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ADAPTIVE DESIGN OF A DECISION SUPPORT
SYSTEM FOR DYNAMIC RETASKING OF
CAS AND BAI ASSETS

THESIS

Peter W. Hoak, B.A., M.S.
Captain, USAF

AFIT/GCS/ENG/87D-14

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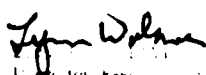
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This research produced a kernel storyboard through the iterative cycles of the design process. This design was then analytically evaluated using measures of effectiveness such as: (1) proper assignment of functions, (2) structural complexity, and (3) compatibility and understandability. This research demonstrated that segmentation of the complex retasking problem into kernels provides a plan for gradual, manageable growth of the DSS. Problems of miscommunication and attempting to prespecify all the users needs at the start were avoided with the adaptive approach. Additionally, it was verified that adaptive design requires a plan and strong organizational support to be effective. Recommendations for continuing the adaptive design and implementing the operational retasking prototype are also addressed in this thesis.

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ADAPTIVE DESIGN OF A DECISION SUPPORT SYSTEM
FOR DYNAMIC RETASKING OF
CAS AND BAI ASSETS

THESIS

Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the
Requirements for the Degree of
Master of Science in Information Systems

Peter W. Hoak, B.A., M.S.

Captain, USAF

December 1987

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Preface

The purpose of this thesis was to investigate how we can best apply adaptive design to build a decision support system (DSS) to meet the current Air Force needs in the Air Support Operations Center (ASOC). The emphasis throughout this study has been on how we can better integrate the ASOC decisionmaker in the iterative design process throughout the life of the DSS. The methods I propose for successful adaptive design of the ASOC DSS require radically different thinking. Perhaps the biggest difference between adaptive design and our traditional system design methods lies in the role of the user; *adaptive design requires continual input from the user as his perceptions of the problem and his needs change.*

Much of the inspiration for this work came from my thesis advisor, Lt Colonel "Skip" Valusek. His guidance and support throughout the project were a great source of strength. I would also like to thank the decisionmakers at the 682 ASOC, Shaw AFB, especially Captain John Meroth, who provided valuable input during the early design phase. Lt Colonel Kozma, and his staff at TAC/DOYF deserve thanks for the advice they provided; I look forward to working with them on tactical system requirements. I also wish to acknowledge Mr. Mike Young, Major Duard Woffinden, and Captain Mark Roth for their time and helpful criticism during the project.

Lastly, I wish to thank family and friends who have supported me with prayers throughout this challenging thesis project.

Peter W. Hoak

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Abstract

The purpose of this study was to investigate a methodology for the ongoing analysis and design of a decision support system (DSS) for retasking decisions made by the fighter duty officer (FDO) in the Air Support Operations Center (ASOC). An adaptive design approach was chosen and modified to minimize the problems of miscommunication and prespecification that traditional analysis and design presents. The research had five main objectives: (1) Determine through concept mapping and discussions with FDOs from the ASOC, the decision processes that the FDO would make during retasking of missions. (2) Establish a central decision process ("kernel") from the ASOC that would benefit from a DSS. (3) Translate the initial requirements established through this analysis into a set of screen representations ("storyboard") that the FDO can use as an initial retasking DSS. (4) Evaluate the effectiveness of the adaptive design methodology for determining initial requirements, and the ability of the techniques to serve as a dynamic statement of requirements as the DSS grows. (5) Investigate details of the adaptive design approach within this application that facilitate or hinder the methodology.

This research produced a kernel storyboard through the iterative cycles of the design process. This design was then analytically evaluated using measures of effectiveness such as: (1) proper assignment of functions, (2) structural complexity, and (3) compatibility and understandability. The Macintosh™ software Hypercard™ was used as a tool to assemble a "part-task simulator" for the DSS. The graphical display and linking capabilities of this software proved useful for design enhancement.

Overall, the research demonstrated that using an adaptive approach to

the retasking DSS design provides a "communication anchor to enable and enhance dialogue" between decisionmaker and designer. It was also found that segmentation of the complex retasking problem into kernels provides a plan for gradual, manageable growth of the DSS. Problems of miscommunication and attempting to prespecify all the users needs at the start were avoided with the adaptive approach. Additionally, it was verified that adaptive design requires a plan and strong organizational support to be effective.

Recommendations for continuing the adaptive design and implementing the operational retasking prototype are also addressed in this study.

ADAPTIVE DESIGN OF A DECISION SUPPORT SYSTEM FOR DYNAMIC RETASKING OF CAS AND BAI ASSETS

I. Introduction

Formulating the Problem

Through recent academic study of system design techniques, this researcher has become interested in the unique challenges that await the designers and builders of decision support systems (DSS). With an interest in further investigating this relatively new multidisciplinary approach to command and control (C2) problems, this researcher began a search for a suitable military application area. One specific area that was suggested earlier this year by engineers in the Rome Air Development Center Decision Aids Branch is the need for further study and work centering around the Air Support Operations Center (ASOC) mission and responsibilities.

Basically, the ASOC is responsible for execution of close air support (CAS) and planning of battlefield air interdiction (BAI) missions in support of the Army. In this role, the ASOC is not well prepared to execute and plan flexibly. When it comes to being able to rapidly replan missions, and to quickly examine the feasibility of retasking or diverting missions, the ASOC has many deficiencies. Part of the reason for these deficiencies is that mission executors in the ASOC have not traditionally envisioned the activity of retasking, or the recommendation to retask, as part of their formal

responsibility. Perhaps the larger problem though, is the absence of a support system to assist the decisionmaker with the retasking decisions. Given these recognized deficiencies, the ASOC appears to be a ripe area for investigating the utility and possible design of a retasking DSS. This application area also appears suitable because of the limited scope of the tactical ASOC environment, coupled with the apparent applicability of an evolutionary or adaptive approach to the design work that needs to be accomplished. The remainder of this chapter discusses several aspects of the tactical environment relevant to the ASOC, and finally, focuses on the deficiencies in the ASOC that will be addressed by a retasking DSS.

The Overall Tactical Challenge

Technology is one of the major forces influencing the progression of military operations and the systems that support those operations. Today's current tactical fighters offer increased capability for initiative against the enemy in a joint scenario. At the same time modern enemy defenses pose new threats for both friendly land and air assets. As another example, sophisticated ground threats such as surface-to-air missiles (SAMs) pose lethal threats for aircraft on CAS and BAI missions. In other high technology areas, the current state-of-the-art communication and computer systems are designed to be less vulnerable to enemy interception and countermeasures. These communication and computer systems are able to capture, process, and transmit substantial amounts of information about the enemy, and thus can provide much of the enemy and friendly force status to battle managers on a near-real-time basis. This information is most useful to the joint tactical planners and mission executors if they realize its significance to those

portions of the tactical environment they manage. They can then include this information in their decisionmaking and joint planning. A more thorough integration of the available battlefield information with the decisionmaking of the command and control cycle is needed.

The way that this decisionmaking information is used may well influence the success of integrating joint military capabilities and forces in a concerted effort, and may ultimately affect the outcome of the conflict. If they are planned and executed successfully, the combined effect of joint operations is to wield a greater impact where and when it is needed on the battlefield; greater than if each of the forces were operating independently. However, the joint tactical battle is becoming exceedingly difficult to plan for and then flexibly execute. Although the technology exists, and the decisionmaking information can be gathered, the systems needed to command and control the joint forces are not all developed or in place. Many of these support systems are still in their early conceptual and design phases. The operational experts in concert with the system designers and builders have not been able to develop the command and control decision support systems to keep pace with recent technological advances. Often, it seems that technology provides the impetus for redefining and refining system requirements; this technology and the information it provides to decisionmakers is heavily influencing the demand and justification for today's decision support systems.

The bottom line is this: if our tactical military forces are to capitalize on the benefits of modern technology, and use it to our advantage in tactical battle, they must possess systems to support their command and control decisions.

Command and Control

A general, all-encompassing definition for command and control is the approved Department of Defense (DOD) definition found in Joint Chiefs of Staff (JCS) Pub 1:

The exercise of authority and direction by a properly designated commander over assigned forces in the accomplishment of his mission. Command and control functions are performed through an arrangement of personnel, equipment, communications, facilities, and procedures which are employed by a commander in planning, directing, coordinating and controlling forces and operations in the accomplishment of his mission.

One of the keys to effective command and control at all levels of future tactical battles will be the smart joint integration of personnel, equipment, communications, facilities, and procedures to accomplish the commander's objectives. Although this definition covers the activities of command and control adequately, it misses a key point that the next definition emphasizes.

This alternate definition, that focuses on the decisionmaking aspects of command and control, is offered:

... a process: or more accurately, a set of related processes. It is, first, a process of getting information to decisionmakers. Second, it is a process of interaction between decision makers. Third, it is a process of implementing their decisions. All three of these vital processes are centered around decisionmakers: the task of command and control is to help them see more clearly what is happening, decide what to do about it and implement the necessary actions (Conwell, 1984 : 13).

This definition of C^2 focuses on the most critical and toughest part of the process: decisionmaking. It also more closely matches the conceptual process model for C^2 developed by the Military Operations Research Society (MORS). This process model includes the activities of sensing stimuli, assessing data, generating options, selecting alternative, and planning and directing a response (Sweet and others, 1985 : Ch 5, 4). These two latter definitions establish a better frame of reference for C^2 and the possible role of a DSS in this process.

With this C^2 frame of reference, several initiatives within the Army and Air Force to improve the C^2 process are discussed below. The Army and Air Force initiatives are of particular interest because these two services provide decisionmakers for the tactical decision making within the ASOC.

US Army Initiatives

The US Army is actively incorporating the latest technology into their current operational concept, or Airland Battle doctrine. This doctrine essentially requires commanders "to attack the enemy through the depth of his formations, bring about and accept close combat on favorable terrain with acceptable combat power ratios, and employ reserves at the decisive (optimal) time to complete the destruction of the enemy" (McKinney, 1984). A former commander of the US Army Training and Doctrine Command clarifies this point:

Airland Battle ... states that the battle against the second echelon forces is equal in importance to the fight with the forces at the front. Thus the traditional concern of the ground commander with the close-in fight at the forward line of own troops (FLOT) is now inseparable from the deep

attack against the follow-on forces. To be able to fight these simultaneous battles, all of the armed services must work in close cooperation and harmony with each other. If we are to find, to delay, to disrupt and to kill the total enemy force, we will need the combined efforts of the Air-Army team" (General Glenn K. Otis)

This statement affirms both the inseparability of the CAS missions and second echelon, or BAI missions, as well as the necessity for the Army and Air Force to accomplish these missions in a combined and closely coordinated fashion.

The Army describes their plan for accomplishing these goals on the future battlefield in their Army 21 doctrine; a plan which "depends largely on high mobility, deep strike and surgical interdiction strategies" (C³I Management, 1986). According to Dr. Mark Epstein, Deputy Chief for C³I in the Office of the Assistant Secretary of the Army, "we've modernized our weaponry substantially over the last five, six seven years . . . and during that period we did not modernize the C³I unit " (C³I Management, 1986). He further states what is needed is a more thorough integration of command, control and information elements including a variety of sensors, communications links, C² support facilities as well as information processing and display equipment with weapons.

Some of the most critical new programs that the Army is developing with the Air Force and Navy to support these C³I deficiencies are the Milstar satellite communications system, Joint Tactical Information Distribution System (JTIDS), Joint Surveillance Target Attack Radar System (JSTARS), and the Joint Tactical Fusion program including the All Source Analysis System (ASAS). The ASAS is a good example of a system that integrates information with the C² decision process; essentially, ASAS will "identify

time-critical tactical intelligence inputs and generate predictions on enemy battle strategy based on new data and known methods of operation" (C³I Management, 1986). Careful joint integration of these and a host of other C³I initiatives with the other military services will allow the Army to meet the goals of their Army 21 doctrine.

Air Force Component

Within the joint tactical Airland Battle environment, the Air Force Tactical Air Control System (TACS) provides the centralized planning and decentralized execution of the air battle, in support of the joint commander's objectives. Each of the different theaters have devised their own slightly different systems based on this general TACS concept. Specifically, the Tactical Air Control Center (TACC) acts as the operational center of command and control for the Air Component Commander (ACC). In the NATO environment, the equivalent of the TACC is the Air Tactical Operations Center (ATOC). The role of the ATOC in planning and execution is almost identical to a TACC that deploys from the US, so no distinction will be made between these two tactical agencies.

Below the TACC is the Air Support Operations Center (ASOC), which is the arm of the TACS that receives and coordinates air requests in support of the Army ground forces (see Figure 1, Proposed Upgraded ASOC System). The ASOC is generally collocated with the corps staff at the Corps Tactical Operations Center (CTOC), but may also be employed at field Army level or with an independent operating division or brigade. The ASOC is concerned primarily with the exchange of combat data between air and ground forces and the coordination and execution of close air support (CAS) of ground units and planning for Battlefield Air Interdiction (BAI) missions with the Army.

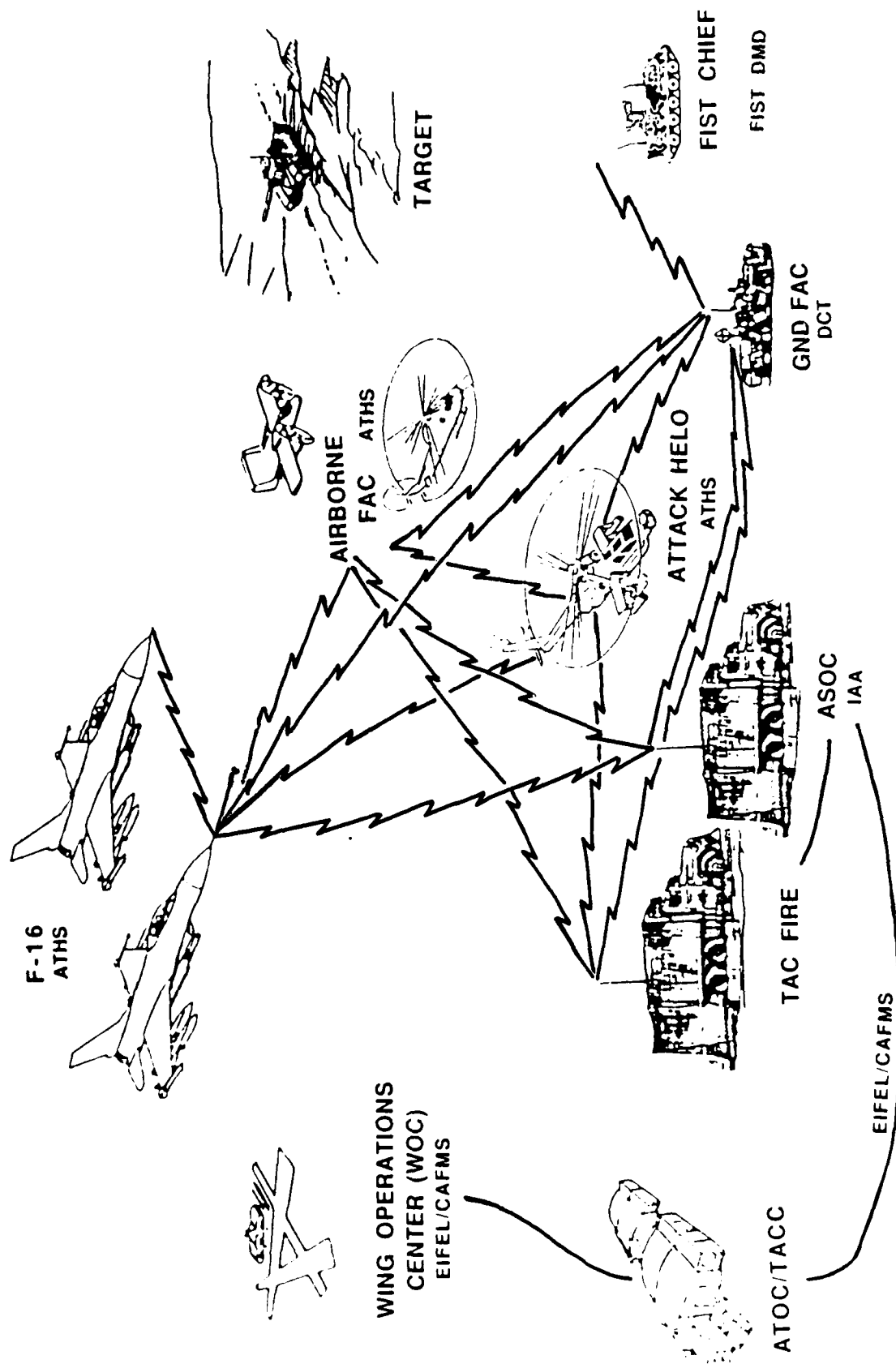


Figure 1. Proposed Upgraded ASOC System (General Dynamics Proposal, 16 June 1987)

In these roles, the ASOC is the arm of the TACS that needs to be most closely aligned and synchronized with the current Army operation. In an Airland battle that begins at the FLOT, extends to the second echelon and may include surgical interdiction and special operations in-between, the requirement for an effective Air Force liaison at Corp level is critical. The ASOC basically functions in this liaison role by providing expert advice on air assets and capabilities, and coordinating the integrated plan between the Army initiatives and Air Force close-air and battlefield interdiction support.

Air Force Initiatives

Two complimentary Air Force TACS programs have been spearheaded in the last year to enhance the command and control capabilities of the air component commander and increase the integration and interoperability during joint operations. The Tactical Battle Management (TBM) program provides a general framework for the two by recommending an evolutionary or gradual-growth approach to developing and acquiring enhanced C³I systems to support contingency TACS planning and execution. At the TACC level, the goal of TBM is to integrate a number of existing and planned automated systems and decision aids. This integration would naturally filter down to the ASOC level as well.

The other Air Force initiative still in its conceptual phase is the Contingency TACS Automated Planning System (CTAPS). This project is aimed at providing an Ops-Intel integrated C² system to: (1) improve operational plans development time, (2) provide theater to theater interoperability and (3) improve command level and execution level communications. This program is like TBM in that an evolutionary approach is planned to field an operational system as quickly as possible using

off-the-shelf hardware and software that exists or is currently being developed.

Evolutionary Approach

Both of these programs are of particular interest to this researcher because they are planned to be evolutionary or adaptive in nature. Specifically, in this case, this translates into a development approach that will employ complimentary user/developer test facilities at Langley AFB, VA and Hanscom AFB, MA. These facilities will be interconnected to share the development effort and exchange information. Many software modules will be modified from existing software and plugged-into the larger system under development. A baseline capability is planned from the beginning and releases/versions of the system will be built incrementally, and quickly fielded for user testing. Strong user involvement in testing and evaluation throughout the program will be emphasized.

From this short description one can guess that the innovative and dynamic management of the programs is likely to field successful systems within a minimum of time, if we disregard the technical problems or political roadblocks that may arise during the programs. These evolutionary programs present many opportunities for further research and study if an effective C³I system is to be fielded at all levels of the TACS. The evolutionary approach that TAC is promoting for these major programs meshes nicely with an adaptive approach to designing the ASOC DSS that is being studied here. As will be discussed later, adaptive design also includes methods for the user to generate and refine system requirements as the DSS evolves; adaptive design addresses many of the front end activities of system design that have traditionally been neglected.

Current ASOC Organization and Responsibilities

The ASOC is commanded by a director and a senior operations officer. Functional positions within ASOC operations normally include: the fighter duty officer (FDO), reconnaissance duty officer (RDO), tactical air command and control specialists, air intelligence and targets officers, intelligence technicians, and information systems operators (radio operators) (TACR 55-46, 1986 : Ch 2, 1).

The ASOC fills Army requirements for immediate tactical air support from allocated sorties or by authorized diversion of preplanned sorties. The ASOC keeps the TACC advised of the air effort needed to satisfy Army tactical air support requirements and will request additional tactical air resources when requirements exceed the sortie allocation. Essentially, the ASOC Director must insure that air assets are used in the most effective manner commensurate with the current threat, the battlefield situation and *the disposition of friendly air defense weapons.*

The system that exists today to accomplish these ASOC missions dates back to the 1960s. Automated systems are non-existent in the ASOC, with the exception of the current plan to provide them with one Computer Assisted Force Management System (CAFMS) terminal. This terminal will be used to receive their portion of the daily Air Tasking Order (ATO) and provide a communications link to the operational flying units for scrambling sorties and reviewing current status of aircraft assets.

Some of the deficiencies in the ASOC are outlined in the recently published Statement of Operational Need (SON) for ASOC Improvements. Although the document does not explicitly state the need for retasking in the ASOC, it does make provision for the development of a future ASOC in the long term (10 years). Through conversations with experts and planners at

various levels, it is widely accepted that the requirement to rapidly retask and divert exists. In addition, much of the hardware system requirements that are outlined in the SON suggest that this is what the planners have in mind for the long term plan, but are more interested in fixing the gaping planning deficiencies at this time. Specifically, the SON states that "the current ASOC is operationally deficient in the areas of mission requirements/request processing, resource status reporting, mission schedule monitoring, mission results and special events reporting." It further states that "as all types of operational message traffic increase, the ASOC operational mission data becomes less current because of workload in manual processing, dissemination, transmitting and posting of information. As a result, operational missions may not be alerted, scrambled, or diverted within acceptable time limits" (TAF SON __-87, 1987: 2).

Perhaps another deficiency just as significant as these is the absence of any mechanism (*automated or manual*) in the ASOC to assist the personnel in integrating their efforts with the Army's airland battle initiatives. Both the battle at the FLOT and that at the second echelon are expected to be changing rapidly in future conflicts. Priorities on Army targets will be shifting, target locations and accessibility will be changing, and new unanticipated targets will require immediate attention and rapid planning. The Air Force FDO in the ASOC will be required to work closely with the Army Operations Officer (G-3) to respond to this changing environment. The Army's integration of targets on the FLOT and second echelon will have to be understood and situationally displayed for the FDO in the ASOC, in order for him to optimally respond to the Army's needs for air support.

It is envisioned by this researcher that there will be a recurring need to retask missions as the battle priorities and targets dynamically change.

Within the scenarios discussed above, there will be a greater need than in the past, to use the most effective weapon against each target. There also exists the potential for a greater variety of targets and the possibility of unanticipated targets immediately rising to the top of the Army's priority target list.

Some of these same issues and questions were addressed in a recent AFIT thesis by Schoeck. Although he focused on Air Interdiction (AI) assets, he proposed that "the ability to make rapid decisions with new information and the capability of our AI assets to flexibly react to a new set of orders would further advance the ability of friendly ground forces to take and maintain the initiative" (Schoeck, 1987 : Ch 1, 4). Three of the pertinent questions he addressed include:

- 1) Should a set of follow-up missions be held in reserve?
- 2) When and where should they enter the battle?
- 3) Should the FDO redirect an airborne aircraft to a new, higher priority target?

Schoeck later proposes a design for a decision aid for the FDO to address these three and other questions as they arise in battle. He admits that retasking will be difficult in a high threat environment in which the aircrews expend considerable effort in planning the original mission. What he implies with these suggestions for retasking though, is that with the technological sophistication of the future, that the FDO, the mission pilot, and other support agencies and aircraft may be all linked through a distributed decision support system (DSS); with this distributed system in place his proposed concept of dynamic retasking becomes both feasible and a

productive alternative for tactical missions.

Statement of the Problem

The ASOC lacks the capability to support the Army in pursuing the joint objectives of the airland battle doctrine. The antiquated manual procedures in the current ASOC barely allow the personnel to keep up with coordinating and tracking planned missions. Improvement is needed in the integrated employment of tactical airpower in support of land warfare both at the FLOT and the second echelon. Today's FDO has no support for dynamically planning and either retasking or recommending retasking of both CAS and BAI missions. A decision aid is needed to assist the FDO in the ASOC in making these dynamic decisions. The FDO must be able to view selected data and the ground situation to make his decision. He may further need the support of analytical models to test the feasibility of selecting different options during the initial planning and retasking processes.

Research Objective

This researcher will investigate the possibilities for enhancing the ASOC support of the ground forces through the use of an automated DSS. As part of this study, the following sub-objectives will be addressed:

- 1) Determine, through use of the technique of concept mapping and discussions with experienced FDOs, the decision processes that the FDO in the ASOC makes in his mission planning, coordinating, and executing roles.
- 2) Decide on a critical or central decision process ("kernel") that would benefit significantly from a decision support aid.

- 3) Translate the initial requirements gathered through the procedure in sub-objective 1 for the critical decision process into a set of screen representations ("storyboard") that the FDO can relate to as the possible steps of the decision process.
- 4) Evaluate the effectiveness of the activities in sub-objectives 1-3 for quickly determining initial DSS requirements, and the ability to build on these initial requirements.
- 5) Discuss details of the adaptive design approach within this application that facilitate or hinder this methodology.
- 6) Provide an early analytical evaluation of the preliminary system design. Further empirical evaluations may be possible as the system prototype is developed.
- 7) Discuss possibilities for enhancing the initial prototype design and what developmental and organizational support is needed for this.

The sub-objectives above provide a rough outline for an approach to building DSSs called adaptive or evolutionary design. The detailed techniques available for adaptive design and the utility of using it will be discussed in Chapter II. Chapter III discusses the application of the adaptive design process in building the ASOC DSS and why it is the method of choice. Chapter IV evaluates the resulting prototype design. Chapter V provides recommendations on the resulting DSS design and on the adaptive design process in general.

II. Methodology

This chapter describes different approaches that could be followed in working toward a solution of the problem presented in chapter I. Particular emphasis will be given to the adaptive design and development of decision support systems (DSSs), with reference to current ongoing research work in this area.

Definitions

The following definitions are offered to provide a common frame of reference for the discussion of different methodologies that follows:

DSS - an interactive system that provides the user with easy access to decision models and data in order to support semistructured and unstructured decisionmaking tasks (Watson and Hills, 1983 : 82).

DSS - a class of information system that draws on transaction processing systems and interacts with the other parts of the overall information system to support the decisionmaking activities of managers and other knowledge workers in organizations (Sprague and Carlson, 1982 : 9).

Two definitions are provided because no single definition was found to include all important aspects of a DSS; these two definitions provide the needed basis for the later discussion of different methodologies.

Sprague and Carlson's intent in the second definition was to eliminate several misconceptions they recognized in the familiar connotational definition of DSS that had evolved over the years. First, Sprague and Carlson felt it is important to realize that decision support is required at all levels

of management in the organization. Second, the decisionmaking which occurs at various organizational levels must normally be closely coordinated and communicated between these levels. These ideas about decisionmaking and required support for it are generally true both in business and also in military C^2 applications; acceptance of the two above complimentary definitions influenced the approach taken during this project.

