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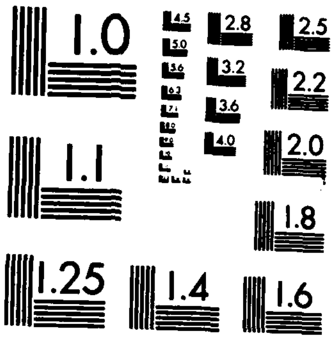

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DESIGN OF A DECISION SUPPORT SYSTEM FOR THE DYNAMIC RETASKING OF AIR INTERDICTION ASSETS

THESIS

James A. Schoeck, B.S., M.B.A.
Major, USAF

AFIT/ENS/GST/87M-15

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This study investigated the design of a decision support system (DSS) for the dynamic retasking of air interdiction assets. The study focused on using a decision support methodology to identify system requirements for using the vast amount of information presently available to the Allied Tactical Operations Centers in NATO for the command and control of air interdiction assets. Encompassing an overall framework of concept mapping and feature charts, this study used the Representations, Operations, Memory Aids, and Control Mechanisms approach developed by Sprague and Carlson to design the DSS. By using the DSS design theories, this study produced a statement of requirements for the command and control functions and processes of future aircraft weapon systems and intelligence capabilities. The use of DSS to attempt to solve large, difficult to define problems involving complex internal interactions in rapidly changing environments is one of the major advantages of using the DSS methodology. Defining system requirements cheaply and quickly before weapon systems begin to drive doctrinal procedures and before technology dictates where the tactical advantage should be exploited is yet another important reason for using this DSS methodology.

Abstract

This study investigated the design of a decision support system (DSS) for the dynamic retasking of air interdiction assets. The study focused on using a decision support methodology to identify system requirements for using the vast amount of information presently available to the Allied Tactical Operations Centers in NATO for the command and control of air interdiction assets. Encompassing an overall framework of concept mapping and feature charts, this study used the Representations, Operations, Memory Aids, and Control Mechanisms approach developed by Sprague and Carlson to design the DSS. By using the DSS design theories, this study produced a statement of requirements for the command and control functions and processes of future aircraft weapon systems and intelligence capabilities. The use of DSS to attempt to solve large, difficult to define problems involving complex internal interactions in rapidly changing environments is one of the major advantages of using the DSS methodology. Defining system requirements cheaply and quickly before weapon systems begin to drive doctrinal procedures and before technology dictates where the tactical advantage should be exploited is yet another important reason for using this DSS methodology.

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DESIGN OF A DECISION SUPPORT SYSTEM FOR THE DYNAMIC RETASKING OF AIR INTERDICTION 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 Operations Research

James A. Schoeck, B.S., M.B.A.

Major, USAF

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Preface

I wish to specifically thank the following people and organizations for their support, comments and suggestions:

Mr. Mike Young -- AFHRL
Lt. Col. Fred Wilson -- 712 ASOC
Ms. Donna Vargas -- WPC

I also wish to thank my advisor, Lt. Col. John R. Valusek, who gave me a balance of freedom and guidance which allowed me to develop this thesis. His patience with my efforts proved effective and yet he knew at which times to step hard on me, especially when motivation was at an all time low.

My classmates were always willing to help and deserve my thanks. They helped me through the hard times and insured that I kept the proper perspectives.

Finally, everlasting thanks to my wife Sue, my daughters Kristie and Jenny, and my son Mike, who as a team can't be matched. They gave me space when I needed it, and encouragement when I was discouraged.

James A. Schoeck

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DESIGN OF A DECISION SUPPORT SYSTEM FOR THE DYNAMIC RETASKING OF AIR INTERDICTION ASSETS

I. Introduction

Air Interdiction

The Air Force mission of Air Interdiction (AI) is:

> .... to delay, disrupt, divert, or destroy an enemy's military potential before it can be brought to bear effectively against friendly forces. Air interdiction attacks are usually executed against enemy surface forces, movement networks (including lines of communication), command, control, and communications networks, and combat supplies.(1:3-3)

The targets are often relocatable or highly mobile, and thus the mission is normally executed as part of a systematic and persistent campaign to limit the enemy's ability to maneuver forces, while forcing the enemy into high rates of consumption. Exact timing by the interdiction assets can provide friendly ground forces with the opportunity to seize the initiative (1:3-4). Many Air Force organizations have recently focused their attention on the command and control of air interdiction assets. One of these organizations is the Warrior Preparation Center.

USAFE Warrior Preparation Center

The Warrior Preparation Center (WPC) is located at Einsiedlerhof, West Germany, near Ramstein AB and is a joint USAFE/USAREUR organization for providing European battle commanders with the opportunities to gain experience through gaming, in force level employment within the European command, control, and communications environment (15:1-1). Simulation wargames are conducted in command, control, and communications to train the commanders and to aid in the development of new tactics. A less obvious benefit is that deficiencies in the current friendly force command and control structure can be explored. One such identified deficiency was the inability to integrate the knowledge from several Allied Tactical Air Force (ATAF) bases while preserving the knowledge lost when the ATAF battle staff experiences personnel changes (46:3).

A specific problem addressed by the WPC involves the vast amount of information which is presently available to the decision makers at the Allied Tactical Operations Center (ATOC) at Sembach AB, West Germany. A requirement exists to describe the process by which air interdiction (AI) resources are assigned against second echelon targets to produce maximum delay and destruction of those same reinforcements.

During an address to the Air Force Institute of Technology (AFIT), MGen Breckner, then commander of the ATOC at Sembach AB, emphasized the deluge of information pouring into his command center. He requested assistance in the interpretation of this glut of data in order to find out ".... what's going on out there?" He needed the information in an easy to grasp, go/no-go format using graphical representations which could summarize the information on a need to know basis. The WPC problem statement for tasking AI assets likewise identified the need for decision aids (6).

Problem Description

One scenario developed by the WPC includes a second echelon enemy force moving forward to reinforce the first echelon. Intelligence information is available to the ATAF commander who must decide how to best allocate and task his air interdiction assets to produce maximum delay and destruction of the second echelon forces. A fighter duty officer, "the FIDO", is the scheduling officer at the ATOC tasked with allocating a given set of aircraft against a set of prioritized second echelon targets. His task is to match the best aircraft with the best available munition against the most significant target array and at the right time to create the greatest impact on the enemy's ability to reinforce the first echelon forces.

Since the enemy is highly unpredictable, the planned schedule rarely goes exactly as devised. New information is pouring into the ATOC, information which often requires changes or modifications to the AI campaign to maintain an advantage. Questions arise such as:

1) Should a set of follow-up missions be held in reserve?

2) When and where should they enter the battle?

3) Should the FIDO redirect an airborne aircraft to a new, higher priority target?

4) Should different munitions be loaded on alert aircraft because weather at the target area has forced different tactical deliveries?

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.

During the development of the AI campaign, which is a portion of the overall air tasking order (ATO), aircraft, weapons, and targets must be matched. If the FIDO departs his assignment, his replacement may not have the experience necessary to estimate the resource allocation. Additionally, nine out of ten of the fighter duty officer positions during a major conflict will be manned by augmentees with little or no duty officer experience (50). Our warfighting effort then may not meet the expectations of our commanders.

In recent years, we have relied on technology to maintain an advantage over our adversaries. As that reliance grows, it becomes more important not to waste that advantage by making poor decisions. Technological advancements in our decision making processes and the command and control structure are just as, if not more important than improving the technological aspects of the executable weapon systems, the instruments for which we make those decisions.

The Air Tasking Order

The Air Tasking Order is produced daily by the ATOC. A portion of the ATO directs the actions of the offensive units assigned to the ATOC for a twenty-four hour period. The ATOC uses two methods in performing their responsibility of directly tasking the offensive distribution of the operational air assets, preplanned and immediate.

Preplanned tasking is accomplished by means of the ATO. It is essentially a list of missions to be flown by each wing assigned to the ATOC during a twenty-four hour period. Air tasking messages (ATM) are used by the ATOC to modify the ATO preplanned sorties. The ATMs are used for all new requests which may come up during that twenty-four hour period, resulting in the immediate taskings.

The Eifel-1 System

A computerized system is in place in the 4 ATAF region in central Europe which is used to coordinate the battle plan for the air forces assigned to the region. The system, called the Eifel-1 system, is used by the ATOC, the Wing Operation Centers (WOCs), and the Air Support Operation Centers (ASOCs). The system contains an automated data processing capability for the ATOC Sembach to exercise command and control over assigned air assets. It consists of a main computer facility at ATOC Sembach with local terminals, remote terminals, and computer-to-computer connectivity. The system also consists of files and subroutines which permit the development and the distribution of the preplanned twenty-four hour AI campaign. It also has the ability to handle immediate air tasking requests (ATRs) generated at the ASOCs and automatically forwarded to the ATOC. The ATOC personnel attempt to match the ATR with available assets and then forward an air tasking message to the WOCs for action. In some urgent cases or when the system is overloaded, telephone or radio nets are used with follow-up messages to the command centers. The ATM is the vehicle by which the ATOC tasks a wing to fly an immediate mission or change a previously preplanned mission. The ATO is used to communicate the preplanned twenty-four hour campaign (9).

The Eifel-1 System provides routines which permit the ASOC and the ATOC to efficiently request and task missions, and for the WOC to receive a timely, concise and complete ATM. A typical battlefield air interdiction mission air tasking message contains information similar to that listed in Table 1.1. A sample of an air tasking message is presented in Figure 1.1.

Table 1.1 Air Tasking Message Components (9:6-15)

ATOC:	Tasking ATOC	REQ:	Request number
AGNCY:	Requesting agency	TYMIS:	Type mission
EX:	Exercise name	PRIO:	Priority
TGTINF:	Target information	TOT:	Time on Target
NLT:	Not later than TOT	DRES:	Desired results
PFF:	Posit of friendlies	CONDET:	Control details
WING:	Tasked wing	TYPAC:	Type aircraft
TSOR:	Tasked sorties	TCL:	Type conventional load
LEMIS:	Leading mission	COMIS:	Co-mission number
SPECAT:	Special instructions	TOBAS:	Takeoff base
LABAS:	Landing base	INIAT:	Tasker initials
DTGAT:	Tasking date/time	INIWG:	Wing oper initials

The files within the system allow the ASOCs to communicate the needs of the ground forces, allow the ATOCs to coordinate the air battle plan in support of those ground forces, and allow the WOCs to execute the tasked air interdiction orders. Additionally, the system allows all agencies the opportunity to follow what is happening to any of the tasked missions (9).

```
+-------------------------------------------------------------------------+
:  ATOC:ATMAA       REQ:3TM451         AGCY:INL      TYMIS :BAI    :
:  EX :      /      PRIO: 1                                TGTINF:  :
:  ARMOR STAGING AREA/LF 434 672                                    :
:                                                                   :
:  TOT:12221600Z   NLT:122216030Z   DRES: NE          PFF:          :
:                                                                   :
:  CONTDET:                                                         :
:                                                                   :
:  WING:081  TYPAC:A10    TSOR:04/        TCL :BA      /            :
:  LEMIS:           COMIS:     *           *      *                 :
:  SPECAT:                                                          :
:  TBAS:EDAS  LBAS:EDAS  INIAT:TJ DTGAT:12220830Z  INIWG:GW:
+-------------------------------------------------------------------------+
```

Figure 1.1 Air Tasking Message Format (9:6-14)

The sequence of messages which are typically used when an immediate ATR is submitted by the ASOC to the ATOC is depicted in Figure 1.2. Two feasibility checks are conducted, one by the ATOC to determine if the mission can or cannot be flown based on the availability of the assets for the specific role, and one by the WOC to insure that time requirements and specific mission loads can be satisfied.

