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SUMMARY

The purpose of this research was to assess the feasibility of developing a decision-aiding support system, through human factors engineering and decision-making analysis, to support one of the Army Corps battlefield tasks -- mobility, countermobility, and survivability as performed by combat engineers. The time period for this research effort was from 09/17/87 to 05/15/88. The research effort included reviews of the literature in the areas of user-computer interface design and technologies, and decision-aiding technologies with respect to software techniques. Literature reviews were augmented by in-depth analysis of the combat engineer's decision-making activities. Specifically, combat engineers stationed at Fort Bragg, North Carolina (307th Engineer Battalion, 82nd Airborne Division and 20th Engineer Brigade, XVIII Airborne Corps) were interviewed. Based on these systematic analysis steps, a solution was found which applied cognitive science technologies to the traditional arts of decision analysis, emphasizing the use of interactive intelligence as a modality to improve combat engineer's decision-making with respect to developing plans for engineering operations. A design of the Combat Engineer decision-aiding system (CETOOLS) to provide decision-aiding support for combat engineer planning activities was developed. The proposed CETOOLS design was judged feasible with a low level of risk.

Keywords: Human factors engineering, Decision support systems, Computer programs, Decision making, Engineering, Decision support systems, Army Corps of Engineers, CETOOLS

Specific conclusions drawn from the research and analyses include: combat engineers are faced with a complex decision situation whereby the combat engineer is striving to support the operational needs of the tactical commander within the context of limited engineering assets and resources as well as time constraints. The combat engineer must possess extensive knowledge, experience, and data to support tactical mission objectives. An interactive decision-aiding support system is warranted to augment the combat engineer's decision-making process with respect to developing their plans to support tactical mission objectives. The CETOOLS system will consist of a multiple-analysis architecture that will utilize a combination of graphical techniques, user-computer interface dialog techniques, as well as statistical and

heuristic techniques whereby the combat engineer is presented inferences concerning the implications concerning their proposed engineer operational plans (i.e., estimated manpower resources needed for specific operations as well as estimated times to complete such operations). Given an effective human-computer interface, the CETOOLS system will enhance combat engineer's planning activities by providing a structure framework for systematic evaluation of Mission, Enemy, Terrain, Troops, and Time available factors (METT-T) and by allowing combat engineers to transcend the limitations of their own experience.

The CETOOLS concept is potentially applicable in any decision-making environment, commercial or government, where plans for actions are required based on matching complex requirements (objectives) against known limited resources, assets and time. Military applications include aiding as well as training combat engineers in the development of effective operational plans. Commercial applications include business decision-making aids for executives, civil engineers, and plant production managers for commercial manufacturing.

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1.1   PHASE I OBJECTIVES

This report was produced as part of a Phase I research effort awarded by the U.S. Department of Defense under the Small Business Innovation Research (SBIR) Program, Contract No. DAAB07-87-C-A034, monitored by the U.S. Army Communications and Electronics Command (CECOM) at Fort Monmouth, New Jersey.

The tactics and doctrine of the modern battlefield have increased the complexity and tempo of modern warfare such that decision makers are required to make decisions under less than optimal conditions. With respect to military planning activities, decision makers must analyze and synthesize complex information, formulate plans, evaluate their feasibility, estimate their potential effectiveness, and then assess the significance of all these factors in formulating an optimal plan. All these activities are usually conducted under severe time constraints. Also compounding the situation is the fact that decision makers have inherent limitations that are the result of human information-processing shortcomings (i.e., short-term memory limitations). Because of these factors, military planners have recognized the need for computerized decision-aids in order to alleviate or minimize the complexity faced by decision makers when evaluating situations. The primary objective of the Phase I research was to investigate the feasibility of developing a decision-aiding support system, through human factors engineering and decision-making analysis, to support one of the Army Corps battlefield tasks -- mobility, countermobility and survivability as performed by combat engineers.

The original Phase I proposal outlined four major tasks to be conducted:

1.   Select a decision situation that will benefit from some form of computerized support via a decision-aiding support system. The direction for this task was to select one of the Army Corps battlefield tasks as the decision situation which warranted further analysis.

2.   Apply a methodology that identifies the decision-making needs found with respect to the selected Army Corps battlefield tasks. Emphasis will be placed on identifying the information requirements for the selected decision situation as well as establishing the appropriate technology options for the design and development of the decision-aiding support system.

3.   Construct a high level user-computer interface (UCI) and functional design for the proposed decision-aiding support system.

4.   Document the Phase I efforts as well as develop a work plan for Phase II.

All objectives for the Phase I research effort have been met. The concept is assessed as feasible. This report presents the documentation of these tasks and forms the basis for the positive feasibility assessment.

1.2   RESULTS OF THE PHASE I RESEARCH EFFORT

After consultation with CECOM personnel, the Army Corps tasks selected as being appropriate for this effort were those performed by combat engineers -- mobility, countermobility and survivability. Interviews with members of the Army engineer community (e.g., US Army Engineer School, US Army Engineer Studies Center and US Army Engineer Topographic Laboratories) further substantiated that combat engineers are in need of decision aids. The combat engineer (CE) is faced with a complex decision situation whereby the CE is constantly striving to support the operational needs of the tactical commander within the context of limited engineering assets and

resources as well as time constraints. As a result, the CE attempts to develop and implement a plan that maximizes the utilization of his assets and resources in a timely manner. The CE is called upon to make decisions concerning the utilization of his resources and assets such that the CE takes into account the Mission, Enemy, Terrain, Troops, and Time available (METT-T) To do so, the CE performs several analytic reasoning steps to derive a plan that best supports the tactical commander's needs.

There are several factors that can disrupt or negatively effect the combat engineer's ability to derive an optimal plan. These factors can be classified as either external/task situation factors or internal human abilities/cognitive processing factors. External/task situation factors are:

- Complexity and dynamics of battlefield operations that warrant combat engineering support,

- Lack of computer support for information requirements and computational support for estimates concerning CE operations,

- Volume and complexity of information to be assessed,

- Need to make decisions in the absence of information, and

- External time constraints imposed on the CE for decision making.

Internal human abilities/cognitive processing factors include:

- Experience level (knowledge) of the CE,

- Inherent human information-processing and high-level cognitive reasoning limitations, and

- Complexity of reasoning steps involved in making decisions concerning combat engineering plans.

All these factors (external and internal) can impact negatively or interact with each other adversely such that the CE is at a disadvantage in deriving an optimal plan. The goal of this research effort was to assess the relative significance of these factors and to identify the features that were needed for a decision-aiding support system that would minimize the impact of such factors.

In order to fully understand the impact of the above mentioned factors, interviews were conducted with combat engineers in operational settings. This was an extremely important step in our research effort. Unlike typical computer systems in a military setting that are designed to satisfy doctrinal or tactical requirements, decision-aiding support systems are designed to satisfy user requirements that can only be derived by user involvement early in the system development process. We conducted interviews with combat engineers stationed at Fort Bragg, North Carolina (307th Engineer Battalion, 82nd Airborne Division and 20th Engineer Brigade, XVIII Airborne Corps). The combat engineers at Fort Bragg were selected because they represent engineers who are working under severe time constraints as well as under imposed limitations with respect to equipment and personnel available for any combat operation. Understanding their decision-making needs during their planning process was seen to typify the needs that any combat engineer may have, especially during actual combat operations when time, assets, and resources will be in short supply. Results from these interviews indicated that combat engineers need a decision-aiding support system that not only provides software support for their decision-making planning process but also provides a "user-friendly" interface.

These two important decision-aiding design concepts ("user-friendliness" and software intelligence) provided the focus for the efforts described in this report. Such findings were further supported by a detailed analysis of the decision-making process that the combat engineers of 307th Engineer Battalion, 82nd Airborne Division perform to develop their plans. As a result of this front-end analysis, subsequent efforts for this Phase I project

concentrated on an investigation of the software techniques and UCI technologies applicable for addressing combat engineer's needs. The proposed Combat Engineer decision-aiding system (CETOOLS) will utilize current human-computer dialogue techniques (i.e., windowing), information display concepts (i.e., graphics) and software techniques (i.e., expert system technologies) to maximize the utility that such a system has to offer. As with any decision-aiding support system, CETOOLS will require an iterative design approach during its developmental cycle (Phase II efforts) to ensure it meets the needs of combat engineers. This is especially important as combat engineer's requirements change depending upon the mission (i.e., offensive or defensive support requirements).

The following steps served as the approach to determining the feasibility of CETOOLS:

1. Review relevant decision-aiding technology with respect to software techniques (i.e., choice models).

2. Review relevant human factors engineering literature to determine relevant techniques for the user-computer interface and dialog interactions.

3. Specify system functionality for CETOOLS, including what the system will do for the user, what the system will demand of the user, and how the system will look to the user.

4. Evaluate the feasibility of constructing a system as described, taking into account such factors as current technology, cost/benefit trade-offs, etc.

5. Develop a preliminary design for the Phase II prototype effort.

1.3   FUTURE APPLICATIONS OF THE CETOOLS SYSTEM

The development of the CETOOLS system will assist combat engineers in developing their plans to support tactical commanders. That is, CETOOLS will provide software support such that adequate consideration will

be possible concerning the factors (e.g., time, resources, assets, etc.) that can impact the feasibility and success of any proposed plan. Also, the system will allow combat engineers to generate alternative plans which otherwise would not be possible because of time constraints. As a result of this system capability, combat engineers will gain valuable experience in analyzing situations in a more flexible and responsive manner. This experience will be important for actual combat situations where changing operational requirements will, no doubt, be the norm and not the exception and will require a flexible approach by combat engineers. This will be especially significant for inexperienced combat engineers who could be easily overwhelmed by the complexity of a battlefield situation. The uses of the proposed system are not limited to operational planning. CETOOLS will also provide an excellent training vehicle for junior leaders during field training exercises, command post exercises, and emergency deployment readiness exercises. The system will offer the ability to view operational situations (i.e., miss ... requirements) via software such that war game type scenarios could be used with CETOOLS for training purposes. As a result, combat engineers will gain valuable experience which otherwise would require on-the-job training. An added benefit will be to relieve the commander and staff of administrative burdens by automating such functions as the Unit Status Report, vehicle maintenance records, load plans, and training schedules.

1.4   REPORT OVERVIEW

This report is organized as follows:

- Section 2 presents the overall technical approach used to develop the CETOOLS system.

- Section 3 presents an overview of the combat engineer working environment as exemplified by the 82nd Airborne Division.

- Section 4 presents a detailed analysis of the combat engineer decision making process as exemplified by the 82nd Airborne Division.

- Section 5 presents a review of decision-aiding technologies relevant for the CETOOLS system.

- Section 6 provides a review of technologies relevant to the CETOOLS user interface.

- Section 7 presents the preliminary design of the CETOOLS system.

- Section 8 presents an assessment of the proposed system's feasibility, including risk areas, and provides a description of the goals and objectives of a Phase II program to develop the CETOOLS system.

- Appendix A presents a historical overview of countermobility principles that combat engineers must consider when developing their plans.

- Appendix B presents the proposed components for the user-computer interface (UCI) for the CETOOLS system. This includes input devices (i.e., mouse), screen layout, and dialogue components (i.e., windows).

2.0   TECHNICAL APPROACH

The technical approach described in this section is based on a methodology developed by Analytics that has been successfully demonstrated in numerous tactical situations (e.g., Zaklad, et al., 1986; Zachary, et al., 1982).

Combat Engineers (CE) typically base their inferences concerning needed assets and resources to support mission objectives on somewhat intuitive reasoning. In many cases, the combat engineer intuitively recognizes that a given task will result in a given expenditure of resources such as manpower and equipment. Experienced CE's tend to develop intuitive models based on previous experience in evaluating mission objectives and inferring possible CE actions. Therefore, the primary objective for the Phase I effort is to define a consistent framework for evaluating CE actions and inferences concerning resource and asset requirements and to conceptualize the features of a decision-aiding support system that captures these reasoning steps. Specifically, the direction of the Phase I research is to identify the technologies (e.g., AI technologies, decision-aiding techniques, etc.) that are relevant to the CE's task and determine what role the relevant technologies should play in the development of a decision-aiding support system to assist CE's in their decision functions.

2.1   CONCEPT DEFINITION

The innovative approach taken to enhance CE decision-making is to develop a decision-aiding support system that is based upon human factors engineering, artificial intelligence, user-computer interface technologies, and expert system technology. This system will be referred to as the Combat Engineer decision-aiding support system -- CETOOLS.

2.2   CETOOLS SYSTEM: HIGH-LEVEL DESIGN GOALS

The establishment of high-level design goals for CETOOLS is the first step in ensuring the development of a practical and functional system. These design goals include the development of a user "friendly" system as well as a system architecture flexible enough to meet the future needs and the changing scope of CE functions. Ease of programming and maintenance will also be a major goal of the design. A top-down analysis, as illustrated in Figure 2-1, was performed as part of the high-level design goal process which focused on:

- Defining user needs and requirements,

- Allocating functions between the user and CETOOLS,

- Evaluating user-computer interface options,

- Defining a software development approach, and

- Defining the requisite software and hardware environment.

The system considerations and research for each of these areas are described in this section.

2.3   USER NEEDS AND REQUIREMENTS

The first step in developing any system is to identify user needs and requirements to be incorporated into the proposed system. To do so for the CE entails a multi-faceted front-end analysis approach. This front-end analysis approach consists of:

- Description of the user population of CE's (user profile) such that the skills and knowledge of the intended users are identified,

- Description of the external environment that the CE must work in and its effects on the decision making process for the CE, and
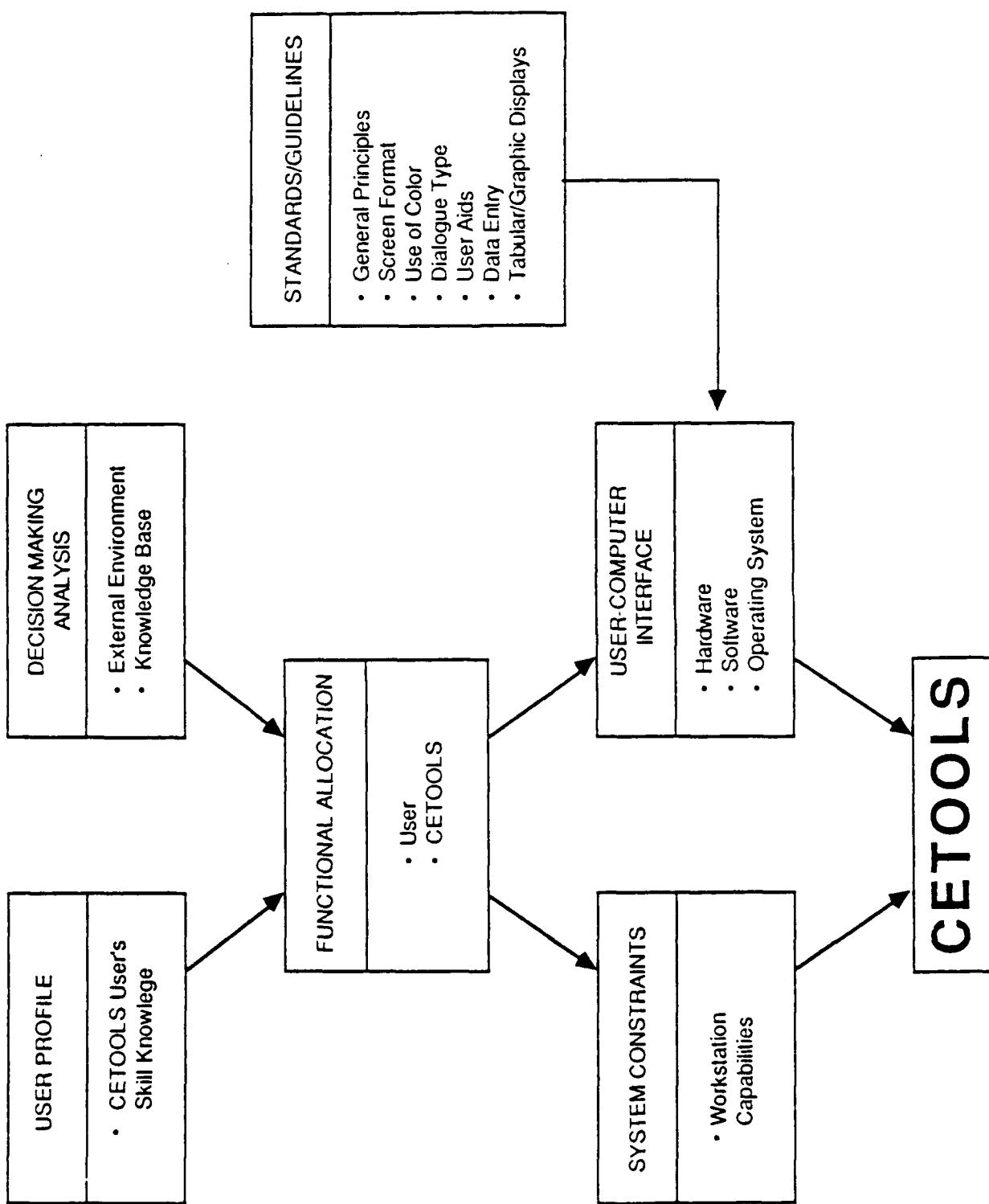
Figure 2-1. CETOOLS Technical Approach

STANDARDS/GUIDELINES
- General Principles
- Screen Format
- Use of Color
- Dialogue Type
- User Aids
- Data Entry
- Tabular/Graphic Displays

DECISION MAKING ANALYSIS
- External Environment
- Knowledge Base

USER PROFILE
- CETOOLS User's Skill Knowlege

FUNCTIONAL ALLOCATION
- User
- CETOOLS

USER-COMPUTER INTERFACE
- Hardware
- Software
- Operating System

SYSTEM CONSTRAINTS
- Workstation Capabilities

CETOOLS

•   Description of the internal decision making processes that the CE goes through to arrive at an assessment of asset and resource requirements to meet mission objectives.

2.3.1   User Profile

The CETOOLS users will probably represent a cross section of computer experience from novices with minimal experience in using computers to sophisticated users. In addition, CETOOLS users may possess varying levels of skills for the CE function. Therefore, the user interface must be "user-friendly", require minimal computer knowledge, promote rapid learning of CETOOLS, and provide the flexibility to solve a wide range of problems. CETOOLS will require extensive dialogue with the user in order to characterize their problem. In addition, CETOOLS will require sophisticated techniques to guide and direct the user in this process. Finally, the needs of the novice must be balanced against the needs of a more experienced user in developing the user-computer interface.

2.3.2   Decision Making Analysis

The CETOOLS system will assist the CE in developing more accurate inferences about the assets and resources needed for future CE operations. Current estimates are presently developed based upon the CE's intuition, upon informal comparisons with previous work (past experiences), or manual labor intensive computation. To determine the nature and type of decision making assistance needed by the CE, a detailed analysis was conducted of the CE's decision making environment. Section 3 describes the CE's functions and the external environment that the CE works in and its effects on the decision making process for the CE. Section 4 describes the internal decision making processes that the CE goes through to arrive at an assessment of assets and resources for future actions. For both Sections 3 and 4, the 307th Engineer Battalion, 82nd Airborne Division, served as the basis for these analyses.

2.4   ALLOCATION OF FUNCTIONS

The functional allocation step is necessary to determine what system functions should be distributed between the user and CETOOLS. Computer support is warranted in those circumstances where users have difficulty in performing some functions because of limitations in human information-processing capabilities (e.g., complex quantitative calculations). Therefore, functional allocation between the user and the system will be dictated according to the functional requirements needed to analyze and evaluate situations.

In accordance with the goal of a high-level, user-oriented interface, as many ancillary functions as possible will be allocated to CETOOLS. These include user aids such as menu-driven interface; on-line guidance via a HELP capability; an explanation facility to assist in the interpretation of results; and detailed and easily understood error messages and recovery procedures.

It is also clear that the human is essential to the CE function and that any automation must be designed to be a tool to assist the CE but not to supplant the CE. Most successful knowledge-based tools have been developed as tools to **assist** but not to **replace** human decision-makers.

2.5   USER INTERFACE APPROACH

Since CETOOLS will be a complex system, the design of the CETOOLS user-computer interface (UCI) will be an important determinant of successful system operation and effective performance. The UCI will be designed to take advantage of the most recent advances in human factors engineering, artificial intelligence, and advanced display technologies. A primary design goal is the development of a system which has maximum flexibility and is adaptable to new applications (e.g., Digital Topographic Support System - DTSS) and which is highly usable in terms of both operation/execution and analysis of results. The design of the UCI must be considered during every phase of the development of CETOOLS to ensure that CETOOLS incorporates high degrees of flexibility, adaptability, consistency,

and responsiveness with regard to the way in which the user will interact with all the components of CETOOLS. It is essential to integrate human factors into the early stages of the design process where it can have the greatest benefit. An efficient user interface design may cost more in terms of time and money to implement, but it may also result in significant benefits during the system's productive life. Non-productive training time can be reduced; user misunderstandings leading to interpretation errors can be avoided; and user satisfaction can be dramatically increased.

The development of the user interface will be based upon analysis of the following:

- **Interactive dialogue analysis** — establishing dialogue style (e.g., menu, command, graphics, etc.), user response, data entry screen design, on-line help, error message design, and color coding.

- **Input device and techniques analysis** — examining properties of available input devices (e.g., keyboard, mouse, graphic tablet etc.) and their interaction with the dialogue.

- **Output requirements analysis** — examining properties of available output devices and information to be conveyed (e.g, text, graphics).

Another design goal is that the user interface should be consistent across all components of the CETOOLS system. Other principles that have been identified in the human factors literature as critical to successful user interfaces include the following:

- "Friendly" dialogues and error handling,

- On-line help routines,

- Meaningful feedback provided to avoid confusion,

- Minimal strain on human memory capacity,

- Simplicity rather than complexity, and

- Demands tailored to the user's skill levels.

Wherever possible, the design of the user interface will be in accordance with established human factors guidelines and standards.

Section 6 describes the technologies that were considered for the development of an effective CETOOLS user-computer interface.

2.6   DEVELOPMENT APPROACH

Traditional software development approaches assume that all system requirements can be precisely determined and specified in detail prior to any contextual design, implementation, or operational experience. The design specifications are frozen at some point and the entire system is based upon these specifications. By contrast, the prototype approach assumes that precise requirements are not always pre-definable so the system is developed utilizing a building block approach. A building block approach to system development establishes the working foundation of a system quickly and in such a manner that it can be gradually expanded one step at a time. The premise of prototyping is that it is easier and quicker to modify and improve a tangible system than to draw up specifications for a system that can handle every conceivable requirement. This is particularly true for expert and knowledge based systems where an iterative approach is required to establish and refine the knowledge base. Several studies have indicated that a prototype approach significantly improves the probability that a useful system will be developed and that the overall development cycle will be shortened (Mason and Carey, 1983). Additional experimental results suggest that prototyping increases the actual utilization of a system by the user, and system performance was rated higher by users of prototyped systems than by users of systems developed using traditional approaches as measured in terms of user satisfaction with the system and its perceived accuracy, utility, and functionality (Alavi, 1984).

Prototyping begins in the analysis phase of system development with a first prototype based on a high-level functional analysis. It does not include

every feature the eventual system might include, but at each stage implements the desired goals effectively with minimal development costs. The prototyping approach, illustrated in Figure 2-2, consists of the following steps:

1. **Specify Prototype Goals** — clearly identify the scope of the prototype and determine how it is to be evaluated.

2. **Develop Prototype** — design and implement prototype; determine what functional modules must be developed and how they will be integrated with modules in the current operational version.

3. **Use and Evaluate Prototype** — demonstrate the prototype to the user in the context of actual applications and elicit feedback from the users in terms of how the prototype meets their needs and requirements.

4. **Implement Required Modifications** — incorporate any indicated modifications into the prototype and repeat the evaluation process.

When a particular prototype is functioning satisfactorily, it is made available to the user for evaluation to determine if the system development is on the right track and performs as expected and/or required. Users can knowledgeably suggest changes that will improve the system and make it more applicable to their needs. The system developers can then incorporate those changes with a clear understanding of what exactly needs to be changed and how it should look when completed. Each succeeding version of the prototype more accurately reflects the users' requirements and incorporates more of the features of the eventual system. The prototyping process is reiterated until all system goals have been developed and evaluated.

The traditional approach to software development is best suited for systems with simple and static requirements. But for dynamic and complex systems, the best way to develop the system is with a prototyping approach. The user's understanding of a system is an evolutionary process. Changes of meaning and structure of the system reflect the learning process and growth that accompany every application experience. In order to increase the usability

of the system, it is necessary to accommodate these changes, not to impede them. An approach that exposes the user to realistic versions of the final application will lead to wide exploration of the application alternatives during the earliest stage of development.

2.7   SOFTWARE AND HARDWARE ENVIRONMENT

A critical aspect of the CETOOLS system is defining the appropriate computer environment to be used for the system that is conducive for both system development and actual CE usage. In order to provide an "intelligent" user-computer interface to the CETOOLS system, it is appropriate that CETOOLS reside on a hardware configuration that provides a self-contained, intelligent workstation. The advantage to this configuration is the flexibility one has in developing a UCI without the constraints imposed by mainframe type systems that offer few UCI options. The highly visual and "friendly" user interface to be developed for CETOOLS requires high-resolution bit-mapped graphics, color monitor, and a pointing device such as a mouse. Bit-mapped graphics permit the rapid display of graphic information. Since effective use of color can improve the user's performance, a color monitor is recommended. A mouse is a pointing device that will allow the CETOOLS user to spatially manipulate information and select commands or locations on the screen without having to learn specialized interface commands.

3.0   COMBAT ENGINEER ENVIRONMENT

3.1   INTRODUCTION

The combat engineer's primary role is to provide engineering support that ensures that the tactical commander's mission plans are successfully implemented. To understand how the combat engineer proceeds in developing his plans, it is important to understand the working and organizational environment in which the CE is a member. By so doing, one can identify the important environmental and organizational factors that the CE must consider when developing his plans.   In addition, these environmental and organizational factors must be considered in the design of the proposed CETOOLS system such that CETOOLS offers assistance to the combat engineer that complements the organizational flow of information and decision-making.

What follows is a description of the 82nd Airborne Division operational environment which illustrates the complex and fast moving environment in which the CE decision maker must operate. Although the 82nd Airborne environment possesses unique features, it exhibits many of the characteristics, such as time constraints and logistical problems, that all combat engineers will face on the modern battlefield.

3.2   82ND AIRBORNE DIVISION OPERATIONAL ENVIRONMENT

The 82nd Airborne division is the cornerstone of the Army's commitment to the Rapid Deployment Force. It has the unique capability to begin deployment on as little as eighteen hours notice.   This significant capability to rapidly project a powerful ground force to trouble spots anywhere in the world provides national decision makers with a range of options that no other force can offer. As recent world events have shown, the introduction of airborne forces provide a powerful deterrent to a would-be aggressor. When

deterrence fails or events move rapidly out of control, airborne forces can be used to achieve strategic and tactical surprise by delivering a strong first blow. Additionally, the division has the capability to conduct sustained ground operations when augmented by additional support units. Past employment of the 82nd Airborne includes:

- A "show of force", Honduras, 1988,

- Evacuation of US nationals, Grenada, 1983,

- Peacekeeping, Egypt, 1981,

- Rapid reinforcement, Vietnam, 1968,

- Stabilization operations, Haiti, 1965, and

- Sustained operations, Europe, 1943-1945.

3.3   COMPOSITION

The 82nd Airborne closely resembles a conventional infantry division in its composition. It is composed of nine airborne infantry battalions organized into three brigades supported by an artillery brigade, an armor battalion, and a number of combat support and combat service support units.

This organization, however, is somewhat misleading. The 82nd Airborne, like other divisions, seeks to optimize its combat forces by creating a task force that combines all of the facets of the division into a cohesive whole. A division cannot operate by employing its units separately. Were it to do so, it could only bring a fraction of its combat power to bear. In order to effectively move, shoot, and communicate, the total combined arms and services of the division must function as a team. This concept of operations is mirrored at every echelon using the airborne infantry unit as a planning centerpiece. Figure 3-1 illustrates how one infantry brigade is supported by other divisional assets. Similarly, each of these supporting assets is further subdivided to directly
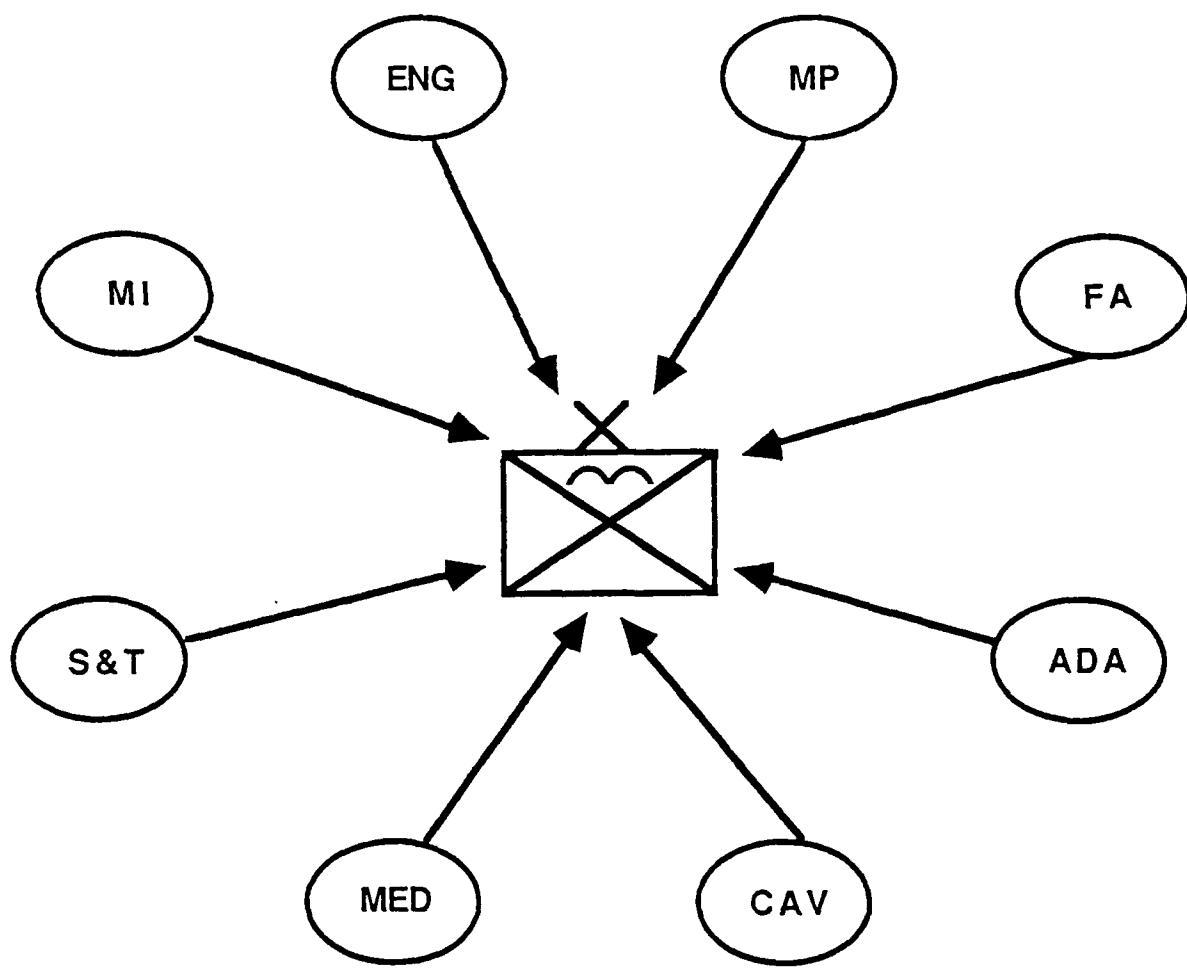
Figure 3-1. Infantry Brigade Task Force

support each of the brigades subordinate battalions. As a result, the 82nd can more accurately be viewed as being composed of three brigade task forces with each brigade task force composed of three battalion task forces.

To facilitate planning and training, the 82nd operates in garrison on a rotating basis. There are three six week cycles through which the brigades rotate. During the "mission" cycle, one brigade will assume the role of the "Division Ready Brigade" and its subordinate battalions will be in high state of readiness. The other brigades will be involved in either the "intensive training cycle" or the "support cycle." Regardless of which cycle the brigade is in, each of the division's nine battalions is denoted by a number which indicates its availability for deployment. In the division ready force, the battalions will be designated as the "Division Ready Force (DRF 1, the DRF 2 and the DRF 3. The brigade involved in the intensive training cycle will consist of the DRF4, DRF 5, and the DRF 6. The brigade in the support cycle will consist of the DRF7, DRF 8, and DRF 9. At the end of each six week cycle, the brigades rotate responsibilities and their subordinate battalions will increase or decrease their level of readiness accordingly. The DRF 1 can be fully assembled in less than two hours time and will be the first unit to depart Fort Bragg within eighteen hours of an alert. The entire brigade task force, referred to as the Division Ready Brigade (DRB) during mission cycle, can be fully assembled in less than six hours.

A further refinement on the task organization concept are generic "force packages." These force packages are troop and equipment lists which facilitate contingency planning for six specific types of missions. Force packages are intended to serve as a planning baseline to assist in rapidly tailoring forces to the specific mission. The six force packages are designed not with a specific mission in mind, but rather by the size of the force the commander estimates it will take to accomplish the mission. The developed force packages are:

    1.   Airfield seizure — Light,

2.   Airfield seizure — Medium,

3.   DRB — Light,

4.   DRB — Medium,

5.   Division — Light, and

6.   Division — Medium.

Table 3-1 illustrates a portion of a Division Ready Brigade's (DRB) Medium Force Package with respect to personnel and equipment for Brigade Headquarters, an Infrantry Battalion and an Engineer Support Company. Should it be necessary to augment any of the above packages, a series of Incremental Force Packages also exist to provide specialized support to the deploying force. The modularity of the 82nd force structure and tactical doctrine allows for diverse units to be molded together on very short notice, develop a comprehensive plan considering all elements of combat power, quickly deploy to the objective area, and accomplish the mission.

3.4   AIRBORNE OPERATIONS

As described above, airborne forces provide national decision makers with a unique capability to project military force. This unique capability is accompanied by unique planning considerations and limitations. It should be noted that the 82nd is capable of performing two types of airborne operations — each with its own advantages and disadvantages. The first is an **airdrop** operation in which personnel and equipment are delivered to the objective by parachute. Airdrop operations are normally used when the objective is in a contested area and the division has no alternative but to make a forced entry. Airdrop operations have the advantage of achieving strategic and tactical surprise at the objective area. The disadvantage of airdrop operations is that they are difficult to plan, conduct, and place severe limitations on the number and type of forces that can be delivered to the objective.

TABLE 3-1 Illustration of Division Ready Brigade's Medium Force Package

UNIT	PAX PER DROP	UNIT A/L	NO OF UNITS	A-ECHELON (HVY DRP)	B-ECHELON (AIRLAND)
DRB ONE					
Bde HQs	22	5	1	3-M998	3-M998 1-M998 (ADA)
- USAF LNO	2	0	1	1-M998	
- USAF TACP	2	0	1	1-M998	
- Bde FSO TM	4	0	1	1-M998	
INFANTRY BATTALION		3			
Bn HQs	28	2	3	1-M998	1-M998
Medical Plt	18	2	3	2-M996	2-M996
Commo Plt	8	2	3		1-M998
Support Plt	8	2	3		1-M35 w/wtr trl
Scout Plt	18	0	3	5-Motor cycles	
81mm Mort Plt	16	4	3	2-M998	1-M998
Bn FSO Tm	4	0	3	1-M998	
ENGINEER					
ENG CO (-)	97	4	1	1-M998 1-Dozer	1-5T Dump Trk 1-15T Tilt Trl
- LARP			1	1-Loader 1-13 Wheel Roller 1-Grader	1-2 1/2T Dump Trk 1-Air Compressor

Airland operations refer to the delivery of troops and equipment to the objective area by landing at a secure airfield. The obvious advantages are that units arrive in an organized fashion as opposed to having to reassemble on the drop zone, more equipment can be delivered quickly and is immediately ready upon arrival. The disadvantage is that using a secure airfield may in some cases signal the friendly force's intention to the enemy.

Wherever possible, airland operations will be the preferred option. For planning purposes, however, the 82nd normally assumes a "worst case" scenario and plans to secure a contested airhead. In many instances, the commander will choose to employ a combination of both options by using part of his force to seize and secure an airfield by airdrop and deliver the rest of the force by the airland technique.

In either case, the personnel and equipment of an airborne force should be delivered to the objective area in the shortest time available. The faster the troops and their equipment and supplies are on the ground, the faster they can develop combat power to secure the objective and defend the airhead.