Armed with these two definitions, several current and noteworthy C^2 DSS research efforts are reviewed in the following sections. The first effort (Hopple) is characteristic of a class of ongoing theoretical C^2 decisionmaking research that, although it covers many of the complicated issues involved in this area, it offers little concrete guidance to a designer of a new DSS. The next class of DSS research that is discussed does offer specific guidelines and examples for designing a C^2 DSS. This latter work closely resembles the current research in DSS adaptive design at the Air Force Institute of Technology (AFIT) under the guidance of Valusek (Valusek, 1987:1-16). An examination of both theoretical issues and practical guidelines are included to show the complexity and difficulty in transitioning from theory to practice in DSS design.

Theoretical Approach to C^2 DSS Design

Perhaps a good place to start this section is by reviewing the research of Hopple. This research examines the dangers that may arise during the initial stages of the system design and development strategy he calls prototyping. Figure 2 depicts the nine primary steps, and the associated activities that a DSS designer should follow at each step of the strategy. The front-end of this methodology (step 1) is somewhat similar to the concept exploration phase of the defense system life cycle, with emphasis on feasibility studies,

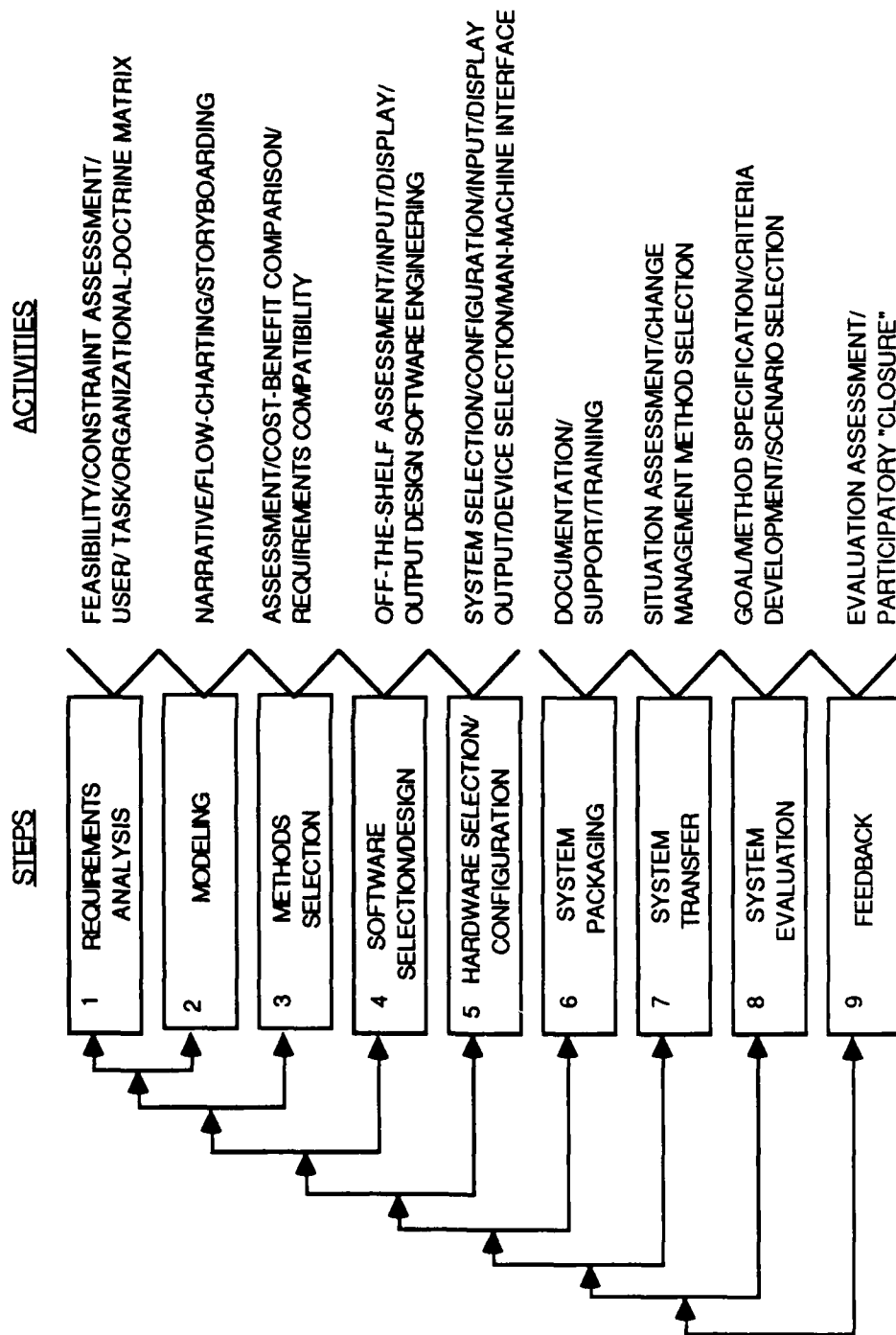


Figure 2. Hybrid Prototyping Strategy (Hopple, 1986:949)

cost-benefit comparisons, and requirements definition. Hopple, in his discussion focuses on dangers that may arise during the first three steps "because the front-end steps are vital preconditions for the development and fielding of viable (useful, usable, valid, and reliable) C^2 aiding systems" (Hopple, 1986 : 948). Unfortunately, he barely addresses the specific activities required in the second step of modeling.

Before beginning any design or development of a decision aid, Hopple cautions that rigorous evaluation is needed to demonstrate that a computer-based system is needed to solve the problem. Later, he calls for a "theoretically validated typology of decisions and a coherent framework for guiding the design process" (Hopple, 1986:949). With this theoretical typology, a designer can supposedly assign a candidate problem to the typology and get an indication of the best approach to solving it. Hopple proceeds at a very theoretical level to lay the groundwork for building such a typology from C^2 decisionmaking theory.

The next step Hopple takes is to develop a simple matrix that includes the two types of uncertainty that may exist in a C^2 decision situation. Figure 3 shows this matrix. To give an example of a situation that is represented by quadrant C in the figure, Hopple describes a tactical decisionmaking situation in support of combined air-land operations. Each of the quadrants contains decision situations that are best supported by different decision aids. For example, decision aids for cell C "will generally concentrate on the facilitation of understanding and meaning (hypothesis and option generation, evaluation, and selection)" (Hopple, 1986 : 950).

		Input Data Quality	
		High	Low
Options	Fixed		A
	Open	B	C

Figure 3. Basic Decision Aiding Scenarios (Hopple, 1986:951)

Those for cell A will focus on the "improvement of the battlefield perception process and the enhancement of the quality of data" (Hopple, 1986 : 950).

This decision aiding scenario matrix is also used as a basis to describe some of the particular problems that arise under crisis situation decisionmaking especially with the perceptual and cognitive limitations of most decisionmakers. This discussion is also relevant to C^2 decisionmaking and DSS, but primarily at a theoretical level.

One important point that Hopple repeats from Wohl is:

The preponderance of work in decision theory has concentrated on techniques for option *selection* with little research on those portions of the process which are of greatest interest to military commanders, namely, the *creation, evaluation, and refinement* of both hypothesis (i.e., what is the situation) and options (i.e., what can be done about it) (Hopple, 1986 : 952).

Recognizing that a classical decision theoretic framework is not appropriate for C^2 decision situations, Hopple continues by introducing a

decision situation typology, as shown in Figure 4.

DECISION PROCESS MODEL TASK TYPOLOGY	CLOSED	OPEN			CRISIS
		INFO INPUT UNCERTAINTY	CONSEQ'S OF ACTION UNCERTAINTY	BOTH	
STIMULUS					
HYPOTHESIS					
OPTIONS					
RESPONSE					

Figure 4. Decision Situation Typology (Hopple, 1986:953)

Hopple borrows the four following decision process categories (as shown in Figure 4) from Wohl, because he feels they encompass the essential functions or tasks of C^2 decisionmaking and provide the essential link between decision aids and real world C^2 decisionmaking:

- 1) stimulus (data)
- 2) hypotheses (perception of alternatives)
- 3) options (response alternatives)
- 4) response (action)

The twenty C^2 decisionmaking occasions that are shown in the matrix in Figure 4 "constitute the universe from which potential decision-aiding opportunities or perceived needs arise" (Hopple, 1986 : 953). Supposedly, the system designer should be able to determine the cells of the matrix that

represent his current effort. As the emphasis shifts to the right side of Figure 4, the "system designer and user are both advised to address the question of aidability more rigorously" (Hopple 1986 : 953).

All of the effort Hopple has suggested so far is intended as a framework to be used during the requirements analysis phase of the nine step process shown in Figure 2. Overall, the following sequence of steps are advocated for performing the requirements analysis (Hopple, 1986 : 954):

- 1) Select and define the decision problem.
- 2) Make a detailed description and decomposition of the problem.
- 3) Determine aidability. Is the domain aidable? If not, can it be redefined to make it aidable in whole or in part?

Difficulty in Applying Theory. The first two activities of the sequence above are extremely difficult, if not impossible to carry out during the first phase of the design strategy, as Hopple suggests. The unstructured nature of most C^2 decisionmaking scenarios prevents the DSS designer from defining and decomposing the problem at the front-end of the project. The suggestion to completely decompose the problem prior to proposing any DSS design is unrealistic as well as inappropriate. Trying to completely define the problem, the user's requirements, and the system specification prior to designing any portion of the system is a method that may work for well understood automatic data processing (ADP) type requirements, but is ill-suited to DSS. A more practical and incremental approach that has proven successful in building DSS is recommended by Andriole and other

proponents of unequivocal design techniques like adaptive design. Before delving into the research on these concrete design approaches, some of the psychological considerations in designing a DSS are briefly discussed.

Psychological Issues in DSS Design. A concern in DSS design is how to most appropriately assign the tasks to the decisionmaker and the system that they each perform most effectively; in other words a splitting of the decision tasks between man and machine. Hopple points out that one of the basic findings of research is "that people are susceptible to a number of biases and errors in describing and otherwise dealing with empirical reality" (Hopple, 1986a : 322).

Specifically, humans have difficulty applying statistical principles; they seem to prefer the "evidence of a vivid, concrete case over abstract, statistical information" (Hopple, 1986a : 322). Another human weakness is that people tend to overestimate the probability of conjunctive events and underestimate the probability of disjunctive events. Within the tactical mission area, the overall success of the mission is usually a conjunctive probability; each event in a series must occur for the mission to be successful. For a mission, success may depend on the probabilities of the aircraft taking off, the aircraft getting to the target, the weapon hitting the target, and the aircraft returning and landing safely.

Schwartz and others describe some related considerations in the area of "cognitive systems engineering focusing on the cognitive (i.e., mental) functions of human-machine systems" (Schwartz and others 1986 : 788). They describe some additional strengths and weaknesses of humans and systems which should be considered during C^2 system design. In the area of correlation, humans are strong in knowing what information to gather (data relevance), knowing to what object a datum belongs, and integrating

data-based information (i.e., military doctrine). On the other hand, humans have problems identifying relationships and the strength of relationships. Humans are also weak at evaluating data integrity (reliability, consistency) and are disproportionately influenced by the way data is presented. System strengths generally lie in the areas mentioned where humans are weak. However, systems are weak in situations which are complex and generally only "rules of thumb" are used (Schwartz and others 1986 : 791). One additional issue that Schwartz briefly addresses is that the decisionmaker's mental model, or view of the system, affects joint decisionmaker/computer system performance as much as more traditional human factors concerns, such as screen design, type of interaction, and input devices (Schwartz and others 1986 : 788). These factors should definitely be considered in designing the DSS dialogue portion; the component that the system and user need to communicate to one another. Additional design features that support the cooperative efforts of man and DSS are addressed in the next section.

Designing Task Cooperation Between Man and Systems

If decision-aiding technology seeks to support and extend human problem-solving activities, then it must be able to address all of the places where human cognition is in need of external support (Zachary, 1986 : 30).

The point to be emphasized in this quote is the ability of DSS to extend or enhance the human problem solving activity, not merely automating the activity through a computer and thereby replacing the human in the process. It is generally recognized that by combining the strengths of the human and the DSS through a sophisticated interface, that both better options can be

generated and better decision choices can be consistently selected. This is achieved by building a system that allows both man and machine to perform their strongest tasks during the decision process.

Representations Through Windows. One of the methods that Zachary advocates to achieve this interface is to use a representation aid or screen display that "captures the mental model used by the expert decisionmaker and incorporate it into the interface as an aid to the more novice user of the DSS " (Zachary, 1986 : 46). One advantage of using the expert's representation as the interface is that the novice user can "presumably be brought to the expert level much more quickly " (Zachary, 1986 : 46).

Zachary also quite eloquently discusses the benefits of incorporating a windowing feature in a DSS. Supposedly, windows provide the following powerful capability to the decisionmaker:

By allowing the decisionmaker to control each window's spatial arrangement, size, shape, and content, the various windows become visual metaphors for separate aspects of the decision problem, separate aiding functions, or separate tasks which may represent one subproblem within the overall decision situation (Zachary, 1986 : 48).

By placing two windows side by side the decisionmaker may be encouraged to frame the problem differently than if he were only able to see each of the displays in isolation. Often, by visually combining the screen display information through a feature such as windows, the decisionmaker is quickly able to make an accurate assessment of the situation, and begin to rapidly formulate possible alternatives to the problem.

Information Control Techniques. Another group of decision-aiding technologies Zachary discusses that are particularly vital in a tactical C² DSS are the information control techniques. Three different types of data control

that are needed are "accessing, organizing, and monitoring" (Zachary, 1986 : 38). Modern database management systems (DBMS) allow a designer to create a database that can be easily accessed by the user, especially with the natural language query techniques available. At the next level of data control, important techniques that are used to organize the data are automatic aggregation techniques. These help to solve the problems that "arise when there are sharp level-of-detail differences between the available data and the knowledge used in the person's decision process" (Zachary, 1986 : 39). For example, for a certain tactical mission requirement, a FDO may only be able to task aircraft that are on a fifteen minute or less alert status. A technique then would be needed to organize or aggregate the data according to this criteria. During the third data control stage, or the monitoring of data, the user may need alerters, which are "algorithms that monitor a dynamic database or datastream transparently to the decisionmaker, looking for predefined key or critical conditions and alerting the decisionmaker when such a condition is detected" (Zachary, 1986 : 39). For example, the tactical planner may need to be alerted when the five minute alert aircraft that he has available for tasking drop below a certain number.

In addition to presenting a thorough taxonomy in decision aiding techniques, Zachary also provides some clear guidelines in designing a system for a particular problem environment. One point he emphasizes is that the designer must consider the "decisionmakers understanding or internal representation of the problem environment and (the decisionmaker's) implicit strategies for dealing with it" (Zachary, 1986 : 51). These guidelines require a method to reveal the decisionmaker's "internal representation"; guidelines that Zachary does not explicitly provide. One

method that has been suggested by McFarren to accomplish this is through concept mapping (McFarren, 1987 : 1-287). How to accomplish concept mapping will be discussed later in this chapter.

Representations, Operations, Memory Aids, Control(ROMC). Although the research of Zachary revealed some explicit techniques that are needed to design DSS, Sprague and Carlson take it one step further with ROMC. They proposed the comprehensive ROMC approach to be used during iterative design of the DSS. By using ROMC, the evolving design remains decision process independent, and so can be used effectively by different users in a variety of unstructured decision processes (Sprague and Carlson, 1982: Ch 4). The four components of this approach are:

- 1) Representations include any graphical or text screen display that the user is able to visually interact with, i.e., tables, graphs, maps, procedural language or other textual display.
- 2) Operations include system functions that operate on the representations and underlying data to guide the user in considering and choosing the alternatives, i.e., operations on tables, graphs, maps, and the database.
- 3) Memory Aids include system features that reduce the memory load on the decisionmaker, i.e., database views, stored results, on-line help for the user.
- 4) Control includes features that help the user easily and flexibly manipulate the representations, operations, and memory aids according to his own style, i.e., menus, system-user dialogues, and macro commands.

Sprague and Carlson's four essential components provide the concrete elements that a DSS designer needs to design and begin to build the system. Their lengthy and detailed documentation of the iterative design of DSS business applications (Sprague and Carlson, 1982), using the four

components just described, strengthens the framework needed to begin design of a tactical military DSS application.

Many of the preceding theoretical issues and practical methods were weighed and appropriately applied during the iterative design of a tactical planning DSS described in the following sections; the design approach taken in this project closely parallels that needed for the ASOC retasking DSS, and so provides a good model to study.

Building a Real World Tactical Planning DSS

Andriole provides an easily understood and documented approach to the design and development of two tactical planning DSSs, and offers a viable approach for other designers. Although the same overall nine step structured methodology from Figure 2 was used during the design of two systems named TACPLAN and INTACVAL, there was no attempt to *unrealistically and completely define user requirements up-front*. The goal of the effort was to develop two decision aids "to support corps commanders in the generation and evaluation of alternative plans or concepts of operation" (Andriole and others, 1986 : 854). The iterative nature of the methodology of Figure 2, as indicated by the recycling arrows on the left, was stressed by Andriole; this methodology was justified for this project since the problem "domain was primarily cognitive" (Andriole and others, 1986 : 854). In fact, Andriole went one step further by describing the methodology as "rapid prototyping". Some of the techniques that were used during the project will help to explain what Andriole means by rapid prototyping.

During requirements analysis, two teams of expert planners were observed working through several Army War College planning scenarios. The

system designers requested that the experts "think aloud" as they worked through "protocols used to assess terrain, capabilities, and courses of action" in formulating their alternative plans. The sessions were video-taped, presumably so that no subtle yet significant steps in the process were missed, and so the tapes could be later reviewed to check the correspondance between the totally manual procedures and the procedures being designed for the new system.

An important part of the follow-on modeling process involved the use of storyboards. Storyboards are described as "nothing more than screen displays of the functions and tasks that the aid might perform when activated by a user" (Andriole and others, 1986 : 855). The power of storyboards is best summed up in the following words of the researchers:

The storyboarding exercise enabled us to validate requirements, identify some totally new ones, experiment with some alternative man-machine interface (MMI) techniques, and - most importantly - select the analytical methods most likely to help drive the aid," (Andriole and others, 1986 : 855).

Through the storyboarding process, it was decided that the system would initially use both decision analytic and artificial intelligence methods. Another system feature that was validated during this modeling phase was the use of video disks to display actual maps of the Corps area of responsibility, at near perfect resolution. The strengths that video disk technology supported during this project included: (1) the ability to create one's own personal symbols for annotation, (2) decluttering, or the ability to selectively display a portion of the map's annotations at a time, and (3) the ability to quickly "fly around" a map and zoom-in on selected locations if desired. The most important capability that video disks added to TACPLAN

was identified as the "ability to communicate symbolically with both the planner and the analytical side of TACPLAN" (Andriole and others, 1986 : 858). For example, if a planner illustrates an enemy course of action by drawing it on the display, TACPLAN immediately knows something about the course of action. This is possible because coordinates on the video display are linked to analytical routines and knowledge bases stored in TACPLAN (Andriole and others, 1986 : 858). The planner is allowed to make "wholesale judgements about area characteristics, mission, and doctrine, and then subjects these judgements to what is contained in the knowledge bases" (Andriole and others, 1986 : 858).

What was strongly suggested through this work is that "tactical planning is inherently graphic and non-numeric. When planners plan, they move icons, refer to illustrations, draw courses of action and argue via references to pictures, graphs, and lines" (Andriole and others, 1986 : 863). The work of this team is important for several other reasons as well. Their overall iterative approach and early prototype testing revealed that a refinement in the role the decision aid should play in the planning was needed, and so INTACVAL actually evolved out of TACPLAN. This was a validation of the feasibility of prototyping for refining system requirements as the system was evolving. Another concept they verified was the use of microcomputers to support this C^2 tactical planning process. Previously, the process had been done strictly manually. Lastly, the benefits derived from their requirements and modeling phases via storyboarding provide valuable ideas for further research and related tactical projects. Almost all of these techniques can also be applied to design of the ASOC DSS. The approach selected to design the ASOC DSS is based on the theory that has been discussed here and on continuing research in adaptive design at AFIT. The

remainder of this chapter looks at the specific techniques that characterize adaptive design, and how and why the methodology has been applied.

Adaptive Design

Adaptive design is an iterative approach which combines the four traditional system development activities (requirements analysis, design, development, and implementation) into a single phase which is repeated over short intervals. The "major components of adaptive design include the builder, the user, and the technical system (DSS)" (Alavi and Napier, 1984 : 22).

Adaptive design as a process seems to mesh well with C^2 decision problems. There is a close alignment between the methods of the approach and the way users seem to think about the decision problem that they need the DSS for. Specifically, adaptive design starts at the user location with a gradual development of the DSS around a central decision process, or "kernel" (Valusek, 1987 : 5). One of the more difficult phases of the approach is establishing the initial kernel and storyboard set. With these in place though, there is an easily understandable and modifiable framework from which the DSS can grow. At this point, the adaptive approach begins to feed on itself. The initial system kernel and storyboard provide food for thought, and stimuli for further design ideas both for the user and the designer/ builder. Future DSS enhancements and refinements are developed and maintained by the user in what is described as the "hookbook" (Valusek, 1987 : 10). The hookbook is a method (manual or computer-supported) to record design ideas for the evolving DSS as they come to mind. Individual entries to the hookbook are made on notecards as shown in Figure 5. The "idea" and "circumstances" under which the idea occurred are all that needs to

to assign "labels", to assist in classifying the growing number of ideas. The user maintains the hookbook and storyboard, refining them based solely on his needs; the DSS is actually being built several iterations behind the *current version of the storyboard*.

<i>DATE</i>	<i>LABEL:</i>
<i>IDEA:</i>	
<i>CIRCUMSTANCES:</i>	

Figure 5. Life Size Template for Notecard in Hookbook

Most importantly, the adaptive design framework and initial design provides "a communication anchor between all parties both to enable and enhance a meaningful dialogue" (Boar, 1984 : 7-8). Boar sees this communication as vital and emphasizes that all analysis techniques to date have failed to address adequately that:

- (1) Users have extreme difficulty in prespecifying in total and final detail their requirements.
- (2) Miscommunication is endemic between project members.

The adaptive design approach described in this thesis includes tools and methods to address both of these formidable problems, not only during initial system analysis, but throughout the life of the evolving DSS.

Adaptive design is ideal for DSS development because its structure allows the system to evolve based on the decisionmaker's thought and decisionmaking processes. For the generally unstructured decisions of retasking and rapid replanning in the ASOC, adaptive design provides the potential to create a system kernel and a strong mechanism for further enhancing the support of the decisions. The specific techniques that are needed for this design process are described below.

Kernel Identification Through Concept Mapping. Concept mapping is an educational tool that has been recently applied to system design and development by McFarren, to assist in revealing early system requirements. Concept maps are literally "schematic devices to represent a set of concept meanings embedded in a framework of propositions" (Novak and Gowin, 1984). Within education, concept maps provide a number of key ideas that must be focused in on for a learning task, and also a summary of what is known or understood by the student.

In McFarren's work, the concept map was used to reveal experts' understanding of a particular process or decision that they were accomplished in. The process of actually sitting down with the expert and drawing out the concept map is often found to reveal, even to the expert, relationships between the concepts that he may not have known existed

(Novak and Gowin, 1984). This particular finding is important because of the difficulty in defining all the important aspects of a complex decision process, and thus the requirements that a DSS should support if it is to be used during the decision process.

McFarren has also found through extensive concept mapping of Air Force experts that maps of different experts can be overlaid as another means to expose common schemes in their maps. These common portions of different maps may well be suitable points at which to begin development of the DSS; these portions of the maps may also be called kernels. Just as concept maps have been suggested as "useful tools to help students negotiate meanings with their mentors" (Novak and Gowin, 1984), they can also be used as tools to exchange ideas and promote dialogue between a user and a system designer adaptively designing a new DSS.

Storyboarding for Refining Requirements. Andriole has been successful in identifying and refining system requirements throughout the life of a DSS project through the use of storyboards.

Storyboards can be used to verify system requirements definitions, tailor design specifications, and direct the software engineers in a full-blown design project. Storyboards are used primarily as a modeling tool in this research project. From the storyboards, the partial system requirements and design specifications for the evolving system are later shaped, or developed.

Users and technical staff involved in a DSS project must review the storyboards at regular intervals to provide their inputs for changes or updates. This process continues throughout the life of the DSS. It has been suggested that the "design team - in conjunction with users - develop a set of displays that represent each and every path users might take once the

system is developed" (Andriole and others, 1987:___). A path refers to an option or alternative that the decision maker has in solving the problem.

Storyboard Testing. Once the sequence of storyboards are designed and prepared, they need to be tested by the user(s). Each user who is evaluating the storyboards can accomplish this using the microcomputer prototype if available, while making annotations on a hard copy of each of the storyboards. Andriole further suggests that it may be helpful to also tape record the evaluators comments as they are working through the system, although this may not be practical under all situations.

After a test run, necessary changes are made to the storyboards and more tests conducted. The final goal in this process is to have a "consensus emerge about what the system should do and how it should do it" (Andriole and others, 1987:___). During this process not only is the sequence of storyboards improved, but any problems with the man-machine interface can be resolved at the same time.

Storyboarding Conserves Resources. Storyboarding is an adaptive design technique that produces a rough draft of a design using minimal amount of user time, and with minimal expense. It also guards against getting started in the wrong direction or defining system requirements inaccurately. Expenses are kept low with storyboarding because the screens are generally developed using off-the-shelf software that runs on a microcomputer. Andriole suggests an Apple Macintosh™, which can produce some fairly sophisticated screens using software that is tailor-made for storyboarding.

Andriole further points out that with storyboarding, "the potential dividends are enormous" (Andriole and others, 1987 : 11).

From a technical perspective, storyboarding permits the verification of requirements via direct linkage with intended users, while from management's perspective storyboarding permits phased, iterative, cost-effective systems design and development; it also yields a product early in the systems design and development process. (Andriole and others, 1987 : 11).

Outline for Chapter III

Chapter III of this thesis discusses application of the general design framework and guidelines for adaptive DSS design reviewed in this chapter, to the specific problem in the ASOC; the retasking of CAS and BAI missions in a tactical C² environment.

III. Applying Adaptive Design to the Problem

Rapid Retasking Requirement

The problem that exists in the ASOC of the TACS is the lack of an effective method or system to assist in decisions that are made about retasking of CAS and BAI missions. Given the quickly changing ground situation of today's airland battlefield, it is hypothesized that air support will have to be ready to flexibly respond to this dynamic situation to be effective. Although preplanning at staff and unit level will still remain an important part of each mission, the need to rapidly replan, possibly retask, and then execute the new mission from the ASOC level will be necessary. Future intelligence sensors currently on the design boards will be able to provide a real-time picture of the enemy's initiatives. With this information, it will be possible to not only react to the changing ground situation, but also to be able to plan initiatives to prohibit the enemy from executing his plan. Combining this technological capability with the dynamic battle situation and changing target priorities underscores the requirement for rapid retasking.

Generally, many of these rapid retasking situations will be considered crisis situations, in which there exists varying degrees of uncertainty in data input and option outcome. Using Hopple's suggested typology from Chapter II, these crisis situations are appropriate for the use of a DSS.

