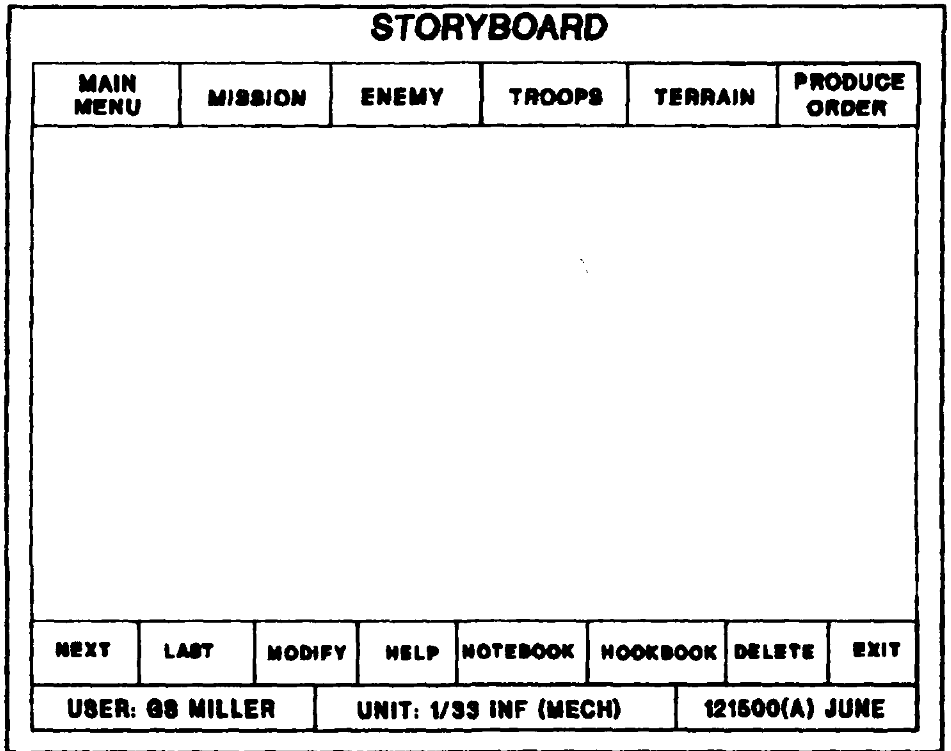


Figure 7. A Storyboard

current manual system through the brigade operation order with its accompanying overlays, appendices, and map sheets.

From the initial storyboard and METT-T storyboards with their subsequent screen displays, the information requirements necessary to array initial friendly forces was refined and more precisely defined.

The storyboarding identified the following requirements:

1. A system that should provide assistance to the user in determining the unit's mission, specified and implied tasks, based on the input of the mission statement, concept of the operation, and the commander's intent.

2. A system that could access models that could provide information on combat power, expected losses, terrain analysis, and templating (friendly and enemy).

3. A system that could assist in maintaining the preferences of the commander during the conduct of subjective evaluations and comparisons.

4. A system that is able to rapidly access, manipulate, compare, analyze, and sort information concerning the state of friendly and enemy units.

5. A system that can incorporate the various concepts of time that exist in planning.

6. A to meet the structured, repetitive, graphic, and non-numeric nature of tactical planning while maintaining system flexibility and user friendliness.

The METT-T storyboards and screen displays are located at Appendix B. Each storyboard and subsequent screen displays have an associated explanation of what is occurring within it. The combination of the displays and explanations demonstrates the type of information flow necessary for the process that the DSS is being designed to support and captures the decision process. Alone these storyboards do not communicate to the user and designer the various paths that can be taken to reach them. To show this interconnectivity, the last tool of the adaptive design process must be used.

Feature Chart

The last tool is the feature chart. The feature chart uses physical device symbols as a tool for communication and analysis. Through the use of these symbols, the representations, operations, memory aids, and control are featured [Belardo:13]. It communicates to the user the proposed system in three ways. First, " {i}t will help assure that the analyst understands the user's needs, and that the user understands what the designer is specifying " [Belardo:19] . Secondly, it only shows," the user's controls, not how the designer chose to implement them " [Belardo:17] . And last, the feature chart, depicts " the interfaces, paths and flexibility of the proposed system " [Belardo:19] , which is required to support, " decision makers faced with semistructured tasks " [Belardo:12].

The feature chart for this DSS is located at Appendix C. As described, the feature chart provides the ligaments that join the storyboards and the screen displays within each storyboard. Each storyboard and associated screen displays represent individual pieces of a puzzle which must be located and pieced together during the process of determining the initial force array. This piecing need not be sequential, though planners are schooled and drilled to perform the process in a systematic manner.

Hookbook

In addition to the three tools that are used in the adaptive design process, the concept of the 'hookbook' [Valusek, June 1988:109-110] was used to capture thoughts, ideas, or recommendations that would affect the evolution of this DSS or any DSS. During the conduct of this research, the hookbook was maintained manually on any piece of paper available ranging from 3 X 5 cards (preferred method) to sides and backs of paper storyboards. At a minimum, the date, the inspiration, and the circumstances that provoked this inspiration were recorded. At the conclusion of the research effort these entries were collected and sorted according to category. The ones that have been incorporated into the design effort were discarded. The remaining entries are located at Appendix D, sorted by category.

Summary

This chapter has covered many subjects and has alternated between a theoretical DSS and design approach and application of this theory to the conceptual design of a battalion level planning aid. The storyboards at Appendix B with their associated text serve as the users statement of requirements since they capture the kernel decision process. Chapter III will focus on the model base requirements to support this kernel system. It will focus on the use and influence of combat power in the planning process in general and 'array initial forces' process specifically, modeling approaches which attempt to capture and quantify combat power, and the differences that exist between the echelons of command when considering the factors that influence the evaluation of combat power.

III. MODEL BASE REQUIREMENTS

> *{He} who is to command ... forces in ... war must regard their absolute strength as a given quantity... There remains nothing ... but to produce, even where an absolute superiority is not attainable, a relative one at the decisive point, by making skillful use of what ... {he has} ... The calculation of space and time appears ...essential in this matter.*
>
> [*Clausewitz*:139]

Introduction

In Chapter II, " array initial forces " was identified as the kernel process that the initial battalion level DSS prototype would be designed to support. As depicted in the second and third concept maps and the storyboards, this process is influenced by the considerations given to the unit's mission, commander's guidance, avenues of approach, the enemy's courses of action (most likely, or most dangerous), and doctrine. The driving factor in array initial forces, the initial process of course of action development, is the quantification of combat power and its overall relationship between friendly and enemy forces and its effective unification with the objective considerations of space and time. Only through the objective consideration of these factors, will a tactical commander be able to achieve a relative superiority at the decisive point when an absolute superiority does not exist.

Currently, the use of tactical quantification in;

> the process of course of action development is rudimentary ... US Army officers rarely apply either the qualitative analysis of ST 100-9 or the exhaustive subjective deliberations of FM 101-5's Appendix E. These methods are tedious and do not meet the requirements of modern battle tempo. The reality ... is that course of action development ... is primarily an intuitive process ... {in practice} [Fastabend:12].

This intuitive process used in the field environment is a reflection of the American adoption of the " German WWII propensity to dispense with mathematical tactical models and rely on the 'spiritual power' and 'aggressive spirit" [Fastabend:25]. This reliance is a two-edged sword. It permits the planner to meet the time requirements of the modern battlefield but frustrates his creativity by requiring him to perform routine, non-creative tasks and a more crippling effect that it fails to provide him the measured feedback so vital to the creative process.

The proposed battalion level DSS can support the planning process by enhancing the creativity of the planner during the 'array initial forces' process of course of action development by freeing him from non-creative tasks and providing the necessary feedback through the interaction of the model base, database, and man-machine interface components of the DSS. The question is: Can a decision aid designed to support a specific echelon of command be scaled down or up to meet the needs of another echelon of command without significant changes except for the size of the forces involved? Chapter III addresses the role and influence that the concept of combat power has on the process of arraying initial forces, modeling approaches that attempt to quantify combat power, and finally the difference in the factors that influence the evaluation of combat power based on the echelon of command that must be considered in the development of the initial model base.

Combat Power and Array Initial Forces

Combat power is the measure of the friendly and the enemy forces' capabilities, respectively. The relative combat power is the overall relationship between the friendly and the enemy forces' combat power. "The basic factors of combat power are maneuver units and supporting fires units " [US Army Command and General Staff College (CGSC), ST 100-9:4-7]. Other factors such as terrain, availability of combat multipliers, and intangibles can also be considered. The importance and perception of the factors change with the level doing the planning. The planner determines his combat power by considering the capabilities of the units two levels below his own as indicated in Table 1.

Planning Level	Considered Level
Corps	All Brigades
Division	All Combat Battalions
Brigade	Infantry, Armor, and Artillery Companies
Battalion	Infantry and Armor Platoons and fire support

Table 1. Units Considered in Planning

The planner through his analysis of relative combat power is able to gain general insight into friendly and enemy capabilities. The fusion of combat power with enemy templates, space, time and other planning factors , as depicted in third concept map, by the planner stimulates ideas on the type or form of military operation that he, the planner, can perform. For example, if the mission is to defend, the planner can see if he must have a strong defense across his entire front or that he can concentrate his forces based on the enemy possessing overwhelming power or not [CGSC,ST 100-9:4-7]. Therefore, the planner through the use of combat power gains an understanding of 'what to', the establishment of a problem boundary, but it does not provide the 'how to'.

The use of combat power and its relationship between adversaries during the arraying of initial forces gives the planner an idea on the number of units that are required to be allocated against the enemy force to have a reasonable chance of success based on doctrinal rules of thumb that are located at Table 2 and Table 3.

Mission	Ratio (F/E)	Remarks
Delay	1:6	
Defend	1:3	Prepared
Defend	1:2.5	Hasty
Attack	3:1	Prepared
Attack	2.5:1	Hasty Position
Counterattack	1:1	Flank
Movement to contact	1:1	
Exploitation	1:1	
Pursuit	1:1	

Table 2. Planning Ratios for Arraying Forces [CGSC,ST 100-9:4-9]

Planning Level	Avenue Size	Array Forces
Corps	Division	Brigade
Division	Regiment	Battalion
Brigade	Battalion	Company
Battalion	Company	Platoon

Table 3. Level of Units to be Arrayed [CGSC,ST 100-9:4-10]

This process enables the planner to determine if he has a pool of units to use during the process of developing a scheme of maneuver (See 2nd concept map, Appendix A). The significant contribution of combat power to array initial forces and the COA generation process is that force requirements are identified and a knowledge base is developed which will aid in future decisions concerning economy of force and risk. As it can be seen from this discussion and the second and third concept maps, the quantification of combat power is a key component in the initial process of creating a course of action, array initial forces. It also provides necessary feedback to the planner which will aid in his development of a COA. With this in mind, what approach exists that captures this concept of combat power.

Representing Combat Power

To represent the idea of combat power in aggregated combat modeling numerous measures of effectiveness have been developed over time by military analysts. The firepower-score approach is one of the approaches used as surrogates for this idea. On the other hand, the Axiomatic Generalized Value System is a general approach that extends the concept of value through time and space. These two approaches will be discussed in the following subsections.

Firepower-Scores

To model the combat capabilities of the heterogeneous combat forces found on the modern battlefield, military analysts have developed numerous methodologies that represent the combat power of a unit with a single static scaler value. Most of these approaches are developed along the same general approach referred to as firepower-scores

[Taylor:85]. These scores are " generally derived by combining military judgment and the ordered ranking of weapons by their technical characteristics " [Stockfisch:17]. There are several approaches that do not follow this general trait but rely solely on military judgment or technical data. Regardless of the approach used, the process of deriving these firepower-scores converts a heterogeneous force into a homogeneous force.

The general process of determining firepower-scores is simple, but requires a knowledge of basic terms and key relationships. The term **firepower score** refers to the "military capability or value of a specific weapon system" [Taylor:86]. Numerous approaches are used to derive this value. Scoring systems based on perceived combat value, historical combat performance, weapon firepower, mission dependent firepower, and what a weapon kills have been used to compute this value [Hartman:4-9]. **Firepower index** "represents the 'combat potential' of a military unit" [Taylor:86]. The value of a unit is obtained by the summation of all weapon systems in the unit using this equation [Taylor:86]:

$$I_x = \sum_{i=1}^{n} S_i X_i$$

where I_x = firepower index of unit x,
S_i = firepower score of ith X system, and
X_i = number effective in unit x.

The force ratio is a measure of relative combat power. It is obtained by dividing the total attacking force's index by the defending force's total firepower index. The use of the force ratio varies from model to model. The force ratio in combination with such factors as terrain, engagement type, and other battlefield factors are used in aggregated modeling for determining missions and combat postures, attrition computation for each side, determining FEBA movement, establishing priorities for fire support, resupply, and reinforcement, and finally in determining mission success [Hartman:4-7]. It should not be surprising that combat power is used in a manner similar to its use in actual planning. These determinations and computations are usually accomplished through table look up which are based on the force ratio and other factors of the battlefield. A representative number of approaches used to quantify combat power using the firepower-score approach and the attrition process are discussed at Appendix E.

The various approaches at Appendix E represent an evolutionary development in the scoring process and the understanding of combat. Initial attempts of quantifying combat power from 1945 to the 1950's were similar to the Army War College efforts that ranked US and German units' value based on the combat experiences of the study participants. At this time, operational research was in its infancy. As analysts became more involved in the modeling of combat, early 1960's to late 1970's, the introduction of objective data derived by the Ballistic Research Laboratory and weapon engineering was incorporated into the scoring approaches. The Index of Combat Effectiveness (ICE) approach is representative of this approach. In addition to the introduction of quantitative data to the process, tools like the Delphi Technique were used to determine subjective weighting schemes based on personnel experience for weapon characteristics and capabilities of which some are quantifiable. This approach is reflected in the Weapon Effectiveness Indexes and Weighted Unit Value (WEI/WUV). The next advancement, late 1960's and 1970's, in scoring resulted in two drastically different approaches. The first approach, Potential Anti-Potential (P-AP), represents a further attempt to quantify value by capturing the stochastic nature of combat by using killer-victim scoreboards from high resolution combat models. The resulting eigenvalues were then applied to 'future weapons'. The second approach, Operational Lethality Indices (OLI), took the historical, econometric approach to modeling to develop scores for weapon systems based on the study of 600 historical battles. The final approach, Weighted Power Value (WPV), could be viewed as a step backwards, but it is not. This approach weapon systems based on the study of 600 historical battles. The final approach, Weighted Power Value (WPV), could be viewed as a step backwards, but it is not. This approach and its concept of power, the ability to influence, enables a modeler to capture the value of battlefield entities which the other approaches cannot since these entities (e.g. civilians, guerrilla forces) possess little or no weapons, but have the ability to influence the combat process. Figure 8 summarizes some firepower-score approaches.

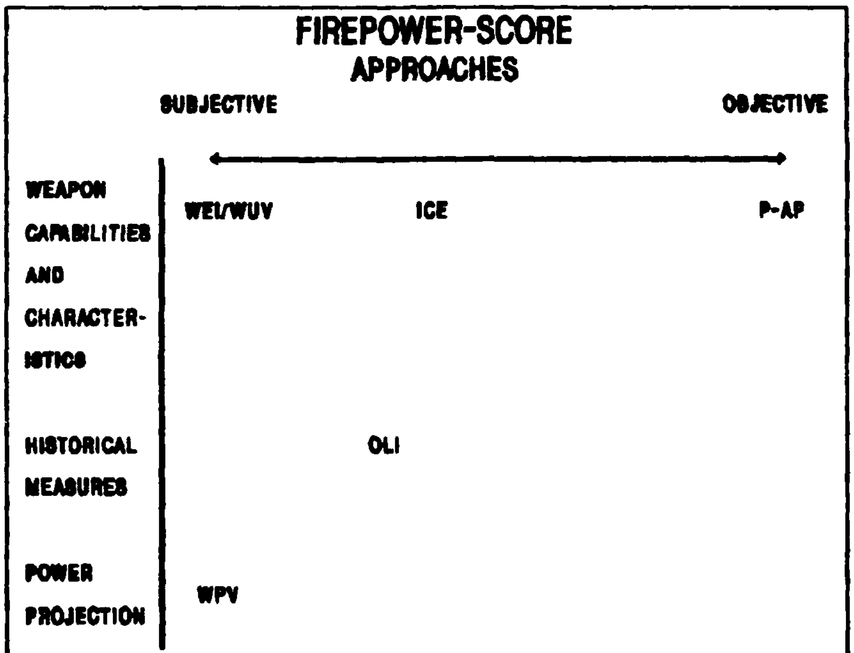


Figure 8. Firepower-score Approaches

All the approaches have their own weaknesses, but there exist several limitations which all the scoring approaches to aggregated attrition modeling share and result in the capture the synergistic effects that exist among weapon systems on the battlefield. This is because of the assumed additive nature of the approach across all weapon systems. Through planned mutual support and interaction of weapon systems in and among units, the tactical commander is able to fight " out numbered " because the sum of the whole is greater than its parts. Second, neither the indexes or the values are capable of depicting the minimum effective force nor decreasing returns to scale as the force increases in size because of the assumed linear relationship. For example, if a rifle's value is one and a tank's value is ten then a force composed of ten rifles is equally capable as the force composed of one tank. Third, there is a loss of information concerning the weapon composition of the aggregated force. This simply means that if a unit is not at 100% strength there is no immediate way to determine the number and type of weapon systems that are present in the force. Fourth, there exists no agreed upon approach on how to determine firepower-score values. Finally, there exist no proven relationships between force ratios, attrition as it is modeled today, and battle outcome. This is due to the fact that there exist no comprehensive and generally agreed upon theory of combat. As a result, it is very difficult to model something accurately when it is not totally understood.

Generalized Value System (GVS)

As indicated by the introduction to this chapter and the results from the application of the tools of the Adaptive Design Process discussed in Chapter II, combat power is situationally dependent upon the factors of time and space (e.g. the geographical areas of the battlefield; rear, close-in, and deep). The concept of situationally dependent value of combat units is an on-going research effort at the Naval Postgraduate School [Schoenstadt, Parry]. The Axiomatic Generalized Value System is based on the premise that the whole of military activity must relate to the engagement [Clausewitz:174].

Based on the preceding premise, the value of a unit is based on the unit's inherent ability to wage war. This basic inherent power is that value possessed by a maneuver or fire support unit which is at 100% of its Table of Organization and Equipment (TO&E) authorizations, when it is most likely to make contact with the enemy, as a result of its ability to conduct combat operations [Kilmer:33]. It should be noted that this concept of basic inherent value is very closely related to firepower-scores [Schoenstadt:5]. The magnitude of this inherent value at time 'tp' is adjusted according to the unit's mission and logistical state (e.g. effective personnel strength, quantity of operational weapon systems, and the availability of ammunition and fuel). It is also assumed that a combat unit in position without logistical support will consume itself monotonically which will give a unit a predicted adjusted basic inherent power at time 't>tp' [Kilmer:34]. The situationally inherent value of a unit is its adjusted basic inherent value "decremented by an exponential factor based on the time interval before that unit is available for commitment or can provide support " [Schonstadt:6]. Stated in an other way, " units that are not directly engaged at the start of the close-in battle still possess a potential for use at some point in the future " [Remias:29]. The variable time captures not only the general term time but also space as the time required to cover the geographical distance which will place a unit in possible contact with the enemy. At Appendix F is a brief expansion of this system. References on this subject are provided in the bibliography.

Factors that Influence Combat Power

The first section of this chapter discussed the general factors that influence combat power and the important contribution that the use of combat power plays in the planning process. The second section discussed modeling approaches to quantify combat power and the various factors that were considered in each method. In addition, an approach that fused time and space with combat power was discussed. Therefore, it should not be surprising that the factors used to evaluate or influence combat power at each echelon of command differ in the way each is viewed and relates to the analysis of combat power. Table 4 depicts the major factors and their influence by echelon on the planner when he evaluates combat power. An explanation of these factors and what they indicate for the initial model base is the subject of this section.

It first should be noted that the factors are the same for each echelon and can be categorized into one of the categories of METT-T, except mission which establishes a threshold force ratio. The first factor to be discussed is terrain. It is best explained by the levels of war and the hierarchy within levels. To gain a positional advantage, the corps planner must understand the general type and flow of the terrain so a battlefield geometry can be achieved that can give him a positional advantage. At the division and brigade level, the influence of the terrain type (e.g. open, rolling hills, restrictive) on combat power is to reduce the enemy's combat power while enhancing the friendly combat power. This is achieved through the use of restrictive terrain that will prevent the enemy from fully developing its combat power, and positioning friendly forces around this terrain so that friendly firepower can be concentrated into kill zones. In addition, routes are identified that

	Corps	Division	Brigade	Battalion
Terrain	General Layout	General Flow	General Character-istics	Specific Character-istics
Units	Generic Brigade Capabil-ities	Generic Battalion Capabil-ities	Generic Company Capabil-ities	Known Platoon Capabil-ities
Weapon Types	Very General	Very General	General Capabil-ities/ Character-istics	Specific Capabil-ities/ Charact-eristics
Personnel	Big Picture	Big Picture	General Concern	Specific Concern
Combat Multi-pliers	Allocates/ Weights Effort	Allocates/ Weights Effort	Allocates/ Weights Effort	Utilizes/ Enhances Abilities
Time Horizon	72-24 hrs	24-12 hrs	12-6 hrs	6-1 hrs

Table 4. Influencing Factors by Planning Level

will permit the rapid transition to the offense with the proper positioning of the reserve. At battalion and below, the planner is also concerned with the terrain type, but he is also heavily influenced by the form of the terrain and the manner in which it affects line of sight, cover and concealment which reduces his vulnerability or the enemy's, and fortifiability of the terrain. The terrain can enhance a battalion's combat power by enabling the unit to maximize the range of its key weapon systems and reduce its vulnerability to enemy fire while the enemy is restricted in the use of its power. Therefore, the influence of terrain on combat power varies with command levels.

The second factor is the units the planner uses to fight. As mentioned in the first section of this chapter, the planner uses the units two levels below his own during the planning process. Consequently, corps, divisions and brigades fight type units that have a generic capability; brigades, battalions, and companies respectively. Recall in Chapter I, it was stated that brigades have no established organization and battalions and companies have five possible organizations with different capabilities. The specific organization and consequently the exact capabilities of these units are established at the next subordinate level of command. On the other hand, battalions fight platoons which are mechanized infantry and armor. These units have known capabilities based on their organization and weapons assigned. Planning and fighting with units with known or unknown capabilities has a great influence on the determination of combat power.

The third factor is weapon type. At corps and division level the planner does not concern himself with a detailed appraisal of weapons in an organization or the quantity on hand. For the purpose of their planning, a general type weapon (e.g. a tank) is sufficient. At brigade and to a greater extent at and below battalion the form of the weapon systems possessed (e.g. M1 tank, M60A3 tank) by the enemy and friendly and the quantity make a difference. Brigade planners are concerned with survivability and punishment consideration for selected weapon systems. The planner at and below battalion is very concerned about the above elements and in addition: lethality, rate of fire, hardness, quantity, range, and many other factors. To a battalion commander, it makes a big difference when that first echelon regiment with approximately 200 armored vehicle comes over the hill with BTR 60s and T-65 or BMP-2s and T-80s and he has M-2s and M-1s and is at 85% of authorized strength in equipment. In other words, weapon capabilities at the point of the engagement is important but the farther away from the engagement a lesser degree of importance is placed on weapon characteristics and capabilities. Consequently, the effect of weapon types on combat power vary at each echelon.

The fourth factor is personnel. The corps and division planners are concerned with the aggregated shortages by military occupational specialty type across the command. At brigade level, concern is placed on units that are short a high percentage of personnel. At and below battalion, the form of the personnel shortage could mean that weapon systems are either partially manned or not manned at all. This reduces the battalion's combat power through reduced weapon effectiveness and firepower. In addition, the line of the defense due to personnel shortages is spread thin which reduces the battalion's ability to absorb the enemy's power. As illustrated, the effect of personnel on combat power is quite different from an aggregated view than it is from 'fill the holes and positions' view.

The fifth factor is combat multipliers. This area covers both combat support and combat service support availability. As mentioned in Chapter I, corps, divisions, and brigades use the allocation of these assets to subordinates as a means to weight their efforts. At and below the battalion level, combat support assets can drastically increase the effectiveness of organic weapon systems. These assets provide the battalion the abilities to reinforce terrain, disorganize the attack, and increase friendly survivability. The scarcity or over-abundance of logistical support at battalion level and lower is usually detrimental to the unit's capabilities. It either forces steps to control fuel and ammunition consumption which drastically affects the ability to fire and maneuver or overburdens the transportation assets of the battalion and subordinate units.