3.5   MISSION PLANNING

As with other US forces, the order to deploy the 82nd will normally be initiated by the Joint Chiefs of Staff. As illustrated in Figure 3-2, this order will then be directed to the responsible theater command. The 82nd is unique in that is supports the contingency planning of five theater commands. The theater command will then direct the order to the 18th Airborne Corps which is composed of the 82nd, the 101st Airborne Division (Air Assault), and the 24th Infantry Division (mechanized). When the deployment of Corps forces is imminent, but not yet ordered, the Corps will initiate a planning sequence known as the X-Hour sequence. This ensures that should the order to deploy come, all staff sections will be prepared to directly support operations. If the Corps Commander chooses the 82nd for the mission, he will initiate what is known as the "N - Hour sequence." This sequence alerts the division that a
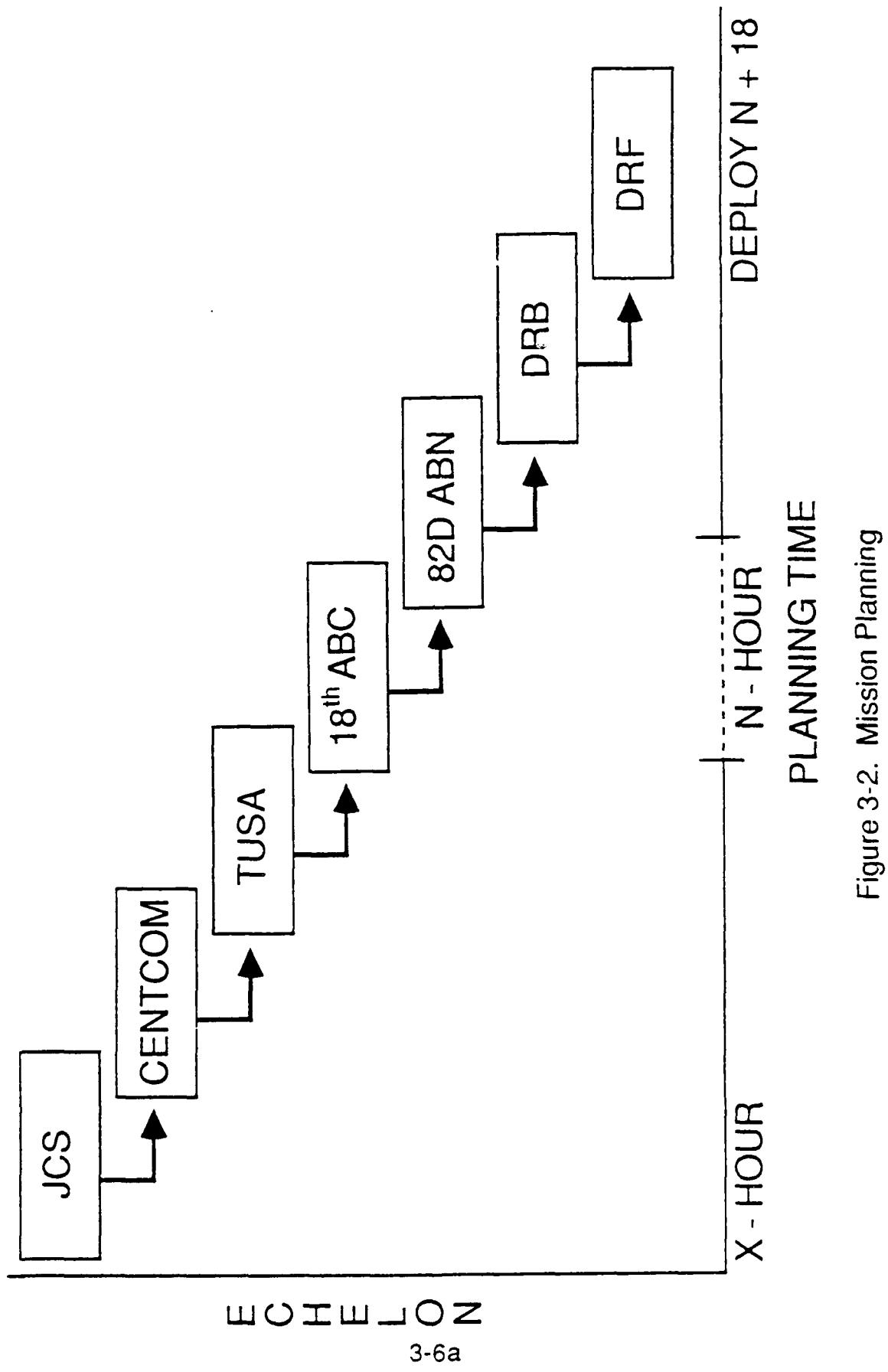
Figure 3-2. Mission Planning

deployment is planned and puts in motion a complicated series of events designed to ensure that the first battalion task force is departing Fort Bragg a minimum of eighteen hours later.

N - Hour is the term used to refer to the time the division is notified or alerted. Two hours later, N + 2, the division commander and staff will brief the DRB and DRF on the mission. The DRB and DRF commanders will then begin their planning. Although the higher echelon will always support the lower echelon, the DRB and DRF planning process will be inextricably linked. For purposes of this study, the focus will be on the planning process of the DRB commander.

Because the DRB commander must adapt his force package to the mission, enemy, terrain and weather, troops, and time available (METT-T), he must have a total understanding of all the assets at his disposal in order to effectively tailor his forces. The commander discharges his responsibility through an established chain of command. The chain of command is fixed and each commander will be encouraged to function properly through the decentralization of authority commensurate with the responsibility and resources of the subordinate commander.

3.5.1 Airborne Operations Planning

In order to ensure a smooth and effective airborne operation, four basic plans are necessary. These plans are essential regardless of the type of mission, size of the force or duration of the operation. The four plans are:

1.   The ground tactical plan,

2.   The landing plan,

3.   The air movement plan, and

4.   The marshalling plan.

Inverse, or backward planning is essential in an airborne operation. The ground tactical plan is always developed first since this specifies what will be done at the objective area and how this will be accomplished. Until the scheme of maneuver is completed, there is nothing on which to base the remaining plans.

Concurrent planning is an essential and unique aspect of airborne operations. For example,to develop the division landing plan the division G3 requires four items of information: the commander's priorities, subordinate unit ground tactical plans, subordinate unit landing plans, and airlift techniques. Since all echelons are working under the same time constraints this poses a difficult challenge. Concurrent planning has been developed to such an extent in the 82nd, that division, brigade, and battalion landing plans are developed and completed simultaneously. The requirement for rapid exchange of data between planning elements at all echelons is obvious. This communication is accomplished using FM secure voice, secure telephone, messenger, and land lines.

The sections that follow illustrate the complexity of planning airborne operations and highlight some of the factors that must be considered by the DRB commander and his staff.

3.5.1.1 The Ground Tactical Plan. Based on METT-T, the airborne force commander (either the DRF or DRB commander as appropriate) will develop the ground tactical plan. The mission may be restrictive or non-restrictive. A restrictive mission requires an airborne force to seize and secure a fixed installation such as an airfield, an embassy complex or a bridge. The force must deny the enemy access to the objective — a mission which is primarily defensive in nature. A non-restrictive mission is more dynamic and permits the commander greater flexibility in its accomplishment. This type of mission is associated with blocking the movement of enemy forces through an area or clearing an area. A non-restrictive mission can thus be offensive or defensive in nature. There are five major considerations in developing the ground tactical

plan:

      1.   Assault objectives,

      2.   Security,

      3.   Task organization,

      4.   Boundaries, and

      5.   Reserve.

Regardless of the ultimate type of mission assigned, offensive and defensive operations will initially be required. First, an assault is made to secure the airborne force assault objectives. These objectives provide the initial security of the airborne force and assist in accomplishing the mission. These assault objectives, once secured, must be defended until the airborne force is organized in the objective area and can continue the mission. The defense of the objective area can continue throughout the duration of the mission.

Upon receipt of the warning order at the N + 2 briefing, the commander and his staff will analyze the mission to determine the stated and implied tasks and whether the mission is restrictive or non-restrictive.

The enemy force is then analyzed in terms of its strength, composition, location, and possible reactions to the insertion of the airborne force. The location of the enemy force relative to the objective area is considered as the most immediate and significant threat. The airborne force is at its most vulnerable during the first few hours of the operation.

The terrain is analyzed closely for available drop zones, landing zones, and extraction zones in addition to the usual significant terrain factors such as obstacles, fields of fire, cover and concealment, avenues of approach

and key terrain.

The commander must then not only consider the forces organic or attached to his task force but also those from other services since airborne operations are by their nature, always a joint operation. For example, Air Force considerations that must be considered are tactical airlift, air reconnaissance, and close air support. In some cases, close coordination with the Navy may also be required.

The commander must finally consider the length of time of the operation before linkup with friendly forces or withdrawal is accomplished. While these considerations are common to the planning of all military operations, one must remember that airborne operations, unlike others, are conducted behind enemy lines.

In considering how to employ the airborne forces in the objective area, the commander must view the mission from two perspectives — the airhead and the area of operations. The airhead is a designated area that when secured, permits the airlanding of follow-on forces. The area of operations is a specific, much larger area, designated by higher headquarters within which the airborne force will operate. At one time, the two concepts were viewed as mutually exclusive, but current doctrine allows for the combination of the two.

Any feature that must be secured to accomplish the unit mission or to ensure the overall security of the unit during the initial phase of the operation will be designated as an assault objective and considered a high priority task.

Security forces protect the main body from attack, develop intelligence, and gain time by disrupting enemy attacks. Security forces employed by the airborne force can include the division recon platoon, light armor, or, when available, attack helicopters form the 82nd Combat Aviation

Brigade.

Considerations for tactically tailoring forces and designated unit boundaries include:

- The location, number, and relative importance of assigned assault objectives,

- The enemy threat and its estimated reaction time to the airborne operation, and

- Maximizing the use of terrain for mission accomplishment.

The reserve element of the force usually enters the AO as part of the assault echelon but is not assigned as assault objective.

3.5.1.2 Echelonment and the Landing Plan. The concept of echelonment is nothing more than a management tool to consider the appropriate order of arrival of each element in the objective area. The force will be organized into three echelons for the airborne assault. These echelons are the assault echelon, the follow-up echelon, and the rear echelon. Figure 3-3 illustrates the the Landing Plan.

The assault echelon is the first element to enter the objective area and contains those units required in the initial stages of the operation to secure the area. METT-T will determine the composition of the assault echelon, however, it will be heavily weighted with combat troops in a forced entry type operation.

The follow-up echelon contains those elements required to sustain operations. The follow-up echelon often contains the parent headquarters of those units fragmented for the assault as well as additional combat support and combat service support units.
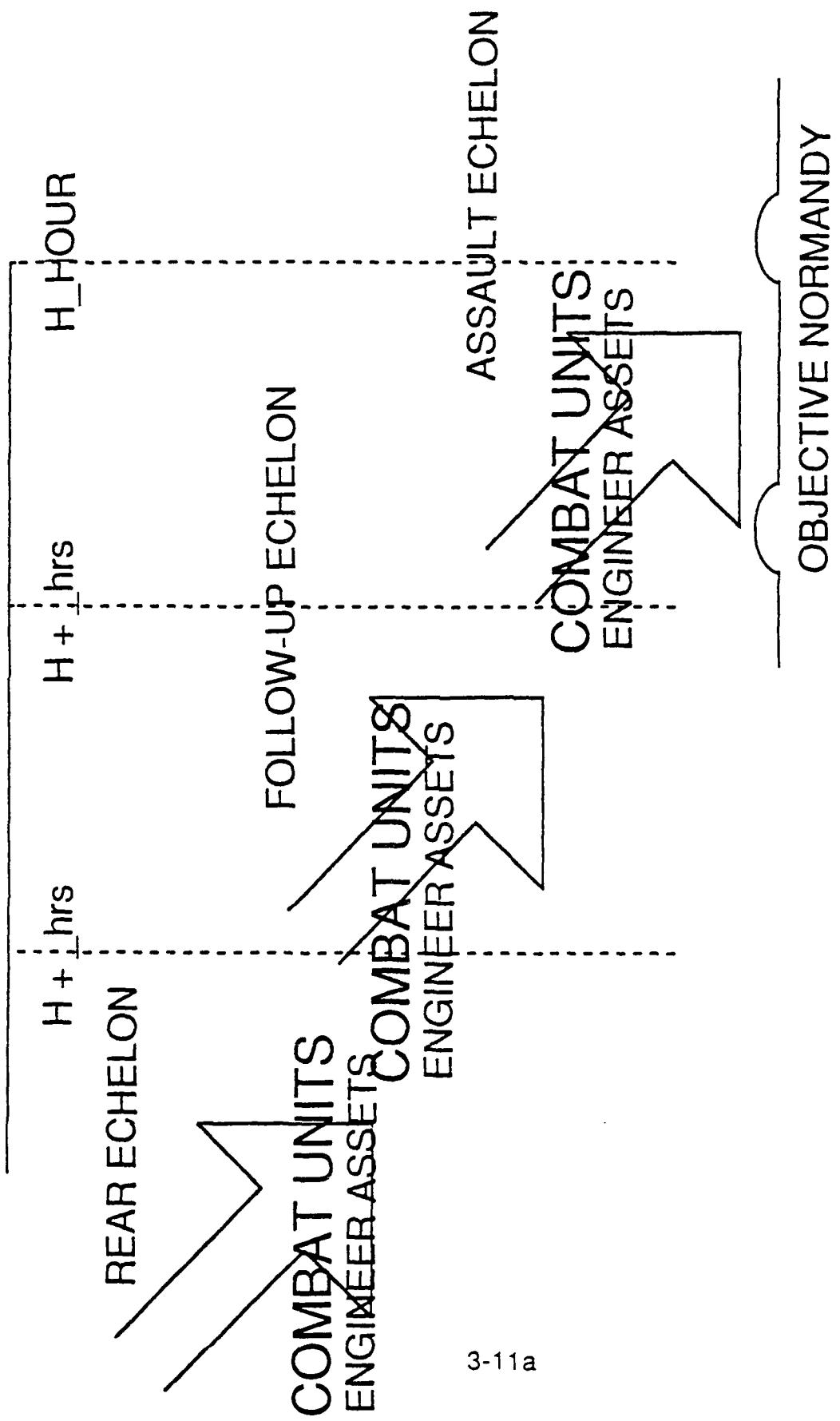
Figure 3-3. The Landing Plan

3-11a

The time interval between delivery of the assault echelon and the follow-up echelon will depend primarily on the availability of aircraft, the capacity of the departure airfield, the number of aircraft sorties flown, and the size and number of drop zones in the objective area. The reason for the distinction between the echelons is to simplify planning procedures by establishing logical priorities for phasing various types of units into the area.

The rear echelon remains at the departure airfield or mashalling area during the offensive and defensive operations. It contains those units that are not required in the AO or can better perform their functions in the rear.

It is important to realize that echelonment applies to almost every unit in the division in that even infantry battalions will have elements in each echelon: combat elements in the assault, maintenance elements in the follow-up, and administrative and mess elements in the rear.

Once the ground tactical plan specifies which units are to seize which objectives and the concept of echelonment of forces is developed, the commander can begin to formalize the landing plan.

The landing plan specifies the sequence of delivery, the method of delivery, and the place of arrival of troops and equipment in the objective area. The time of delivery is not yet considered since the sequence of arrival must first be determined.

The landing plan is not a formal plan. It is an informal plan to ensure that the air movement plan supports the scheme of maneuver. As an example, the commander must be able to tell the airlift planners, "I want to drop x number of parachutists on DZ Normandy as priority number 1."

In small scale operations, where only one drop zone is used, it is possible to determine the air movement plan directly from the ground tactical

plan. However, even in this instance, it will be necessary to mentally prepare a landing plan.

The remaining information that planners must have concerns the means by which the Air Force will deliver the airborne force to the objective area. There are a number of different aircraft used by the Air Force for strategic airlift. Each of these aircraft have unique capabilities and limitations in terms of the number of parachutists and equipment they can carry. There are also various techniques that can be used for the delivery of heavy equipment.These techniques will vary according to METT-T and USAF resources available. It is essential that the Army planners consider how the Air Force intends to accomplish their mission in order to ensure that the arrival of troops and equipment are synchronized with the ground tactical plan. Examples of these considerations are:

- Formation to be flown,

- Sequence of personnel drop, heavy drop, and LAPES, and

- Time interval between serials (serials are groups of like aircraft with the same method of delivery going to the same drop zone).

3.5.1.3 The Air Movement Plan. The air movement plan is prepared jointly by the Army and the Air Force. It covers the phase of the operation form the time the units load the aircraft until they arrive at the objective area. As stated earlier, this plan directly relates to the preceding plans but is primarily an Air Force responsibility. The air movement plan is depicted in Figure 3-4.

3.5.1.4 The Marshalling Plan. The final plan to be developed is the marshalling plan. The marshalling plan is the process by which units of the airborne force make final preparations for combat, move to departure airfields, and load for takeoff. It begins when the division is first alerted and it continues until all units and equipment have been loaded onto the aircraft. It is essential
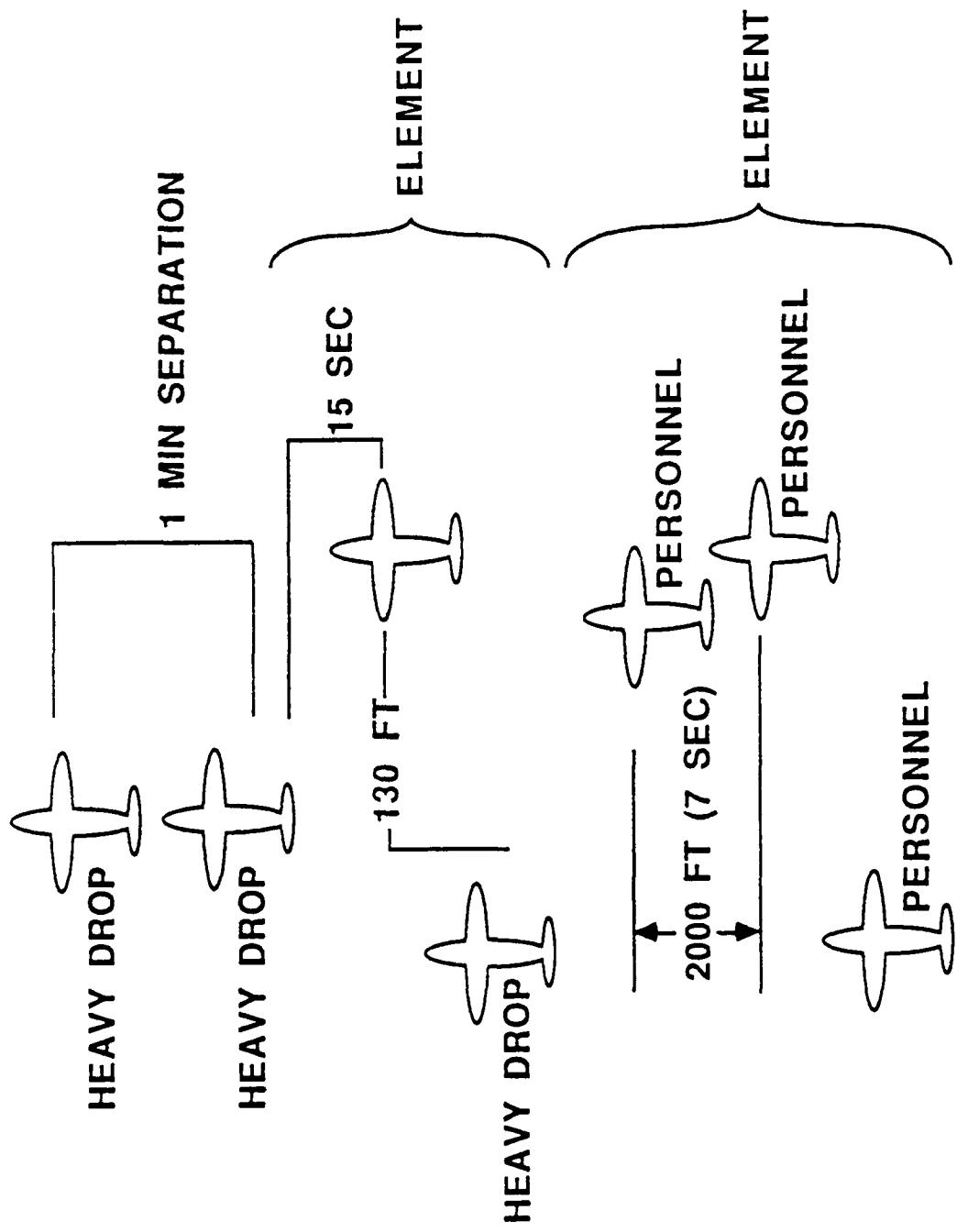
Figure 3-4. The Air Movement Plan

that many of the functions required by the marshalling plan be carried out by units other than the deploying unit. In the 82nd, the DRF 9 is the only battalion in the division with the same state of readiness as the DRF 1 for precisely this reason. Figure 3-5 illustrates the marshalling plan.

The supporting DRF 9, division and corps support units provide transportation, medical, communications, food service, engineers, maintenance, supply and airdrop equipment. The size of the support, of course, varies with the size of the deploying force. Parent headquarters of attachments deploying with the task force also have an important role in ensuring that the attachments have sufficient resources to support the deploying commander.

An important part of the marshalling plan includes movement of the force from the unit areas to a Personnel Holding Area (PHA) and to the departure airfield itself. The planning functions described earlier are performed continuously despite this movement.

Actions taken by the Departure Airfield Control Group (DACG) and the Airlift Control Element (ALCE) at the airfield are the culmination of the marshalling plan. These elements ensure that the movement from the PHA to the airfield and the loading of the aircraft occur in accordance with the air movement plan

3.5.1.5 Summary. It should be apparent from the above descriptions that the DRB commander has mutliple factors to consider when providing guidance to his staff for their planning estimates and recommendations for the tactical plan. Also the DRB commander has the ultimate responsibility to approve all plans. As a result, the combat engineer must be in a position to clearly state the combat engineering operations plan such that the DRB commander will understand its implications for the tactical mission plan.
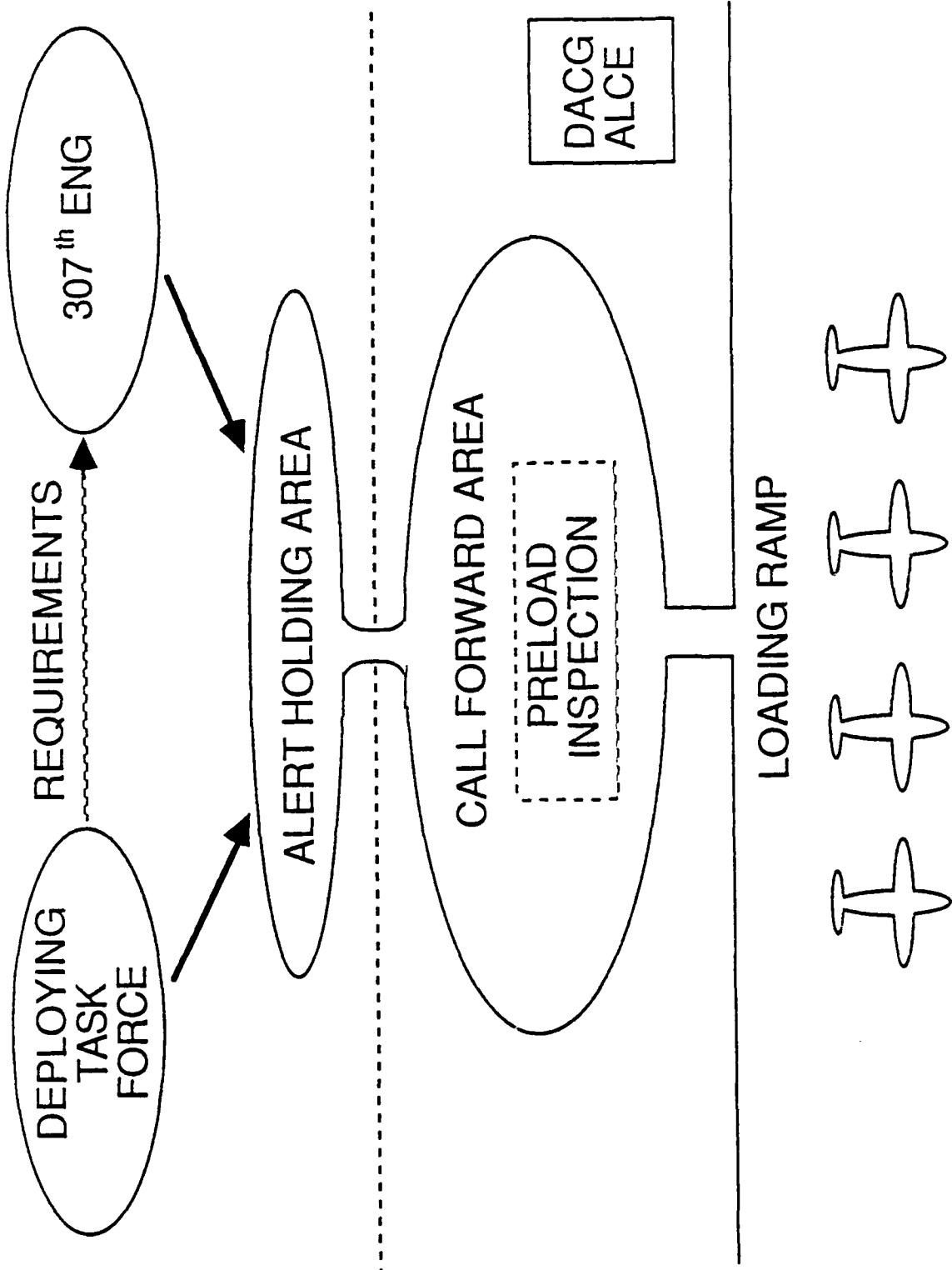
Figure 3-5. The Marshalling Plan

DACG
ALCE

307th ENG

REQUIREMENTS

DEPLOYING TASK FORCE

ALERT HOLDING AREA

CALL FORWARD AREA

PRELOAD INSPECTION

LOADING RAMP

3.6   82ND AIRBORNE DIVISION ENGINEER SUPPORT

Every US Army division has an organic engineer battalion to provide continuous and responsive engineer support. In the 82nd Airborne Division, this support is provided by the 307th Combat Engineer battalion. The mission of the 307th is to increase combat effectiveness by providing mobility, countermobility, survivability, and general engineering support to the division. Figure 3-6 shows the composition of the 307th Combat Engineer Battalion of the 82nd Airborne Division.

Mobility missions include breaching enemy minefields and obstacles, route improvement, and water crossing operations. Countermobility operations include the enhancement of fire through obstacle and minefield employment. Survivability missions enhance the total survivability of the force through fighting and protective position construction. General engineering tasks are not normally performed by the combat engineer battalion at the division level but XVIII Airborne Corps can provide a special force package known as the Light Airfield Repair Package to meet the division's unique requirements.

Table 3-2 shows the equipment associated with the 307th Engineer Battalion. All of the equipment can be air-dropped. If heavier equipment is required from the Corps Engineer Brigade (20th Engineer Brigade, XVIII Airborne Corps), it must be air landed after the objective area is secured.

Airborne operations rely on the precise synchronization of literally hundreds of key events. The sequence of these events are all driven by the ground tactical plan which specifies the tactical objectives and the times at which they must be achieved. Once approved, the ground tactical plan serves as the baseline for all subsequent decisions. The combat engineer plays a vital role in advising the DRB commander on how engineer operations will contribute to mission success. The following section describes how the CE currently accomplishes this demanding task.

82

XX

307

82

HHC 307

A
B
C

1
2
3
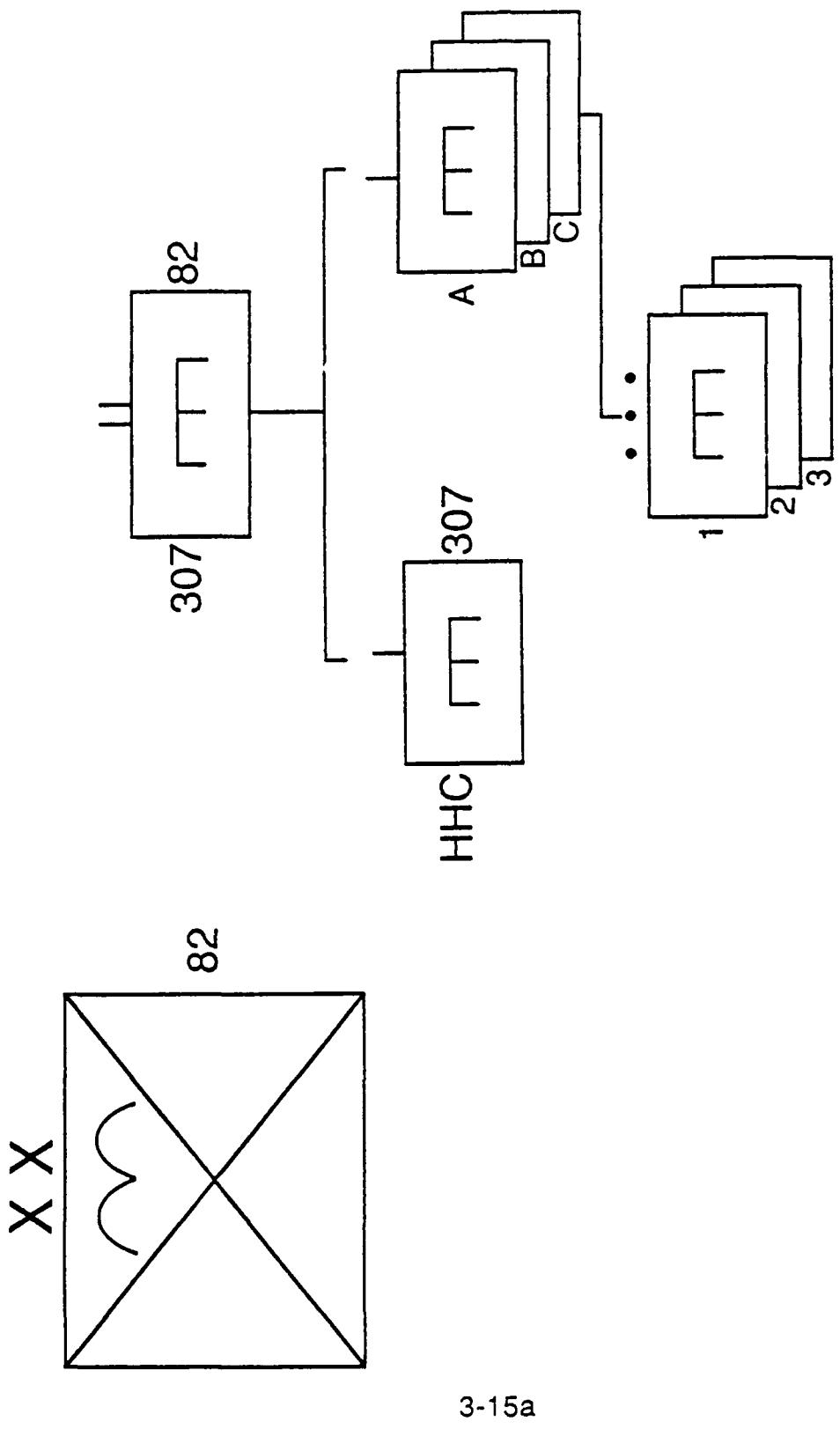
Figure 3-6. Division Engineer Support

TABLE 3-2 Illustration of Engineering Assets

• HHC	NUMBER
D-5 Bulldozer	6
5 Ton Truck, Dump	6
15 Ton Trailer	6
2 1/2 cu yd Front End Loader	4
2 1/2 Ton Truck, Dump	12
1 1/2 Ton Trailer	8
Grader	4
250 CFM Air Compressor w/ Pneumatic Tools	2
420 Gallon Per Hour Water Purification Unit	8

• Engr Co HQ	
Machine Gun, .50 Cal w/Ring Mount and AA Mount	1
Machine Gun, 7.62mm	2
Radio Set, AN/PRC-77	1
Radio Set, AN/VRC-47	1
Radio Set, AN/VRC-64	1
Tractor, Whld Ind (JD 410 Backhoe)	1
Truck, Cargo, 1 1/4 Ton	2
Truck, Cargo, 2 1/2 Ton	1
Truck, Dump, 2 1/2 Ton	1
Truck, Utility, 1/4 Ton	2
Trailer, Cargo, 1/4 Ton	1

• Engr Plt HQ	
Boat, Recon 3-man	1
Demo Set	1
Machine Gun, 7.62mm	1
Radio Set, AN/GRC-160	1
Tool Kit, Carp, Engr Plt	1
Tool Kit, Pioneer, Engr Plt	1
Tool Outfit, Portable Electric	1
Tracker, Guided Missile (DRAGON)	2
Trailer, Bolster, 4 Ton	1
Truck, Cargo, 1 1/4 Ton 6X6	1
Truck, Dump, 2 1/2 Ton	1
Truck, Utility, 1/4 Ton	1
Tool Set, Air Assault Engr Sqd	1
Trailer, Cargo, 1/4 Ton	1

• Engr Sqd	
Demo Set	1
Grenade Launcher, M203, 40mm	2
Machine Gun, 7.62mm	1
Radio Set, AN/PRC-77	1
Tool Kit, Carp, Engr Sqd	1

Figure 3-7 shows how the the 307th provides direct and general support to the division. Each of the three engineer companies is task organized to support and is habitually associated with one of the maneuver brigades. For example, Alpha company supports the 1st Brigade (504th Airborne Infantry Regiment) , Bravo company supports the 2nd Brigade (325th Airborne Infantry Regiment) and Charlie company supports the 3rd Brigade (505th Airborne Infantry Regiment)

Figure 3-8 shows how each of the three platoon organic to the combat engineer company is habitually associated with one of the three battalions subordinate to the brigade.

The commander of the combat engineer company associated with the brigade serves as both the commander of his company and as a special staff officer to the brigade commander. In the role of special staff officer, the company commander is referred to as the Assistant Brigade Engineer (ABE). These dual responsibilities place an extraordinary burden on the CE company commander. This burden is exacerbated by the additional burdens of a time constrained environment, limited experience and reliance on manual methods for acquiring and processing large volumes of information.