The specific problem situation in the ASOC seems to fall somewhere between quadrant A and quadrant C of Hopple's Decision Aiding Scenarios matrix in Figure 3. By performing some decomposition of the retasking problem, it is likely that the input data quality will vary between the high and the low end of the matrix, depending on many variables involved in collecting the data and disseminating it to the agencies that need it. On the

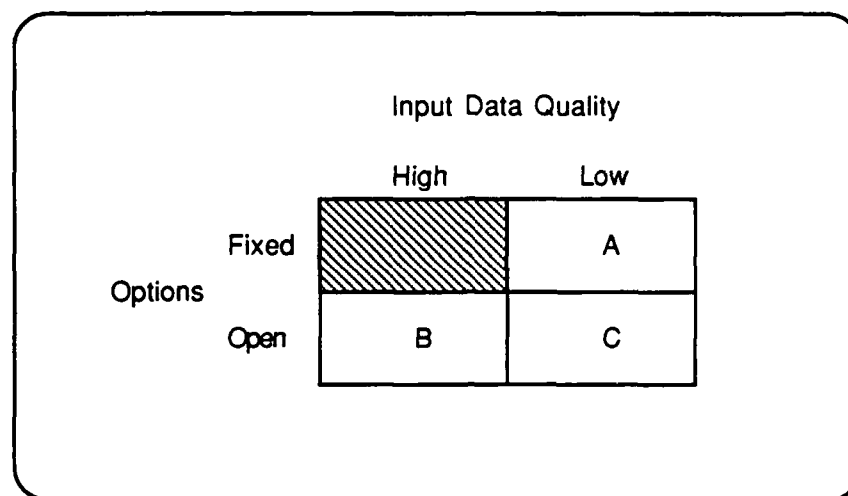


Figure 3. Basic Decision Aiding Scenarios (Hopple, 1986:951)

other hand, the options available to the ASOC decisionmaker in either recommending or performing the retasking are fairly limited. There are a limited number and type of aircraft that will be available for CAS and BAI retasking, and an equally limited number of options for how they might be used, depending in part on their weapon configurations and delivery systems. Thus, the decision will normally fall within the fixed options portion of Hopple's matrix. Based on these assumptions about the decision aiding scenario, Hopple states that scenarios falling into this general category on the matrix can be best aided by a DSS that focuses on the "improvement of the battlefield perception process and the enhancement of the quality of data" (Hopple, 1986 : 950). Despite the fact that the options will generally be limited, the DSS should be designed to work effectively with a greater range of options. As more resources become available to the decisionmaker for retasking, the DSS needs to support the evaluation and selection of the best option from the total range of options. For example, the DSS should adapt equally well to weapon constrained or weapon-rich

situations.

With this established requirement for retasking, there is a need to discuss the reasons why an adaptive design process, that incorporates prototyping, is the most appropriate approach.

Why Adaptive Design is Needed

Assuming that one of the significant advantages of using adaptive design is the ability to respond to changing and evolving system requirements, it is necessary to examine how this advantage will support the retasking requirement in particular.

New Doctrine. Officially, the concept of dynamic retasking being done by the ASOC is not currently recognized, despite the fact that considerable retasking has occurred in recent conflicts. Retasking of air interdiction assets has also been discussed in detail in a recent AFIT thesis (Schoeck, 1986).

Retasking is even more viable from the Airborne Command and Control Center(ABCCC), which occasionally serves as an airborne ASOC. The ABCCC, because of its orbiting position, generally would have access to the real-time mission/aircraft information that would permit the decisionmaker to make some smart retasking decisions. Without a retasking DSS, the potential for increased effective use of forward aerial control from the ABCCC is wasted.

Despite these arguments, retasking is generally only briefly mentioned or alluded to in official Air Force regulations, and then without any explanation as to how the retasking might be accomplished. There are a number of knowledge-based planning DSSs being built for the long range planning cycles in the TACS. Many of these systems will allow the planner the capability to consider different options and examine the trade-offs of several different plans before one is decided on. However, little emphasis

has been given to the similar problem that faces those executing planned missions in which alternate planning is required "on the fly", because the original mission cannot be executed exactly as planned. Some of the primary triggers that may necessitate the need to retask include:

- 1) predicted targets do not materialize
- 2) predicted targets are different than expected
- 3) predicted targets cannot be attacked due to environmental conditions
- 4) priorities change
- 5) another target of opportunity arises
- 6) status of weapon delivery platform changes

Because this dynamic retasking concept has not been formally addressed by the TAC staff and other interested policymaking organizations, there is bound to be a considerable amount of negotiation and reworking of the issue as planners begin to address the deficiencies that currently exist. A DSS that can evolve with the corresponding evolving doctrine in this area is required.

Different Theaters. Another reason for adaptive design is the fact that the operation of the TACS, and the ASOC in particular, varies from theater to theater. The organizational alignment, the specific tasks, the system and agency interfaces are all slightly different from one place to another. What must be agreed upon then, is a generic model around which the retasking DSS can be designed. This researcher has attempted to define this generic model and use a general approach in designing the retasking DSS; the goal is to be able to test the feasibility of the DSS in a variety of theaters and scenarios. Tailoring of the generic DSS to best match each of the theater's

needs will be a later refinement to the basic system that should be possible using the adaptive approach in each theater.

Need to Integrate CAS and BAI. Another factor that must be considered is the evolving role of the Air Force in the Airland Battle planning and execution. As previously mentioned, there is a recognized need by the Army to better integrate the close-in and second echelon targets on the battlefield. This equates to CAS and BAI targets that the Air Force may be requested to hit. It seems logical that not only the long range planning, but also the more immediate missions including the retasking of missions, must be integrated. Since little integration seems to have occurred in the past between CAS and BAI missions, there will likely be extensive study and discussion on this issue. Consequently, any DSS developed for ASOC use will have to be changed as requirements in this area also evolve.

Different User Inputs. Besides the more doctrinal issues discussed above, there are a host of more practical reasons to advocate adaptive design. This researcher has already experienced one of these reasons in working with the potential system users at different organizational levels. Most of the operational requirements for the ASOC are generated at TAC Headquarters, while the greatest user experience and familiarity with the missions exists at each of the ASOCs at 9th Air Force, and 12th Air Force. The system builder must work with these different organizational "users" to get the best starting point for a generic system. Throughout the life cycle of the DSS, it is likely that a comparison of the requirements generated at the different organizational levels will sometimes conflict, or may sometimes be too detailed for a generic design; in all of these instances the need for adaptive design becomes apparent.

Funding Levels Vary. Another practical consideration has to do with

funding for a program; one year it may be impossible to spend all the money allocated, and the next the funding may literally dry up. Since funding for military programs is highly variable, it makes sense to develop the system by starting small and growing. Using an adaptive approach avoids spending an exorbitant amount of money on the conceptual design and then not being able to implement any of the program because of funding problems. A related benefit can be realized if an initial incorrect design is generated. Because the adaptive design process forces the design of a small portion of the system at a time, there will be a minimum amount of wasted resources if an evaluation uncovers a poor design.

Selection of Kernel. Another important benefit of the adaptive design process for the retasking problem is the selection of the critical or most important kernels at the beginning. Since the system should be functional, in a limited manner, with the first testable prototype, the user and builder are compelled to decide on an initial design that can actually be used for a retasking decision when implemented. For the problem of retasking in the ASOC, the initial kernel includes an aircraft/weapon representation or screen, a target representation, and a ground situation representation. By using these in an integrated manner, the FDO in the ASOC can evaluate the situation and generate possible courses of action. The complete detailed range of operations or control mechanisms that may be needed in the retasking DSS are not all known at this time. Generally, only by working with the user over time, will the builder and user perceive requirements for analytical models or appropriate knowledge-based techniques within the system.

Testing the Prototype. The approach that TAC is planning during the TBM program will mesh perfectly with an adaptive design for the ASOC

retasking DSS. As mentioned in Chapter I, the plan is to bring new TACS software modules on-line incrementally, after joint testing at the prototyping facilities at Langley AFB and Hanscom AFB. The prototyping testbeds provide the needed central facility to do extensive testing and evaluation of the software systems under development. These testbeds will allow major software problems to be solved and refinements to be quickly made before the systems are fielded; potentially maximizing user satisfaction with each fielded software version. The central prototyping facility will conserve resources, flush out unnecessary or error-prone portions of the initial system, and allow integrated testing with the other developing software systems of the TACS. The central facility, if managed correctly, will make it easier for contractors developing the systems to respond to users' needs because users will be heavily involved in all phases of the process; all communications between the user and the DSS builder should be coordinated through this central facility.

Instead of hindering the transition from the use of strictly traditional system design methods to adaptive design, the prototyping facility should ease the transition; it will satisfy the needs of managers who are responsible for central system software maintenance and control. Using this central prototyping facility for software control and testing will not interfere with the activities that the user is responsible for at his own site under adaptive design. The problem of choosing which users to bring to the prototyping facility should be handled by a "referee" at TAC; he should make these decisions based on the contributions that individual users can make to the evolving DSS and the diversity of ideas that can be generated by using a great variety of users with diverse backgrounds. Further discussion on the role of the referee is included in Chapter V.

Actual System Design

Concept Mapping. As a tool to try to reveal the full range of elements or concepts that experts consider in planning an air support mission in the ASOC, the concept mapping approach was used. An operational requirements expert and experienced FDO at TAC Headquarters, and an experienced FDO at the 682 ASOC, Shaw AFB were used for this exercise. At the time the concept maps were created, the ASOC retasking decision problem had not yet been identified, so the maps do not particularly focus on the retasking decision process. However, the concept maps do identify many of the critical elements involved in planning and coordinating ASOC missions under less of a crisis environment than the retasking decisions. Despite the emphasis of the concept mapping exercises and the resulting maps that were accomplished, many of the revealed concepts also can be applied to the retasking decision process. In fact, the concept map with the expert at TAC centered on BAI mission planning. Generally, there will probably be more time for decisionmaking during retasking of BAI missions versus retasking of CAS missions, primarily because of the difference in distances between aircraft and potential targets in the two different missions. It is possible that some of these concepts from the original map for BAI planning will be applicable to either retasking or recommending retasking of BAI missions. The two original maps that were created appear in Figures 6 and 7.

Building the Storyboard. Based on the ideas generated from the concept maps and further information gathered during visits to TAC/DOYF and the 682 ASOC/DO, this researcher generated several preliminary storyboards representing critical elements of the decision process used during retasking. From these conversations with experts, it seems likely that the vast

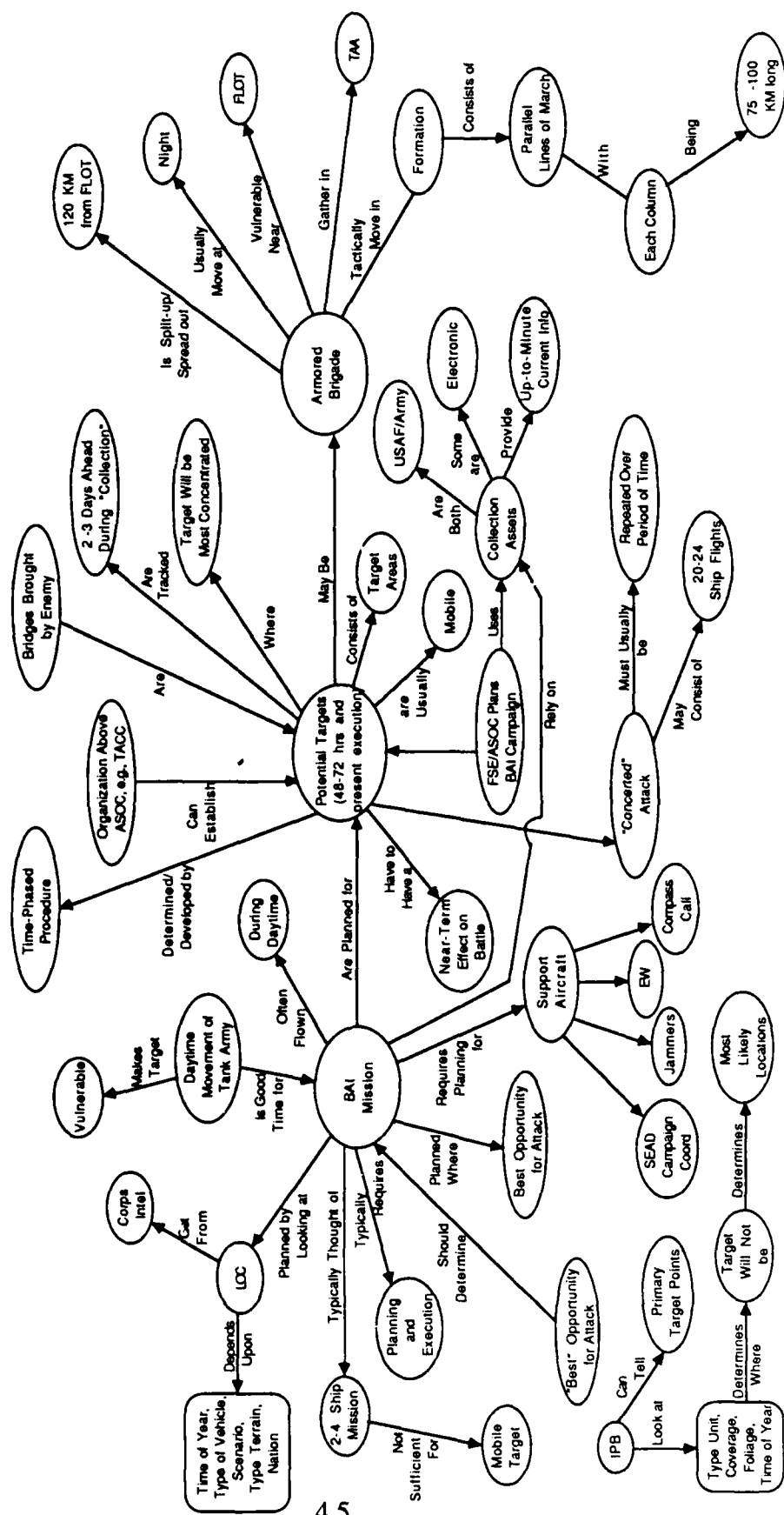


Figure 6. Concept Map of ASOC BAI Planning: Lt Colonel Kozma, TAC/DOYF, 22 July 1987

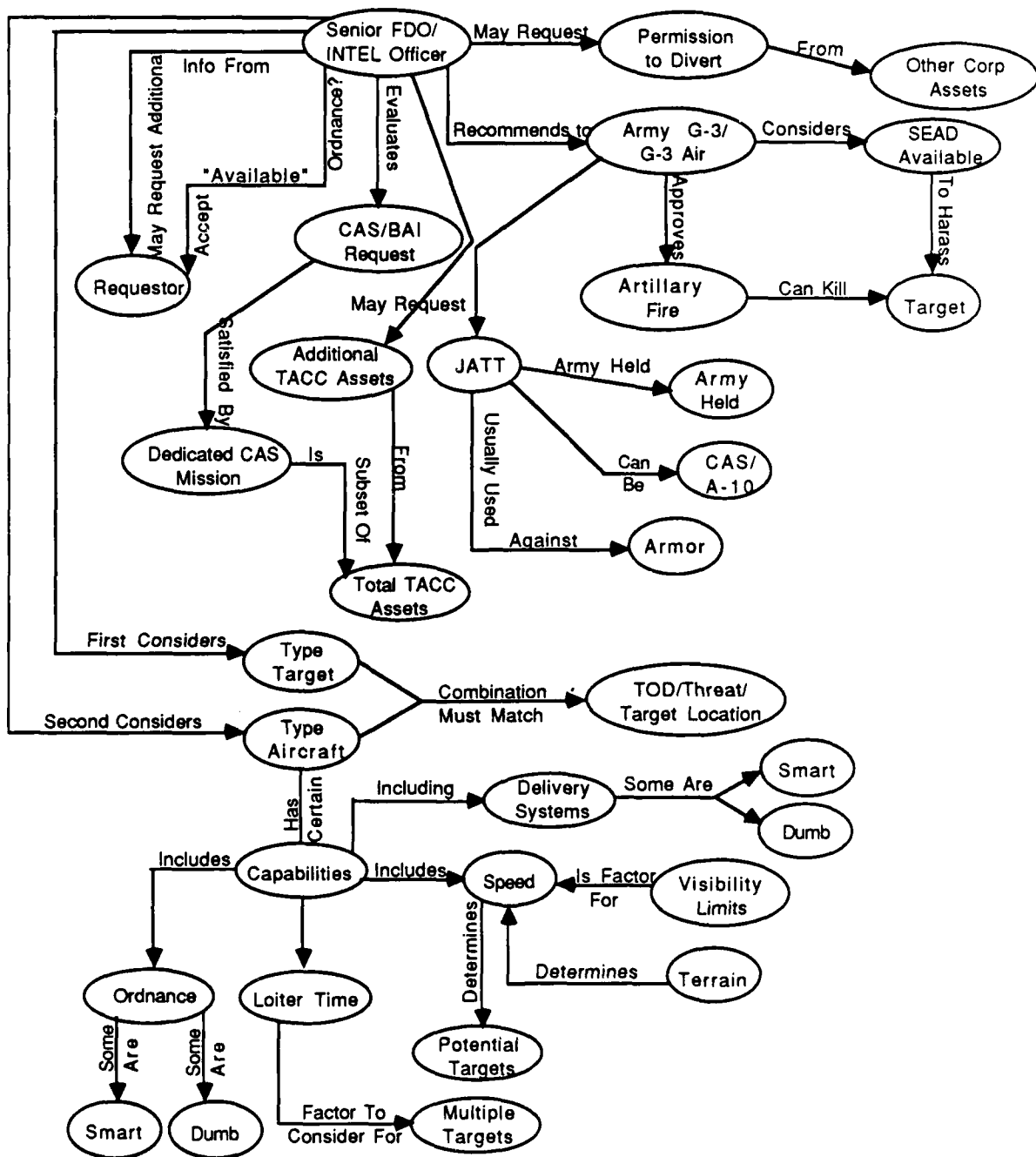


Figure 7. Concept Map on CAS/BAI Request Process (FDO Task Process: concept mapped Capt John Meroth at 682 ASOC on 24 Jul 87)

majority of times that retasking situations might arise would be triggered by some sort of change to the target or target area. As stated officially in the General Operating Procedures for the Joint Attack of the Second Echelon (J-SAK) and verified by experienced FDOs, the following prioritized list of triggers may necessitate the need to retask:

- 1) priorities change
- 2) another target of opportunity arises
- 3) predicted targets do not materialize
- 4) predicted targets are different than expected
- 5) predicted targets cannot be attacked due to environmental conditions

The J-SAK procedures pamphlet further states that the TACC will evaluate the new target for compatibility with planned sorties. Principal considerations are:

- 1) Can the new target be attacked effectively with planned ordnance?
- 2) Can the mission be accomplished without unacceptable losses?
- 3) Is there sufficient time to notify the various support elements of the force package or can a mission be flown without support?
- 4) Will the change allow aircrews sufficient time for planning?

Although the TACC is supposed to consider these questions, it is often the ASOC that can provide better answers; in the case of CAS, the ASOC executes the mission and in the case of BAI, the ASOC accomplishes much of the initial planning and mission following. Even if authority to retask or divert

remains only at the TACC level, a recommendation from the ASOC on the retasking decision will be necessary. Consequently, the FDO working in concert with the G-3 Air in the ASOC will be required to answer these questions and make the recommendation. Naturally, the decisions to be made in the ASOC will revolve around these same questions, and the necessary DSS representations should be designed to support the answering of these questions and making these decisions.

To address the first consideration listed above, the aircraft/ordnance that have been allocated to the Corps and are available for retasking should be scanned to see if effective ordnance against the new target is available. It is necessary to support the FDO with embedded weaponeering operations that present feasible weapon alternatives. To decide whether losses can be minimized to an acceptable level, it is likely that the FDO will examine the ground situation, paying particular attention to threats the aircraft may encounter. Weather also plays a significant role in this portion of the decision process; i.e., can the ordnance be delivered effectively with the given weapon and delivery system under the current weather conditions? The chances of missing the target altogether and wasting the ordnance should be considered.

Some of the BAI missions will require some degree of support either on the ground, or airborne, or a combination of both. With retasking or diverting, the question of notifying and repositioning support elements must be considered. The FDO may need to review the support elements that were tasked against the initial mission to decide if any of these can be shifted to the new mission. If not, and it is decided that their type of support is still essential with the new mission, replacements will have to be generated. This will most likely involve another survey of the ground situation for

ground support and possible review of available airborne support. Whether all the coordination with the support elements can be accomplished prior to the mission will become a primary consideration.

Technological Limitations on the Kernel. With current technology, it is unlikely that retasking will allow aircrews sufficient time for replanning, unless of course the mission scenario is limited and planned for a low threat target area. This inability of the aircrew to rapidly replan will provide a significant hindrance to the possibility of retasking and diverting missions, until technology allows mission planning to be accomplished "on the fly", through a sophisticated integration of pilot, aircraft system, and ground systems. Nonetheless, planning for this eventuality should continue.

Ground Situation Display. With the initial emphasis for the DSS on the decision tasks previously discussed, there appears to be a heavy dependence on a geographic ground situation representation. This requirement was validated by all experts that made inputs to the retasking design. The idea of using a high resolution video disk to display actual geographic maps, with the ability to selectively display pertinent symbols, and link appropriate nongraphical data with the graphical display, was inherently appealing to all experts that made inputs to the design; most experts felt that a display of this sort was absolutely necessary. Considering the validated results of Andriole's work with video disk displays used in airland battle planning, it was decided this would be a beneficial feature of the retasking DSS as well. Because of the close coordination between Army and Air Force during CAS and BAI missions, it was also decided that the geographic displays the Army uses would be the most helpful during the retasking decisions. The ability to zoom into a certain area of a map and display finer detail was mentioned as a desirable feature; this feature was

included in the storyboard. Based on the expected need for the FDO to use the full geographic display during several different phases of the decision sequence, it is believed that a separate geographic display is needed, on a separate screen from the other decision screens that are used. It is also envisioned that the representations of aircraft/weapon and target data will need to be examined either simultaneously, or back to back. One good way of offering this feature is through either a split screen representation or the capability to use windows for the different database relations and other displays. The flexibility inherent in windowing influenced the incorporating of this feature in the kernel DSS.

Specific Kernel. The specific kernel is based on the six primary retasking triggers earlier described as:

- 1) priorities change
- 2) another target of opportunity arises
- 3) predicted targets do not materialize
- 4) predicted targets are different than expected
- 5) predicted targets cannot be attacked due to environmental conditions
- 6) status of weapon delivery platform changes

Since the first trigger is somewhat unspecific, and can be included as a general case of the four triggers that follow, trigger two was used to provide specific examples in the storyboard. The sequence of screen representations and corresponding descriptions of the storyboard design are presented in Appendix A. A sequence of decision screens to decide whether to retask and divert an aircraft/weapon and attack a new high priority target is

considered. First, it must be determined whether an effective weapon for the new target is available under the time constraints; then the trade-offs involved in retasking/diverting must be considered; the FDO must also decide how the target that results from retasking the weapon assigned against it will be attacked.

Evaluating the Design

As discussed in the C² Evaluation Workshop Report of the Military Operations Research Society (MORS), it is essential to begin the formulation and application of measures of effectiveness (MOEs) during the early conceptual phases of a C² system:

As a process, the formulation of MOEs is recursive and iterative the determination of shortfalls in MOEs applied to a C² system is fed back into the conceptual model so that this model can be modified, refined, or changed. Over time, the MOEs can become accurate measures of an existing system or can be modified to cope with the evolutionary changes in the system, the environment, or the scenario. (Sweet and others, 1985 : 4-24).

Based on this guidance, the development of the MOEs should begin and evolve along lines paralleling the system development. The system designer must continuously derive conclusions and findings from applying the MOEs, and judge how this analysis should contribute to future design and implementation decisions. The specific analytical MOES for the retasking DSS design as well as other implementation issues are discussed in Chapter IV.

IV. Evaluation and Implementation Issues

To fully support the "start small and grow" objective of adaptive DSS development, it is necessary to merge the DSS implementation and evaluation activities. Evaluations are particularly vital during all phases of the adaptive design and development of a DSS. This is true for two primary reasons. First, the benefits of the adaptive design process with its inherent flexibility would not be realized if the ongoing evaluations were not performed to determine system refinements; early evaluation would also prevent the possibility of initially proceeding down the wrong path. Second, without regular evaluation during the entire process, the adaptive design would begin to resemble the more traditional system development life cycle in which initial evaluations are performed much later in the process, often times uncovering user dissatisfaction too late to remedy the problem.

Fortunately, an early evaluation that rates a prototype design for a DSS as unsatisfactory will not necessarily hamper further development of the DSS; instead it leads to an improvement in the general problem approach, or necessary refinements in the design process. Recognizing these potential problems early facilitates their proper correction and the building of a more valid system to support the decision-making process. By tackling the problems early, there is no need later to apply any quick fixes to portions of the system that do not meet the user's needs as they should. On the other hand, it is much more likely that a poor evaluation phase during a traditional system life cycle approach will cause considerable consternation and possibly abandonment of the system, if the problems detected are thought to be monumental and the projects funds are nearly depleted.

Evaluating Effectiveness, Efficiency, and Reliability

Because of the importance of iterative evaluation during the adaptive design of DSS, it is appropriate to evaluate the preliminary storyboard and kernel design for the retasking DSS for the ASOC. This calls for some type of evaluative model or approach to be used during this phase of the adaptive design process. In general, it is admittedly difficult to formulate objective measures of effectiveness (MOE) to evaluate a specific DSS within a specific environment. However, several current researchers working in the area of tactical DSS offer some specific guidelines for evaluating a DSS during the design phase.

Samet has proposed that DSS effectiveness can be measured at the design phase by " 1) correct assignment of functions to people or computer, 2) structural complexity (simple is better), and 3) correctness of algorithms for their stated purpose" (Riedel and Pitz, 1986 : 982-983). Two other evaluative measures that Samet describes to be used during the design phase are (1) efficiency or a measure of the number of user steps for an operation, and (2) reliability, as a measure of the effect the failure of one module will have on others.

A general evaluation of the retasking DSS can be started using several of these recommended measurements. Beginning with the criteria for effectiveness, the following assessments of the retasking DSS can be made. Table I summarizes the assignment of system functions to either the computer or the user, depending on their strengths.