The important point which must be considered when examining the Eifel-1 system is that the system contains no programs or models which aid in the tasking of a certain aircraft with a particular ordnance load against a specific target. The Eifel-1 System, as such, is a data base and a data transfer system which allows the command centers to communicate the air tasking order and immediate air tasking messages in a standard format. The feasibility checks at each center are performed by people outside of the Eifel-1 system. These feasibility checks are heavily dependent on the FIDOs and the ATOC personnel using their previous experience to make judgments and choices regarding the allocation of resources.

```
+------+               +----------+               +----------+
:      :Submits Request:          :               :          :
: ASOC :-------------->:   ATOC   :               :   WOC    :
:      :Acknowledge Req:          :               :          :
:      :<--------------:          :               :          :
:      :Refuses Request:FEAS.CHECK:Tasks Wing ATM :          :
:      :<--------------: NO    YES:-------------->:          :
:      :Accepts Request:       :  :Acknowledge ATM:          :
:      :<--------------: ------+  :<--------------:          :
:      :               :          :Refuses Tasking:FEAS.CHECK:
:      :<--------------: -------- :<--------------:  NO  YES :
:      :               :          :Accepts Tasking:        : :
:      :<--------------: -------- :<--------------: ------+  :
:      :               :          :               :          :
+------+               +----------+               +----------+
```

Figure 1.2 ATM/ATR Data Flow Pattern (9:7-22)

Research Problem

Fighter duty officers currently have no means of adequately and quickly manipulating a vast data base to execute an accurate, timely, effective and adaptable air interdiction campaign. Although much of the needed information is available and standard formats exist for the development of the game plan within the Eifel-1 system, a problem arises when time becomes a factor and decisions external to the Eifel-1 System are required of an inexperienced, augmentee FIDO. As judicious as the FIDO may be, time does not allow him the luxury of scanning and precisely interpreting large amounts of near-real-time and real-time information.

There are two methods used by the ATOC to directly task the offensive air assets: immediate and preplanned taskings. Both offer certain advantages and disadvantages. The advantage of preplanning is that it permits a careful optimization process to take place. Its disadvantage is that it cannot be as timely or as flexible in reacting to the tactical situation. The advantage of immediate tasking lies in the very nature of the term. Although it does not permit as much planning time, it offers tremendous advantages because it provides the quick reaction and increased ability to flex with the tactical situation.

Because of the two types of tasking, immediate and preplanned, there exist two missions which can respond to the types of targets associated with the missions. Straight AI missions are targeted against well-defined, immobile structures or target arrays which require the planner time to coordinate his options. On the other hand, battlefield air interdiction (BAI) missions are often targeted against highly mobile, fluid targets whose priority may change based upon the changing tactical situation and their projected influence on the ground battle. BAI missions are those air interdiction missions assigned to attack targets having a possible near term effect on the ground battle and these targets are typically situated close to the friendly ground forces on the battlefield.

Currently, the air interdiction missions are included in the twenty-four hour ATO. They, of course, are subject to change by the FIDO during their specific period of vulnerability through the immediate tasking network, but because of the nature of their targets, more planning time is required prior to execution. The BAI missions operate both in a preplanned mode similar to deep air interdiction mission taskings, but these missions also resemble close air support (CAS) in the respect that they execute in an immediate tasking role. In either situation, BAI missions require joint level coordination during the planning phase, and unlike CAS, once the BAI mission is tasked it is controlled by the air commander as part of the overall air interdiction campaign requiring little or no in-flight coordination with the ground commander (1:3-5).

The BAI missions are not always included in the ATO and grouped with other preplanned AI sorties. Instead, detailed preplanning is conducted against the "deep" interdiction targets, which may include second echelon forces and equipment. These particular missions are reflected in the AI portion of the daily ATO. Other assets in the AI apportionment are withheld for use in the subsidiary BAI campaign. These other assets are tasked on an "as required" basis through the immediate tasking requests submitted by the ASOCs (48). Frequently, however, the AI portion of the ATO will include assets which maintain a ground alert status in the BAI role.

The criticality of the mission is not forgiving. Mistakes are possible when either tasking preplanned or immediate response to a given situation. These mistakes may result in the loss of aircraft, crews, or the very initiative which the commander attempts to establish with air power. Sometimes there is an unwillingness or inability on the part of the aircrew to deviate from the original game plan. The unwillingness occurs because they want to do the job right and want to have the time to plan the flight and then fly that plan. The resistance to change the plan is natural when the structure is not in place to give them the needed equipment to perform repeated changes to their missions effectively and quickly (course changes without the proper maps and charts versus having moving map displays and inertial navigation systems). The dynamics of a battle will not allow the time to plan to the "gnats ..." Aircrews must be willing and able to accept last minute changes, enroute diverts, delays and less-than-ideal, hasty planning to insure the larger sum of their individual sorties create a greater influence on the overall battle. Flexibility has always been the key to airpower, most largely exhibited by the flyers themselves. The command and control structure must also develop that flexible attitude.

In the case of ATO development, attention to detail by the decision maker during the feasibility checks is necessary to prevent scheduling errors. For example, the FIDO must insure that the aircraft has the range to fly the mission corridor and perform the attack on the selected target at his designated time over target (TOT). To launch an ineffective sortie is actually worse than not launching one at all, because a sortie launched with no possibility of performing the mission may actually return a negative gain: the commander may lose the aircraft.

To prevent the making of such poor decisions, the commander must get inside the enemy's decision cycle, not merely react to his moves and gain the momentum. In essence, the goal is to force the enemy to react. Making the enemy react, not reacting to his movements or plans, and getting inside his decision cycle to disrupt his plans is a large effort and extremely time dependent.

The technological advances in the area of near-real-time intelligence information and communications, displays of threat information, and capabilities to provide information to airborne aircraft are not yet fully realized. Although the capabilities to dynamically retask AI assets up to the very point of target engagement do not presently exist, the attempt to solve the scheduling portion of this problem provides an initial definition of requirements. It is important to identify the areas where the process of using experience as the backbone for making judgments and choices is enhanced through the use of new and projected technological techniques. By identifying these areas, a reshaping of the tools needed for the next generation of technological advances can occur. The identification of these processes will prepare future leaders for the on-slaught of technology by focusing on the development of a purposeful, systematic way for directing technology to support the command and control elements of the Air Force, preventing technology from driving those leaders in the development of future doctrine.

Through problem identification and the establishment of a baseline set of requirements, a partial solution to the retasking problem can be attempted before actual weapon systems capabilities are fielded. This will allow planners time to influence the technological upgrades of the new weapon systems and of the even newer command and control systems. Even though at present we do not possess the operational ability to flex with the situation by instantaneously sensing the enemy's posture, anticipating his next move, maintaining up-to-the-minute status of friendly forces, and changing an aircraft mission in mid-course; they will soon become common occurrences. The need exists to examine our decision processes now so that the commander of the future can be better prepared to manage these emerging capabilities. An examination of the opportunity to shape future doctrine in light of the current and projected thrusts to maintain our technological edge is necessary. Flexibility is not only the key to air power but also the key to waging and winning the overall command and control battle. This thesis attempts to offer an improved, flexible design to support the decision making processes for a portion of that command and control structure: air interdiction retasking.

Research Objective

The major research objective of this thesis is to identify in detail the kernels, or initial focuses, of a decision support system (DSS) as a decision aid for the ATAF FIDO at an ATOC in Europe. The analysis of the development of the daily AI campaign, the allocation of air interdiction missions, and the retasking of the air assets permits the examination of the processes which provide the initial inputs for executing the air offensive. Given the sorties available to the air interdiction mission (type aircraft and base), the munitions available for each aircraft, and a prioritized, weighted target listing of enemy second echelon forces, this research identifies the areas where processes are used to effectively and efficiently match the three to create sufficient destruction and disruption of enemy forces. Thus, the research objective is to design a decision support system and to offer evaluation criteria for future implementation of a working system which assists in the scheduling and retasking of air interdiction assets.

Subsidiary Objectives

To accomplish the research objective, the following subsidiary objectives were established:

1) Identify variables impacting on the development of the daily AI campaign order.

2) Identify the criteria and the information the FIDO uses to compare various decision options in order to make the ATO and resource reallocation decisions.

3) Identify the elements required in developing the data bases for use with the DSS.

4) Identify the kernel processes to be supported.

5) Identify and capture the decision processes of the mission FIDO.

6) Identify the key process by which the most effective weapon can be matched with the most effective aircraft against the highest priority target to produce the highest probability of kill in conjunction with the highest probability of survival for the aircraft and investigate the associated trade-offs.

7) Develop evaluation criteria to support the evolutionary design of the DSS.

Documentation of the formulation and evolution of the design process is a continuous task. This process provides the foundation upon which further research in the area of the reallocation of air interdiction sorties may be based, as well as a starting point from which evolutionary design of a decision support system will be evaluated. To this end, the documentation is maintained and organized in a 'hook book' format which consists of a series of exploratory questions, facts and findings. Most importantly, the experiences involving judgment and choice which help identify and develop the fundamental processes of the kernel system are documented by this tool.

Scope, Limitations, and Assumptions

This thesis effort is focused on the ATAF level FIDOs in the ATOC at Sembach AB, West Germany. The design does not make any decisions for the FIDO, but instead assists him by supporting his decision processes. The emphasis of this research focuses on the evolutionary approach in designing a decision support system. An interactive system, the DSS is designed to work in the dynamic and fluid flow of a battle where friendly and enemy dispositions change constantly and in an unpredictable fashion. The classification level of many of the documents, sources, and the "real world" scenarios used for this research restricts full explanation and development of the problem area. As a result, the WPC air interdiction retasking problem is developed in a generic mode.

The scope of this research is to provide a preliminary design of a DSS to aid battle staff members at the ATAF level in producing and changing the daily AI campaign order, the ATO. The ultimate goal is to get the right aircraft with the right weapon against the right target at the right time to produce the acceptable disruption of the enemy's ability to execute war plans. The search is for a statement of system requirements to interface computers with the key players in the offensive air battle. Ultimately, this interface will improve the flexibility of the command and control structure and permit the aircrews the freedom to use their skills, talents and weapon systems to accomplish their assigned missions.

The following chapters continue to develop the statement of requirements. The approach to the problem definition (Chapter II) and a description of the adaptive design process (Chapter III) are applied to the design of a specific decision support system (Chapter IV). Criteria for the evaluation of the DSS design (Chapter V) precedes the recommendations and conclusions (Chapter VI).