It is the aim of CETOOLS to lessen these burdens by providing a system that will support the decision making process of the ABE. The ABE is a critical member of the DRB staff and as such, must be capable of accurately assessing the tactical mission objectives and evaluate the role CE supporting units will have. The ABE must perform this mission by making multiple decisions under severe time constraints The next section will focus on these critical planning activities performed by the ABE in order to identify areas where the ABE may be in need of decision-aiding support.
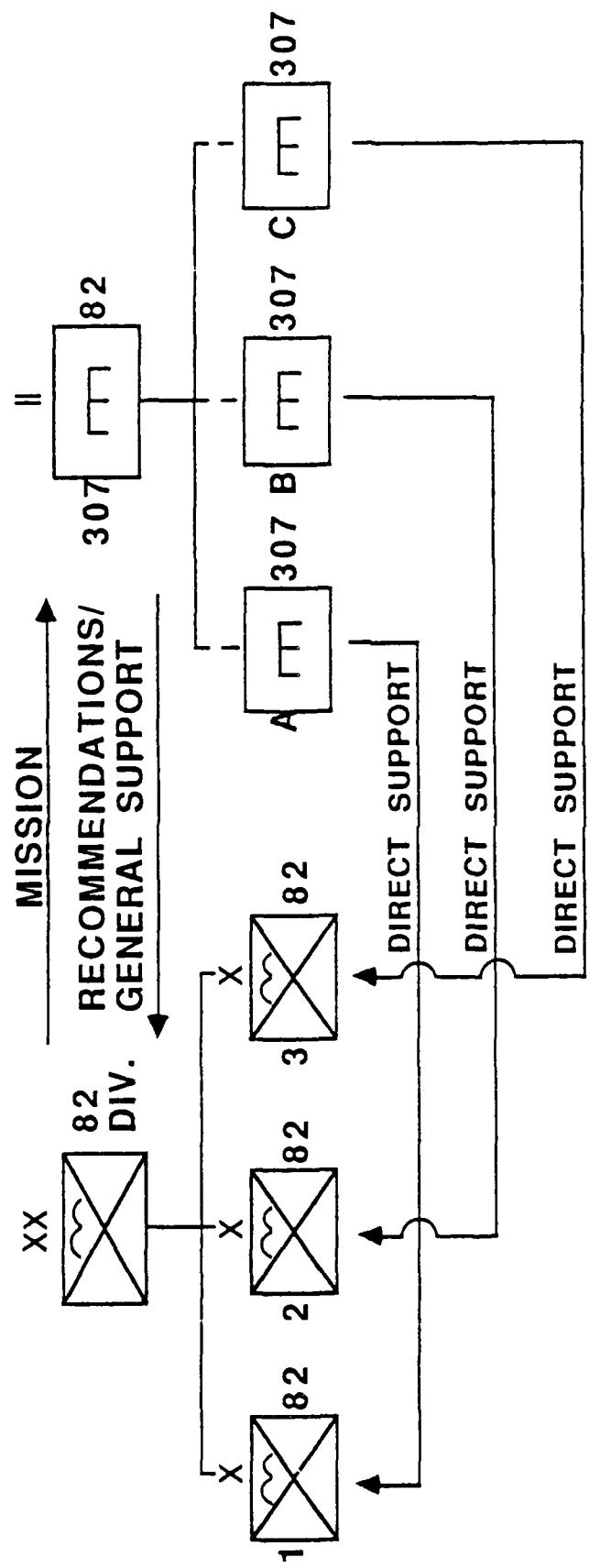
Figure 3-7. Engineer Company Support to the Brigades
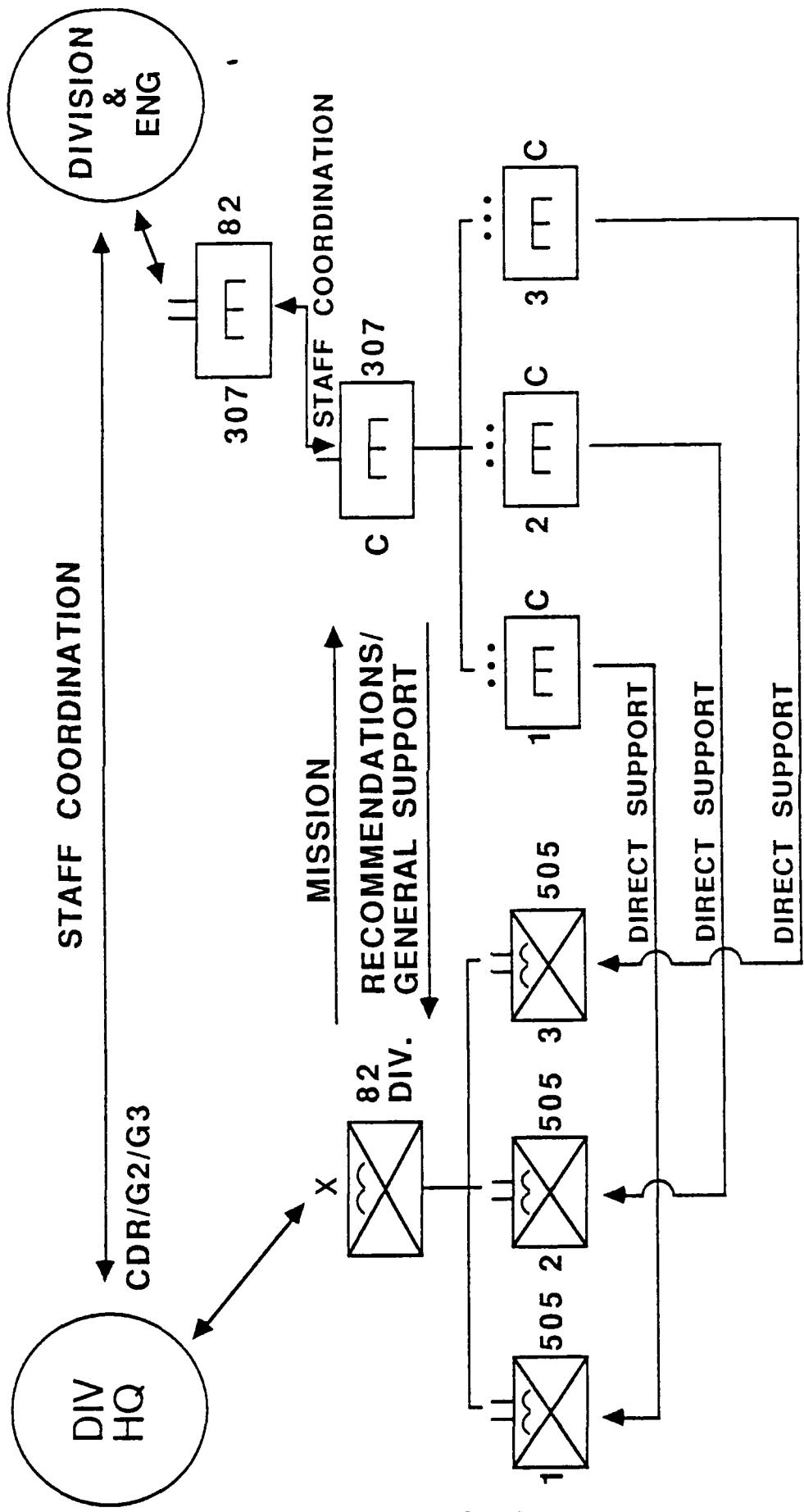
Figure 3-8. Engineer Support to the DRB

4.0   COMBAT ENGINEER PLANNING AND DECISION-MAKING PROCESS

Our approach to the design of a decision-aiding support system for combat engineer planning activities is cognitively-based. In analyzing a user's environment such as faced by the combat engineer, it is necessary to understand the user's decision-making process at a level that reflects the intrinsic information processing limits of human cognition which negatively affect user-computer interactions and decision-making itself. With respect to user-computer interactions, it is important to understand how combat engineers perceive and use information to make decisions. By so doing, user-computer interactions can be tailored and designed to maximize the utilization of the information obtained from such interactions. With respect to decision-making, it is important to understand how combat engineers attempt to derive optimal plans for engineering operations based on informational requirements and tactical mission objectives. By so doing, software support can be designed and developed to assist the combat engineer in formulating optimal plans. Critical to this approach is the identification of user information processing limits to effective decision-making and user-computer interactions. Based on this analysis appropriate user-computer interface technologies (i.e., computer graphics) and software techniques (i.e., Artificial Intelligence) can be identified that can extend the limits and increase the quality of decision-making on the part of combat engineers.

The following subsections will described the decision-making steps that a combat engineer performs when formulating engineering plans to support tactical commander's mission objectives. The decision-making steps performed by the Assistant Brigade Engineer in the 82nd Airborne Division will illustrate this decision-making process for combat engineers. By so doing, combat engineer's decision-making needs will be identified that will serve as requirements for software support to be incorporated into the proposed design of the CETOOLS system.

4.1   THE ASSISTANT BRIGADE ENGINEER

This subsection will describe the decision-making environment of an Assistant Brigade Engineer in the 82nd Airborne Division. It is essential to fully understand the unique aspects of combat engineer operations in support of an airborne force before attempting to design the automated aid that will enhance the ABE's ability to make timely and accurate decisions.

The ABE is responsible for:

- Determining the requirements for engineer support to include recommending to the DRB commander the allocation of resources and the command and support relationships to be used.

- Advising the brigade commander on and planning the use of engineers in the functional activities of mobility, countermobility, survivability, topography, general engineering, and airfield repair.

- Preparing the engineer portions of plans and orders to include the engineer annex, supporting munitions annex, obstacle plan, and denial plan.

- Exercising command and staff responsibility for engineer operations.

The ABE must be integrated into the brigades decision flow early. Although the ABE is not able to attend the N + 2 briefing to receive the division order, he will receive this information from the 307th Battalion commander and Assistant Division Engineer (ADE). To effectively accomplish his mission, the ABE must:

- Receive the brigade warning order early, understand the mission, and the 82nd commander's intent,

- Participate in all staff planning sessions and develop an engineer concept to support the ground tactical plan,

- Identify engineer requirements,

- Give decision briefings to the commander and the S3,

- Contribute to the brigade operations orders.

- Monitor and coordinate engineer operations.

The greatest challenge faced by the ABE is in his role as a special staff officer supporting the brigade commander. The brigade commander, normally a very senior officer will rely on the ABE, a relatively junior officer for fast, expert advice on engineer support. Answers to the brigade commanders questions and support to his tactical plan must be provided quickly since the N-Hour sequence allows little time for lengthy deliberations. It is extremely important that the ABE has a clear understanding of the interactions that must occur between the commander and his staff. Without such an understanding, the ABE will be forced to operate in an information vacuum and be unable to either support the commander or direct his subordinate engineer platoons.

Every commander must perform the following critical functions:

- Know the situation,

- Make decisions,

- Assign missions,

- Allocate resources,

- Direct forces, and

- Sustain forces.

The commander has a staff to assist him and the staff fulfills the following functions:

- Gather information,

- Make estimates,

- Anticipate changes and events,

- Keep the commander and the subordinate units informed,

- Make recommendations, and

- Prepare and issue orders for the commander.

The commander is responsible for deciding how the elements of his command will be employed to accomplish his missions. The commander controls the operations of his forces by the issuance of timely orders. It is a major function of the staff to assist the commander in arriving at and executing his decisions. Routine decisions may be made by the staff within the authority delegated to them by the commander. However, operational decisions are of such fundamental importance that the commander must personally influence the preparation of orders implementing these decisions.

To follow is a description of the planning process that the DRB commander and his staff perform when developing the mission tactical plan. The ABE is a member of this decision-making team.

4.2   SEQUENCE OF COMMANDER AND STAFF ACTIONS

The sequence of actions in making and executing decisions involves a series of separate actions or steps known as the sequence of commander and staff actions. The basic sequence describes a logical and systematic procedure to solve major problems and arrive at a properly considered decision. It should be noted that the sequence is flexible and that steps may overlap, be

accomplished concurrently, or even omitted in some cases. The sequence of commander staff actions consist of the steps described below.

4.2.1 Step 1 — Mission

Though estimating and planning are continuous in nature, they are put more into focus upon receipt of a mission. Normally, higher headquarters assigns the mission, but the commander may develop or deduce the mission. It is the mission or task to be accomplished that activated the sequence of commander and staff planning sequence. The commander may initiate his mission analysis at this point. Mission analysis is discussed in step 3 below.

4.2.2 Step 2 — Information Available

The staff provides the commander the information available based on their knowledge of the latest facts and current situation. Subordinated commanders receive information concerning the mission (warning order) and the situation as early as practicable in the planning phase and at least by the time staff estimates are being prepared.

4.2.3 Step 3 — Mission Analysis and Planning Guidance

Based on the information available, the commander completes his mission analysis and issues his planning guidance as follows:

1. The purpose of mission analysis is to ensure that the commander fully understands his mission and to allow him to develop those tasks that are essential to the accomplishment of this mission. The commander, normally assisted by his staff, performs his mission analysis by identifying the specified and implied tasks in the mission. Specified tasks are those tasks delineated in the mission received from higher headquarters or the missions developed or deduced by the commander. Implied tasks are those additional tasks that the commander identifies as essential to ensure accomplishment of the mission. When identifying implied tasks, the commander should exercise caution not to include tasks that are routine or inherent in his mission. It should be noted that at brigade and

battalion levels, the commander will seldom develop implied tasks because the division (or brigade) mission to its subordinate units normally is quite definitive.

2.   Planning guidance results from the mission analysis. To guide the staff along common lines of investigation in the search for the best possible way to accomplish the mission, the staff uses the commander's planning guidance in preparing or revising their estimates. Planning guidance provides the necessary staff direction for concurrent planning by providing a framework for making studies and estimates. The amount of planning guidance varies with each mission, the volume and validity of information available, the situation, and the experience of the commander and staff. Planning guidance is not limited to one specific step in the sequence of actions. However, initial guidance should precede the preparation of estimates. Planning guidance must include, as a minimum, the restatement of the mission as determined in mission analysis. This stated mission is used as paragraph 2, in all of the staff estimates. Additionally, planning guidance may include tactical determinations, courses of action the commander desires his staff to consider, key terrain within the overall objective area of defensive sector, use of nuclear and chemical fires, security, tactical cover and deception objective, restrictions on operations, allocation of means, Priority Intelligence Requirements (PIR) or other intelligence requirements, and pertinent assumptions. Unless higher headquarters has directed a specific course of action, the commander does not select or specify a course of action at this time because to do so would prevent objective and unbiased staff estimates.

4.2.4.   Step 4 — Staff Estimates (Including Recommendation)

The staff members, having received the commander's planning guidance, are prepared to focus their individual efforts on the problem to be solved. It involves a consideration of all circumstances affecting the situation and a systematic analysis and evaluation of possible ways to accomplish the task or mission. Staff officers furnish information, conclusions, and recommendations through preparation of an estimate. They summarize the significant aspects of the situation, evaluate, and determine how the means available can best be employed to accomplish the mission. The development of individual estimates requires staff officers to consult with each other to insure

coordination of all factors affecting the situation. When the mission requires a basic decision as to the tactical employment of the unit, the operation estimate, made by the S3, is the key staff estimate and incorporates the conclusions of the other staff estimates. This then becomes the coordinated staff recommendation. As the staff concurrently prepares their estimates, the information provided by and furnished to each is as follows:

1.   The S2 furnishes the S1, S3, and S4 with the results of his analysis of the weather, terrain, and enemy.

2.   The S1 and S4 provide the S3 with information pertaining to the personnel situation and logistic support, respectively.

3.   The S3 determines the possible courses of action he plans to consider in his operation estimate and advises the other unit staff officers.

4.   The S2 refines his own estimate in the light of the courses of action given him by the S3 and plans for the production of additional intelligence, if appropriate.

5.   Based on the information received from other staff members and an evaluation in their own areas of responsibility, the S1 and S4 complete their estimates to determine what major problems exist in providing the required support and which of the proposed courses of action can best be supported from a personnel (S1) and logistical (S4) viewpoint.

6.   Meanwhile, the S3 completes his operation estimate. The result will be the determination of that course of action which offers the greatest probability of success from a tactical viewpoint, i.e., operation recommendation. After coordination with other staff members, to include consideration of any advantages or limitations developed as a result of their estimates, the operation recommendation becomes the coordinated staff recommendation.

7.   The S3 presents the coordinated staff recommendation to the commander as a statement of the general scheme of maneuver to be adopted. The S3 should comment upon any significant problems and elaborate on the recommendation to the extent necessary to insure that the commander is fully informed. As desired, the commander will question the staff officers for additional information needed to arrive at his decision.

4.2.5.   <u>Step 5 — Commander's Estimate (including Decision and Concept)</u>

The commander's estimate consists of the following processes:

1.   While the staff members are each completing their estimates, the commander is concurrently making his own estimate. He may consult with his staff members during this time. His estimate prepares him to receive and evaluate the staff recommendation and to make a decision.

2.   Upon receipt of the recommendation of the staff, the commander completes his estimate and states his decision. In a tactical situation, the decision is a statement of the general scheme of maneuver (placement and movement of major maneuver elements) to be adopted and, if applicable, any nuclear fires (nuclear rounds to be fired and their targets, or nuclear rounds to be held in reserve or on call status). It is based on the course of action offering the greatest probability of success in accomplishing the unit's mission.

3.   To assist the staff members in preparing the detailed plans to execute the decision, the commander usually elaborates upon the decision by stating his concept to his staff. These instructions outline to the staff the intent of the commander with regard to the operation. Although detailed plans are made by the staff, the commander should outline the direction he desires the plan to take. No form is prescribed for this concept, although it may, at the commander's discretion, include additional guidance, and elaboration on the general scheme of maneuver, organization for combat, general plan of fire support, combat service support, and other details for preparation of the orders.

4.   The commander's decision and concept are the basis for preparation of paragraph 3A, <u>Concept of the Operation</u>, of the operation order by the S3.

4.2.6. Step 6 — Preparation of Plans or Orders

Although the staff plans continuously, it is not until they receive the commander's decision with respect to the tactical employment of the unit, that their plans can be finalized. Throughout their estimates the staff develops areas, not essential to the commander's basic decision, requiring further study and planning. Having received the commander's decision and concept, the staff must finalize all of the operational details by continuing with their planning and preparing the orders necessary to implement the commander's decision. The S3 has primary staff responsibility for the preparation of the operation plans or orders (oral or written).

4.2.7. Step 7 — Approval of Plans or Orders

The operation plan or order is presented to the commander for approval. This step may be omitted if the urgency of the situation so warrants and if a higher commander has delegated such authority.

4.2.8. Step 8 — Issuance of Plans or Orders

After approval, the S3 supervises final preparation of the plan or order, authenticates copies and insures proper distribution if issued in written form. At battalion level, oral orders are often used. Time permitting, written orders may be published to confirm or change the oral order, or to serve official record purposes.

4.2.9. Step 9 — Supervision

After the order is issued, the commander and staff supervises its execution. The primary purpose of the staff in this respect is to assist subordinate units wherever possible to carry out the intent of the commander's order.

4.3   APPLICATION OF THE SEQUENCE OF COMMANDER AND STAFF ACTIONS

The extent to which each of the above steps (exclusive of the decision) will be performed personally by a commander depends on a number of factors. Some of these factors are: time available, the size of the command, the situation, and the experience and training of the commander and the members of his staff. However, it must be recognized that the manner in which these steps are performed and their relationship to each other depends on many factors. The basic sequence, described in Section 4.2, describes a logical and systematic procedure to solve major problems.

The very nature of staff activities requires that many of the steps be acted upon concurrently by individual sections. Delineation of staff responsibilities often overlaps the areas of interest between staff officers and requires not only close supervision, but mutual assistance as well.

Particularly at brigade level, the sequence is applied on an informal basis. Time available, experience of the commander and his staff, and the relative urgency of the situation may necessitate variations in application of the sequence. Nonetheless, the basic steps of this sequence of commander and staff actions are employed to ensure the best possible solution.

4.4   ROLE OF THE ABE DURING THE PLANNING PROCESS

During the brigade planning process, the ABE will study maps, imagery, and terrain intelligence to formulate the engineer plan. The engineer plan will be a detailed task analysis to quantify the requirements for the mission, the recommended task organization, and required augmentation from either the 307th Battalion or the 20th Engineer Brigade belonging to the Corps.

The development of the engineer plan must be flexible to ensure that it adapts to changing requirements throughout the N - Hour sequence.

The ABE must coordinate with several other engineer decision nodes to include the assistant division engineer (ADE), the 307th commander and S3, and the DRF engineer platoon leaders.

Communications between the ABE and the 307th commander is essential in order to maximize the use of engineer assets. The commander will allocate assets on a mission priority basis. Communication with the ADE ensures that engineer information and intelligence at the division level is passed to the ABE in a timely fashion. Subordinate platoon leaders must be kept informed of the overall brigade plan and be supported by the ABE. During the N-Hour sequence this communication is performed largely by face to face meetings and messenger. Currently, there is no secure means of transferring data in an automated fashion.

Once deployed in the Area of Operation, the ABE will rely on messengers, secure FM voice radios, radio teletype and multi-channel systems.

Within the DRB planning cell, the ABE must interface with the:

- Intelligence Officer (S2) — Based on the S2's intelligence preparation of the battlefield, the ABE can estimate the combined effects of enemy, weather, and terrain on mobility, countermobility, and survivability planning. Using terrain analysis and estimates of the threat engineers capabilities, the S2 and the ABE determine the enemy's most likely avenue of approach. Together the two staff officers will identify choke points, obstacles, and trafficability. If the objective of the airborne operation includes seizing an airfield, it will be especially important to know the status of the airfield.

- Operations Officer (S3) — With the S3, the ABE receives the brigade commander's intent and guidance, develops estimates and courses of action, and develops input to the brigade operations order to include assembly on the DZ and linkup with heavy drop equipment, assault objectives, logistics release points, and follow-on missions.

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- Logistics Officer (S4) — The ABE provides early estimations of the class IV (construction material) and class V (munitions) supplies needed to fulfill the engineers requirements. Especially important is coordinating transportation of these supplies from the DZ to the engineer squads dispersed throughout the airhead.

- Fire Support Officer (FSO) — the ABE coordinates with the FSO to ensure that all obstacles are covered by fire. Obstacles must appear on the fire Support overlay as target reference points. Coordination is also required to ensure pre-planned artillery delivered scatterable mines enhance both the maneuver and obstacle plans.

There are two extremely significant constraints upon the ABE's planning process. The first is time. With only eighteen hours to plan for a mission, the ABE engineer is often forced to rely on intuition and experience to make critical decisions. The second is resources since airborne forces are severely constrained by the limitations of strategic airlift.

4.5   COMBAT ENGINEER DECISION SITUATION

In order to understand the internal cognitive processing that the ABE performs in developing his plans, we applied a decision analysis methodology that characterizes the decision functions that the ABE performs within the context of his overall high level goal or objective (e.g., support the DRB commander's tactical mission plan). By examining the high level interactions between decision functions, a unit of analysis — the decision situation — can be determined. The decision situation is the most amenable unit of analysis to a cognitively-based decision analysis.

This analysis will serve as the basis for determining the functional design and the nature of the user-computer interactions for the proposed CETOOLS system. Past efforts in applying this unit of analysis have successfully identified decision making needs for various kinds of military decision-makers.(Zachary, et al., 1981; Zaklad, et al.,1986)

The decision situation for the ABE is characterized as follows:

- The ABE strives to support the ground tactical plan by identifying the mobility, countermobility and survivability operations that must be performed in support of the tactical mission. Included in the ABE's assessment are the resources, assets, and time needed to perform engineering operations within each of the combat engineering tasks and balancing those estimates versus available resources. This activity represents the major decision situation faced by the ABE.

The following subsections describe the decomposition of the major cognitive information-processing activities that the combat engineer (ABE) performs with respect to the above decision situation. This decomposition will serve as the basis for identifying the user requirements that must be addressed by the proposed CETOOLS for the combat engineer. See Section 5 for a general description of decision-aiding support systems and the rationale supporting this type of cognitively-based decision analysis.

4.5.1   Decision Situation for the Combat Engineer

This decision situation is described below, and summarized in Table 4-1.

4.5.2   Objective

Combat Engineers support the tactical commander's mission through a mix of mobility, countermobility, survivability and general engineering tasks. The unique considerations of airborne operations, however, present the airborne engineer with numerous decisions in the face of severely constrained resources. The deployment of airborne forces will normally occur under circumstances of great urgency with little time to develop detailed plans. In many cases the tactical situation at the objective area will radically change even before the deployment is complete. The introduction of the airborne force into the objective area will be incremental and possibly subject to hostile action.

Airborne engineer operations are heavily driven by the mission, the duration, the airflow and the tactical environment. Based on these considerations, the engineer decision maker must continually reevaluate and prioritize the relative level of effort directed toward the goals of mobility, countermobility, survivability and general engineering. In the airborne decision making environment, changes in the tactical situation may impact on decisions made hours earlier and thousands of miles away.

Thus, the airborne combat engineer requires a decision aid that will allow him to rapidly assimilate new information, accurately assess its impact on his mission and provide him with the ability to make the necessary changes to the time phased deployment of the task force's engineer support.

4.5.3   Task Dynamics

Because the decision situation is basically repeated each time additional reports or messages arrive, the dynamics of the decision situation can be characterized as a closed loop iterative.process. Thus, the combat engineer must repeatedly perform the following steps:

- Receive the mission from the commander and understand its implications for engineer operations.

- Analyze the area of operations so that the combined effects of weather and terrain on operations will be fully considered. In the case of 82nd Airborne operations this information is often fragmentary and must be continually evaluated as it is received throughout the planning cycle.

- Identify the commander's specific and implied tasks. From this list of tasks, the combat engineer will determine which of these tasks are absolutely essential to the accomplishment of the mission. Having identified the essential tasks, the engineer is able to restate the mission as a series of engineering tasks to be performed.

- Evaluate all assets available to include personnel, equipment and materiel. *Additions or shortfalls to what is currently available must be identified .*

- Constraints and limitations placed on engineer operations must be identified and incorporated into the engineer' s decision. These include limitations due to aircraft, airflow and logistical requirements.

- Continually analyze the time available for planning and executing operations. Time is a particularly critical consideration is airborne operations since there is not only a limited amount of time in which to plan the operation but all critical tasks must be performed exactly on time so that the ground tactical plan is supported by the airflow.

- Present his decision in the form of a plan to the commander and supervise the execution of the plan or make revisions as required.

4.5.4   Choice Criteria

At any point in time, the Combat engineer is faced with the requirement to decide which types of information are needed to enhance his understanding of the overall tactical situation and his ability to support the mission through engineer support. That is, the Combat engineer must choose the essential pieces of information relating to METT-T that he feels will have the greatest value in allowing him to quickly evaluate the impact of the information without time-consuming perusal of excessive and irrelevant data (information overload). Similarly, the Combat engineer must decide what vital information is lacking and forcing him to make assumptions or decisions without the required data. Applying this criterion requires a high degree of knowledge about the implications of each combat engineering task. For example, the combat engineer may be inundated with terrain and climate studies that fail to provide him with the weather in the last 24 hours and its effect on trafficability in the primary enemy avenue of approach.

4.5.5   Underlying Process

The process that underlies the Combat Engineer's decision situation are the implications of the ground tactical plan with respect to future combat operations.   The combat engineer must make his choices for information and subsequent decisions relate to the emerging picture of the objective area, the commander's evolving plan, and the possible outcomes that may result from combat.   Because of the complexity inherent in such a dynamic situation, it is almost impossible to anticipate the course of events and actions that may occur beyond those standard actions anticipated in division standard operating procedures

4.5.6   Information Environment

The types of information that the Combat engineer requires are characterized as follows:

- **Inputs**: There are many dynamic inputs to the Combat Engineer's decision making.   These include primarily information on the elements of METT-T. All of these variables will be changing throughout the duration of the deployment and subsequent combat operations while the Combat engineer is conducting his assessment of how to best support the operation with combat engineering support.

- **Parameters**: There are some elements of information available to the engineer decision maker that will not change during the course of the decision making process. Among these are the basic missions of combat engineer and the means to accomplish them, the basic structure of the command and control relationships of the DRB, the physical constraints of the transport aircraft, and the critical events that must occur in order to deploy the task force in eighteen hours.

• **Outputs:** In the course of the engineer assessment, the engineer will determine his critical tasks and the priority in which they will be accomplished. This determination will often be informally coordinated with the commander and other staff officers before a final, approved, decision is made as to how engineer assets will be employed. Based on the commander's decision for engineer employment, the plans and orders are prepared. These operational plans or orders (OPLAN or OPORD) will be written or presented orally by the combat engineer as an annex to the supported task force OPORD and as a separate OPORD to subordinate engineer units..

4.5.7   Intermediate Reasoning and Analysis Steps

There are several steps that the Combat engineer will follow in order to arrive at his decision, based on his intuition, and professional judgement. The accuracy of his decision based on these factors will be directly related to his experience and training. The engineer first must recognize the desired end toward which his efforts are directed in order to focus his reasoning and analysis. Second, he must establish a baseline of the initial conditions based on an analysis of the engineer tasks involved and the knowledge needed to accomplish these tasks. For example, he must know the composition and capabilities of the engineering assets at his disposal. Next, the engineer must create plausible visualizations of situations and formulate a hypothesis on the possible outcome of decisions. The objective here is to predict those events that are most likely to occur and assess the impact of those events on the task objectives. During the development of the ground tactical plan, for instance, the engineer mentally considers the effect of each obstacle emplaced on the movement of an enemy armored force. His first inclination may be to believe that the enemy will establish a hasty defense and await the arrival of breaching equipment. The engineer must then identify gaps in his knowledge about the situation being visualized so that he can gather the information and reduce his uncertainty to an acceptable level. After identifying these gaps, the obvious next step for the engineer is to gather and interpret the information he needs to test his hypothesis. For example, when the engineer is considering the effect of an obstacle on the enemy's armored force, he will require information on what actions are prescribed by enemy doctrine upon confronting an obstacle. This

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new information, once gathered and interpreted will allow the engineer to test his original hypothesis based on his perceptions of the reliability and validity of the information. If the engineer receives and accepts information that indicates enemy doctrine dictates that all obstacles will be bypassed immediately, this contradicts his original hypothesis. On the other hand, if his baseline knowledge of the terrain indicates that bypassing the obstacle is impossible, his originally theory is validated by the fact that the evidence supports it better than any rival hypothesis. If a decision cannot be reached based on the available evidence, the engineer may choose to defer his decision until such a time as new information is received. In the airborne planning environment, however, the engineer will not be able to afford the time required to create a complete picture of the battlefield. In these instances, decisions will revolve around division standard operating procedures.

4.5.8   Decision Representation

The combat engineer's reasoning steps used to determine how engineer assets will be employed in support of the ground tactical plan explicitly involve the use of maps and graphic overlays to aid in the decision making process.

4.5.9   Required Quantitative Judgements

There are numerous quantitative judgements made by the combat engineer when arriving at a decision. These judgements are based on the existence of large volumes of empirical data that exist for engineer operations. This data is in the form of tables and formulae that describe the necessary expenditure of personnel, resources and time in the accomplishment of many engineer functions. While these functions will be situationally dependent , the existing data provides a useful starting point in arriving at decisions.

A summary of the decision situation just described is provided in Table 4-1.

TABLE 4-1   COMBAT ENGINEER DECISION MAKING

DECISION SITUATION: Develop a plan that supports the tactical commander's mission through a combination of mobility, countermobility, survivability and general engineering operations.

TASK DYNAMICS: Closed loop iterative

SITUATIONAL OBJECTIVE: Provide continuous evaluation of requirements for engineer support to the ground tactical plan.

CHOICE CRITERIA:

1. Information related to METT-T
2. Trade-off analysis between mobility, countermobility, survivability and general tasks.

UNDERLYING PROCESS: Formulation of the ground tactical plan during the N-Hour sequence and its implications with respect to actual battle.

INFORMATION ENVIRONMENT:

Inputs	Outputs:	Parameters
Mission	Plans	CE Missions
Enemy	Orders	CE Techniques
Terrain		Force Structure
Troops available		Aircraft
Time		N-Hour Sequence

INTERMEDIATE REASONING/ANALYSIS STEPS:

1. Recognize goals.
2. Establish baseline
3. Create hypothesis
4. Identify gaps in knowledge.
5. Gather and interpret information.
6. Test hypothesis.
7. Make decision.

REPRESENTATION: Standard military maps and graphic overlays showing topographic data, the location of enemy and friendly forces , and planned engineer operations will be required to facilitate decision making.

REQUIRED JUDGEMENTS: THE CE WILL BE REQUIRED TO MAKE BOTH QUALITATIVE AND QUANTITATIVE JUDGEMENTS.

4.6   SUMMARY

The ABE's requirements for software support to aid in decision making can be summarized as follows:

- Support in evaluating and prioritizing combat engineer objectives with respect to the mission, resources, and time. The ABE also requires the capability to examine multiple mission scenarios.

- Support in visually depicting key terrain features, OPFOR assets and planned engineer operations.

- Support in managing and maintaining status of engineer assets and resources.

- Support in identifying the aircraft and logistical requirements to support the engineer plan.

5.0   DECISION-AIDING SUPPORT SYSTEMS

Decision-aiding support systems are unique among computer-based information systems in that their common label arises not from their shared technology or common application but rather from their intended effect -- improving human decision-making performance. The discipline of decision-aiding represents a recognition by scientists from several fields that decision makers are in need of computer assistance that alleviates or minimizes the complexity involved in evaluating situations. This discipline encompasses several disciplines such as cognitive science, psychology, and computer science as well as technologies such as data base management, expert system, and artificial intelligence. Because of the diversity of disciplines and technologies that are involved in the design and development of decision-aiding support systems, it may not always be apparent how such systems work or what they are needed for.

This section will attempt to clarify this multi-discipline area. This section will discuss several definitions that help to clarify the distinction between decision-aiding support systems and other types of computer systems, the reasons for developing such systems, and finally the software techniques and/or technologies that have been applied in the development of decision-aiding support systems.

5.1   DEFINITIONS

Several authors have espoused that decision-aiding support systems differ from other computer systems such as management information systems and automatic data processing systems based on several considerations. These considerations are the following:

- The type of problem that decision-aiding support systems are designed to address,

- The type of support that decision-aiding support systems provide, and

- The significance that such software support provides to the decision-maker.

Keen and Scott-Morton (1978) define decision-aiding support systems from the viewpoint of the role that such systems are to play. They see such systems as assisting decision makers in their decision processes especially in semistructured tasks, support but not replace human judgement, and improve the effectiveness of decision-making.

Alter (1975) defines decision-aiding support systems by making the distinction between traditional automated data processing (ADP) applications' and decision-aiding support systems' goals. Decision-aiding support systems are designed to help managers (decision makers) make decisions whereas ADP systems are designed to automate clerical tasks and foster efficient record keeping. Alter further distinguishes decision-aiding support systems based on the requirement for greater user involvement with such systems than with ADP systems. Also, decision-aiding support systems are characterized as providing data that decision makers request in a manner that depicts the significance of such data (via process models) in order to allow decision makers to make a judgement.

Finally, Sprague and Carlson (1982) distinguish decision-aiding support systems from traditional ADP systems by the nature of the relationship between the user and the decision-aiding support system. They see this relationship as one that requires a symbiosis between the decision maker and the system to be effective.

It is apparent from this brief discussion of definitions that decision-aiding support systems are intended to assist but not replace human judgement. Decision-aiding support systems represent a unique class of

computer systems that are designed to alleviate or reduce the complexity involved in analyzing situations as represented by information. A critical question however remains unanswered from this discussion. What are the circumstances that dictate the need for computerized assistance such that decision makers are better able to make sound judgements? The following subsection will address this important question.

5.2 SITUATIONS REQUIRING DECISION-AIDING SUPPORT

To understand the situations that dictate the need for decision-aiding support, one must first be cognizant of the underlying assumptions that form the framework for such descriptions. Specifically, the human information-processing architecture has deficiencies and limitations that interact with situational demands such that decision makers are at a disadvantage in assessing situations. As a result, decision makers will be prone to make judgements that can be characterized as less than optimal. It is because of these human information-processing limitations that decision-aiding support systems are needed. Specifically, such systems are intended to overcome or lessen human information-processing inadequacies so that decision makers are better able to make sound judgements.

The approach needed to identify the situations and circumstances that require decision-aiding support must be one that is cognitive in nature. To do so requires an understanding of the limitations that humans have in assessing situations as a result of information-processing inadequacies. Based on previous efforts, Analytics has developed a framework that characterizes the cognitive processes involve in acquiring, organizing, and retrieving information which may hinder a decision-maker's ability to assess a situation and decide upon an optimal course of action (Zachary, et al., 1981, Zaklad, et al., 1986). These cognitive processes and the situations and circumstances that may interact with these cognitive processes are summarized below. They represent the possible circumstances in which decision-aiding support may be warranted.

1) <u>Ability to predict processes</u> — If there is an underlying process, does the person have difficulty predicting it in the time available? Or, could they make better decisions if they had good process predictions? Humans have difficulty projecting real-world processes forward into the future, especially when the processes involve uncertainty (e.g., combat).

2) <u>Ability to combine competing attributes or objectives</u> — If multiple criteria must be combined or multiple alternatives compared, is the decision maker able to do so reliably and without bias? In many decision situations, several attributes or criteria can describe an expected outcome of a decision (e.g., its cost in expendable hardware, its cost in time, its gain in enemy losses, etc.) or must be evaluated to make trade-offs among competing objectives (.e.g, mobility vs. countermobility). When many possible outcomes must be compared to determine the best one, the combination of these attributes can be difficult, especially if they are all numerical. This arises from the limitations in short term memory and in ability to process numeric information (see Simon, 1981, and Dawes, 1979).

3) <u>Ability to manage information needed in the decision process</u> — If a large amount of knowledge and/or data must be manipulated, is the person able to do so in the time available? Is the person ignoring available information or knowledge in favor of faster or less mentally taxing rules of thumb? Decision makers often fail to make use of all the information available to them simply because they are unable to manage it effectively "in their head." This is particularly true in tactical decision situations where there is a large volume of data coming in from sensor and message network sources and a large quantity of knowledge that needs to be applied selectively to the available information. Because all information being used in the decision process must pass through the very limited short term memory and because people have unreliable recall processes from long term memory, a human decision maker can easily be overwhelmed by a large amount of information. As a result, he may fail to process key inputs or fail to recall and apply crucial pieces of knowledge. Decision makers may make excessive use of "rules of thumb" or other "quick-and-dirty" formulae that provide simple generalizations of much more complex pieces of knowledge/information.

4) <u>Ability to analyze or reason about the situation</u> — If the person has specialized ways of thinking about a problem, is he able to apply these within the time and mental resources available? Does he know ways of attacking the decision that could yield better results but can't be applied within the limited time/resources available? Difficulties in analyzing decision problems arise from a broad combination of basic human information processing limitations, including the size of short term memory, the difficulties in performing numerical calculations, and the inability to project processes forward in time. Because each decision situation involves a different unaided decision process, the kinds of analysis and reasoning problems that people have in decision making vary a great deal.