Consequently, the influence of combat multipliers on combat power varies with command level.

The final factor is time. In all cases it represents the planning horizon for each level of command. It carries two connotations. It refers to the time available to the planner for decision making and to the time horizon for which the resulting decision is applicable. The second meaning is important because all planners must be concerned with the quantity of forces an echeloned enemy can commit against the command within that time horizon. Therefore, time affects all levels of command in the determination of combat power for both friendly and enemy forces, because the side that can get the most to the right place at the right time will be the victor. This effect is particularly strong at battalion level due to near-real-time planning requirements and decision applicability.

Two conclusions can be made from the preceding discussion concerning these factors. First, the general trend in almost all the factors going from corps to battalion is that they go from a general type to a specific form. This is no surprise from the point of view of information requirements and measures of effectiveness. As a planner approaches the point of contact, the value of information concerning the capabilities of weapon systems and their ability to destroy the enemy and vica-versa, increases.

The second and maybe the most important conclusion is that a decision aid designed to support planning at one echelon cannot be simply scaled down or up for the next echelon of command. It must be recognized that changes occur in key elements of the problem and planner bias at each echelon of command due to familiarity and experience of the planner at that echelon. The predominate change that occurs is in the analysis of combat power and its use in the planning process. At battalion level, combat power aids in determining the form of the military operation type that was determined at corps and refined at division and brigade. If this is ignored, the models of the problem and the goals of the planner will not provide the appropriate view of the situation for the user of the scaled down aid. The consequence of this failure will result in the decision aid being abandoned for a more intuitive 'shoot from the hip' approach [Noah:909]. This relates directly to the statement by Carlson cited in Chapter II that a " specific decision may be of a different type in different organizations ..." [Carlson:6]. Consequently, the building of the initial model base for this DSS must capture the needs of the battalion planner and the way he perceives combat power and the factors that influence it, rather than how a corps, division, or brigade commander handles those factors.

Summary

This chapter has discussed the key role that the quantification of combat power and its relationship between both the friendly and enemy forces in time and space play in arraying initial forces. Five different static approaches for quantifying combat power and a general approach that 'discounts' combat power based on the time required to have the unit in position to use its power were discussed. None of these approaches captures the true essence of combat power nor the true value of a unit. To compound this shortcoming, military planners at each echelon consider the factors that influence the evaluation of combat power or the relationship among these factors in the same light. These changes must be reflected in the model base of a decision aid if the aid is to be a success.

Chapter IV will discuss the finding of this effort in the areas of the proposed kernel DSS and the adaptive design process. Recommendations for improvement and enhancement of this proposed DSS will also be made.

IV. Conclusions and Recommendations

Everything is very simple in war, but the simplest thing is difficult.
[*Clausewitz*:53]

Introduction

This chapter presents the conclusions and recommendations in three major areas that dominated this thesis effort:

1. Several conclusions are presented concerning the requirements for the initial kernel Battalion Decision Aid.

2. Some conclusions concerning the merits of the adaptive design process in the establishment of the initial design requirements for this kernel are discussed.

3. The differences that would exist in the dialogue, database, and model base components of this decision aid as compared to a decision aid designed to support another echelon of command are discussed.

4. Finally, recommendations concerning the development of decision aids within the Army and direction for further effort at the battalion level of command are provided.

Appendix C contains other recommendations pertaining to improvements and enhancements for this decision aid.

The Kernel Battalion Decision Aid

As indicated in Chapter II, the environment in which the decision maker - planner operates is an ideal environment for a DSS. The military planning process and specifically "array the initial forces" process are very involved and subjective decision processes. The unique, dynamic, unstructured nature of tactical problems requires the decision maker to acquire, review, fuse and manipulate large amounts of information that will feed the planning process which will ultimately lead to the commitment of scarce and valuable resources. All this must be accomplished in a time sensitive and violent environment which combined produces a friction that degrades his mental faculties. The number of forces that are arrayed during this process are based on the evaluation of combat power and its relationship with space and time. Based upon the characteristics of the problem domain and the environmental requirements, the design and development of a DSS appeared to be the best approach to aid the tactical planner - decision maker at the battalion level.

The initial phase in the design of this battalion decision aid is done from the user - designer standpoint. The storyboards and the associated text serve as the user's statement of requirements. The storyboards and text not only provide the documentation for the system which captures the decision process, but also provides the vital communication link between the user and the builder which generally does not exist in the traditional approach. It must be remembered that " array initial forces " is but the kernel decision process that this DSS will initially support. Consequently, there intentionally exists considerable room for expansion and enhancement of this kernel system before the initial prototype could be built and used in the field. This is especially true in the model base component of this DSS. The design of this DSS, like all other DSSs, will never reach completion due to the dynamic nature of the environment, problem, and the users.

The Adaptive Design Process

In the conduct of this research, the adaptive design approach proved to be an ideal and flexible process for the 'front-end' analysis of a proposed decision aid based on the user's increasing understanding of the decision process used to solve a specific problem. This understanding lead directly to the identification of user requirements, as compared to the structured and builder orientated traditional approach to design that tells the user what he needs. Through the use of the adaptive design tools (e.g. concept mapping, storyboarding, feature charts, and hookbook) and its premise 'start small and grow', the initial focus of support for this DSS was identified to be the decision process of arraying initial forces which was determined to be the initial decision in the creative process of developing a COA. The use of the tools and their application to this decision process and more generally the military planning process became the focus of this research effort.

The first tool used in the adaptive design approach is concept mapping. The use of concept mapping in the development of this DSS proved to be a very good way to quickly bound the problem space and identify key decision elements. Its flexibility and semi-structured form enables the user to quickly add or alter concepts and their relationships with each other, respectively. It enables the user to explore deeply into processes that he uses routinely to reach a decision. It brings to focus relationships that he has habitually used but never considered in detail before, because the process is executed in such a rapid manner due to the user's familiarity with the decision process and subject matter. Concept mapping also provided a quick and easy way to capture initial information requirements for the decision process.

The next tool of the adaptive design approach is the storyboarding process. In the opinion of this researcher, storyboarding is the most powerful of the user-orientated tools in the adaptive design tool bag. First, it captures the decision process on the screen displays, and therefore serves as a convenient means to capture system requirements for the development of the kernel DSS and acts as a guide for future development and enhancement of the system.

Second, from the point of view of a user/designer with a recently acquired operations research education, it serves as a means to identify potential modeling approaches that may be applicable to the problem domain. This may be the answer to the old operations research question, ' I have a model, what problem fits ? ' Finally, it can be a self-documenting process which greatly reduces the problems associated with many decision aids developed in the traditional approach which habitually come with very poor documentation or none at all.

The only difficulty experienced using this tool was bridging the gap between the concept map and the storyboard. The approach that was used in this thesis to bridge this gap was an adaptation of the backward planning process used in military troop leading procedures. This approach required the development of the last screen display first based solely on user input and then work backwards to the beginning. In this case this meant starting with the forces arrayed and working backwards to the receipt of the order by using the concept map like a road map. This approach capitalized on the structure and sequential nature of military planning.

A key element in the adaptive design process is the frequent interaction between the user and the designer. It should be noted that this effort was developed with no specific user (e.g. battalion commander or operation officer) in the formal sense. The design is based on extensive review of military literature concerning military decision making and tactical planning, and informal discussions with fellow Army officers at the Air Force Institute of Technology (AFIT). These officers are all branch qualified combat arms officers, infantry and armor, with an average time of active duty service of eight years with the bulk of that time spent in company and battalion level positions. In addition, almost every officer's last duty position was command of a line infantry or tank company in the European environment. These officers, who have a vested interest in this area, formed the 'ad hoc' user. Consequently, this 'user' was readily available. Through the frequent face-to-face interaction with the user, a correct understanding of the problem and the decision process between the user and designer was obtained. This understanding of the problem and the decision process can now be conveyed to the builder via the storyboards. The traditional design approach does not provide the necessary flexibility to capture problems that are 'squishy.'

What is Different About a Battalion Decision Aid

Through the conduct of this research and the application of concept mapping and storyboarding to the military planning process, some conclusions were drawn concerning the differences that exist between the decision aid designed for use at the battalion as compared to a higher echelon of command. For a decision aid to be successful in assisting the planner at the battalion level of command (or any other level of command), it must properly aggregate, summarize, analyze, model, and display the information in a way that meets the planner's needs in terms of his goals and the way he views the battlefield. Therefore, the differences that exist in a battalion level decision aid can be explained from the standpoint of changes that must occur in the dialogue, database, and model base components of the battalion decision aid.

COMPONENT SUMMARY

COMPONENT	COMMAND LEVEL CORPS	DIVISION	BRIGADE	BATTALION
DIALOGUE	SCOPE ADJUSTED	SCOPE ADJUSTED	SCOPE ADJUSTED	SCOPE ADJUSTED
DATA	GOALS	ORGANIZATION	ORGANIZATION	SYSTEM PERFORMANCE
MODEL	GOAL ACHIEVEMENT	SCHEME	SCHEME	SYSTEM BASED

Figure 9. Component Summary

First, the man-machine interface or dialogue component of the battalion decision aid would closely resemble the screen displays and information presentation techniques used by a decision aid at a higher command level. The military planning process's non-numeric, graphic, and verbal characteristics do not change from one command level to the next. The hatred toward being made a 'bean counter' is universal among tactical planners and offends his 'warrior' image of himself. It is true that the scope and physical domain of each command echelon would cause changes in some of the representations (e.g. map scale and resolution) that are linked to the size and type of forces in the command and geographical area. The military terminology and graphics used in the planning process are standardized and relatively static. They convey the same information and concepts to a planner at battalion or corps, therefore the interaction between the machine and the man basically remain unchanged regardless of the level of the planner.

Second, the database component of the battalion DSS would be quite similar in design as any of the other decision aid for a higher echelon of command. This is due to the fact that METT-T information is the same at each echelon except that it becomes more aggregated with its associated loss of detail as it moves up. At the battalion level, the database would be structured around the management of information concerning systems performance whereas at the brigade and division level the information would be structured around organizations and processes (e.g. intelligence, logistic, electronic warfare), and at corps the information would be structured around the achievement of goals and the identification of aberrations. Consequently, the database component of a decision aid changes with command level, but is built on information provided by subordinate commands.

Finally, the model base of the battalion decision aid would be quite different when compared to another command level. The first requirement is that all the models used must provide results in real time due to the considerably shorter planning horizon at the battalion level. The second requirement at battalion level is that the terrain model must provide more capabilities beyond just identifying avenues of approach. The terrain model must provide information concerning pass time and throughput capacities for each avenue of approach. It must also be able to locate possible platoon positions that provide good line of sight, cover, and concealment based on the terrain data.

The major change in the models for a battalion level decision aid will be in the modeling of combat power due to the interpretation of METT-T which forms the basis for all tactical decisions and the use of combat power in the planning process. As illustrated in Chapter III, the METT-T factors that influence the determination of combat power and its relationship with space and time change as the planner descends the command structure. This reflects a different use of combat power in the decision process at each echelon. These changes in the key decision elements must be modeled correctly. A model used to compute combat power and model the battlefield at the battalion level must be built around weapon system performance. If not, the resulting form of the military operation type would be incorrect or inappropriate. This would also be true at higher command echelons except the selected type of military operation and its refinement would be affected. The goal that must be pursued in the development of a decision aid's model base is that for the intended use of the model in supporting the decision process it must be like the real thing [Cushman:5].

Based on this discussion, it can be seen that the building of a battalion decision aid is not just a simple matter of reducing the scope of a decision aid built for another echelon. It will require more complex changes in the system, especially in the area of the model base development. Unless these factors are considered in the building of a decision aid, the result will likely be that the decision aid will be abandoned for the 'gut feel' approach that is currently used in the field.

Recommendations

The following three recommendations are made based on the results of this research. The first and most important recommendation is to the decision aid designers and builders within the Army. Do not assume that a current or future decision aid designed specifically for an echelon of command can merely be reduced in scope to meet the needs of a lower echelon. To do so without recognizing the changes in the key elements of the problem space and bias at each echelon of command will likely result in a decision aid that will be abandoned because the model base will not correctly model the problem or the planner's goals and bias.

Second, the Army in conjunction with the Air Force Institute of Technology should pursue the development of this kernel DSS through thesis work of AFIT students. The result of this course of action would be that when it was time to start development of a battalion level planning aid the front end analysis contained in the storyboards would serve as the statement of need for the initial prototype. This would be accomplished at considerably less cost than having a contractor do the 'front end' analysis which users are capable of doing given the proper tools. The next logical step in the development of this initial design is to expand the DSS into the development of a scheme of maneuver.

The author can provide some initial 'cut' storyboards in this area.

Finally, the Army should review its procedures concerning the development of decision aids. This is especially true today with a tightening purse string. Users have the ability to identify their needs and requirements for decision aids through the adaptive design process. Through user involvement, an initially small system can be designed based on identified user requirements. Designed for growth, this small initial system will grow, requiring organizational support.

Summary

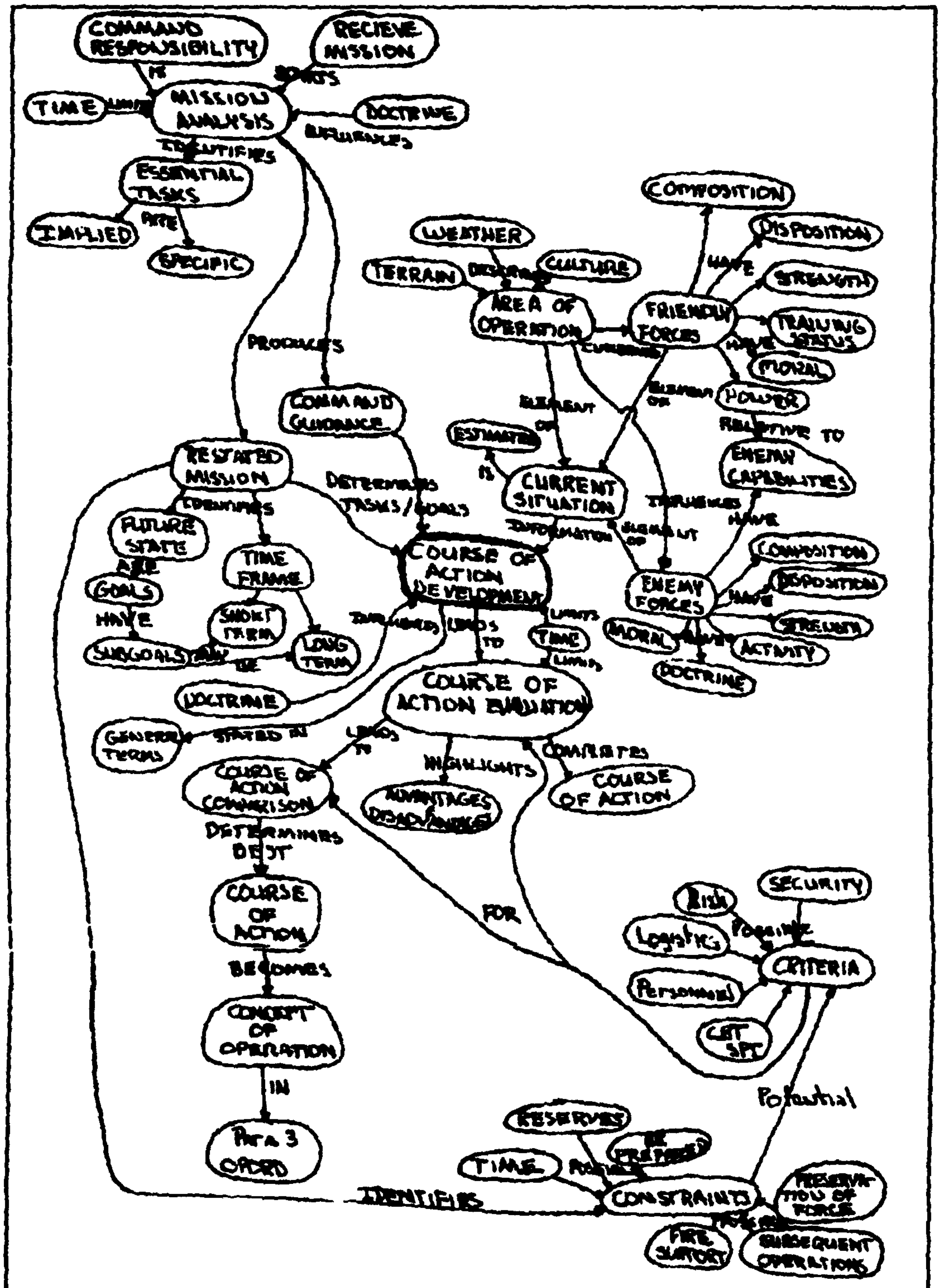
The major contributions of this thesis effort in the design of a battalion level decision aid are in two areas. The first area is the identification of existing models that could possibly be incorporated into the model base of a decision aid. The first step as indicated in this thesis is not to go out and build a new model and reinvent the wheel, but to do a literature review to find existing models that could be used directly or modified in some way to meet the requirements of the system. If this were practiced by builders - contractors, considerable savings in system design and development could be achieved.

The second area in which this thesis made a contribution is in the realm of military planning and decision aiding. It would be easy to fall into the trap that the military decision making process is the same regardless of the echelon of command due to the similarities in the outward appearance of the process. The observations made of the planning process during the Carlisle experiment are true for all levels after adjustment for the size of forces involved. Herein lies the trap. Though the process is outwardly similar, significant changes occur in key relationships of the decision process due the planner's goals and view of the battlefield. This implies that the military decision making process changes and that designers, builders, and users must not assume a decision process is static based solely on outward appearance and can be supported by scaling down an aid designed to support another echelon of command.

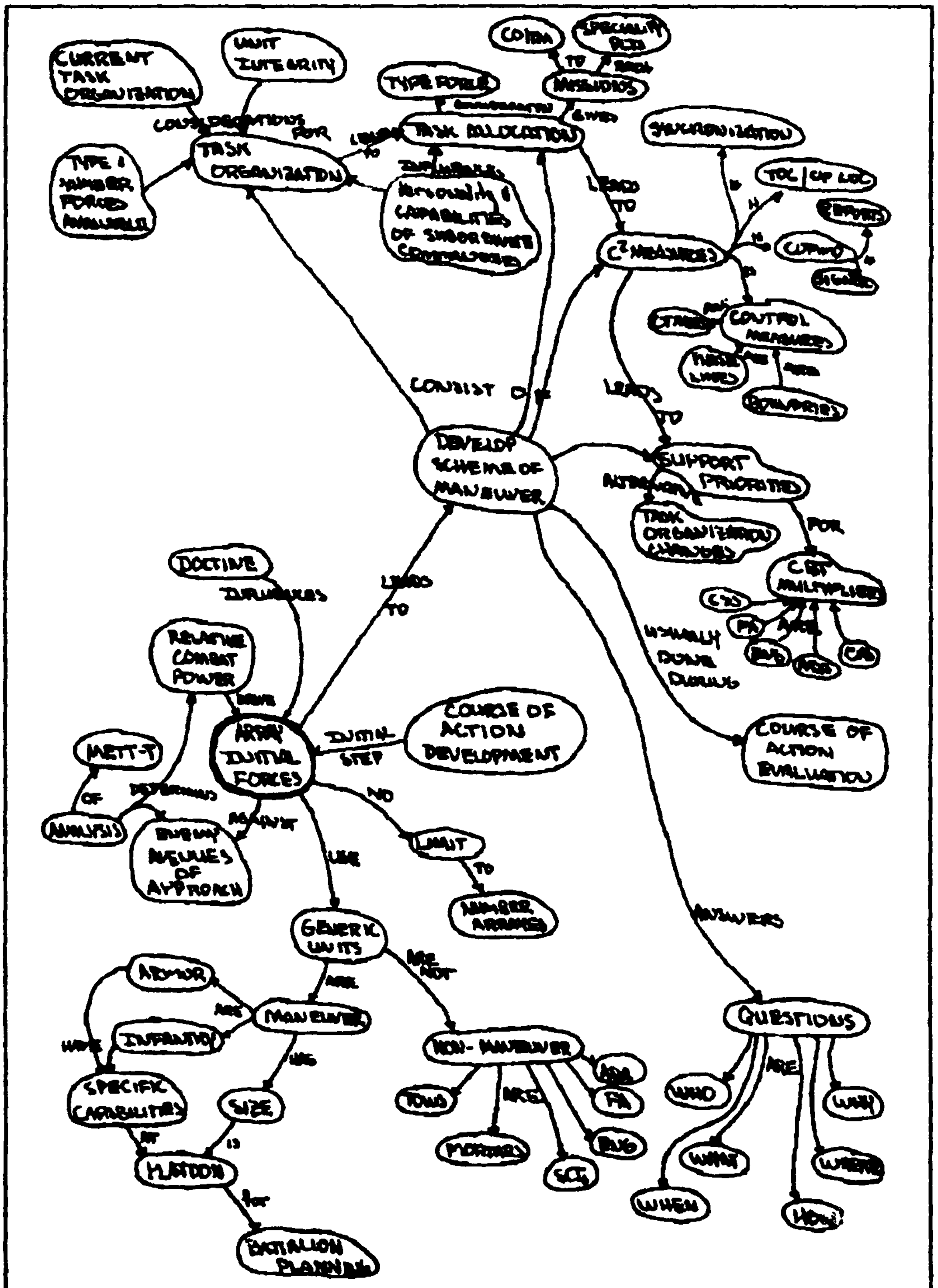
Appendix A

Concept Maps

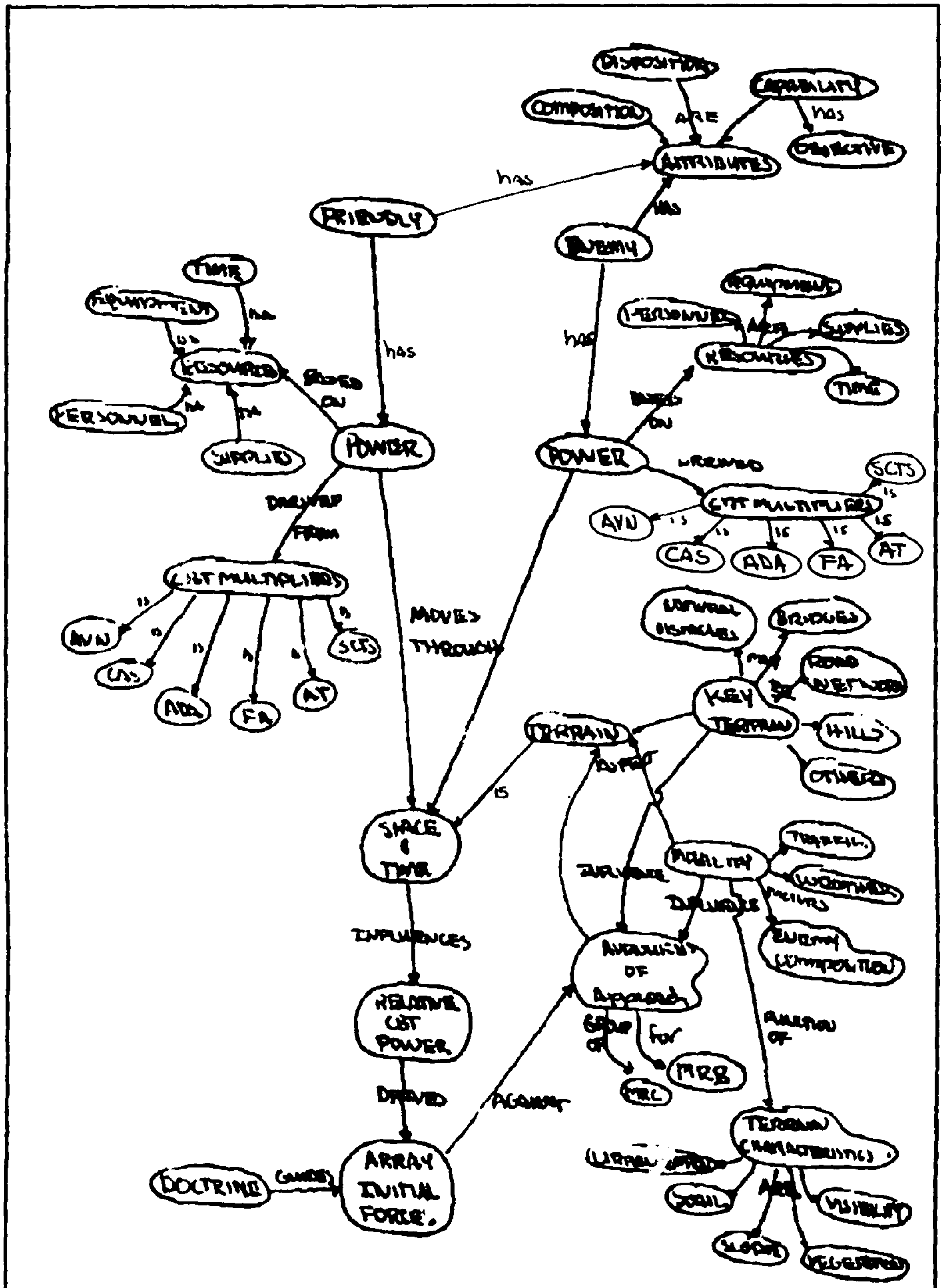
This appendix contains the concept maps which were used in identifying the kernel decision element which the initial design of the Battalion Decision Aid is to support. Three concept maps are contained within this appendix. The first concept map is of the military planning process at the macro level. The second concept map is focused on the course of action generation process. The final concept map is of the "array initial forces" process and its relationship with combat power, time, and space.