II. Background

Previous Solution Efforts

The main emphasis throughout the literature search has been in the area of scheduling, resource allocation, and the attempts and approaches to solve similar problems. The discussion of previous research efforts in the area of scheduling and allocating scarce resources is presented in five parts. The first part deals with a general review of the various types of scheduling problems and the assignment selection solution technique. The next part examines the use of expert systems as an approach to the problem solution. The third part looks at a decision support systems approach to the problem. The fourth part addresses recent Air Force efforts in the area of allocating AI assets. The final portion of this review offers a discussion of other efforts in the area of command and control and battle management.

Scheduling/Assignments. The duties and tasks of a FIDO are by their very nature scheduling because they require deconfliction of aircraft. But the FIDO also has an assignment task because he must assign aircraft against individual targeting requests. Four types of scheduling problems were investigated to determine possible uses in this research effort. Job shop problems, goal programming, cyclical, and maintenance scheduling were examined. This section addresses the techniques used to solve these types of problems.

The scheduling of items moving through a shop or assembly area is often referred to as the job shop problem. The item which requires work moves through the shop stopping at individual machines either in a set pattern or in a random manner. The solution techniques for these types of problems include integer linear programming (ILP) or heuristic reasoning, and in most cases they are developed for specific job problems. The scheduling algorithms used to solve these types of problems assume that personnel can complete the activities which occur at various times and locations, in any order (14:749).

Producing the AI battle plan does require the completion of a varying set of activities, but the order of completion is important and adds to the FIDO's tasking problem. Completion order must be considered because all the activities cannot be completed by all types of aircraft from all bases. The FIDO's scheduling problem requires a completion order which is not addressed in the above approach, as distinct and unique activities are not necessarily performed by all the different AI assets. For example, not all types of aircraft can carry all types of munitions, and not all types of aircraft are suited for attacking certain target areas defended by specific threat arrays.

A scheduling optimization technique which provides increased flexibility to the scheduling process is called goal programming. This approach attempts to optimize all the goals which are included in a single objective function. Goal programming is similar to techniques used with Multi-Criteria Decision Theory (47:844-850). Both techniques appear attractive for use in the AI problem because of the requirement to dynamically process information interactively.

Similar to job shop scheduling, cyclical scheduling uses heuristics and ILP to solve the scheduling of people for shift work. The activities of the workers are considered identical, that is a shift is a shift (5:1-16). The AI tasking problem, however, requires the scheduling of many different activities for each of the assigned assets. Because of the variety of tasks and activities which must be scheduled by the FIDO, this solution technique is not an appropriate approach.

Another type of scheduling technique, maintenance scheduling, addresses the optimal allocation of repair crews and money to a set of equipment being maintained. The objective of maintenance scheduling is to reduce repair costs or manpower requirements (21:335);(40). Both this type of scheduling and the FIDO's tasking problem require the scheduling of scarce resources, and both must consider a structured schedule of activities. However, the FIDO has the additional task of considering the deconfliction of aircraft flight paths enroute to the target area and the allocation of specific TOTs for phasing purposes.

A special type of linear programming solution technique where resources are allocated to activities on a one for one basis is called the assignment problem. A cost is attached with each resource so that an objective function can be formulated. This function is then matched with resource constraints to minimize total costs (13:151). The complexities of the AI problem make it extremely difficult to attach cost to the individual AI assets and create a single objective function without the possibility of oversimplifying the problem. The possible inclusion of any of the above scheduling or assignment techniques, however, should not be overlooked as possible model tools for sub-portions of the system which address the overall air interdiction retasking problem.

<u>Expert Systems</u>. Since 1980 much attention has been directed toward research in the area of artificial intelligence. Expert systems (ES), a subset of the artificial intelligence field, are similar to decision support systems but they are also quite different. In general, an expert system requires a specific, structured problem domain so that the ES can employ a set of rules or search strategies to arrive at a solution. The key to an effective ES is the tailoring of the problem to a well defined and specified problem domain, a difficult task for

even the most competent designer and knowledgeable expert (22).

The ability of a DSS to capture the problem space indicates that it may be appropriate to incorporate an ES as a model within a decision support system architecture, but the reverse of deriving or developing a DSS from an ES is not at all appropriate. It is important to note that the two systems both attempt to aid the decision making processes of the user and to improve the quality of the user's performance in the areas of judgment and choice. However, each has a specific method for achieving its goals.

While the DSS uses data, dialogue, and model bases to support the decision making process, an ES tries to replace the decision making process of the user with that of an expert in an attempt to force the most correct answer. Because of the 'bottom up' structure of an ES design, the initial prototypes tend to solve rather small areas within the problem domain. A DSS, however, searches the entire problem space to identify the decision processes. A DSS is not hindered by the restrictions inherent with a tight, dependent rule based structure of expert systems.

Because the ES tends to be a push of the button approach to problem solving based on rules, i.e. if this ... then that, the user has little chance of interacting with the system to permit refinement of the decision processes. The result of using the two techniques on this particular research problem is that the ES would not afford the opportunity to explore the entire problem space. Instead it would restrict the development of the statement of requirements by binding this particular research to a predetermined model. However, the use of DSS to identify the requirements does not necessarily dictate that the use of ES would be inappropriate during certain process implementations.

An expert system which is used to address the problem of resource allocation for air and artillery assets of the Marine Corps was developed by Slagle and Hamburger at the Naval Research Laboratory. The system, "Battle," allocates weapons versus specific targets and provides recommendations for the allocation of specific battle resources. The system works in two phases. First, the determination is made as to what level of damage each particular weapon can inflict on specific targets. The weapon effectiveness is the expected portion of the target that would be destroyed if the weapon were fired at it. The second phase requires operator involvement to either establish new levels of effectiveness for each weapon-target match, or to choose from several overall plans as offered by the system (33).

This expert system was also applied to the Army artillery allocation problem in 1986. It used advanced artificial intelligence techniques to assign weapons to targets. A dynamic inference network allowed the user to update battlefield conditions, and allow the operator to evaluate alternative plans as with the Marine version (17).

Still another planning and decision aid which has been developed by the RAND corporation is the Tactical Air Target Recommender, or TATR. It's purpose is to help planners decide on an overall offensive counterair mission campaign. Described as a 'smart aid', this system incorporates artificial intelligence knowledge bases and production rules to develop the plan (3).

Decision Support Systems. While the above techniques may deal effectively with the creation of schedules and data displays, they do not specifically concern themselves with the decision maker and the information required to make effective decisions. The ability of a decision maker to experiment and watch the impact of different decisions is one of the most important features of a decision support system (12:45). Although some of this analysis can be accomplished through linear programming and decision analysis, choosing a specific operations research tool tends to bind the researcher, causing less than full investigation of the problem area by creating too many front-end assumptions. DSS methodology allows a researcher to explore the problem from the user output point of view, unconstrained by the need for solution techniques during the initial phases of problem definition. These features make DSS an appropriate solution technique for the reallocation problem considered in this research.

In addition, the above techniques do not specifically concern themselves with the decision maker and the information required to make effective decisions. Making decisions when many variables and alternatives are presented to the user requires human interaction and demands information consumption in 'chunks or bursts' (e.g. graphical displays). This approach, which assists the cognitive processes of judgment and choice, is the central feature of a DSS (43). A DSS allows the FIDO to recall needed information from selected data bases, consider the data presented, operate on the data if necessary, make a decision, and input the decision into the schedule. The schedule will be updated to determine the effect of the decision, and in this way, plans can be formulated that reflect a decision maker's desires in an efficient manner.

Sprague and Carlson explain that DSS are designed to facilitate semi-structured as well as unstructured decisions. Although some portions of these types of problems are not easily solved by analytical or quantitative linear programming methods, the dynamic nature of scheduling problems still requires some quantitative solution techniques to cope with the ever increasing amount of information with which the FIDO is being presented. A DSS is not totally structured. It tries to model a decision maker's process of choice by capturing his experience and methodology. It should allow creativity and judgment to enter into the solution process (35);(44). Using the adaptive design process, one or several of the preceding models may be identified as appropriate for the DSS. Eventually models will apply, but in the early phases of problem formulation their particular application is not well defined.

Because the major focus of a decision support system is on decisions and decision making as a process, there is a heavy emphasis on model bases and data or knowledge bases. The information from both is used, but it is streamlined for the user in a graphical format. The benefit of the DSS is that during development of the system a great degree of flexibility exists to cope with change. Additionally, a decision support system is often used to aid in the development of problems where changes may occur in the environment or problem space, or in the user's perceptions of the needs and tasks involved (44).

Recent Air Force Efforts. Several Air Force research efforts have addressed the air interdiction problem with the use of software and computers. Early efforts involved attempts to allocate assets in a static or slowly moving scenario. More recent attempts have included the development of mission planners for the aircrews at squadron level, a Force Level Automated Planning System (FLAPS), a Resource Apportionment Aid (RAA), the Tactical Air Operations Team Training System (TAOTTS), and the development of the Rapid Application of Air Power (RAAP) concept.

Mission planning systems/aids are designed for use by aircrews at the squadron level. Typically, the crews enter the data received from the ATO such as targets, routing, and configuration. An interactive map display allows the crew to then examine their route, comparing terrain features and enemy threat rings with their routes. Thus, they are able to plan both enroute and target area tactics. This system involves detailed planning for aircrew members at the unit level, but is of little value to the force planner who must provide the crew with their mission parameters in the first place (32);(36).

FLAPS is a computer software package which automatically performs various force planning functions. The system has been designed to meet the requirements of USAFE planners operating in central Europe. The benefit of FLAPS is its ability to demonstrate how modern mathematical optimization techniques and computer systems can assist planners in quickly generating operating plans while using limited assets in the most effective way possible (42:1-3).

RAA is the most ambitious of the four systems described. As a decision aid, it allows battle staff members to rapidly evaluate alternative apportionments of aircraft sorties to specific target arrays. The commander can set his relative priorities across objectives, and the aid will allocate sorties to mission areas and display the apportionment and the allocation.

The RAA performs this function by using a matching model technique which searches data files for the highest priority target nominated and matches that target with the untasked aircraft and munition load possessing the highest probability of destroying the selected target. The system then proceeds to the next highest priority target and performs a matching without reconsidering any previously tasked aircraft as available. The user can interactively modify the apportionment and examine the degree of achievement of overall mission objectives. The aid also allows targeting officers to investigate in detail an enemy target array and develop aim points for weapons delivery. The system uses a video diskette to display map graphics and permits interactive development of targeting priorities (8);(26). RAA approaches aspects of this research, but does address the processes by which a FIDO redirects assets. The RAA is viewed as a partial solution to the overall retasking problem, the type of aid which is necessary in the overall design of the DSS to perform rapid retaskings. However, it is not a tool which by itself would solve the retasking problem.

TAOTTS is a system designed to gather data on the processes involved in building the ATO. The major contribution of TAOTTS is that it eliminates most of the vast quantities of paper worksheets and maps currently used in constructing the ATO. However, because of the large amount of information required in the planning process, large and very fast mainframe computers are needed (39:1). TAOTTS is presently used as both a training aid and an information gathering tool. It provides information on the structure of the different data sets involved with the retasking process by identifying those essential elements which must be considered when initially constructing the ATO.