5) <u>Ability to visualize</u> — If the person has a mental model of the problem, particularly a visual model, does he need or want to make manipulations of it that he can't on a completely mental imagery basis? People tend to use visual representation in their unaided decision processes, but they frequently have difficulties in manipulating these representations, particularly in a quantitative manner. For example, a decision maker may visualize a tactical problem in a map-like fashion, but will be unable to mentally calculate where a target's trajectory will cross his own path. This is another instance of the general inability to perform quantitative calculations mentally. At the same time, however, people are much better able to make such quantitative projections with their visual representations if they can deal with a concrete (i.e., explicitly drawn) representation instead of a purely mental one.

6) <u>Ability to manipulate quantitative information</u> —If quantitative judgments are needed, is the person able to make them without bias and within the needed range of accuracy? There are many situations where the human decision maker is required to make some inferences that can only be described as "judgment calls." Highly skilled and experienced decision makers can make such judgments with high reliability and consistency, but when they have a numeric aspect to them, there is often a systematic bias or "noise" in the judgments provided (see Kahneman and Tversky, 1982).

The six cognitive processes and the circumstances just described represent potential situations which may require decision-aiding support for

decision makers. In Section 4 of this report, we have characterized for the combat engineer those circumstances that are in need of decision-aiding support because of human information-processing architecture inadequacies.

The identification of software solutions to overcome or minimize the impact of these situations is just as important as the identification of the situations that require decision-aiding support. The following subsection describes functional categories of decision-aiding software techniques and technologies that may be appropriate to overcome or lessen human information-processing inadequacies.

5.3   TAXONOMY OF SOFTWARE TECHNIQUES AND TECHNOLOGIES

Because decision-aiding support systems have entailed a plethora of software techniques and technologies, there may seen at first glance to be no systematic way to characterize the use of such techniques and technologies. Based on previous efforts, Analytics has devised a taxonomy that offers direction in the use of such techniques and technologies (Zachary, 1980; Zaklad, et al., 1986). This taxonomy of technologies for decision-aiding support systems is based on a review of publications both within and outside of DoD and is presented in Figure 5-1. The figure presents an overview of the complete taxonomy down to the second and third levels. The identified technologies include a variety of information management aids, problem analysis/reasoning techniques, and judgment refinement/amplification methods. The six general cognitive deficiencies described in Section 5.2 and the associated technologies found in the taxonomy that may overcome or lessen these cognitive deficiencies
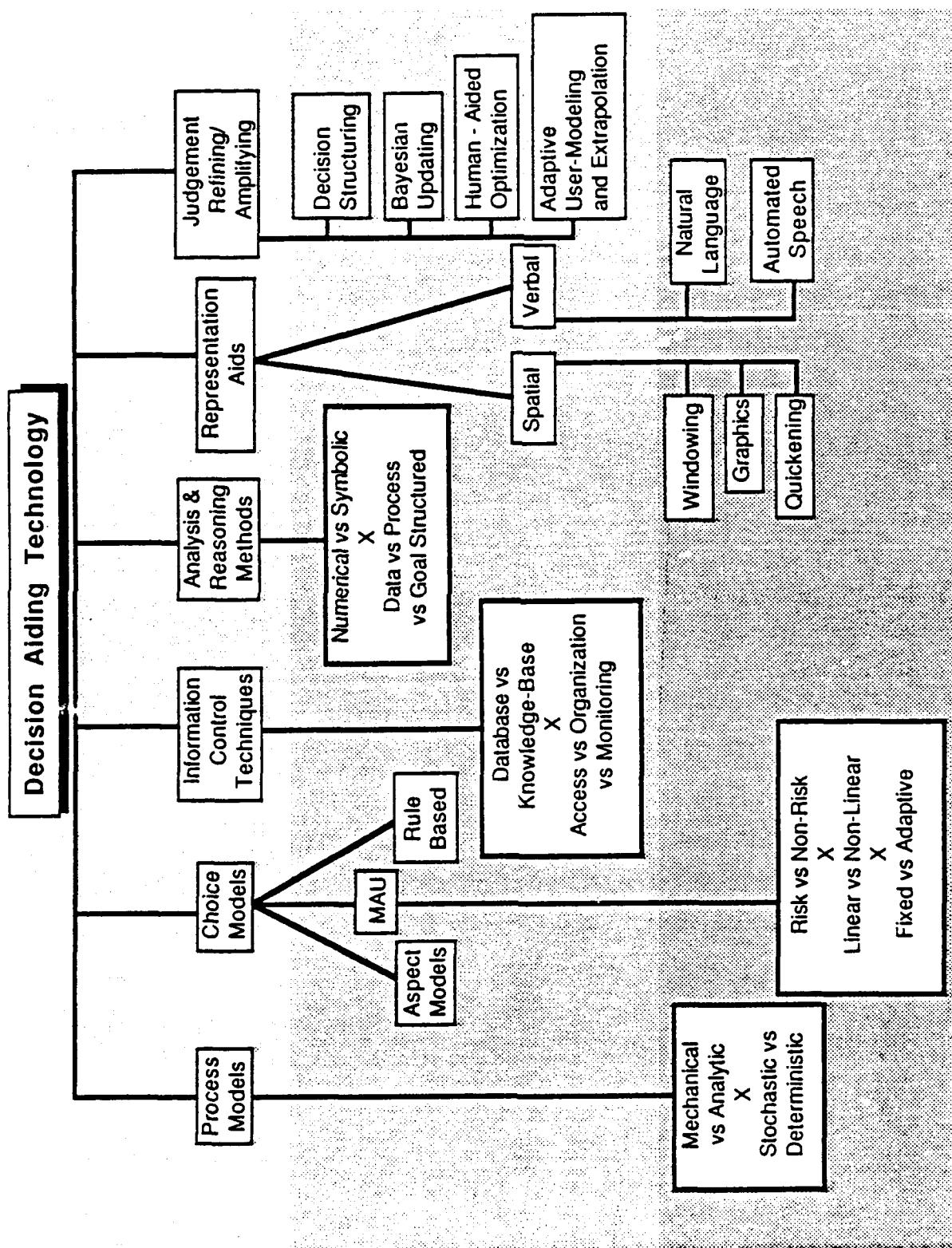
Figure 5-1. Decision-aiding technique taxonomy.

are described below:

- **Underlying process ==> process prediction problems** — can be improved through the use of process models which are algorithmic or mathematical models that calculate or predict the outcome of a real-world process, i.e., a situation which unfolds over real time. They are useful in problems where the decision maker has only partial or no control over the outcome of the process. For example, in air battle management, the decision maker controls the actions of his own forces, but cannot control those of the enemy. In such situations, outcome calculators may be used to predict the result of the process given a proposed course of action and an estimate or set of alternative estimates concerning the possible actions of the enemy. Examples of process models include Lanchester equations which predict attrition of forces in battle (Lanchester, 1916, Craig, 1975), battle engagements (Garnero, et al., 1978), and air strike timing decision aids (Glenn and Zachary, 1978, Epstein, 1978).

- **Choice criteria ==> difficulties in combining attributes** — can be improved through the use of choice models which describe or guide the user in weighing of all information that is available on all alternatives and selecting one for further attention or implementation. Choice models may be designed to systematically integrate attributes of decision alternatives, either mathematically in the form of multi-attribute utility models (see Weisbrod et al., 1977), sequentially in the form of aspect models (see Tversky, 1972), or constructed as collections of production rules which embody diverse problem-related knowledge (see Duda and Shortliffe, 1983).

- **Information requirements ==> difficulties in retrieving information** — can be assisted through information control techniques for accessing, organizing, and monitoring data and knowledge. These include database management functions (see Martin, 1980, for a review), numerical analysis techniques (see Irving et al., 1977), and alerters (Buneman and Morgan, 1977).

- **Intermediate analyses ==> problems in analyzing or reasoning** — can be improved through the use of analysis and reasoning methods dependent upon whether the problem involves numeric or symbolic information and whether the inferences is goal-based (e.g., the General Problem Solver of Newell, Shaw, and Simon, 1965), data-driven (e.g, the KNOBS system (Engleman et al., 1979) for air battle management), or process-based (e.g., Vere, 1983 for mission-planning).

- **Decision representation ==> difficulties in visualizing or relating data to a mental model** — can be improved through the use of representation aids for the form in which information is presented to the human verbally or spatially. The principal aiding techniques for verbal representations are natural language processing (see Rich, 1984) and automated speech processing (an application of automated speech in the Forward Area Alerting Radar (FAAR) workstations in the SHORAD system is described by Smyth, 1985). The principal visual representation techniques are computer graphics (see Rubenstein and Hersh, 1984), windowing, (see Buneman et al., 1977), and quickening (see Birmingham and Taylor, 1954).

- **Required judgments ==> quantitative inaccuracies in heuristic judgments** — can be improved through the use of judgement refinement/amplification techniques such as decision structuring (see Pearl et al., 1980), Bayesian updating, human-aided optimization (see Schecterman and Walsh, 1980 and Hurst and Krolak, 1982), and adaptive user-modeling and extrapolation (see Weisbrod et al., 1977).

By providing this set of functional categories of decision support, a taxonomy of decision-aiding technologies and techniques, and its relationship to human information-processing inadequacies, one is able match the appropriate techniques that offer a solution to a decision maker's inability to adequately assess a situation and reach a sound judgement. In Section 7 of this report, the appropriate software techniques and technologies with respect to the combat engineer needs for decision-aiding support are described in the context of the proposed functional design for the CETOOLS system.

6.0   USER COMPUTER INTERFACE TECHNOLOGIES

The CETOOLS system will provide powerful capabilities to the user to assist them in their role as CE in developing engineering plans. However, these functions will go to waste if the user finds it difficult to communicate with CETOOLS, specify the characteristics of their problems, or decipher the results. Therefore, the nature of the user computer interface (UCI) is a critical determinant to the successful use of CETOOLS. This section presents the results of research conducted into several critical areas for the user interface, namely the user-computer dialog and user profiling.

This discussion of user interfaces assumes that CETOOLS will be developed on a microcomputer and that the microcomputer is equipped with 1) a high resolution color graphics monitor with windowing capability, 2) a pointing device such as a mouse, and 3) direct graphics input device such as a digitizing tablet. A mouse is a small box (about the size of a deck of playing cards) with one to three buttons on its top face that functions as a pointing device. The mouse motion translates into corresponding movements of a pointer (e.g., a cursor) on a display. It allows the user to manipulate information and select commands or locations on the screen without having to enter specialized interface commands via the keyboard. A digitizing tablet is a separate touch-sensitive surface operated with a pointing device such as a stylus that can be used to trace over graphical material for direct entry of coordinate information.

Since it was decided that CETOOLS is to provide a highly visual interface, particular attention was paid to guidelines available for designing interactive graphic interfaces. Fairly detailed and comprehensive guidelines have been developed for various areas of UCI's, including keyboard design, display legibility, and ergonomic considerations, that are based on empirical data which has been organized in several reference handbooks (Engle, 1975,

and Brown, 1983). Unfortunately, few guidelines are available to assist the designer in developing interactive interfaces that take full advantage of the features accorded by a highly graphic system. This section will present "guiding principles" but it is expected that the exact nature of the user interface will evolve iteratively in conjunction with the development of the CETOOLS prototype through early and extensive involvement of the proposed user community and their feedback. This interaction between the CETOOLS designers and the CE community is critical to the successful development of the system in order to ensure the system effectively meets the needs of the user. The exact nature of the user interface will also be considered in conjunction with system requirements such as time criteria. Sophisticated user interfaces frequently make heavy demands on the system and and trade-offs may be required to ensure that the benefits of the user interface are not nullified by slow system response time.

This section presents a compendium of the following interface design issues considered relevant for the CETOOLS UCI and any available design principles:

- **Interactive Dialogue** — identify the techniques used for communications between the user and CETOOLS including dialogue style and user aids.

- **Input Capabilities** — identify the appropriate input devices (e.g., keyboard, mouse, graphic tablet, etc.) and their use for user communication with the system for the CE functions.

- **Output Capabilities** — determine how information is to be presented to the user in such a way that maximizes the user's perception and understanding of information including screen design and layout, use of color, and use of graphics.

6.1   INTELLIGENT USER DIALOGUE

One of the key issues in designing a user interface is the selection of the techniques used for communications between the user and the computer.

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This not only involves selection of a dialogue type, but the development of techniques to assist and guide the user's interactions with the computer system. As described in Section 2, CETOOLS users will possess varyir- levels of computer usage skills and CE expertise. The user-computer interface (UCI) must supply a meaningful structure within which the two-way dialogue between the user and CETOOLS occurs.

6.1.1   <u>Dialogue Types</u>

The user communicates with the system by specifying commands and objects to be manipulated. There are six primary dialogue types that are relevant for a decision support system such as CETOOLS:

1.   Command-Driven,

2.   Menu-Driven,

3.   Question-Answer,

4.   Form Fill-in,

5.   Graphics-Driven, and

6.   Natural Language.

Each dialogue structure type has a particular user appeal depending on a user's knowledge of the system and their computer expertise. Many systems are now based on a hybrid of these techniques.

6.1.1.1 <u>Command-Driven Dialogues</u>. Command-driven dialogues typically display a brief prompt to the user (e.g., a question mark) and expect the user to type in a command name, phrase, or associated mnemonic (e.g., PRINT or PR). Since the system offers very few prompts or choices, the user is expected to know which system features are currently available and their syntax. If the

system does not recognize a command that the user enters, it typically responds with an error message. The biggest advantage of a command-driven interface is speed. Very few keystrokes are required to initiate any action, and it eliminates stepping through multiple levels of menus to specify an action. Command-driven interfaces appeal to experienced users since the system functions are more readily accessible. Command dialogue's biggest shortcoming is its inherent "unfriendliness." A system or computer novice viewing a display with nothing but a prompt has no guide as to what to do next. Novice users have many problems learning a command dialogue system since they are unfamiliar with both the functions that can be accomplished and the command names required to invoke the functions. Additionally, in order to invoke a command, the user has to first remember the designated command. If there are too many commands to be able to remember them easily, users tend to find this facility too frustrating and time-consuming to use.

6.1.1.2 Menu-Driven Interfaces. Menu-driven interfaces display every possible choice that the user can make in a menu that is typically arranged in a hierarchical manner (i.e., one choice or action must be taken before another). The selection of one menu item generates another menu, which brings up yet another until a final selection allows the desired function to be accomplished. The major advantage provided by menu dialogues is the ability to guide a user through the steps needed to accomplish a task. Menus reduce memory demands because they only require the user to recognize rather than recall the correct option (Martin, 1973). However, menu-driven interfaces are not without problems. New users might find that learning larger systems is difficult because information must be integrated across a series of displays. As each menu is viewed in isolation, relationships between menus are difficult to grasp and the user may get lost in the hierarchical structure. However, menu interfaces do facilitate use by novices. On the other hand, experienced users are often frustrated when they must step through a number of menus before reaching the desired function since not all functions are available from all menus.

A strategy that is effective for workstations with display windowing and mouse capabilities is the pull-down menu that combines command and menu-driven techniques. Pull-down menus display a command bar at the top of a window with a submenu displayed in a new window box beneath it showing all available options. The user can use the mouse to move a pointer to one of the choices displayed in the box. As the pointer moves among the menu options, the current selection is highlighted and the user depresses a keyboard or mouse key to indicate the desired selection.

6.1.1.3 <u>Question and Answer Dialogues</u>. Question and Answer (Q&A) dialogues present the user with a series of questions to which the user responds one at a time. The question and answer process is repeated until the system has received the necessary information. Q&A dialogues typically decide the next question based upon the answer(s) to the previous question(s). Some incorporate a degree of natural language capabilities in order to avoid simple yes/no responses. If the system cannot understand a response or require additional information, clarification questions may be generated. Similarly, if the user cannot understand a question, an explanation facility is typically provided. Q&A dialogues are typically used in advice providing expert systems.

Q&A dialogues are most successful with novices who are unfamiliar with the problem to be solved. However, experienced users quickly become impatient when forced to step through a lot of questions. One way to alleviate this problem is to provide multiple modes of use — e.g., full sentence mode and abbreviation mode. Additionally, default response can be set for the particular user (this is described in more detail in Section 6.2) as part of their "user profile." An additional consideration is how to permit the user to change the response to a previous question. Finally, the ability of Q&A dialogues to be utilized within the time constraints imposed on the CE needs to be considered since Q&A dialogue techniques require a certain amount of time per question. This fact generally precludes their usage for time critical applications.

6.1.1.4 <u>Form Fill-In Interfaces</u>. Form fill-in (or fill-in-the blanks) interfaces provided the user with input forms in which the user enters necessary commands and data. A display of labeled fields and an area for entry of input are shown and the user moves the cursor between the input areas and enters the appropriate information. This type of design is well suited when there is a correspondence between the input display and paper forms familiar to the user. This type of interface requires the user to be cognizant of the field labels, permissible field values, and the data entry techniques to be employed in moving among the displayed fields. Form fill-ins are most appropriate for frequent users.

A variant of form fill-ins are input templates developed on computers with graphics capabilities. In addition to boxes for entry of text material, various fields can be defined to be check boxes for on/off parameters, click boxes for parameters containing ranges of numbers, and radio buttons for the user to select only one of a set of parameters. Recent research in the area of input templates, such as those used on the Apple Macintosh computer, will be considered in the development of the user interface (Smith et al., 1982 and Norman and Draper, 1986).

6.1.1.5 <u>Graphics-Driven Interfaces</u>. Graphics-driven interfaces are a fairly recent development and generally provide an interface that is both "friendly" and nonrestrictive. Graphic icons replace or supplement words as command designators in menu-based systems. Instead of a temporal order display such as a menu, the user is presented with a spatial order of possible actions that are represented by "iconic" or pictorial representations of actions. The user positions a graphics pointer, such as a mouse, over the icon representing the desired action. Icons take advantage of the human ability to discern pictorial differences more quickly and easily than textual differences. However, the icons must be designed carefully in order to maximize their usefulness and are best suited when a limited set of clearly distinguishable options are available. The visual interfaces made possible by iconic representation provide an object

orientation rather than a procedure orientation and enhance the user's knowledge about the system and its capabilities. However, there currently exists a very limited body of information about the effectiveness of iconic representations and how they should be designed to maximize information transfer.

6.1.1.6 <u>Natural Language Interfaces</u>. Natural language interfaces provide the ability of the computer software to process plain English user requests. English is a very complex language and contains many structural and semantic ambiguities. This complexity requires a vast amount of knowledge in order to understand even a simple sentence. Although unrestricted natural language is the least limiting to the user, it is not currently practical to timely machine-parse with available computer systems and technology because of it's extreme complexity. Many advances are being made in the field of natural language processing but it is doubtful that they could be incorporated into CETOOLS in the near future without significantly affecting the machine resources available to the primary function of CETOOLS, i.e., assisting the CE in decision-making functions. Additionally, a body of evidence suggests that limiting the vocabulary and syntax available to the user improves the user's ability to utilize and comprehend the system language (Bailey, 1985; Hendler and Michaelis, 1983). Other studies have shown that arbitrarily approximate treatments of natural language may cause more problems than they solve (Bornw, Burton, and deKleer, 1982).

6.1.1.7 <u>User Dialogue Recommendations</u>. It is recommended that the initial dialogue style for the prototype CETOOLS system be a combination of menus and input templates as illustrated in Section 7. Menu-bars can be used to show a list of available CETOOLS functions on a line at the top of the screen. Pull-down menus can list submenus in a separate window displayed beneath the menu bar and will contain the list of commands available for a particular selection from the menu bar. Once the user has specified the CETOOLS function, additional dialogue with the user will occur using a series of input

templates. Since many of the parameters specified by the combat engineer utilize standard symbiology (e.g., obstacles, unit designators and capabilities, etc.) these will be represented by icons where appropriate. As described above, the exact nature of the UCI will be developed iteratively in conjunction with the user community.

6.2 USER AIDS

User aids provide the means to assist the user in making effective use of the system. They must be implemented in a consistent manner both for the user indicating that additional assistance is needed and in the form of the assistance.

6.2.1 HELP Keys

Supplementary on-line guidance in the form of brief command summaries and tool descriptions which assist the user in making decisions is an essential feature of a user-friendly system. HELP displays serve as cognitive development tools to assist the user's understanding of the system. A simple, standard action that is always available to the user should be developed to obtain HELP messages. For example, HELP might be requested by an appropriately labeled function key, by selection of an always available menu option, or by keying a question mark into a displayed entry area. The content of the HELP response should be related to the contents of the current display or the current sequence of activity. The explanations should be developed in conjunction with the user community in order to tailor the response to the user's likely needs.

6.2.2 Default Values

Default values represent the systems best guess of the responses expected by users. They must be developed carefully to represent clear, logical, and meaningful values. The use of default values can both speed data

entry and reduce input errors for a defined task. The default values should be clearly displayed in a consistent manner. The user should have the capability to easily define, change, or remove default values for any data entry field. In addition to the default values specified by the system developers, the user should also be allowed to override and specify defaults where appropriate — such as the specification of the units of measurement.

6.2.3   Status Information

Status (or progress) information which signifies that the system is performing a time-consuming function and which also provides an approximate indication of when the function will be completed is also an important user aid. Information is provided to the user to indicate that the system is actually doing something and is not waiting for any user actions in order to continue execution. Since the CE may be interrupted at any point to perform a more critical task, the availability of status information will allow the analyst to make a determination about whether to continue or terminate the current function.

6.3   INPUT CAPABILITIES

6.3.1   Input Devices

6.3.1.1   Keyboards. Alphanumeric keyboards used for data entry should conform to the Qwerty arrangement and the keyboard should include a keypad to assist in entry of numeric data (Van Cott and Kinkade, 1972).

6.3.1.2   Pointing Devices. The UCI also requires the use of a device that can point quickly to items on the display and that are faster than the directional cursor keys such as a mouse, joystick, trackball, light pen, etc. Of these devices that are commonly available, the mouse has been identified as the preferred one for most video pointing needs. The mouse is a hand-held pointing device with a sensor on the bottom to detect motion over a flat surface and one to three buttons on the top which can be sensed by system software. The system

provides the user with continuous feedback as to where it thinks the mouse is pointing by displaying a cursor on the screen. The user slides the mouse around on a flat surface (causing the bearings or wheels on the bottom of the mouse to rotate), and the system moves the cursor on the display. The user indicates that the mouse has positioned the cursor at the desired location by pressing a button on the top of the mouse.

The most common use of a mouse is to move a cursor to a precise screen location and depress a mouse button in order to initiate some action, such as selecting a menu option, that otherwise would require the depressions of special function keys and/or directional cursor movement keys. The mouse is the preferred pointing device for text-editing applications because it is the most comfortable to use and is also among the fastest (Card, et al, 1978, Warfield, 1983).

6.3.1.3 Direct Graphics Input. CETOOLS requires a method to rapidly and easily specify selected graphics information for map and terrain information. The CE will generally be given a map of the area of operation. In order to transfer this information into CETOOLS, a digitizing tablet would be used to that the CE would move a pointer (e.g., a stylus or puck) over the surface of the map which had been placed on the tablet. At each point where critical information is to be specified, a tablet buttons would be pressed to indicate the type of information to be entered. Single point data can be entered as well as continuous information such as curves. The computer display would provide information about the entered information and the status of the tablet. In addition to the information on the map, the CE could also directly enter information such as obstacle emplacement by using the pointer to trace over the desired areas on the map. Digitizing tablets are available with drawing space ranging from 11 x 11 inches to 48 x 60 inches.

Limited information is available about how the characteristics of digitizing tablets impact performance (Ward and Phillips, 1987). However,

empirical research does indicate that the maximum acceptable response time from input of coordinates to their display is 0.20 seconds (Engle and Granda, 1975).

6.3.2 Data Entry

Data entry concerns the ways the user should be able to communicate with the system when entering data. The key to effective data entry is to reduce the amount of information required to be entered by the user to the absolute minimum. The system can predict likely data values and the user can manipulate auxiliary input devices such as a mouse to point to the desired response instead of requiring the user to type the full response wherever possible. The development of standard templates for input of commonly occurring information greatly speeds data entry and reduces user errors. These templates should contain clearly indicated default values for the most commonly occurring cases. Data entry should also permit natural expression of values such as indicating coordinate information using the standard grid specification. The cues or prompts for data entry should contain terminology that is used consistently throughout the entire system and the use of abbreviations should be avoided.

Whenever the user completes an input, the system should provide immediate feedback and not leave the user wondering whether or not his entry has been received. If the input requires extended processing that will not be commensurate with the user's expectations of system response, an indicator should be displayed to communicate to the user that system processing is occurring.

Users will make errors and system software should deal appropriately with incorrect entries. Not only should they incorrect entry be clearly indicated but the user should be provided with explicit guidance on what actions are required and how to abort the current process. The human factors guidelines indicate that the user should be provided with immediate feedback, directional

guidance, and that informative messages should be displayed that pinpoint as close as possible the particular user entry that caused the error (Morland, 1983). An additional consideration is to require confirmation from the user before performing a potentially disastrous operation such as deleting a file to occur. The user should be able to cancel the operation without loss of data and resume the current processing function.

6.4   OUTPUT CAPABILITIES

To fulfill a goal for effective presentation of information to the user, the design of the UCi output capabilities and features must minimize the effort required by the user to scan, perceive, and interpret the myriad data involved in a complex arena like CE functions.

6.4.1   Screen Layout

Screen format and content concern what information is to be placed on the screen, how it is presented, and the physical layout of information appearing on the display. A well-designed screen reflects the needs of its user community and the tasks to be accomplished via use of the system. A well-designed interface allows the user to place everything relevant for accomplishing a particular task on the screen. This section focuses on human considerations in screen design which are oriented towards **simplicity, clarity,** and **understandability.** Important human characteristics to be considered in screen design are:

- **Perception** — the awareness and understanding of the elements on the screen which help establish order and meaning. Eye fixation studies indicate that initially one's eyes usually move to the upper left corner of the display and then quickly move in a clockwise direction. During and following this movement, users are influenced by the symmetrical balance and weight of the titles, graphics, and text of the display. A cluttered or unclear screen creates the requirement that some effort must be expended in learning and understanding what is presented.

- **Memory** — short-term memory is highly susceptible to interference and its contents are quickly replaced by new information. Its capacity is about seven items plus or minus two (Miller, 1956). An important memory consideration, with significant implications for screen design, is the limited ability to recall the significance of many colors and/or symbols.

- **Learning** — a design developed with the intent of minimizing human learning time can accelerate human performance. Learning can be enhanced if it provides complete and prompt feedback.

- **Individual Differences** — the design must permit people with widely varying skill levels to satisfactorily and easily learn to use the system.

One of the biggest problems of screen display design arises when too much information is put on the screen which leads to user confusion and increased error rates. Screens should provide only relevant information because the more information, the greater the competition among screen components for a user's attention. Visual search times will be longer and meaningful patterns more difficult to perceive if the screen floods a person with too much information. Therefore, only information relevant to the user's current need should be displayed and the user should be able to selectively control what information is being displayed at any point in time (Geiselman, et al, 1986, Brown, 1980). The user should be able to control what information is on the screen through such features as scrolling and also be able to eliminate information that is no longer of interest (Brown, 1980 and Martin, 1973).

The layout of the screen should be structured so that the amount of user confusion is reduced. The user's perception of the structure among the different areas and/or objects on the screen can be enhanced by the careful and consistent use of a variety of techniques including different intensity levels, colors, numbers, and letters. Specific areas of the screen should be designated for certain kinds of information, such as menu options, input fields, status

information, etc., and these areas should be maintained consistently on all screens.

6.4.1.1   Windows.   One of the most popular techniques to manage the information overflow problems of screen displays is the use of windows. Windows permit the simultaneously display of two or more sets of information on a single display screen.   Each window is usually (but not always) delimited by a border which separates it from the rest of the data on the screen.   The major benefit of the capability to display multiple windows on a display screen is the reduction of the load placed on the limited cognitive resources of users, particularly short-term memory.   Reducing this load would free these cognitive resources for other tasks.   The following kinds of tasks derive the most benefit from a windowing capability:

- The display of supplemental information relevant to the user's primary task — e.g., help messages. Typically, Help messages result in a totally new display screen overwriting the primary screen, thereby forcing the user to remember the situation requiring assistance (which is no longer displayed). Similarly, the user must remember the help message since once the user returns to the primary task, the help message is done. Alternatively, Help can be displayed in a separate window which can be viewed simultaneously with the primary screen.

- Monitoring changes. For example, the user can modify data in one window and then have the result immediately reflected in a graph displayed in another window.

6.4.1.2   Display Features.   Contrasting display features (e.g., different intensities and character sizes, blinking, reverse images, color, etc.) can be used to draw attention to different screen components, items being processed, and urgent items.   However, these features should be used in moderation since their overuse is very distracting to the user.   Blinking is excellent for attention-attracting.   However, it reduces legibility and is distracting.   Its use should be limited to situations where a user must respond quickly and it should be turned off as soon as the user has responded (Smith and Goodwin, 1971).   It is also

recommended that instead of blinking a message (which will make the message difficult to read), an adjacent symbol should be blinked instead. This would assist the user in remembering which parameters were changed. Inverse video is good for attention-getting but it also reduces legibility. It should be used with discretion mainly to call attention to errors or important screen components. Its use to highlight an individual item as it is selected by the user, such as indicating a menu selection, provides timely and accurate feedback to the user (Engel and Granda, 1975). Inverse video is recommended for error messages, classification markings, indication of special function keys, and menu option prompts.

6.4.1.3 Typeface. For display of text, the use of both upper and lower case letters assist the user's perception. Lower case fonts with initial letter in upper cases should be used wherever possible because this format provides greater legibility (Marcus, 1984). Several studies have found that regular-type text is read significantly faster than text in all capitals because words are perceived by the shape of their outline and not deciphered letter by letter (Brown, et al., 1980). For brief captions, labels, and prompts, all upper case can be used for emphasis but should be used sparingly because their use results in a decrease in reading speed by as much as 13 percent (Marcus, 1982). The font size of the characters should be at minimum 7 by 9 pixels (Vartabedian, 1971) and should use a single typeface such as Roman or Helvetica.

6.4.2   Use of Color
The use of color concerns the methods used for making consistent and effective use of color for differentiating screen components and as an attention-getter. The use of color can assist the user in understanding the logical structure of the data on the screen. As a visual code, it can assist in giving meaning to the data or information displayed, the differentiation between required and optional data, and the indication of incorrect responses. However, color must be used carefully because its use alone will not guarantee improved performance and its misuse may impair performance by distracting the user and

interfering with their handling of information. Since the use of color is attention-getting, it may prove distracting to the user who may notice differences in color, regardless of whether the difference has any meaning. Users also tend to visually group items of the same color in a way that may conflict with the intention of color coding.

The human eye cannot effectively distinguish more than eight colors at one time. In general, the use of color in displays should be limited to between five and seven colors (Murch, 1981). This is based upon the studies done by cognitive scientists demonstrating that humans experience great difficulty in maintaining more than 5-7 elements simultaneously. As the number of colors (in a display) increases, the probability of confusion among colors also increases. The cognitive aspects of remembering the association between a particular color and what it stands for also increases the user's workload and, in turn, increases the time to respond to a specific color. Color meanings should also be consistent with the user's expectations (e.g., red means danger). Another rule of thumb for assigning colors to display features is to avoid the pairing of opponent colors such as red/green, yellow/blue, and black/white. These combinations may produce afterimages that degrade the legibility of other items on the display (Durrett and Trezone, 1982).

Another factor affecting color discrimination is the environment in which the system is to be used. The presence of artificial or natural lighting has an effect on foreground-to-background contrast. Additionally, as illumination decreases the visibility of certain colors also decreases. Therefore the selection of colors should be based on the luminance levels at the workstation.

In conclusion, color should be used mainly to differentiate screen components and fulfill an attention-getting role. If each color is to communicate a specific significance, then the number of colors should be limited to about 6 clearly discriminable colors. Most importantly, the use of color must be consistent in all screen displays. Recommendations for the use of color for the

UCI are ordered so that bright colors emphasize important data and colors lacking brightness are used for less important data.

6.4.3 Graphics

Interactive, high-resolution color graphics are a feasible and cost-effective presentation medium for CETOOLS because of the advancement of computer technology that permit the representation of data in a graphic form that can readily be stored, manipulated, and displayed by computers. Advanced graphics facilities can considerably enhance the communication between the user and the system by providing constant visual feedback to provide guidance to the user and improve the overall quality of the system. Graphic displays not only provide a technique for presenting data but also provide a mechanism by which the complexity of the information can be reduced by making interesting data points, trends, and relationships more apparent. Several research studies have indicated that:

- Spatial and visual information is easier to remember than verbal and textual information (White, 1983).

- Graphical presentations of problem data and solutions result in faster perception of changes from previous results and faster determination of problem solutions (Ives, 1982).

Graphics support the rapid scanning of the implications of a course of action and permit rapid identification of the need for further exploration.

CETOOLS will involve both the dynamic and static display of graphic data. A major problem for the display of information is the large amounts of potentially relevant data that must be examined in order to find the significant information for the user's current problem analysis. Moreover, what is relevant depends on what the CE is currently doing, which could change over time, and what the user is currently interested in. Graphic representations can assist this extraction process by making more apparent interesting data points, trends, and

relationships. The most common method of presenting information graphically uses position and reference shapes (e.g., the x and y axes of a graph) to indicate the value of the data and codes (e.g., color, label, textures) to identify the data. Research indicates that color is a better data identifier than size, angle, or shape; texture codes are better suited for distinguishing the display of several data sets on a combined graph (e.g., dotted/dashed lines); and surface texture is useful for dividing the bars of a bar graph into their component parts (Morse, 1979).

However, graphics must be used carefully to prevent cognitive overload when the user is presented with complex and cluttered graphical displays. Determining the right mix of text and graphics is another area where few guidelines are available for the interface designer. The available guidelines indicate that a consistent graphic vocabulary is necessary and that legibility and readability require the careful use of color, symbols, and typefaces (Marcus, 1982).

6.5   USER PROFILES

Typically, each user of a computer system develops a personal methodology for interconnecting seemingly isolated techniques and strategies in using a specific system. Over time the user develops a great deal of problem-specific declarative and procedural knowledge and as a result the user becomes proficient in operating that particular system. During an individual's tenure in a specific position, he or she is exposed to various computer systems. The time and effort spent to learn a new system can be significant. The learning phase is not productive and can be considered "lost" time. If the "time to learn" could be reduced to a reasonably short amount of time, the "lost" time would be negligible and the user would be able to benefit more quickly from the system. Each user will also be applying the system to the needs of a particular organizational level. A CE oriented towards the developing an engineer plan for an airborne entity will probably have a different focus than a person oriented towards land-based entities. Since CETOOLS will be applicable to all CE's, it is

important for it to include a capability to communicate with the user using a unique terminology applicable to the user's needs. For these reasons, it is recommended that CETOOLS include the capability to construct a user profile. The user profile module will be a tool designed to capture user preferences, store them, represent them, and permit the user to interact with CETOOLS in a customized manner that accommodates that particular user's knowledge rather than being restricted by system defined commands and protocols.

This user profile capability will permit a computer user to tailor the CETOOLS interface by allowing the user to specify the terms used for communicating with CETOOLS using his/her particular jargon. This tailoring tool would also significantly reduce the training time required and therefore reduce the cost associated with training. For novice users, user profiles can assist in eliminating computer anxiety so that the individual will be willing to learn a new system rather than expend time and effort avoiding it. For the expert user, it will allow them to use their personal preferences in constructing their user protocol which will result in increased productivity.

Once the issues that need to be addressed to initially construct the user profile have been resolved, the potential techniques employed to cause the system to recognize a particular user and then load the user's profile into the system's working memory will need to be explored. Issues concerning maintaining, updating, and reconfiguring a user profile, once it has been initialized, will require investigation with regard to the various functions of the operating systems, the issues of compatibility, usability, and portability.

There are a few techniques currently available that allow a user to define system commands through the use of personal preference, such as macro and command files. However, such files are awkward to construct and may not be obvious to the infrequent or inexperienced user. Since many users do not possess a programming background, a criterion level of understanding needs to be established and then the degree of user control can be

investigated. In addition, other variables, such as hardware limitations, may affect the degree of user freedom possible, and therefore, factors such as these need to be examined.

7.0 CETOOLS SYSTEM

The primary focus of CETOOLS is to support the Combat Engineer's decision making process and provide the necessary information that is required to develop the engineer plan. In the sections which follow, the high-level system design of CETOOLS will be presented, the major system modules described, and an example of the application of CETOOLS to a hypothetical operational situation.

7.1 HIGH-LEVEL DESIGN

The major functional components of CETOOL are presented in Figure 7-1. System responsibilities are divided between these software modules as follows:

- **CONTROLLER** — controls activity of all other system components and directs human-computer interactions.

- **DATA MANAGER** — manages the knowledge and data bases.