First Concept Map



Second Concept Map



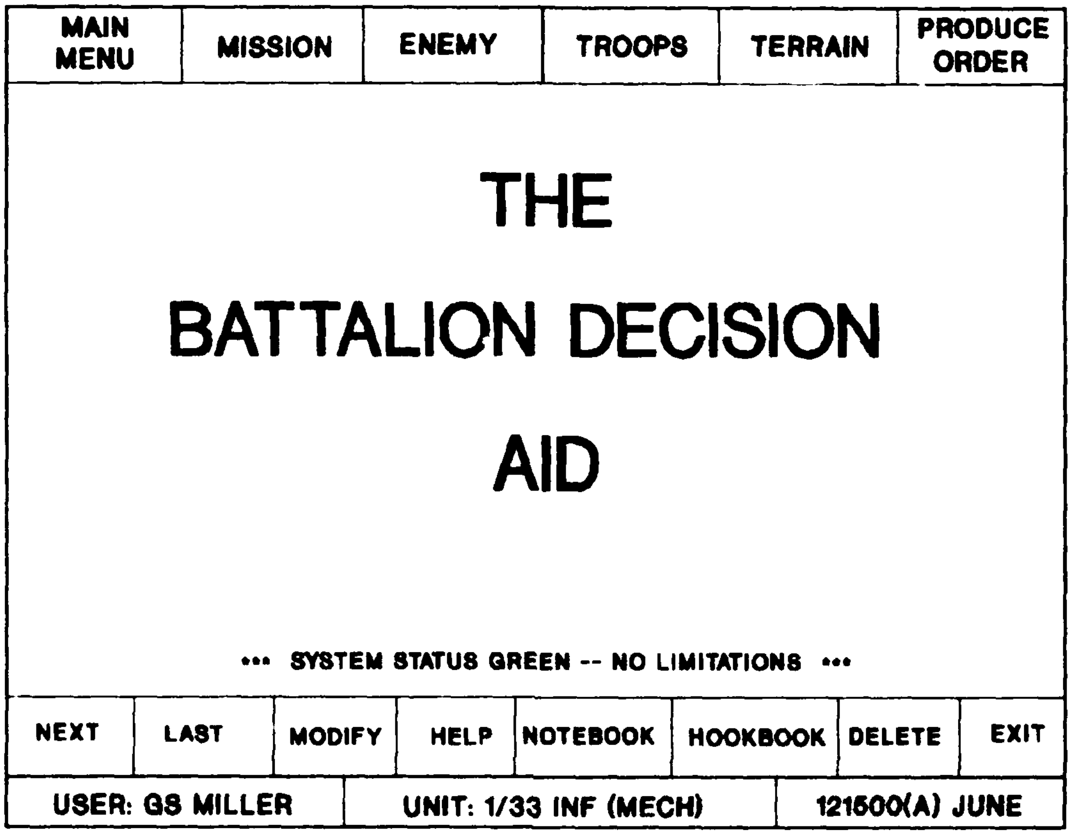
Third Concept Map

THIRD CONCEPT MAP

Appendix B

The Storyboard

This appendix contains the results of the storyboarding process as applied to the array initial forces problem. The storyboard and the accompanying text provide the user statement of requirements. The storyboards along with the concept maps serve as the communication link between the user and the system builder.

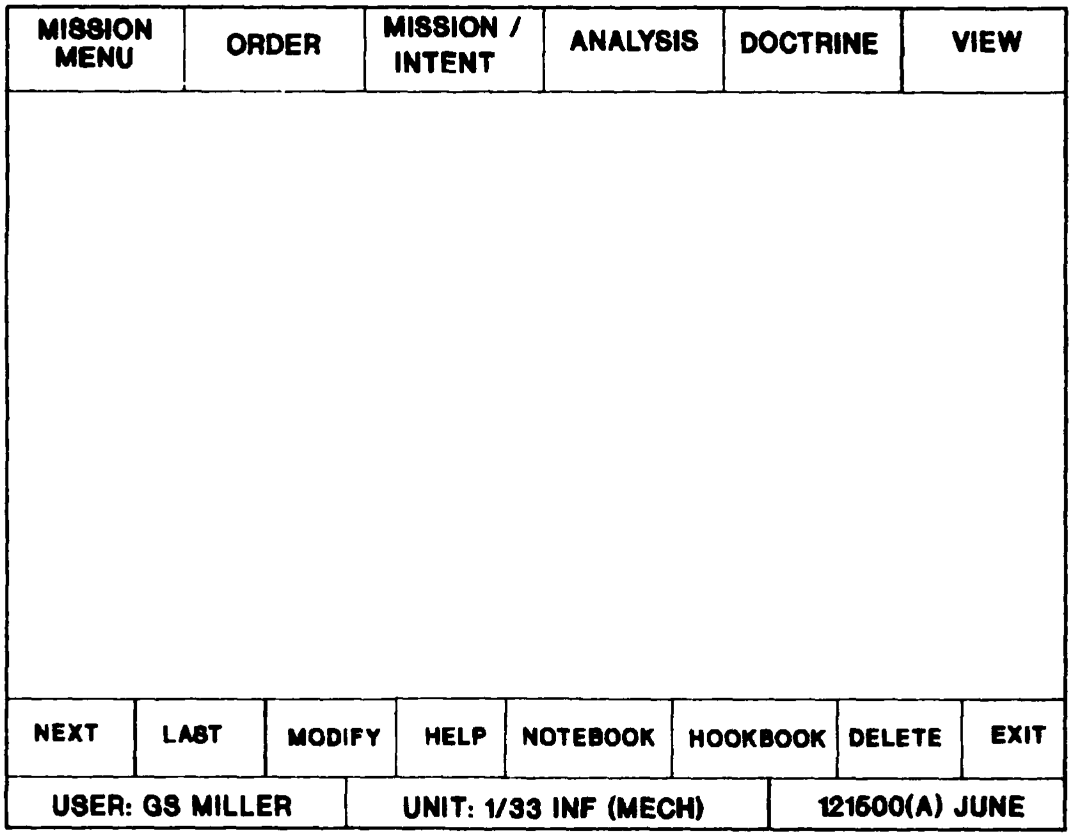


The purpose of the Main Menu is to provide the user access to the necessary data and functions that will enable him to successfully plan and produce an order.

There are five options. Based upon the user's training, the button labels give him a very good idea what information could be accessed.

The function of the top row lower buttons are:
- **NEXT**: Allows the user to move to the next screen.
- **LAST**: Allows the user to move to the last screen.
- **HELP**: Access system help facilities.
- **NOTEBOOK**: Provides an on-line notebook.
- **HOOKBOOK**· Provides an on-line means to document proposed changes in the system during its use.
- **DELETE**: Deletes user entered data.
- **EXIT**: Exit user from system after save option.

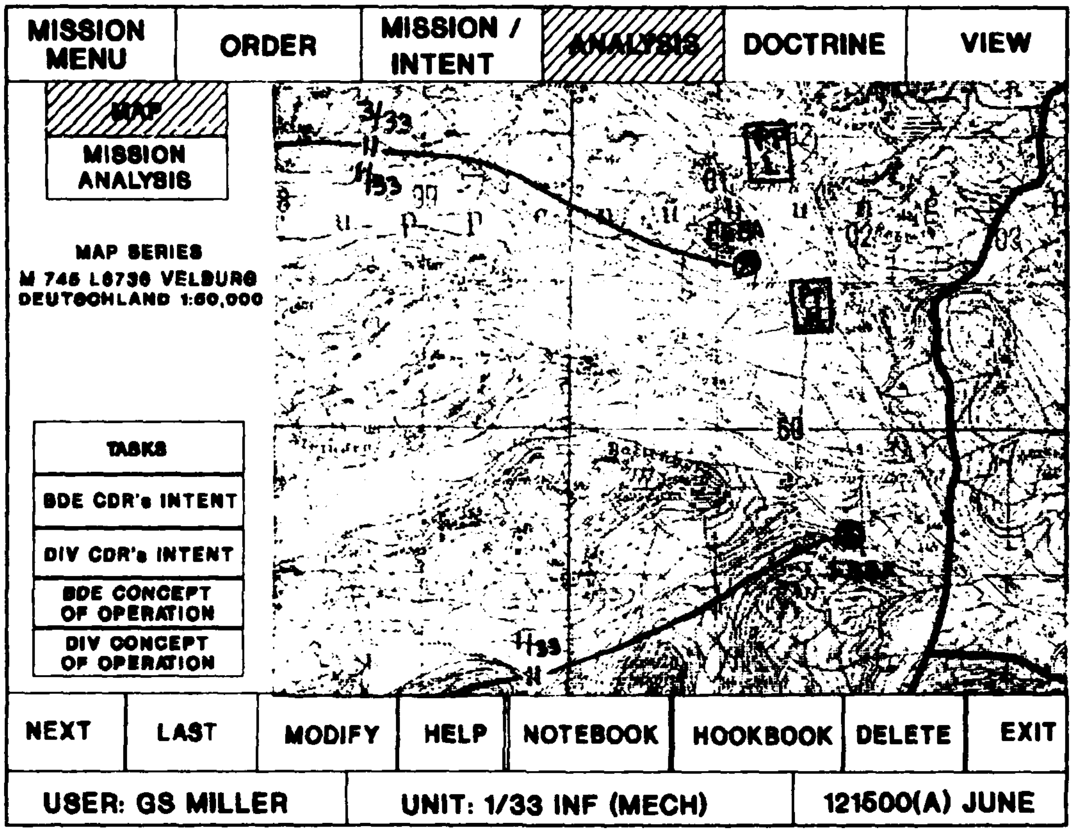
The last row of buttons and the status line assure the user that the system knows who and what unit it is assisting, the current date, and that the system has all of its capabilities.



The purpose of the Mission Menu is to assist the user in gathering information about his assigned mission, and to analyze that mission so as to determine all essential tasks. Option activated by cursor.

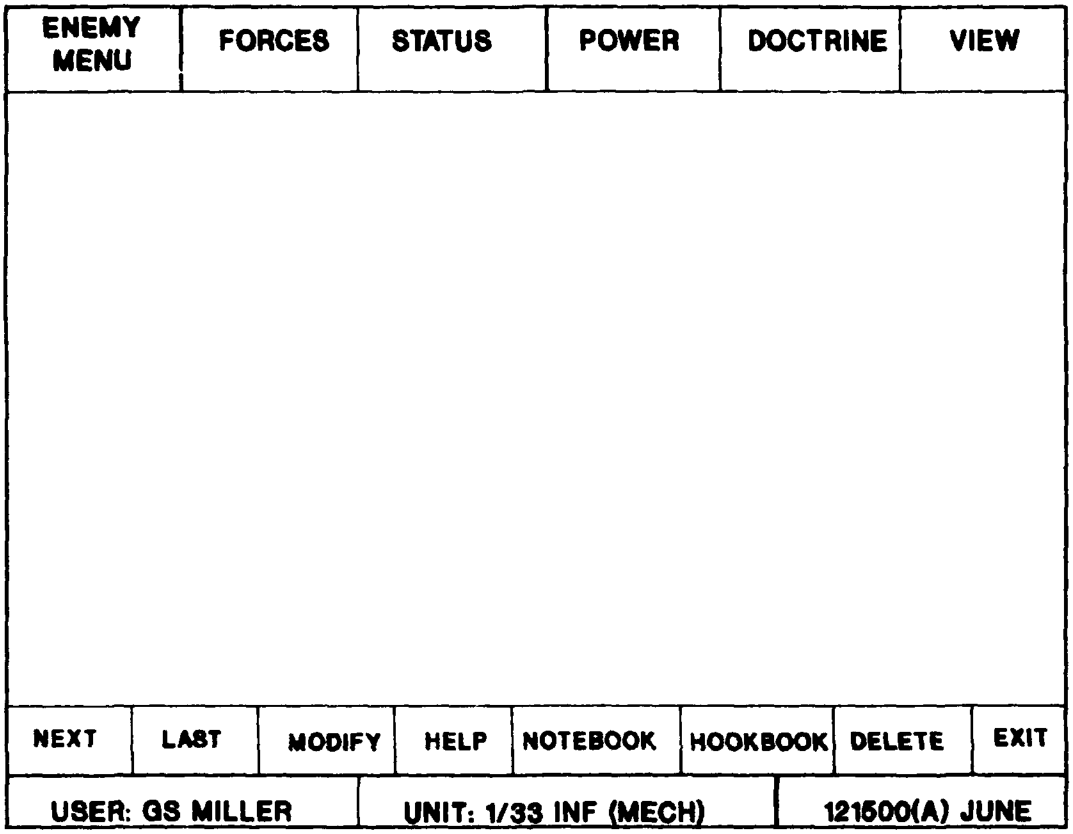
The options provide the following functions and information:

ORDER: Access the new OPORD or FRAGO.
MISSION/INTENT: Access the units mission and the brigade and division concept of operations and commander's intent, respectively.
ANALYSIS: Provides the work space and retrieves the mission, intent, doctrine, map, and overlays, and activates the model base. The user may then selected what he wants or have the system get additional information.
DOCTRINE: Provides friendly and enemy doctrine. Key words are matched by system to associated tasks.
VIEW: Enables the user to access other functions of the system without leaving his current location in the system.



This screen display shows that the user has selected the ANALYSIS option. The user is starting the process of breaking down the mission into its essential task which in turn will be decomposed. The intent of superior commanders is essential to the proper analysis of mission requirements.

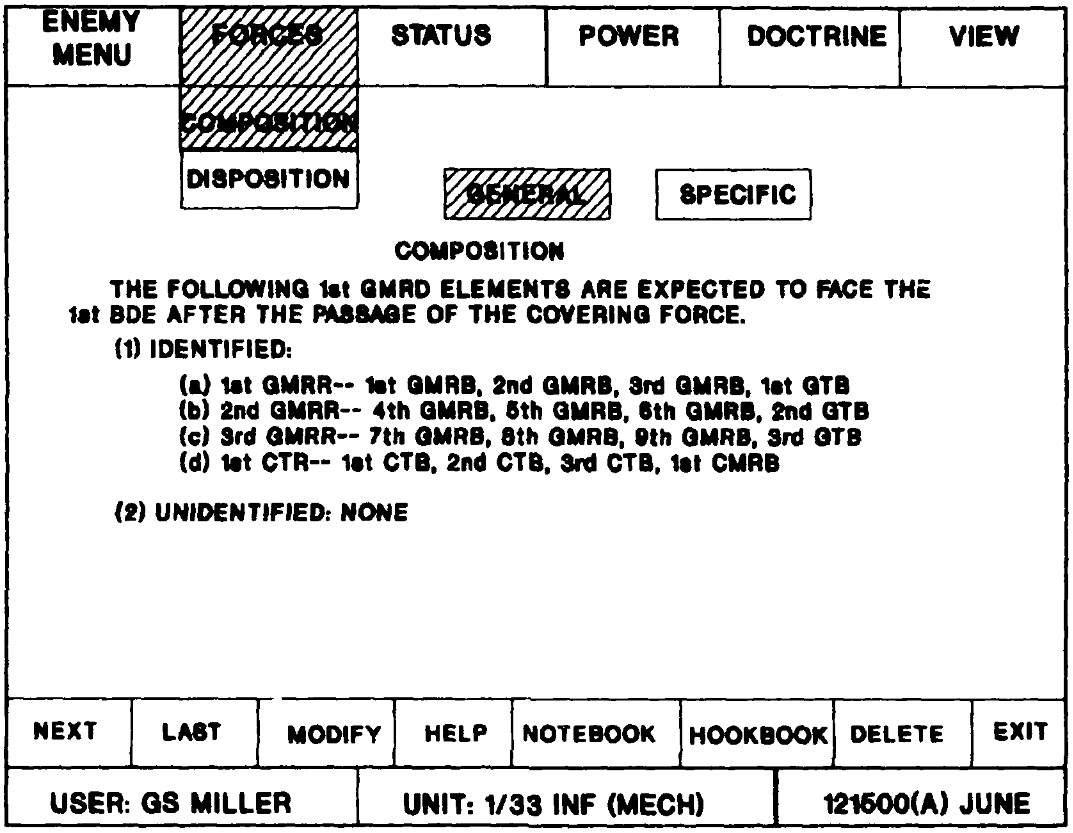
As a result of this process, the user will gain an understanding of the desired future state and the role his unit will play in the process of achieving it.



The Enemy Menu enables the user to gain an understanding of the enemy situation. This understanding will provide the planner insight into the most probable course of action the enemy will take, and what weaknesses or strengths of the enemy can be exploited or be avoided.

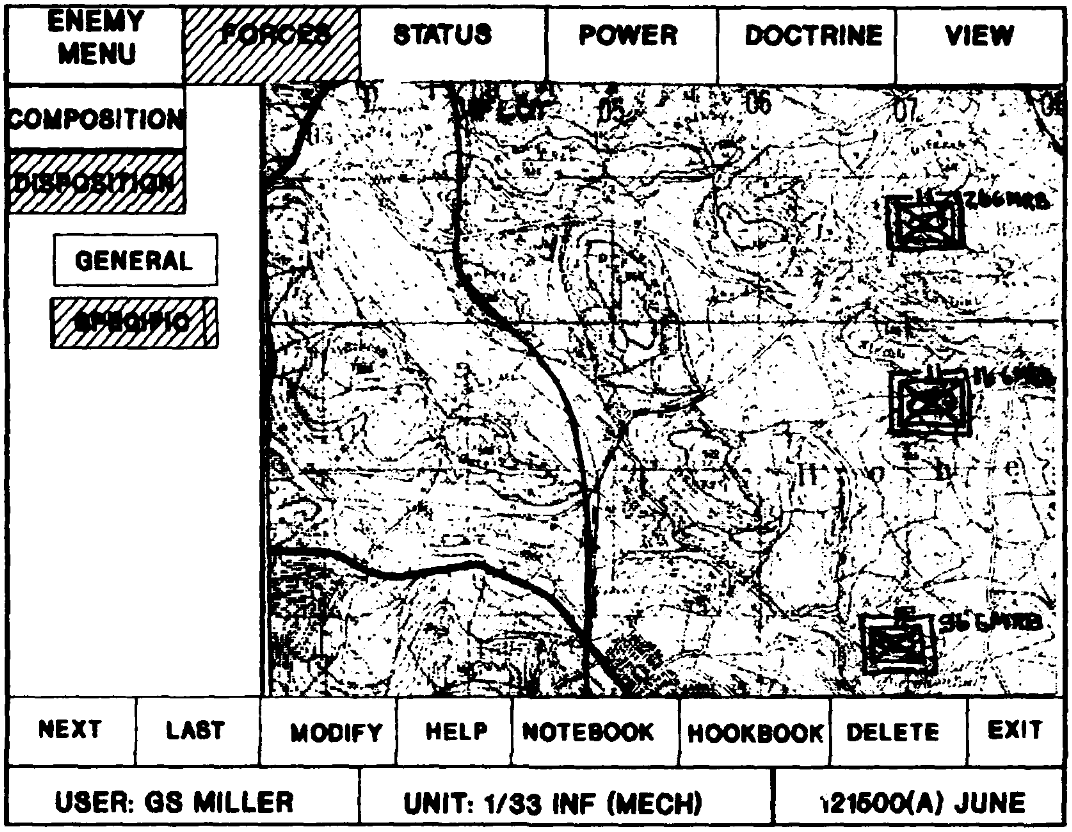
The following options are provided:

FORCES: Provides the composition and disposition of the enemy force.
STATUS: Provides the resource status, personnel and equipment, recent activities, capabilities as determined by higher headquarters.
POWER: Provides an estimated level of combat power possessed by the enemy force based on key factors considered important by the planner.
DOCTRINE: Provides enemy doctrine.
VIEW: Provides the user the ability to access other features of the system without leaving his current location.



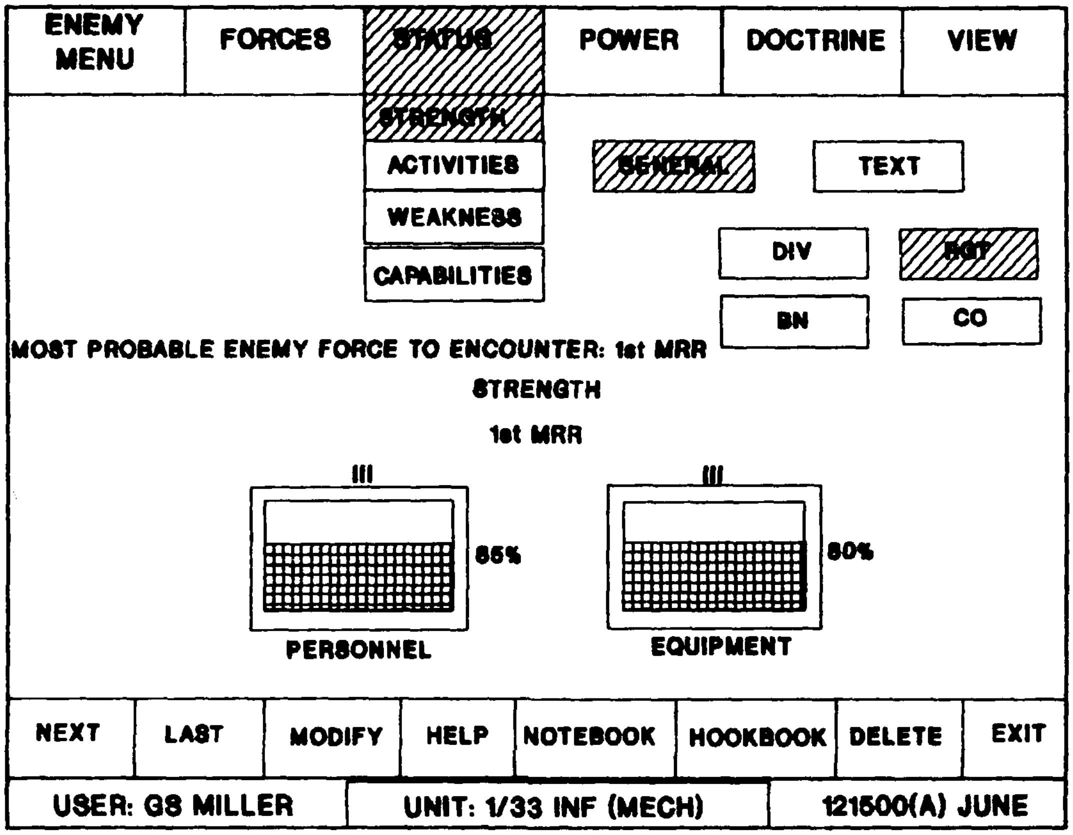
This screen depicts the planner acquiring information concerning the enemy force's composition.

At the general level, the user is provided information concerning the enemy force that the brigade is facing. From this view the planner gets a larger view of the enemy situation and what factors that might be important to him during the development of the battalion plan.