RAAP is a concept for focusing information to permit decisive application of air power against enemy ground forces. The concept is to exploit friendly knowledge of enemy doctrine and capabilities, integrate target development and force application factors proactively, not reactively, using today's technology to evolve this capability. RAAP has begun to address the multiplicity and near glut of information present to battle commanders, but it is still an unrealized, future concept. Work is currently underway to demonstrate the concept's capability later this year (24:1);(27);(28).

The four systems described are not the only on-going efforts in the Air Force, but each one has features which adds enhancements to this particular research effort. TAOTTS has recorded much of the essence of the ATO process over the past three years. RAA provides many of the decision aid specific structures for the apportionment of scarce resources while FLAPS adds specifics for the European theater. RAAP attempts to conceptualize the value of attacking ground forces with air interdiction assets, concepts which this research also attempts to define.

Other Efforts. Several other research efforts are addressing aspects of the command and control of scarce resources. Although incorporating highly technical methods and resources, the Defense Advanced Research Projects Agency (DARPA) is studying the management of navy ships through development of its Fleet Battle Management System. This command and control system is designed to investigate the use of advanced computer technology to aid in the management and employment of both the surface and subsurface vessels associated with a task force size unit. Similar to the Navy effort is the DARPA examination of a similar command and control system for the Army's use as an Airland Battle Consultant (25).

Although DARPA's efforts are futuristic and not intended for near-term operational employment, several of the concepts developed by the agency have entered the next echelon of development closer to full contracting and eventual development. The U.S. Army at Ft. Sill, Oklahoma is developing a fire support command and control system for command of their artillery assets in conjunction with the Army Ballistics Laboratory. Their Fire Support Execution (FSX) functional requirements analysis has focused on several aspects similar to the retasking of air interdiction assets. A major portion of the FSX effort is the establishment of a target prioritization methodology.

Establishing target priorities is a necessary ingredient in the measurement of possible benefits from executing options proposed for the resource allocation problem. The priorities are needed to determine payoffs for choosing the best aircraft and munition against the most lucrative target (23).

A detailed effort is also underway at RADC to develop an integrated battle information management system. A central laboratory exists at RADC which is connected to other buildings where research is being conducted in the areas of sensor collection, intelligence fusion, and surveillance. The central node of this interconnected system is the Battle Information Management Laboratory (BIML). The RADC objectives are to provide a test bed for developing information fusion capabilities and decision aids for mission and force planning. A recent conclusion produced by BIML investigations points to the importance placed on thesis efforts of this type.

> One of the critical needs within TACS is an automated capability for mission and force planning. While some capabilities exist today, the extent is a function of the theater of operations and is largely the result of initiatives of the users themselves. Technology is available, however, which can support a more robust capability than is currently fielded. A methodology is needed to facilitate the rapid transition of that technology.(41)

RADC is presently working with many decision aids which will eventually find their place in one of the nodes attached to the BIML. The aids, such as the Target Prioritization Aid, are used as prototypes to assist target planners in the development of the daily target nomination list for inclusion into the Air Tasking Order. Other aids which include the Route Planning Decision Aid and the Decision Aid for Threat Penetration Analysis are designed to assist the aircrews at the unit level to become more efficient in their pre-mission planning activities. These decision tools are only a few of the ones currently under development by RADC, but again they tend to indicate that the technology is there to do great things with the information we are obtaining from the battlefield sensors. Much more work is required, however, in the area of requirements identification for determining the composition of the future operation centers and the tools the battle managers must use to rapidly interpret this information (26:2);(41).

Lastly, the intelligence community is making progress toward completing a capability which will afford future "... commanders the equivalent of a seat in their enemy's operations center." (11:43) An intelligence processing program, called Joint Tactical Fusion (JTF), consists of two main elements, the Army's All Source Analysis System (ASAS) and the Air Force's Enemy Situation Correlation Element (ENSCE). The JTF will process the overwhelming amount of information which the sophisticated sensors can now collect and perform the time consuming clerical tasks so the analysts can perform their primary task of determining enemy intentions and present them to the commander. Since this capability is " ... as little as four years away from its initial deployment to field units ... " (11:43), increased emphasis is needed now to identify the means to effectively use the processed intelligence information in the command and control of today's weapon systems.

Review Conclusion

Many problems similar to the battle campaign problem have been solved by various methods. However, none of the problems approach the size or scope of the dynamic retasking of air interdiction assets. Even with the ability to reallocate and divert the mission aircraft, the aircrews and the C3 elements do not presently possess the technological, organizational, or procedural capabilities to change rapidly and repeatedly. The sheer number of variables and the changing, unpredictable conditions which are encountered in a battle (the "fog of war") complicate the solution. Many of the solution techniques require too many simplifying assumptions which may hide the true essence of the process. Thus, the danger arises of diluting the solution, blurring the "big picture" and generating false solutions.

Achieving an optimal set of requirements criteria is not the goal of this study. A quick, workable, and feasible structure of the problem is produced through the design of a DSS. The DSS will accomplish an initial statement of requirements which through evolution can be refined and implemented to further the process of problem definition. Additionally, the results of this study will afford still another reference point for the evaluation and the comparison of present systems.

Attempts to solve the dynamic scheduling of air interdiction assets do not lend themselves to the simple push of a button. Because of the highly unstructured nature of the problem, it cannot be solved at this time by computer algorithms. Any commander would be wary of a solution with no human in the decision loop. Presently, this type of problem is solved with intense human involvement which affords maximum throughput, with minute attention to detail, by relying on user experience. An algorithm will most likely not contain all of these features. However, the use of an adaptive design process would permit parallel growth of the system and simultaneously define how and where algorithms may fit into the system. This process will require changes to the DSS during exercises conducted in the field, where the experienced FIDO today may be replaced by an augmentee tomorrow.

Problem Definition

There are many differing opinions on the definition of a DSS. There is even a greater disparity among developers as to the features which a DSS should possess. One thing is certain and is agreed upon throughout the DSS community: a DSS must be user oriented. The creation of a decision support system is meaningless without first having identified the end user, for the design of the system is defined to support that person. The user oriented approach of a DSS is focused on the user's needs and as such, a DSS bridges the gap between a seemingly shapeless problem domain of the user by adding structure to an otherwise cluttered decision task or process.

One of the most valuable features of a DSS is its ability to help define a problem through its adaptive design process. Problem definition is not an easy task and is usually the most difficult aspect in the solving of any problem. The two step process of recognizing the problem and identifying the key features of the problem allow a problem solver to begin applying solution techniques. The development of a DSS supports this two step process.

Problem recognition or detection becomes apparent from two sources, either the user himself or someone external to the user and his organization. In the case of the air interdiction problem, it is recognized that the sensor information flow, the improved intelligence capabilities, the ever increasing enemy threat posture, and the need to do more with less are all combining to form an even more difficult command and control environment for the commander of the AI assets. The need exists to improve the procedural and doctrinal applications of the air interdiction assets to fully utilize the capabilities which the advances in technology are presenting.

The more difficult task of problem identification requires the DSS builder to collect information from the users on their perceptions of the problem, specific areas where an initial system may be useful, and most importantly, provide the DSS builder an interpretation of the areas which require the users to make decisions. These insights are used to gain a further appreciation for the problems facing the user and his organization in the accomplishment of the unit mission.

The next chapter develops the reasons for using the adaptive design process and the accompanying methodology for designing the DSS. Chapter IV applies the design approach and its methodology to the specific problem by defining key elements of the decision support system. Criteria for the evaluation of the DSS design in Chapter V precede the recommendations and conclusions found in Chapter VI.

III. Problem Approach

Why Adaptive Design

The process of design is one in which a specific pattern or set of patterns is developed to solve a particular problem. It is a systematic method of creative planning through which a series of actions or a specific course of action is aimed at changing an existing situation into a more desirable outcome (31). By iterating a solution technique, the design process adapts to the problem space and becomes a useful method for understanding and capturing the essence of the problem. Possible resolutions to the problem are also identified through the continual iteration of the technique. Thus, design could really be considered a process of satisfying needs, and in nearly all tactical situations needs change, forcing adaptation to a new situation or environment (44);(45).

Adaptive design can be divided into three stages:

1) Information requirements determination, consisting of selecting the right problem and identifying the key or critical issues.

2) Information digestion process, consisting of the feasibility study and the analysis of the system.

3) Information design structure, consisting of an implementation of the system and the iterative or repetitive attempts to improve the system (44).

The basis for the usefulness of adaptive design lies in its ability to solve unstructured or semi-structured problems. Through the use of this design technique, a large, unbounded problem space can be examined to determine areas where the essential elements of judgment and choice are employed by the decision maker. The adaptive design process is not bound initially to a particular model required to solve the problem, and thus a more straightforward approach toward problem definition is possible. Identifying decision processes at a relatively low level in the hierarchy helps to shed light on the environment surrounding each decision process. This identification of the 'kernel process' develops as the requirements of the decision maker are explored. Eventually, the kernel expands to fill the problem space and capture its solution even if the shape of the problem space changes, which often occurs as the user's perceptions of the problem change.

A second reason why adaptive design was used in the research of this problem area is that Air Force requirements change, and change rapidly. The specific missions of the Air Force change with the needs of the nation and the national objectives, the missions change as dictated by the threat posed by enemy forces. The advanced capabilities and improved weapon systems introduced at one level of operation tend to ripple through the entire structure of the organization and impact, or even change service requirements. In the traditional design approach to problem solving, specific goals and milestones are set forth to meet rigid system specifications. The major drawback of this approach is often the time required to field a working system. Quite often a system is delivered with little chance of meeting the present requirements of the user because the initial problem definition has changed from the user's original view of the problem space.

Finally, the adaptive design process through its rapid, iterative examination of the problem space from the bottom up, affords the user the opportunity to state his or her requirements as they perceive them. By taking multiple looks at these perceptions with quick fix solutions to a small portion of the problem environment, a statement of requirements is developed which can then be assigned to the traditional design engineers for implementation. The system requirements can be repeatedly revised to allow the kernel system to grow and capture the problem space.

This evolutionary aspect, then, is the most important application of the adaptive design process and the reason why the decision support systems methodology is chosen as the means to identify the requirements of the allocation and retasking of air interdiction assets. The remaining sections of this thesis describe how the adaptive design process can be applied to this very complex problem area to develop a statement of requirements by identifying the critical retasking processes of the FIDO. The question might arise, does adaptive design really solve problems? In time, yes, but the more important aspect of the design process is that it allows the designer to anchor his or her ideas through development of the kernel and adjust those anchors upwardly to respond to smaller problem domains.