- **MEDIATOR** — manages all human/computer interface processes, including dialogue, keyboard, mouse, and digitizing inputs, windowing, graphics, and formatting of data outputs.

- **DECIDER** — manages decision support capabilities.

- **DRAWER** — manages graphics knowledge and display capabilities.

Each of these primary modules will be configured independently for maximum system flexibility. For example, the use of a different computer display system will only require code modification to MEDIATOR. Likewise, incorporating a
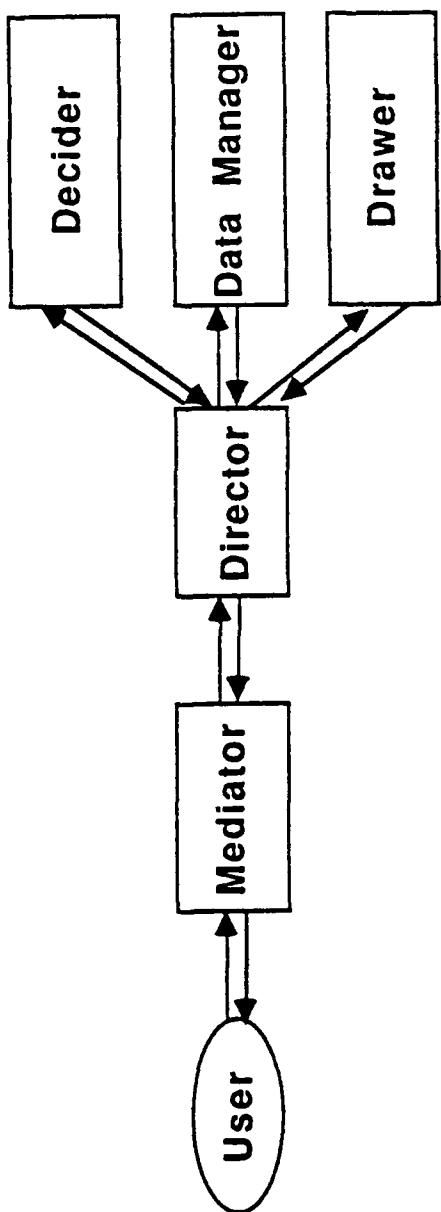
Figure 7-1. Block Diagram of CETOOLS System Organization

new data or knowledge base will only require modification to DATA MANAGER. This approach will enhance both portability and the flexibility for CETOOLS to incorporate changes necessitated by the dynamic nature of the CE function, equipment, and methodology.

With the exception of DRAWER, the components of CETOOLS are clearly feasible in the microcomputer environment. Window, graphics, and mouse interfaces are now available for microcomputer hardware configurations. Data base, knowledge base, and decision support systems are also becoming commonplace. However, it is not immediately obvious that it is feasible to develop a microcomputer-based system which can rapidly respond (i.e., seconds) to a request to graphically depict a situation and can display it with the necessary resolution. As part of the Phase II effort, various approaches for generating the graphics component of CETOOLS will be developed and evaluated.

7.1.1   DECIDER

In developing solutions to complex problems, it is generally necessary to develop a hybrid system that combines the best of several techniques. CETOOLS will incorporate a multiple-analysis architecture to support decision making that will utilize a combination of algorithmic and heuristic techniques since it is doubtful if a single **best** technique can be identified that would provide the optimal solution for all cases. The DECIDER capabilities will incorporate a variety of techniques based upon their suitability both for providing decision-aiding support to the Combat Engineer but also for their ability to produce accurate results within a reasonable time period. CETOOLS differs from traditional applications of artificial intelligence, decision-aids, and expert systems in that it is significantly constrained by time; by the fact that it must operate in the real world and not a laboratory where specialized workstations are available that provide very sophisticated computing power and interfaces; by the dynamic nature of real world situations where situation information is continually changing; and by the demands of the Combat

Engineer's assignments where multiple and often-times conflicting tasks are made upon the available time.

It should be apparent that CETOOLS is not intended to simply supply a single answer to a single question. CETOOLS is a workbench environment for the Combat Engineer. The CE user must be involved in the analysis process and ultimately make the decision about the engineering plan for a mission The system provides a tool to support the decision making process based on historical records, standard engineering practices, and knowledge base rules about the planning process. The system will have more knowledge and data available than any single Combat Engineer and will in that sense be a superior DECIDER. However, the system will only capture part of the human expertise involved in the planning process and must therefore be provided with an interface which will allow it to function as part of a human/machine planning team.

7.1.2 MEDIATOR

Since the CETOOLS interface is dependent on both user characteristics and the exact nature of the planning process, which will only be specified during the course of knowledge engineering in a Phase II effort, it is premature to present an interface design at this stage of development. However, since the intent is to rely on rapid prototyping, it is possible to present a plausible first-cut configuration which could be constructed quickly, given a reasonable development environment. Traditional applications of AI, expert systems, and decision support systems rarely are constrained by time requirements and typically use question and answer dialogues to ascertain the necessary information. CETOCLS will use a series of input templates to obtain the necessary parameters from the templates and the UCI will be tailored to allow the Combat Engineer to speedily and accurately supply this information. The CE will also be provided with the capability to specify necessary information in **both** text and graphics form depending upon the CE's particular view of the optimal method for his data entry tasks. The time constraint in which

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the CE is working also impacts the formats in which the results are displayed. The results of any analysis must be presented in a manner that facilitates the ability of the Combat Engineer to rapidly understand the results and to quickly evaluate multiple inferences and options.

Graphics are also an integral part of the CE's decision-making process. However, the overuse of graphics tend to negatively impact the ability of a user to quickly infer the needed information from a display and result in cognitive overload. Recent studies (e.g., Geiselman, Landee-Thompson, and Samet, 1986) suggest that information can more readily be assimilated if the information is split into logical groups and the user is provided with the ability to selectively indicate which information is to be displayed at any point in time. Therefore, CETOOLS will provide a display option capability to permit the user to control the contents of the display.

Section 7.2 illustrates the initial design of the user-computer interface for CETOOLS

7.1.3 DATA MANAGER

The DATA MANAGER module will control access to all system data. The representation of knowledge is the heart of any decision support system and refers to employment of explicit symbolic representation of the information in its domain of concern. The successful operation of CETOOLS requires several information components including combat engineering practices, "rules of thumb", terrain data, OPFOR knowledge, user knowledge, etc. In order to process these different information sources, CETOOLS will include both database software and knowledge base software. A knowledge base is distinct from a database in that a knowledge base represents not just data but also representations (e.g., rules) that use the data as a basic for decision-making.
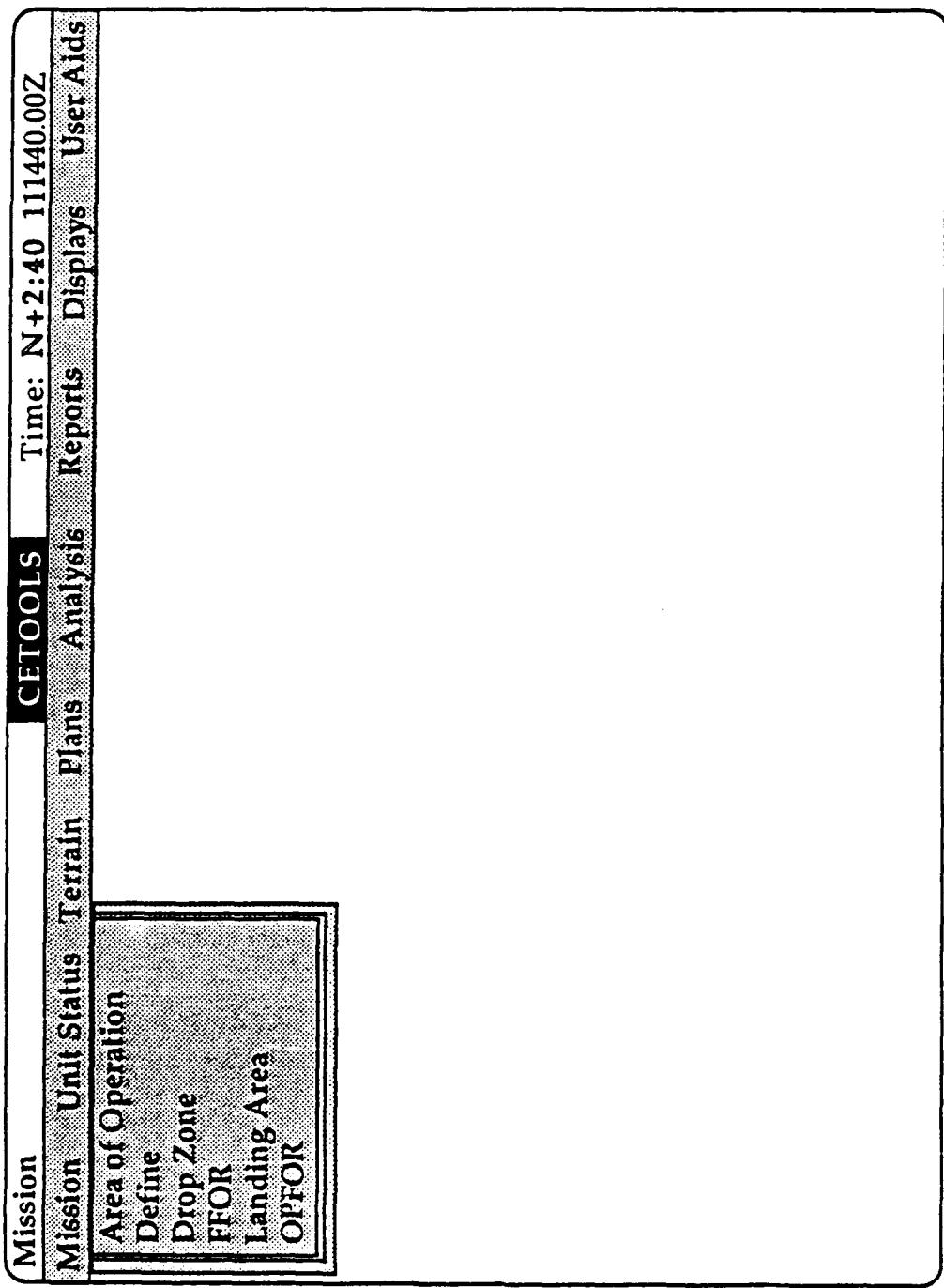
Figure 7-2. Mission Pull-Down Menu

CETOOLS databases about historical OPFOR data, available resources, and geographical data will utilize standard database management technology. The attributes required to characterize this data can easily be arranged in table format with rows representing components and columns representing their attributes. This structure can be readily accommodated using standard database management systems (probably of the relational type). The technology driving this aspect of DATA MANAGER is well understood and readily available in "off-the-shelf" software packages.

Combat Engineer knowledge, operational capability knowledge, and tactical knowledge require a totally different management technique. The knowledge bases will contain the kind of information required by CETOOLS concerning engineering "rules-of-thumb" and OPFOR characteristics, and how that information needs to be encoded. The knowledge bases will also contain information concerning the user which will be required for user profiling and the intelligent dialog aspects of the system. The knowledge scheme developed for CETOOLS must be capable of representing the full range of knowledge required by the system, be easy to use, and provide the flexibility to be applicable to a wide variety of applications. Research in knowledge-based systems has identified several major types of knowledge representation (KR) techniques which are summarized below.

7.1.3.1   Procedural Representation. In a procedural representation, relevant knowledge is embodied in "procedures," i.e., subroutines that can do specific things in well-specified situations. Procedural representations have the advantage of capturing a large amount of knowledge. including heuristics, economically. On the other hand, the "big picture" may be lost and the underlying knowledge is not easily retrievable or modifiable.

7.1.3.2   Semantic Nets. A semantic net represents objects, concepts, and events as nodes in a network, and the interrelationships between them as links and are based upon the concept formulated by Woods (1975). The nodes can

be linked either through memberships in class (the "is-a" concept) or as a sub-property of another node (the "has-a" concept). Semantic nets provide a very flexible structure and additional nodes and links can be added at any point. The semantic net is most useful to represent relationships between objects. The "is-a" and "has-a" relationships permit an inheritance capability such that any characteristics altered in an node can be automatically carried through another node. However, a major problem with the semantic net for knowledge representation is that a given net may have several interpretations and a given meaning may be reflected in several different nets.

7.1.3.3 <u>Frames and Scripts</u>. Frames and scripts, based upon the ideas on Minsky (1975), are techniques used to represent the sequence of events and properties that <u>typically</u> occur in a given situation in an organized fashion. A <u>frame</u> is a knowledge representation structure in which new data is interpreted in terms of previous experience. A frame has <u>slots</u> to represent all the attributes of interest. Slots can contain factual, descriptive, or procedural information. Slots can also represent another frame so that an inheritance hierarchy is established (i.e., lower level frames inherit knowledge about the associated higher level frames). Most frame techniques for knowledge representation also incorporate provisions for generic frames to be established for various object types. Frames have the capability to represent a great complexity of information and are a very active current research area. Some of the important unresolved frame-related issues are control issues, such as determining the appropriateness of a given frame and selecting a second frame if the first is not appropriate.

Scripts may be viewed as a special class of frames in that scripts embody a large amount of previous knowledge in "typical" situation representations. Scripts are specifically designed to represent knowledge about <u>events</u>; a normal or default sequence is represented as well as possible exceptions or errors. As with frames, there are procedural attachments with scripts.

7.1.3.4 <u>Production Rules</u>. Production rule knowledge representation schemes are based upon conditional statements that specify an action that is to occur under a certain set of enabling conditions. The rules are generally stated as two-part statements in the form: "If this premise is true, then perform this action or make this conclusion." Each rule is evaluated and when the current condition matches the premise stated in the IF rule (i.e., the condition is TRUE), then the indicated action is performed. Such rules permit explanation of system conclusions as a sequence of logical steps. Production rule techniques are most useful for presenting procedural knowledge, i.e., methods for accomplishing goals. Frequently, production rule techniques also incorporate forward and backward chaining rules and a pattern-matching capability. Forward chaining matches rules against facts to formulate new facts; backward chaining attempts to prove a new rule by determining what facts are required. Pattern-matching utilizes complex algorithms to formulate decisions based upon the best match to current conditions. Rule-based knowledge representation techniques have become dominant in current expert systems development. However, production rules become unwieldy and difficult to manage as the number of rules increase since rules can be added that conflict with previous specified rules.

A production rule system is the probably the appropriate form of knowledge representation for CETOOLS. Such a system can easily capture both the relationships between data items and the relationships between data and required actions. Unlike procedural representation, production rule representation is also consistent with a rapid prototyping approach to development since a rule base can be continuously modified in an efficient manner. The exact combination of knowledge representation schemes to be used for CETOOLS will be determined as part of the Phase II effort.

Information encoded for use by DATA MANAGER will derive from several sources. System knowledge of combat engineering heuristics must be incorporated into the basic structure of CETOOLS. The knowledge itself must

be elicited from Combat Engineer experts during the course of system development. Historical and geographic data may be entered by users as part of the installation process, making the system immediately usable for estimation, or built up over time by the entry of data. Part of the Phase II effort will be to determine the attributes that will be required by the DECIDER decision-aiding process. Profiling information is specific to a single user, but it is expected that the acquisition of this data will occur during system use and be largely transparent to the user, as noted in the discussion of MEDIATOR.

7.1.4   CONTROLLER

As its name implies, the CONTROLLER module of CETOOLS will control the flow of information between the MEDIATOR, DECIDER, DRAWER, and DATA MANAGER modules. It will decide what needs to be done, when it will be done, and who (what module) has to do it. All interactions between the other modules will flow through the CONTROLLER; this will facilitate both system implementation and system enhancement by keeping the functions of each module well defined.

CONTROLLER will have the same basic use to CETOOLS that an operating system has to a computer program; it will control all of the aspects of the system, while allowing the other modules to perform their own functions. It will contain the access paths to the "overhead" types of functions that each module will need, either y directly controlling the process or by calling on another module to do so. This design strategy will enable the components of CETOOLS to be developed separately with a minimum of integration headaches when the system is connected.

7.1.5   DRAWER

DRAWER will manage the presentati : of graphics information. It will be developed, as much as possible, to be device independent and to utilize software based upon one of the graphic standards such as Graphical Kernel

System (GKS) which is the proposed ANSI standard for interactive two-dimensional graphics. DRAWER will be designed and developed so that it can be integrated with proposed systems that will be available in the future, such as the Digital Topographical Support System (DTSS) which also utilizes GKS.

7.2   CETOOLS INTERACTIONS

In the paragraphs which follow, one simple interaction sequence is presented which integrates many of the interface technology options discussed in Section 6. It does not represent a final design, but rather a potential starting point. Appendix B presents a first cut User-Computer Interface (UCI) design specification that describes in detail the various components of the UCI. The exact nature of the UCI is closely coupled to the particular hardware and software environment selected for implementation of CETOOLS. The terminology used throughout the remainder of this section is based upon the descriptions of the UCI components described in Appendix B. The example presented in this section illustrates the procedures the Combat Engineer would follow in order to develop a plan for the operational scenario described in Section 7.2.1.

The CETOOLS user dialogue is based upon the concept of "selection not entry" where the user is presented with a list of menu or input template options and selects the desired one with the mouse instead of keying a command name or character string. Since the user is always presented with a list of the available choices, the user is not required to remember the exact set of commands or syntax available nor the current spelling of the identifiers. The experienced user will be provided with the capability to override the use of the mouse and enter desired information directly from the keyboard as desired.

7.2.1   CETOOLS Dialogues

The UCI dialogue consists of the following components:

- •.   **Menu Bar** — a list of available options displayed on a line at the top of the screen.

- •   **Pull-Down Menus** — a submenu which is shown in a separate window displayed beneath the menu bar containing the list of commands available for a particular selection from the menu bar.

- •   **Input Templates** — forms containing all the data items and clearly indicated default values required to specify simulation data.

- •   **Status Bar** — a informati‍ line displayed on the bottom of the screen indicating the cu..ent CETOOLS functions and time information.

These items are described in more detail in Appendix B.

When the user first enters CETOOLS, a menu bar appears at the top of the screen (see Figure 7-2). The UCI closely follows the Macintosh style of interface. The menu bar remains in place throughout a session. Control between the various CETOOLS modules is accomplished through the options presented on the menu bar. Menu-bar selections are made by moving the mouse cursor over the label of interest and holding down the mouse button. A pull-down menu then appears in a box drawn in a separate screen window positioned directly beneath the title of the selected menu bar option. The pull-down menu contains a list of the names of the available commands. While holding down the mouse button, the user moves the pointer to the desired choice. As the pointer moves to each option, the command is highlighted. The command that is highlighted when the user releases the mouse button is invoked, and the pull-down menu window disappears. The selected command may present additional menus or input templates or perform the selected task if all necessary information is available. These submenus present only a short list

of the commands that are applicable for the selected operation and thereby avoid confusing the user with massive, largely irrelevant lists of possibilities The pull-down menu lists are arranged so that the commands are arranged alphabetically. Any command that is not available to the user for the particular menu option at the current time is shown in a lighter font, and the user is not allowed to choose them.

The menu bar also contains an User Aids option that will provide the user with the capability to obtain guidance and help messages about system usage and view/modify basic system parameters such as units of measurement (English or Metric), time (local area, objective area, or zulu), graphic parameters (e.g., grid size), and user profiling (e.g., color coding). It also provides utility functions to review and modify information in CETOOLS data bases.

In order to maximize the flexibility of the system and provide the ability of the user to tailor it to their needs, the information displayed on each screen will be controlled through DATA MANAGER with display information contained in both the data and knowledge bases depending upon the nature of the display. For example, the data base elements used to define equipment may consist of the following: equipment type, authorized, on-hand, bumper number, current location, and weight. Associated with each element will be a flag for each display associated with equipment to indicate whether that piece of information should be included. For example, these elements could be defined so that the unit status display includes only the equipment type, authorized, and on-hand elements while the marshalling analysis display would include equipment type and location. The utility command provided under the User Aids option would allow the user to easily access these flags to modify the elements to be included for a particular display. This type of capability alleviates the need for software modification whenever the user information requirements change and access is needed to different types of information that is included in the CETOOLS knowledge and data bases.

Input templates are used for the specification of a group of related information. They are mainly used for supplying additional information required before a system command can be processed. The following techniques are used to request necessary inputs:

- **Check Boxes** — square boxes which allow the user to check the desired attribute options. More than one option box can be checked for a particular attribute. The option is on if the box is checked; otherwise it is off. The check boxes appearing together on an attribute line are independent of each other; any number of them can be off and/or on.

- **Radio Buttons** — circles which force the user to select only one of the options available for a particular attribute. A circle is filled in with a smaller black circle when the value is selected. Radio buttons occur in groups, and at any given time, only one button in the group is on. Selecting one button in a group automatically turns off the button that is currently on.

- **Text Entry Boxes** — rectangular boxes which allow the user to enter textual data (numeric or alphanumeric), with the size of the box indicating the maximum number of characters permitted.

7.2.2 CETOOLS Input Devices

The CETOOLS UCI utilizes three input devices:

- A keyboard to enter alphanumeric text and numeric data,

- A mouse to specify menu options, controlling the cursor, selecting information, manipulating graphic information, and specifying insertion points, and

- A graphics tablet to enter graphic information such as terrain features.

The user controls which of these input devices is used at any point in time. For example, to specify graphic information, either the mouse or the graphics tablet

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can be utilized. However, the use of the graphics tablet provides more precision. It is up to the user to decide which device is appropriate for the task at hand.

7.2.3   CETOOLS Usage

An overview of the CE planning process is illustrated in Figure 7-3 with the functions to be provided by CETOOLS distinguished by a gray background. A hierarchical task decomposition analysis was performed to identify the functional groupings required for CETOOLS in order to provide a structure for the planning process. The CETOOLS menu bar contains an entry for each of the major system functions as described below:

- **Mission** — defines the mission objectives.

- **Unit Status** — supplied information about the assets available to the unit .

- **Terrain** — defines terrain information.

- **Plans** — develops and refines all aspects of the engineering plan.

- **Analysis** — evaluates the developed plans and indicates any problems.

- **Reports** — generates the reports required to present and implement the plan.

- **Displays** — specifies the type of graphical representations to be included on the display.

- **User Aids** — provides the ability to change basic system parameters such as measurement units, time format, define map features such as grid spacing, print selected information, obtain additional help, and set system parameters.
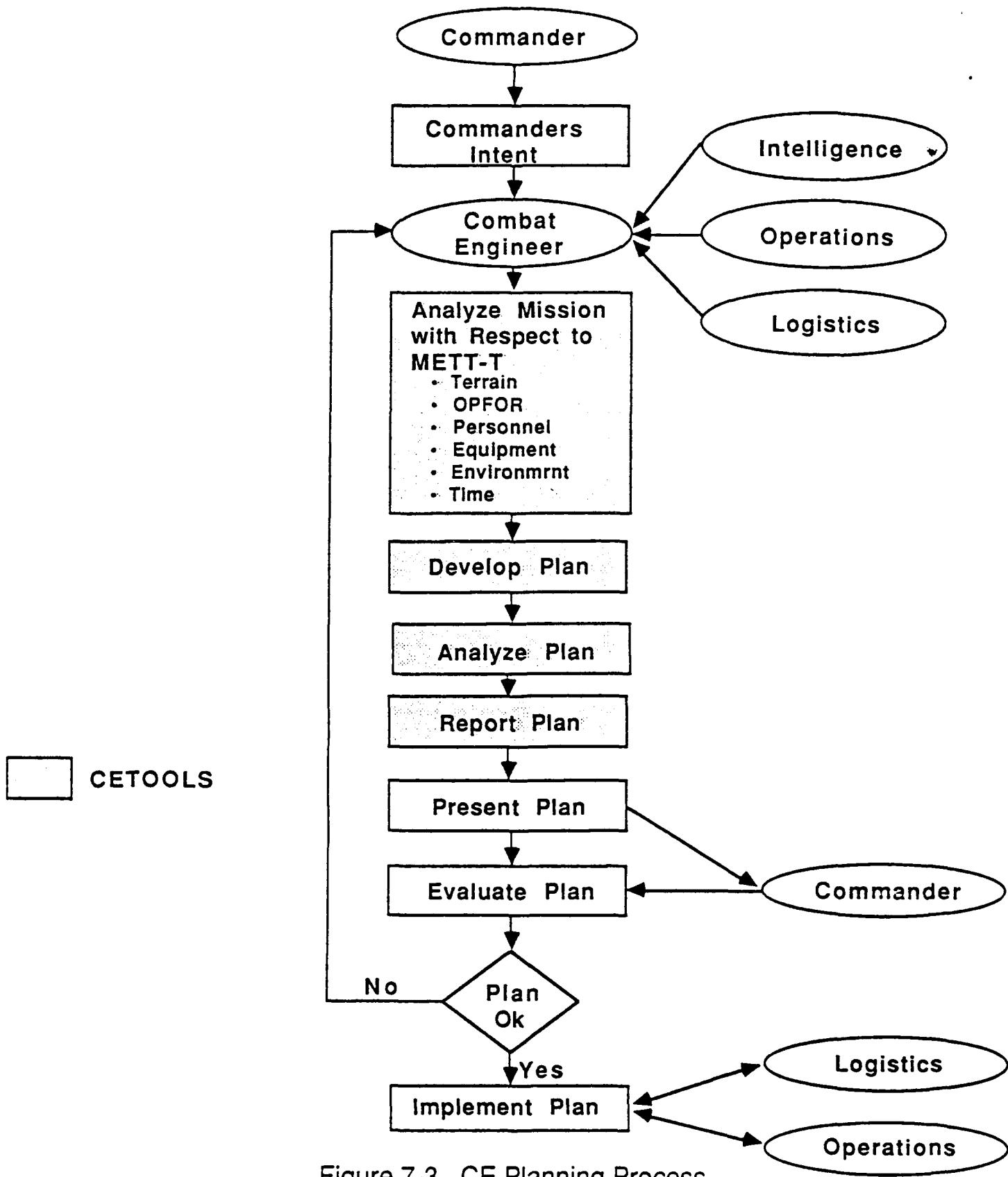
Figure 7-3. CE Planning Process

- **Files** — provides general system features such as indicating which data and knowledge bases are to be used, defining output medium and parameters, and terminating CETOOLS.

7.3   CETOOLS EXAMPLE

This section illustrates how the ABE could use CETOOLS to develop an engineering plan for a hypothetical operational scenario. The following discussion suggests the general approaches that will be used to develop the engineer plan but the exact details of the techniques to be used will be developed as part of the Phase II effort.

7.3.1   Operational Scenario

Forces of the radical Islamic regime of Amiran are massing along the border of the strategically important US ally, Dromar. Amiran has long been supporting the Islamic Revolutionary Front (IRF), a guerilla movement in the north of Dromar. Recently, Dromarian forces began an offensive against the guerilias which has been highly successful and has threatened the IRF with complete annihilation. In a show of support for the IRF, the government of Amiran has brought its forces to full alert and has positioned some within five kilometers of the border. Dromarian forces are both qualitatively and quantitatively inferior to those of Amiran and have therefore requested US support.

The National Command Authority has decided to commit US ground forces to the region in a show of force designed to intimidate Amiran and, if necessary, prevent them from seizing control of the Dromarian oil fields. The JCS warning order was issued at 0930 13 May. At 0300 15 May, a "redline" message alerted all units in the 82nd Airborne Division at Fort Bragg, North Carolina. The division ready brigade (DRB) was the 3rd Brigade (505th Airborne Infantry Regiment) support by C Company of the 307th Engineer Battalion. The following scenario depicts the complex series of interactions that occur when planning engineer support to an airborne operation.

Key leaders from the division assemble at Division headquarters to receive a mission and situation briefing from the Commanding general and his staff. Among these key leaders are the commander of the 307th and the Assistant Division Engineer. The Assistant Brigade Engineer (Company Commander for C Company) does not attend this initial briefing, but reports to the 3rd Brigade headquarters and reports that the engineer company is 100% assembled. At N + 2:30, the 3rd Brigade commander and his staff assemble at the Brigade headquarters to develop the ground tactical plan. This process is simultaneously occurring at the DRF1, DRF2, and the DRF3. The mission of the 3rd Brigade is stated as follows:

> "3rd Brigade will conduct a parachute assault in the vicinity of Nawa (BS2343), secure the airstrip for follow-on echelons, linkup with Dromarian government forces, and establish defensive positions along the Northwest - Southeast road in zone."

7.3.2 Mission Definition

Once the mission has been received, the ABE must now interact with each of the staff sections to extract information necessary for developing his contribution to ground tactical plan. The ABE must have the plan completed and approved by N + 6:30. The ABE will first define the basic parameters of the mission by utilizing the **Mission** option including the definition of the various mission phases. The characteristics of the opposing forces and anticipated US response would be obtained from the responsible staff member. The pull-down menu that contains the commands associated with Mission is illustrated in Figure 7-2. To select one of the options (e.g., "Define"), the user places the arrow-shaped mouse cursor over the "Mission" label in the menu-bar, depresses the mouse button ("clicking"), and selects "Define" from the pull-down menu which appears. The user can selectively move between these options and select them at any point during the session. This would allow the user to broadly outline the mission early in the planning process and then return to refine the information as more details and intelligence becomes available. Mission contains the following commands:

- **Area of Operation** — allows the user to define the parameters associated with the geographical area assigned as the area of operation (AO).

- **Define** — allows the user to define the mission phases, tasks, time, location, and indicate the type of engineering support required. The information required to define this information will be a dialog window as illustrated in Figure 7-4. The input template contains text entry boxes for entering the phase and task numbers, start and complete time, grid coordinates, and phase description. ABE support is specified using check boxes with the entry of an X indicating that the item is selected. The user moves the cursor to anywhere within area defined by the box and its associated legend to the right and clicks. If the box will previously blank, an X will appear. As shown in Figure 7-4, the first phase of the mission is the parachute assault and no engineering support is required. The None box is checked to indicate that the ABE reviewed the tasks and decided that no support was required. The user clicks in the Next pushbutton to indicate that an additional phase/task is to be defined and clicks in the OK pushbutton to close the define window.

- **Drop Zone** — allows the user to define the parameters associated with the drop zone (DZ) area upon which airborne troops, equipment, and supplied will be air-dropped.

- **FFOR** — allows the user to define the friendly forces. The input template for defining friendly forces is illustrated in Figure 7-5. The selection of the unit to perform a particular task is accomplished through the use of radio buttons. The black dot in the middle of the circle indicates the current selection. The dot can appear in only one of the options available to the user on an input line. For example, only one of the brigades can be selected at a time. CETOOLS provides a hierarchical capability for unit selection. That is, if a brigade and battalion are specified, all associated companies, platoons, and squads are selected.

- **Landing Area** — allows the user to define the parameters associated with the landing area.

Figure 7-4. Mission - Define Screen

Mission - FFOR

Time: N+2:40 111440.00Z

Mission   Unit Status   Terrain   Plans   Analysis   Reports   Displays   User Aids

Phase: [1]   Task: [0]

Start Time: H + [00:00]   Complete Time: H + [00:15]

Grid Coordinates: BS2343

Brigade: ○ 1st   ○ 2nd   ◉ 3rd

Battalion: ○ 1st   ○ 2nd   ◉ 3rd

Company: ○ A   ○ B   ○ C

Platoon: ○ 1   ○ 2   ○ 3

Squad: ○ 1   ○ 2   ○ 3

Type of Unit: [X] Infantry   [X] Armor   [ ] Artillery

               [ ] Engr Assets [X] AT   [X] Other

Figure 7-5. Mission - Friendly Forces

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• **OPFOR** — allows the user to define the opposing forces. The user will be provided with the ability to select standard templates that represent various opposing forces. The screen illustrated in Figure 7-6 illustrates the selection of the Amiran rifle regiment template. The user can also indicate the map display option so that the template will be placed on the map. The user can then use the mouse to select the OPFOR template and move it to the appropriate location and rescale and orient the template as appropriate. The icons on the left side of the screen can also be used to add additional elements that were not contained in the standard template. The components of the template can also be rearranged by using the mouse to click on a unit and dragging it to a new location on the map grid.

7.3.3   Unit Status

The ABE then accesses the system to review the status of his personnel and resources. In order to review current unit status, the user would select the **Unit Status** option from the menu bar. The pull-down menu that contains the commands associate with Unit Status is illustrated in Figure 7-7. The status template contains a time parameter that can be used to indicate the particular time for which the status information is desired. For example, both the current status plus the estimated status of assets at time N + 18 may be requested. Unit Status contains the following commands:

• **Aircraft** — allows the user to obtain information about available aircraft .

• **Class III** — allows the user to obtain information about available petroleum, oils, and lubricants (POL).

• **Class IV** — allows the user to obtain information about construction and barrier materials.

• **Class V** — allows the user to obtain information about ammunition.

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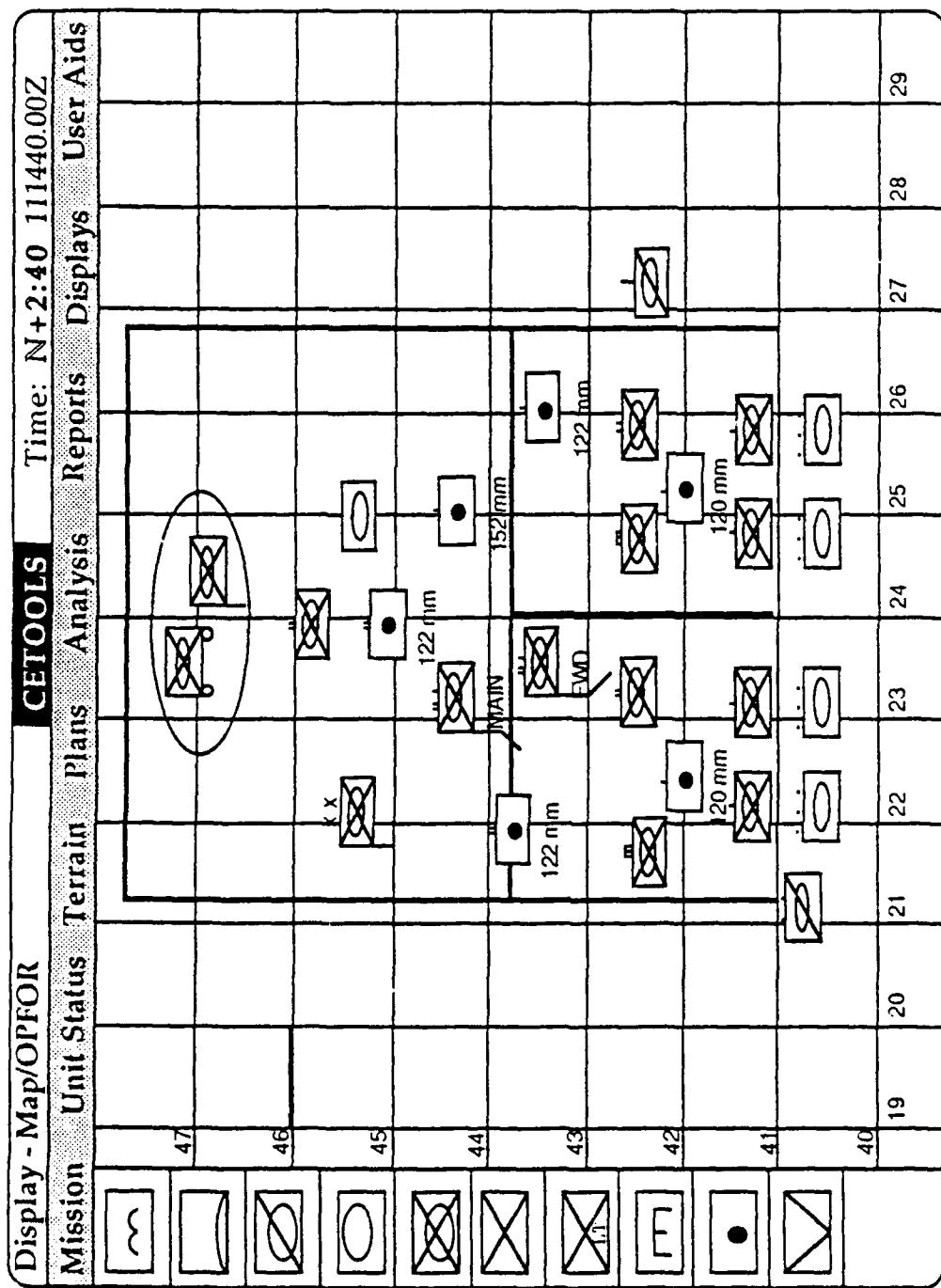
Figure 7-6. OPFOR Display Screen

Unit Status - Equipment | CETOOLS | Time: N+2:40 111440.00Z

Mission Unit Status Terrain Plans Analysis Reports Displays User Aids

Aircraft
Class III
Class IV
Class V
Equipment
Personnel
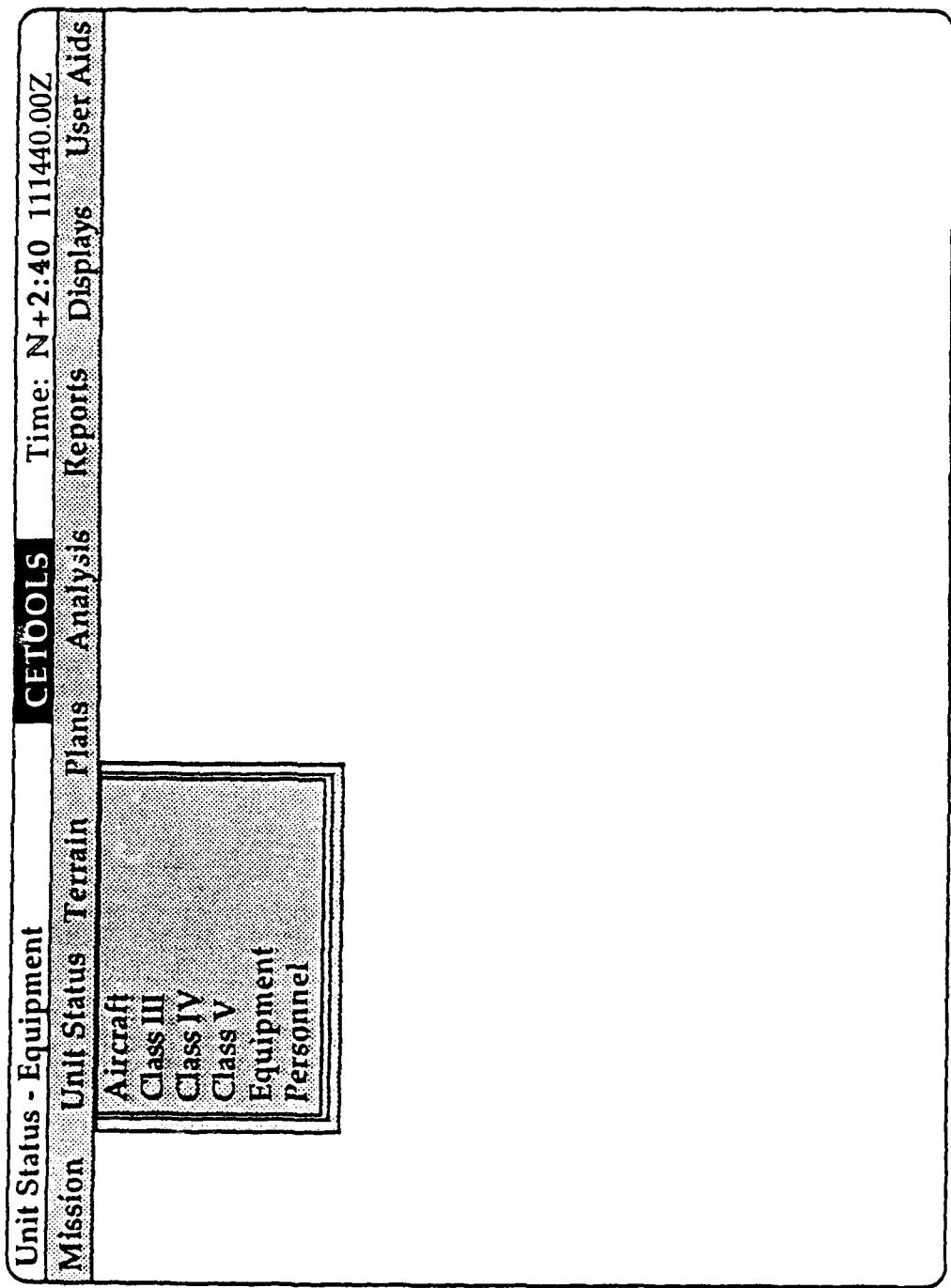
Figure 7-7. Unit Status Pull - Down Menu

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- **Equipment** — allows the user to obtain information about equipment as illustrated in Figure 7-8. The top portion of the screen contains the window to specify time and unit. The unit information is available hierarchically. The authorized and on-hand information for each piece of equipment assigned to the selected unit is displayed along with a difference column. Negative differences will be displayed in red (shown as bold typeface in the figure).