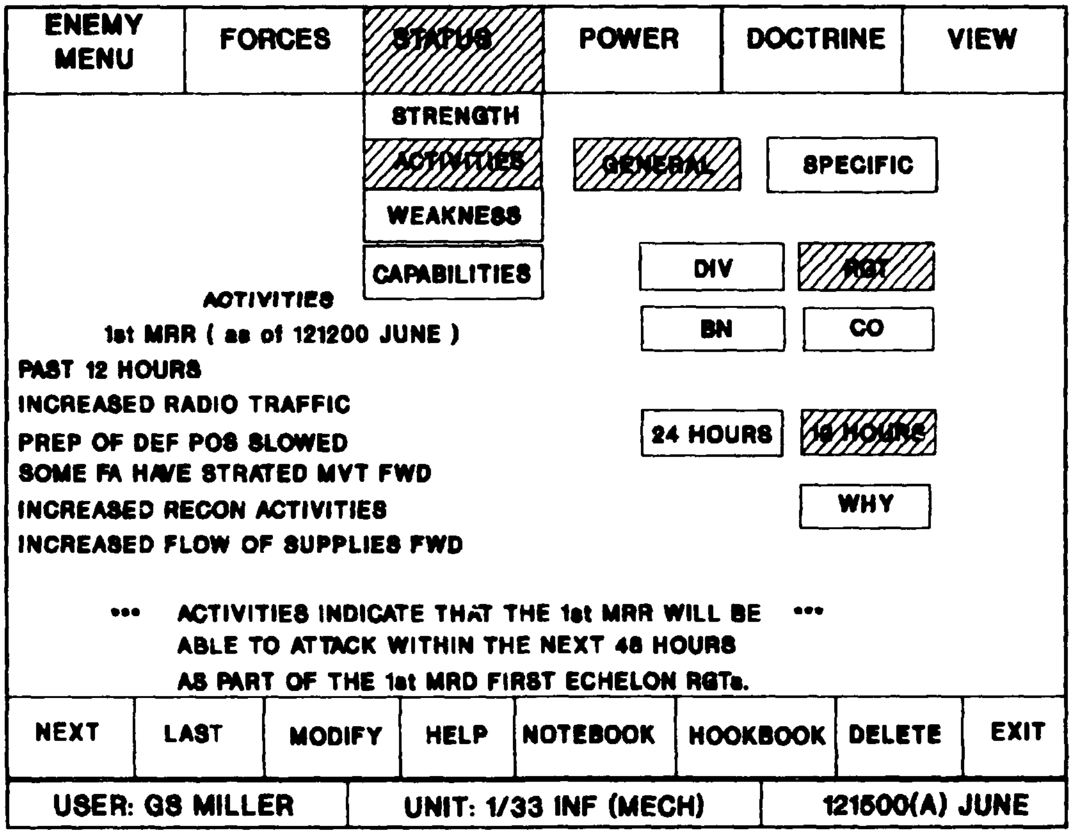
In this screen the user is reviewing the disposition of the enemy forces as compared to his assigned sector to determine his most probable adversary. The specific button focuses the map and graphics on the battalion sector and corresponding enemy locations.

The user can obtain information on any of the units he desires by just 'clicking' on the unit symbol.



The user is now gathering information on the status of the 1st GMRR. The general strength of the regiment is given in the conventional format of personnel and equipment.

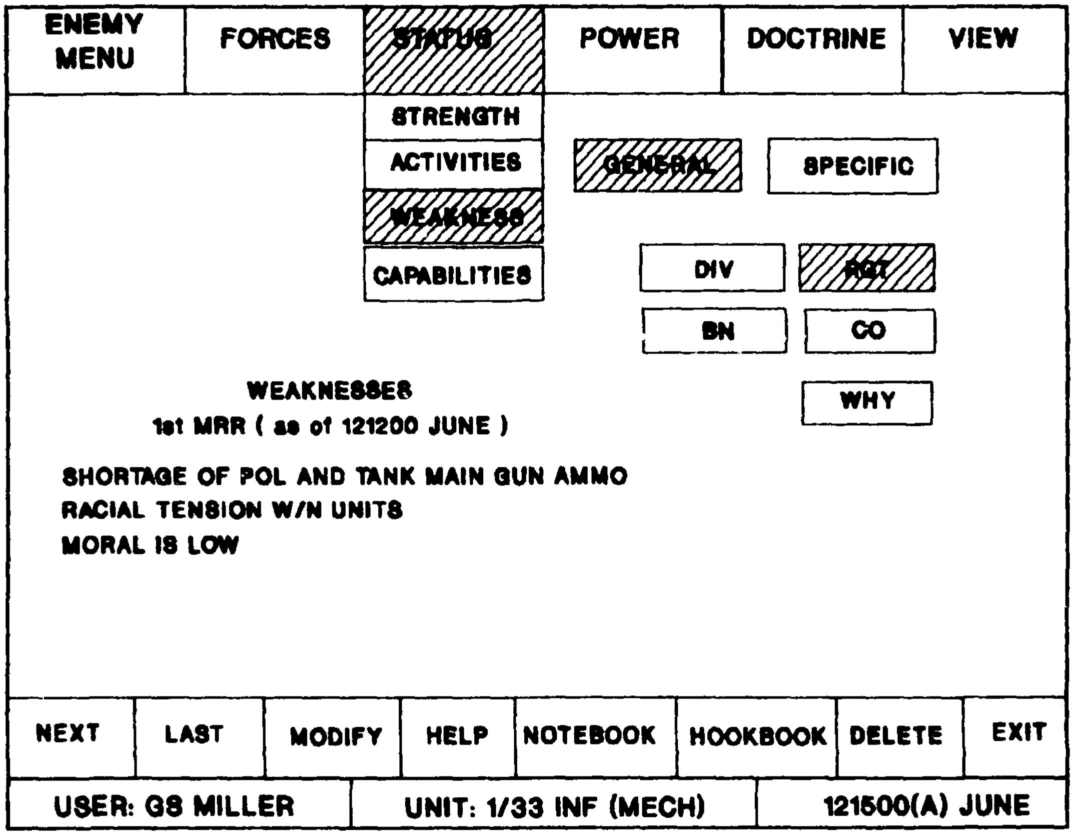
If the planner desires a breakdown of this information, the user may click the detail button and the corresponding type unit.



The user is now investigating the past activities of the 1st GMRR. He has the capability to select the time span the information covers.

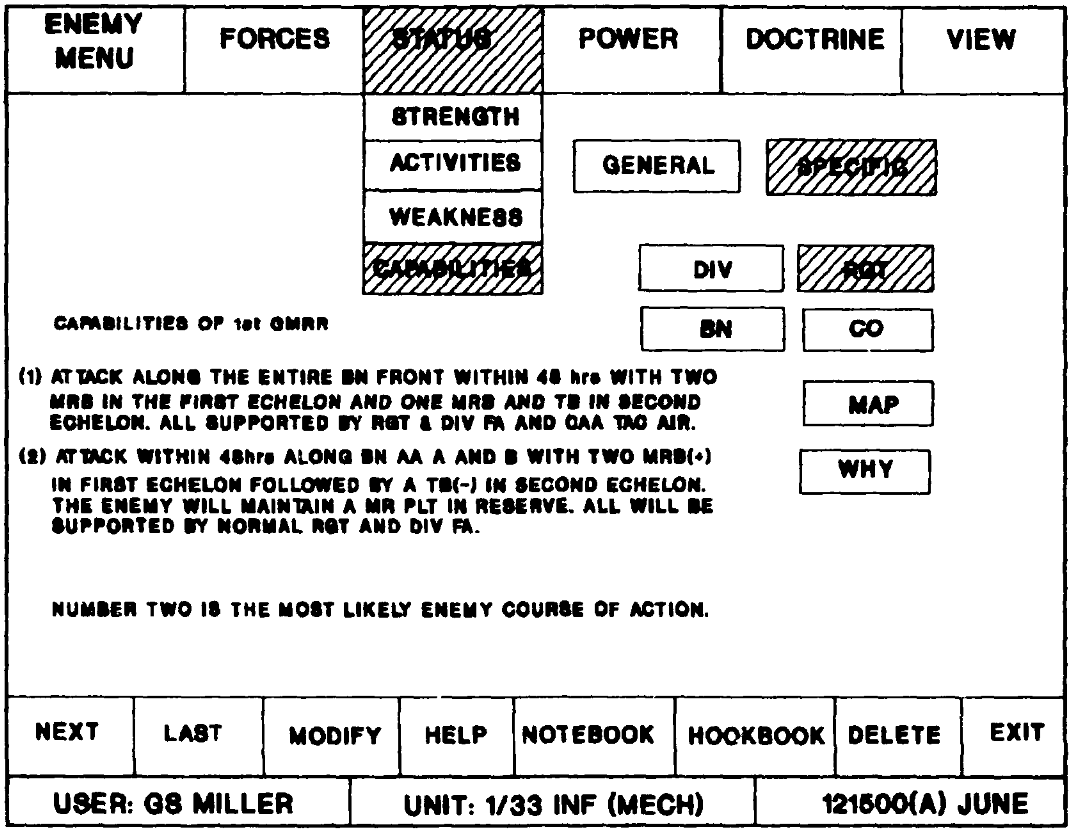
In this case he has selected general activities for the past 12hrs. He then is presented with the results of the correlated reports for the time period.

Based on the intelligence model a conclusion is presented to the user for his review. The user may accept this conclusion, alter it, or ask 'why.'



As in the past screens the user is investigating the status of the enemy regiment so he can identify the appropriate defeat mechanism. Therefore, he reviews the known enemy weaknesses. This information will be combined with the rest of the information on the enemy force in the hopes that enemy traits and characteristics can be identified for exploitation.

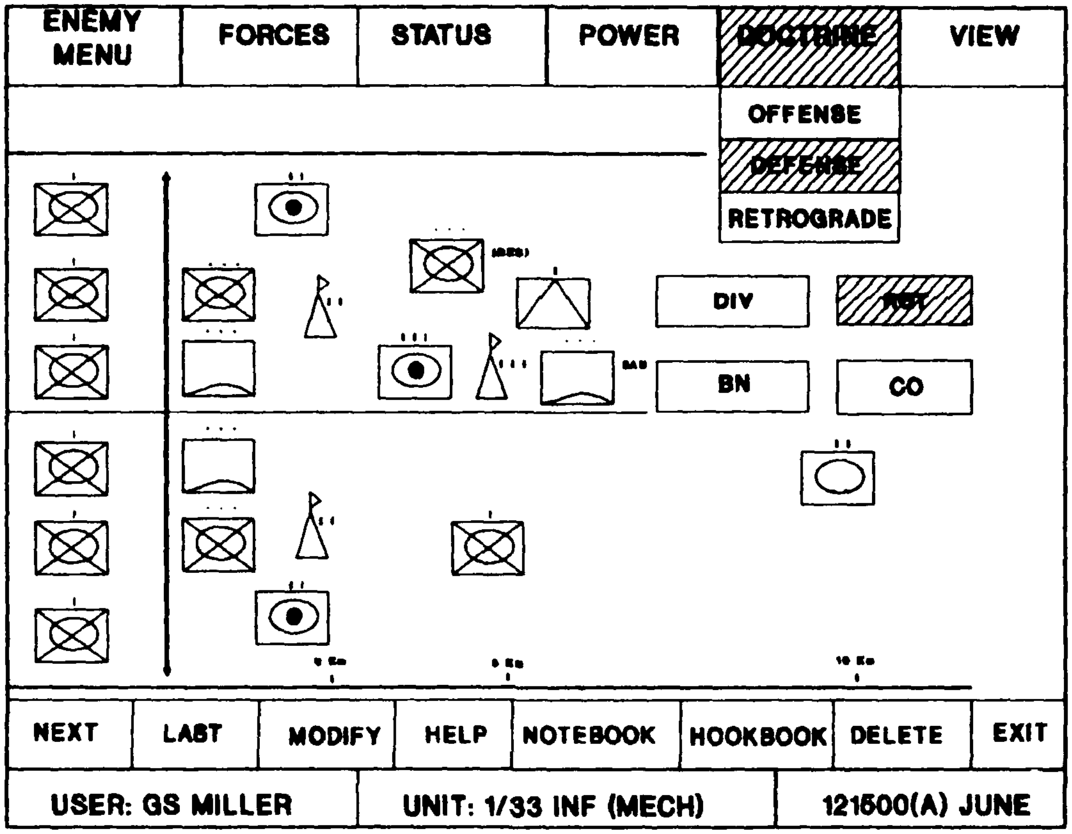
The planner may desire more detailed information concerning a particular weakness and the reason way that conclusion was reached. The planner need only activate the 'why' button to start the inquiry.



This screen depicts the user asking for the enemy's most likely course of action based on all intelligence information.

At this level of command, the planner is concerned with the form of the enemy's attack and the routes taken.

The planner may elect to have each enemy course of action displayed on a map. He may also query the system for reasons why the selected course of action was selected over the others.



This screen depicts the user calling upon enemy doctrine to gain an understanding of the possible array of enemy forces he could encounter during the execution of his mission. This echelon of forces along with the other information must be consider by the planner during the development of the plan.

The user has selected offensive doctrine at the regimental level.

From the display the planner can gain an understanding of the time and space relationship of the enemy formation which is necessary in fighting the battle in depth.

TROOPS MENU	FORCES AVAILABLE	STATUS	POWER	DOCTRINE	VIEW

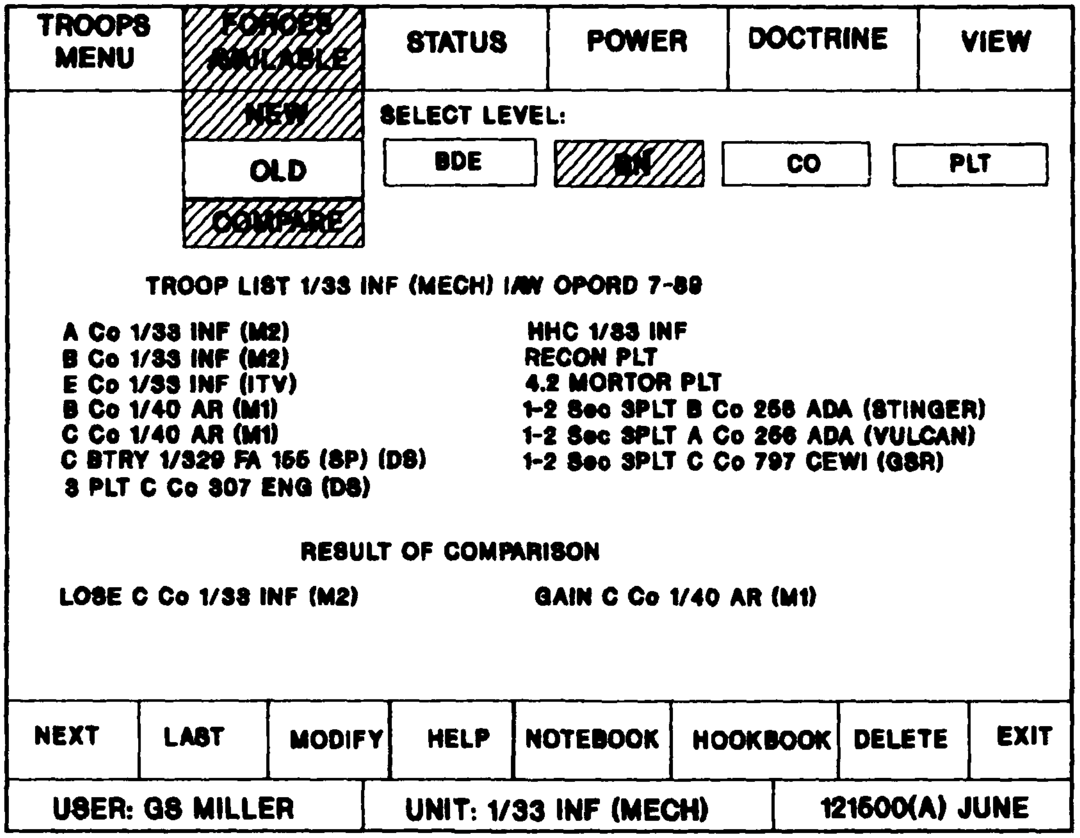
NEXT	LAST	MODIFY	HELP	NOTEBOOK	HOOKBOOK	DELETE	EXIT

USER: G8 MILLER	UNIT: 1/33 INF (MECH)	121500(A) JUNE

The Troop Menu assist the planner in gathering information on the resources provided to him by the brigade and the condition of these forces (e.g. strengths, weaknesses, combat effectiveness). Information one level above and two levels below is available.

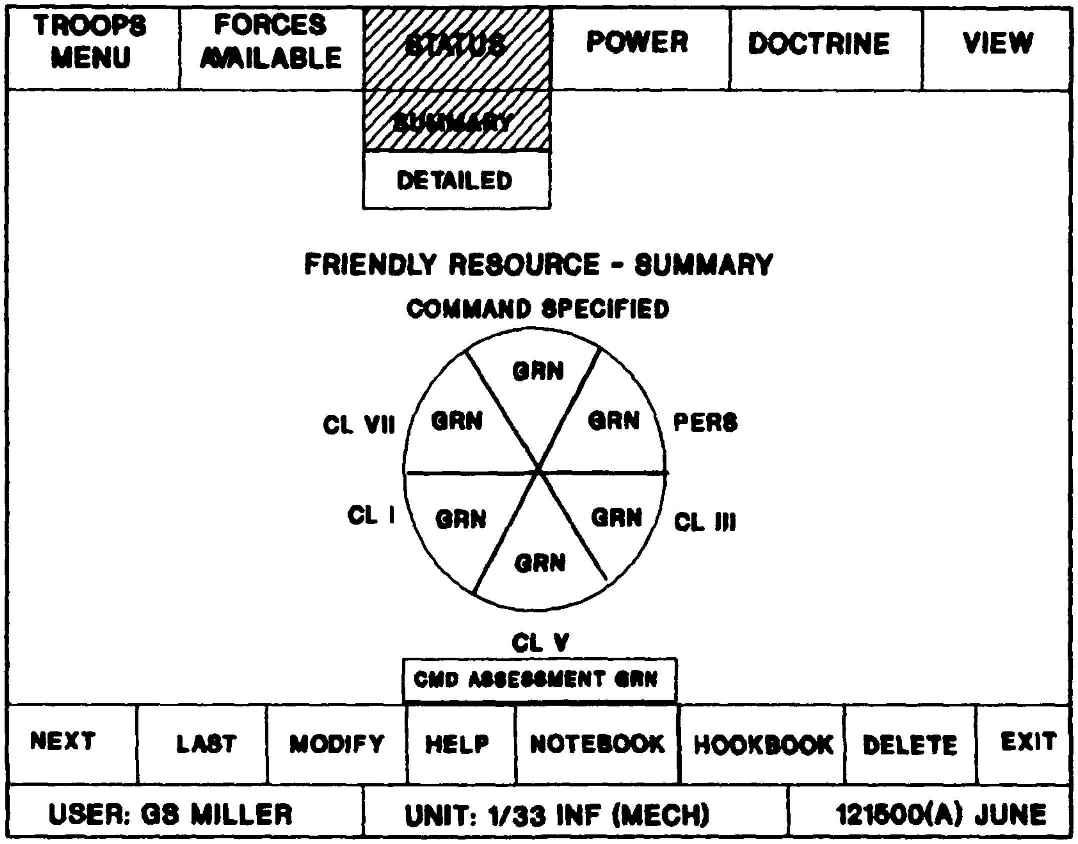
The following options are provided:

FORCES AVAILABLE: Access new troop list or old task organization. Can inform user of changes in task organization.
STATUS: Provides the user a summary or detailed report on the logistical and personnel status of the unit. This includes status of key personnel.
POWER: Provides an estimate on the units combat power based on current information.
DOCTRINE: Provides information concerning friendly doctrine.
VIEW: Enables the user to use other facilities of the system without leaving his current location.



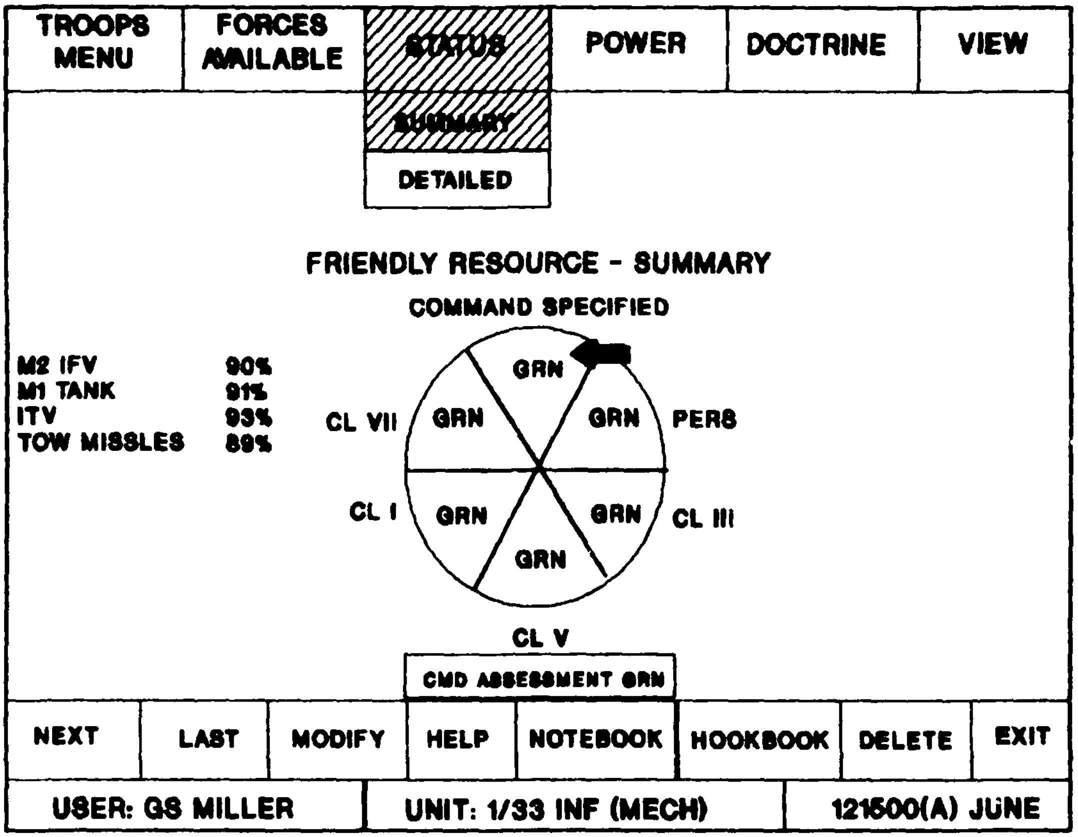
This screen depicts the user determining what forces he has available to him to use in the accomplishment of the mission. In addition, he is able to determine the directed changes in the force under his command.

From this display, the user is able to determine that he has a balanced task force with his habitual attachments.

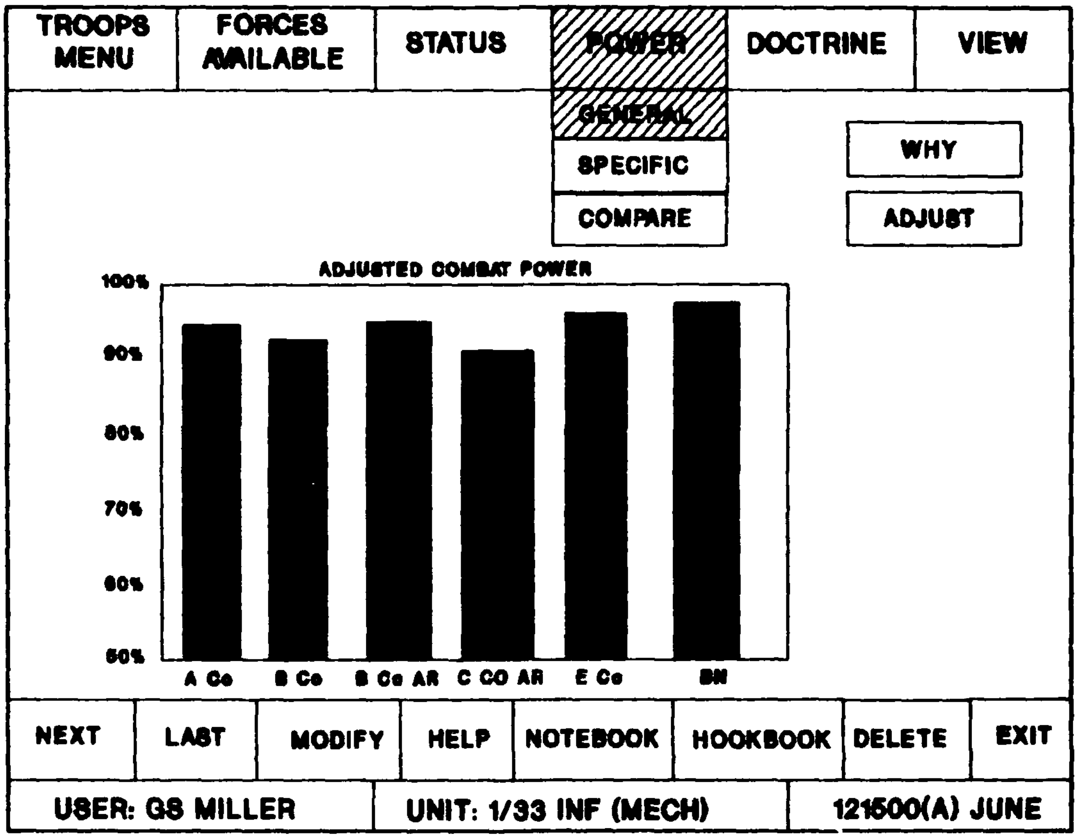


In the next two screens, the planner is acquiring the initial information necessary for assessing the combat capability of an unit.