Methodology

The method used to address this particular problem stems from an evolutionary design process and its application to a decision support system capable of assisting ATAF air interdiction fighter duty officers at the ATOC in Sembach AB, West Germany. There are four essential steps which are taken to construct this planning system and achieve the research objectives. Figure 3.1 shows how this methodology for the statement of requirements can be viewed as a function of time.

```
  :
  :
  :
  :========================================================>>>
TIME  :         :       :       :      :     :      :
  :   :         :       :       :      :     :      :
  : Problem  Concept  Feature  Story  Eval  Story  Kernel
  :   ID       Map     Chart   Board        Board    ID
  :                              :            :
  :                              V            V
  : (HOOK BOOK)-------------------------------------->>>
  :
```

Figure 3.1 Statement of Requirements Continuum (44)

The first step involves documentation of the daily frag formulation. This process involves tracing the flow of information used in building the daily AI campaign: where the information comes from, where it is used, how it is maintained, and how the information is linked. The technique to establishing these linkages, 'concept mapping', provides an understanding of this network of rules and guidelines. These rules and guidelines are then organized in as simple a way as possible without losing the important aspects of the planning process. Although these initial steps sound traditional, it is at this point the difference between traditional design and adaptive design becomes evident. The definition of requirements is compressed in time, the requirements are not dri en by detailed specifications, and the end goal of this study does not focus on the feasibility of implementation with current available technologies.

The second step involves using a graphic technique called 'feature charts' to communicate to the designer the the needs for the storyboard development (37). A hierarchy of key features within the problem domain as determined by the concept map is constructed as a means of identifying those data elements and relationships which the user needs to perform his decision related tasks.

Storyboarding, which is designing a set of initial screen representations of the decision process, is the third step. The screen representations contain elements which allow the FIDO to operate on the data, present it in highly graphical chunks of information, permit the FIDO control over the data displays, and offer the user memory aids which do not interfere with the decision process but allow the user to further map the decision making process. This ROMC approach to storyboarding is attributed to Sprague and Carlson.

The FIDO needs all of the necessary information displayed on a screen, or series of screens, so that he is able to explore alternatives and construct a plan. Step one identifies what information is necessary, step two aids in establishing key relationships and the third step captures that information in an easily digestible format to assist in determining the key decision processes. Additionally, the screen displays and format must present enough of the facts to prevent errors and oversights. Storyboarding is the facilitator through which the processes of the user are identified and examined.

The final step is the identification of the kernel processes which are used by the FIDO to resolve the particular retasking problem. By examining the relationships between the screen displays and the connections between the various data elements on those displays, the individual decision processes which the FIDO uses to retask sorties are identified. By identifying the processes, the core issues of the system, or baselines, are established from which an initial user evaluation can be used to further develop the worth of the system.

Once the kernel processes are identified and examined, a set of evaluation criteria is established to aid in assessment of the system during implementation. This evaluation and subsequent feedback of information by the user are crucial steps in the evolutionary design of a decision support system, because it is the evaluation of the DSS which gives the system a direction for growth and expansion. Although this researcher initially felt that the evaluation of a system could be performed using similar existing decision aids such as the Resource Apportionment Aid developed by Rome Air Development Center, the most effective evaluation is undoubtedly by the user in his environment. By documenting comments, investigating common benefits, and examining disassociations, further modifications of the kernel processes are identified. Thus, the initial DSS design is accomplished in an effort to begin tracing the evolution of the total system.

In summary, the four steps discussed above are developed using the following methodology in order to accomplish the overall object of this thesis effort, the definition of systems requirements for the dynamic retasking of air interdiction assets:

1) Use concept mapping to become familiar with the problem boundaries, system components, and potential kernels.

2) Identify the appropriate variables impacting on the planning process from the battle staff's perspective.

3) Investigate the FIDO's decision tasks to develop the storyboards and prototype design of the DSS.

4) Capture the requirements for the decision processes, using storyboards.

5) Identify the data base structure and kernel processes.

6) Maintain a "Hook Book" to capture the design process and insure continuing evolution of the DSS.

7) Recommend and establish an organizational structure of the problem definition process.

8) Develop evaluation criteria for the DSS.

The "Hook Book" is an integral portion of adaptive system development. The theory of the hook book approach is that the user initially cannot fully state the nature of the specific problem. The user may not be aware of particular problem aspects or may have just missed them when initially questioned during problem definition. Additionally, the user's perception of his or her needs may change with time and the system in use may require changes to fulfill those new requirements. As a memory aid, the hook book allows the user to record items which do not require immediate attention, but if left unrecorded would be lost. For instance, most people only remember those thoughts which are of such a nagging nature that they cannot be forgotten. The hook book provides a means of capturing those ideas which may fade if not recorded and, although not apparently important at the moment the idea was generated, these thoughts may be crucial to the system improvement when related to other ideas recorded over time. The hook book then gives the user and designer the opportunity to capture new or overlooked ideas which were not addressed before the construction of the system began. The goal of the hook book is to help the user, through the adaptive design process, to improve the problem approach and offer redesign criteria for subsequent iterations of the system by offering further system enhancements.

The hook book contains a list of items which may later be incorporated into the DSS, descriptions of possible improvements to the system, and directional topics for consideration in the area of advanced engineering concepts and technologies. It is the mapping and record of the entire DSS construction and as such, it becomes not only the springboard from which future evolution of the DSS can be accomplished, but it also is used to investigate the actual decision processes of the user. The hook book for this research is contained in Appendix F. Although created chronologically, it has been ordered by broad subject content with similar sub-items attached to an appropriate category. The reorganization of the hook book becomes a tool by which the user can adapt this research in further pursuit of requirements determination.

Concept Map Analysis

Conceptual mapping details each portion of the decision process using words or concepts and linking words or phrases in a top down structure (19). This technique captures the components of the decision maker's process and provides an initial cut at problem definition. A general example of developing a concept map is depicted in Figure 3.2. Using the concept mapping techniques as applied by McFarren, an initial structuring of the scope of the problem is constructed. The purpose of mapping the concepts of the reallocation problem is to identify the areas which require more detailed attention and areas where further investigation of the decision processes involving judgment and choice is required.

In addition, the concept map aids the researcher in determining which portions or concepts are interrelated and how the network as a whole, functions. This is where the real power of concept mapping lies: its ability to use facts to represent and capture processes by identifying factual relationships and by exploring the meaning of the linkages between facts. Concept mapping is intended to be a user oriented approach toward capturing problem specifics. It is essentially an unstructured technique which requires little training or machine dependency as is the case with influence diagrams, semantic nets, or object-value-attribute relationships.

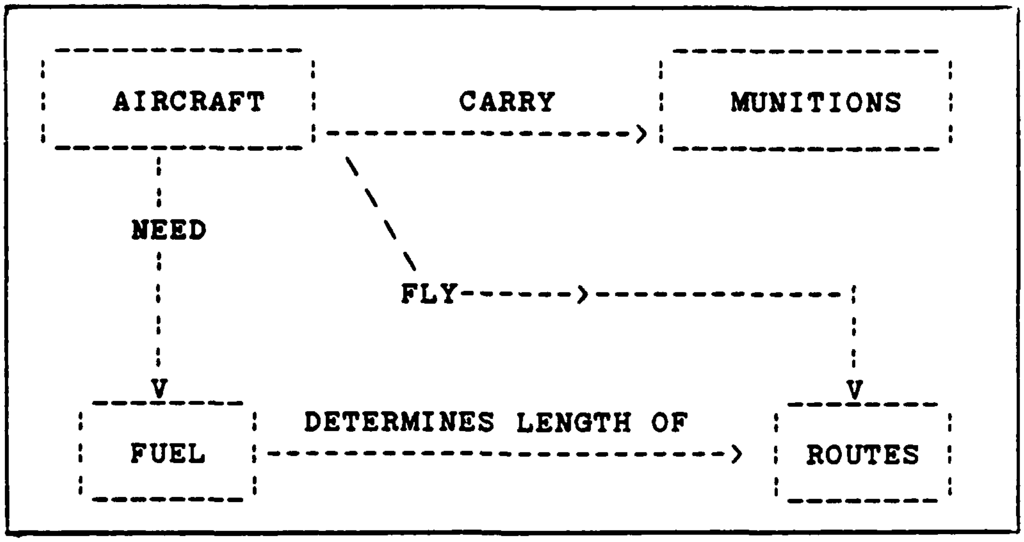


Figure 3.2 Concept Map Example

Feature Chart Development

The completion of the concept map and the identification of the data elements permits the more detailed focusing and structured development of the problem. The feature chart shows the interrelationships of the displayed data and allows for a more pictorial depiction of their relationships with one another. The feature chart identifies interactions of the screen displays and output format of the FIDO's decision processes (30:12-14). This researcher developed the feature chart from the concept maps and data analysis in the preceding sections.

This chart, unconstrained by requirements, is a representation which captures the key tasks and the significant features which the FIDO uses to accomplish his individual responsibilities. Because each FIDO operates with a different degree of mission experience, the DSS must provide assistance at various levels of AI problem solving proficiency. This implies that the DSS must be powerful enough to support various decision sequences and at the same time remain easy to interpret and manipulate.

Particular software and hardware for the user are not discussed or produced as this research project focuses on a definition of requirements and test and evaluation versus a full-up, user capable implementation of the system. The research stands on its own, and the processes identified are intended to facilitate requirements identification for a kernel DSS to reach a partial solution to the problem.

The next chapter shows how the approach developed in this section is applied to the design of the specific decision support system for the fighter duty officer. Chapter V follows with a presentation of proposed evaluation criteria for the DSS. The conclusions and recommendations stemming from the design of the system are contained in Chapter VI.

IV. The Decision Support System

Introduction

This chapter describes the DSS design while applying the adaptive design process discussed in the previous chapter. The concept mapping process is detailed and a development of the feature chart is depicted. Two different sets of storyboards are presented, one for the overall retasking problem and then a second set aimed at the development of the front end of the system as a working decision processor for the FIDO. As a result of this three step process and a subsequent iteration of the methodology, several kernel processes are identified.

A subproblem identified earlier in this research is offered as a further example of the power of the design methodology. The reconfiguration of AI aircraft is described through the development of a concept map and storyboard. The concept matrix is introduced as a tool for expanding the interpretation and construction of the concept map.

Fido Duties

The FIDO who is assigned the specific mission of air interdiction tasking, performs scheduler-type tasks. Allocated aircraft sorties from higher headquarters, his task is to plan the air interdiction campaign by matching available resources (aircraft and munitions) against a set of prioritized targets provided by the intelligence community.

His duties fall into three general categories:

1) Gathering the information
2) Exploring the alternatives
3) Formatting the data for delivery to the appropriate mission element (Figure 4.1)

Whether the FIDO is tasking assets for the first time, or reallocating already committed resources, this three step process remains the basic premise. The iterative approach to this planning system requires a FIDO to repeatedly gather more information to expand his exploration of the alternatives (retrace loop).

```
    +-------------+         +--------------+        +---------+
 -->|   GATHER    |------>|    EXPLORE     |----->| FORMAT  |-->
    | INFORMATION |        | ALTERNATIVES |        |  DATA   |
    +-------------+         +--------------+        +---------+
          |                        |
          +---<---RETRACE--------+
```

Figure 4.1 FIDO Duties

Data Required by the FIDO

A sample of the appropriate variables and data categories of interest for the air interdiction FIDO are presented in Table 4.1. The data analysis is derived from task definitions. The analysis follows the data in a pattern throughout the decision process to ensure a proper matching of each task to data. Although this approach may seem traditional, the data investigation is a pivotal step toward determining the significant factors which show promise in developing as complete a system as possible and to facilitate total process identification. By identifying a data flow, the actual definition of the DSS databases is also greatly enhanced. In addition to the data specific items listed in Table 4.1, the FIDO must have weather information for the various routes of flight and target areas.