- **Personnel** — allows the user to obtain information about personnel as illustrated in Figure 7-9 The top portion of the screen contains the window to specify time and unit. The unit information is available hierarchically. The authorized and on-hand information for personnel assigned to the selected unit is displayed along with a difference column. Negative differences will be displayed in red (shown as bold typeface in the figure).

7.3.4   Terrain Specification

The next step is for the ABE to confer with the S2 on the terrain to be found at the objective area, determine the status of the airfield at Nawa, and identify key terrain and avenues of approach. The S2 provides the ABE with the following terrain intelligence:

1.   Hills 710 (BS2045) and 635 (BS2345) dominate the highway approach into the area of operations (AO) from the northwest. hill 630 (BS2721) dominates the highway approach into the AO from the southeast as well as cross-country approaches from the east and south. Hills 607 (BS2546), 612 (BS2645), and 629 (BS2843) provide long-range observation and direct fire to the north and east of the AO.

2.   The area lying generally east of Hills 710 and 635 is primarily cultivated and interspersed with scattered clusters of boulders. Cultivated fields are frequently divided by low rows of rocks that local farmers have cleared from their fields. These rows of rocks are irregular in form and length but will provide cover from flat-trajectory fire.

Unit Status - Equipment

| CETOOLS | Time: N+2:40 111440.00Z |

Mission Unit Status Terrain Plans Analysis Reports Displays User Aids

Time: N + 18:00

Brigade: ○ 1st   ○ 2nd   ● 3rd
Battalion: ● 307th ○ 618th
Company: ○ A   ○ B   ● C
Platoon: ○ 1   ○ 2   ○ 3
Squad: ○ 1   ○ 2   ○ 3

Force Package: ○ Light Construction   ● Light Repair

Type	Authorized	On Hand	Difference
Machine Gun, 50 Cal w/Ring & AA Mount	1	1	
Machine Gun, 7.62 mm	2	1	-1
Radio Set, AN/PRC-77	1	1	
Radio Set, AN/VRC-47	1	1	
Radio Set, AN/VRC-64	1	1	
Tractor, Whld Ind (JD 410 Backhoe)	1	1	
Truck, Cargo, 1 1/4 Ton	2	1	-1
Truck, Cargo, 2 1/2 Ton	1	0	-1
Truck, Utility, 1/4 Ton	1	1	
Trailer, Cargo, 1/4 Ton	1	1	
TOTAL	12	9	-3

Figure 7-8. Unit Status - Equipment Screen

Time: N + [18:00]

Brigade: ○ 1st   ○ 2nd   ● 3rd

Battalion: ● 307th   ○ 618th

Company: ○ A   ○ B   ● C

Platoon: ○ 1   ○ 2   ○ 3

Squad: ○ 1   ○ 2   ○ 3

Force Package: ○ Light Construction   ● Light Repair

MOS	Authorized	On Hand	Difference
62N3P	1	1	
62E1P	4	2	-2
62J1P	2	2	
64C1P	2	1	-1
TOTAL	9	6	-3

Figure 7-9. Unit Status - Personnel Screen

3.   Old lava formations on and in the vicinity of hills 630, 607, and 612 restrict tracked and wheeled vehicle movement and provide excellent cover from flat-trajectory fire.

4.   The streambeds that run generally north-south (BS2652—BS3241 and BS3350—BS3241—BS2329) are normally dry and fordable. The steep banks and old lava formations along these streambeds restrict east-west vehicular movement to a few existing crossing sites.

5.   The marsh in the vicinity of BS2554 will not support heavy vehicle traffic.

6.   The area generally west of Hills 710 and 635 is slightly rolling with numerous shallow dry gullies and old lava formations consisting of many large and moderate-size boulders. Cross-country vehicular movement is possible in these areas with moderate-to-extreme difficulty. The streambeds that run generally north-south from BS8051—BS7332 are normally dry. The steep banks and old lava formations along the banks restrict east-west vehicular movement. Numerous depressions and hummocks north and west of Hill 635, combined with old lava formations in the area, make vehicular cross-country movement slow and extremely difficult.

7.   Observation and direct fire are excellent from the hills in the AO. Cover from flat-trajectory weapons is excellent in the old lava formations and numerous clusters of boulders throughout the area. Concealment is fair throughout the area. The major northwest-southeast highway provides the high-speed approaches into the AO. Cross-country movement of vehicles through cultivated areas of the AO is good and is impeded only by occasional clusters of boulders and low rows of rocks separating cultivated fields.

8.   The village of NAWA (BS2343) is populated by an estimated 200 to 300 people who remained behind when their village was overrun by IRF forces. They are expected to be passive and cooperate with US forces when the airborne assault begins. Buildings are generally one-story dwellings constructed of rock and mud bricks.

9.   Sufficient drop zones are available in the area. Landing zones are restricted to the major highway running through the AO.

10. The airfield east of Nawa (BS2443) is an unimproved C-130 capable airstrip. Imagery indicates that recent fighting in the area has damaged the airstrip.

The S2 provides the ABE with the following weather and climate intelligence:

1. **Climate** — Dromar has essentially a two-season climate; winter lasts from November through April and summer lasts from May through October. Precipitation from June through September is negligible.

2. **Temperature** — Temperatures for the period of the airborne operation will range from a daily high in the nineties and low hundreds to a daily low in the sixties.

3. **Prevailing Winds** — Westerly winds are persistent much of the year. The average windspeed during the period of operation is 9 knots. Winds generally reach their maximum speeds in midafternoon with calm winds prevailing in the early morning and early evening hours.

4. **Light Data** — The light table is shown below:

	BMNT	BMCT	SR	SS	EECT	EENT	MR	MS	%
15May	0351	0423	0450	1834	1901	1933	0705	2135	.02
16May	0351	0424	0450	1834	1901	1933	0710	2140	.07
17May	0352	0424	0451	1834	1900	1933	0715	2145	.14
18May	0352	0425	0451	1833	1900	1932	0720	2151	.22

In order to specify terrain and weather information obtained from the S2, the ABE would select the **Terrain** option from the menu bar. The pull-down menu that contains the commands associate with Terrain is illustrated in Figure 7-10. Terrain contains the following commands:

• **Avenue of Approach** — allows the user to specify parameters about the avenue of approach. Figure 7-11 illustrates the screen after the user has defined the avenues of approach and the slow/no-go areas. The icons on the left side of the screen were used to specify these areas. The icons are used to create objects that represent key features. Each object
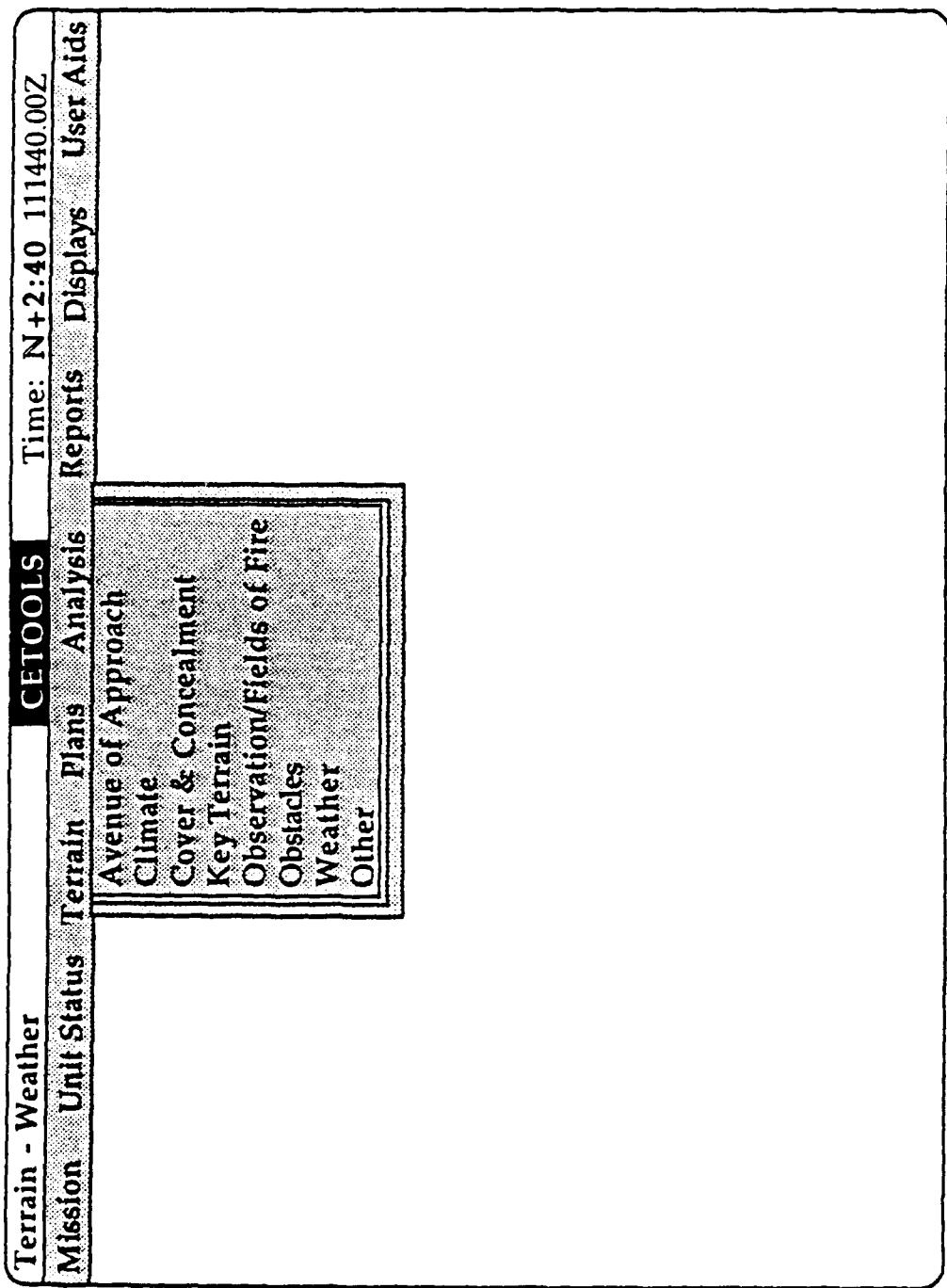
Figure 7-10. Terrain Pull-Down Menus

The menu contents:

Terrain - Weather

Mission | Unit Status | Terrain | Plans | Analysis | CETOOLS | Time: N+2:40 | 111440.00Z | Reports | Displays | User Aids

- Avenue of Approach
- Climate
- Cover & Concealment
- Key Terrain
- Observation/Fields of Fire
- Obstacles
- Weather
- Other
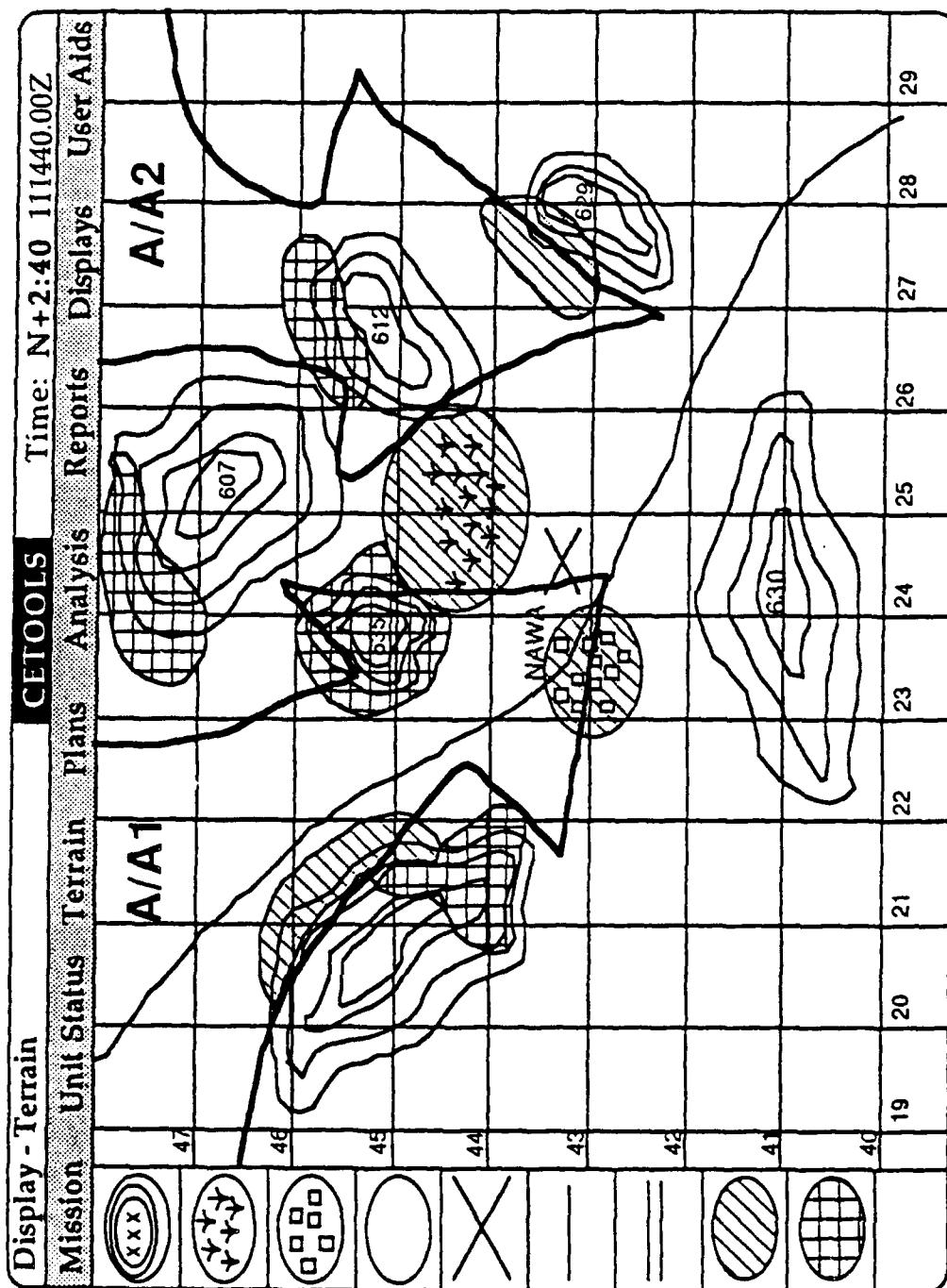
Figure 7-11. Display Terrain With Avenues of Approach

is an independent item that is stored in a CETOOLS data bases. Associated with each object is a set of characteristics that define the features of the object such as size, location, etc. To select one of the icons, the mouse is used to click on the desired icon. Then the mouse is moved to the point on the map where the corner of the object is to be placed. The mouse button is again clicked and the user sketches the desired shape and clicks on the beginning point of the shape automatically closes the shaped and stops the definition procedure for the object. This process would be repeated until all information has been specified.

- **Climate** — allows the user to specify parameters about the climate.

- **Cover and Concealment** — allows the user to specify parameters that affect cover and concealment. .

- **Key Terrain** — allows the user to specify parameters about the key terrain features. Figure 7-12 illustrates the screen after the user has defined key terrain features. The icons on the left side of the screen were used to specify key features as described above. If the object requires additional information, such as the highest elevation point for hills, an input template window will be displayed for the user to enter the necessary data.

- **Observation/Fields of Fire** — allows the user to specify parameters that relate to observation and fields of fire.

- **Obstacles** — allows the user to specify parameters about existing obstacles.

- **Weather** — allows the user to specify parameters about the weather. Figure 7-13 illustrates the input template for the entry of weather information. Text entry boxes are shown for each field of information associated with weather.

- **Other** — allows the user to specify other information which could impact the engineer's plan.
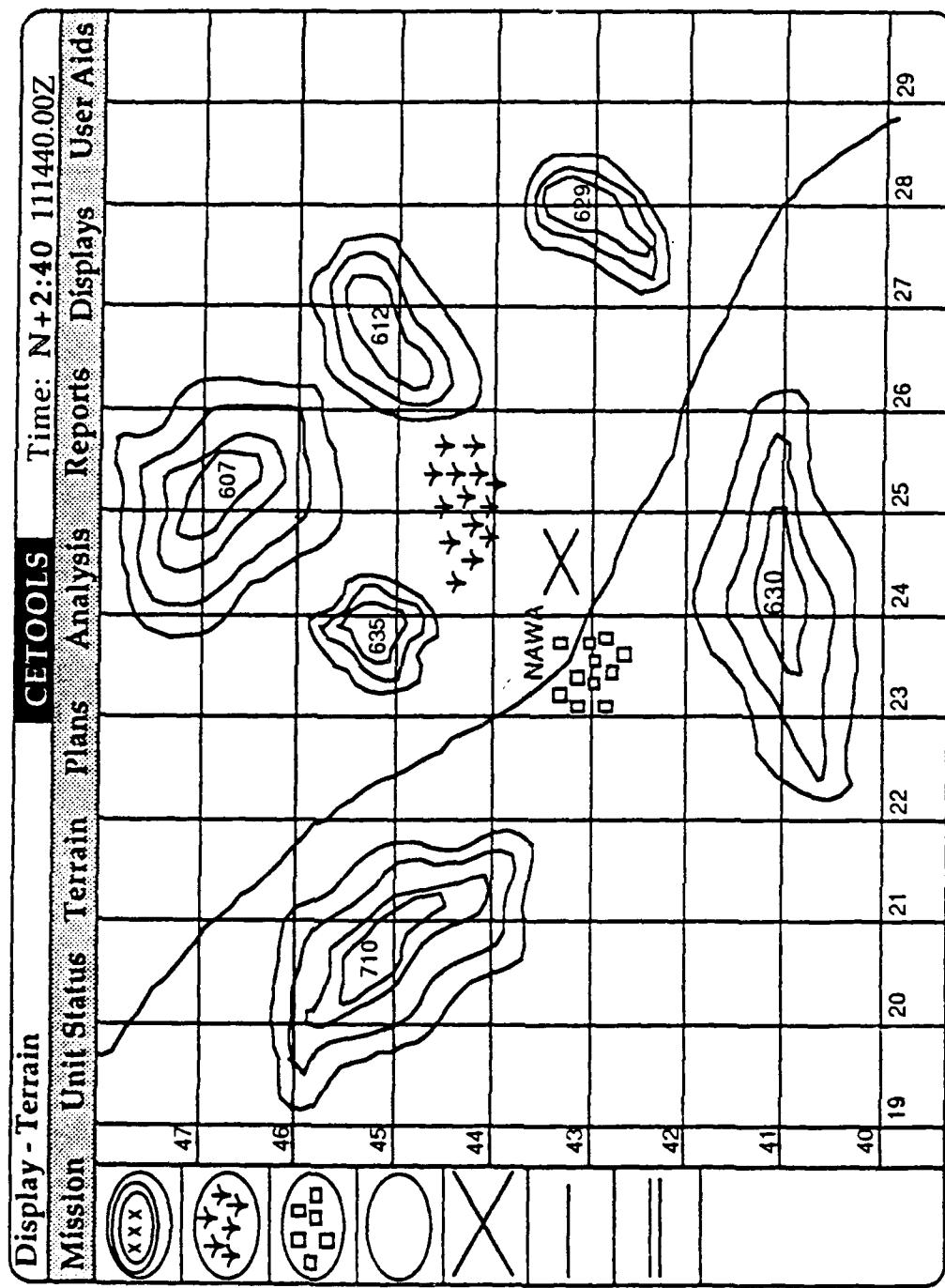
Figure 7-12. Display Terrain Screen

Figure 7-13. Terrain Weather Screen

Terrain - Weather   CETOOLS   Time: N+2:40 11440.00Z

Mission Unit Status Terrain Plans Analysis Reports Displays User Aids

Date: 15May88   Time: H+ [00:00]

Description: Westerly winds are persistent. Average windspeed is 9 knots.
                Max speed in midafternoon with ca. . winds prevailing in early
                morning & evening hours

Temperature: Low: [60]F   High: [100]F

Humidity: [22]%

Intervisibility:

Surface Winds: [9] Knots

Precipitation: [0]%

Snow/Ice cover: [0]%

Winds aloft: [12] Knots

Cloud Data:

Light Data: BMNT: [0351]   BMCT: [0423]   SR: [0450]   SS: [1834]   EECT: [1901]
                EENT: [1933]   MR: [0705]   MS: [2135]   %: [02]

Severe Weather: [0]

Fog: [0]

7-21b

7.3.5   Plan Development

Having specified the available information from the various staff members, the ABE will next initiate the process of sketching out a rudimentary engineering plan. As part of the development of the engineering plan, he will decide how to best integrate it with the ground tactical plan and evaluate various alternatives. As the ABE receives newer information from the various staff members, for example, the operation plan from the S3; he can explore different options for emplacing obstacles to support the anti-armor defense.

The **Plan** option on the menu bar contains a list of the plans that the engineer can develop. Any or all of the plans may be chosen and the planning options can be selected in any order. The pull-down menu that contains the commands associated with Plan is illustrated in Figure 7-14 and contains the following commands:

- **Airfield Repair** — is used to generate the plan required for airfield repair.

- **Air Movement** — is used to generate the air movement plan.

- **Countermobility** — is used to generate the countermobility plan. Figure 7-15 illustrates the screen after the user has defined the initial set of obstacles using the icons on the left side of the screen to specify key features as described above. If the object requires additional information, such as details of an obstacle and personnel/equipment assignments, an input template window will be displayed for the user to enter the necessary data. This is illustrated in Figure 7-16 for obstacle 307XP3001, a strip mine field. The personnel assignment portion of the input template would be used by the ABE to indicate which unit is to emplace the indicated obstacle. The specifications are attached to the object so that the user can also review and/or modify this information about a particular object at any point in time by clicking on the object.

- **Echelonment & Landing** — is used to generate the echelonment and landing plan.

Plan - Countermobility						
CETOOLS			Time: N+2:40 111440.00Z			
Mission	Unit Status	Terrain	Plans	Analysis	Reports	Displays	User Aids

Airfield Repair
Air Movement
Countermobility
Echelonment & Landing
General Engineering
Marshalling
Mobility
Survivability
Other
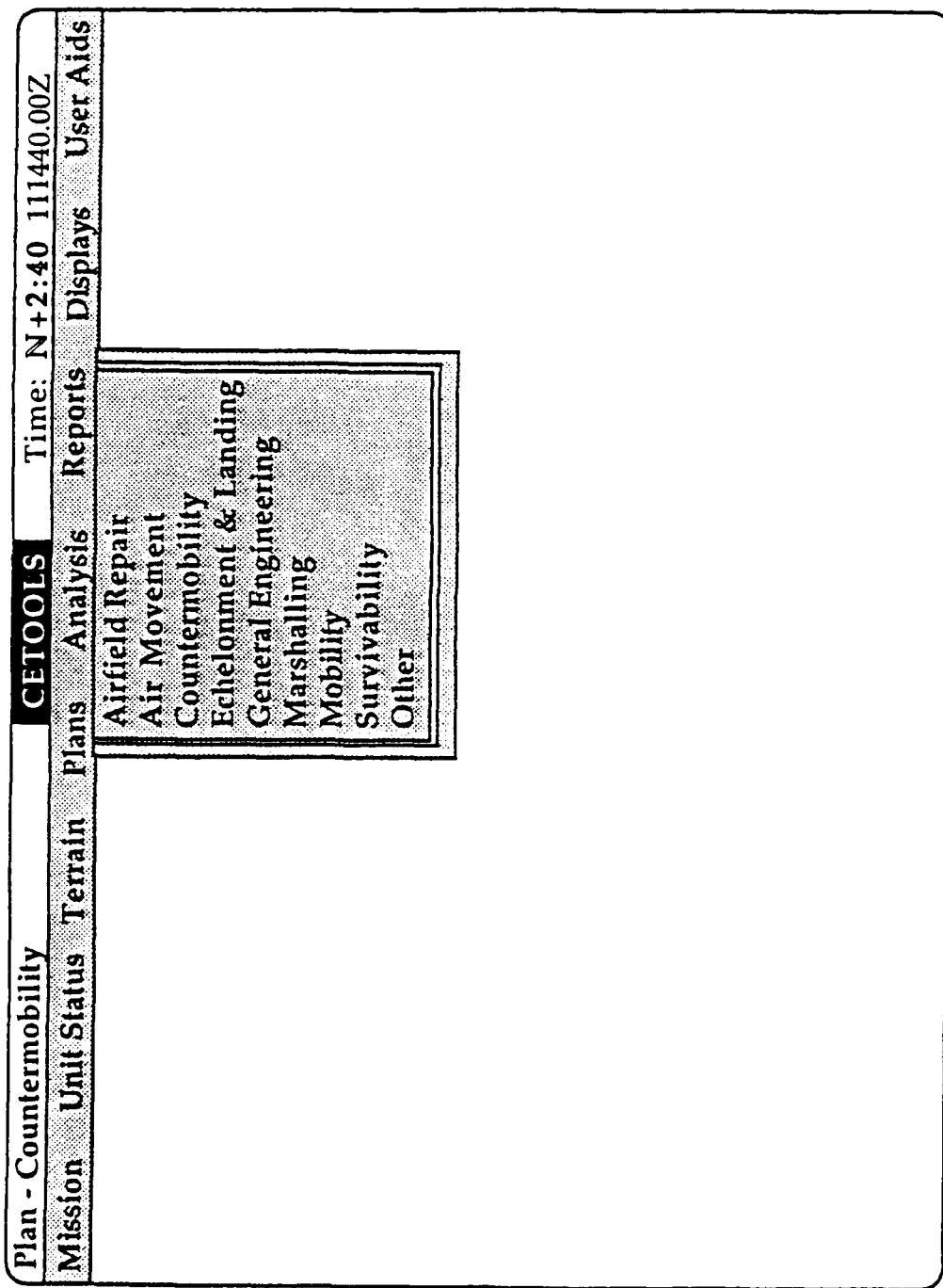
Figure 7-14. Plans Pull-Down Menus
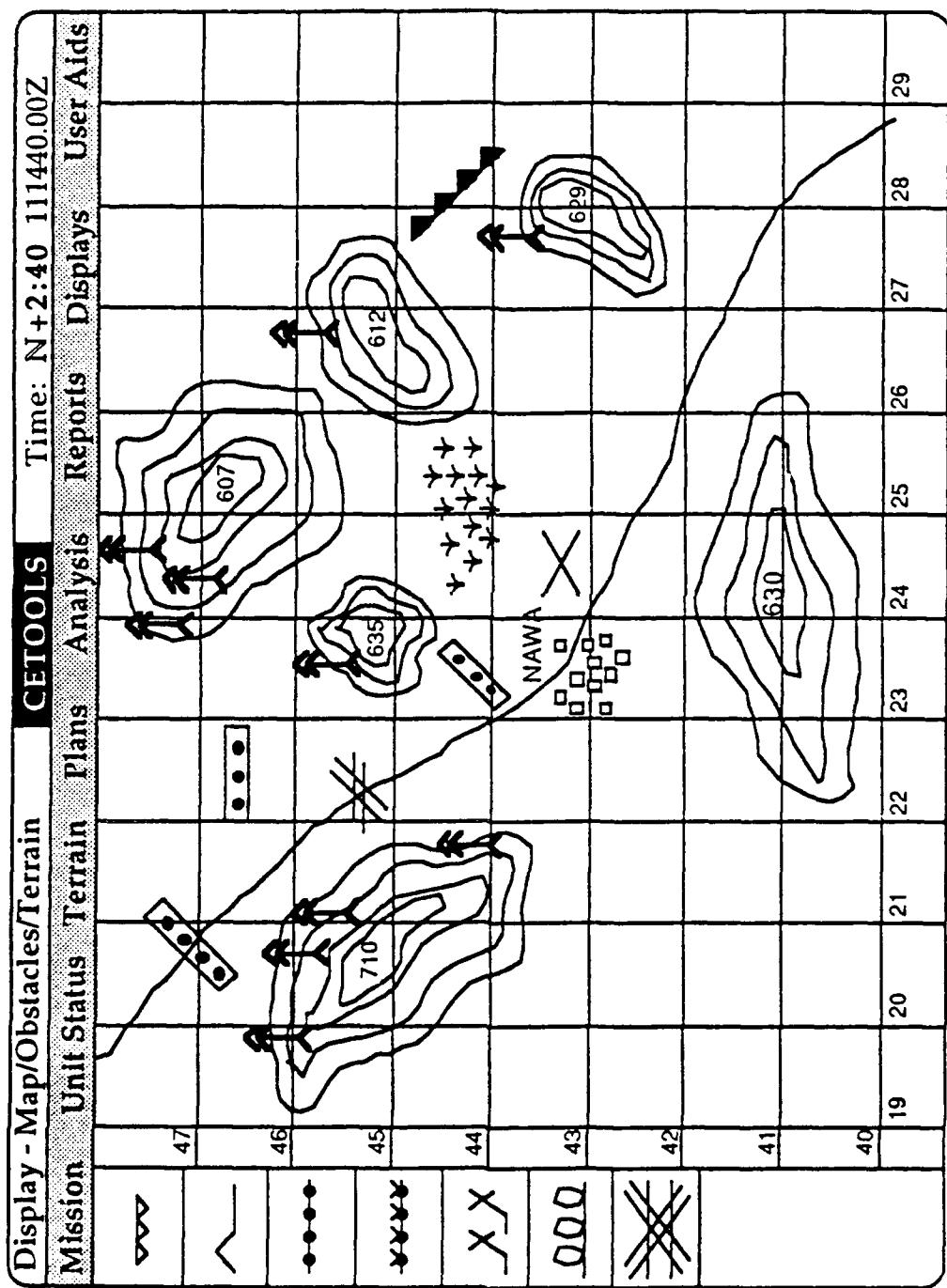
Figure 7-15. Display - Map/Obstacles/Terrains

7-22b

Mission   Unit Status   Terrain   Plans   Analysis   Reports   Displays   User Aids

Phase: 4

Start Time: H + 02:00   Task: 3   Complete Time: H + 10:00

Obstacle: 307XP3001

Grid Coordinates: BS2047   Description: Strip Mine Field

Type: ● Minefield   ○ AT Ditch   ○ Crater   ○ Abatis   ○ Wire

Mine: ● AP   ○ AT   ○ Phony   ○ FASCAM

Length: 100 Meters

Brigade: ○ 1st   ○ 2nd   ○ 3rd

Battalion: ● 307th   ○ 618th

Company: ○ A   ○ B   ● C

Platoon: ● 1   ○ 2   ○ 3

Squad: ● 1   ○ 2   ○ 3

Force Package: ○ Light Construction   ● Light Repair

Figure 7-16. Obstacle Window

- **General Engineering** — is used to generate the plan required for general engineering tasks.

- **Marshalling** — is used to generate the marshalling plan.

- **Mobility** — is used to generate the mobility plan.

- **Survivability** — is used to generate the survivability plan.

7.3.6   Plan Analysis

Having formulated his tentative plan, the ABE can now begin the process of evaluating the impact of the plan on various requirements such as the availability of needed resources (e.g., weight of equipment, fuel consumption requirements, etc.) and the amount of time required to implement the plan. The **Analysis** option from the menu bar is then used to analyze the plans from various perspectives, e.g., personnel usage. Each analysis will be displayed in a separate window so that the ABE user can view more than one piece of information at a time. Similarly, the Unit Status information can also be displayed in windows so that the ABE could have current unit status information for personnel displayed simultaneously with personnel usage for the developed plans. This capability allows the ABE to predict the expenditure of resources for any given countermobility plan thereby allowing him to establish priorities and logistics requirements.

The pull-down menu that contains the commands associated with Analysis is illustrated in Figure 7-17 which contains the following commands:

- **Class III** — allows the user to analyze POL usage.

- **Class IV** — allows the user to analyze the construction material usage.

- **Class V** — allows the user to analyze ammunition usage.