In this screen the user has selected a summary report on the resource status of the task force. The color coding of the pie communicates to the user the condition of the unit in key areas of interest. The color code is red, yellow, and green. The code is established by unit standard operating procedures.

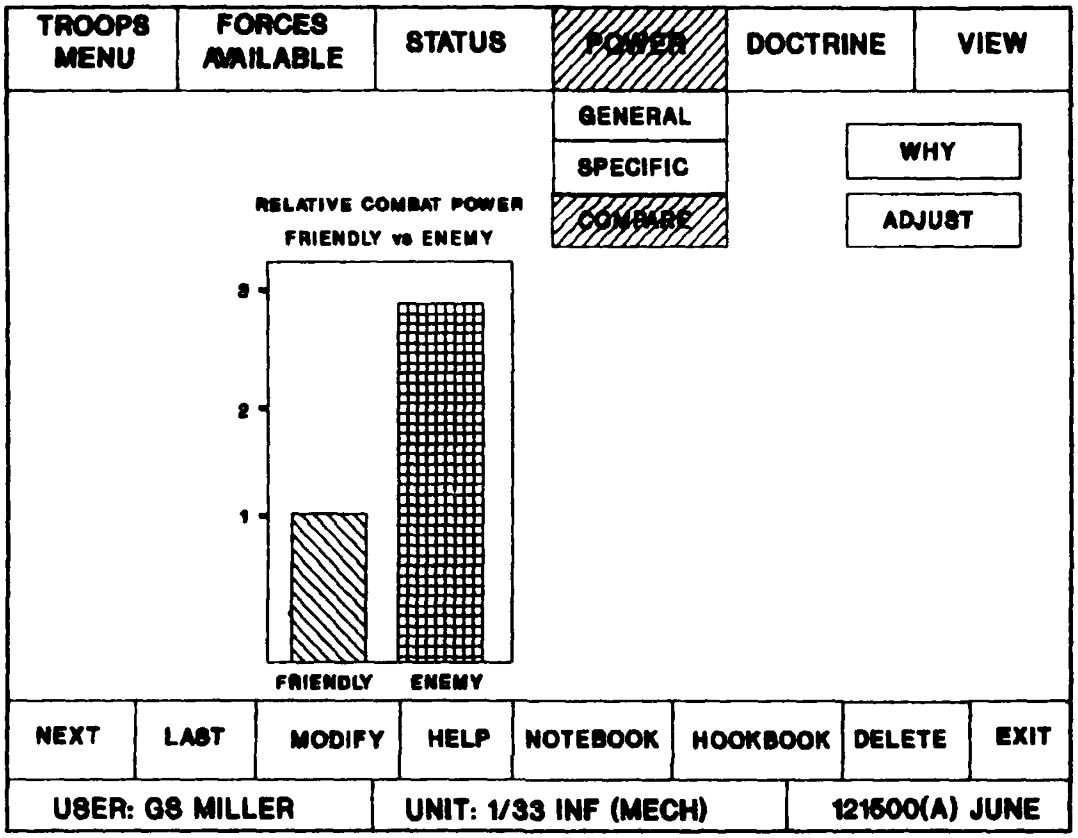


This screen depicts the user asking for more information concerning Command Specified. The information is obtained by 'clicking' on the corresponding portion of the pie. Items in this section or any of the other section could be specified by the user, higher headquarters, or a combination of both.



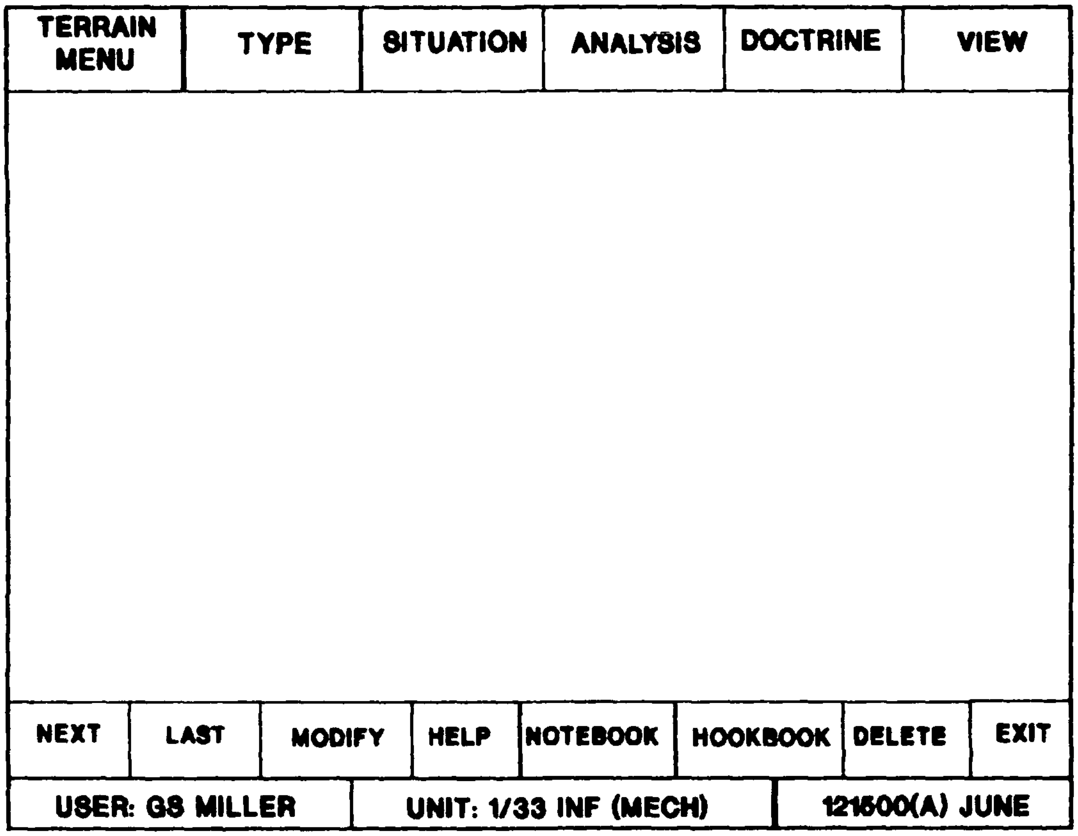
This screen display depicts the user requesting a general appraisal of the task forces combat power be made. The model, utilizing such information as personnel strength, operational equipment, logistical status (CL III and V), and combat support, computes a value for each major subordinate unit and for the task force.

This provides the user a means to determine his units combat power in the absence of experience or provides an experienced commander with a sounding board. In either case, the user can ask for an explanation of the results by activating the 'why.'



In this screen the user is comparing the combat power of his force with that of the enemy force. As with the previous screen the user may ask for an explanation and/or adjust the evaluation.

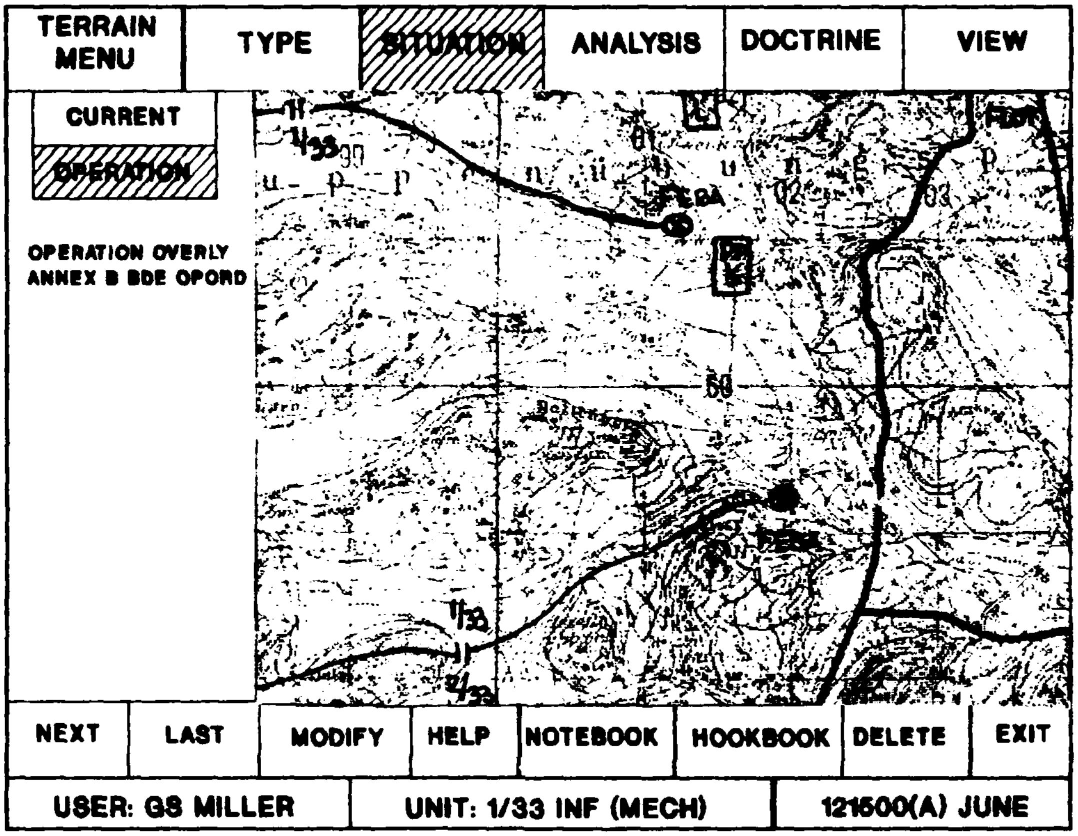
This comparison of combat power gives the planner insight into friendly and enemy capabilities (the 'what' to not the 'how to'). The user is able to approximate the number of forces required to array against the enemy so as to have a reasonable chance of accomplishing his mission. In short, this comparison identifies force requirements and forms a knowledge base on which future decisions can be based.



The Terrain Menu provides the user the necessary information, functions, and environment to do terrain analysis, course of action development, evaluation, and comparison. Cursor activates buttons and manipulates map.

The option that are provided are:

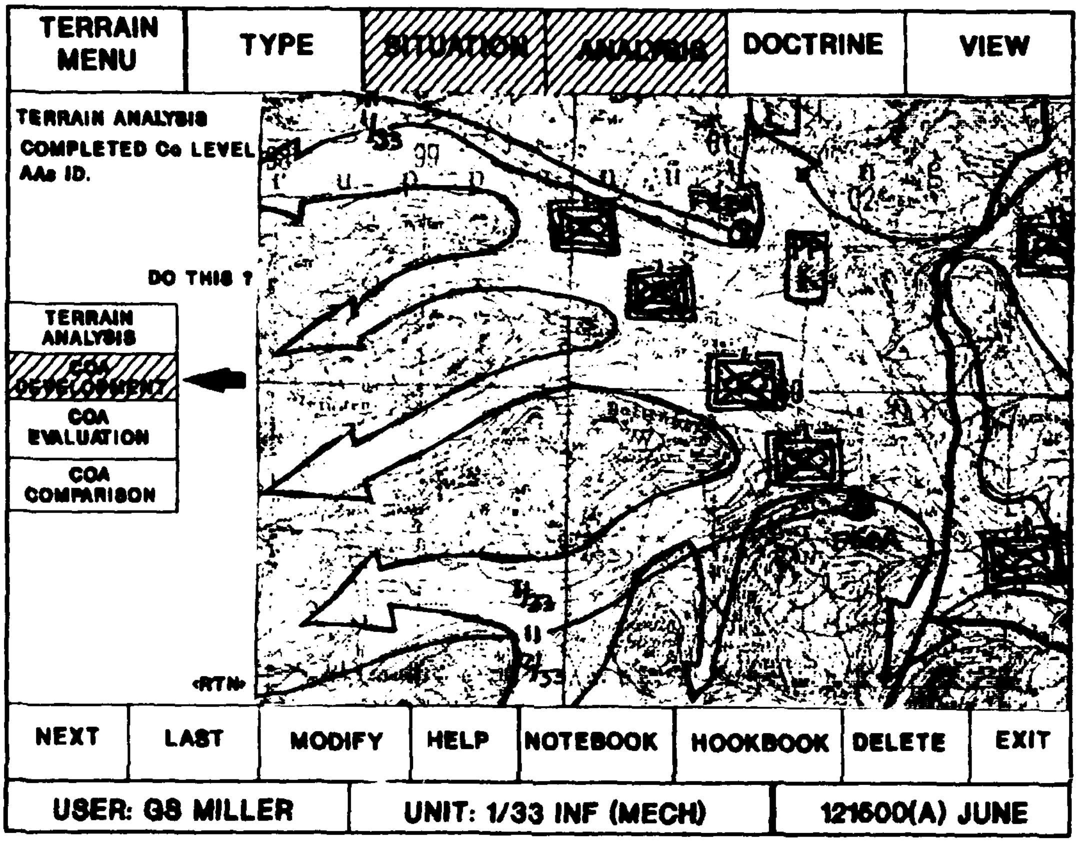
TYPE: Allows the user to select map type, scale, series, and location for the map(s) to be used during the planning process. (Default: topographical, 1:50,000)
SITUATION: Retrieves current or operation map of the tactical situation. It can retrieve the situation maps one level up and two down. (Default is own level.)
ANALYSIS: Assesses the necessary information and functions that will enable the planner to develop an operation plan. This option provides: terrain analysis, and course of action development, evaluation, and comparison.
DOCTRINE: Provides access to friendly and enemy doctrine.
VIEW: Allows the user to use function located in another area of the system.



The user in this screen is exploring the environment and the tactical situation in which he must operate.

The initial map display is the task force's assigned sector. The user can move around the map and explore the entire brigade sector to gain appreciation of the terrain and its relationship[with the enemy's current disposition.

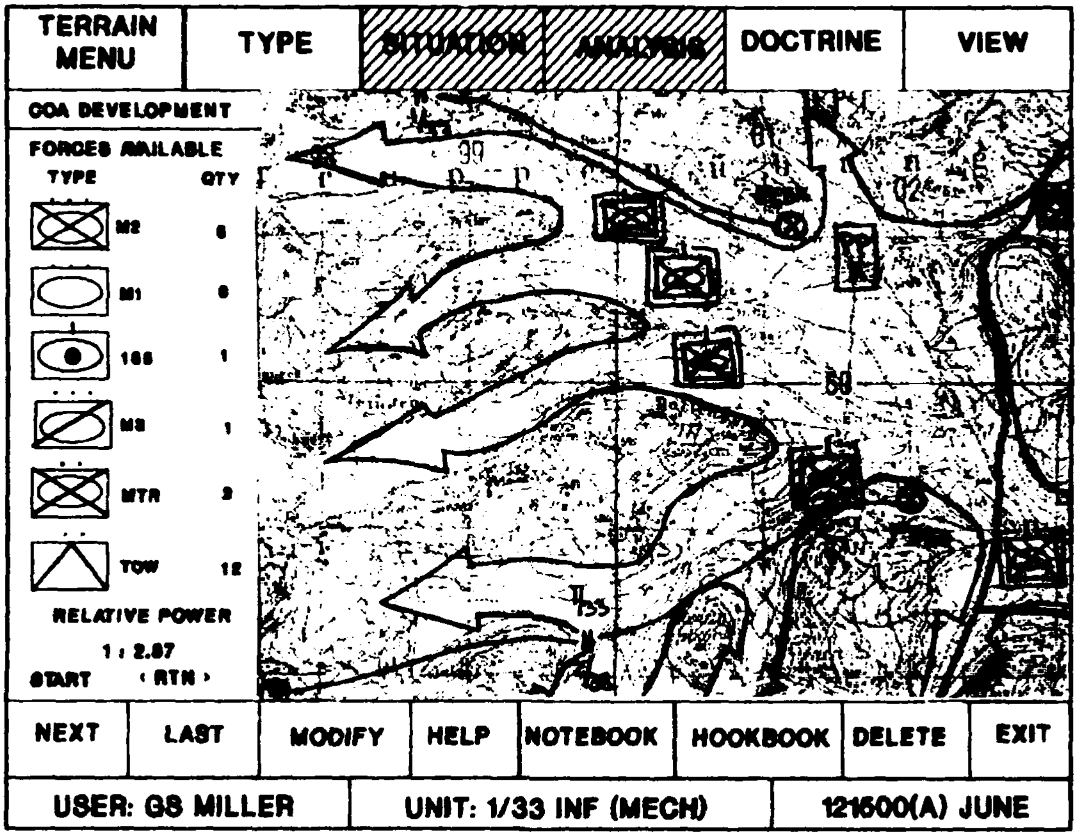
The resolution of this map must be as good as a paper map.



At this point, the analysis of terrain has been completed. All company sized avenue of approaches into the battalion sector have been identified.

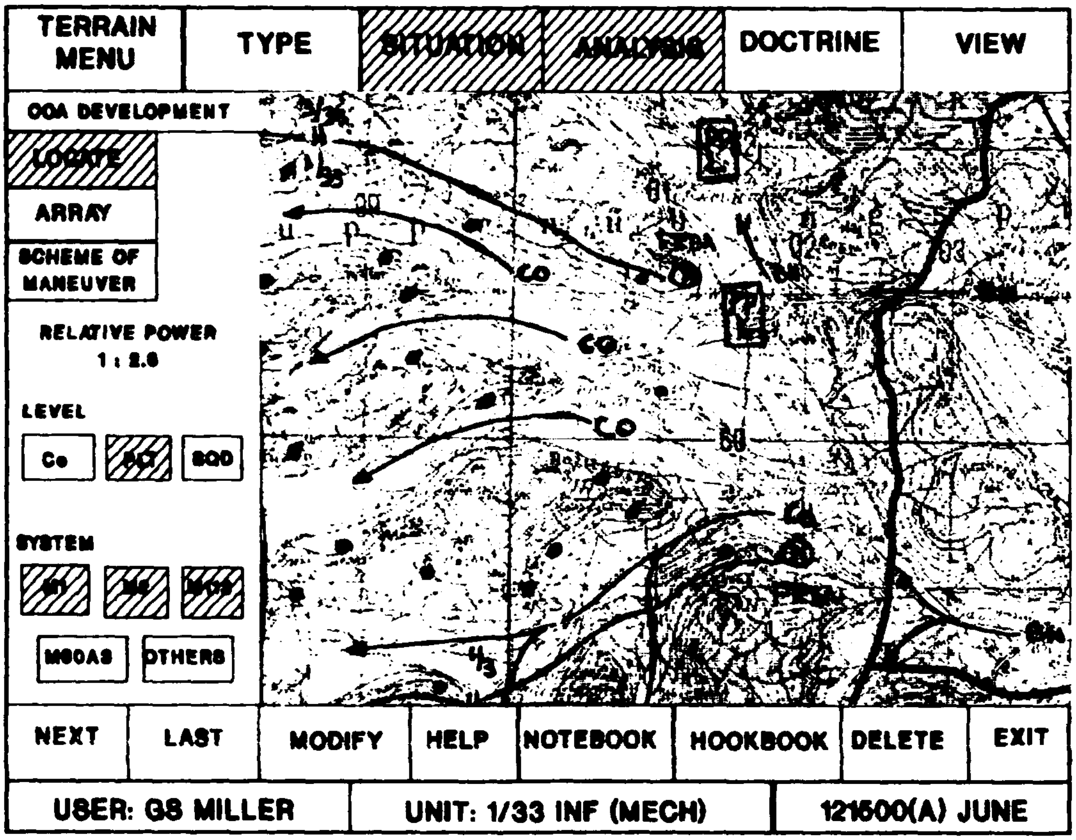
Through this screen the user can visualize the flow of the enemy force through his sector.

The system is automatically set to execute course of action development upon completion of terrain analysis. This is based on the structure that is inherent in the military planning process. Each step builds upon the results of the last. The user may select another path through the process. This will require the system to generate at least one course of action on its own. This course of action may be modified or totally rejected by the user.



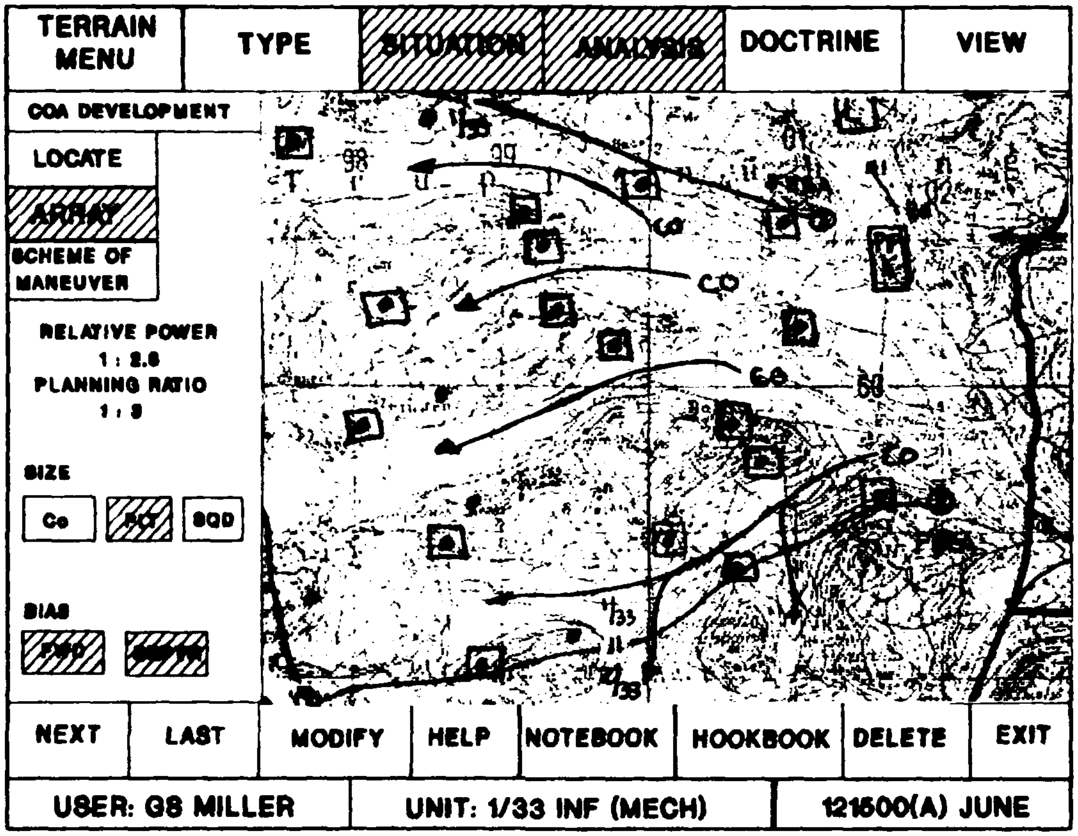
The user has activated the course of action generation button. As depicted the map with associated graphics remain, but the user is provided a breakdown of combat units and fire support units. He is also provided the force ratio. The units are broken down into the normal unit size used during planning.

This break down of forces is based on the fact that a battalion fights platoons (infantry and armor). The other units are the smallest size of that type deployed as a separate unit and are used to augment the combat power of the fighting platoons if the user desires to develop a detailed course of action during this phase.



As depicted the user has started the course of action generation process and the LOCATE subprocess. The location process identifies possible platoon size positions based on weapon systems selected by the user. Otherwise, the system will use the default weapon type for the units that makeup the task force. The number of positions located is not bounded by the number of platoons available.