Table 4.1 Initial Data Requirements

Aircraft	Base	Target
type	ramp/shelters	priority
number available	weather	defenses
munitions capability	fuel	weather
range	munitions	history
location	launch status	location

Several assumptions were made toward the development of this DSS to limit the scope of the problem and make it workable. These assumptions were also postulated to permit investigation of possible future configurations for the air interdiction forces and the command and control system supporting it. Thus, these assumptions are used in an effort to explore future capabilities of the AI force and facilitate the possible establishment of requirements for future C2 systems. The major assumptions are:

1) The aircraft fly individually, independent of large strike packages, and have the ability to receive and to plan with updated mission information, "on the fly."

2) A base is capable of servicing any of the AI aircraft, including the upload of available munitions. Major maintenance problems require home or like-base support.

3) A prioritized, weighted target list of second echelon targets is available. Intelligence personnel are continuously updating this list.

Concept Map Definition

Problem definition is one of the most difficult and yet most important steps in the problem solving process. Among the difficulties inherent in defining and scoping a complex problem are identifying all relevant elements influencing the problem and recognizing and understanding the relationships between these elements. The ultimate goal in the problem definition stage is to identify relevant criteria (elements) and organize or partition the problem into manageable parts so interactions among those relative elements clearly stand out. Not all elements are identified during this stage of the investigation, but the adaptive design process attempts to capture all of them through an evolutionary process starting with the key ("kernel") components.

The concept maps developed for this research are located in Appendix A. Because concept mapping is intended to be a user oriented tool, the concept maps are presented in their raw form. The FIDO concept maps were constructed during an interview with Captain McFarren in the earlier stages of this research. Used as an aid to define the problem space, the concept map shows a broad problem and mission scope and depicts general interrelationships between the different tasks and the user. The maps were developed in two phases. As with the diagram in Figure 4.1, two viewpoints were used: the inputs which the FIDO receives and the outputs which the FIDO must produce.

The two maps focus on the FIDO. Several of the kernel processes were initially identified using the maps. A second concept map is also located in Appendix A for the kernel identified as the reconfiguration of the air interdiction aircraft. This map is provided to demonstrate how the technique of concept mapping can be used for a more specific detailing of a problem area. It demonstrates how a particular kernel identified with the initial concept maps can be expanded to further capture a separate decision process, the reconfiguration of air interdiction assets on ground alert. Thus, the map displays a refinement of the concept mapping process used for the more general FIDO retasking process.

The refinement of the reconfiguration concept map included the construction of a "concept matrix" which was developed in parallel with the mapping process. The concept matrix, also located in Appendix A, shows promise as a tool for future designs using concept mapping. It produced significant inputs for this pre-storyboard phase of the system design. First, it allowed complete enumeration of the complex interactions of the key elements developed with the concept map. Second, the blocks of the matrix accurately depict the branches between the nodes of the concept map. They also show the inverse path relationships for each element, relationships which may be missed when using single, one way links in the construction of the concept map. Third, through this enumeration, more specific kernels were identified for the larger problem of reconfiguration of air interdiction assets.

The two FIDO concept maps were the initial attempt at problem formulation. They were subsequently used to expand the problem definition and construct the feature chart hierarchy. Additionally, they were repeatedly referenced during the creation of the storyboards and used as an established baseline for the user's screen representation and display requirements.

Feature Chart Definition

During the research it became necessary to develop a hierarchy of the different types of data and its structure as viewed through the concept maps. This aided in the identification of several of the variables impacting on the development of the daily AI campaign order, one of the subsidiary objectives. This was accomplished using feature charts to describe the key linkages and events in the concept map and translate them into essential elements of information upon which a FIDO would operate. The feature chart became the bridge between the initial user concepts and the development of the storyboards. It provided a structure to the earlier developed concepts without restricting the free flow of ideas during the storyboarding process.

Although this feature chart definition may suggest a task analysis in the traditional design sense, in actuality most users need something to grasp in a more familiar, structured hierarchy. The highly data oriented approach of the present duties of the FIDO demanded an approach which was later discarded because of the lack of a decision process orientation. Although the retasking problem initially demanded a data approach and structured format, it was not necessary in the system design to use each data element in the development of the storyboards.

The feature chart hierarchy developed in Appendix B presents the data oriented approach to the concept maps developed previously. The hierarchy presents features which quite naturally follow a similar structure as that presently being used by the FIDOs to develop air tasking messages within the Eifel-1 system. It does not specifically address in its structure the areas where judgment and choice are used to make decisions regarding air assets. Individual data elements may also be duplicated within the structure. Although the feature chart hierarchy does not directly address the immediate retasking of air assets or how the individual data elements relate, the first version of the storyboards were designed with reference to the chart.

A feature chart hierarchy was not used to develop the second set of storyboards, to avoid the data dependency which the first feature chart had introduced. In its place, the first version of the storyboards were used as the catalyst for construction of the second version. In the case of the reconfiguration storyboard, the concept map and matrix provided sufficient insight into the problem area and the display requirements. They were the focal point for the construction of the reconfiguration storyboard.

Storyboards -- Version 1.0

The first version of the storyboards is presented in Appendix C. A direct representation and much more specific set of displays is developed in the second version of the storyboards and for the reconfiguration kernel process. They represent the general design and structure of the retasking DSS. The initial cut at the storyboards is heavily data oriented in the first case and extremely model dependent in the second case, and both sets lack specific graphical characteristics. Their benefit as baselines or anchors from which to generate changes and improvements for subsequent use in development of a full-up prototype system make them effective and essential products of this research. Comments on the individual storyboards are provided with each representation and highlight the general use and definition of the individual display functions plus the overall anticipated uses of the display by the user.

Both sets of storyboards are an attempt to design a system without setting final goals. The emphasis during development of these displays was to attempt to capture the individual processes or kernels which up to this point had been only partially identified during the construction of the concept maps and feature charts, and to project those kernels into future design requirements. The advancement of ideas and concepts developed during the processes described in this chapter, then, are offered in an attempt to steer and drive technological improvements in a more significant direction.

User Evaluation. The first version of the storyboards was reviewed by members of the 712th ASOC, Bergstrom AFB, Texas. Former FIDOs as well as battle staff personnel who had worked at ATOC Sembach provided comments about the displays and the problems facing the duty officers involved with tasking offensive air assets.

In order to properly manage and employ the available air combat assets, it is necessary for the battle managers to have current, accurate and detailed data on the location, condition and quantity of their assets. Lieutenant Colonel Wilson indicated that this is one of the major shortfalls of today's current operations, the lack of timely and complete updates of information flowing from subordinate units to the command centers (48). Efforts are under way to improve this information flow between the wings and the higher command echelons.

Using the user inputs on the problems a FIDO encounters during the tasking process and user review of the first cut of the storyboards, a second version of the storyboards was developed. Before this second version could be built, however, it was necessary to refocus the initial viewpoint of the retasking problem.

Retasking Triggers

After evaluating the first set of storyboards and completing one iteration of the DSS design, the observation was made that the first version of the storyboards failed to capture the processes by which the FIDO would actually retask the aircraft. The first version required the FIDO to browse through the data while trying to make decisions about the assets. The key question which afforded the basis for the transition from the data intensive first set of representations was, "What particular aspect of the situation has changed to cause considering the retasking of the AI assets?"

This question was applied to the concept map, feature chart and storyboards of the first iteration. It was determined that their were particular elements of the information structure which, if changed, would trigger a retasking option. These retasking triggers present themselves from two vantage points. A retasking may be triggered as the result of the situation worsening, or their may occur a point in the tactical situation where a retasking would help establish the advantage. Table 4.2 presents the two categories and their associated triggers. This table helps to establish the criteria and the information the FIDO uses to compare various decision options in order to reallocate his resources. In the table, "weapon" refers to the munition and delivery vehicle combination.

Each of the triggers is explained in Appendix D with their accompanying storyboards. Examples of the different triggers are also provided. The weather trigger is all pervasive in that it affects each of the others, but weather itself is unaffected by those other triggers.

Table 4.2 Retasking Triggers

SETBACKS	OPPORTUNITIES
Weapon lost	Weapon gained
Base closes	Base opens
Weather deteriorates	Weather improves
Tasked target uncovered	Lucrative target appears

Storyboards -- Version 2.0

The identification of the retasking triggers allowed the development of the "front end" displays for the retasking DSS. This set of storyboards, located in Appendix D, provided the means for capturing the decision processes of the FIDO. An important part of this version of the storyboards is the identification of a necessary capability by the FIDO to evaluate and visualize how the battle will proceed with newly configured assets using different taskings.

The ultimate goal, as stated in the first chapter, is to get the right aircraft with the right weapon against the right target at the right time to produce acceptable destruction of enemy assets. This problem is supported by the second set of storyboards in that through this set of heavily model dependent displays, the FIDO is assisted in making decisions as to the most effective use of the assets available. Judgment and choice are required to determine what is acceptable damage and destruction of the enemy's assets, and this set of front end displays provides a support tool for making those decisions. The first version of the storyboards becomes the backup to this second set and remain available to the FIDO for acquiring detailed information on any specific data element desired.

Reconfiguration Storyboard

A unique storyboard is provided in Appendix E. This single display shows how a process, that of the trade-off between aircraft survival and target destruction can be represented. The display provides a simple operational control and allows the battle manager to quickly examine the expected outcomes of his decisions to allocate aircraft against certain targets. Future elements could be added to assist the FIDO using such a system in making decisions by following a systematic series of processes in the choosing of aircraft configurations. Resources allocated in such a manner would prove to be more flexible and more effective in execution of the air interdiction battle plan. Further explanation is presented with the storyboard.

Kernel Identification

The development of the DSS and its key elements of the adaptive design process as applied across two separate iterations of the general retasking problem and a brief examination of the sub-process of reconfiguration of air interdiction assets, including numerous hook book items located in Appendix F, resulted in the identification of several kernels. Inputs from others involved in this research (Wilson, Young, Valusek, Staton) produced insight into areas where specific kernels currently exist and where others may be required in a future version of the system.

Table 4.3 Selected Kernels

Weaponeering
Gathering the Data
Maintaining Accuracy of the Data
Target Prioritization
Target Weighting
Matching Tactic to Threat
Matching Tactic to Weather
Matching Munition to Target
Matching Munition to Aircraft
Matching Tactic to Munition
Matching Aircraft/Munitions to Tactic to Threat
Matching Aircraft/Munition/Tactic
Selecting Aircraft/Munition/Tactic for Target
Minimize Exposure Time (function of tactic)
Identifying when not to Retask
Forcing a Retask/What Prompts it/What Priorities
When to Reconfigure Ground Alert Aircraft
Formatting Data for Aircrew (based on aircraft location and specific retasking)
Filtering of Mission Feasibility (Weather, Range, Assets Available)

The following two chapters describe how these individual kernels may be evaluated when implemented and attempt to predict some of the anticipated results. The suggested set of evaluation criteria is provided in Chapter V. The conclusions and recommendations of this research effort are contained in Chapter VI.