7-23
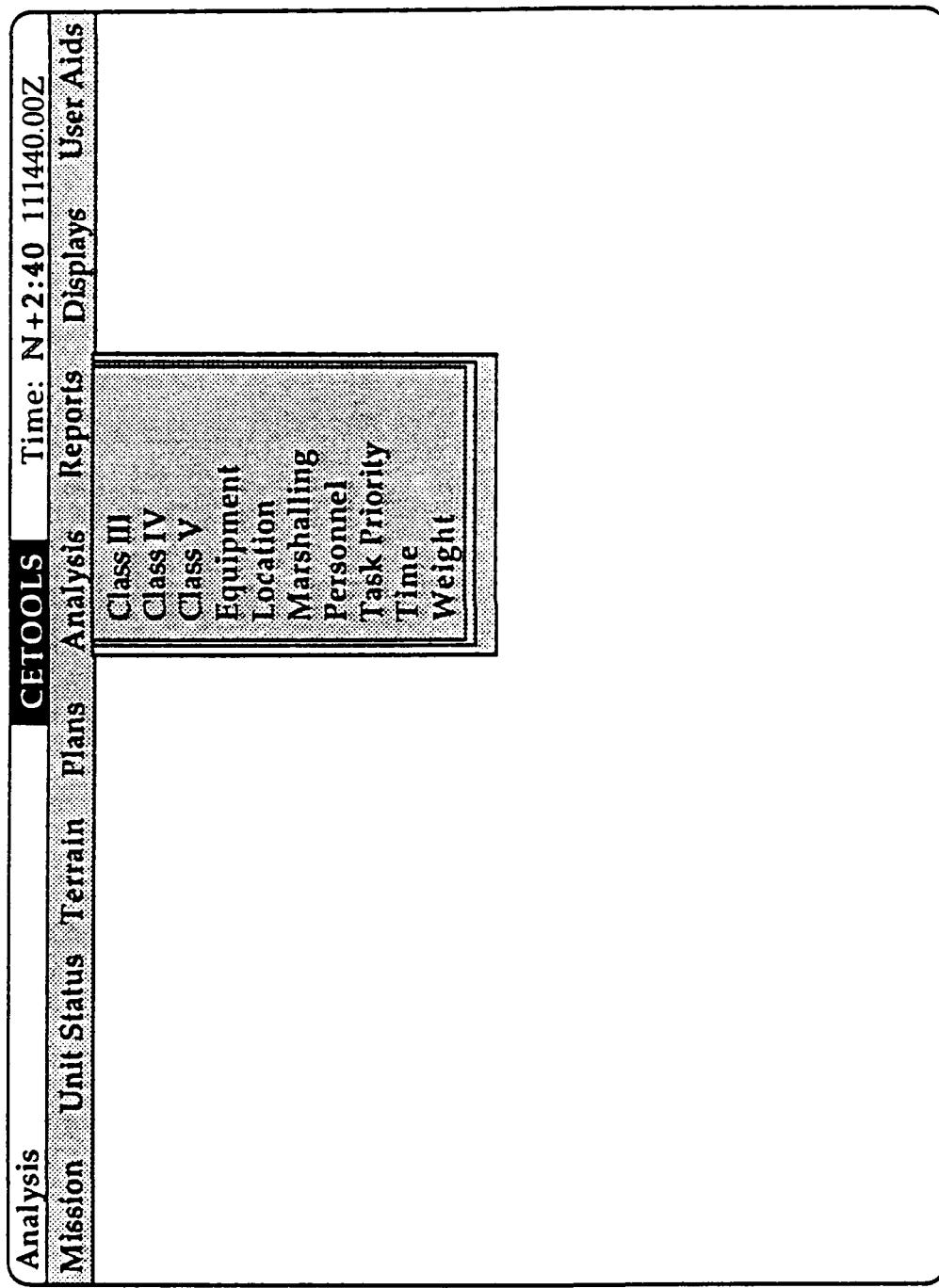
Figure 7-17. Analysis Pull-Down Menus

The menu bar shows:

CETOOLS   Time: N+2:40 111440.00Z

Analysis

Mission Unit Status Terrain Plans Analysis Reports Displays User Aids

The Analysis pull-down menu contains:

- Class III
- Class IV
- Class V
- Equipment
- Location
- Marshalling
- Personnel
- Task Priority
- Time
- Weight

- **Equipment** — allows the user to obtain analyze equipment usage as illustrated in Figure 7-18. It displays all the equipment that has been identified as being used for one of the defined plans along with identifier information such as obstacle number. It displays the quantity and time required along with the time the equipment asset is needed. If CETOOLS detects any conflicts, they will be shown in red (bold typeface in Figure 7-18). For example, the plan requires the use of 2-1 1/4 Cargo Trucks at H+2:00. However, the current unit status for equipment indicates that only 1 of these trucks is available. In order to resolve this conflict, the ABE can change the entries in any column and the resource information will be updated accordingly. In this case, another vehicle could be substituted or the start time for the use of the vehicle modified.

- **Location** — allows the user to analyze where key components of the plan are located are various points in time.

- **Marshalling** — allows the user to analyze the marshalling plan.

- **Personnel** — allows the user to analyze personnel usage for the various plans as illustrated in Figure 7-19. The screen indicates that conflict exists since the 1st platoon of the 1st squad is assigned to two different tasks that are to begin at the same time. Again, if any conflicts are detected, they would be displayed in a distinctive color.

- **Task Priority** — allows the user to analyze defined tasks and their usage requirements.

- **Time** — allows the user to analyze the plans from a time perspective.

- **Weight** — allows the user to analyze weight usage.

7.3.7   Plan Reports

The ABE must now brief other staff members on the engineering portion of the OPLAN. The **Report** option from the menu bar is used to develop these reports. Each report will be displayed in a separate window so that the ABE user can view more than one piece of information at a time. The reports

Type	Obstacle	Obs Type	Quantity Needed	Usage Time (Hrs)	Start Time (H+)
Truck, Cargo 1 1/4 Ton	307XP3001	MF	1	6.6	02:00
Truck, Cargo 1 1/4 Ton	307XP3002	MF	1	6.6	02:00
Truck, Cargo 2 1/2 Ton	307XP3003	MF	1	6.6	02:00
Truck, Cargo 1/4 Ton	307XP3004	HRC	1	7.5	09:06
Dozer, ATD1	307XP3005	TD	2	3	09:06
TOTAL			5	30.3	

Figure 7-18. Analysis - Equipment Screen

7-24a

CETOOLS   Time: N+2:40   111440.00Z

Mission   Unit Status   Terrain   Plans   Analysis   Reports   Displays   User Aids

Unit Designer	Obstacle	Obs Type	Squads	Usage Time (Hrs)	Start Time (N+)
1st Squad/1st Platoon	307XP3001	MF	1	6.6	02:00
2nd Squad/1st Platoon	307XP3002	MF	1	6.6	02:00
3rd Squad/1st Platoon	307XP3003	MF	1	6.6	02:00
1st Squad/1st Platoon	307XP3004	HRC	1	7.5	02:00
2nd Squad/1st Platoon	307XP3005	TD	1	3	10:00
TOTALS			5	30.3	

Figure 7-19. Analysis - Personnel Screen

can be previewed on the screen and, in addition, hard copies can be generated. The pull-down menu that contains the commands associated with Report is illustrated in Figure 7-20 which contains the following commands:

- **Class III** — allows the user to report POL usage.

- **Class IV** — allows the user to report the construction material requirements.

- **Class V** — allows the user to report ammunition requirements.

- **Equipment** — allows the user to obtain report equipment requirements.

- **Location** — allows the user to report where key components of the plan are to be located are various points in time.

- **Marshalling** — allows the user to report the marshalling plan as illustrated in Figure 7-21. The entries, U/K and TBD, indicate information that has not yet been supplied.

- **Orders** — allows the user to report the engineer part of the orders.

- **Personnel** — allows the user to report personnel usage for the various plans

- **Task Priority** — allows the user to analyze defined tasks and their usage requirements.

- **Time** — allows the user to generate timeline reports.

- **Weight** — allows the user to report weight usage.

7.3.8   Display Options

Graphics provide an effective technique for quickly absorbing critical information and presenting information to other staff members. However, they
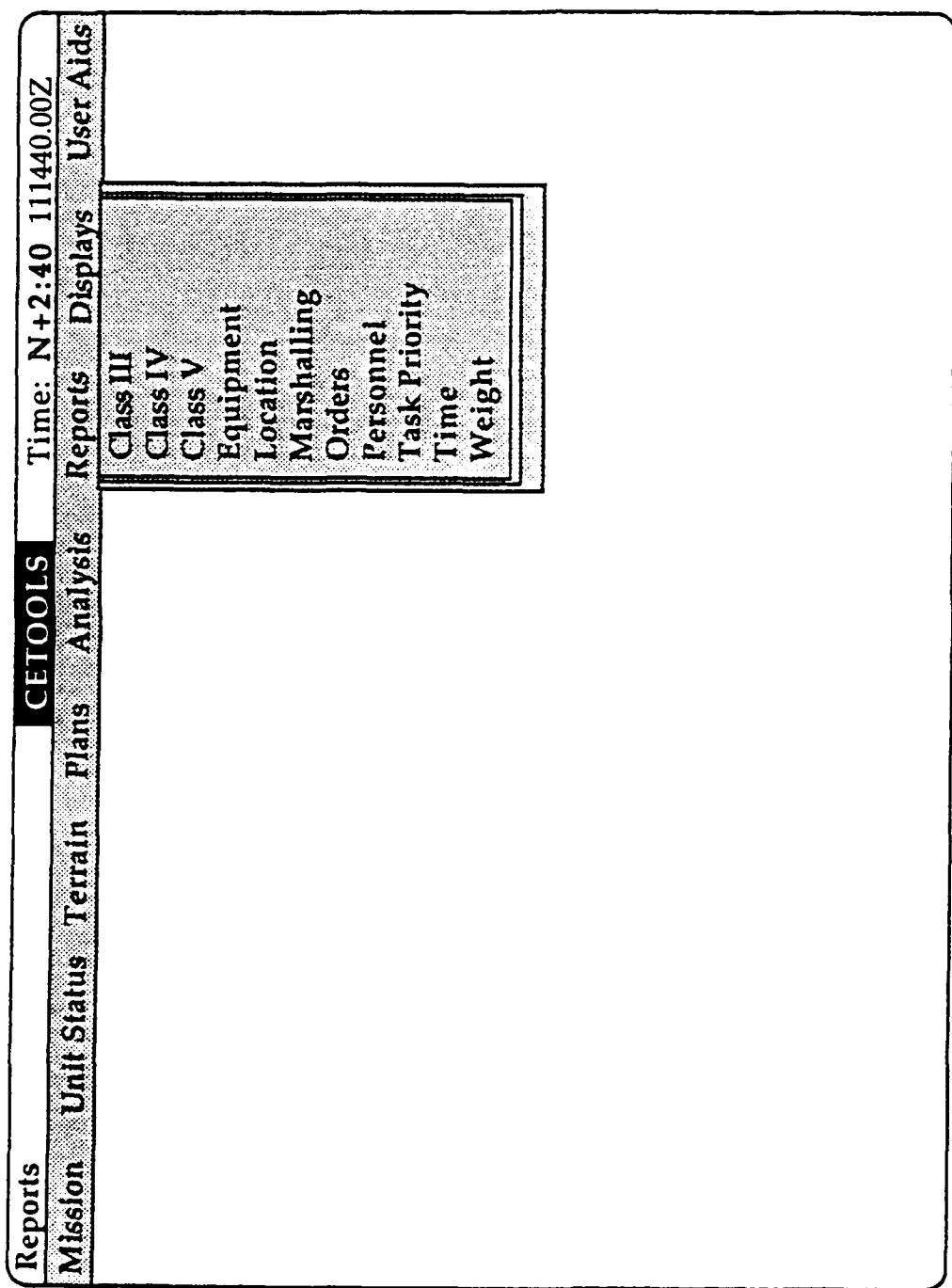
Figure 7-20. Reports Pull-Down Menus

UNIT	CHALK#	TAIL#	PARKING	PAX		DOOR BUNDLE	STATION TIME(N+)
				AIRDROP	AIRLAND		
1/1/C	2	-043	GR 3	9		90mm RR	1630
2/1/C	5	-193	GR 6	10			1630
3/1/C	6	-024	GR 7	13		8cs 90mm HEAT	1630
LARP	1	-211	GR 2	8		80 M-60 FUZE	1630
1/2/C	11	-017	GR 9	10			1830
2/2/C	13	U/K	U/K	12		18 15LB SHAPE	1830
3/2/C	14	U/K	U/K	9			1830
1/3/C	16	U/K	U/K		10	TBD	U/K
2/3/C	18	U/K	U/K		11	TBD	U/K
3/3/C	22	U/K	U/K		10	TBD	U/K

Figure 7-21. Marshalling Report Screen

must be used judiciously to avoid overloading the CE's cognitive capabilities with a cluttered screen. Since each type of display, i.e., map, terrain, OPFOR, FFOR, etc., contains extensive information, the ability to control what is displayed at any point of time will assist the ABE in quickly perceiving the relevant information. Therefore, CETOOLS incorporates the ability for the ABE to tailor the display of graphic information for his particular requirements at any time. The **Display** option from the menu bar is used to control the combination of graphics that are currently displayed on the screen and available on hard copy outputs. The currently selected options will have a checkmark before the command. Figure 7-12 illustrates the simultaneous display of both map and terrain information while Figure 7-15 illustrates the display of map, terrain, and obstacle information. The pull-down menu that contains the commands associated with Report is illustrated in Figure 7-22 which contains the following commands:

- **FFOR** — allows the user to display graphical FFOR information.

- **Map** — allows the user to display graphical map information.

- **Obstacles** — allows the user to display graphical obstacle information.

- **OPFOR** — allows the user to display graphical OPFOR information.

- **Terrain** — allows the user to display graphical terrain information.

7.3.9 User Aids

The **User Aids** option from the menu bar provides a variety of aids to assist the ABE in his use of CETOOLS. The pull-down menu that contains the commands associated with User Aids is illustrated in Figure 7-23. It contains the following commands:

7-26
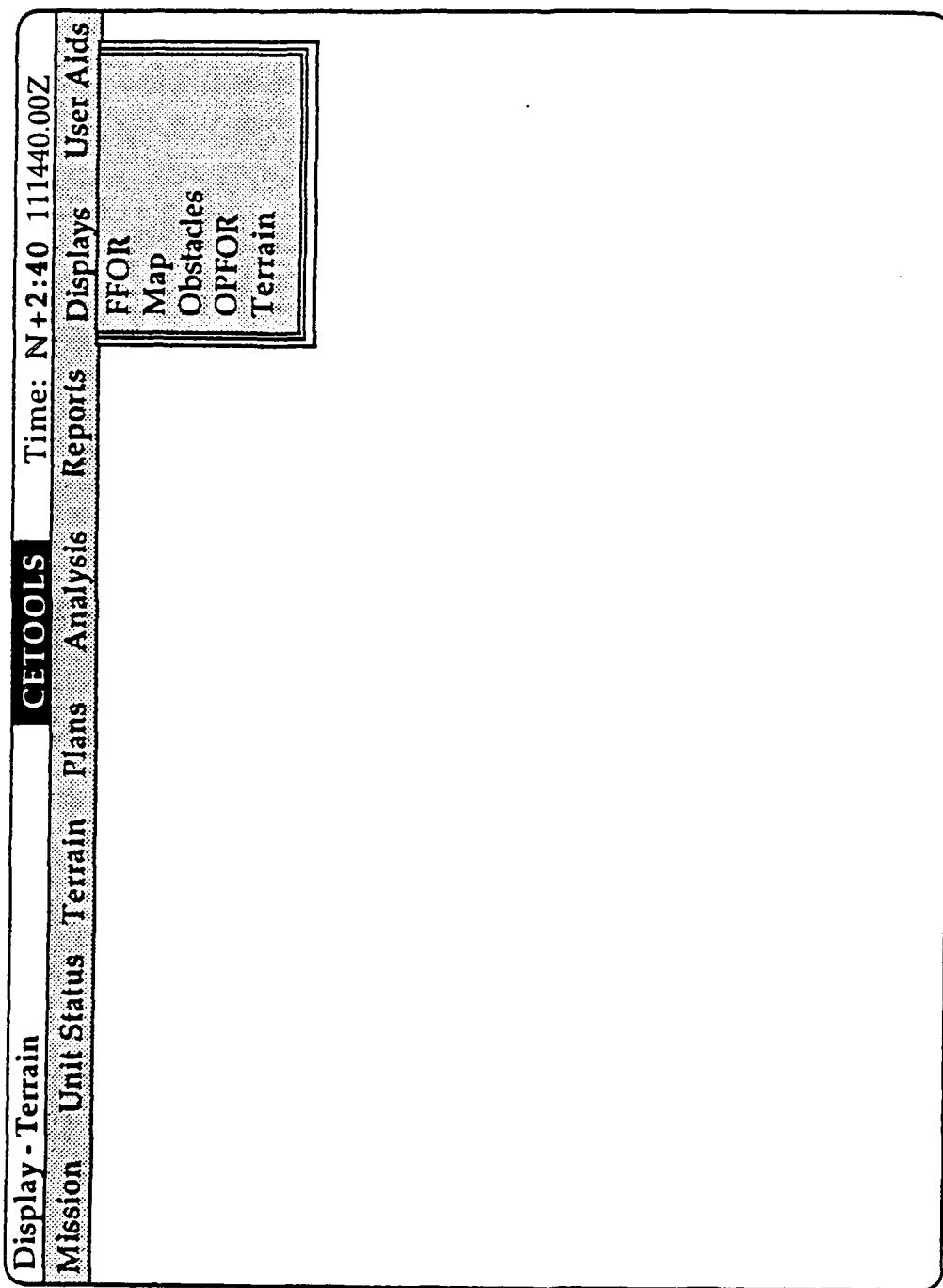
Figure 7-22. Display Pull-Down Menus
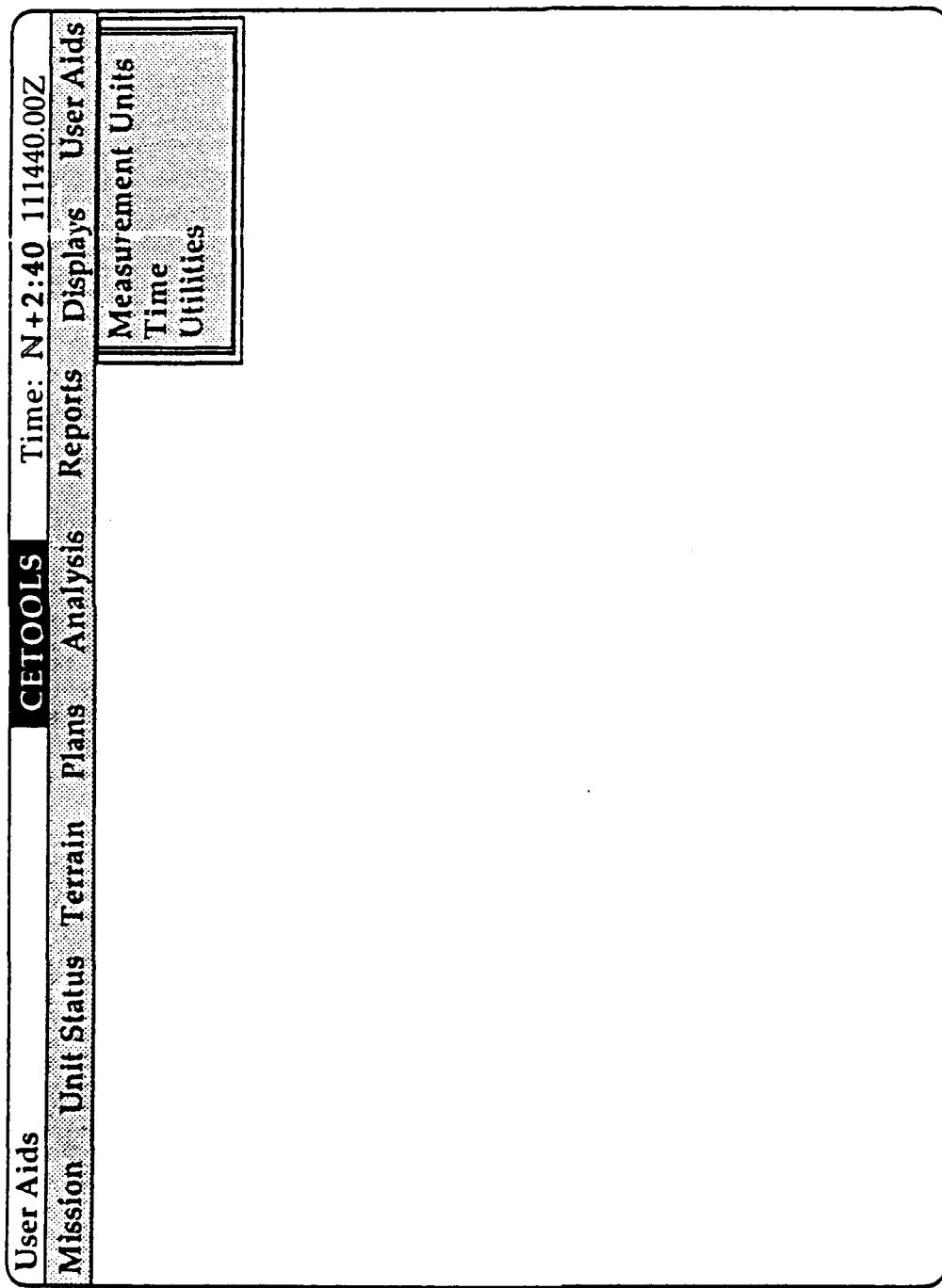
Figure 7-23. User Aids Pull-Down Menus

- **Help** — allows the user to obtain information on how to use CETOOLS.

- **Map** — allows the user to modify various map information such as scale.

- **Measurement Units** — allows the user to specify whether English or Metric units are to be utilized.

- **Time** — allows the user to indicate the format for the display of time information as local time, objective time, or Zulu time.

- **Utilities** — allows the user to access and modify the data bases that indicate what information is to be displayed for the various screens and input templates.

7.3.10 Conclusions

This example illustrates the capability of CETOOLS to be an effective decision support system for the ABE and support the development of an effective engineering plan. It provides the flexibility to explore myriad mission scenarios and their impact on the plan. In addition, the use of CETOOLS would shorten the amount of time required for generating an effective plan thus allowing the commander and staff more time for the evaluation process. This is a critical factor for such forces as the 82nd Airborne where the engineer is subjected to severe time constraints in the development, evaluation, and approval of his plan. Since CETOOLS will be used a very dynamic, real-world environment where the parameters are continuously changing, the ABE can more readily react to these changes. CETOOLS will provide an analytic framework for the ABE regardless of his experience level. A systematic approach provided by a system like CETOOLS will ensure that all facets of the operational environment are considered.

8. PHASE II DEVELOPMENT

8.1   PHASE I FEASIBILITY ASSESSMENT

The Phase I assessment has been completed, and the objectives stated in the original proposal have been met. The CETOOLS concept is assessed as feasible. The detailed investigation and analyses surrounding this innovative concept have produced the following conclusions:

- Accurate judgements concerning the feasibility of combat engineer plans is critical to the success of any tactical plan for Army combat missions.

- Engineer planning, as performed currently, is a complex process that may be prone to developing plans that are less than optimal, particularly within the severe time constraints under which many plans must be developed.

- Current technologies can be combined to produce an automated decision support system to be used by combat engineers for planning combat engineering operations.

- User profiling, intelligent dialogue systems, graphical representations, and an explanation facility will enhance the usability of the CETOOLS system.

The primary risk areas associated with the development of the CETOOLS system are the system performance requirements that must be met if the system is to offer utility in an operational setting. As a result, careful selection of the hardware and software environment and the efficacy of the software development effort throughout the Phase II effort will address this area. System and subsystem performance will be evaluated as each software module is developed and tested (i.e., planning algorithms, accessing data and knowledge bases, and the ability of the targeted computer system to support the user-interface and knowledge based processing.)

Based on the above findings, the concept is judged feasible with a low level of risk. The Phase II effort will focus on the development of an CETOOLS version to assist combat engineer planning as defined during the first task in conjunction with the panel of U.S. Army combat engineers from the 307th Battalion, 82nd Airborne Division.

8.2 GOALS OF PHASE II RESEARCH EFFORT

The primary goal of the Phase II research effort is to develop a prototype version of CETOOLS. The primary emphasis of the Phase II effort is on the system design and prototype implementation. The prototype development process will culminate with an actual tool to assist in combat engineer planning activities.

8.3 PHASE II OBJECTIVES

The primary objective of the Phase II research effort is development and demonstration of the prototype CETOOLS system. The effort will involve knowledge acquisition and data and knowledge base development; hardware and software configuration and installation; detailed system design; system development; system evaluation, and system documentation. Specific technical objectives for each of these areas is presented below.

Task 1: Knowledge Acquisition

- **Interview CEs from the 307th Battalion** — Analytics will interview ABEs as well as other members from the 307th Battalion. Each CE will be interviewed separately. Interviews will concern the identification of ABE's "rules of thumb", short-cuts, heuristics, evaluation techniques, etc. used during their planning activities.

- **Compile baseline information** — The development team will analyze, combine, and synthesize the information collected from the CE interviews into a cohesive form.

- **Review with CEs** — After the baseline information is compiled, Analytics will then review it with the entire panel of ABEs.

- **Refine CE knowledge** — The information generated from the CE analysis will be refined based upon the comments elicited from the panel of experts.

Task 2:   Hardware and Software Acquisition

- **Install equipment and software** — All necessary computer hardware and software will be purchased, configured, and installed at Analytics's offices.

Task 3:   Detailed System Design

- **Design and prototype algorithms** — The algorithms for planning combat operations, management of assets and resources, evaluation of plans, and prioritization of engineer operations will be designed and prototyped with simulated operational data

- **Design databases** — The databases (i.e., engineer assets and personnel, standard OPFOR templates, map data) will be designed based on information obtained during Task 1.

- **Design knowledge bases** — The CE "expert" knowledge for planning activities will be designed based on information obtained during task 1.

- **Design and prototype user interface** — The user interface will be designed and prototyped. Particular attention will be devoted to the interface dialog for entering and viewing graphical information such as terrain data.

- **Design and prototype intelligent dialogue mechanism** — The intelligent dialogue mechanism will be designed and prototyped.

- **Design and prototype user profiling mechanism** — The mechanism for the user profile will be designed and prototyped.

- **Finalize the design** — The design of all of the components of the CETOOLS system will be finalized and analyzed to determine how they will be integrated.

Task 4:   System Development

- **Implement CETOOLS con' jl mechanisms** — The high-level system shell will be implemented on the target computer system.

- **Implement algorithms** — The algorithms designed and prototyped in Task 3 will be implemented in the delivery environment.

- **Implement databases** — The databases which were designed during Task 3 will be implemented and populated.

- **Implement knowledge base** — The knowledge bases which were designed during Task 3 will be implemented and populated.

- **Implement user interface** — The user interface prototyped and validated during Task 3 will be implemented in the delivery environment.

- **Implement intelligent dialogue mechanism** — The intelligent dialogue mechanism prototyped during Task 3 will be implemented in the delivery environment.

- **Implement user profiling mechanism** — The user profiling mechanism prototyped during Task 3 will be implemented in the delivery environment.

Task 5:   System Evaluation

- **Refine algorithms** — The algorithms prototyped in Task 3 will be refined using data obtained during Task 1.

- **Refine knowledge bases** — The knowledge bases for CE expertise will be refined using data obtained during Task 1.

- **Refine user interface** — Opinions on the user interface prototype will be solicited from the 307th Battalion and U.S. Army personnel and their suggestions incorporated into the final design.

- **Refine intelligent dialogue system** — Opinions on the intelligent dialogue system prototype will be solicited from the 307th Battalion and U.S. Army personnel and their suggestions incorporated into the final design.

- **Refine user profiling system** — During the review of the user interface and intelligent dialogue system, the user profiling system will be analyzed and refined as necessary.

Task 6: System Documentation

- **User's Guide** — A user's guide will be developed for use with the phase II version of CETOOLS.

- **Phase II Report** — A report of progress and a discussion of future development will be written.

8.4 SUMMARY

A set of system design criteria were established following the Phase I interviews with the 307th Battalion, 82nd Airborne Division, and a survey of the current technologies available. The following primary system components comprise the CETOOLS concept:

1. The decision support module;

2. The system manager;

3 The knowledge/data bases;

4. The graphics manager; and

5. The user interface.

The results of the Phase I research effort indicate the technical feasibility of the CETOOLS system. The obvious utility of an intelligent tool to

assist in the Combat Engineer function warrants the development of a prototype CETOOLS system during a Phase II effort.

The CETOOLS system will be optimized continuously during the Phase II development. The two primary goals which will drive the optimization are:

1. The ability of the CETOOLS system to support the Combat Engineer in the development of **effective** and **timely** engineering portions of the OPLAN and

2. The ability of the Combat Engineer to utilize the user-computer interface of CETOOLS with minimal training.

The first goal must be achieved in order to provide a useful answer to the user. The second goal is also important in order to obtain user acceptability of the CETOOLS system. In summary, the CETOOLS system provides for enhanced combat engineer planning capabilities to meet the goals of future U.S. Army missions.

The advantages of the decision support approach incorporated into CETOOLS include the following:

- **Ability to incrementally improve the system.** Since the Combat Engineer's knowledge is represented in knowledge bases that are separate from the techniques that are used to develop a plan, the capability of CETOOLS can be incrementally extended by modification of the knowledge bases as new situations occur and parameters change over time.

- **Ability for the Combat Engineer to evaluate a plan and analyze how to best utilize available resources.** CETOOLS will incorporate provisions for the Combat Engineer to evaluate a plan based not only for effectiveness but also to evaluate the impact on available resource and time constraints.

8-6

- **Ability for CETOOLS to complement the Combat Engineer's skills.** CETOOLS will provide useful capabilities to assist the Combat Engineer as much as feasible but still permit the human to make the final judgement. The interweaving of the Combat Engineers skills and the CETOOLS system capabilities provides a more optimal solution than utilizing either one separately.

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APPENDIX A:
COUNTERMOBILITY AS A FORCE MULTIPLIER

A: COUNTERMOBILITY AS A FORCE MULTIPLIER - HISTORICAL PERSPECTIVE

A.1. BACKGROUND

Countermobility, the effective use of natural and man-made obstacles to halt or redirect a threat force advance, has become an ever more important factor on the modern battlefield. A foot soldier can traverse almost any terrain, but tanks, APCs and trucks that comprise modern armies are limited to restrictive avenues of approach. Countermobility is a force multiplier in that as the enemy is stalled by obstacles or a series of obstacles, Friendly Forces (FF) may engage the enemy with near impunity from defensive positions incorporated into the obstacle plan. For example, the current numerical superiority of the Warsaw Pact forces in armored fighting vehicles, coupled with their known doctrine of Blitzkrieg-like attacks, requires that friendly forces plan and provide for the use of multiple obstacles in depth. Also, light forces such as airborne infantry units require the effective use of obstacles in order to counter the potential superiority of Opposing Forces (OPFOR). If properly planned and implemented, countermobility can provide the decisive edge needed to ensure a successful operation.

The use of obstacles can be found throughout the annals of military conflict. In fact, military history has shown that the judicious use of obstacles by armed forces can offset the superiority of opposing forces (i.e., numerical superiority and firepower superiority of the assets comprising opposing forces.) However, the success found with the use of obstacles is shown to be based on a well conceived countermobility plan that follows several principles. A description of such countermobility principles, illustrated with historical examples of armed conflicts in which such principles were either followed or ignored, is presented below. The consequences from adhering to these principles or ignoring them provide evidence to their validity. In order to understand the importance of these countermobility principles on impacting the

success of future conflicts, it is first necessary to describe today's battlefield environment.

A.2   TODAY'S BATTLEFIELD ENVIRONMENT

Several key points concerning OPFOR doctrine and tactics (i.e., Warsaw Pact) are important to understand in order to see the utility of countermobility plans.

The future battlefield will be intense, fast, and deadly. Enemy forces, such as the Warsaw Pact, will attempt to gain as much ground as quickly as possible, through penetration attacks designed to put large armored forces in the friendly rear areas thus compromising friendly C^2 and logistics elements. Loss of the rear areas will cause the forward combat element to fight along two separate and opposite directions -- trying to hold the enemy along its front while ridding the enemy from its rear. With the loss of C^2, combat units will be virtually blind in opposing both the front and rear threat. With the combined loss of the logistics bases in the rear, the intensity of combat will soon drain the supplies on the front lines. Threat indirect fire and NBC capabilities will be directed against those same command, control and logistics elements further degrading their capability to support the combat units. As a result, friendly forces must work to slow and divert as much as possible the threat advance. With proper planning and execution, a defending army can halt an enemy in its tracks -- exposing the enemy force to friendly anti-tank and artillery fires. To ensure this possibility, obstacles are employed such that the enemy is channelized into "killing zones" where the diminutive size of the area and friendly weapon placements combine to provide an imposed target rich environment.

In response to OPFOR doctrine and tactics, US planners have developed an AirLand Battle doctrine whereby it is envisioned that friendly forces will be facing either 1) numerically superior armored and mechanized

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forces attacking along a broad front or 2) insurgent forces conducting hit and run operations only when they can achieve local superiority. AirLand Battle doctrine calls for a forward defense and a slow withdrawal until reinforcements can arrive on the scene to counterattack. At all times, local commanders should be prepared to turn upon and attack the enemy. This principle extends from the strategic planners at national level down to the enlisted squad leader in the trenches. Maximum flexibility, initiative, and resourcefulness coupled with intensive training and superior weapons should be able to contain the advancing enemy until a major friendly counterattack can be launched. Under this doctrine, obstacles are envisioned as fulfilling three functions:

1. Enhance the effectiveness of friendly anti-tank fires,

2. Delay the enemy's advance, upset his timing, disrupt and channelize his formations, and delay or destroy follow on formations, and

3. Enhance friendly economy of force measures.

In addition to these OPFOR doctrine and tactics that focus mainly on high-intensity conflicts on the Western European front, countermobility is of even greater importance for low to mid-intensity conflicts that can be expected to be faced by light forces in today's army such as the US Army XVIII Airborne Corps (82nd Airborne Division). Lightly equipped airborne FF must be prepared to encounter enemy forces all along their defensive perimeter which could encompass a 360 degree perimeter. Also OPFOR, such as insurgent forces in low-intensity conflicts, can be expected to have a better knowledge of the local terrain than will friendly forces. In these low-intensity conflicts the obstacle plan takes on even greater importance due to the relative freedom of movement of such light and guerilla forces. As a result, countermobility tactics will play an important role in determining the success and survivability of lightly equipped FF.

A.3   PRINCIPLES OF COUNTERMOBILITY

When preparing and considering the operational and logistical plans for a tactical operation and deployment, the tactical force commander must consider the METT-T (Mission, Enemy, Terrain, Troops and Time available) factors inherent to the situation at hand. At the same time , the combat engineer (CE) is considering these same METT-T factors when developing countermobility plans. Also, the CE is following several key principles that are considered to be paramount to the planning process and to its ensured success. These principles are the following:

1.   Countermobility plans must complement and be integrated with the tactical and strategic mission plans,

2.   Countermobility strategy must take into consideration the terrain on which the battle is to be fought in order to maximize the use of limited resources, assets and time to implement any obstacle plan as well as to enhance the effectiveness of such plans,

3.   Countermobility strategy must plan for obstacle deployment in depth as well as breadth to ensure effectiveness, and

4.   Countermobility strategy must take into consideration the anticipated enemy assets and doctrine to be encountered.

These major countermobility principles are described in the following subsections with historical examples used to illustrate the importance of such principles.

A.3.1   Principle 1: Countermobility plans must complement and be integrated with the tactical and strategic mission plans.

Effective countermobility plans are ones that are fully integrated into the FF tactical mission plans. Specifically, obstacles serve as a force multiplier only if obstacles are deployed complementary to emplacement of fire power (i.e., anti-tank, artillery, etc.) such that there is a synergistic effect from these two

combined assets. To ensure such an effect, obstacle locations must be carefully coordinated with the location of battle positions and the use of direct and indirect weapons. Except for mines, obstacles emplaced outside the range of friendly weapons are of little use. This is because the tactical commander's intention is to engage the enemy at the maximum range of FF weapons and force OPFOR to breach and fight their way through a series of obstacles while under intense fire. In addition, countermobility plans implemented through the use of extensive obstacle systems coupled with effective fields of fire allow limited numbers of friendly forces to better hold their own against numerically superior enemies. Friendly forces are able to fight from protected defensive positions while the stalled enemy is fully vulnerable to friendly anti-tank, artillery, and air attacks.

The two basic types of obstacles that the CE will use to complement the tactical mission plan are **existing** and **reinforcing** obstacles. Existing obstacles are any obstacle that was in place prior to the start of hostilities or that has been placed through the forces of nature (such as snow and ice). Examples of existing obstacles include rivers, mountains, cliffs, soft farmland, forests, buildings and villages, and any other terrain features that prevent or impede enemy movement during battle. Reinforcing obstacles include such features as tank ditches, abatis (a defensive obstacle formed by felled trees with sharpened branches facing the enemy), blown bridges, mine fields, road craters, and even rubble in and around populated cities can be considered obstacles to an enemy's advance. Thus a reinforcing obstacle is placed on the battlefield by utilizing combat engineering assets and is designed to strengthen the existing natural terrain features. An obstacle is not only something placed in the enemy's path such as the tank ditch, it can also be something denied to the enemy such as a blown bridge over a major river or a geographic feature that cannot be crossed.