Table I. Assignment of DSS Functions

<u>Function</u>	<u>Done By</u>
Scan database	computer
filter out bad alternatives	computer
transit time calculation	computer
loiter time calculation	computer
weapon recommendation	computer
reminder of priority activities	computer
storing decision sequence	computer
input criteria for database	user
establishing constraints	user
choose retasking aircraft	user
choose retasking weapons	user
display select graphical data	user
choose decision sequence	user
select windows displayed	user

Assignment of Functions. The assignment of functions to the user or the computer were designed using knowledge about the strong and weak areas of both the human and the computer. Rapid scanning of the database to filter out inappropriate user options and the quick calculation of transit and loiter times are functions assigned to the system, while the particular criteria to be used in scanning the database and the decision of what missions or aircraft to consider for retasking is left up to the decisionmaker. Most importantly, the process or sequence of steps to be used in making the decision are left up to the user; the system only reminds the user of other high priority activities that must be managed.

Structural Complexity. The structural complexity of the system should appear rather simple and easily navigable to even the novice user. There was a deliberate attempt in designing the DSS to give the user as much or as

little complexity as he desires and can handle during the decision process. This is accomplished through the use of a common work area where clear pull-down menus are accessible and the user can open multiple decision windows as needed. Models (operations) do not require complicated procedures for inserting input data, they are simply selected by the user, and the system performs the insertion into the operation with the highlighted data on the screen. There is a consistency in the structure of the decision windows that the system presents, so the user does not become uncomfortable in using a function that is seldom accessed. The design allows the addition of models and operations without making the DSS appear additionally complex to the user.

Correctness of Algorithms. The algorithm for making the retasking decisions must be flexible, depending on the environment constraints input at the time. Two of the constraints (time and weapons) can be initially input to the system by the user, to determine the data that the system uses to run certain models, and the criteria used to search the database. The algorithm is not fixed, and the system design keeps the decision process under full control of the user, and as variable as needed.

Efficiency. Efficiency of the DSS design can also be measured by the structural consistency and relative simplicity of the system in the user's eyes. The number of user steps needed to perform an operation in the retasking DSS is generally limited to two, with the second step normally being the option to update the current environmental constraints prior to the system performing an operation, or running a model.

Reliability, or ability to recover from failure, of the DSS is also an important design consideration, although it comes more into play during the actual building of the system. The current DSS design permits the user to

return to an earlier point in the decision process if an error or failure in a system module is detected. Currently, the design is divided into three overall system modules. One is the module that interfaces with the user through screen displays. This module is crucial to the operation of the system; its failure would require the decisionmaker to revert to manual means. There is no alternate method to access data and models except through interface with the system's screen displays. The accuracy of the system recommendations and output depend on the currency and correctness of the second module, the database. Detected inconsistencies or failure of the database altogether could be corrected by reloading the system's database through its interface with the master database, or a CAFMS-like database to which it would be connected. On the other hand, the reliability of the model portion of the DSS would be more difficult to insure. The best way to guarantee to the user that the models are providing consistent results is to make their source code inaccessible to everyone except the model manager, or other appointed individuals. This could be accomplished by locking the model code in secure files, to which there was limited access. The models should be checked at routine intervals by personnel intimately familiar with their workings, to insure they are performing as expected, and to make any necessary changes or updates. The users should be informed whenever the models have been updated, especially if the change will be reflected in the results the user sees during the decision process.

Evaluating Compatibility and Understandability

Rouse and others (Riedel and Pitz, 1986 : 983) have proposed the additional criteria of compatibility and understandability to analytically

assess the DSS during the design phase. Compatibility refers to "the degree to which the demands an aid places on users sensory-motor abilities are within the limitations of the user population" (Riedel and Pitz, 1986 : 983). Understandability is "the extent to which users can be expected to have the knowledge required to understand the messages displayed" (Riedel and Pitz, 1986 : 983). Both of these evaluative criteria seem to focus on the man-machine interface requirements. Compatibility of the DSS design was achieved through a matching of the typical sensory-motor skills of a future retasking DSS user with those skills required to use the designed DSS. Many recommendations were taken from design checklists and recent man-machine interface research. Additional inputs were made by functional area experts at the ASOC at Shaw AFB and personnel at HQ TAC. Understandability was achieved by formulating the system messages so they are straightforward and easily understood by the typical DSS user. Of course, what is meant by the "typical user" is predominantly the view of the DSS designer during the design phase. The impression that this designer has of the typical user has been formed by minimal interaction with a limited number of potential users on two occasions. This impression was further molded by a meeting with the operational requirements experts at HQ TAC, to form a picture of the generic user and further substantiate general user needs. Unfortunately, there has been no opportunity for regular, face-to-face meetings between user(s) and designer throughout the design phase, to further clarify design issues and discuss problems as they arose. This is often a common limitation of academic research projects, unless the potential user is colocated with the designer, and face-to-face communication is possible on regular intervals. This limitation has impacted the design process and the resulting storyboard to a certain degree.

primarily in the area of the amount of detail that was incorporated into the design.

Evaluating to Provide Information

All of the previously mentioned evaluative criteria are particularly important for focusing on the user-DSS (U/DSS) interface portion of the design. However, the early evaluative process during the DSS design phase should also consider two other interfaces: the user-decisionmaking organization (U/DMO) interface, and the decisionmaking organization-environment (DMO/ENV) interface (Adelman, 1985 : 286-288; Riedel and Pitz, 1986 : 981). Evaluation of the DSS from the U/DMO interface level would include such questions as:

- 1) How well does the user with his DSS fit into and support the larger decision making cycles of the ASOC and the Corps?
- 2) To what degree does use of the DSS contribute to effective decisionmaking at the ASOC and Corps level?
- 3) How well does the DSS mesh with the organizational climate, the constraints, and requirements of the ASOC and Corps?

Each of the above evaluation decisions and those at the higher DMO/ENV interface level appear considerably more complex and difficult to quantify than those at the U/DSS level; perhaps evaluations at these two upper levels can best be measured during actual use of the prototype DSS in an operational exercise. In fact, Adelman and Donnell propose a rigorous plan to be used to evaluate all three interfaces (Adelman and Donnell, 1986 : 285-309). They have devised a lengthy series of questions for users and

specialists to evaluate the utility of DSS prototypes. Experimentally, the questionnaire was found to be "an acceptable instrument for measuring people's subjective assessment of DSS prototypes" (Adelman and others, 1985 : 334-342). This research is important because it is aimed at learning the distinct ways that specialists and users each evaluate a DSS, and how these differing subjective assessments may interfere with implementation of the DSS. As the retasking DSS grows and a working prototype is developed, it may also be a ripe candidate for application of this type of evaluation questionnaire that has been developed. This will help to assess whether potential users and R&D specialists are evaluating the DSS similarly, and how this will impact implementation.

Ideally, the total design evaluation should provide information to decisionmakers at different levels. At the first level is the DSS designer who needs information for design decisions; at the second level is the project manager who needs information for project decisions, i.e., whether to recommend further funding for continued development; at the third level is the larger tactical research organizations who may be able to use the findings of the current DSS evaluation for their related research and development.

Measures of Productivity, Perception, Process, and Product

Sprague and Carlson suggest use of the measures of (1) productivity, (2) perception, (3) process, and (4) product to evaluate the impact of a specific DSS on users, the organization, and the environment (Sprague and Carlson, 1982). The following discussion outlines a plan for evaluating an operating prototype of the retasking DSS later in the development. To accomplish such an evaluation, the impact of the DSS on four critical categories should be

examined. Using this evaluative model, the potential impact of the retasking DSS on these categories is examined below:

Impact on Decisions. Impact on decisions is measured by looking at DSS productivity. Included in this group are measurements of the time and cost in reaching a decision and the results of the decision. The following suggested measures are appropriate within this category:

- 1) Measurement of the difference in requested Time On Target and actual Time On Target with and without use of the DSS;
- 2) Measurement of time needed to execute mission (time difference between arrival of the request and the time that the aircraft launch order/controlling data is passed) with and without use of the DSS;
- 3) Measurement of the actual effect of weapon on target and comparison with desired effect, with and without use of the DSS;
- 4) Measurement of the number of sorties required to achieve the desired effect on the target with and without use of the DSS;
- 5) Measurement of the effect of a retasked mission on the Army initiatives it supports; did the retasking contribute to a significant Army breakthrough?

Impact On Decisionmaker. This impact is measured by looking at the user's perception. These measures center around the affinity the user feels for the DSS, and the trust and confidence that he has in the system. The two techniques that may work well in this category are attitude surveys and cognitive testing to get at the real preferences of the user. Attitude surveys

are difficult to construct to get the greatest benefit from them, and cognitive testing is still a very new concept and still under development (Sprague and Carlson, 1982 : 161-164). Some other practical measures that may work include:

- 1) Measuring the amount of time the user is actively using the DSS;
- 2) Measuring the percent of time the user actually implements the decision he arrived at through use of the DSS, without reconfirming the decision through other means;
- 3) Measurement of the satisfaction of the supported Army unit with the response and effectiveness of retasked sorties;
- 4) Measurement of the number of new and creative decisions that result through use of the DSS that were previously not considered without use of the DSS;
- 5) Measurement of frustration level that user reaches when using the DSS versus the frustration level without use of the DSS; frustration level may be measurable in a user questionnaire.

Impact on Decisionmaking. This impact is measured by looking at the decision process. Here, different variables of the decision process are examined: the number of alternatives and participants, and different time measurements of the process are considered. Measurements that could be taken to evaluate the DSS in this category include:

- 1) Measurement of the amount of time spent on different decision activities with and without use of the DSS;
- 2) Measurement of the number of alternative aircraft/ordnance combinations and possible weapons that could be used against a target;

- 3) Measurement of the amount of time DSS is used by FDO and other personnel in the ASOC;
- 4) Measurement of the different views of the data of weapons/targets/geographic map that the user generates in reaching the decision;
- 5) Measurement of different stages the user is in along the decision timeline with and without use of the DSS.

Technical Merits. The technical merits are measured by looking at the technical aspects of the product. These measures revolve around the different costs (development/operating/maintenance) associated with the system. Measurement of costs during the early design and implementation phases of a DSS should be considered similar to Research and Development (R&D) costs, which may appear high for the product performance. However, if they were considered as operational or maintenance costs, they may be unacceptably high, which may reflect unfavorably on the DSS program. Education costs may also be high with a system like this, especially if a central prototyping and training facility is established.

Other Evaluation Methods

It is also suggested that elements of the external environment are important target systems during evaluation. Perhaps the best external "customer" to examine with the retasking DSS is the Army unit that receives the air support. Some type of evaluation of the effect on their small portion of the Airland Battle may be appropriate. A general attitude survey of Army personnel may also uncover a change in attitude with the use of the DSS.

Whatever method is used, evaluation will be difficult because of the

everchanging and unpredictable tactical environment. A controlled study conducted during an exercise in which two groups of FDOs receive the same inputs, with only one group able to respond using the DSS, may also prove to be a valid evaluation tool.

In addition to evaluative criteria, the following guidelines on DSS generators are provided for implementing the prototype.

DSS Generators

After design and evaluation of the preliminary storyboard, it is appropriate to execute the plan for building the DSS kernel, either by designing and writing the system software from scratch or using a DSS generator, or more likely through a combination of generator tools and software written in-house. A DSS software generator can be defined as a software package (either off-the-shelf or developed in-house) used to develop a specific DSS. Sprague and Carlson point out that because there currently are no well-integrated packages of tools or DSS generators, that the development will most likely be a "combination of software purchase and internal development to integrate and fill in the gaps" (Sprague and Carlson, 1982 : 63).

To establish a framework for building the DSS and specifying the DSS generator requirements, the following four step, top-down analysis is recommended by Sprague and Carlson:

- 1) Identify Overall Objectives. This category is very general and focuses on the decision-making system, consisting of the user, with a task in an organizational setting and using a specific DSS. The generator should be able to be used to build a specific DSS that (1) supports all phases of the decision-making process, (2) supports a variety of decisionmaking processes or

cognitive styles, and (3) is easy to use. The generator should also be flexible enough to facilitate the iterative design process that characterizes development of the DSS. Another important requirement of the generator is to support communication between the user and the builder; communication that is necessary for enhancing and refining the DSS as it grows.

- 2) **Identify General Capabilities.** These flow naturally from the overall objectives and include the following three capabilities: (1) the generator should be easy for the DSS builder/user to use, (2) the generator should provide access to a wide variety of data sources that supports problem-solving and decisionmaking activities, and (3) the generator should provide access to analysis capabilities.
- 3) **Specific Capabilities.** This category includes the specific capabilities that support the general ones. For instance, an integrated DBMS as part of the generator would satisfy the general capability of accessing a wide variety of data and then using the data in conjunction with the other components of the DSS.
- 4) **Specific Features.** This category includes specific features needed to implement the specific capabilities. For example, one of the features needed to maintain a database would be the feature that would allow the creation of new relations. Another example of a feature would be the capability to write unique mathematical equations that could be used in model development.

Selecting a Generator. What Sprague and Carlson infer with the above framework, and what other researchers claim is needed in choosing the right DSS generator is "a thorough and systematic selection process" (Reimann and Waren, 1985 : 167). The point that most of these researchers also make is that the evaluation criteria for selecting the generator should

emphasize end-user needs because of the key role of the user in the DSS growth process. A complete and detailed checklist of key user-oriented characteristics available in DSS generator packages is presented by Reimann and Waren (Reimann and Waren, 1985 : 168). This comprehensive list should be used carefully in comparing DSS generators; simply counting features can ignore the underlying structure of the DSS and its potential for growth and expansion. Using these criteria to evaluate and choose a generator would be an appropriate thesis in itself.

The capability to grow and expand is one of the overall core requirements needed during the adaptive design process. The potential generator should be equipped with sophisticated graphics capabilities for the user and designer to generate the initial storyboard. After designing the screens of the storyboard, there is a need to tie them together logically to demonstrate the different potential sequences of screen displays that are possible during the decision process. Rouse suggests a "part-task simulator" to simulate the DSS in appearance, static and dynamic characteristics, and range of decision-maker activities (Rouse, 1986 : 279). After the initial design is demonstrated and accepted, the supporting database and model base must be created with the generator tools. These two capabilities of the generator should especially be examined for growth potential, since the database and model base are generally the two portions of the DSS that will expand the most. Ideally, the generator should be structured to be operated by both the novice user and expert programmer alike, with on-line help messages and full-screen entry and editing of input with appropriate prompt or menu formats, if needed. The generator should be equally strong in the ability to document the growing DSS both through automatic documentation features and user-selected ones.

This chapter provided many of the crucial implementation issues in building and evaluating the specific retasking DSS. Chapter V critiques the major techniques of the adaptive design methodology and discusses how it has supported growth of the retasking DSS so far. Additional recommendations for the continuation of this project are also provided.

V. Conclusions, Recommendations, and Enhancements

Where Adaptive Design Has Led

If adaptive design is partially characterized by the phrase "start small and grow" (Valusek, 1987:2), then it is appropriate to say this design approach has facilitated the building of a small basic framework from which the retasking DSS for the ASOC can root itself and grow. However, it is naive to think the process can be successfully continued without the support of some strict organizational structures and mechanisms. A good approach to adaptive design is not necessarily any less structured than the traditional life-cycle approach. The fact that adaptive design appears less structured to those unfamiliar with and unpracticed in the approach is due to the lack of documentation that exists to explain how the approach has been applied. One of the goals of research and development such as this project, is to derive a recommended approach which includes design activities and some sort of schedule or scheme for applying the activities. The following sections encapsulate the accomplishments of each of the following recommended adaptive design modules. Further discussion on what supporting organizational mechanisms are needed to nurture the DSSs growth is also included. The particular facilitators and hindrances to adaptive design during this project are also examined.

Concept Mapping Growth. Concept mapping as a method of uncovering and refining the decision process should not be limited to the early phases of the system growth; it should be continued throughout the life of the retasking DSS. As the decision processes which the system is based on change and grow within the operational environment, concept

mapping will help to translate the changes to the DSS. If this growth of the concept maps is continued throughout the life of the system, the maps will serve as useful supporting documentation both for the user and the builder. If maintained, the concept maps should correspond closely with the evolving system. They are a portion of the system that the user would be capable of and may even enjoy maintaining; they graphically reflect the user's knowledge and understanding of the retasking decisions, and most likely the user would want them to reveal his most detailed understanding of the decisions involved. Additionally, concept maps of various users of the DSS can be made available for the exchange of information and understanding of the decision process. Users should be able to further enhance their own understanding through the maintenance and exchange of concept maps.

The specific concept maps used as a starting point for the retasking DSS also need to be refined as the DSS develops. Limited opportunity to meet with operational experts and potential users during this project restricted the creation of extensive maps. Although the DSS is designed to support the Army in the Airland Battle, only one Army artillery expert participated by creating a concept map. There are still numerous ideas about the retasking decisions, especially in the areas of (1) BAI missions and (2) diverting CAS resources to a BAI mission, that could be revealed through the development of further maps with both Air Force and Army personnel.

Kernel Selection and Growth. Through a combination of (1) ideas from concept maps, (2) ideas generated during dialogue with experts, and (3) user reactions to draft storyboards, the kernel of the retasking DSS was initiated. Although some of the design (Ground Map portion) is based on a particular theater scenario for the sake of demonstration, the kernel design

is essentially generic. If the DSS design were to become too theater specific during the early phases, it might easily be rejected by other theaters as inappropriate for their needs. Some of the basic battle strategies and operational concepts do vary significantly from theater to theater; however, there has been an attempt in the kernel design to avoid focusing on these unique aspects. The advantage of a properly chosen kernel in this case is its applicability to different theaters with diverse operations. The flexibility designed both into the structure and operation of the kernel DSS supports this. Of course, this generic design is especially beneficial to the Conus ASOCs, who could deploy to a variety of locations, each with a slightly different mode of operation. It may in fact be useful to develop a series of "shells" to be used for deployments to different locations. The shell would set up the system for its customized use in a particular environment. It may (1) alter parameters in models slightly, (2) modify or create different data base relations, (3) vary the sequence of possible screen representations, and (4) permit the interface with other tactical systems. Any alterations to the DSS caused by the shell would be intended to make the user as comfortable as possible within the particular environment he is operating.

Feature Chart Growth. The feature chart is another important part of the system that both simplifies communication between decisionmaker, analyst and system designer/builder (Seagle and Belardo, 1986 : 19), and serves as especially useful documentation while the DSS is evolving. If all three individuals work from the same or similar feature charts, there is much less of a chance for misunderstanding. The feature chart represents the system as seen through the eyes of the decisionmaker, and insures that the decisionmaker and analyst/builder have a common understanding of the system linkages, and the interactions involved in it. The feature chart does

not suffer from the complexity and abstract nature of more traditional analysis and system structure diagrams that analysts and builders have used exclusively. Feature charting serves the analyst, builder, and user equally well.

A modified feature chart is used in the retasking DSS to guide the user through the storyboard. Below each screen representation in the storyboard is a miniature feature chart with the portion of the feature chart highlighted that corresponds to the screen design above it. As the DSS grows, it is essential to update the hierarchy of feature charts in step with the evolving DSS, to assist in the communication between the user, the analyst, and the builder. Updating the feature chart can be easily accomplished by the designer or analyst working with the user. The software that is chosen for the user to keep the storyboard updated should also allow update of the feature chart. This way he is able to maintain a current storyboard set and the supporting documentation provided by the feature chart.

Storyboard Growth. The storyboard is a critical part of the adaptive design approach that begins in the early design phase and continues throughout the life of the DSS. It is critical for two reasons. First, it represents the key link that integrates the user both into the design process and the system growth or evolution. Secondly, the storyboard serves as the crucial tool to help the DSS evolve with the evolving user needs. With the sophisticated and easy-to-use graphics software that is available today, users should have little difficulty creating new screens and refining old ones. To be most effective, the operational DSS should have this graphics design software capability built-in. Since most ideas for DSS enhancement and growth will come to the user while he is using the DSS, there must be support for allowing the user to experiment with new ideas. One method

that would work is the ability to quickly produce an annotated copy of a current screen representation during the decision process for later examination. The decisionmaker may be having difficulty with a particular display format. In his opinion, there may be critical information missing or a restriction in what data or models are accessible. Perhaps the series of steps necessary for a certain decision process is clumsy, or distracts the user and prevents him from using the display as intended. With many of these potential DSS flaws, the problem may be subtle and forgotten shortly after it is encountered, unless the user can produce a copy of the deficient display on the spot to trigger his memory at a later time. This DSS capability would complement the hookbook capability. Ideally, the user would be able to easily link his hookbook entries with the corresponding annotated copy of the screen display for better clarity and recall.

Users of the DSS should be encouraged to satisfy their evolving decision needs by creating and refining the storyboard. This evolving storyboard becomes a dynamic statement of requirements. The advantage to having the user maintain it is that it never becomes outdated, and remains several steps ahead of the operational DSS. In addition, the evolving DSS is always moving in the direction of better satisfying the users' needs. This researcher believes that many users will savor their role in the evolving DSS as storyboard designers, and will take their storyboard development responsibility seriously. The key though, is to provide a mechanism that will allow them to quickly accomplish this, without having to do a lot of writing, or struggling with foreign software. In effect, the user is coaxed into generating his decision needs within the environment he is most comfortable and familiar. The results should be more thorough and appropriate than other approaches can provide; new requirements are

generated during the actual decision process.

Although the initial Retasking storyboard set was designed by this researcher, further storyboard maintenance and refinement should be turned over to the operational users as soon as possible. The diversity of ideas that could be generated at this early stage of the DSS development through the direct user's involvement would improve the evolving DSS kernels. The difficulty that exists is how to manage the evolving storyboards from all the user locations until the requirements can be incorporated into the operational DSS. A proposed organizational solution is offered later in this chapter.

Hookbook Growth. The hookbook is a readily accessible method of recording ideas for DSS enhancement. This purpose ties it closely to the storyboard enhancement method. During design of the retasking DSS, this researcher used the method suggested by Valusek (Valusek, 1987:11). This manual method of recording an idea for enhancing the DSS, with the date and circumstance under which it occurred seemed to work better as the project progressed. Its success depended on (1) the accessibility of small notecards when the idea occurred and (2) the discipline to write down the idea concisely and as soon as possible. This method resulted in a modest number of notecards near the end of the design phase. The majority of the cards were produced in the latter half of the project period, when the practice became more ingrained and the frequency of concrete ideas coming to mind seemed to increase. It seems natural that the frequency of ideas should increase with increasing array of storyboards and designs to stimulate new ideas.

To combine the effects of the developing storyboards and hookbook ideas, it would be helpful to be able to link the two within the operational DSS

software. The user should be given the capability to link the hookbook ideas together among themselves and with the storyboards for future perusal and maintenance. He should also be able to easily vary the sequence of display of these linked documents. This flexibility will allow the user to view the ideas in a variety of sequences and categories; this variety should encourage the formulation of further ideas by providing the freedom to look at the ideas already generated in a new perspective (Valusek, 1987:11).

HypercardTM is one example of off-the-shelf software that provides this capability to create idea notecards and then link them in a variety of ways.

Growth of the Retasking DSS

The methods described in the preceding sections provide the means for the user to support the DSSs incremental growth. One idea with potential for further development that was generated during the initial design phase involves support for extended range and more complex CAS mission planning. With this enhancement, the DSS would be able to support situations in which tactical air to support land force units operating beyond the Forward Line of Own Troops (FLOT) will be needed. Retasking for this type of operation parallels that of BAI, but final attack control will follow CAS procedures, and may require special force packaging. Retasking for this type of mission would be more complex than retasking CAS missions for the FLOT area. First, the distances that aircraft would have to fly to reach a new target area beyond the FLOT would generally be greater. Certain aircraft, i.e., A-10s might be unsuitable for these extended missions; the DSS would have to support selection of proper aircraft/weapon for a mission of this sort. The possibility of using aircraft planned for BAI missions would be much greater with an extended CAS mission requirement; the DSS would

have to support integrated CAS/BAI retasking to a much greater degree. Command, Control, and Communication (C³) procedures with CAS aircraft beyond the FLOT would be different than with CAS aircraft behind the FLOT; the DSS would have to operate effectively using information from these alternate procedures. The threat environment for aircraft operating beyond the FLOT would also be different; more specific support for transiting aircraft through these high threat areas would be needed, as well as any control or orbit points along the way.

Other Enhancements. The list of DSS capability enhancements does not stop here. Additional ideas are included in Appendix B. Ideas in the appendix were derived from concept maps and storyboards, inputs from users, and possible mission scenarios presented in official joint operation manuals. These ideas seem to be several of the major enhancements that will require smart integration of the mechanisms for the evolving DSS. They are certainly not enhancements that the DSS builder will be able to simply add without comprehensive storyboard input from the users.

Plan for DSS Growth

The plan for the growth of the retasking DSS must be well thought out, and should proceed using all the mechanisms of adaptive design. The current effort for upgrade of the ASOC is focusing on a modular approach to hardware integration. It is believed that considerable technology transfer from related applications, and off-the-shelf hardware and software will satisfy the needs of the ASOC of the future. Although these beliefs about modularity appear valid at this time, there remains a gap in the early design phases so far. That gap is the lack of an adaptive design structure that will lead the development of an ASOC DSS based on the important role

and stimulus of the decisionmaker throughout the life of the DSS. As Boar warns: complete "definition of the system occurs through gradual and evolutionary discovery as opposed to omniscient foresight" (Boar, 1984 : 5). The following organizational structures are required to support the gradual learning about and incremental development of the retasking DSS.

Organizational Requirements. Specific organizational requirements exist at several levels. Within the CONUS, there is the user level at the ASOCs at Shaw AFB and Bergstrom AFB. Prototypical models of the DSS must be installed at these two sites as soon as they are available. In the meantime, users at these locations must be given the means to explore requirements through the Storyboard and hookbook mechanisms as described. Each of the sites should have a representative to coordinate and encourage this effort. He should be well versed or taught about the adaptive design process, and the importance of his or his replacement's role throughout the life of the system. With the problem of assignment transfers, it would be best to have two individuals at this level knowledgeable about and co-managing this effort.

At the next level, TAC/DR should be responsible for the critical job of integrating the storyboard and hookbook requirements that are generated at the ASOC level, and formulating the ongoing plan for implementation of this gradual growth. TAC/DR should insure that ASOC users are thoroughly trained in the adaptive design process and in use of the design tools incorporated in the DSS. Valusek, in his paper on adaptive design has suggested the establishment of a DSS "referee" and two assisting individuals, the Data Administrator (DA) and the Model Administrator (MA) (Valusek, 1987:12). The referee is perhaps a user expert with systems knowledge who is quite high in the organization, and will not be bogged

down by political roadblocks. He is responsible for validating and prioritizing user generated design requirements, and resolving any conflicts that arise. The DA and MA also interface with the user at the ASOCs and insure the integrity of the data and models used in the DSS. This researcher believes these three individuals are critical at this level. They are required to coordinate the inputs from the users and also serve as a liaison between the users and the prototyping facility. The DA and MA are needed to manage the different data and model requirements for the different theaters.