V. Evaluation Criteria

Introduction

The evaluation of a DSS is used to determine whether the decision makers are using the system and whether it is helping them in their decision processes of judgment and choice. The following chapter delineates an evaluation strategy for the specific elements of the designed DSS following initial prototype implementation. Sprague and Carlson describe four measures which can be applied during an evaluation of a DSS (35). Sweet and others involved with the Military Operations Research Society have conducted command and control evaluation workshops to force development and improvements in this area (37). The following paragraphs will apply these two evaluation methodologies to selected kernels identified in the previous chapter and offer criteria for their individual evaluation.

An important by-product of the evaluation of any DSS is that it can suggest areas where the system might be improved or expanded to assist the decision maker. An evaluation can give insight into an expanding or changing problem domain or even help forecast future decision requirements unknown to the user. Because an evaluation produces benefits by checking system performance and providing possible areas for system improvement, the evaluation becomes a vital exercise in the iterative design process. If the system is not being used, then the evaluation must take on a different focus which is to examine the reasons why it is not being used. In the end, the evaluation of a DSS should present a picture of what the DSS is supposed to do, and then measure it (44).

There are certain criteria which are important in evaluation even if they are not quantifiable. It is important not to overlook those types of criteria because they often reflect the system's quality performance as judged by the user. Although often easier to collect and evaluate quantifiable measures, the key to an effective evaluation is often the user's feelings, likes and dislikes with the system. The evaluator should ask why the system is being evaluated, then make sure that the evaluation criteria applies to that purpose.

Sprague and Carlson

DSS, as evaluated by Sprague and Carlson, should address four measures. These measures will be briefly described and then applied to the retasking DSS design.

Productivity Measures. The evaluation of a DSS by specifying measures of productivity is in the real sense measuring the DSS impact on the decisions being made. Specifically, the information should be displayed in 'real time' so that the decision maker is capable of making timely decisions. The DSS should be evaluated to determine whether the added cost of the decision aid itself is less than the cost of making bad decisions, and to determine that a better decision is being made with the DSS than without it while simultaneously meeting overall mission objectives. Although a DSS cannot creatively generate alternatives, if the interaction between the user and the decision support system results in more alternatives being considered, the DSS is probably improving the decisions. More importantly, the DSS should afford the user alternatives which are cost effective to implement; alternatives which can be implemented in time to make a difference.

Specific criteria for this measure could evolve by using the system and feeding it inputs provided during a previous conflict or exercise. The time required to make decisions should be measured and compared to those times required during the previous exercise when not using the system. Input new weather information for a given target area to FIDOs with and without the DSS. Measure the differences in their planning time for retasking assets. Beginning from a static situation, change the parameters on the screen displays one at a time and observe the planning time deviations. Use these measures to identify the most time sensitive and critical components of the storyboard. Expand these time sensitive components in subsequent versions to enhance the system.

At what cost has this increased ability to make decisions by centralizing the command and control process affected the flying units and their performance? Can the aircrews act swiftly enough to the mission changes offered by the decision aid? If the limiting factor is the communication links or ability of the aircrews to perform in-flight planning, then possibly the appropriation of funds should be directed toward research in those areas rather than into the decision aid. Use the system during exercises at Red Flag or the Army's National Training Center and measure how the aircrews, command center personnel and maintenance sections react to the new aid. Measure the amounts of munitions delivered, the effectiveness of meeting times over targets, and the delivery accuracy for retasked sorties.

As a result of this increased decision making power have we truly made an impact on the battle by getting inside the enemy's decision cycle and planning process? Can we really force the enemy to react to our planning process? Wargame simulation with a well trained aggressor force would provide data on how the enemy would react when confronted with retasked AI aircraft employing the best munition-to-target match with the best tactic-to-threat match. Measure the number of enemy deviations from his game plan. Observe how the enemy rearranges his threat arrays to defend his targets as a result of our retaskings and our tactics-to-munitions matches. Examine the increased flexibility provided by the system for our forces; are they performing their missions as trained or are they waiting for orders? How rapidly can our forces adapt to the changes introduced by the procedural implications of the system?

Process Measures. These measures attempt to evaluate the influences and impacts on the decision making viewed as a process. The types of processes which are examined in this area include the formulation, analysis, and selection of different alternatives. The idea is to measure a change in the number of alternatives which are made available to the decision maker because of the existence of the DSS. Necessarily though, the alternatives should be analyzed using a DSS sensitivity analysis. The decision maker should have access to the data relevant to the generation and the selection of alternatives. By analyzing how the decision maker uses the data, further investigation of the decision processes is possible.

Process evaluation encompasses an analysis of decision making. The decision cycle process should remain short enough so that the forces under the decision maker's control can be tasked to perform their missions and functions in time to make a difference in the overall outcome of the situation.

Measure the number of different courses of action which have been examined. Measure the amount of time which a user spends on any one particular screen display. Observe the pattern of displays for different FIDOs. What are the common patterns among different operators? Does the system support the different processing patterns for the different FIDOs? Which FIDOs are the risk takers, and which are averse to risk? Measure the differences in the number of targets destroyed, munitions expended, sorties flown, and aircraft attrition for each user.

Determine who are the key players in the decision making process. How are they linked organizationally and how do they communicate with one another? Measure the system's performance in a degraded mode with communication links removed. Examine the player's situational assessment and selected courses of action when only partial information is given and sensors are not operating.

How much data is being used? How much historical data which was collected prior to the conflict on the enemy's behavior has changed during the conflict (his pre-determined patterns versus his actual conduct)? Measure the data flow from the sensors versus the data flow output to the forces. Measure the number of times when an aggressor force changes its method of operation because of the existence of the new decision aid and its added capability. Using the aid at the National Training Center, Fort Irwin, California, retask BAI sorties against the predetermined tendencies of the aggressor force and note how the enemy's objectives change. Record the number of times that the retasked sorties are able to influence changes to the enemy force's plan or objectives. How long does a user take to analyze a situation? Set time limits on the duration a screen display or frame is in view. Determine if at a certain point FIDOs have gathered enough information to make the intelligent choice without getting involved in obtaining the perfect solution in an imperfect situation. Again, measure the time to assess situations by using the differences in time from the activation of a retasking trigger to the actual decision to retask.

Is the DSS time responsive to the commander? Does it maintain a simple structure to prevent overloading the FIDO? How well does the system aggregate essential data elements? Inject erroneous aircraft, threat and weather information into the system to test the performance of the feasibility filters. Measure peak power requirements when the system is heavily overloaded by inputs and outputs. Use previous battle results and compare the actual aggregate versus machine batch results using individual item inputs.

Perception Measures. The impact on the FIDO, the decision maker, is the focus of this measure. This type of measure tries to determine how easy the DSS is to use from the user's perspective and how comfortable the decision maker is in the decision making process. It is based on the user's degree of control over the situation. This type of measure should determine if the decision maker feels confident and trusts in the decision resulting from the use of the DSS. More importantly, the decision maker should perceive that the DSS has enabled him to understand the problem better.

Is the DSS user friendly? How much on-line help is available (documentation)? Embed training which monitors the FIDO performance and tailors the system to the user's experience with the system. How often is the help function used? Is this a result of the complexities of the DSS, poor user training, or a misinterpretation of the process? Does the user really have the luxury to spend time with the help function when aircrews and munitions personnel are waiting for guidance? Experiment with the system involving a group of trained and untrained FIDOs. Conduct a simulation and develop questions which may be answered and weighted to afford statistical analysis of the user's perceptions of the DSS. Such questions may be:

1) Do you like the mouse driven control?

2) What other data would you like access to?

3) Are the color graphics pleasing?

4) Should different symbology replace present icons or images

5) Should the user have control over his environment and customize his displays to accommodate personal preferences?

Is the retasking problem presented in a format which is easily understood? Again, a survey may be the best approach, with short answer questions or a multiple choice good-marginal-poor grading scheme.

Is the system transportable and interoperable with the sister services and allies? Insure that the system is compatible with delivery modes (airlift and sealift). Query allies to determine what they think of the decision aid, how it could be modified to meet their doctrinal requirements, and ask for their critical ideas of the system. Conduct a full-up command and control exercise with an allied command structure at the Warrior Preparation Center and solicit the allies perceptions, observe their decision processes with and without the system in use.

Product Measures. These types of measures attempt to weigh the technical merits of the DSS. To mea ure the system's productivity, it should be examined for operational cost effectiveness and it should require little training of new personnel. The DSS should be reliable, requiring very little maintenance while operating under "field" conditions. Additionally, the evaluation should insure that the system is able to respond to new information quickly, and not hinder the user or his decision process by forcing the user to wait for interactive queries or responses. The DSS should be a step ahead of the user, nearly anticipating the user's next command. This could be accomplished through a historical mapping by the machine of the patterns which the user has followed to make previous similar decisions based similar situational factors.

Who is responsible for the software updates? How quickly can software changes be accomplished? What is the down time when this occurs? Take the system out of the laboratory to a wing command post and have their personnel maintain the system. Give them system update tasks to perform and measure the time required to perform those functions. In other words, develop an update-type test plan and see how well the average command center personnel can perform compared to the expected results listed in the test plan. Is outside assistance required for these updates? Can the command center personnel keep the the system in a deployable configuration? Can they rapidly tear down and set up the system? Conduct a field test by deploying the system from a operational location to a field exercise at Blue Flag or other command and control exercises.

Is the DSS survivable, rugged, and redundant? Are we so dependent on the new system that everyone has forgotten how to do business without it (writing backwards with grease pencils on plexiglas)? Place the DSS in the command and control center during an exercise. After a period of time, unplug the system and observe how well the personnel can handle the situation and how well they revert to previous methods of operation. How long does it take to train individuals on the use of the system? Train both career FIDOs and augmentees from various backgrounds. Get supervisor feedback on the trained individual's progress in performing their duties during operational exercises.

What are the monetary costs of bringing the system from the initial conceptual design to a working prototype which would be usable in an operational exercise? What are the operating and maintenance costs? Perform a cost analysis to determine an answer to the question of how much it is going to cost for a particular level of effectiveness. To answer that question, it may be necessary to relate the cost to effectiveness by a ratio such as dollars per retasked ton of ordnance delivered. Compare the effectiveness of a set of aircraft whose mission profiles have not been altered with a group of retasked sorties. Use as measures of effectiveness the number of aircraft lost and the delivery accuracies for each group.

Command and Control Workshop

The ultimate goal as presented by the MORS command and control evaluation workshop is to identify the mix and match of applications, boundary conditions, models, measures and techniques for data collection. It is emphasized that this evaluation should be accomplished without interfering with the decision making process of the user. There were four categories identified by the workshop which should be evaluated. The following paragraphs address these categories and suggested criteria and questions.

Physical. The evaluation of this area encompasses the computers, peripherals, modems, antennas, and people. The dimensional parameters and the properties or the characteristics of the DSS are used as the measures of merit. Typical measures in this category include an evaluation of the DSS to determine its size, weight and power requirements. This is necessary to insure the system can be deployed and is durable in a mobility configuration. Can the power requirements be supplied by the tactical air control system? What is the screen resolution? For large, wall mounted screen monitors, can the images been observed clearly from various angles within the command center?