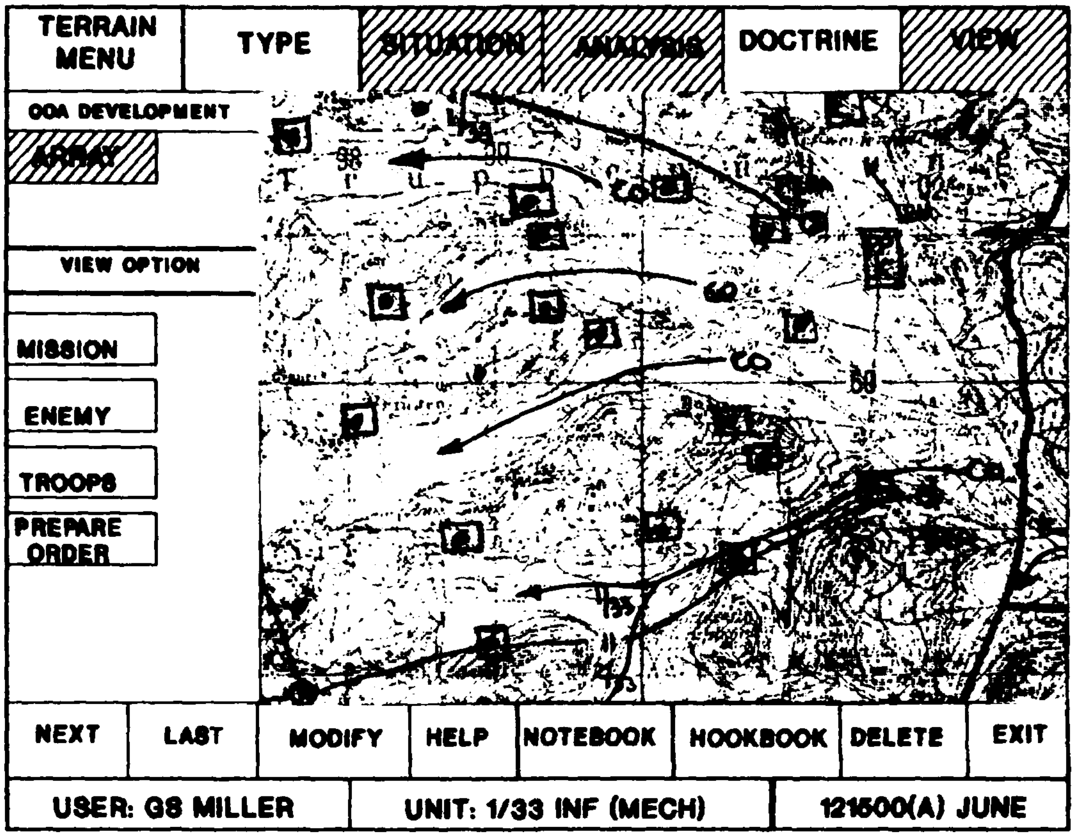
The user may review the characteristics of a position by 'clicking' on it.



After reviewing the desired positions, the user has selected the array subprocess option. Platoon size units will be arrayed in the battalion sector with a bias toward the forward positions to break ties. Units are also being positioned in depth.

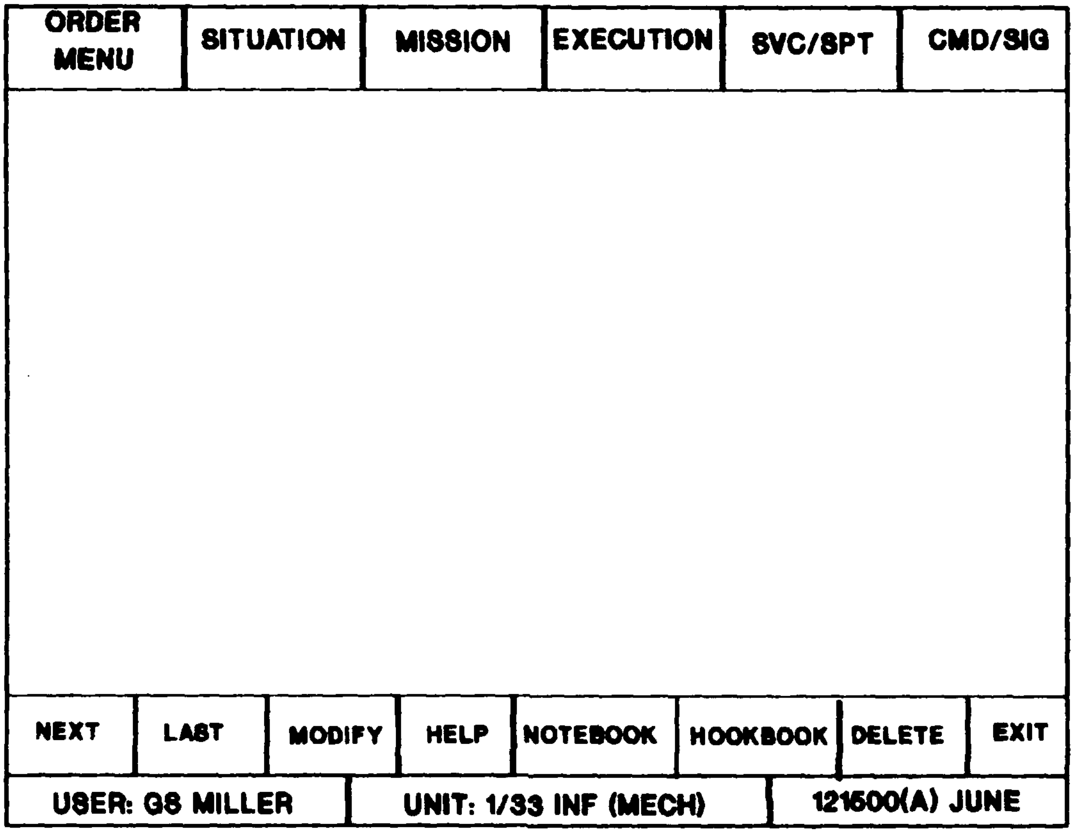
The model that arrays forces does so by arraying enough forces to meet the planning ratio requirements for the given mission. This is done without regard to the number of platoon available.

From this process the user gain insight into force requirements and develops a knowledge base for future decisions concerning acceptance of risk.



In this screen the user has activated the VIEW option. Due to some stimulus, the user needs to investigate some matter further. This option provides him the ability to do this without losing the stimulus in the process of going to another menu to obtain the information.

This option is available in all the sub-menus.

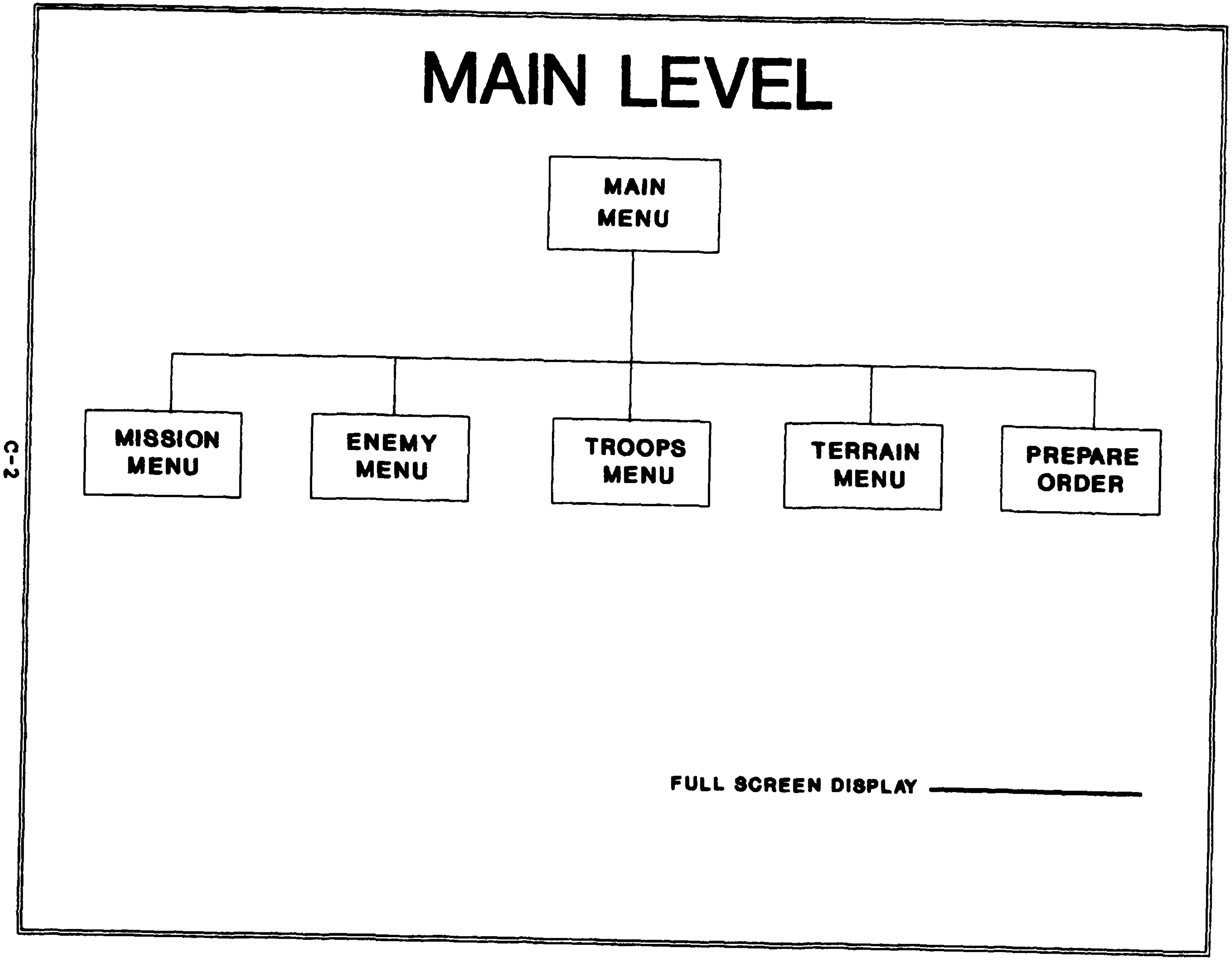


The purpose of the PREPARE ORDER MENU is to provide the user the facilities and capabilities to quickly and accurately produce an operation order which may be sent to subordinate units for their planning.

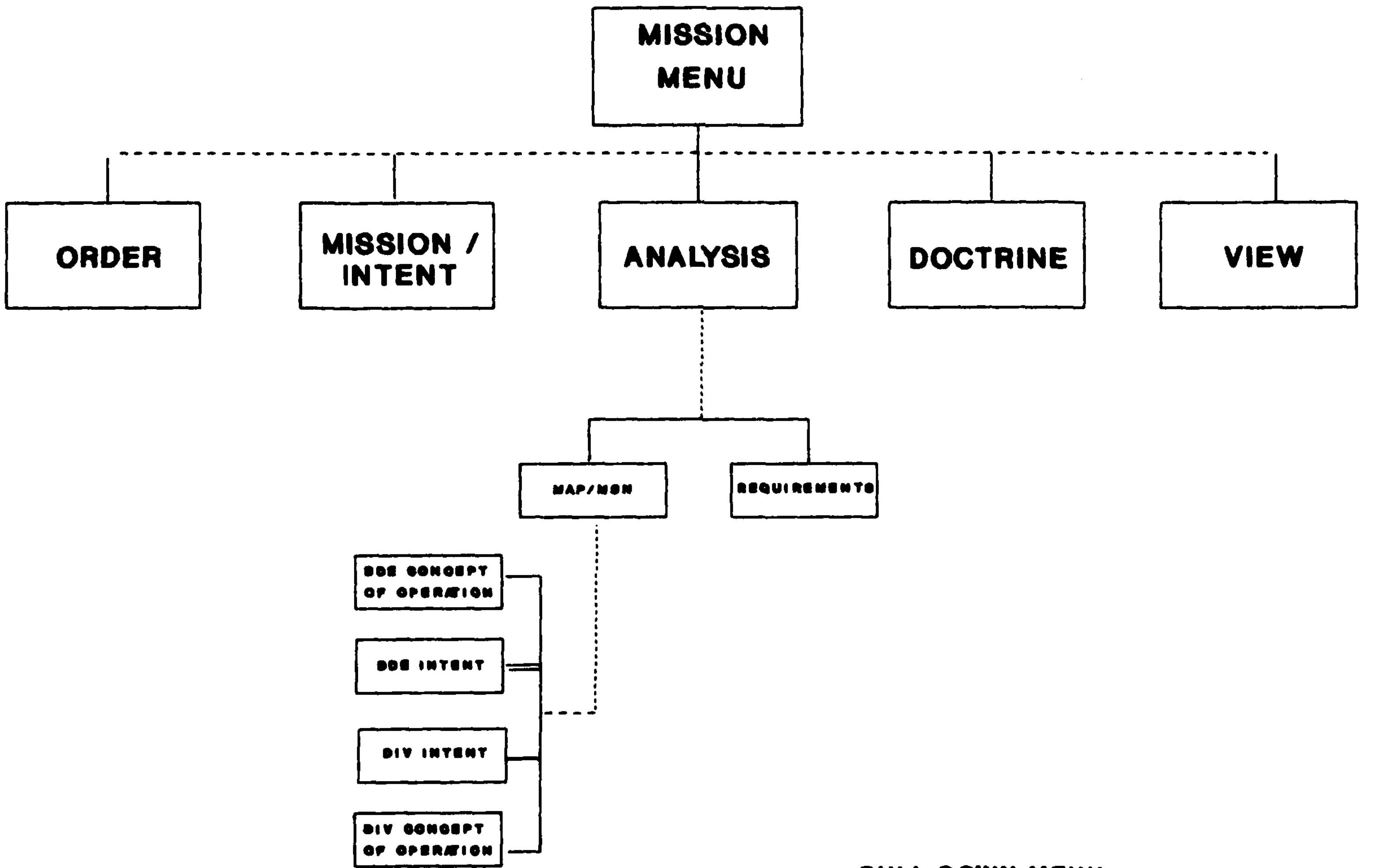
Appendix C

The Feature Chart

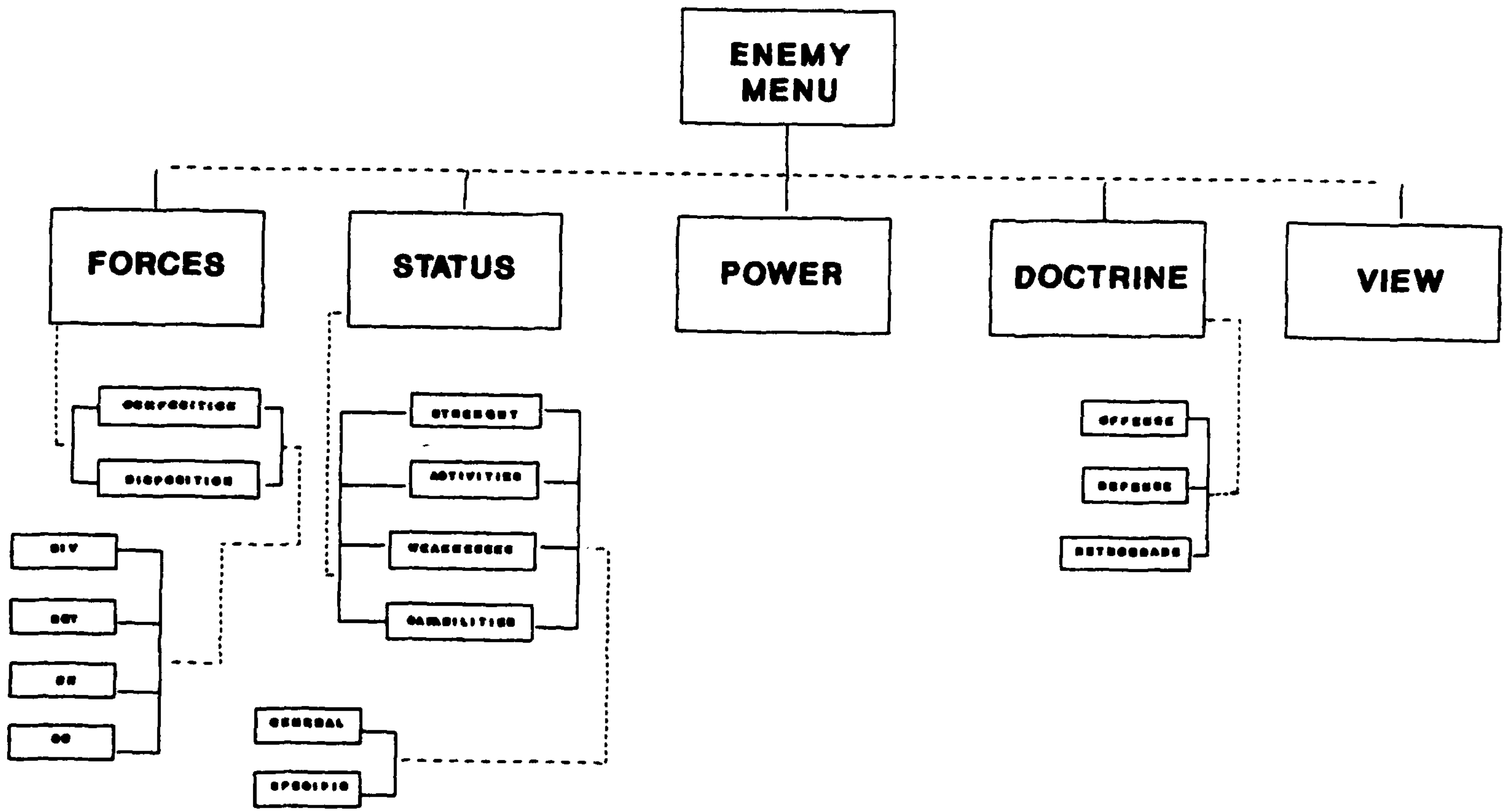
This appendix contains the feature chart of the proposed battalion level decision aid. They are broken down by menu. This chart depicts the paths that the user could take to reach a position in the storyboards located in Appendix B.


MAIN LEVEL
MAIN MENU
MISSION MENU
ENEMY MENU
TROOPS MENU
TERRAIN MENU
PREPARE ORDER
FULL SCREEN DISPLAY

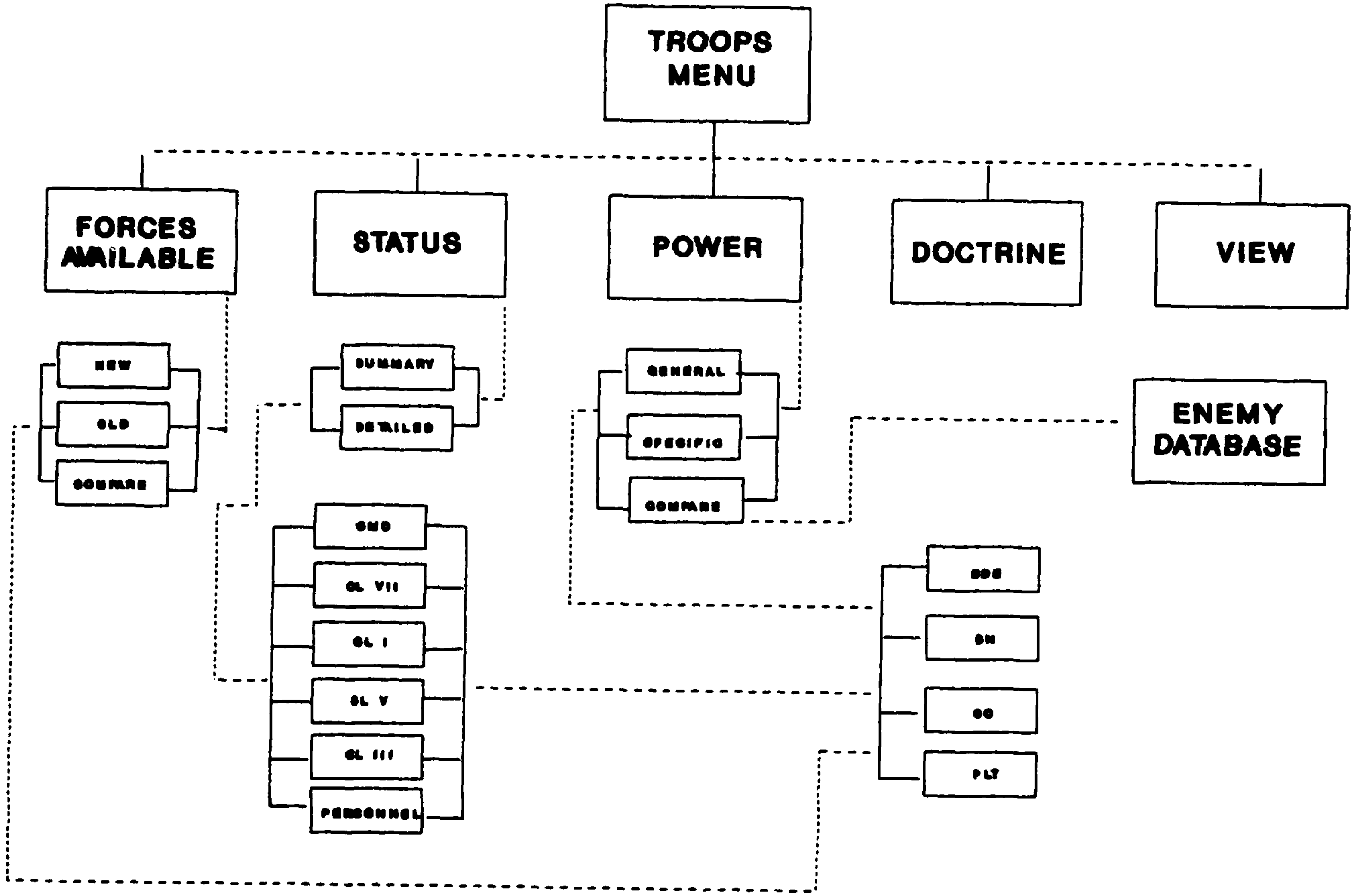
MISSION MENU



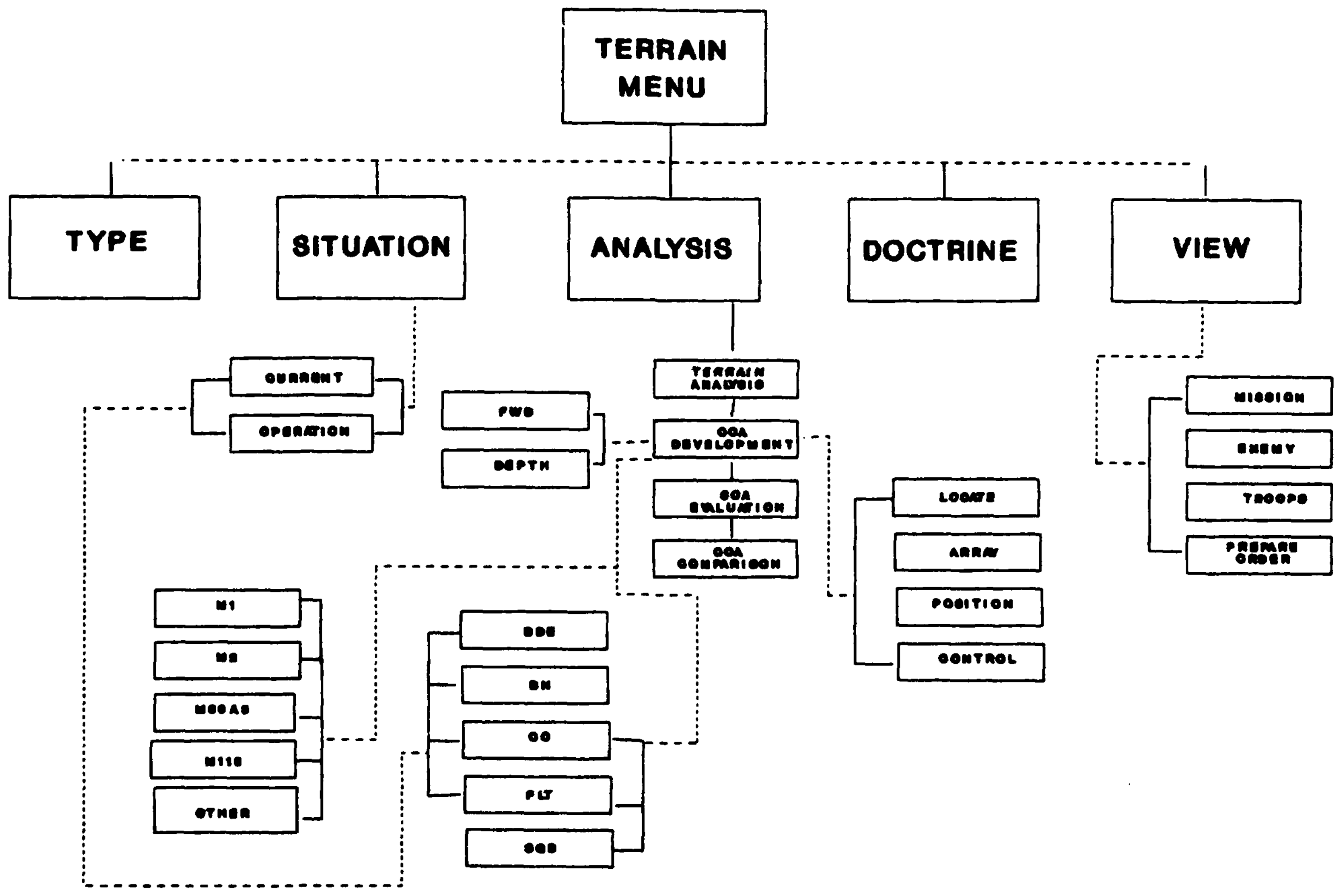
ENEMY MENU



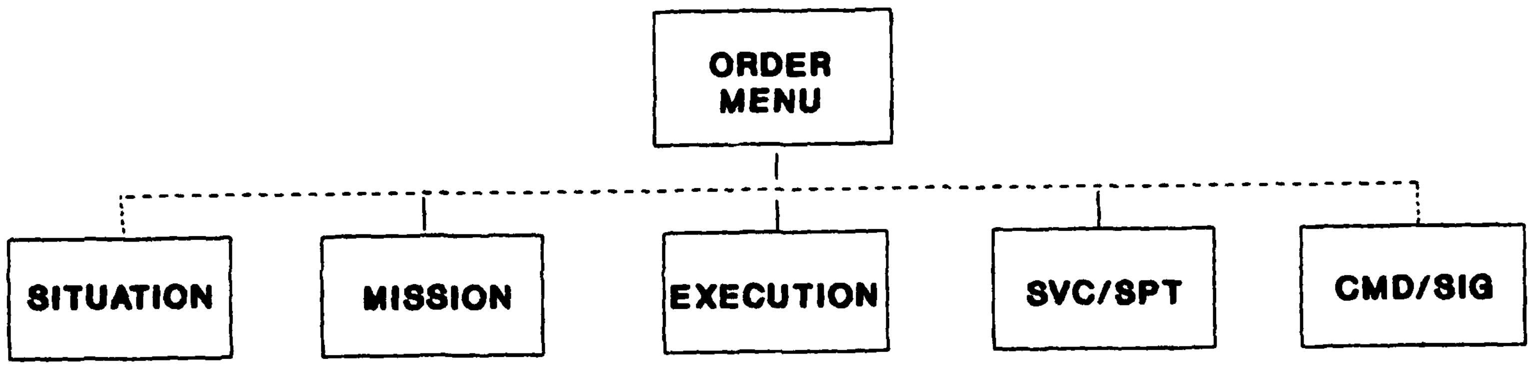
TROOPS MENU


TROOPS MENU
FORCES AVAILABLE
STATUS
POWER
DOCTRINE
VIEW
NEW
OLD
COMPARE
SUMMARY
DETAILED
GENERAL
SPECIFIC
COMPARE
ENEMY DATABASE
CMD
CL VII
CL I
CL V
CL III
PERSONNEL
BDE
BN
CO
PLT

TERRAIN MENU



PREPARE ORDER



Appendix D

The Hookbook

This appendix contains the hookbook entries that have not been incorperated into the Battalion Decision Aid. The hookbook entries are the thoughts, ideas, or recommendations that would effect the evolution of this DSS. These entries have been sorted into the following categories: dialogue, database, models. Since most of the hookbook entries were written on the paper storyboards, they were incorporated into the next iteration of the storyboards. Consequently, most of the entries deal with the modeling.