TAC/DR should have the additional responsibility of managing the incremental building and testing of the operational DSS at the TAC prototyping facility. In this role, they are responsible for bringing together user, builder, technical experts/consultants, and outside contractors. The timing for these meetings and tests is perhaps best gauged by closely managing the incremental growth of the DSS, and anticipating when the assembly of different players will most benefit the adaptive process. One of the first appropriate times for an assembly would be after implementation of the initial kernel, to investigate the design of additional kernels and evaluate the success of the first.

The technical work of Rome Air Development Center (RADC) and project management of Electronic Systems Division (ESD) for the ASOC DSS needs to be more closely integrated with the adaptive design at TAC and the ASOCs. Part of this integration will be provided by interaction and exchange of ideas at the prototyping facilities. An improved integrated approach to the DSS growth could be realized if RADC and ESD modified their modular growth philosophy to include the adaptive design techniques. The success of TAC/DR in organizationally supporting and using adaptive design may

heavily influence the response of RADC and ESD.

Backup System Requirements

As the DSS is created and begins to grow, it is essential that a plan and supporting materials be developed as a manual backup to the system. It is likely that the expected tactical environment communication outages will sever the ASOC from the TACC and other agencies that provide real-time data links with master databases. The current manual system status boards used by the CONUS ASOC at Shaw AFB (682 ASOC) to maintain status of the battle and make their decisions include:

- 1) CAS Mission Status Board
- 2) RECCE Mission Status Board
- 3) FAC Mission Status Board
- 4) Geographic Wall Map
- 5) Weather Status Board
- 6) Radio Circuit Status Board
- 7) TACP Status Board
- 8) Standard Conventional Load(SCL) Board
- 9) Unit Call Sign Board

It would only be necessary to revert to use of these manual boards if the retasking DSS failed or the overall ASOC system lacked sufficient redundancy. However, decisionmakers would resist using the retasking DSS if they knew that no reliable backup system existed. Consequently, a portion of the design includes the backup information that would be generated by the retasking DSS to support the decisionmaking during DSS downtime. At regular intervals the system should produce a hardcopy of

the information exactly as it would appear on the manual boards. The frequency of producing the hardcopy information should vary depending on the level of current activity and the amount of decision-relevant information generated. The DSS should monitor this level of activity automatically and adjust the frequency of hardcopy printout as needed. Producing the hardcopy in the status board format would allow the information to be easily transferred to the boards if the back-up system went into effect. It would also be necessary to produce hardcopy overlays of the geographic map displays with key symbology shown. These would be used as overlays on the geographic wall map if decisions had to be made using the manual system. Additionally, under a weapon constrained scenario, a hardcopy of adjacent Corps assets would also be needed to aid in the retasking process. The DSS should automatically include all hardcopy printouts needed for the manual decisionmaking process under any constrained situations that they are currently operating.

What Facilitates and Hinders Adaptive Design

Discussion of what helped and hindered adaptive design of the retasking DSS reflects some of the personal limitations and experiences of this researcher. It is believed that what may help or hinder a particular DSS design project will vary to a great degree from project to project. However, several "universal" variables will effect most design projects similarly. This universal category includes:

1) Facilitators:

- a) Regular interaction between the user and the designer for extended periods of time; ideally, the designer should work at the user location at least until the kernel design has been decided upon;

- b) Working with users who are willing to try the adaptive design process and if possible commit themselves for the life of the DSS; their support will be needed to evolve the storyboard as a dynamic set of requirements;
- c) Design for the initial kernel should be small and possible to implement quickly; the small implemented kernel will generate considerable ideas for what direction to expand the DSS;

2) Hindrances:

- a) An environment in which the underlying decisions are not clearly understood or there exists disagreement on the decision process;
- b) An environment in which the underlying doctrine or policy that guides the decisionmaking is in a state of change;
- c) Initial unfamiliarity of designer with operational environment for which DSS is being designed;
- d) Failure to find a DSS champion who strongly believes in and will consistently support the design and evolution of the DSS.

In addition to these universal factors, several additional factors influenced the retasking DSS design project:

1) Facilitators:

- a) User that has microcomputers and design software to maintain initial storyboard and generate new ones;
- b) User familiarity with microcomputer capabilities to help in envisioning what capability an automated DSS can provide;
- c) Designer having strong background in human-computer interface design; possibly some knowledge in human factors;

- d) Two man design team; one to design with user while the other builds DSS with inputs from designer (speculative);
- e) Sophisticated DSS generator software (speculative);

2) Hindrances:

- a) Separation between designer and user during critical initial kernel design phase;
- b) Having to work with multiple users at different organizational levels all with different views about the design of the kernel DSS;
- c) No existing automated system to support decision; transition from an entirely manual system is difficult because it is not always clear how the different manual tools all are linked together;
- d) Nonexistence of applicable automated models to incorporate into DSS;
- e) Inability or failure to build the operational DSS in small increments starting shortly after the kernel is designed;
- f) Weak background of the designer in decision theory;
- g) Inexperience of the designer in general system/software design

Final Remarks

DSSs should offer tactical decisionmakers an effective means of assessing battlefield information, formulating and choosing alternatives and deciding on a final course of action. With today's sophisticated tactical data gathering and fusion capability, real-time critical decisionmaking information is

available to the decisionmaker at all levels of the tactical battlefield. Within the ASOC, decisionmakers need to use this information to make rapid decisions on whether or not to retask previously assigned CAS and BAI missions in a dynamically changing environment. The FDO in the ASOC does not currently have a DSS to accomplish this. The DSS is needed to integrate changing CAS and BAI requests to use the best available weapons at the time and place of the battlefield commander's choice. It supports vital decisionmaking for joint C² operations.

DSSs for tactical decisionmaking environments like the ASOC are difficult to design and build. The decisions that it must support are unstructured and changing, and the exact system requirements are not completely known. This thesis focused on describing and applying an appropriate methodology to translate the evolving needs of the ASOC FDO for the retasking decision. The methodology used was adaptive design; it can be effectively applied throughout the life of the system, and involves the critical participation of the decisionmaker. The primary activities that were used to support the adaptive design process were concept mapping and storyboarding. Concept mapping was found to quickly reveal critical elements of the retasking decision process and was one tool used to design the initial DSS storyboard. Storyboarding was found to be an equally powerful tool for the decisionmaker, who can use it throughout the life of the DSS to refine the system to meet his changing needs.

Concept maps and storyboards for the retasking DSS were created and evolved with the graphics oriented software MacDraw™. A partial system simulator was implemented using Macintosh Hypercard™ software. The Hypercard environment combined with other Macintosh™ graphics software, i.e., MacDraw™, was found to provide the flexibility and ease of use needed

for a user (inexperienced in computer use) to easily create the initial storyboard and then enhance it over time. The ability to link stacks of designed representations in a variety of user-controlled ways was found to be an invaluable tool for the user to build the system simulator.

The critical role of the ASOC decisionmakers in designing the retasking DSS must be continued through the initiatives of TAC/DR; their dynamic management of the adaptive design process is needed to keep the retasking kernel evolving. The needs of the retasking decisionmaker must continue to drive the design of this DSS.

Appendix A: CAS/BAI Retasking Storyboards

The overall design of the operating environment for the retasking DSS is modeled after the desktop operating environment that MacintoshTM has successfully promoted. Several of the features of such an operating environment that are particularly suited to the retasking environment are as follows:

- 1) Adaptable system for the user to selectively call up functions and operations in varying sequences and at different times in the decision process;
- 2) Clearly organized and visible menu system that prevents the decision maker from getting lost in a maze of hierarchical menus;
- 3) Concise menu driven filing, retrieval and printing capabilities to quickly store and retrieve significant steps or partial results in the decision process;
- 4) Flexibility to add or remove selected functions or operations as the system is refined without having to totally redesign the system;
- 5) Responsive environment for both beginners and experienced users.

Having briefly touched on these advantages, the general features of the design for the kernel DSS will be described in the storyboards and accompanying explanations that follow. The first six storyboards depict the pull-down menus that are available, and the remaining screens provide some examples of the system's designed features and how the decisionmaker might flexibly use them to reach a decision. The highlighted feature chart below each screen display shows the user exactly where he is in the DSS when using that display.

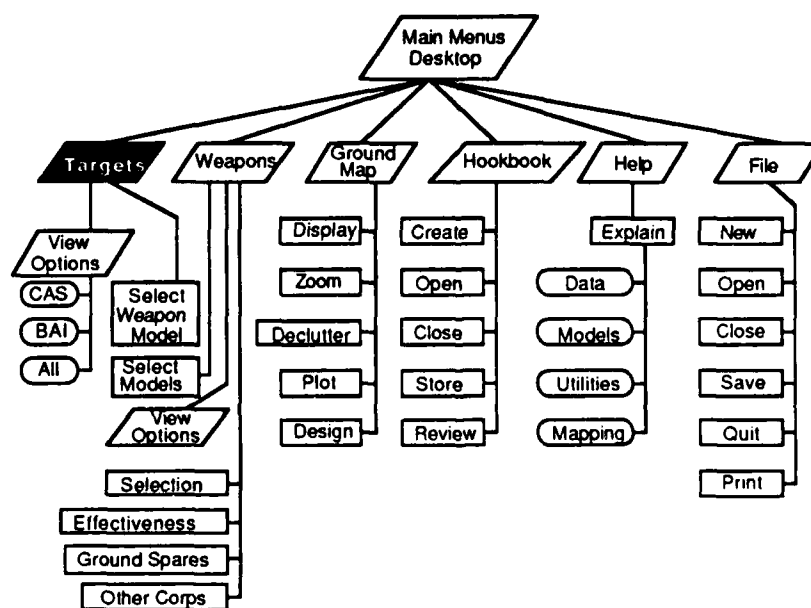
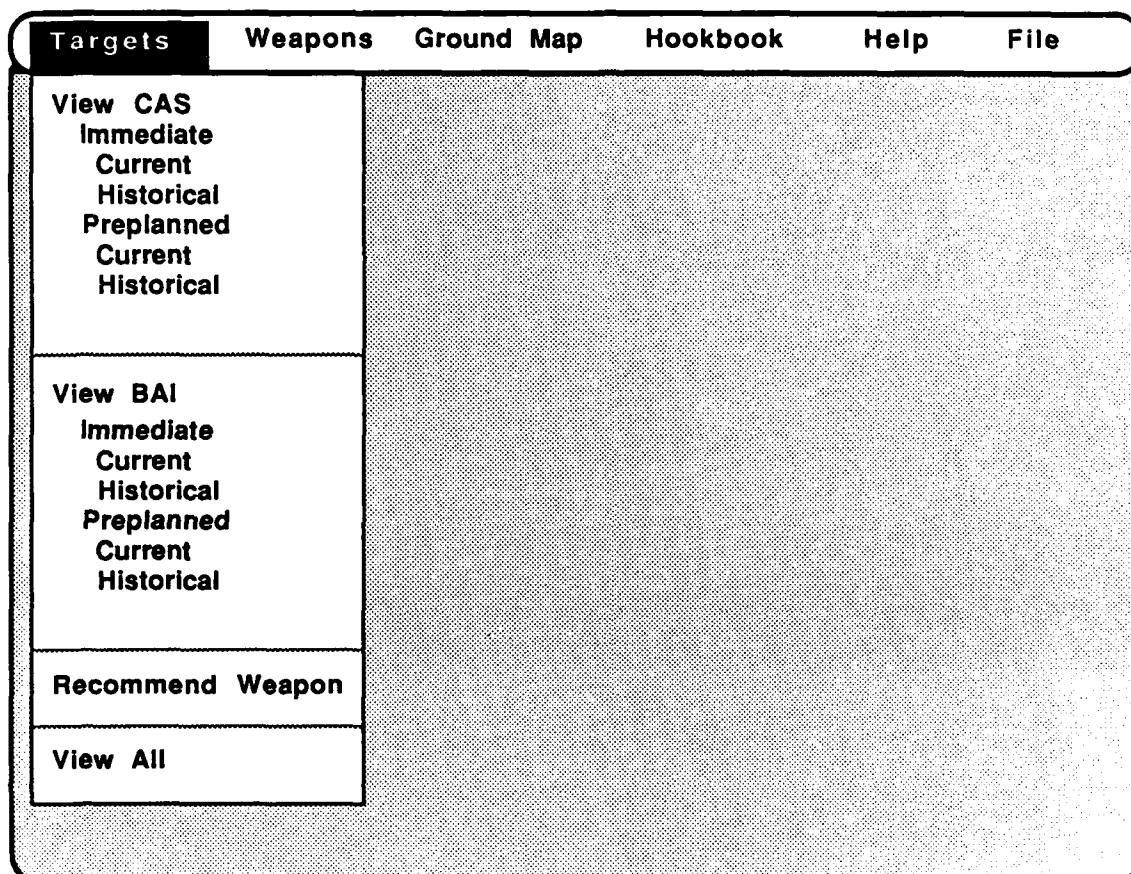
TARGETS MENU

All the menus are placed in an order that approximates their importance and frequency of use in the system; the first three menus from the left are at the top of this order. The first one, the targets menu, is designed to allow the user to access different portions of the entire targets database.

Immediate and preplanned targets are listed separately to allow the user to quickly select and view minimal critical data or the results of his query.

Under certain circumstances in a battle, (i.e., when the friendly efforts are shifting from a defensive battle to an offensive one) it may be necessary to consider CAS assets for BAI type targets because some of the CAS targets may be replaced by BAI targets by higher level planners. The breakout of the database into CAS and BAI targets allows one to do this. If all targets need to be viewed together, there is an option to display consolidated CAS and BAI targets through selection of *View All*.

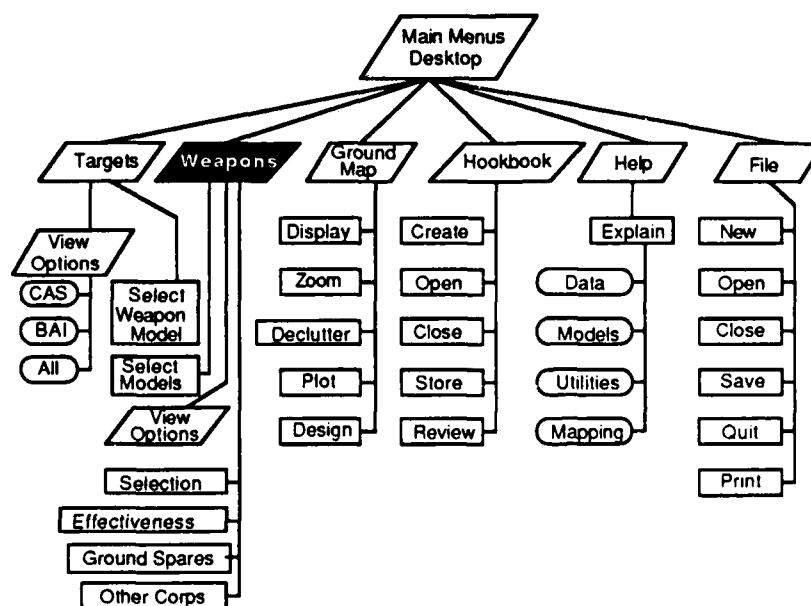
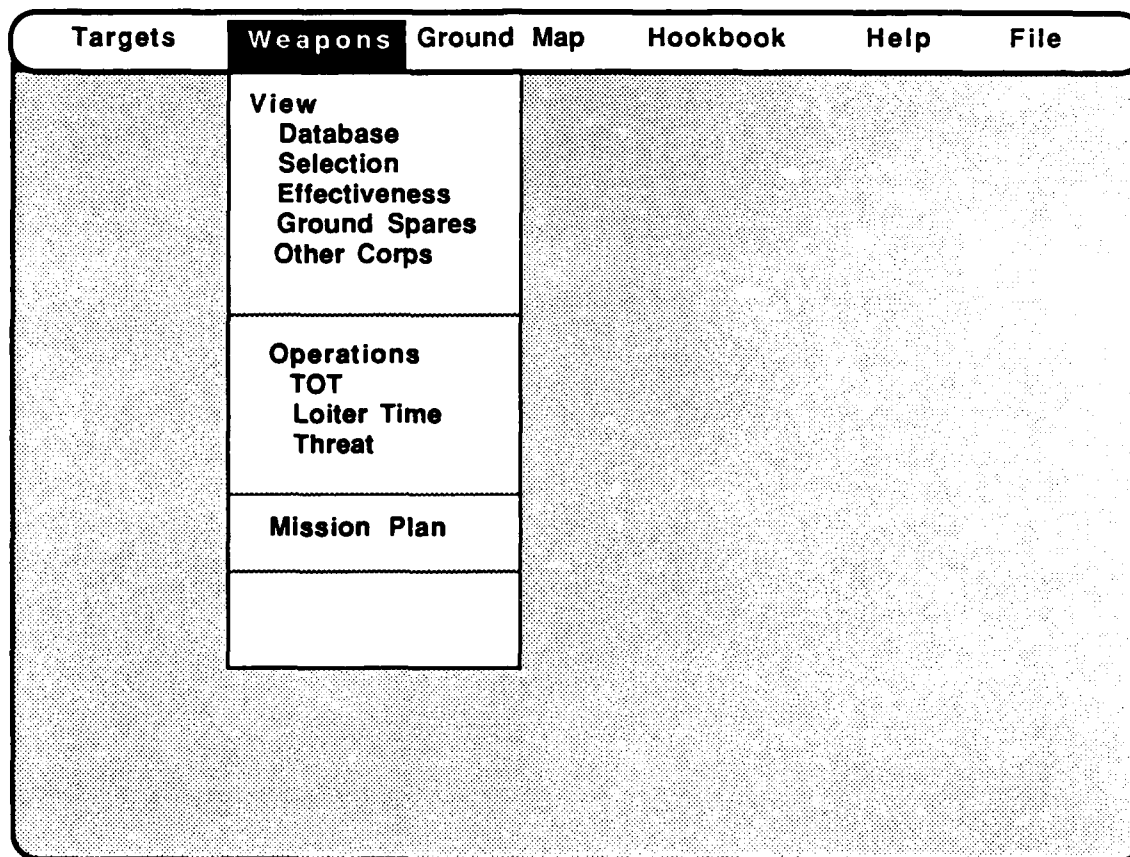
The other important feature under this menu is the *Recommend Weapon*. This model is available to the decision maker for a system recommendation of available aircraft and weapon combinations for the high priority targets that may emerge without prior warning, or under other retasking circumstances. The reason this option is under the targets menu is that the user will most likely be viewing targets while he is looking for a system recommendation on what assets to use against these targets. It may work just as well under the weapons menu. In this case, the option may also be useful for giving the user an estimation of the effectiveness of a certain weapon that is being considered for an immediate target. This model can also be run when the system presents an option window to perform weapon/target pairing.



WEAPONS MENU

The weapons menu also offers separate views of the CAS and BAI weapons. Under time constrained situations, the user may want to limit his view to aircraft on short ground alert or already airborne. The system queries the user for this time constraint as he enters the system. The other view options in this menu allow the user to quickly select the type of view of the database desired; each of these views can be used in conjunction with screen representations that the system presents. For instance, while the user is viewing the ground spares available for reloading on aircraft, he may want to consider the probable effectiveness of these potential weapons. In this case, he would select the *Effectiveness* option on the menu.

The options available under this menu all relate to specific information the user may need in retasking a specific aircraft. The *TOT* operation would figure the approximate time an aircraft would arrive at the desired target area, and whether or not it would meet the requested TOT. The *Loiter Time* operation provides an estimate of the remaining time that an aircraft has in the air without refueling. This information is essential if the decisionmaker is to consider recommending the moving of aircraft from one target area to another. The *Threat* operation provides the user with a rough vulnerability assessment, or an aircraft's probability of success against a specific threat that may be encountered under retasking. Part of the results of running this model would be a display of threat lethality contours that may impact a new mission. It may be unwise to consider certain weapons given specific threats in the target area. This operation would alert the user to these potential problems.

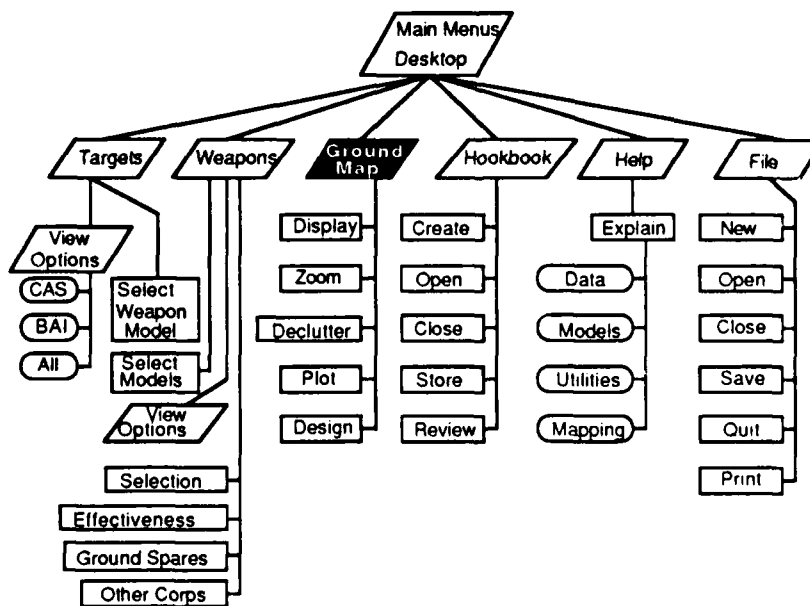
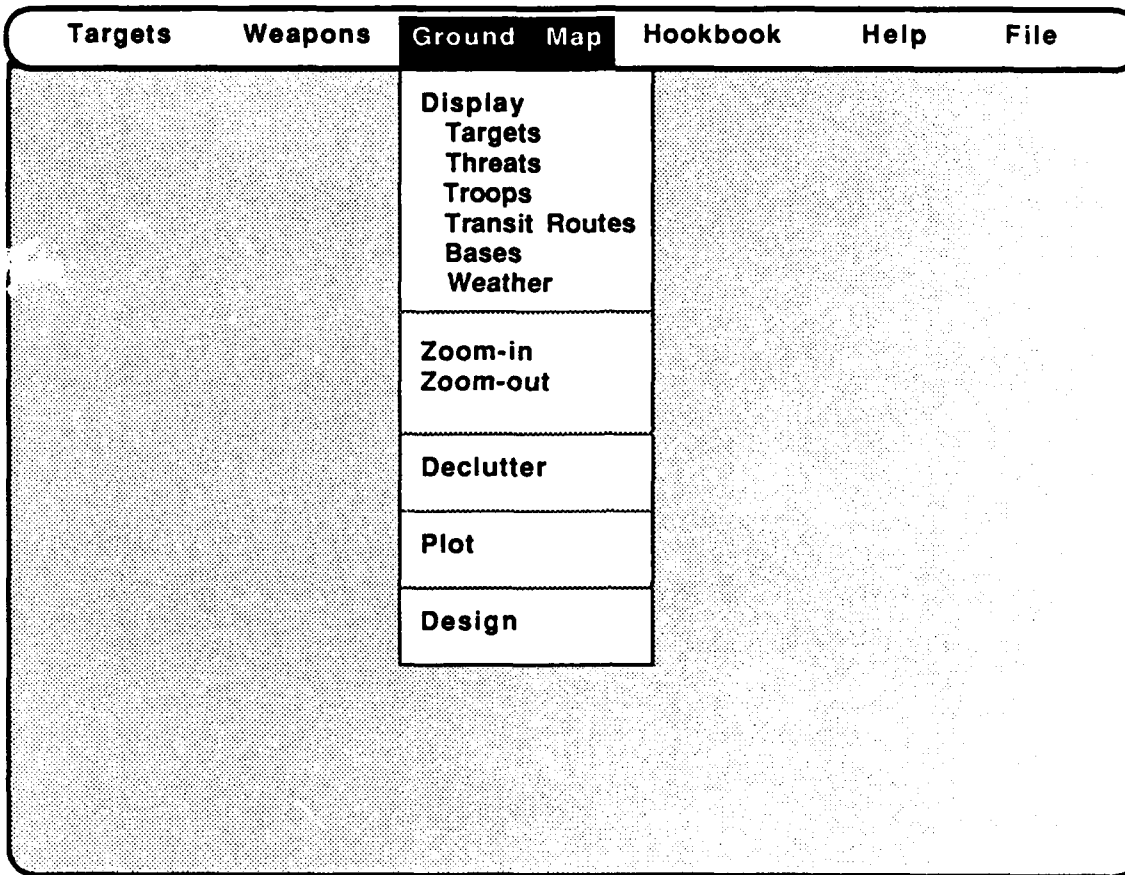


GROUND MAP MENU

This menu presents the features available in using the video disk map display that complements the system. Through this menu, the user selects the type of map symbology he needs displayed at various points in the decision process. He has the option of working with three different scale maps (1:50000, 1:250000, 1:500000) of the same area, and with these can *Zoom-in* for greater detail or *Zoom-out* to view the bigger picture.

Decluttering allows the user to hide either all instances of a certain class of symbols (i.e., all low level transit routes); it also allows the hiding of specific instances of a particular symbol if the user only needs to clean up a certain portion of the map to focus in on another aspect of that area. Plotting and designing fall into the same category, and allow the user to create and annotate his own symbols on the map display as needed. For example, plotting would allow the user to depict a specific ingress or egress route on the map. Once the theoretical route is plotted, it can be analyzed with the available models to study its feasibility. A plot showing the alternate route of a retasked aircraft could be used as a basis for a TOT calculation or the threat model.

The *Design* feature allows the user to create new symbols that he may need for a particular scenario. It also allows the user to create a template that could be used (and stored for future use) to display specific user preferences for particular situations. For example, one template might contain all threats that are potentially lethal to an A-10 aircraft. Another might contain a template of all targets that are vulnerable to a particular weapon; only those targets where the pk of the weapon exceeds a user established value would be displayed. The user may want to layer these templates so that they appear in a certain sequence; this could also be accomplished with the design functions.