The effective use of obstacles is illustrated by the Israelis during the 1973 Yom Kippur Syrian invasion summarized below (Allen, 1982; Asher & Hammel, 1987).

> The Israelis made perfect use of the rugged terrain of the Golan Heights in their defense during the October 1973 Yom Kippur Syrian Invasion. A system of bunkers was positioned on all of the major rises along the 1967 Cease Fire Line in the Golan Heights. Supporting all of these fixed positions, numerous tank emplacements were constructed taking full advantage of the slope of the land, high ground advantage for anti-tank fires, interlocking fires from multiple positions, and prepared tank positions providing sheltered locations from which the Israeli army could engage the Syrian forces at ranges from 2 - 3 kms. The Israelis were able to direct withering, accurate anti-tank fires against the Syrians from their prepared positions and significantly reduce the attackers strength until the overwhelming number of the Syrian forces forced the Israelis to withdraw. In the end, however, the stubborn Israeli defense of the Golan Heights gave them enough time to organize their counterattack which virtually destroyed the Syrian army and moved the Israeli army to within artillery range of the Damascus airport. In the end the Arabs on the northern front (Syrians, Jordanians and Iraqui) lost approximately 1,300 main battle tanks, 867 of those in the Golan region alone. The Israelis lost only 250 tanks, of which 150 were later returned to battle (at least once) during the course of the war.

In contrast to the Israelis' effective use of obstacles to complement tactical mission plans, the Falklands campaign shows the dire consequences when this principle is not adhere to as summarized below (Hastings & Jenkins, 1983).

> In the Falklands campaign by the British Commando and Paratroop units, this determined, light force was able to overcome obstacle emplacements set-up by the Argentine

defenders. Granted the British were not facing elite well trained units, but by their own analysis, the obstacles and mine fields they overcame should have held much longer. For example, the Argentines destroyed bridges in an attempt to impede the British. However, the Argentines did not attempt to defend the far side of the river crossings. The British crossed the rivers with impunity. Similarly, the Argentines' use of mine fields was ill-advised. The Argentines constructed elaborate mine fields but failed to cover the mine fields with supporting firepower once the British had entered such areas. In fact, during a lull at night in the Battle for Goose Green, British troops slept in depressions on the ground while waiting for the next phase of the attack. Only with the first light of day did the British troops realize that they were sleeping in the depressions left by exploded land mines from cattle that were grazing in the area.

A.3.2   *Principle* 2: Countermobility planning must take into consideration the terrain on which the battle is to be fought.

Countermobility strategy must take into consideration the terrain on which the battle is to be fought in order to enhance the effectiveness of such plans as well as to maximize the use of limited resources, assets, and time to implement any obstacle plan. Maximum use must be made of the terrain as it exists. Rivers, steep slopes, narrow valleys and mountain passes, and towns and villages must be incorporated into the countermobility plan. The enemy's probable avenue of approach must be identified and analyzed to find the best areas to interdict his forces. Where possible, natural choke points should be used to form killing zones to reduce enemy forces. Terrain analysis by the CE should not only consider terrain's detrimental effects on the enemy, but also identify key terrain that will aid in the friendly defense, such as rises and defilade positions that will allow friendly forces to observe and fire on the enemy while providing cover and concealment to the friendly unit. Only after the terrain has been analyzed should attention be turned to the possibility of enhancing the effectiveness of the chosen battlefield. Historically, this idea has been neglected at critical times during campaigns as described below (MacDonald, 1983).

The Ardennes region of northern France and Belgium is an ideal illustration of a region whose role in strategic events has been overlooked continually in modern warfare. The rough, hilly, wooded country was believed too rough for rapid advance by mechanized forces. But the German armies used this route in their lead attacks in both 1914 and 1940. The French and British in both cases failed to notice that the road network of the region directed traffic into France was pointed straight for Paris. The French and British did not attempt to build obstacles to circumvent the use of these roads. In fact, second and third line troops were placed in this front line area in the belief that the Germans could not possibly launch an attack through this region. In 1914, the Germans were stopped, but not so in their advance of 1940.

However, the Germans failed to learn from their past successes in this region as described below.

In December, 1944 the Germans again attacked through the Ardennes, but this time they neglected to plan their advance to capitalize on existing road networks. The German armored columns tried to maneuver against the road network. The German advance was slowed down enough to give the Allied armies in other areas enough time to disengage, reorient their axes, and counterattack before the Germans reached the open plains of northern France.

Terrain analysis, with respect to countermobility planning, involves understanding the implications of terrain features. That is, how can one best use terrain features to one's advantage when developing and implementing an obstacle plan. To follow are descriptions that highlight some of the major natural terrain features which are important considerations for countermobility planning.

Drainage features are one of the most obvious natural terrain obstacles. Deep, swift rivers and streams will stop most armored forces. These features can be rendered even more effective by stormy weather or controlled flooding. Most armored vehicles can ford small streams and river while very small streams are no obstacle at all as the AFVs can self-bridge them. Major drainage features will usually require some sort of additional engineer support to exploit. As an enemy tries to send numerous vehicles across a fordable stream, bottom conditions at the ford site will increase the tendency for vehicles to become bogged down in the churned up bottom. Some AFVs have snorkeling or swimming capability but this is also dependent upon the width, depth, and speed of the river. Rivers with steep banks also increase the difficulty that a force will have in crossing. Lakes and ponds, by their nature, tend to make excellent obstacles. Because it is usually easier to go around rather than across one of these bodies, large forces will tend to do just that. Thus drainage features tend to slow the enemy on the far bank as they prepare for the crossing operation. Once the crossing or bypass operation has been started, the enemy forces must be channelized through the crossing points or close ranks as they maneuver around the edges of lakes and ponds. This provides target rich environment for friendly weapons.

The use of natural terrain features such as rivers is one that has impacted the success of military operations as illustrated below (Calvocoressi & Wint, 1972).

> As the Allied forces during the later stages of WWII advanced on the Rhein River, the Germans pulled back to the Siegfried Line. As part of the German withdrawal the bridges across the Rhein were destroyed. The Allies were effectively stopped in their advance except for one remaining bridge that was still intact -- Remagen Bridge. The Remagen Bridge was being held intact by a reinforced infantry company to allow for the escape of German forces on the west bank of the river. The engineer detachment commander was ordered to demolish the bridge only on the written order of the infantry commander, but

the infantry commander did not have clear orders concerning the fate of the bridge. When large numbers of troops started streaming east across the bridge, the German LXVII Corps commander sent MAJ Scheller to assume command of the situation with orders to hold the bridge until the last possible moment. When American tanks and infantry appeared at the west end of the bridge, the Germans fired a crater in an attempt to slow the American advance. Next, when they tried to blow the bridge electrically, they found that the circuit had been damaged. The Germans then tried to ignite the explosives manually but this failed to destroy the bridge. This was their last chance as the bridge fell into American hands with the next attack. Eight thousand US soldiers, including one tank battalion were able to cross the bridge in the next 24 hours to continue the Allied advance into Germany. Such actions by the Allied forces substantially impaired the German effort to re-group and counter the Allied advance.

The **slope of the land** can inhibit enemy movement. Vehicles cannot easily traverse steep ground. Cliffs, wadis, and embankments will tend to slow an armored vehicle or truck, if not outright stopping it. This will require the use of engineer support to cross the obstacle or require the diversion of the force around the terrain. Hills and mountains tend to be bypassed by armor in a rapid advance. Yet this same high ground provides perfect vantage points for defensive observers and weapon systems. Reverse slope positioning along the crest of the hill or ridge allows the defender the protection of the very ridge upon which he sits. Prepared positions scraped from the hillside can provide this same advantage along the crest or forward slope of the terrain. An example of the use of terrain with respect to the slope of the land is provided below (Greenwald, 1988).

The increasingly successful Mujahadin in Afghanistan have shown that proper use of terrain can help turn the tide away from heavily armored forces in favor of lightly armed forces. The recent Soviet action to resupply the garrison town of Khost

in the mountains of eastern Afghanistan demonstrates the difficulty of directing armored units through well defended mountain passes. Although the Soviet push was successful, it was a costly and slow advance. Reports put the guerilla casualties at only 50 dead and several dozen wounded while medical authorities in Kabul report "hundreds" of dead Soviet and government Afghan soldiers and a "record number" of casualties from the fighting around Khost.

In contrast, the Argentine Defense of Port Stanley during the Falklands campaign shows that poor implementation of a countermobility plan is doomed to failure regardless of the advantages offered by terrain features as described below (Hastings & Jenkins, 1983).

The Argentine defense of Port Stanley was based on two mountain ridges around the city. But despite excellent stockpiles of weapons and numerically superior troops, the Argentines could not hold the ridges. By British admissions, the defense network built into the ridges should have held longer than what actually occurred. However, the Argentines made no provisions to transport large stockpiles of food, clothing and ammunition from Port Stanley to these mountain ridges. As a result, the British were able to defeat the Argentines with impunity.

Vegetation can be an important impedence to cross country travel by armored forces. Dense forests cannot be navigated by armored forces. The vehicles usually are simply too large to fit between the trees. If tree spacing does permit the vehicles to pass through, progress is usually slow as the vehicles must constantly alter course to avoid another tree that appears in the way of advance. For example, this type of maneuvering can wear on the psychological condition of tank crews. Scrub brush and grasses on relatively open areas present their own difficult conditions. Such vegetation may hide ditches and gullies that present major obstacles to armor. If the unit is not aware of these gullies, the gullies could immobilize the first vehicles to encounter them and thus slow the entire force. This is especially important

when the gullies are too small to be shown on tactical combat maps. Friendly defenses can also take advantage of these same depressions as ambush sites. Once again when the enemy force slows or stops to bring engineers forward to breach these areas, friendly fire can be brought to bear on the enemy.

The effects of vegetation on defending and attacking forces can best be viewed from the experiences of the US Army in South Viet Nam as summarized below (Calvocoressi & Wint, 1972).

> The jungle greatly curtailed the forces that the US could bring to bear on the Viet Cong. The light infantry forces were able to maneuver in the jungle with ease, but the guerillas were also able to take advantage of the jungle (i.e., use of concealed tunnel systems). What few mechanized units the US sent were limited to patroling the road network in the south.

> Simliar effects of vegetation on military tactics were experienced during the Burma Campaign of WW II. As a result, traditional military tactics were found to be of little use under these circumstances.

Besides natural terrain features, **cultural features** have long been used as elements of defense. Typically cities are bypassed by armored forces in an effort to avoid such man-made obstacles. Cities, with their tall buildings and narrow streets, are virtual deathtraps to armor. They provide innumerable vantage points for observers and anti-tank weapons. Stone walls, hedgerows, dikes, and canals in urban and suburban areas also tend to slow and channelize the enemy while providing excellent cover and concealment to friendly forces. An example of the use of cultural features for defense is presented below (Calvocoressi & Wint, 1972).

> During WWII the Germans decided it was more advantageous to starve and bombard the inhabitants of the city of Leningrad than to direct an assault

against the city and face heavy losses because of the vantage points offered by city buildings and architecture against their forces. However, the Russians were able to withstand the prolonged German bombardment and encirclement of Leningrad.

A.3.3   *Principle* 3: Countermobility strategy must plan for obstacle deployment in depth as well as breadth to ensure effectiveness.

Each natural, as well as man-made obstacles, can individually stop and divert the enemy, but when combined their effectiveness is even more telling. Forested slopes have the potential to block even the most powerful tank. But, fallen trees on a slope or hill will have a synergistic effect on preventing tank maneuverability. The tank simply cannnot gain the momentum required to overcome both obstacles. Mixing of these features in depth is especially valuable when trying to guide an enemy into a killing zone because a force will usually try to bypass obstacles in depth rather than breach them.

The 1973 Yom Kippur war illustates the effective use of obstacles in depth (Allen, 1982; Asher & Hammel, 1987).

> On the Golan Heights tank trenches, mine fields, concertina, pill boxes and tank ramps were placed in depth by the Israeli. As recounted earlier in this section, the Syrians tanks were effectively neutralized by the Israeli countermobility plan (i.e., 867 Syrian tanks were put out of operation).

By contrast, the French defenses prior to the outbreak of WWII violated the principle of deploying obstacles in depth as presented below (Calvocoressi & Wint, 1972).

> The French built a sophistacted line of obstacles, fortified bunkers and gun emplacements along the French/German border known as the French Maginot Line. At the outset of WWII, the Germans simply

bypassed the defenses of the Maginot Line and attacked through the relatively undefended Ardennes region.

A more recent example involves the Israeli defense along the Suez Canal prior to outbreak of the 1973 Yom Kippur War as described below (O'Ballance, 1978).

> The Israeli defensive positions were too far forward along the Suez Canal with little, if any, prepared defensive tank positions. Also, this Israeli Bar Lev Line contained no defensive positions in depth in case the Egyptians were able to breakthrough the defensive positions along the Suez Canal. Because of this poor countermobility strategy, the Egyptians were able to cross the Suez Canal before the Israeli forces were able to recover from the Egyptian preparatory artillery barrage. Once the Egyptians had established an adequate bridgehead for their forces, they were able to bypass the other Isreali positions along the Suez Canal. If it were not for the reluctance of the Egyptians to take the initiative and breakout from their bridgehead, the Israeli forces could not have been able to mount a successful counterattack.

A.3.4   *Principle:* 4: Countermobility strategy must take into consideration the anticipated enemy assets and doctrine to be encountered.

Since countermobility entails the use of many different types of natural and man-made obstacles, the selection of obstacles will be dictated to a large degree by the anticipated enemy assets and doctrine to be encountered. Namely, some obstacles are more effective than others in neutralizing specific enemy assets (i.e., tanks) as well as disrupting enemy tactics (i.e., high speed execution of offensive operations). The combat engineer must take into account the effectiveness of obstacles to counter specific enemy assets and tactics. For example, Soviet doctrine presupposes strict time schedules and routes with most operations planned to the smallest detail. Soviet tactical commanders rely

on well-rehearsed battle drills that foster a high degree of coordination between combined arms teams. Because of such training, it is anticipated that Soviet tactical commanders will not be able to deal decisively with unanticipated conditions that require a flexible response. As a result, obstacles which effectively slow the tempo of battle for a Soviet advance could disrupt not only their plans but also create potential bottlenecks whereby reinforcing and succeeding units combine with those already at the front to create a target enriched environment for friendly fire. Thus denying the enemy full use of facilities along his chosen avenues of approach could cripple an otherwise devastating attack.

To illustrate how the use of obstacles can be enhanced by knowledge of enemy assets and their military tactics, a brief description of mine warfare follows. Mines are either anti-personnel or anti-armor. Mine fields are usually sown with a combination of different mine types (i.e., anti-personnel and anti-armor) with the ratio dependent upon the anticipated threat (i.e., number of armored vehicles and/or troops). They can be emplaced by a variety of means to include hand emplacement, mechanical mine planters, artillery, and/or aircraft. Conventional mine fields are usually planted before the battle begins, and then as the battle progresses, the original mines are reseeded and supplemented by scatterable mine fields from artillery or aircraft. Mine fields, like tank ditches, are best used to slow the enemy while the enemy forces are entering or traversing a choke point, thus allowing friendly forces to bring all weapons to bear from concealed positions. The makeup of a mine field with respect to type and number of mines (density) will be dictated by the anticipated enemy force composition.

During the Viet Nam conflict, claymore mines (anti-personnel) were effectively used to counter the Viet Cong as described below.

Claymore mines expel their projectiles outward in a wide arc thus killing more of the enemy than just the one who triggers it. For example, claymore mines

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were used to trigger ambushes such that portions of Viet Cong patrols were allow to pass before the mines were manually triggered by American forces to start the attack. Claymore mines were often detonated manually when the Viet Cong could no longer be controlled with small arms. Also, claymore mines were sown around the perimeters of fire bases to offset the Viet Cong's ability to conduct snipper attacks up-close at night.

However, mines are not the panacea that they may appear to be. There are numerous examples of mine warfare that failed to deter the enemy, or to even wound the enemy because the forces employing the use of mine fields failed to take into account the enemy's tactics or the element of luck. Examples from the Falklands campaign are described below (Insight Team of the Sunday Times of London, 1982).

During the Falklands campaign the British SAS advanced toward the Argentine troops at Grytviken on South Georgia island. The British were met by an incredulous Argentine officer complaining that they had just walked through a mine field and had failed to detonate a single mine. Luck was on the side of the British that day.

During the British advance on Port Stanley on East Falkland Island, the British had ample opportunities to reconnoiter their advance routes with engineers marking out the mine fields and paths through them. Although these missions did produce some British casualties, they were successful in clearing many of the British avenues of approach.

A.4   CONCLUSION

As illustrated in this section, the success of any countermobility plan will be determine to a large extent by the careful consideration of METT-T factors (Mission, Enemy, Terrain, Troops, and Time available) inherent to the situation at hand.

APPENDIX B:
CETOOLS USER-COMPUTER INTERFACE COMPONENTS

B: CETOOLS USER-COMPUTER INTERFACE COMPONENTS

This section describes the proposed components for the user-computer interface (UCI) for CETOOLS.

B.1   INPUT DEVICES

The UCI input devices consist of the following complementary devices — a keyboard, a mouse, and a digitizing tablet.

B.1.1   Keyboard

The keyboard is used to enter alphanumeric data and as an alternative to the use of the mouse to move the text cursor between input fields on dialogue boxes. The keyboard consists of a standard typewriter keyboard, numeric keypad overlaid with cursor move keypad, and a set of function keys.

The numeric keypad includes keys for the numbers zero through nine arranged in an adding machine format; it also has keys for special functions (such as a minus sign, equal sign, etc.) and is used to speed entry of numeric information. The cursor movement keypad contains an up-arrow, down-arrow, right-arrow, left-arrow, home, and end keys and are used to control cursor movement within a window as an alternative to the use of the mouse. The user controls the functioning of the keypad as either a numeric pad or cursor movement pad through the use of the **NUM LOCK** key. Above the num lock key is a small red dot light. If the light is lit, then the keypad is functioning as a numeric pad; otherwise it functions as a cursor movement pad. The special function keys are used to select menu options as an alternative to the use of the mouse for experienced users with certain modules.

B.1.2   Mouse

The mouse is used as a pointing device to select commands from menus, to control cursor (pointer) movement, and to manage file scrolling. In CETOOLS, the standard pointer is an arrow ($\nearrow$). Every move you make with the mouse moves the pointer in exactly the same way. The following terms describe various actions associated with mouse utilization:

- **Clicking** — positioning the pointer with the mouse, briefly pressing and releasing the mouse button without moving the mouse.

- **Pressing** — positioning the pointer with the mouse, holding down the mouse button without moving the mouse.

- **Dragging** — positioning the pointer with the mouse, holding down the mouse button, moving the mouse to a new position, then releasing the button.

These terms will be used in subsequent sections to describe user interactions with CETOOLS.

B.1.3   Digitizing Tablet

The digitizing tablet will be used for direct input of graphics information from a hard copy map or diagram. The user will utilize the tablet to trace over key features and input into CETOOLS. The buttons on the digitizing tablet will be under control of CETOOLS so that their function can be modified depending upon application. For example, when defining terrain, the buttons will correspond to various terrain features such as high points, roads, rivers, etc. When defining obstacles, the buttons will correspond to obstacle features such as mine fields, road cracters, and tank ditches.

B.2 SCREEN LAYOUT AND COMPONENTS

This section describes how information is arranged on the display and how the user interacts with the particular component. The screen is arranged into four main areas:

1. The **title bar** which is always on the top line of the display as described in Section B.2.1;

2. The **menu bar** which is always the second line of the display as described in Section B.2.2;

3. The **function key bar** which is always the last line on the display as described in Section B.2.3; and

4. The **CETOOLS window** which occupies the remainder of the screen. The CETOOLS window is used to conduct a dialog with the user. It will either display information to the user or display an input form for the user to supply the information CETOOLS requires. The contents vary dependant upon the current function. The windows are described in Sections B.2.4 through B.2.8.

Within the CETOOLS window, a variety of components have been developed for the user to specify particular simulation data items or supplying additional information required before a system command can be processed. These components include:

1. **List Selection Box** — a scrollable list of available items for the user to select from as described in Section B.2.9;

2. **List Viewing Box** — a scrollable list of currently defined terms for the user to view as described in Section B.2.10;

3. **Pushbutton** — a distinct area of the screen that is used to specify actions as described in Section B.2.11;

4. **Click Boxes** — a box containing the range of numeric values that can be modified by the user via mouse clicks as described in Section B.2.12;

5. **Text Entry Boxes** — a rectangular box which allow the user to enter textual data (numeric or alphanumeric) with the size of the box indicating the maximum number of characters permitted as described in Section B.2.13;

6. **Scroll Bar** — a rectangular box that is used to modify the current view of a window as described in Section B.2.14; and

7. **Labels** — text descriptions used to indicate the type of information to be entered by the user as described in Section B.2.15.

8. **Radio Buttons** — small circles that are used to indicate that the user can select only one of a set of mutually exclusive options as described in Section B.2.16.

9. **Check Boxes** — small rectangular boxes that represent options that can be activiated simulaneously and contain an X when activiated as described in Section B.2.17.

CETOOLS uses two distinct cursors to represent the focus of attention for the user and point to a precise point on the screen. The **mouse cursor** is controlled by the mouse and always represents the last mouse screen location. When the user moves the mouse, the mouse cursor moves proportionately. The mouse cursor is described in Section B.2.18. Additionally, a **keyboard cursor** represents the location where any keyboard actions will occur and is described in Section B.2.19.

In subsequent sections the following terminology is used to describe various aspects of the screen components:

- <u>Location</u> — indicates where the component is placed on the display. In some cases, the exact location will vary depending upon the contents of the screen;

- <u>Background Color</u> — indicates the color to be used for the screen background upon which text and/or graphics will appear;

- <u>Text Color</u> — indicates the color to be used for all alphanumerics and text symbols;

- <u>Graphics Color</u> — indicates the color to be used for graphics symbols;

- <u>Border</u> — indicates the color to be used for the line border enclosing a particular element of the screen;

- <u>Characters</u> — indicates the case to be used for text, e.g., all upper case, initial upper case, etc.; and

- <u>User Action</u> — describes how the user will interact with the particular screen component.

B.2.1   <u>Title Bar</u>

The title bar presents information about the currently selected CETOOLS function to the user; the user does not enter any information. The title bar is continuously displayed. The title bar is split into three areas:

1)   Current activity on left side of line, left justified with initial caps, if required.

2)   Function name centered in middle of line in uppercase white letters on black background.

3)   Status information on right side of line with initial caps, if required.

<u>Location</u>:   Top line of screen.
<u>Background Color</u>: White
<u>Text Color</u>:   Black
<u>Graphics Color</u>:   None
<u>Border</u>:   None
<u>Characters</u>:   Varies depending upon area.
<u>User Action</u>:   Information only, no user response permitted in the title bar area of the screen.

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B.2.2 Menu Bar

It contains a list of the menu titles of the primary options that are available for the current CETOOLS function. The menu bar is continuously displayed on the screen. The last two menu options are always User Aids and Exit. Each menu title is separated from other menu titles by one leading and two trailing spaces.

Location:	Second line on screen.
Background Color:	Blue.
Text Color:	White.
Graphics Color:	None.
Border:	None.
Characters:	Initial upper case only.
User Action:	To select an option from the menu bar, the mouse is used to position the mouse cursor anywhere on the desired menu title. Without moving the mouse, any mouse button is pressed and held (clicking). Once the mouse button is depressed, the selected menu title will be shown in reverse video (white background and blue foreground) and a box containing the available commands (pull-down menu) will appear immediately beneath it in a separate window. The pull-down menu will disappear as soon as the mouse button is released. In order to view all the pull-down menus, the user can drag the mouse across the menu bar and as each menu title is selected, the accompanying pull-down menu will be displayed.

B.2.3 Function Key Bar

The function key bar contains a descriptive legend for each of the operational function keys; the user does not enter any information. The function key bar is continuously displayed. The function key legend shows a mnemonic

for each function key as Fn where n is the function key number followed by an equal sign and a brief descriptor of the function such as F10=Exit.

Location:	Bottom line of screen.
Background Color:	White.
Text Color:	Blue.
Graphics Color:	None.
Border:	None.
Characters:	Initial upper case.
User Action:	Information only, no user response permitted in the function key bar area of the screen.

B.2.4   Pull-Down Menus

The pull-down menu is a separate rectangular window displayed beneath the menu bar containing the list of commands available for a particular menu title on the menu bar. It is displayed only from the time the mouse button is held down and the mouse arrow is dragged down through the menu options until the mouse button is released. The pull-down menu window may obscure the previous contents of the screen while it is active.

Location:	A separate rectangular window whose top is immediately beneath the menu bar and upper left corner is aligned with the selected menu title. The menu text is indented two spaces to the left of the selected menu title. The window is one space wider than the title of the longest command title.
Background Color:	Blue.
Text Color:	White.
Graphics Color:	None.
Border:	None.
Characters:	Initial upper case only.
User Action:	To choose one of the listed commands in the pull-down menu, the mouse is used to move the mouse

pointer to the displayed menu title on the menu bar. While the mouse button is held down, the mouse is used to move the mouse pointer to the desired command (dragging). When the mouse pointer is located over the selected command, the mouse button is released. As the mouse pointer moves to each command line, the currently selected command is highlighted in reverse video (white foreground and blue background). The command that is highlighted when the mouse button is released is invoked and the pull-down menu disappears. If the mouse cursor is relocated within the menu bar line and the mouse button released, no action will occur and the pull-down menu will disappear. Similarly, if the mouse cursor is dragged outside of the pull-down menu window and released, the pull-down menu will disappear and no command will be chosen.

B.2.5   Message Windows

Informative messages are about the current system action requesting the user to indicate subsequent actions such as whether the currently selected action should occur or be cancelled. The options available to the user are displayed as pushbuttons and one of the pushbutton must contain a CANCEL option that permits the user to cancel the current request and resume the previous activity.

Location: A separate rectangular window that is located in the
                     workspace beneath the menu bar.
Background Color: Blue.
Text Color: White.
Graphics Color: White.
Border: Double line.

Characters:	Message displayed in sentence format with initial caps centered in window. Pushbutton labels follow pushbutton format.
User Action:	The mouse is used to move the mouse cursor to the pushbutton containing the desired action and depressed.

B.2.6   Dialog Windows

Rectangular windows are ones in which the user enters necessary information in pre-defined fields consisting of pushbuttons, click boxes, check boxes, text entry boxes, labels, and scroll bars.

Location:	A separate rectangular window that is located in the workspace beneath the menu bar.
Background Color:	White.
Text Color:	Black.
Graphics Color:	Blue.
Foreground Color:	Blue.
Border:	Double line.
Characters:	Title in upper case centered in top line of window.
User Action:	The text cursor (cyan background, black foreground) is initially placed in the beginning of the first text entry box for the user to enter the indicated information. When the entry is completed, the user can depress the return key to move the text cursor to the next item in the sequence or, alternatively, use the mouse to move the mouse pointer to the desired field and click to obtain the text cursor in the desired location. In addition, the tab key can be used to move forward to the next text entry field.

B.2.7   Information Windows

Informative windows are ones that present informative messages to the user about current system activity.

Location:	A separate rectangular window that is located in the workspace beneath the menu bar.
Background Color:	Blue.
Text Color:	White.
Graphics Color:	White.
Border:	Double line.
Characters:	Message displayed in sentence format with initial caps centered in window.
User Action:	Information only, no user response permitted in the information window area of the screen.

B.2.8   Text Entry Screens

User scrollable windows are ones in which the user can enter textual/numerical information in a free-format. A scroll bar is displayed on the right side of the window.

Location:	A separate rectangular window that is located in the workspace beneath the menu bar.
Background Color:	White.
Text Color:	Black.
Graphics Color:	Blue.
Border:	Double line.
Characters:	Title in upper case; contents dependent upon user entries.
User Action:	The rectangular text cursor is initially placed at the upper left corner of the window. The user can use the mouse or arrow keys (right, left, up, down, home, page up, and page down) to position the text cursor to the location where the next keyboard entry is to be placed. All key strokes are inserted at the current location of the text cursor. If the entry causes the length of the current line to exceed the display width, all text following the previous delimiter (space) is

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moved to the next line. The depression of a carriage return moves the text cursor and any text after it to the next line. The home key moves the text cursor to first window of text; the end key moves the text cursor to the last window containing text.

B.2.9   List Selection Box

A list selection box contains a list of all items available to the user for the current function, e.g., list of rules for the rule editor, actions for the action editor, objects for the object editor, etc. It requires a scroll bar on the right side of the window to be used to alter the viewing area of the window. The list box window may obscure the previous contents of the screen while it is active.

Location:	A separate rectangular window that is located in the workspace beneath the menu bar.
Background Color:	White.
Text Color:	Black.
Graphics Color:	Blue.
Border:	Double line.
Characters:	Title in upper case in center of top line of window; pushbutton labels follow pushbutton format; remainder dependent upon user inputs.
User Action:	The mouse pointer is initially located on the first item in the window. The mouse is used to move the mouse cursor so as to point to the name of the item to be selected. The currently selected item is shown in reverse video. If the desired item is not currently displayed within the window, the user can move the mouse cursor to the red triangles located at either end of the scroll bar and then depress the mouse button. Each click on the red triangle will display the next set of items in the window. if the user clicks on the up (down) triangle and the pointer is already

located at the first (last) item, the contents of the
screen will remain identical. Once the desired item is
selected, the mouse cursor must be moved to the
appropriate pushbutton to invoke the desired action

B.2.10   List Viewing Box

A list viewing box contains a list of all defined items for the user to
view, e.g., list of alphabetics for the object editor, etc. It requires a scroll bar on
the right side of the window to be used to alter the viewing area of the window.
The list viewing box window may obscure the previous contents of the screen
while it is active.

Location:	A separate rectangular window that is located in the workspace beneath the menu bar.
Background Color:	White.
Text Color:	Black.
Graphics Color:	Blue.
Border:	Double line.
Characters:	Title in upper case in center of top line of window; pushbutton labels follow pushbutton format; remainder dependent upon user inputs.
User Action:	The mouse pointer is initially located on the first item in the window. If the desired item is not currently displayed within the window, the user can move the mouse cursor to the red triangles located at either end of the scroll bar and then depress the mouse button. Each click on the red triangle will display the next set of items in the window. If the user clicks on the up (down) triangle and the pointer is already located at the first (last) item, the contents of the screen will remain identical. Once the viewing of the defined items is complete, the mouse cursor must be

moved to the appropriate pushbutton to invoke the
desired action

B.2.11   Push Buttons

Pushbuttons perform instantaneous actions as described by the text
label with a mouse click anywhere within the button area.

Location:	A separate rectangular window that is located in the workspace beneath the menu bar.
Background Color:	Assumes background color of item beneath.
Text Color:	Red.
Graphics Color:	Assumes foreground color of item beneath.
Border:	Rectangular box with double line on top and bottom; single line on left and right. It is sized so that there are at least two leading and trailing spaces around the pushbutton legend.
Characters:	Upper case button label centered in box.
User Action:	The mouse is used to move the mouse cursor so that the pointer is located anywhere within the rectangular area and then a mouse button is clicked. Once any mouse button is depressed, the button label is shown in reverse video (red background and white foreground) and the indicated function immediately invoked.

B.2.12   Click Boxes

Click boxes are used to specify numeric values. It requires a scroll
bar on the right side of the window to be used to alter the numeric value
currently displayed in the window.

Location:	Varies but always within a dialog window.
Background Color:	White.
Text Color:	Black.

Graphics Color:	Blue.
Border:	Rectangle with double line border.
Characters:	Title in upper case in center of top line of window;.
User Action:	The user can modify the currently displayed value by:

1. Moving the mouse pointer to the red triangle located above the box to increase the number shown in the box by 1 each time a mouse button is depressed or

2. Moving the mouse pointer to the red triangle located beneath the box to decrease the number shown in the box by 1 each time a mouse button is depressed.

B.2.13   Text Entry Boxes

Text entry boxes are fields where textual or numerical data are entered.

Location:	Varies but always within a dialog window.
Background Color:	White.
Text Color:	Black.
Graphics Color:	Blue.
Border:	Rectangular box drawn with single blue line. If the entry in the box can be bigger than the box size, a double blue line is placed on the left and right to indicate that the user can scroll right and left within this box.
Characters:	Label with initial caps terminated with a colon to the left of the box; entries in box are based upon user actions.
User Action:	The rectangular text cursor is initially placed at the left side of the box. The user can use the mouse or arrow keys (right and left) to position the text cursor to the location where the next keyboard entry is to be

placed. All keyboard strokes are inserted at the current location of the text cursor. If the entry causes the length of the current line to exceed the display width, either of the following will occur:

1. If the box is the exact size of the permitted entry (i.e., the right and left side are single lines), a beep will be sounded and future keyboard entries (except backspace and delete) will be ignored until a non-text key is depressed or

2. If the entry can be larger than the box (i.e., the right and left sides are double lines), the text will be scrolled to the left as additional keys are depressed until the maximum field size is reached.

The left and right arrow keys move the cursor one space in the indicated direction within the text entry box. The home key moves the text cursor to the first character in the box; the end key moves the text cursor to the last character in the box.

B.2.14   Scroll Bar

Scroll bars are used to change which part of a list of items (list window) or contents of a file (text entry window) is shown the window. Double red scroll arrows are used at the top and bottom of the scroll bar rectangle to indicate the direction the viewing area is to be moved. The top arrow (▲) is used to scroll up one line at a time; the down arrow (▼) is used to scroll down one line at a time. The second up arrow (↑) is used to scroll up one page at a time; likewise the top down arrow (↓) is used to scroll down one page at a time.

Location: Rectangular box shown on right side of text entry and list boxes.

Background Color: White.

<u>Text Color</u>:	None.
<u>Graphics Color</u>:	Blue.
<u>Border</u>:	Double line.
<u>Characters</u>:	Graphics characters of ▼ and ▲.
<u>User Action</u>:	The user uses the mouse to position the mouse cursor at the desired scroll arrow and clicks to alter the contents of the window. The content of the window is moved in the opposite direction from the arrow. For example, when the user clicks the top scroll arrow, the contents moves down, bringing the view closer to the top of the list or document. Each click of the single arrow moves the window contents one line in the chosen direction; each click of the double arrow moves the window contents one page in the chosen direction. Continuous depression of the mouse results in continuous movement in the chosen direction. Once the top or bottom of the window contents is reached, depression of the scroll arrows in that direction are ignored.

B.2.15   <u>Labels</u>

A label is an alphanumeric description of the information to be entered for a component of a dialogue window.

<u>Location:</u>	Varies.
<u>Background Color</u>:	White.
<u>Text Color</u>:	Blue.
<u>Graphics Color</u>:	None.
<u>Border</u>:	None.
<u>Characters</u>:	Initial upper case and terminated with a colon.
<u>User Action</u>:	None.

B.2.16   Radio Buttons

Radio Buttons are used to select mutually exclusive options. They are displayed as small circles that appear to the left of the option label. When selected, a smaller black dot appears within the circle. Whenever an option is selected, the previous selection is deselected.

Location:	Varies but always within a dialog window.
Background Color:	White.
Text Color:	Black.
Graphics Color:	Black.
Border:	Circle with single line border.
Characters:	Label for option to the right of the circle
User Action:	The user selects the desired option by moving the mouse to the radio button next to the desired option.

B.2.17   Check Boxes

Check boxes are used to select options that can be activiated simultaneously. The selection of an option will not deselect previously chosen options.

Location:	Varies but always within a dialog window.
Background Color:	White.
Text Color:	Black.
Graphics Color:	Black.
Border:	Rectangle with single line border.
Characters:	Label for option to the right of the box.
User Action:	The user moves the mouse cursor within the desired box and clicks.

B.2.18   Mouse Cursor

The mouse cursor is a pointing device used to select commands from menus, to control cursor movement, and to manage file scrolling.

Location:	Varies.
Background Color:	Assumes background color of object beneath.
Text Color:	None.
Graphics Color:	Assumes foreground color of object beneath.
Border:	None.
Characters:	Arrow (↗).
User Action:	The user moves the mouse cursor to the desired location by moving the mouse in the desired direction. Every mouse movement moves the mouse cursor in exactly the same way. The following mouse actions can be performed:

- **Clicking** — positioning the mouse cursor with the mouse, briefly pressing and releasing the mouse button without moving the mouse.
- **Pressing** — positioning the mouse cursor with the mouse, holding down the mouse button without moving the mouse.
- **Dragging** — positioning the mouse cursor with the mouse, holding down the mouse button, moving the mouse to a new position, then releasing the button

B.2.19   Text Cursor

The text cursor indicates where next keyboard stroke will be entered.

Location:	Varies.
Background Color:	Cyan.
Text Color:	Black.
Graphics Color:	Assumes foreground color of object beneath.
Border:	None.
Characters:	Rectangle the size of a single character (▮).