Dialogue

27 November

Idea: Must minimize key strokes. Function keys must be labeled in such a way that the user has a general idea of what he will get before he pushes it.

Situation: Working on initial storyboards.

2 December

Idea: Incorporate split screen if the comparison being made requires it.

Situation: Working on storyboards.

20 February

Idea: System must follow the structure of the planning process, but have the flexibility so that the user modify process based on environmental reasons. The system must be able to feel in the gaps.

Situation: Reviewing military decision making.

2 March

Idea: Must include capability to generate course of action sketches in next iteration.

Situation: Reading ST 100-9.

7 March

Idea: The map used in the system must be of a resolution as good as the paper maps.

Situation: Looking for a map to use in storyboards.

Database

28 October

Idea: The basic concept of the MCS is a large scale MIS. Data entry must not overburden the staff. It must be natural. Is there a need for information backup in hard copy in the event of system crash. Is this double work?

Situation: Reading MCS literature.

7 February

Idea: How is the integrity of the database going to be maintained. Conflicting reports are common place.

Situation: In database class.

Model

15 August

Idea: Models used must closely follow the current process. Could this lead to user confidence in the system?

Situation: Not entered.

8 October

Idea: Model to locate positions is a function of LOS, weapon, weather, unit size, and mission requirements.

Situation: Combat modeling class.

28 December

Idea: Need a model that can provide a weapon fan for a user selected weapon, location, and orientation.

10 January

Idea: GVS --> adjust units value, based on requirements for combat power unit sectors could be generated.

AI --> Recommends allocation of units to meet required force levels.

Man --> Allocates, Adjust values, and Controls the process.

CBT Simulation --> Must be procedural, interactive so the required power level may be maintained by allocation of units and fire assets.

Situation: Working on storyboards.

4 February

Idea: System must have the capability to develop numerous coerces of action at the same time. One actively on the screen the remainder in the background. user can develop background COA by inserting key decision options not taken in the active COA.

Situation: Working on storyboards.

10 March

Idea: The system model would consist of a AI model overhead that accesses other sub-models in the area of mission analysis, enemy course of action generation, terrain analysis, and a procedural event sequenced combat model.

Situation: Reading an articles concerning the application of AI in the planning process.

APPENDIX E

Firepower-score Methodologies and the Attrition Process

This appendix is a discussion of some of the static fire power scoring methodologies that have been or are currently used in aggregated combat models. In addition, the attrition process used in most of the models that employ firepower-scores is discussed. This discussion will focus on the general approach used to compute combat power and the basic factors that are considered in the quantification of a units battle field capabilities and the general process of decreasing that ability over time due to enemy contact. Criticism of the approaches will also be provided.

Perceived Combat Value

This approach to quantifying combat power based solely on military experience and judgment are historically based in procedures which have been used for situation assessment and planning for many years " [Hartman:4-9]. Initial efforts in this area were conducted at the Army War College following WWII which rated American and German battalions based on students' combat experience. Since this approach is subjective there exist numerous methods of deriving the scores for weapon systems. The common characteristics of these approaches is the establishment of a relationship among weapon systems of a certain category (e.g.anti-personnel, anti-tank, anti-air) or units (e.g. motorized rifle battalion BTR equipped equivalence) . These values are then adjusted by weighting factors based on mission, terrain, tactics, training, and other situational factors deemed important. The results of this process is a relative ranking of weapons or units which are highly sensitive to changes in the scenario.

A modern example of this type of approach can be found in the State of the Art Contingency Analysis (SOTACA) Model. This model utilizes a user established Weighted Power Value (WPV) which is determined through the use of pairwise comparison technique developed by Thomas L. Saaty in his book titled The Analytical Hierarchy Process. This process requires the user, a military expert or group of experts, to identify or define the pacing (primary) weapon system which is capable of projecting power in each unit, the confronters which are the smallest units (e.g. tank, squad) capable of projecting power, the power projection categories which are the functions of combat that the force must be able to perform to accomplish its mission, and the mission modes that the force can perform during the analysis. Once this is completed, the user will start at the lowest level of the hierarchy and apply the pairwise comparison and repeat the process at each level using the fixed value scale from 1 to 9 for all possible paired set of elements. The final results are then aggregated by the number present in the force and then summed across the force to obtain the WPV. To illustrate this approach of obtaining a perceived firepower score and index, a demonstration of the process and computations required will be developed below.

Once the pacing weapon systems, confronters, power projection categories, and mission modes are defined, the user must determine the confronter power level in each power category. This is the lowest level in the analytical hierarchy were the relative relationship among confronters is established . The judgment matrix is formed based on the preceding definitions and is filled by the user's subjective judgments.

		CATEGORIES		
		anti-personnel	anti- armor	
CONFRONTER	TANK (M1)			
	IFV (M2)			
	CFV (M3)			
	MRT			

Table 5. Judgment Matrix

This requires the user to make n(n-1)/2 comparisons to fill half the matrix. Table 6 shows the comparisons for the anti-personnel category for the Blue force.

BLUE ANTI-PERSONNEL CATEGORY POWER PAIRWISE COMPARISON

	ABSO-LUTE		VERY STRONG		STRONG		WEAK		EQUAL	WEAK		STRONG		VERY STRONG		ABSO-LUTE		
M1	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	M2
M1	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	M3
M1	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	MRT
M2	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	M3
M2	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	MRT
M3	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	MRT
* Note conversion scale.	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	

<---- POWER ---->

Table 6. Comparison

It is assumed that the other half is filled with the reciprocal values. Table 7 shows the filled matrix.

JUDGMENT MATRIX

	M1	M2	M3	MRT
M1	1	1/5	1/5	1/3
M2	5	1	1	1/3
M3	5	1	1	1/3
MRT	3	3	3	1

Table 7. Judgement Matrix

A consistency check is done for all comparison matrices using the methodology established by M.K. Kendall in the

1940s. The final step is to calculate the geometric mean, EQN 1, and then normalize the geometric mean, EQN 2, [Martin:4-33].

$$\text{Geometric mean:} \quad GMV(i) = \sum_{j=1}^{n} a(j)1/n \qquad \text{(EQN 1)}$$

n= number of confronters
$a_{(j)}$= jth elements of row j

$$\text{Normalized mean:} \quad GMV_n = GMV_i \;/\; \sum_{j=1}^{n} GMV \qquad \text{(EQN 2)}$$

Table 8 shows these computations.

CATEGORY ANTI-PERSONNEL BLUE POWER VALUE

JUDGMENT MATRIX	GMV(i)	GMV(n)	
¦ 1 .2 .2 .33 ¦	.339	.0694	M1
¦ 5 1 1 .33 ¦	1.1334	.2320	M2
¦ 5 1 1 .33 ¦	1.1334	.2320	M3
¦ 3 3 3 1 ¦	2.2795	.4666	MRT
	4.8853		

Table 8. Computation

This normalized mean represents the relative value and ranking of each element in the anti-personnel category. This process is also applied to the Red forces.

The next level in the hierarchy requires the user to establish confronter vulnerabilities. The vulnerabilities of a confronter is its susceptibility to opposing confronters. This vulnerability is composed of two parts, general and relative vulnerabilities. General vulnerability establishes how vulnerable " each confronter is when compared to other confronters of the same side and considers only the general scenario and threat within each of the mission modes " [Martin:4-35]. This general comparison among confronters is done by a single pairwise comparison for each mission mode. This is depicted in Table 9.

GENERAL BLUE VULNERABILITY/ATTACK MISSION MODE

	M1	M2	M3	MRT	GVM(i)	GVM(n)
M1	1	.33	5	.14	.6985	.112
M2	3	1	5	.2	1.3161	.211
M3	.2	.2	1	.14	.2749	.044
MRT	7	5	7	1	3.9563	.633
					6.2458	

Table 9. General Vulnerabilities

This general vulnerability will be weighted by the relative vulnerability of each confronter when considering each opposing categories of power. The relative vulnerability deter mines how " vulnerable each confronter is when faced with the power projected by the opposing categories " [Martin:4-37]. Each BLUE confronter is pairwised compared against each RED category and vica-a-versa. " The pairwise entries, . . ., become an allocation of BLUE confronter vulnerability across the kinds of opposing power that each might meet in conflict " [Martin:4-37]. Table 10 and 11 depict this process.

RELATIVE BLUE VULNERABILITY/ M1

	RED ANTI-ARMOR	RED ANTI-AIR	RED ANTI-PERS	GMV(i)	GMV(n)	
ANTI-AR	1	7	3	2.7598	.6694	.7
ANTI-AIR	.14	1	.33	.3625	.0879	.1
ANTI-PERS	.33	3	1	1.0	.2426	.2
				4.1214		

Table 10. Relative Vulnerability M1 Tank

(Doing four sets of pairwise comparisons, relative vulnerabilities of BLUE for mission mode attack is determined.)

BLUE RELATIVE VULNERABILITIES/ATTACK MISSION MODE

	RED ANTI-ARMOR POWER	RED ANTI-AIR POWER	RED ANTI-PERS POWER
M1	.7	.1	.2
M2	.5	.2	.3
M3	.7	.1	.2
MRT	.8	.1	.1

Table 11. Relative Vulnerability Blue Attack Mission Mode

The relative vulnerability reflects the decision makers conceived killer-victim scoreboard (power-confronter) for each mission mode. Considering the general vulnerability as a confronters total vulnerability to all the opposing forces power, the relative vulnerabilities are the percent age breakdown of the general vulnerability due to each category of opposing power. In essence, the vulnerability determination is the anti-potential of each confronter.

The final level in this hierarchy is the relative force valuation. Up to this point, the consideration of power and vulnerability has been done in the absence of the quantities of the confronter types in the area of operation. By now considering the number of each confronter, the power it can project, and its vulnerability to opposing power, a relative force valuation can be determined for each category of power. Prior to this calculation, two intermediate calculation must be done. The first calculation is to determine the category power values. These values represent the total power value considering all confronters present to perform a given category and individual confronter values. The values are computed using Equation 3 [Martin:4-39]. Table 12 provides the result of the computation for the Blue force.

	QTY BLUE CONF VALUE	BLUE ANTI-PERS CONF VALUE	BLUE ANTI-PERS CATEGORY VALUE	BLUE ANTI-AR CONF VALUE	BLUE ANTI-AR CATEGORY VALUE
M1	54	.0694	3.748	.3343	18.052
M2	10	.232	2.32	.1495	1.495
M3	6	.232	1.392	.3872	2.323
MRT	9	.4666	4.199	.129	1.161
			11.659		23.031

BLUE CATEGORY POWER VALUE/ATTACK MISSION MODE

Table 12. Blue Power Value Attack Mission goal

$$CPV_{i,k} = \sum_{j=1}^{n} [QC_{j,k} \times CP_{i,j,k}] \qquad \text{(EQN 3)}$$

i = category side k
j = confronter type j for side k
k = side
n = number of confronter types
$QC_{j,k}$ = Quantity of confronter j side k
$CP_{i,j,k}$ = Category power value i for side k confronter j.

The other component of the relative force valuation is category vulnerability values. It considers the number of BLUE confronters present and their general and relative vulnerabilities against specific power projections by the opposing force for each mission mode. It is computed using EQN 4, and normalized by dividing EQN 4 by EQN 5 shown at

EQN 6 [Martin:4-41]. Table 13 contains the results for RED category vulnerability.

$$CVV_{i,k} = \sum_{j=1}^{n} QC_{j,k} \times GV_{j,k} \times CV_{i,j,k} \qquad \text{(EQN 4)}$$

i = category
j = confronter type
k = side
n = number of confronter types
$QC_{j,k}$ = quantity of confronter j side k
$GV_{j,k}$ = general vulnerability of confronter type j
$CV_{i,j,k}$ = relative vulnerability of confronter j to opposing category i

$$GVV_{j,k} = \sum_{j=1}^{n} [\ QC_{j,k} \times GV_{j,k}\ ] \qquad \text{(EQN 5)}$$

$$NCVV_{j,k} = [\ \sum_{j=1}^{n} CVV_{j,k}\ ] \ / \ [\ \sum_{j=1}^{n} GVV_{j,k}\ ] \qquad \text{(EQN 6)}$$

RED VULNERABILITY VALUE/ATTACK MISSION MODE

	QTY RED CONF VALUE	RED GEN VUL	GEN VUL VALUE	VUL TO BLUE ANTI-PER POWER	RED ANTI-PER VUL VALUE	VUL TO BLUE ANTI-AR POWER	RED ANTI-AR VUL VALUE
T72	60	.039	2.34	.6	1.404	.4	.936
BMP	20	.1232	2.464	.556	1.37	.444	1.094
ARTY	18	.2266	4.0788	.125	.5098	.875	3.569
A/C	10	.565	5.65	.5	2.825	.5	2.825
SPTZ	5	.0462	.2310	.7	.1617	.3	.069
			14.7638		6.2705		8.424
NORMALIZED			1		.4247		.5706

Table 13 Red Category Power Value

The combination of the two intermediate calculations represent the force's composite powers and vulnerability. "This relative force value reflects the projection of one side's power and the vulnerability of the opposing side to it" [Martin:4-43]. The aggregation of these products over all the categories determines the WPV which represents " the synergistic effects of all tasks the force may be called upon to perform." [Martin:4-43] The equation is [Martin:C-9]:

$$WPV_{j,k} = \sum_{i=1}^{n} CPV_{i,k} \times NCVV_{i,k+1} \qquad \text{(EQN 7)}$$

i = power category value side k
j = mission mode side k
k = BLUE ($k+1$ = RED)
n = number of categories
$CPV_{i,k}$ = Category i power value side k
$NCVV_{i,k+1}$ = Normalized vulnerability value category i, category i, side k+1 .

A weighted power value (WPV) calculation is done below, at Table 14.

BLUE WEIGHTED POWER VALUE	=	BLUE ANTI-PER POWER VALUE	x	NORMALIZED VULNERABILITY OF RED TO BLUE ANTI-PER POWER
	+	BLUE ANTI-AR POWER VALUE	x	NORMALIZED VULNERABILITY OF RED TO BLUE ANTI-AR POWER
	=	(11.659 x .4247)+(23.031 x .5706) = 18.0931		

Table 14. Weighted Power Value Computation

The methodology used in SOTACA is representative of other judgmental scoring methods. Though the mechanics of the methodologies differ, weaknesses of the approach are shared. First, all subjective scoring systems are situationally dependent as mentioned earlier. Therefore, a change in the weapon systems, force composition friendly or enemy, or the area of operation will require the recalculation of the scores. Second, there is no means to include or exclude factors of interest. Finally, the scores by their very nature are very subjective. The scores cannot be verified and are the results of that person's or group's view of the world.

Historical Combat Performance

Almost all scoring systems used in the aggregated models currently in the active inventory use a varying degree of subjective judgment in the process of determining a force's combat capability. Consequently, personal experience and history have a direct impact on the analytical study of the phenomenon of war. The Quantified Judgment Model (QJM) developed by Trevor N. Dupuy draws heavily upon the understanding of historical data in the valuation of units and the determination of battle outcomes. He so strongly feels that an understanding of the history war is an essential for good military analysis that he states, " No model should be allowed to influence important military decisions unless it can accurately reflect what has happened on real battlefields " [Dupuy,1987:59]. In short, this is the econometric approach to modeling as compared to the more generally used stochastic approach to modeling.

The methodology used in the QJM to score modern weapons requires the establishment of a subjective set of scores for weapon systems that were within the force structure of a known battle. These subjective scores are then adjusted by applying selected environmental and operational variables. These adjustments result in the determination of a forces potential and combat capability. The resulting scores establish the base for the judgmental model which is used to compare the observed results with the historical outcome of the selected battle. Once a good fit is achieved between the historical data and the judgment model, characteristics of future and current weapons can be introduced for analytical purposes.

In the QJM, firepower scores are referred to as Theoretical Lethality Indices (TLI). Weapons are categorized into two class, hand-carried and mobile.

The lethality for hand-carried weapons is determined by this equation [Dupuy,1979:20]:

$$TLI_h = RF * PTS * RIE * RN * A * R \qquad \text{(EQN 8)}$$

where RF = Rate of fire
PTS = Possible targets per strike
RIE = Relative incapacitating effect
RN = Effective range
A = Accuracy, and
R = Reliability.

The lethality of mobile weapons is determined by this equation [Dupuy,1979:20]:

$$TLI_m = [(\sum_{1}^{n} TLI_n) * M * RA * PF] * RFE * FCE * ASE * CE \qquad \text{(EQN 9)}$$

TLI_n = Lethality of weapon system n
M = Battlefield mobility
RA = Radius of action
PF = Punishment factor
RFE = Rapidity of fire effect
FCE = Fire control effect
ASE = Ammunition supply effect, and
CE = Ceiling effect (aircraft only).

Subjectively derived tables and formulas are used to determine the value of these weights. The resulting TLI is then divided by a dispersion factor (D(i)) which produces an Operational Lethality Indices (OLI). A D(i) = 1 represents the density of 100,000 men per 1 square kilometer.

The firepower index, combat power potential (CPP) in QJM, of the force is determined in the following manner [Dupuy,1979:43-47]:

$$CPP = \sum_{1}^{n} OLI_n * EV * OV \qquad \text{(EQN 10)}$$

where EV = Environmental factors and
OV = Operational factors.

The environmental and operational factors collectively are referred to as combat variables of which there is 73 which are categorized into 11 groups. The groups are shown at Table 15. The weighting of these variables is also determined by subjectively derived formulas or tables.

Combat Variables	
Weapon effects	Mobility effects **
Terrain effects *	Vulnerability factors **
Weather factors *	Tactical air effects **
Season factors *	Other combat processes **
Air superiority factors *	Intangible factors **
Posture factors **	

* Environmental Factors, ** Operational Factors

Table 15. Combat Variables [Dupuy,1979:33-34]

The force ratio is determined by dividing the friendly force's CPP by the enemy force's CPP. If the value is greater than 1, the friendly force wins otherwise the enemy wins. This value is compared to the historical outcome of the actual battle and reviewed for consistency. If the results do not agree the model is 'tweaked' by identifying and adjusting the critical variables. This is accomplished through the use of the Land Warfare Database which contains over 600 battles spanning the time period from 1600 to 1973.

This approach is criticized for the following reasons. First, the approach of analyzing historical battles is based on the comparative performance of the opposing forces in terms of their accomplishment of their respective missions, their ability to gain or hold terrain, and their efficiency in terms of casualties incurred [Dupuy,1979:50]. The basis of analysis and the evaluation are both subjective judgments. Second, the mean by which the model is adjusted so as to conform to history is arbitrary. The values of all weights are the results of subjective evaluation. Finally, the accuracy and completeness of the historical data is very doubtful.

Weapon Firepower

An example of a scoring system that is based on a weapons 'firepower' is the Index of Combat Effectiveness (ICE). This method is used in the ATLAS model which was developed in the 1960s. Data from ballistic research conducted by Army laboratories is used in the computation of the firepower score. Weapon systems are classified into two categories, point and area fire. The general computation of the score is based on the daily expected ammunition expenditure and the " physics of fragmentation and their dispersion, and wound pathology " [Stockfisch:29] for area fire weapons and conditional probabilities given a hit for point fire weapons. The unit value, ICE, is determined through the use of a judgmental weighting scheme that relates historical casualty data with the mix of the two weapon classes. The firepower index for a sector is the summation of each unit ICE adjusted by effectiveness factor. The unit effectiveness attempts to capture the degradation of the units effectiveness due to logistic shortages and casualties.

The firepower score for indirect fire weapons, artillery and mortars, is determined by [Hartman:4-9]:

$$FS_i = DEAE_i * LA_i \qquad \text{(EQN 11)}$$

where FS_i = Firepower Score
$DEAE_i$ = Daily Expected Ammunition Expenditure
LA_i = Lethal Area.

Ammunition expenditure rate data can be obtained from planning factors contained in FM 101-10-1 and FM 101-10-2, Army supply bulletins, or ammunition model output. The concept of lethal area represents the complex interaction of the energy released in the chemical explosion, the fragmentation and dispersion of the shell's casing as a result of the rapid energy release, and the target capability to withstand or absorb that energy. Therefore, the lethal area is dependent on the " weapon system characteristics, target type and protection, and type of combat task" [Veditz:28]. In addition, all rounds are considered independent. This greatly simplifies the computation by not considering overlapping bursting radii.

The firepower score for direct fire weapons, anti-personnel and anti-tank, is determined by [Hartman:4-9]:

$$FS_i = DEAE_i * P_i(K/H) \qquad \text{(EQN 12)}$$

where FS_i = Firepower Score
$DEAE_i$ = Daily Expected Ammunition Expenditure
$P_i(K/H)$ = Conditional Probability of Kill Given a Hit.

The kill criteria is based on medical judgment of the human bodies ability to absorb the round's ballistic characteristics. A personnel kill is sensitive to range, weapon type, and battlefield conditions that affect accuracy and protection [Veditz:29]. An anti-tank kill is dependent on the characteristics of the munitions and vehicle. Some of these factors are method of penetration, armor thickness, impact parameters, and location of impact.