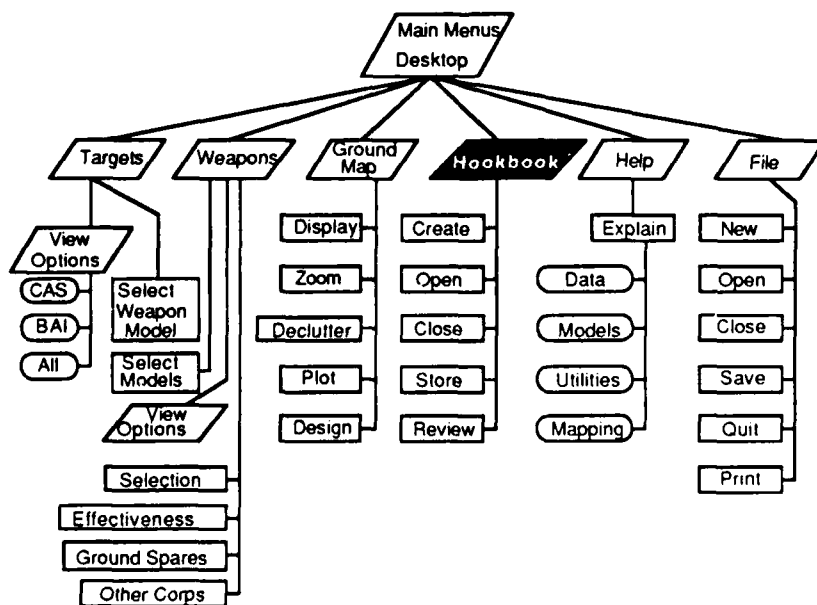
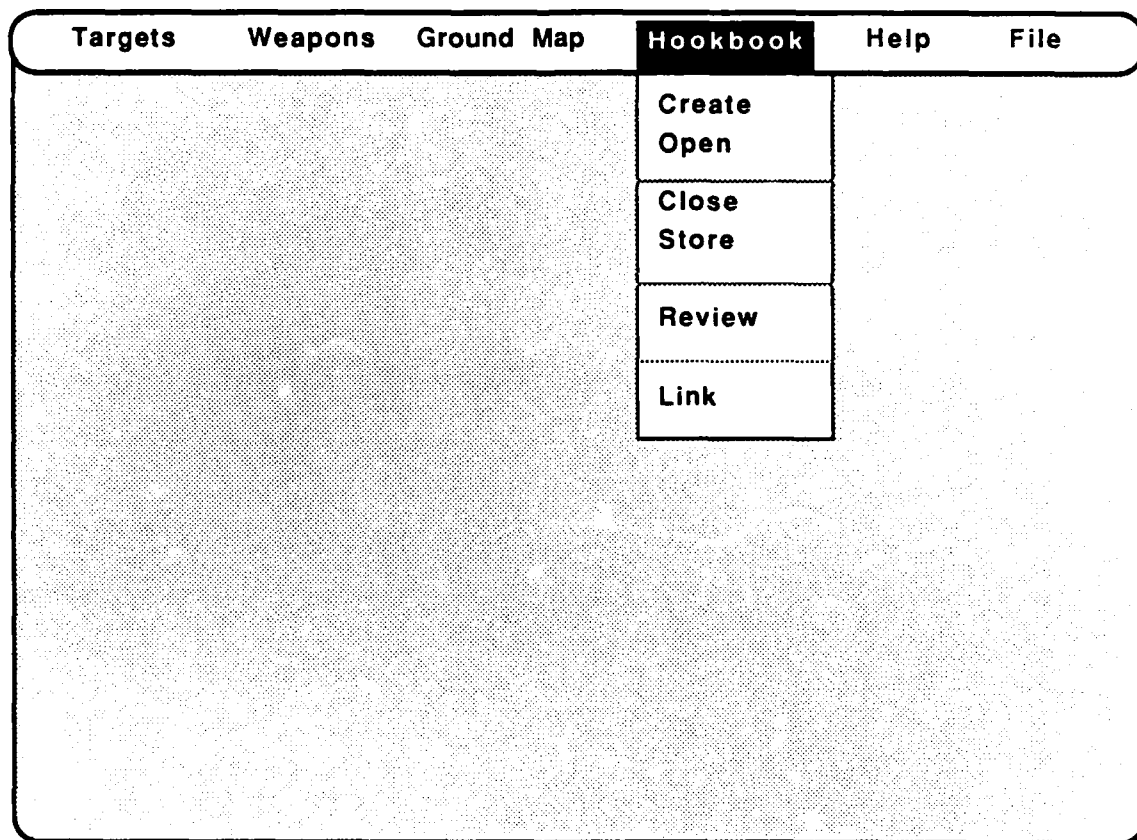


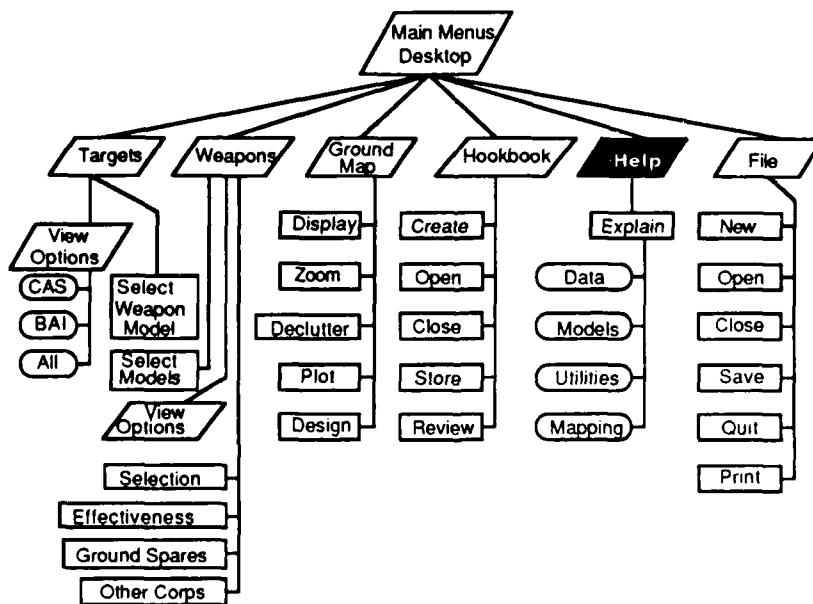
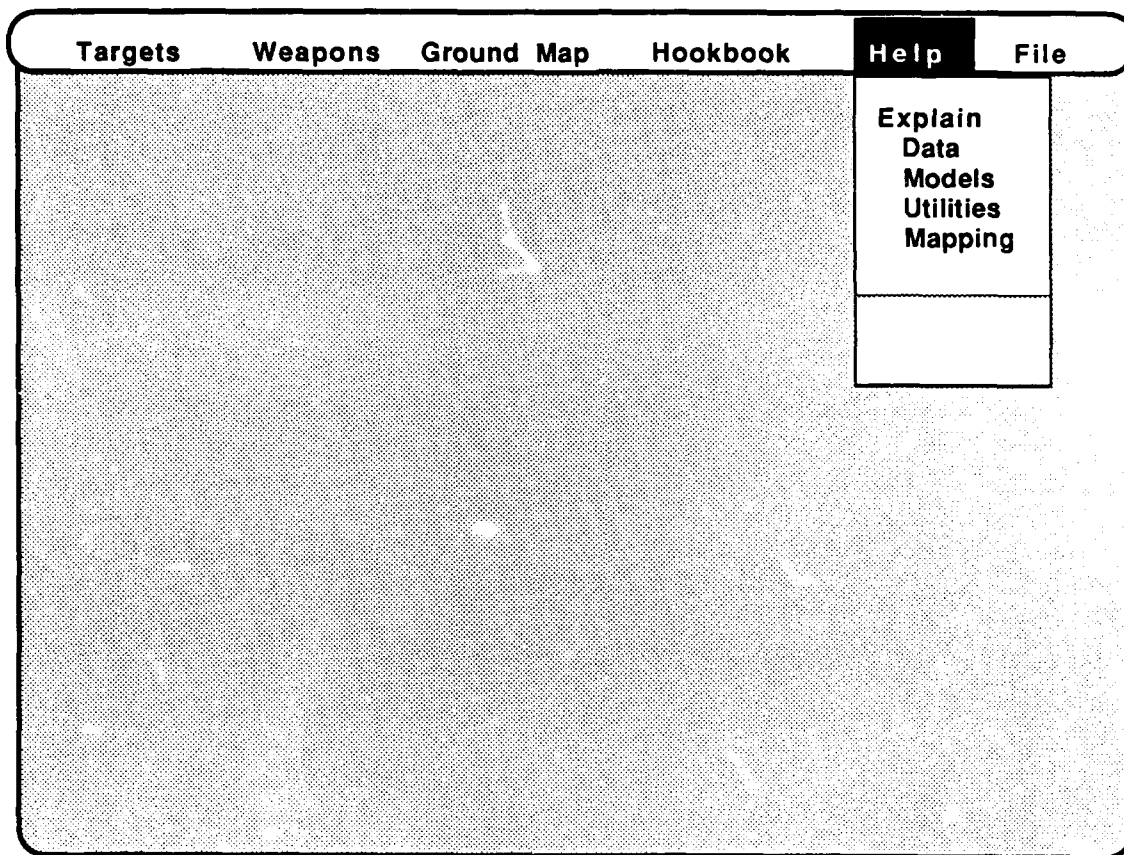
HOOKBOOK, HELP, and FILE

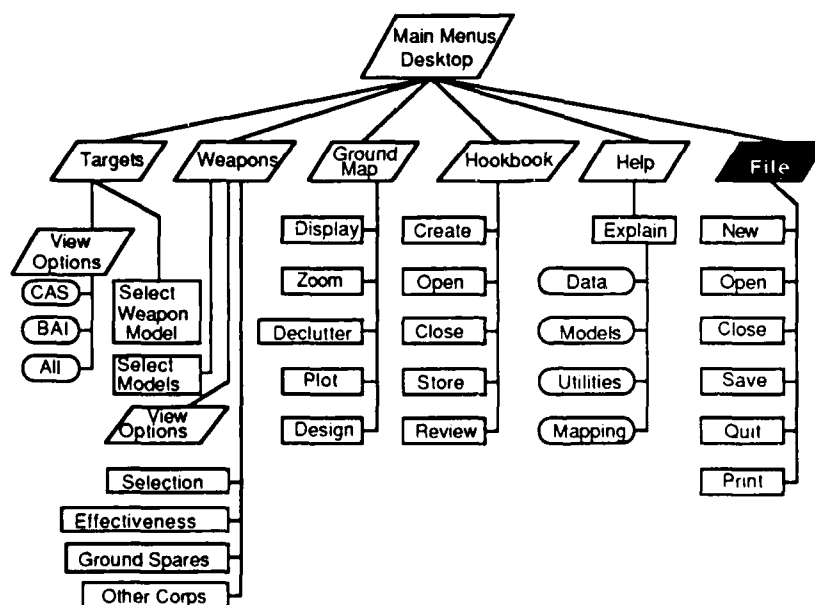
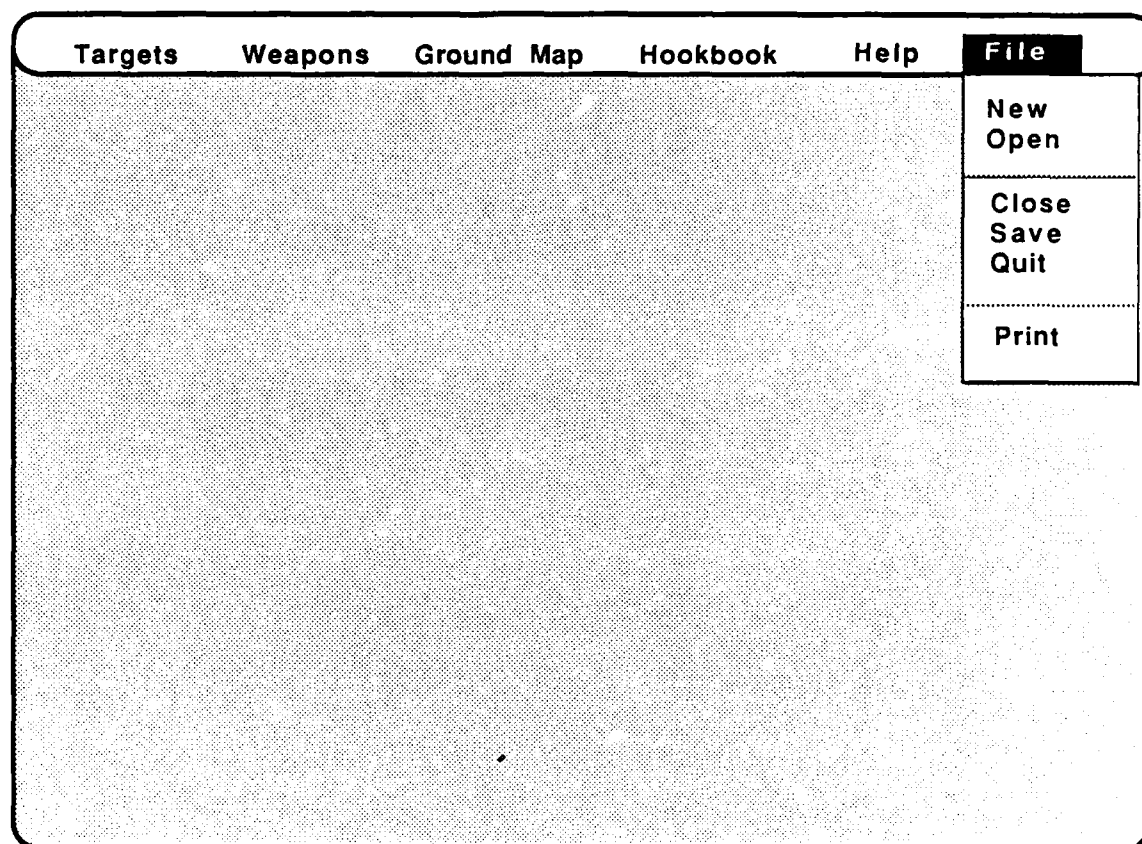
The following three menus provide the necessary storage and retrieval of information and model results being generated. The hookbook is an idea germane to adaptive design; by breaking it out under a separate menu it may be a constant reminder to the user of the importance of documenting all ideas for system refinements or changes that he thinks of during use of the system. It could be used to simply create narrative files that contain user ideas for system enhancements, as a type of notebook organized according to subject. Another use of the Hookbook is the option of storing the sequence of decision steps the user goes through in making a decision. This could be done by automatically recording a specific number from the series of screen displays that are presented within a certain scenario. When faced with a similar decision in the future, the user may want to recall the same sequence of decision screens, if this sequence were particularly effective the first time. This option of recall would also work well as a training tool for new personnel to review the process more experienced users take.

Help provides detailed explanations of the features of the other menus and some background on how the models work. The parameters used in the model calculations would be described, as well as any assumptions that had been made in deriving the models.

The File menu offers typical filing and printing features that may be needed to support the decision process.







WELCOME/CONSTRAINT SCREEN

This screen allows the user the choice of working exclusively with either CAS or BAI assets/targets during the retasking process. As mentioned earlier, if the nature of the battle is shifting and there is a need to rerole or reassign some of the CAS assets to BAI type missions, the combined retasking approach would be desirable. With the combined feature selected, the system would work with the CAS and BAI targets and weapons together. This would potentially maximize effective use of the full complement of available resources by considering both types of weapons for the two types of missions. For instance, a CAS A-10 loaded with a Mk82 may be more efficient and cost effective against armored vehicles in the BAI range than an available BAI aircraft loaded with a maverick. The combined approach would allow the decision maker to consider these types of trade-offs while looking at the full range of available assets. This capability would also allow the ASOC to respond flexibly to either CAS or BAI requests; instead of referring requests for aircraft allocated for a particular mission up to the TACC, the system assists the decision maker in meeting the request at the ASOC level by examining all possible weapons.

The next portion of the screen allows the user to indicate the constraints he is working under; the constraints indicated will influence the results of many of the system database queries or models available to the user. With the time constraint selected, the system would only present those aircraft options that would meet the requested TOT. If the requested TOT were not entered, the system would restrict the options presented to those that could reach the target within a pre-established period of time; a cutoff time of one hour may have been established as the criteria. This established time

Targets	Weapons	Ground Map	Hookbook	Help	File
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Welcome to the CAS/BAI retasking DSS. Please select the type of mission for retasking.

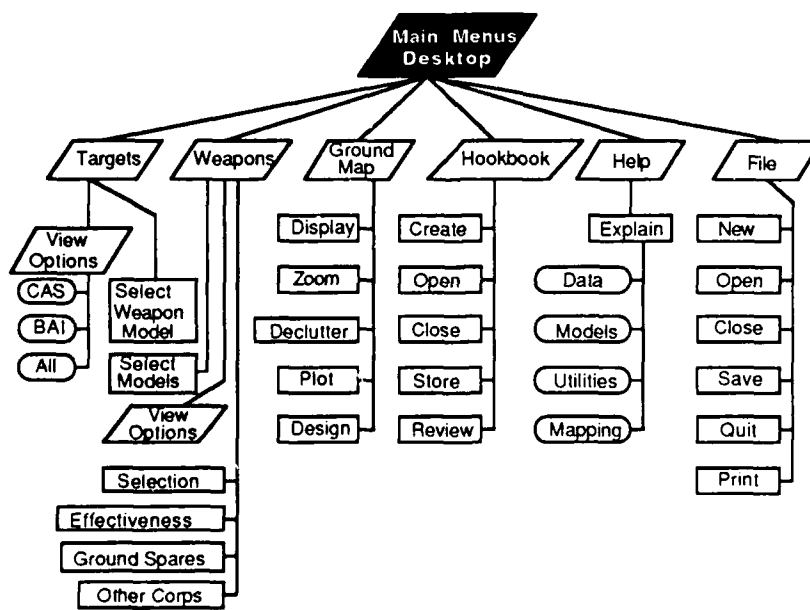
Select: CAS Only ☒ BAI only ☐ Combined ☐

Please indicate all the constraints with the current mission retasking or replanning.

Select: Time Constraint ☒ Weapon Constraint ☐

Requested TOT: - - - - -

NOTE: If time constraint is selected, you must indicate TOT for the DSS to limit selection to options that should meet this time. If weapon constraint is selected, the DSS will automatically consider airborne and ground assets in adjacent Corps.



criteria would naturally be variable, and could be easily altered by the user.

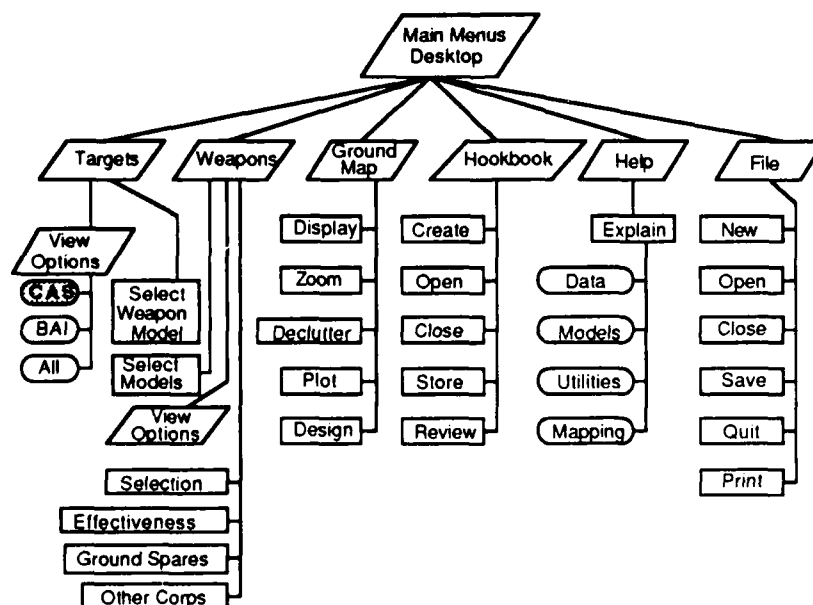
The weapon constraint option would indicate to the system that in the user's eyes, the available aircraft/weapons in the Corps are constrained. Under these circumstances, it is appropriate to consider aircraft in an adjacent Corps. If this option is not selected, the system limits alternatives to both ground and airborne alert aircraft within the Corps' organic assets. Further along in the decision process, the user has the option of further limiting the selection to only ground alert assets or only airborne alert assets; he also has the option of changing the overall weapon constraint that may have been selected when entering the system.

CAS TARGETS WINDOW

This screen is entered by selecting the *View Immediate CAS* under the Targets menu, or by responding directly to the system message to the user that a new high priority target has been entered into the target database. Generally, the decision maker would be cognizant of targets that are being considered by the Army for attack by air assets, so he would normally select the target menu option to start the decision process after the target had been approved for air attack. The Targets Window will open with the highest priority target highlighted for emphasis; priority of targets is assigned by the Army G-3 Air Officer. If aircraft for a mission have already been selected and scrambled, the *Msn Num* field will contain the mission number identifier; *None* indicates that aircraft have not yet been assigned. The *Loc* field specifies the geographic map grid coordinates of the target that corresponds to the system's map displays. The *TOT* field is the time that the requestor needs the weapon at the target location, to be properly coordinated with ground fire and the momentum of the friendly battle initiatives. The *Threat* field lists the threats in the vicinity of the targets; additional threats could be displayed by selecting *Display Threats* from the ground map menu. The *Cont/Callsign* field is the initial contact point and callsign for the pilot flying the mission against the target; the *Freq* field is the initial contact frequency.

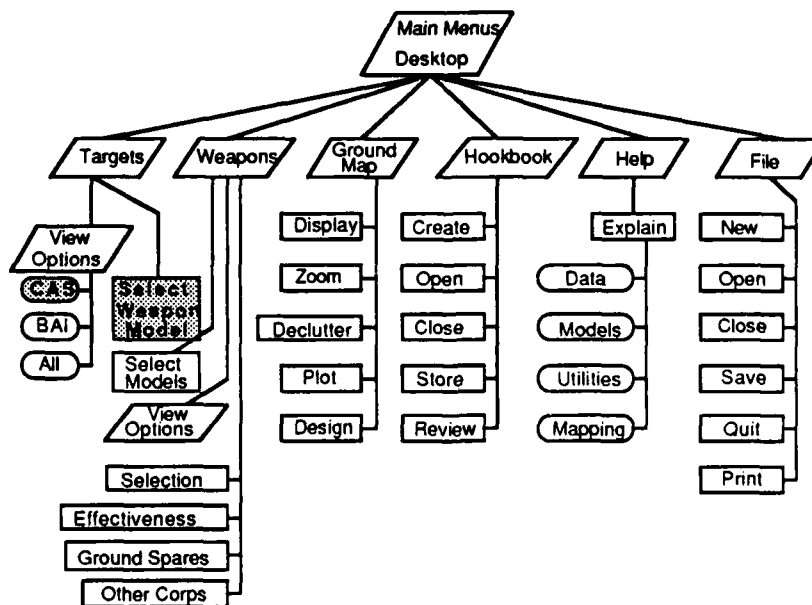
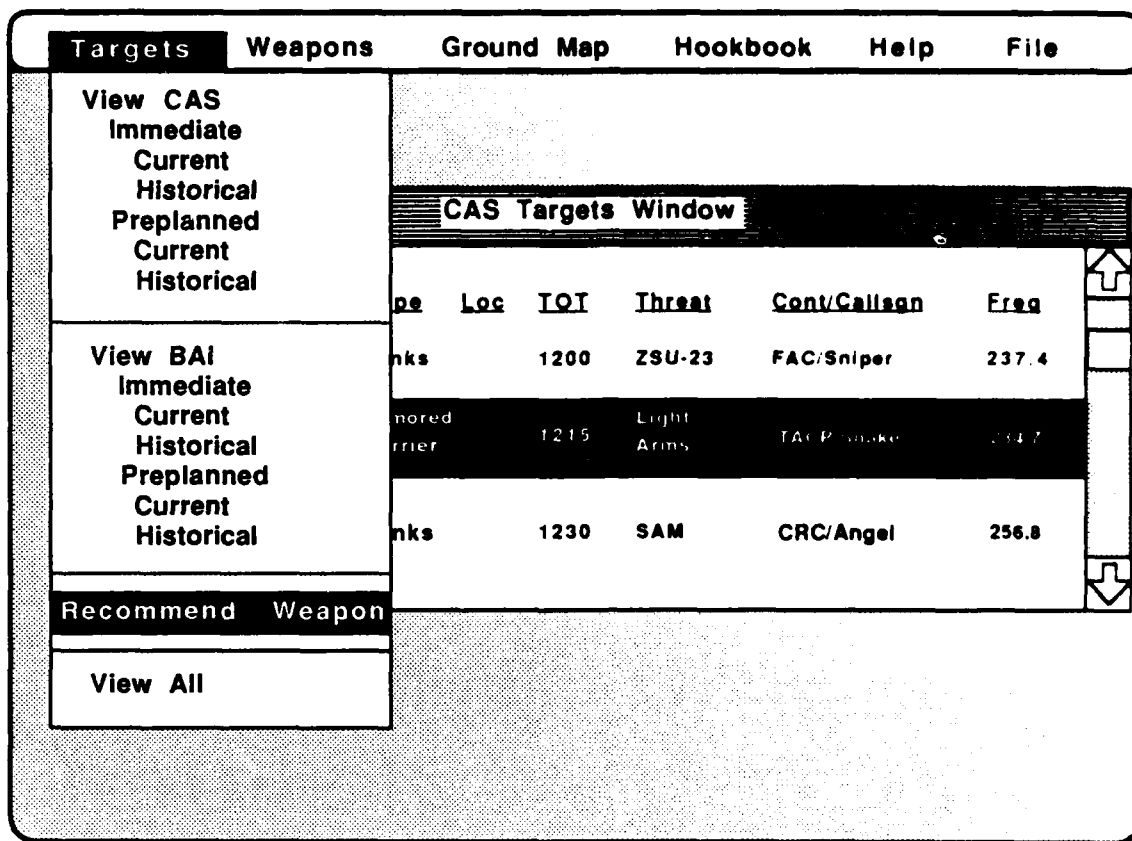
The window can be moved to any corner of the screen, and resized to allow for the simultaneous display of other windows. The scroll bar on the right of the window with the up and down arrows allows the user to scroll through all targets that do not fit in the window size.

Targets Weapons Ground Map Hookbook Help File							
CAS Targets Window							
Msn Num	Priority	Type	Loc	IOI	Threat	Cont/Callsign	Freq
54341	2	Tanks		1200	ZSU-23	FAC/Sniper	237.4
None	1	Armored Carrier		1215	Light Arms	TACP Snake	234.7
None	2	Tanks		1230	SAM	CRC/Angel	256.8



WEAPON MODEL

This screen displays one method of running the *Weapon Model* with the current highest priority target as input to the model. Two alternate and faster ways of invoking the model would be for the user to (1) respond to a system generated query of whether the model should be run, or (2) simply double clicking the mouse to start the model running. The purpose of running the model is for the system to quickly scan the available weapons in the database and filter out any of those that would be inappropriate to consider for the target in question; the results of the model are a listing of the recommended optimal weapons, based on the probability data available in the Joint Munitions Effectiveness Manuals (JMEM). The minimal weather requirements to achieve a desired probability of kill (pK) are also included because they are a significant factor in the success of the mission.