In relating these two weapon classes to WWII casualty data several problems are encountered in the determination of an ICE. First, there exists doubt on the relevance of WWII casualty data to modern combat and some scenarios [Hartman:4-15]. Second, a subjective weighting scheme must incorporate the historical data with projected ammunition expenditures. Third, another subjective model must be used to account for partial kills. Fourth, no consideration is given to other critical factors such as mobility and vulnerability. Finally, the linear nature of the scores produces questionable results. Increasing the ammunition expenditure rate will produce a proportional increase in the firepower score which in turn will cause a proportional increase in the opposing force's casualty rate due to the relationship between the force ratio and the attrition process.

The firepower index for a sector is determined by [Hartman:4-14] :

$$FPI_A = \sum_{i=1}^{n} ICE_i * U\%E_i \qquad \text{(EQN 13)}$$

where FPI_A = Firepower Index Attacking Force
ICE_i = Index of Combat Effectiveness Unit i
$U\%E_i$ = Unit Percent Effectiveness Unit i.

The summation is limited to forces at the front line of the sector. The U%E is the combination of the degradation due to logistics and casualties. Though this degradation of effectiveness is plausible, the correctness of its application to all units and scenarios is not [Hartman:4-13].

Characteristics of the Weapon System

An example of this type of weapon scoring system is the Weapon Effectiveness Index (WEI) and its corresponding unit index, Weighted Unit Value (WUV). This scoring system, developed in the 1960's, is an effort to combine a "weapon's firepower with other system characteristics such as mobility, vulnerability, and reliability " [Hartman:4-10]. The weights of the weighting scheme which are based on the subjective evaluation of weapon performance based on personal experience are determined through the use of the Delphi technique are then combined with the weapon systems characteristics and summed to determine a firepower score. The listing of scores has been expanded over time to include most of the weapon systems in the Army inventory with the exception of such systems as mines [Veditz:30].

This approach, classified weapons into seven categories based on battiefield function. These categories are " man portable small arms, vehicle mounted small arms, tanks, armored reconnaissance vehicles, anti-tank weapons, tube artillery, and mortars " [Veditz:30]. As in many systems that classify weapons into classes, a single weapon must be selected as the group standard. Once this is done, a list of predominate attributes of the weapon category is made and weighted by their relative relationship to weapon effectiveness. After this is done for all seven categories, another judgment model is used to establish a relative weighting scheme among the seven categories. With this weighting scheme, a score for all weapon types can be calculated and normalized.

Using a man portable small arms weapon category, an illustrative WEI calculation will be done [Lester]. The dominate attributes are firepower (F), mean number of rounds fired between malfunction (M), and weight (W). As depicted below, a weighting scheme derived by Delphi analysis defines the WEI in terms of these characteristics.

$$WEI = .6F + .3M + .1W \qquad \text{(EQN 14)}$$

Each dominate attribute is also decomposed to its major components. These components are also weighted using the technique. In the example, the major components of fire power are lethality (L), ammunition availability (A), sustained rate of fire (SR), range (R), and secondary weapon (B). As with the weapon category attributes, these components are subjectively weighted by weapon system and com pared to the components of the standard weapon (e.g. Ls, As, SRs ...). This is depicted in the following equation;

$$F = .61L/Ls + .13A/As + .12SR/SRs + .12R/Rs + .02B/Bs \qquad \text{(EQN 15)}$$

With the establishment of a relative ranking among weapons within a category that is established by the resulting scores of the previous two equations, another judgment model is applied so a ranking among categories can be done. The resulting scores are normalized to a reference weapon and mission.

	WEI						
	RIFLE M16A2	MG M254	MG M60	MORTAR 107mm	HOWITZER M109	IFV M2	TANK M1
ATK	1	6	10	20	35	65	100
DEF	1.7	10	18	28	96	110	198

TABLE 16. WEI Scores

This approach attempt to capture a more complete picture of a weapons battlefield capabilities by combining firepower with other key characteristics. The approach is overly dependent on subjective judgment in both weights and the determination of key characteristics. It established standards which are applied evenly across all the categories of weapons.

What a Weapon Can Kill

The Potential Anti-Potential or eigenvalue method used in the IDAGAM combat model computes firepower scores in a totally objective manner. Like the AHP method used in

SOTACA, the value of a weapon system is based on the weapon's capabilities and its interaction with enemy vulnerabilities. Unlike any of the other approaches, the data used in the computations is the output from high resolution combat models and therefore contains elements of the heterogeneous approach to aggregation. The resulting scores, indices, and force ratios are still only a homogeneous representation of a unit's combat power [Hartman:4-22] and totally objective (subject to the biases and values incorporated in the high resolution model).

The basic principle of this approach is " the value (score) of a weapon system is directly proportional to the rate at which it destroys the value of opposing enemy weapon systems " [Hartman:4-22]. This principle leads to a circular definition of value. The value of a friendly weapon system is dependent on the rate and value of the enemy weapon systems it kills, and the value of the enemy weapon system is dependent on the rate and value of the friendly weapon systems it kills.

As previously mentioned, this method utilizes input from high resolution models to determine the scores. The kill rate values are easily obtained from the killer-victim scoreboards of a high resolution model. These values are non-negative numeric values which implicitly depend on such scenario factors as composition of friendly and enemy forces, force missions, target acquisition conditions and selection rules, and the results of one-on-one duels. The Two matrices, a friendly (F) m by m matrix and an enemy (E) n by n matrix, are formed from the killer victim pairings. The two matrix products FE and EF yield a set of linear equations (m+n) with an equal number of unknown. For each matrix product's largest eigenvalue, an eigenvector is calculated. The eigenvector for FE and EF contains the weapon system values for the friendly and enemy forces respectively.

Since the matrices F and E contain only positive elements as stated earlier, the Perron-Frobenius Theorem applies. This theorem guarantees that for every positive square matrices there exists a positive real eigenvalue which is strictly greater than the absolute value of any other eigenvalue and that the elements of the corresponding eigenvector are real and positive. Consequently, this method is not valid for those weapon pairings in which a weapon system kills another system but is not killed by that system. With the value of the firepower scores determined, the index values and force ratio can be calculated using the standard approach.

Several criticism of this approach exist. First, the score values are scenario dependent because the kill rates are influenced by the characteristics of the battlefield.

Second, a change in one kill rate will cause changes in all the scores for both sides in unpredictable ways (e.g. giving a major weapon system a value of zero). The cause of this behavior may be best explained by the fact that the process of determining the scores is linear and the process being modeled is non-linear. Finally, this process total excludes military judgment from the scoring process. Subjective review and adjustment of the kill rate is totally appropriate.

The Attrition Process

In many of the aggregated force-on-force combat models which use firepower-scores, casualties are assessed by the use of a loss-rate curve which plots percent daily casual ties verse the force ratio of attacker combat power divided by the defender's combat power. These loss-rate curves derived from historical data can be modeled by a differential equation model [Taylor:39]. By using this differential equation model, the fractional casualty rate can be modeled by Lanchester's equation for modern warfare between two homogeneous forces:

$$\frac{dx}{dt} = -ay \quad \text{with } x(0) = x_0$$
$$\frac{dy}{dt} = -bx \quad \text{with } y(0) = y_0 \qquad \text{(EQN 16)}$$

where x(t) and y(t) represent the quantity of X and Y at time t after the start of the engagement, and a and b are the Lanchester attrition-rate coefficients which are constant and represents the effectiveness of each side's firepower [Taylor:21]. To consider X's fractional casualties per unit time, EQN 16 is rewritten in the following form:

$$\frac{-1}{x}\frac{dx}{dt} = \frac{a}{u} \qquad \text{(EQN 17)}$$

where u is the force ratio of X's firepower index to Y's firepower index.

It can also be shown that if the fractional casualty rate is just a function of the force ratio. The Helmbold-type equation with a term added for losses not due to enemy contact is also a good fit to the curves [Taylor:98]. The equation for X's fractional casualties is [Taylor:94]:

$$\frac{-1}{x}\frac{dx}{dt} = \frac{a}{u^w} + cx \qquad \text{(EQN 18)}$$

where c is the term that represents losses not due to enemy action and w is the Wiess parameter. If w is set at 1, .5, or 0, the result of EQN 18 corresponds to Lanchester's equations which yield the square, linear, or logarithmic law respectively.

It is generally agreed that attrition should be modeled between the logarithmic and square laws. The square law, $dx/dt = -ay$, or $w = 1$ is the best fit for the casualty rate of the defending force. However, the linear law, $dy/dt = -b$, or $w = .5$ is a reasonable attrition rate for the attacking force [Taylor:99].

The preceding portion of the attrition process is generally agreed upon. The determination of the attrition coefficients is were the disagreement occurs. The a in EQN 1 means

$$a = 1 / E [T_{xy}], \qquad \text{(EQN 19)}$$

where $E[T_{xy}]$ is the expected value of the random variable T_{xy}. It denotes the expected time required for a Y firer to kill an X target. There are two approaches in the US for determining $E [T_{xy}]$. The first method uses the output from a high resolution model and statistically derives the Maximum-Likelihood Estimation (MLE) of the attrition rate coefficients [Clark]. The second method attempt to analytically determine the point estimate of the attrition coefficients based on the impact of the target acquisition and engagement process on the attrition process [Bonder, Barefoot]. Interested readers should refer to sources cited in the bibliography for a more detailed treatment of this subject and the attrition process.

APPENDIX F

A Brief Development of Situationally Dependent Power

This Appendix addresses the development of situationally dependent value in a little more detail than in the main text. It also covers the development of the average value of a unit over time.

The situationally inherent value of a unit can be expressed in mathematical terms based on the following assumption. The inherent value of a force like a battalion at the start of the engagement is the sum of all subordinate combat unit's basic inherent value at the start of the engagement. Therefore, the basic inherent value of a force at time t(0) is expressed by this equation [Schoenstadt:5]:

$$V = \sum_{i=1}^{n} V_i \left(S_i(t_0)\right) \qquad \text{(EQN 1)}$$

where V = inherent value of the force
V_i = inherent value of unit i, and
S_i = state of the unit i at time t.

Now assuming that this force will not be available for use in the area of contact until some future time t > t(0), the future value of this force is discounted to its present value which can be expressed by the following equation [Schoenstadt:6]:

$$V = \{ \sum_{i=1}^{n} V_i \ (S_i(t_0))\} \ e^{-A(t-t0)} \qquad \text{(EQN 2)}$$

where $e^{-A(t-t0)}$ defines the discount factor and A is the decay constant which is used in the determination of the future inherent value of the force. For example, an enemy force that is within the area of influence of a battalion, which is defined as being within 6 hours or 15 kilometers of the close-in battle, has the ability to become engaged with the battalion. A force which is 6 hours from entering the close-in battle has an insignificant value (0.01), the solution for A is straight forward. The value is determined in this manner:

$$e^{-6*A} = 0.01 \qquad \text{(EQN 3)}$$

which can be reduced to:

$$A = \frac{\ln 0.01}{-6} = 0.768 \qquad \text{(EQN 4)}$$

With the determination of the decay constant, the present value factor of a force at the start of a battle can be written in the following form:

$$Z = e^{(-0.768 * (t-t0))} \qquad \text{(EQN 5)}$$

where Z = weighting of the present value of a force's future combat value.

Thus far the discussion of value has focused on its instantaneous value of a force at time t. However, the state of active combat units changes over time due to attrition and consumption of supplies. Therefore, an average value may be more meaningful in providing insight into questions concerning success or failure of extended operations. In order to maintain consistency with exponential discounting of future value, the following expression is given for average value of a unit which could be easily extended for a force [Schoenstadt:7]:

$$G(V) = Z \int_0^{\infty} \{\Sigma\, V_i(s_i(t_0))\}\, e^{-\lambda t}\, dt \qquad \text{(EQN 6)}$$

where current time is (t) = 0. Consequently, at the start of an engagement when (t) = t_0 = 0 then EQN 6 reduces to EQN 1 for the committed forces.

Any reader interested in a more detailed discussion of GVS, approaches to adjusting inherent value, and application of GVS in the AirLand Research Model is referred to sources cited in the bibliography (Criag, Fletcher, Geddes, MacLaughlin).

BIBLIOGRAPHY

Alavi, Maryam and Albert H. Napier. " An Experiment in Applying the Adaptive Design Approach to DSS Devevopment." Informatiom and Management.7: 21-28 (July 1984).

Andriole, Stephen J. and others. " Intelligent Aids for Tactical Planning." IEEE Transactions on Systems, Man, and Cybernetics, 16: 854-864 (Nov/Dec 86).

Andriole, Stephen J. The Design and Development of an Intelligent Planning Aid: Interim Report, January - December 1984. Contract MDA 903-83-C-0382. Alexandria VA: US Army Research Institute for the Behavioral and Social Sciences, July 1986 (AD-A178332).

Barfoot, C.B. " The Lanchester Attrition-Rate Coefficient: Some Comments on the Seth Bonder's Paper and a sugges ted Alternate Method," Operations Research 17, 888-894 (1969).

Belardo, Salvatore and John P. Seagle. " The Feature Chart: A Tool for Communicating the Analysis for a Decision Support System." Information and Management. 9: pp. 11-19 (Jan 86).

Bonder, Seth. "Combat Model," Chapter 2 in The Tank Weapon System, Report No. RF 573 AR 64-1 (U), System Research Group, The Ohio State University, Columbus, Ohio, June 1964 (AD 447 494).

Bonder, Seth and R.L. Farrell (Editors), " Development of Models for Defense Systems Planning," Report No. SRL 2147 TR 70-2 (U), Systems Research Laboratory, The University of Michigan, Ann Arbor, MI, September 1970 (AD 714 677).

Carlson, Eric D. " An Approach for Designing Decision Support Systems," Database, pp. 3-15, (Winter 1977).

Clark, G.M. " The Combat Analysis Model," Ph.D. Disertation, The Ohio State University, Columbus, Ohio, 1969.

Clausewitz, Carl von. On War. Translated by O. J. Matthijs Jolles. Washington: Infantry Journal Press, 1950.

Collins, COL D.R. and LTC(P) T.A. Baucum. Knowledge-Based Planning Model for Course of Action Generation. Military Studies Program Paper. US Army War College, Carlisle Barracks PA, 7 April 1986 (AD-A170 608).

Craig, Dean E. A Model for the Planning of Maneuver Unit and Engineer Asset Placement. MS Thesis, Naval Postgraduate School, Monterey, CA, September 1985 (AD-A159871).

Cushman, John, Wayne Hughes, Sam Parry, and Micheal Sovereign. "On Representing Warfare." Report to Joint Analysis Directorate, OJCS, Washington, D.C.,1986.

Dacunto, Lawrence J. "Army Command and Control Initiatives," Signal, vol 43, pp. 63-69, (November 1988).

Department of the Army. Operations. FM 100-5. Washington: HQ DA, August 1982.

______________________. Army Focus. Washington: HQ DA, November 1988.

Dupuy, Trevor N. Numbers, Predictions and War. London: Macdonald and Jane's Publishers, Ltd., 1979.

______________. " Can We Rely Upon Computer Combat Simulation ?," Armed Forces Journal International: 59-63 (August 1987).

Fastabend, MAJ David A. Fighting by the Numbers: The role of Quantification in Tactical Decision Making. Military Studies Monograph, School of Advanced Military Studies, U.S. Army Command and General Staff College, Fort Leavenworth KS, December 1987.

Fletcher, Douglas L. Model for Avenue of Approach Generation and Planning Process for Ground Combat Forces. MS Thesis, Naval Postgraduate School, Monterey, CA, March 1986, (AD-A175318).

Geddes, John M. Jr. An Algorithm for Allocating Artillery Support in the AirLand Research Model. MS Thesis, Naval Postgraduate School, Monterey, CA, September 1986 (AD-A175302).

Government Accounting Office. Report to the Congress of the United States; Models, Data, and War: A Critique of the Foundation for Defense Analysis, PAD-80-21. US Government Printing Office, 12 March 1980.

Hartman, James K. Lecture Notes in Aggregated Combat Modelling. Unpublished; Naval Postgraduate School;1985.

House, William C. Decision Support Systems. Petrocelli Books, Inc., New York, 1983.

Jarvis John J. Decision Support Systems: Theory: Final Report, 1 Oct 1981. Contract DAAG29-76-D-0100. Alexandria VA. US Army Institute for Research in Management Information and Computer Science, 1 Oct 1981 (AD-A104 885).

Kilmer, CPT Robert Allen. The Generalized Value System and Future State Decision Making. MS thesis, Naval Postgraduate School, Monterey, CA, Mach 1986 (AD-A168-446).

Lester, D.M. and R.F. Robinson. "Review of Index Measures of Combat Effectiveness." Report to OSD/SA. OSD, Washington, D.C., 1973.

MacLaughlin, Joseph R. The Extension of Unit Allocation and Countermobility Algorithums in the AirLand Research Model. MS Thesis, Naval Postgraduate School, Monterey, CA, March 1986 (AD-A168393).

Maddox, David M. and Stephen C. Moore. " The 'Five Whats' Approach to Military MS/OR". Interfaces, vol 17, pp. 108-111, (July-August 1987).

Martin Marietta Enegry Systems. SOTACA Analyst's Guide to Theory. Oak Ridge: SYSCON Corp., June 1986.

McFarren, Capt Michael R. Using Concept Mapping to Define Problems and Identify Key Kernels During the Development of a Decision Support System. MS Thesis AFIT/GST/ENS/87M-12. School of Engineering, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, June 1987.

Noah, William W. and Stanley M. Halpin. "Adaptive User Interfaces for Planning and Decision Aids in C3I Systems." IEEE Transactions on Systems, Man, and Cyberneticitics. 16: 909-917 (Nov/Dec 86).

Novak, Joseph D. and Bob D. Gowin. Learning How To Learn; Cambridge University Press; NY; 1984.

Powell, Gerald M. " A Knowledge-Based Model of Operational Military Planning", To appear in Defense Applications of Artificial Intelligence: Progress and Prospects. Lexington Books, D.C. Heath and Co. (Summer, 1988).

Remias, Micheal S. An Analytical Framework for Efficiency Evaluation and Determination of the Preferred Main Battle Tank Fleet. MS Thesis, AFIT/GOR/OS/86D-13. School of Engineering, Air Force Institute of Technology (AU), Wright Patterson AFB OH, December 1986.

Sassenfeld, Helmut M. The Use of Combat Primatives for Combat Analysis. US TRADOC Systems Analysis Activity, White Sands Missle Range, NM, December 1984.

Simon, Herbert A. The Science of the Artificial. (2 ed.) The MIT Press, Cambridge MS, 1981.

Schoenstadt, Arthur L. and Sam H. Parry. Toward an Axiomatic Generalized Value System. Naval Postgraduate School, Monterey, CA, May 1986. (AD-A168078)

Sprague, Ralph H. Jr. " A Framework for the Development of Decision Support Systems", MIS Quarterly, no. 4, pp. 1-26, (December 1980).

Sprague, Ralph H. Jr., and Eric D. Carlson. Building Effective Decision Support Systems. Englewood Cliffs NJ: Prentice-Hall Inc., 1982.

Stachnick, Gregory and Jeffery M. Abram. Army Maneuver Planning: A Procedural Reasoning Approach. Contract 7A40B0820M. Mountain View CA: Advanced Decision Systems, November 1988.

Stockfisch, J.A. Models, Data, and War. A Critique of the Study of Conventional Forces, R 1526 PR. Contract F4462073C0011. Santa Monica, CA: the Rand Corp., March 1975 (AD-A 01 7609).

Sun Tzu. " The Art Of War." In The Roots of Strategy edited by Brigadier general Thomas R. Phillips, pp. 13-66. Harrisburg PA: The Military Service Publishing Company, 1955.

Taylor, James G. Force-on-Force Attrition Modelling. Arlington, VA: Ketron, Inc. January 1980.

Teter, MAJ William A. Expert Systems: Tools in the Commander's Decision-making Process. MS thesis, US Army Command and General Staff College, Fort Leavenworth KS, 6 June 1986 (AD-B105 718L).

US Army Combined Arms and Services Staff School. Military Decisionmaking. E104. Fort Leavenworth KS, April 1985.

__________________. Combined Arms Operations, Vol 1. E716. Ft Leavonworth KS, April 1985.

__________________. Organization of the Army in the Field. E709. Ft Leavonworth KS, April 1985.

US Army Combined Arms Combat Developments Activity. Required Operational Capability for The Family of Army Tactical Command and Control Systems. Fort Leavenworth KS, December 1986.

__________________. Analysis of Tactical Automation Requirements for the Maneuver functional Area: Final Report. Fort Leavenworth KS, November 1987.

__________________. ANNEX D (The Family of Maneuver Control Systems) of the Operational and Organizational Plan for the Family of Army Tactical Command and Control Systems (ATCCS). Fort Leavenworth KS, 8 August 1988.

US Army Command and General Staff College. The Command Estimate. ST 100-9. Fort Leavenworth KS, 1 July 1986.

Valusek, Lt Col John R. Class notes distibuted in OPER 699, Decision Support Systems. School of Engineering, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, July 1988.

__________________. " Adaptive Design of DSSs: A User Perspective." DSS-88 Transactions, pp.105-112, (June 1988).

Veditz, James E. A Scoring System Approach for Combat Model Analysis. MS Thesis, AFIT/GOR/ENS/87D-21. School of Engineering, Air Force Institute of Technology (AU), Wright Patterson AFB OH, December 1987.

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[redacted]

[redacted]

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SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

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2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) AFIT/GST/ENS/89J-4	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION SCHOOL OF ENGINEERING; 6b. OFFICE SYMBOL (If applicable) AFIT/ENS	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) AIR FORCE INSTITUTE OF TECHNOLOGY (AU) WRIGHT-PATTERSON AFB, OH 45433-6583	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION; 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS: PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO / WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)

THE BATTALION DECISION AID: A KERNEL DECISION SUPPORT SYSTEM

12. PERSONAL AUTHOR(S) GREGORY S. MILLER CPT, INF, US ARMY

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
MS THESIS	FROM ______ TO ______	~~1988~~, JUNE 1989	157

16. SUPPLEMENTARY NOTATION

17. COSATI CODES		
FIELD	GROUP	SUB-GROUP
05	01	
25	05	

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)

MILITARY PLANNING; ARMY PLANNING; ADAPTIVE DESIGN; RAPID PROTOTYPING; DECISION SUPPORT SYSTEM; DECISION AID; COMMAND AND CONTROL

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

THESIS CHAIRMAN: JOHN R. VALUSEK, Lt Col, USAF
ASSISTANT PROFESSOR OF OPERATION RESEARCH

ABSTRACT: SEE REVERSE SIDE.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT: [X] UNCLASSIFIED/UNLIMITED [ ] SAME AS RPT. [ ] DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION
22a. NAME OF RESPONSIBLE INDIVIDUAL Lt Col JOHN R. VALUSEK	22b. TELEPHONE (Include Area Code) 513-255-3362; 22c. OFFICE SYMBOL AFIT/ENS

DD Form 1473, JUN 86 Previous editions are obsolete.

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ABSTRACT

The purpose of this research was twofold:

1) To investigate the development of a user orientated, conceptual design of a decision support system (DSS) that would aid battalion level planners in generating course of action during the military planning process.

2) To investigate the military decision making that occurs during the planning process, to identify differences if they exist between echelons of command, and the feasibility of a scaled-down version of a corps, division, or brigade decision aid in meeting the needs for a battalion decision aid.

The adaptive design methodology was used to develop a user orientated design of a kernel system which has the designed capability to 'start small and grow.' Through this design process, the second purpose was also investigated.

The use of the adaptive design tools; concept mapping, storyboarding, and feature charts; enabled the user-designer to determine the initial requirements for a battalion decision aid. Through the use of these tools, the problem space was bounded, and a key subproblem or kernel selected and descriptively modeled. Within the course of action generation subprocess of the military planning process, the ' array initial friendly forces ' process was identified as the kernel for the initial design of the battalion decision aid.

The ability of a planner to accomplish this process of arraying initial friendly forces rapidly and correctly is the cornerstone for successful planning at all command echelons. Though this similarity and the outward appearance of the decision process are identical at all command echelons, it was determined during the design of the initial system that the fundamental determination of combat power and its relationship with space and time changes due to the planner's goal structure and view of the battlefield. This suggests that a battalion decision aid cannot be a scaled-down version of a corps, division, or brigade decision aid.

This research indicates that the adaptive design process provides the proper approach and tools that enable a decision maker to gain understanding of the decision process and to directly map this understanding into a user's statement of requirements.