WEAPON MODEL OPTIONS

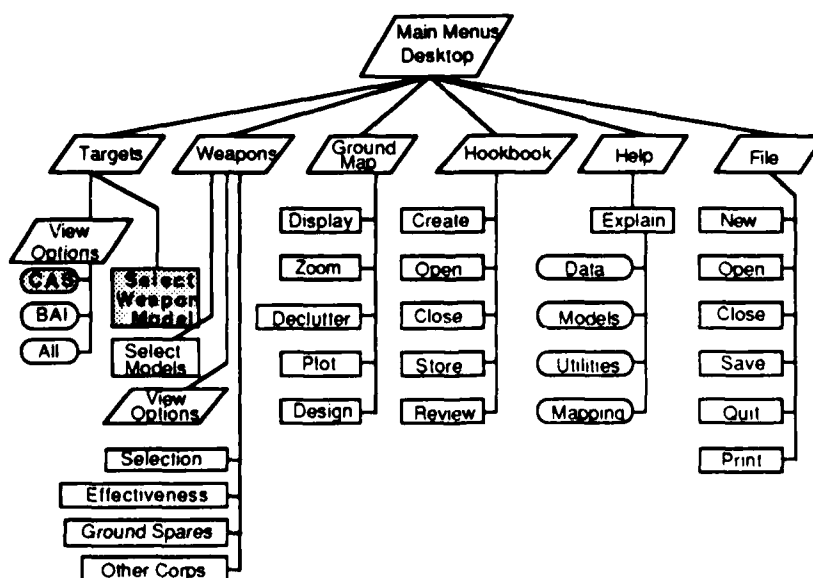
To run the weapon model (*Recommend Weapon*), the user is required to specify certain variables in the model. The first variable is the category of alert aircraft to be considered; the three categories being (1) airborne alert, (2) ground alert, or (3) both airborne and ground alert. Through selection of this variable, the user is indicating the urgency of the mission, or how quickly a weapon must be at the target area. Even though there may be no aircraft on airborne alert to be used as needed during the battle, other aircraft that may already have been assigned a mission but have not yet reached their final contact point may be considered as viable alternatives. Once aircraft have reached their final control or orbiting point and are talking to their contact, it is generally too late and too complicated to retask them, and their fuel level too low to consider moving them to another target area.

Besides selecting the type of alert aircraft to be considered, the user must indicate a desired pK for the mission. If no pK is indicated, the system default is to select the three weapons with the highest pKs, regardless of what the actual pK values are. The advantage of this limited list of alternatives is that under severe time constraints, the user would not be inundated with a long list of weapons to consider.

Targets	Weapons	Ground Map	Hookbook	Help	File																								
View CAS Immediate Current Historical Preplanned Current Historical	CAS Targets Window <table border="1"> <thead> <tr> <th>Type</th> <th>Loc</th> <th>IOI</th> <th>Threat</th> <th>Cont/Callsign</th> <th>Freq</th> </tr> </thead> <tbody> <tr> <td>Tanks</td> <td></td> <td>1200</td> <td>ZSU-23</td> <td>FAC/Sniper</td> <td>237.4</td> </tr> <tr> <td>Armored Carrier</td> <td></td> <td>1215</td> <td>Light Arms</td> <td>TACP Snake</td> <td>234.7</td> </tr> <tr> <td>Tanks</td> <td></td> <td>1230</td> <td>SAM</td> <td>CRC/Angel</td> <td>256.8</td> </tr> </tbody> </table>					Type	Loc	IOI	Threat	Cont/Callsign	Freq	Tanks		1200	ZSU-23	FAC/Sniper	237.4	Armored Carrier		1215	Light Arms	TACP Snake	234.7	Tanks		1230	SAM	CRC/Angel	256.8
Type	Loc	IOI	Threat	Cont/Callsign	Freq																								
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Armored Carrier		1215	Light Arms	TACP Snake	234.7																								
Tanks		1230	SAM	CRC/Angel	256.8																								
View BAI Immediate Current Historical Preplanned Current Historical																													
Recommend	Weapon																												

Consider both airborne and ground alert assets?

Select: Airborne Alert ☐ Ground Alert ☐ Both ☒



RECOMMENDED AIRCRAFT/WEAPONS

The results of the weapon model are displayed here. The format used is a window which can be altered in size and displayed with other relevant windows, as the sample screen shows. The user has the capability to scroll through the resulting aircraft/weapons if they do not all fit in the window.

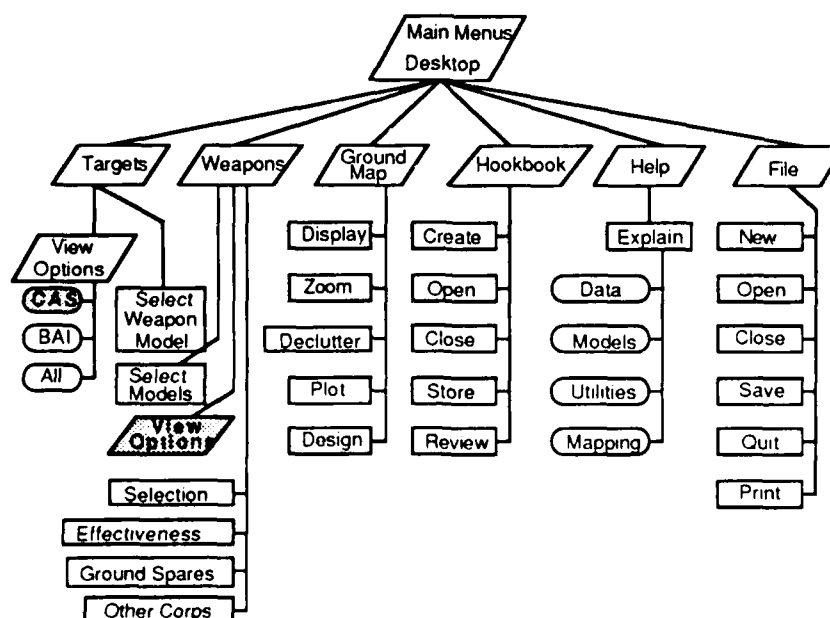
The *Type* field describes the type of aircraft available in the database that would be suited to attack of the highlighted target in the targets window. The *Ordnance/No* field contains the type and quantity ordnance currently loaded on the aircraft. The *Fuzing* field indicates the type of fuzing, which is an important factor in the pK of the weapon. The *pK* is indicated to give the user a general criteria for ranking the aircraft/weapon alternatives. It is important to note that the alternatives presented all meet the requested TOT within a certain degree of error. For the sake of the example given, the degree of error is *fifteen minutes*. The last two fields, *Ceiling* and *Visibility* represent the minimal weather required to achieve the pK provided. One of the requirements of the model is to filter out those aircraft/weapon alternatives that would not be appropriate under current weather conditions in the target area.

With the alternatives presented, the user has several options he may choose. The most logical may be to select an aircraft/weapon and query the system for more detailed information for planning the mission. Alternatively, he may want to view the target area on the ground map with projected weather overlays. If a change in the target area weather is anticipated near the requested TOT, it may be advantageous to run the model with the projected weather forecast, to see what new alternatives are produced.

Targets	Weapons	Ground Map	Hookbook	Help	File
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CAS Targets Window							
<u>Msn Num</u>	<u>Priority</u>	<u>Type</u>	<u>Loc</u>	<u>TOI</u>	<u>Threat</u>	<u>Cont/Callsign</u>	<u>Freq</u>
54341	2	Tanks		1200	ZSU-23	FAC/Sniper	237.4
None	1	Armored Carrier		1215	Light Arms	TACP/Snake	234.7
None	2	Tanks		1230	SAM	CRC/Angel	256.8

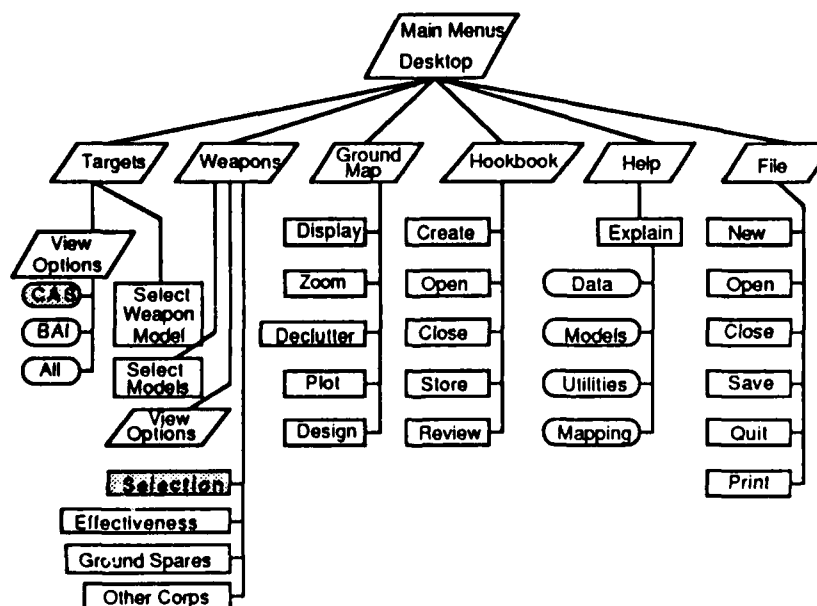
Recommended Aircraft/Weapons					
<u>Type</u>	<u>Ordnance/No</u>	<u>Fuzing</u>	<u>Pk</u>	<u>Weather Ceiling</u>	<u>Requirements Visibility</u>
A-10	MK-84/2	15msec	.84	5	2
A-10	MK-84/4	15msec	.89	5	2
A-7	MK-84/4	15msec	.72	5	3



AIRCRAFT/WEAPON SELECTION

This screen displays the sequence of actions in selecting an aircraft/weapon and displaying detailed information on the different alternatives. The user can highlight the desired aircraft/weapon with the mouse; a double click of the mouse will bring up a window with detailed data on the single alternative selected. However, if the choice of aircraft/weapons is not clear-cut at this point in the decision process, the user may decide to select the *Selection* option from the Weapons menu. Choosing this route will display further information on all of the recommended aircraft/weapons, so an examination of the trade-offs of using each of the different alternatives can be made.

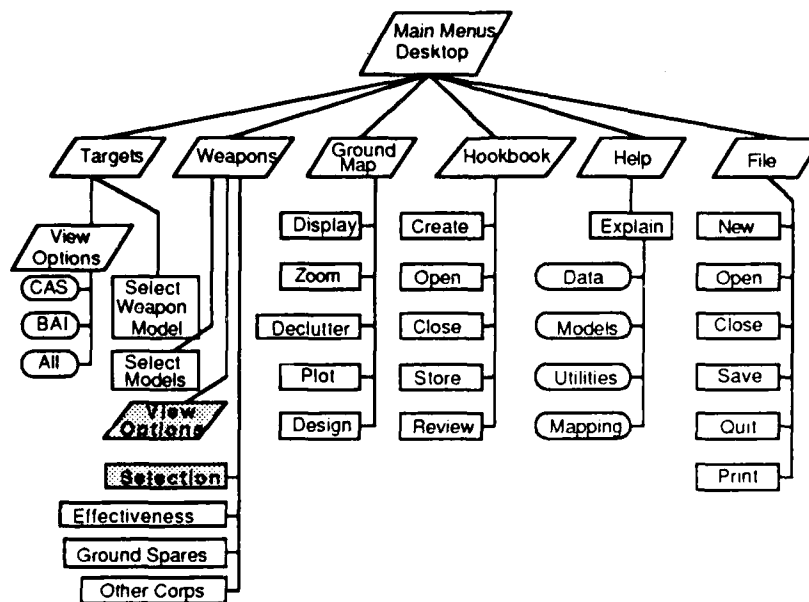
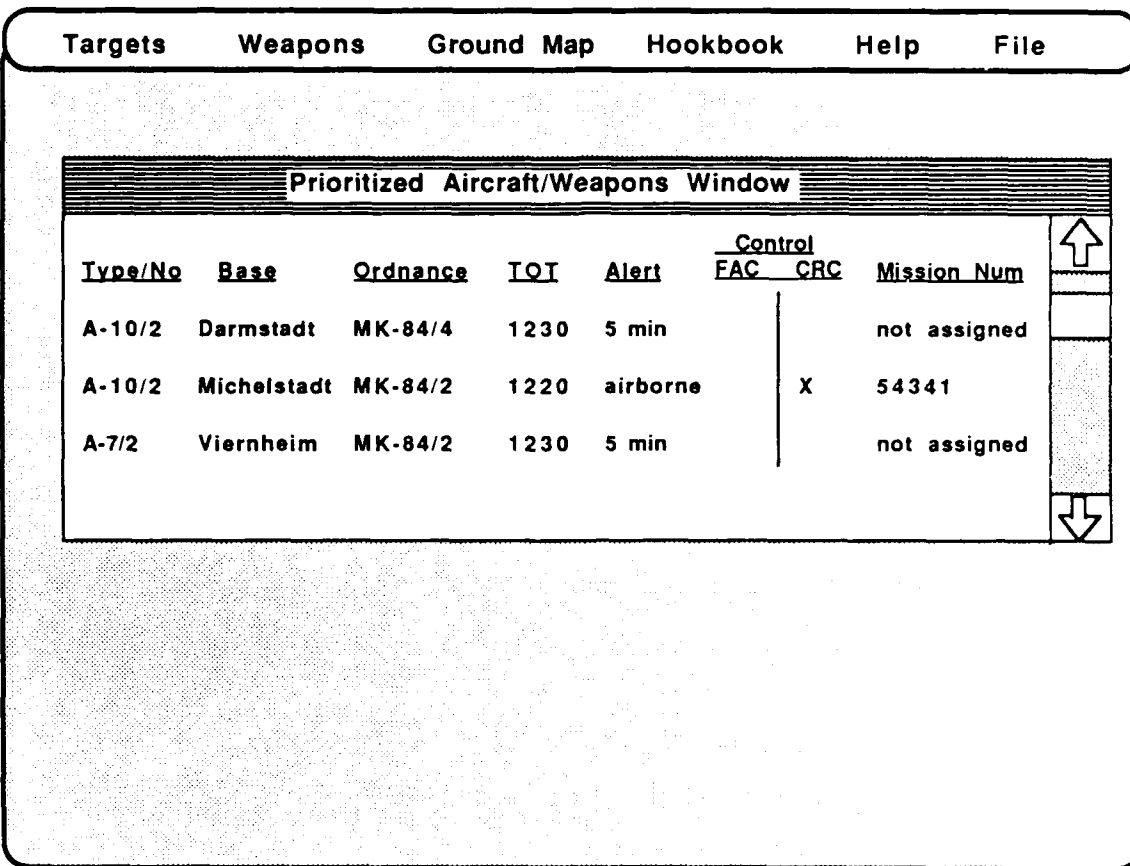
Targets		Weapons	Ground Map	Hookbook	Help	File
		View Database				
		Selection				
		Effectiveness				
		Ground Spares				
		Other Corps				
<u>Men Num</u>	<u>P</u>	Models	Targets Window			
54341		TOT	<u>TOT</u>	<u>Threat</u>	<u>Cont/Callsgn</u>	<u>Freq</u>
None		Loiter Time	1200	ZSU-23	FAC/Sniper	237.4
None		Threat	1215	Light Arms	TACP Snake	234.7
		Mission Plan	1230	SAM	CRC/Angel	256.8
Recommended Aircraft/Weapons						
<u>Type</u>	<u>Ordnance/No</u>	<u>Fuzing</u>	<u>Pk</u>	<u>Weather Ceiling</u>	<u>Requirements Visibility</u>	
A-10	MK-84/2	15msec	.84	5	2	
A-10	MK-84/4	15msec	.89	5	2	
A-7	MK-84/4	15msec	.72	5	3	



PRIORITIZED AIRCRAFT/WEAPONS WINDOW

Since the *Selection* option was chosen on the previous screen, all three of the aircraft/weapon alternatives are listed according to the ranking of their pK values. The decision maker may need to review this data to further differentiate between the alternatives presented. For example, the pKs given for the three alternatives are fairly close in value. Clearly, their pKs will not be the deciding factor. The target in question may be extremely mobile and there may be little allowable variation from the requested TOT. In this case, the alert status of the aircraft and actual TOT calculation may be necessary information for the decision.

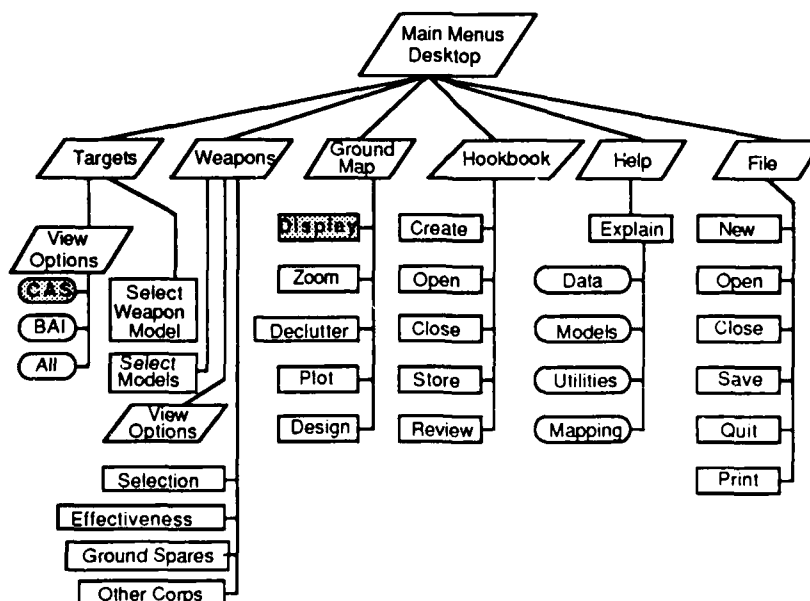
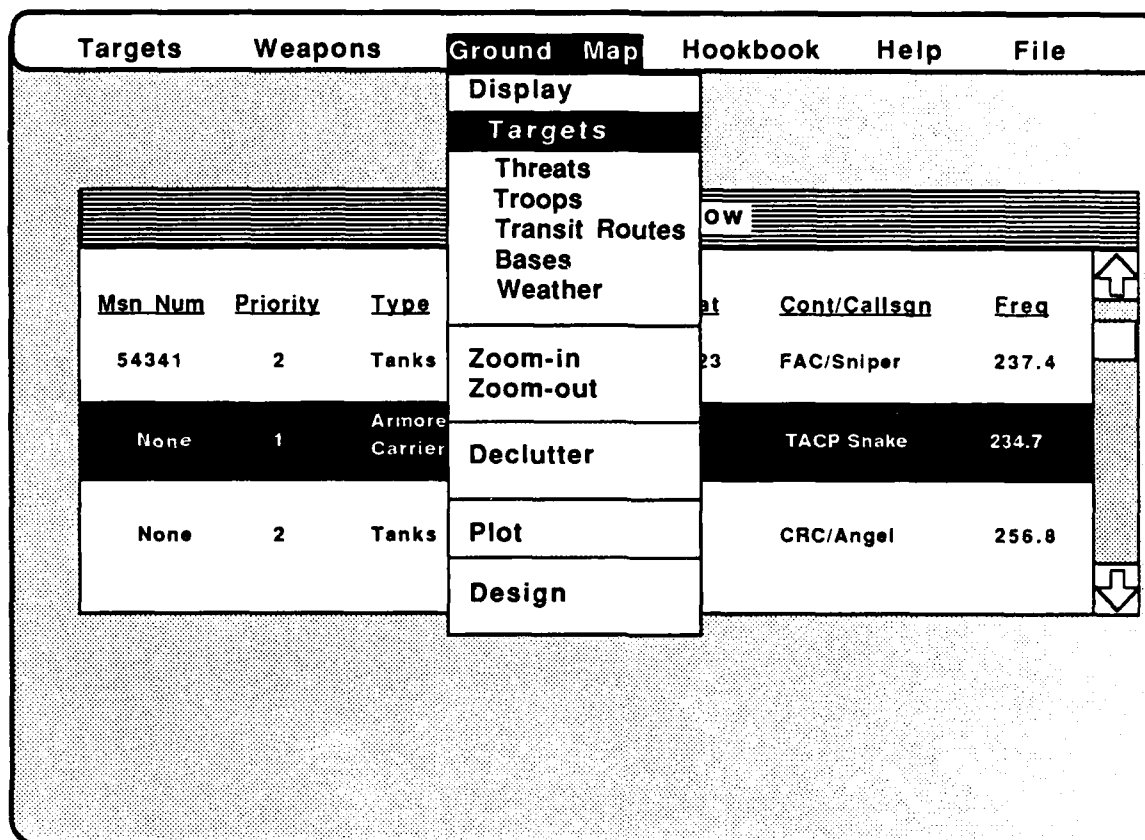
Within the window displayed, the *Base* field indicates the home base of the aircraft or the base it is currently operating from. This information is relevant for the user to know where he is selecting assets from, so that an imbalance in aircraft distribution is not unknowingly created. The *TOT* field is the result of another background system model that automatically calculates the actual TOT for each of the alternative aircraft. This field is important because the weapon with the highest pK value may be the last to be able to reach the target area. An airborne aircraft that is currently under control of the Control and Reporting Center (CRC) may be able to reach the target area nearest the requested TOT. The *Alert* field shows the time for the aircraft to take-off or indicates *airborne* if the aircraft is orbiting or headed to a previously assigned target area. The *Control* field shows the agency currently controlling the aircraft, if the aircraft is already airborne. The *Mission Number* field provides further confirmation of whether the aircraft has been previously assigned to a mission. With this information, the decision maker may be fully armed to proceed with final selection. However, he may want to review the alternatives in relation to other graphical data on the ground map display.



GROUND MAP

With the target selected and several alternative aircraft/weapons recommended, it may be necessary for the decisionmaker to move to the Ground Map display to view the same data in its graphical relationship and in relation to the bigger picture of the battle.

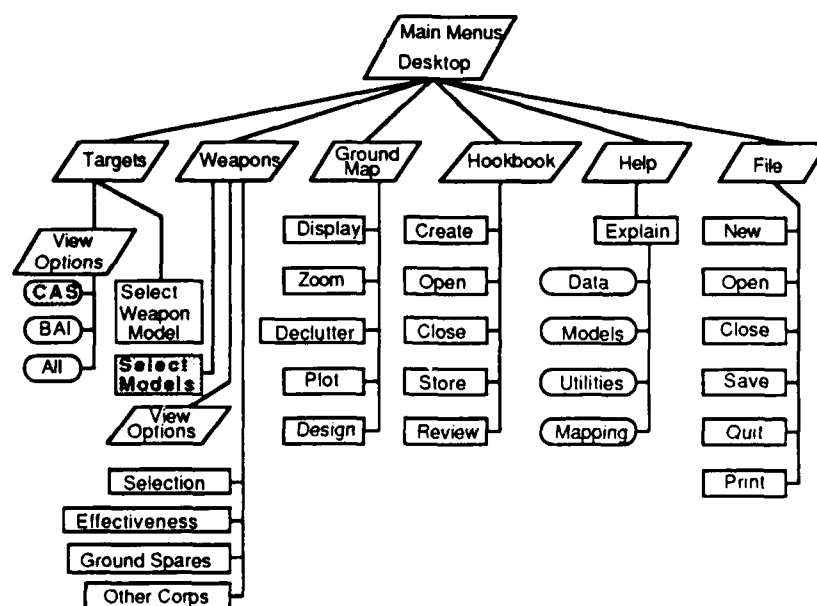
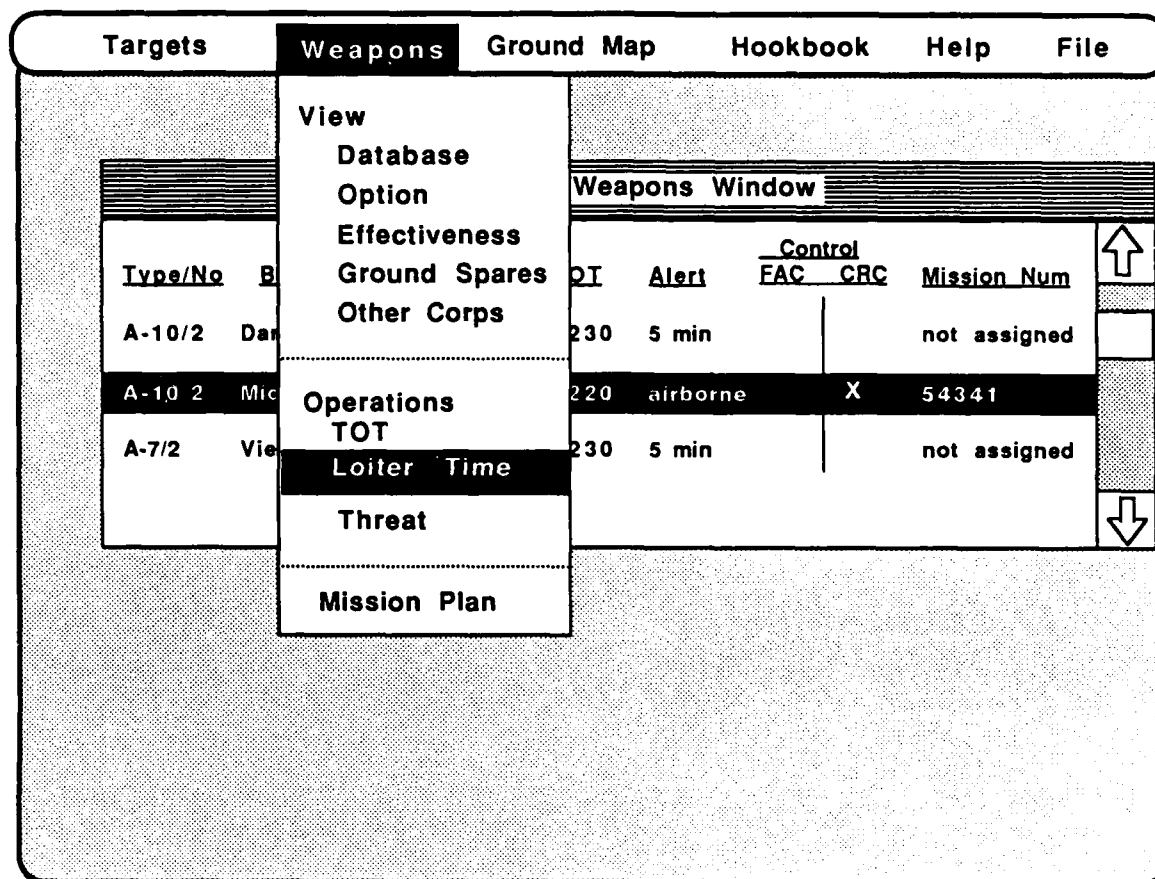
This is achieved by selecting those items to be displayed on the map from the Ground Map menu. The highest priority *Targets* at the current time may be displayed to show the (distance and terrain) relationship between those targets that may already have aircraft assigned and those that still do not have aircraft assigned. By viewing these targets in relation to one another and the big picture, it may quickly become apparent how each fit into the overall friendly initiatives, and perhaps which aircraft/weapon would be better suited to the particular target environment. By displaying *Threats* and corresponding lethality contours, the specific areas of vulnerability for aircraft would become vivid. It may be extremely difficult to get an aircraft from its current location to an alternate target with the threats in between. This would not be evident without viewing this selected graphical data. In highly congested airspace, in which low-level transit routes are required to move the aircraft to the battle area, it may become important to view these routes and the current location of the aircraft that would be required to fly the route if retasked. It may also be important to view aircraft orbit areas to determine the overall utility of retasking an aircraft already in one orbit area for another orbit or for a different target area.



LOITER TIME

This is another system tool or model to use in selecting an aircraft from different alternatives for retasking. It is particularly important to evaluate the feasibility of retasking airborne aircraft for an alternate mission. This model requires real time information on an aircraft's fuel level; this information is currently not available without talking directly to the pilot. However, with several of the future tactical information distribution systems, this real time data could very well become a reality. To use this model, the user must select a particular aircraft/weapon to be used against the highlighted target. Although the target window is hidden on this sample display, the target selected is still the original one displayed in the targets window. For an aircraft that will be moved to an alternate target area under retasking, the model will calculate the fuel needed to fly to the new target area and then figure loiter time from the remaining fuel. Although an aircraft may be able to reach an alternate target, it may be unsuitable for use because of a small amount of remaining loiter time.

It is generally believed that minimal, if any, aerial refueling capability will be available for CAS or BAI missions. With this limitation, the loiter time model could currently calculate remaining loiter time if an accurate aircraft take-off time was known for each mission.

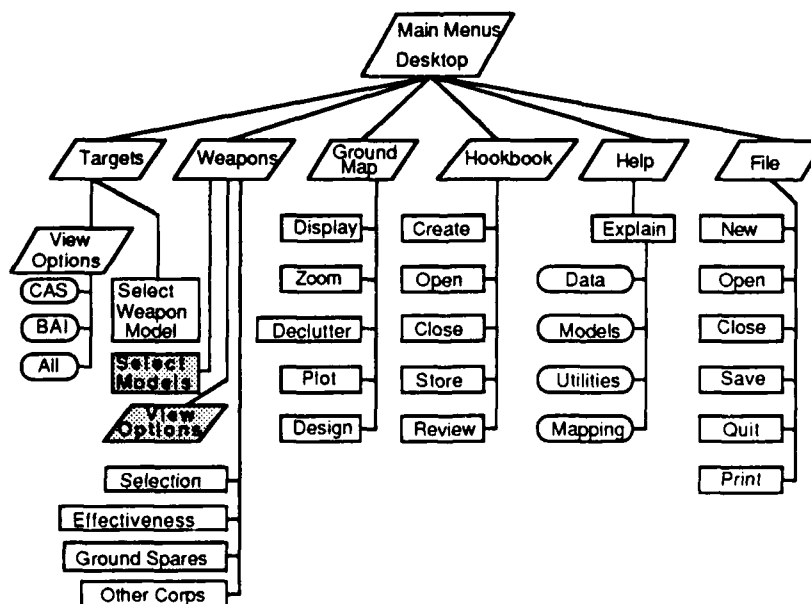


LOITER TIME WINDOW

The results of the loiter time model are displayed on this screen. The *Mission* field indicates the mission number that has previously been assigned to the aircraft that has already been tasked. If the loiter model were used with an untasked aircraft, the field would read *none assigned*. The *Type* field contains the type and quantity of aircraft that were used as input to the loiter time model. If there are multiple aircraft with different loiter times, the results will report the corresponding loiter time for each aircraft separately. The *Target* field holds the target that has been selected in the target window, even if the aircraft has already been assigned to a different target. In a case like this, the model will subtract the time needed to get to the new target from the loiter time so that the user will not have to make this calculation. The *Loiter Time* field contains the amount of time in minutes that the aircraft can remain over the target area before it must begin its egress to a recovery base. The last field, *Holding Area*, is pertinent for CAS missions. These holding areas are temporary orbit areas where the aircraft may wait for a short period of time before ingress to the target area and their final contact point in the battle area. Holding areas may be another piece of data that are particularly suited for graphical representation on the map display. It may be beneficial for a decision maker considering retasking to see an aircraft's current holding area in relation to a new target area and its corresponding new holding area.

Targets Weapons Ground Map Help File Hookbook							
Prioritized Aircraft/Weapons Window							
Type/No	Base	Ordnance	TOT	Alert/ Loiter	Control FAC CRC	Mission Num	↑
A-10/2	Darmstadt	MK-84/4	1230	5 min		not assigned	↓
A-10 2	Michelstadt	MK-84 2	1220	20 min	X	54341	↓
A-7/2	Viernheim	MK-84/4	1230	5 min		not assigned	↓

Loiter Time Window					
Mission	Type	Target	Loiter time	Holding Area	↑
54341	A-10/2	Tanks	15 min	XX-23	↓

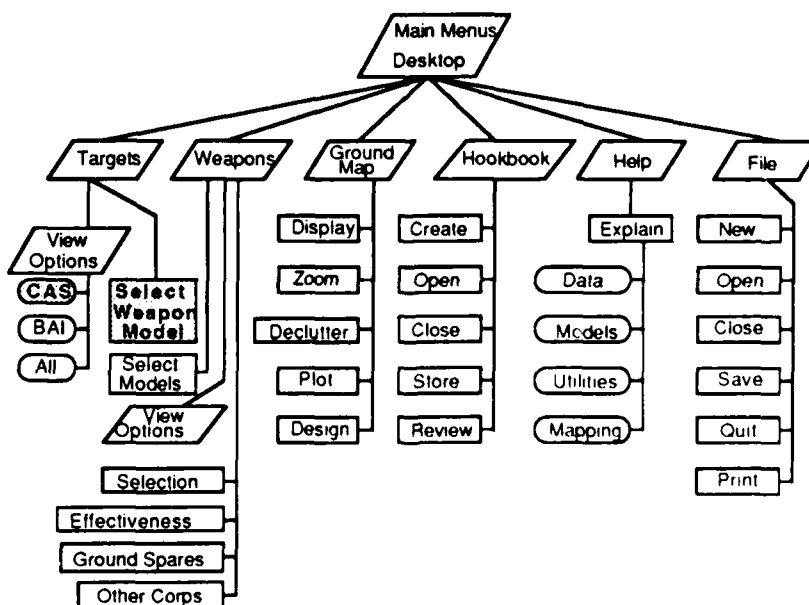


WEAPON MODEL WITH WEAPON CONSTRAINT

This screen representation does not follow in sequence from the preceeding ones. Instead, it presents the questions that the system would ask the user in order to run the weapon model under a weapon constrained scenario. When the user earlier entered the system, he was asked to indicate if there was a weapon constraint with the current mission retasking or replanning. If no weapon constraint is indicated at this initial point, the system will only consider weapons that are organic to the Corps associated with the ASOC doing the retasking. However, if the weapon constraint is selected, the system will consider aircraft/weapons from adjacent Corps that would be appropriate for possible retasking.

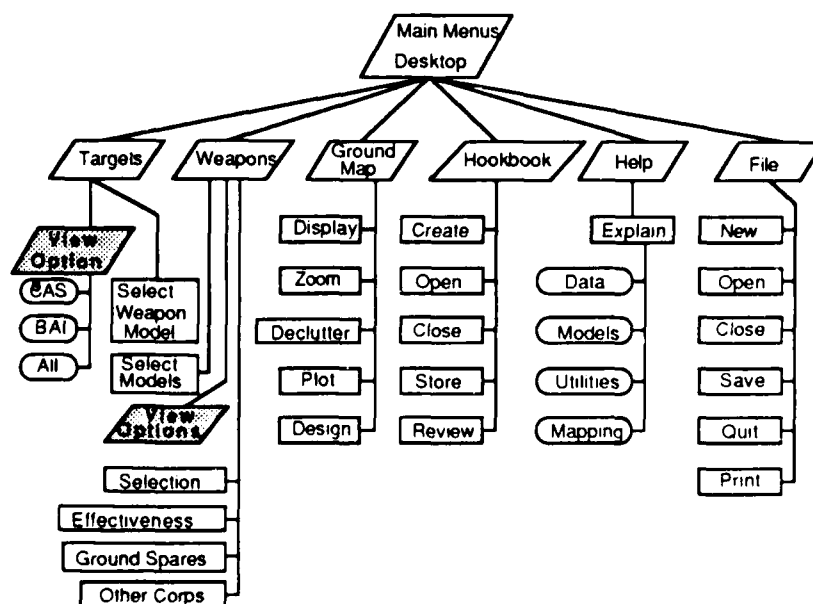
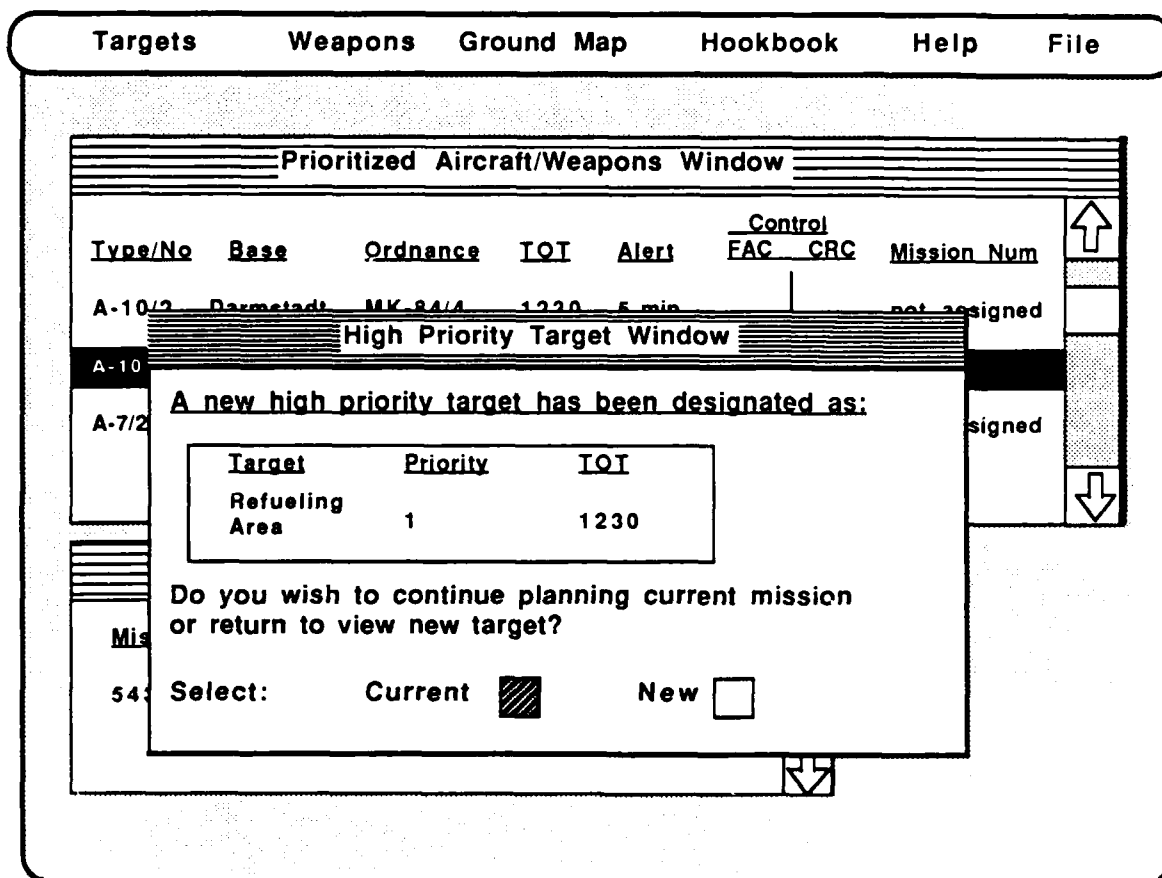
This screen display shows that the system repeats the weapon constraint question, in case the situation has changed since the retasking system was entered. The user is also asked to select whether airborne alert, ground alert, or a combination of both should be considered in running the weapon model. The third selection that the user must make is whether both CAS and BAI type aircraft/weapons should be considered in running the weapons model. Under a scenario in which the requirement for CAS missions is suddenly and dramatically increased, it may be necessary to consider BAI assets as well as CAS for possible retasking.

Targets	Weapons	Ground Map	Hookbook	Help	File																								
View CAS Immediate Current Historical Preplanned Current Historical View BAI Immediate Current Historical Preplanned Current Historical Recommend Weapon View All	CAS Targets Window <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th>Type</th> <th>Loc</th> <th>TOI</th> <th>Threat</th> <th>Cont/Callson</th> <th>Freq</th> </tr> </thead> <tbody> <tr> <td>Tanks</td> <td></td> <td>1200</td> <td>ZSU-23</td> <td>FAC/Sniper</td> <td>237.4</td> </tr> <tr> <td>Armored Carrier</td> <td></td> <td>1215</td> <td>Light Arms</td> <td>TACP Snake</td> <td>234.7</td> </tr> <tr> <td>Tanks</td> <td></td> <td>1230</td> <td>SAM</td> <td>CRC/Angel</td> <td>256.8</td> </tr> </tbody> </table> Do you wish to consider both airborne and ground assets? Select: Air Only ☐ Grnd Only ☐ Both ☒ Select: Weapon Constrained ☒ Unconstrained ☐					Type	Loc	TOI	Threat	Cont/Callson	Freq	Tanks		1200	ZSU-23	FAC/Sniper	237.4	Armored Carrier		1215	Light Arms	TACP Snake	234.7	Tanks		1230	SAM	CRC/Angel	256.8
Type	Loc	TOI	Threat	Cont/Callson	Freq																								
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Armored Carrier		1215	Light Arms	TACP Snake	234.7																								
Tanks		1230	SAM	CRC/Angel	256.8																								



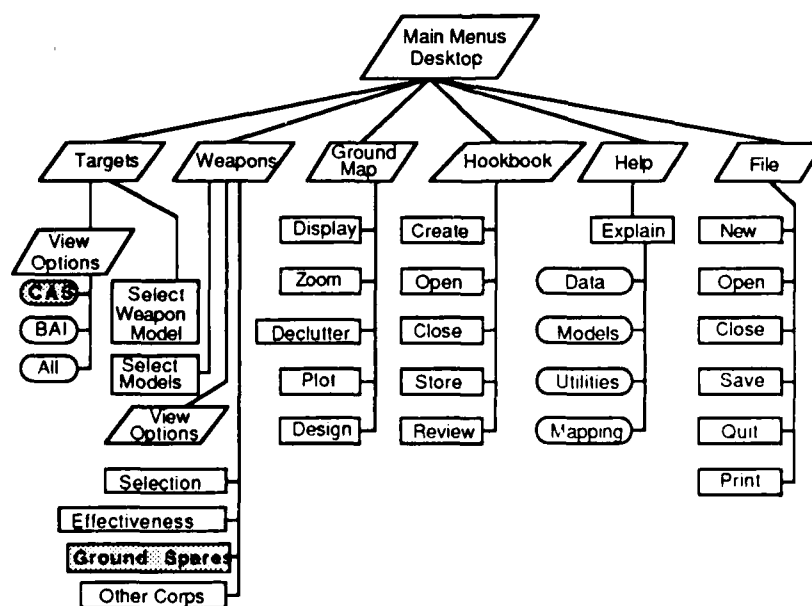
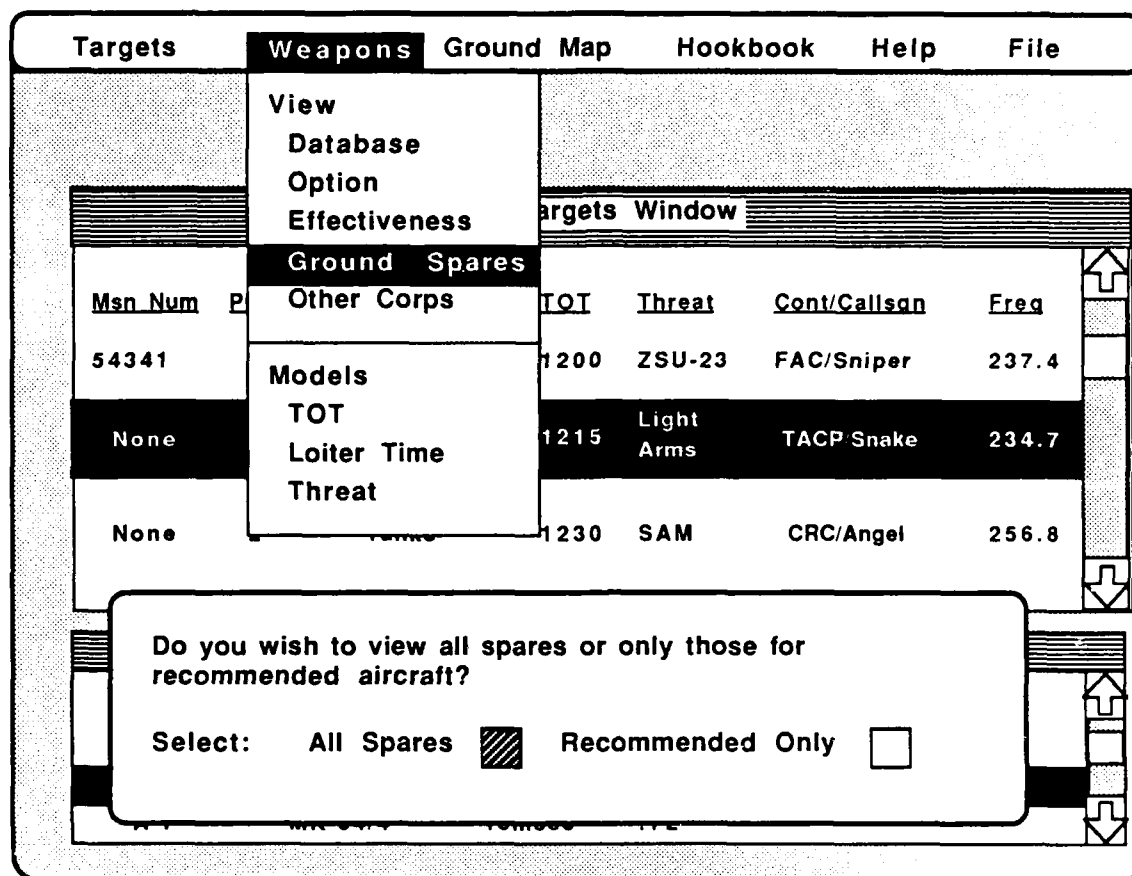
HIGH PRIORITY TARGET WINDOW

This window is presented to the user automatically without any input from him. The window alerts the user to the recent addition of another high priority target to the database's list of targets. The user can quickly see the designated Army priority and requested TOT of the new target in this abbreviated display. He has the option of continuing with his current mission retasking or can select *new* , which presents the full targets window with the corresponding information on the new target. If the user selects to continue his current planning, the window will disappear; however, it reappears in a short time period if the system detects that the target has not been selected for planning a mission against it. This feature prevents the decision maker from getting so engrossed in a current mission plan that he lets incoming high priority requests pile up unattended.



GROUND SPARES

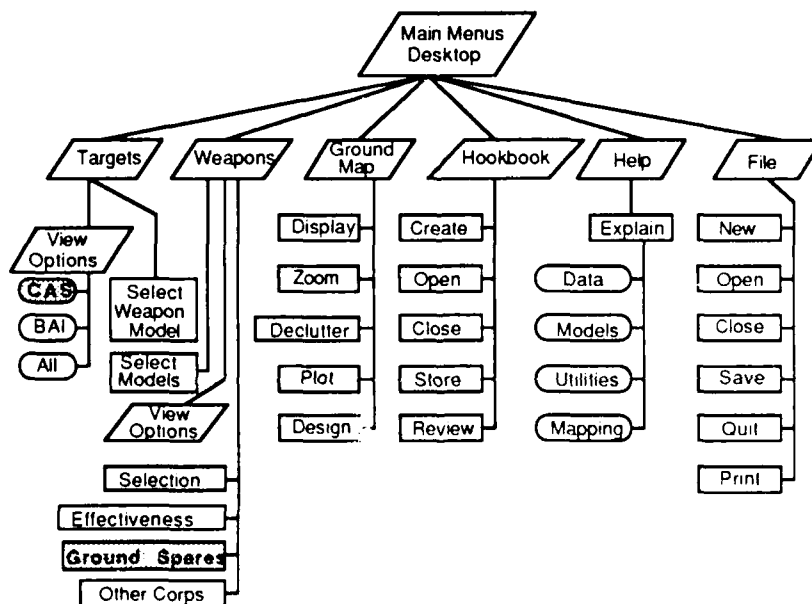
This display would appear when the user selected the *Ground Spares* option from the Weapons menu. Although the likelihood of examining ground spares for CAS missions is small, it may be necessary when time constraints are not a major factor and the target requires a unique aircraft/weapon configuration. A particular target must be highlighted for the system to search the database and present the available ordnance that could be reloaded on the aircraft. If a recommended aircraft has already been selected in the Recommended Aircraft/Weapon Window, then the system will ask whether the user wishes to view all spare ordnance appropriate against the target, or only that spare ordnance that is available to be used with the selected aircraft. The user may have already decided that a particular aircraft must be used, and only wants to see whether other ordnance is available to be loaded on it. On the other hand, the choice of a particular aircraft may be secondary; the objective might be to find the best ordnance available to be loaded on any available aircraft of a certain type. In other words, the type of aircraft/weapon combination may be critical, but the location of the aircraft and timing of the aircraft over the target may not be as critical a factor.



SPARE WEAPONS WINDOW

This window displays the results of the *Ground Spares* menu selection that was previously made. The *Target* field repeats the type of target that was selected in the Targets Window. The *Base* field shows where the indicated weapons or ordnance are located. The last six subfields of the *Weapons* field are the types of weapons that are effective against the target. An *X* checked under a certain column indicates that at least one load of spares of that type of weapon is available at that base. Only spare ordnance that can be used on the available CAS or BAI aircraft is displayed. If there remains spare ordnance at a base where there are no longer any available aircraft, the ordnance will be displayed. This will allow the user to consider the possibility of reloading aircraft from other locations with the spare ordnance at a certain base, or recommending recovery of aircraft at bases where the ordnance level is most favorable. The spare ordnance window would also assist the decision maker in considering the possible rerolling of CAS-configured aircraft to BAI missions, or vice versa.

Targets	Weapons	Ground Map	Hookbook	Help	File		
CAS Targets Window							
<u>Msn Num</u>	<u>Priority</u>	<u>Type</u>	<u>Loc</u>	<u>IQI</u>	<u>Threat</u>	<u>Cont/Callson</u>	<u>Freq</u>
54341	2	Tanks		1200	ZSU-23	FAC/Sniper	237.4
None	1	Armored Carrier		1215	Light Arms	TACP Snake	234.7
None	2	Tanks		1230	SAM	CRC/Angel	256.8
Spare Weapons Window							
<u>Target</u>	<u>Base</u>	<u>Mk82/Mk84</u>	<u>Mk20</u>	<u>Weapons</u>			
				<u>M247</u>	<u>GAU-8</u>	<u>GBU-8</u>	<u>AGM-65</u>
Armored Carrier	Darmstadt	X	X			X	
	Viernheim		X	X			X



Appendix B : Hookbook

Many of the ideas for enhancing the retasking DSS were triggered by working on the initial storyboard design; others were contributed by decisionmakers and thesis advisors commenting on the requirements for the initial design. The power of the hookbook is that the decisionmaker is not constrained by technology, or other external influences when refining and documenting his needs through the hookbook entries. Some method for the user to maintain a hookbook, preferably automated as described in Chapter V, should be supported as soon as possible. Many of the detailed DSS display and operation refinements can be documented through this technique. On the other hand, the hookbook ideas that are presented below are more general in nature, and would require considerable more preliminary design and implementation effort. They have been prioritized by this researcher based on criteria for more carefully integrating the spectrum of battlefield initiatives that are often linked to the ASOC retasking decisions:

Commander's Priorities. The DSS should support retasking and rapid replanning based on a prioritization of missions that correspond closely with the Commander's guidance and overall priority of targets for a particular timeframe. The requirement here involves the FDO being able to see the "bigger picture" through use of the retasking DSS. The system scanning of the database and later the knowledge-base must be able to incorporate the Commander's priorities into the criteria it uses. The options presented to the decisionmaker must meet this criteria. A knowledge-based system

evaluation of the final option that the decisionmaker chooses could also check for alignment with the overall priorities. It is believed that use of the geographic display would be very important for support in this area.

Corps to Corps Integration. The DSS should support the integrating of potential targets that may be entering Corps area from another Corps, or exiting the Corps area to another Corps. This requirement also involves presenting the "bigger picture" to the decisionmaker in a manner that is not overwhelming for him. Much of the information for this enhancement will be dependent on the availability and reliability of intelligence sensors. The DSS must incorporate this information into its knowledge-base, and use it as a filter when presenting views of the data and viable options to the decisionmaker.

Integrate With Fire and Maneuver. The DSS should be able to support retasking and rapid replanning through detailed coordination and integration with the fire and maneuver plans of friendly surface forces. Satisfying this requirement depends on interfacing the retasking DSS with the Army integrated Sigma Star system; the system that supposedly will support decisionmaking and C² with information from the five major information sources on the battlefield. It also depends on the ability of the DSS's knowledge base to incorporate the surface forces' plans and use them as criteria in presenting options for the ASOC decisionmaker. During the crisis retasking decisions, the FDO must be able to quickly assess the potential role of the surface forces in the new plan that is being drawn up. It is important to assess the capabilities and support that the surface forces already in place have; sending an aircraft in may be extremely wasteful, and worst yet, it could place the crew in a high threat environment unnecessarily.

Forecasting. The DSS should be able to support a certain degree of forecasting of both anticipated CAS and BAI mission requirements in a certain scenario; it should also offer a plan for the general mission tasking over a period of time. Not all of the FDO's retasking will be immediate in nature. Occasionally, there will be time, because of a longer range target or special intelligence information, to evaluate the retasking with a fully integrated weapon database. As weapon delivery platforms become more multi-role capable, it is essential that they be closely integrated in the DSS. The DSS must also possess the capability to predict where and how the weapons can best be used; in an extremely weapon constrained scenario it will be essential for the FDO to have some reliable tools through the DSS to predict the most effective battlefield points to use the limited weapons on.

Airborne Operations. The DSS should be able to support specialized retasking and immediate planning in support of joint airborne operations; the supporting ASOC in this case may be airborne. The advantage of the ASOC in an airborne position would be access to real-time battlefield information and positive and direct C². The ability of the DSS to rapidly present options to the FDO in a quickly changing scenario would be crucial. In this role, the DSS may require an air situation display to support the direct C².

Integrate With SOF. The DSS should be able to support the consideration of Special Operating Forces (SOF) that may be available to contribute to a retasked mission. This capability meshes closely with the other DSS capabilities that use a fully integrated data/knowledge-base to present options to the FDO. In certain scenarios, or certain battlefield areas, the

combined efforts of CAS/BAI assets and SOF may be required to achieve the desired results. The DSS should be able to assess when this situation exists and tailor the presentation of information and options for the FDO.

These prioritized hookbook ideas should be further examined and refined by the TAC referee and the ASOC decisionmakers as the retasking DSS evolves.

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