Structure. The structure of the system applies to the arrangement and the interrelationship of the standard operating procedures, rules, concepts of operations and information patterns. It reflects the doctrine which is being modeled. Measures of Force Effectiveness (MOFE) are developed as a criteria for evaluation of the structure of a DSS. What is the data rate to the system? How does the system function, if at all, when communications links are disrupted? How many links or communication nodes can be removed and still permit efficient operation in that degraded mode? What is the error rate of the sensors supplying the information to the system? How is the DSS to be supported by the logistical system?

Function. The measures in this area cover the behavior of the system such as sensing, assessing, generating and selecting alternatives. Measures of performance (MOP) are used as the variables of system behavior. How susceptible is the system to jamming or command, control and communications countermeasures? Is the system getting the proper intelligence support? Does the DSS receive inputs from redundant and backup sensor sources and intelligence centers? Are reports being received from every available national intelligence asset or is certain information withheld without consideration of its possible mission impact?

Boundary. This area concerns itself with the delineation between the system and the environment. Outside of the boundary measures of effectiveness (MOE) are used as criteria. Possible MOEs include how many targets are being rendered useless and comparing that with the individual target priorities. What are the aircraft loss rates and how do they compare with the enemy's loss rates? How much of the enemy's air defense assets have been expended in an effort to prevent the attack? Measure the overall reduction of enemy air defense capability and compare that with a tracking of the enemy's air and ground orders of battle.

Summary

Specific measures of effectiveness measure how the system functions within an operational environment and the measures of performance measure the inherent physical and structural parameters of the system. The following specific criteria for those two measures apply to the retasking storyboard design and represent a summary of the two methodologies described above.

1) Are sufficient memory aids provided which make it possible for the FIDO to remember the results of his previous decision process?

2) Is all relevant information necessary for making the decisions presented on the displays?

3) How many times on the average does the FIDO iterate through the storyboards and the options before he makes a decision?

4) What is the average time spent on any one display or window frame?

5) How many times does the FIDO repeat a reference to a display before he makes a decision?

6) What confidence level does the FIDO and his commander place on the recommended alternatives?

7) Can the FIDO learn to operate the system in less than one day?

8) Are changes in the threat, weather, and weapon availability reflected by the system in time to select alternatives within the decision cycle?

9) Does the FIDO arrive at a decision which can be implemented before the target, threat, or weather changes his decision?

Conclusion

These general evaluation criteria can be applied to categorize potential areas for evaluating individual kernel systems. The ability of the DSS to increase the effectiveness of the air interdiction forces is difficult to evaluate. As a "force multiplier," the measurement of productivity would also be hard to define. In either case, the evaluation produces results which are more directly related to the specific purpose of a DSS which is that of being a tool to aid the decision maker in the decision process. These criteria can best be used to evaluate systems which are already operational and in the field. Systems which have not been employed yet are very hard to evaluate for force effectiveness. However, given proper simulators and test conditions, such as those which may be found at the Warrior Preparation Center or at Blue Flag exercises, the DSS could be evaluated under realistic conditions using most of the criteria identified above.

After specifying the evaluation criteria, the analysis must continue by generating data through the use of the system in exercises, simulations, experiments, and a more detailed look at a set of subsidiary objectives. These data measurements may then be aggregated to form the basis of the evaluation analysis, permitting the adaptive design process to take hold. Although the ability exists to closely simulate the conditions of an actual conflict, the best test of the system would only occur during actual wartime conditions. If an opportunity presented itself to introduce the system in a conflict involving our allies, valuable insights into system enhancements could be gained.

In conclusion, evaluation is a necessary and important part of the adaptive design process. As a first attempt to define a retasking DSS for the *FIDO* and the air interdiction mission, a large and complex problem, the system must be expanded through the process of evaluation and iterative design. Any kernel identified during this design process, when implemented, may not work for the users completely. The evaluation of the individual kernels will require checks to determine an accurate and reliable system. The next chapter presents the conclusions and recommendations of this research.

VI. Conclusions and Recommendations

Introduction

This research has taken the adaptive design process and the technique of storyboarding and applied them to the problem of retasking air interdiction assets. This approach has provided a process of incrementally changing a system's design through an inexpensive, hardware independent approach to the rapid prototyping of command and control systems.

This chapter will highlight the conclusions and recommendations which were discovered during the adaptive design approach to the problem of retasking air interdiction aircraft. The observations and issues presented at the end of this chapter are offered as further insight into future directions for the command and control structure in support of the air interdiction mission.

Conclusions

Many objectives were pursued in this research. The major objective was to investigate the processes by which an air interdiction FIDO would retask the essential mission elements of the air tasking message. This objective is addressed by individually referring to the steps taken to adaptively design this retasking DSS. At the conclusion of these comments, a list of recommended extensions to this thesis is presented.

The first conclusion that can be drawn is that decision support systems and the adaptive design process facilitate the digestion of large, complex, unstructured problems. The ability of a DSS to involve the user early in the design phase of this type problem, where the initial difficulty is often simply defining the problem cannot, be over emphasized.

Concept Maps. The use of concept maps allowed this researcher to initially visualize the problems associated with the command and control of air interdiction assets. An initial cut at the identification of the problem proved to be concept mapping's greatest benefit. The concept maps also proved to be a very useful transition from the user's perception of his problem to the displays with which the user might wish to operate. The process of going from the concept map to the storyboards initially required the development of a feature chart, but once the retasking triggers were established, the use of the feature chart for mapping the decision processes was not required.

Storyboards. The purpose of the storyboard is to allow the user to transfer his or her ideas to the designer. As such, they were the tool used in the initial design phase of the overall system. The use of screen displays for mapping the decision processes of the user proved to be a powerful tool. By applying the adaptive design approach to the storyboarding effort, several required processes were identified for the retasking of air interdiction aircraft.

The adaptive design process was used to incrementally change the storyboards from the first version to version 2.0.

Oftentimes, when faced with complex, unprogrammed situations, a decision maker seeks to reduce the decision process into sub-problems to which he applies general purpose, often interchangeable sets of procedures and routines. The storyboards provide the user with a means of demonstrating to the designer those smaller sub-tasks which he or she performs. In essence, the decision maker can use the storyboarding technique to factor the unstructured situations which he or she has difficulty visualizing and through the development of screen displays present them to the designer in a familiar, structured format.

Why DSS. There are basically four significant ways in which the retasking of air interdiction assets usefully employed a DSS to aid in identification of the decision processes:

1) The amount of information is so large and the present access to it is so great that the user has great difficulty in grasping the individual pieces of information and their interrelationships.

2) The information must be 'worked on' to generate alternatives or solutions. Alternatives need to be formed and some type of alternative prioritization is required.

3) The need for judgment either to recognize or to decide what constitutes the sub-problem, and to iteratively create alternatives is necessary.

4) As new information is discovered and proven significant or related to other data, some previously incorporated data requires removal.

The vast proliferation of computer assisted tools such as are now available in the areas of expert systems, artificial intelligence machines, and advanced data base management systems have provided a recent impetus toward demonstrating the true significance and power of decision support systems. This researcher believes that DSS will become the leader in the command and control arena by virtue of its ability to capture the decision processes and even more so through more complete and detailed implementations using the newer, user-oriented tools. Thus, DSS will become the integrator of the formerly traditional tasks of data base management and decision oriented approaches to problem solving by identifying the decision processes involved in solving a problem and relying on user "hands on" interface with these advanced tools.

Still a further benefit of DSS is realized when dealing with problems which do not always fall into one of the two categories of structured or unstructured problems. The problem may appear at one time structured and at another time totally unstructured to the decision maker. The context of a problem's particular environment or time phase within the decision maker's process dictates the degree of structure. Scheduling during increased readiness demands an increased dependence on judgment, because decisions must be reached under conditions of relative uncertainty. More rapid priority changes and increased personnel pressure mean rapid alterations. More changes mean that a DSS becomes a more desirable approach, especially since the keys to an effective air interdiction campaign are responsiveness and flexibility, keys to which a fully automated, structured system cannot continuously respond.

DSS and Operations Research. Perhaps one of the primary benefits of using DSS as an approach to attacking this type problem is the ability of a DSS to maintain knowledge about the problem domain during the building process through the use of a hook book and user involvement. As the user's perception of the problem changes, the DSS is able to capture that new knowledge while still maintaining the vast amount and assortment of previous facts and their relationships as perceived by the decision maker. This was found to be the case in going from the first to the second version of the storyboards. Following user evaluation of the first set of storyboards, it was determined that a "front end" was needed to emphasize the decision processes of retasking and thus the design of the second version of the storyboards.

Commanders will always be leery of computer aided systems which depend heavily on invisible models and tend to give a single answer with the simple push of a button. DSS can provide those commanders with a "comfort" level. A commander can develop high degrees of confidence in a system when he is aware that a DSS begins the building process from the user's perspective and solely with the user's desired output as a starting point. The DSS allows the user to work the problem from the decision process viewpoint, indicating where certain operations research models and techniques may fit, allowing the user to develop that comfort level as the system evolves rather than having a design team brief the user after the system has been built (i.e., when the system may no longer fit the user's needs or perceptions of the problem domain).

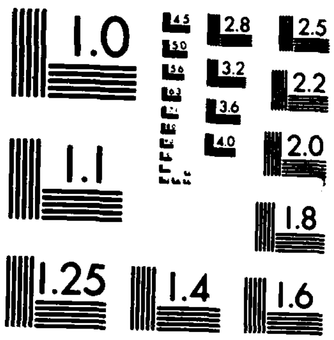
The decision support system approach to problem solving proves itself to be a strong means for building a bridge between the user in the operational commands and the DSS designer. The technological gap is growing between the users' problem domains with their inherent inability to articulate those problems properly and the designers' increasing availability of tools with the ability to service the needs of the user. The gap is growing and needs to be bridged. DSS offers both sides of this gap a better opportunity to communicate the set of problems and decision processes involved and offer possible designer solutions by using storyboards.

Although as mentioned earlier the commander may be leery of an automatic analysis without user involvement, the very nature of the retasking problem and the time constraints of the compressed decision cycle necessitates some degree of automation internal to the DSS. Model identification is a crucial step in the design of a DSS. For example, expert systems embedded within the system could prove an excellent technique for the prioritization of the retasking triggers. Thresholds could be set for particular occurrences and when a threshold was exceeded by the system, rules could be fired to prompt the user to proceed to a higher priority retasking venture. Inferring data from the tactical situation and offering alternatives would first require a detailed knowledge engineering study, a study which lends itself extremely well to the DSS approach of storyboarding as offered in this research.

Several other areas where models may apply in future implementation of the system are suggested. Forecasting would lend itself to the formulation of patterns and anticipated enemy movements. It could be supported by an expert system with a pattern directed inference engine to aid in the determination of enemy intentions, while multi-criteria decision making could narrow the attack tactics and options by providing expected results. Several linear programming packages could constitute the necessary module for the assignment of resources to a given target, while the actual deconfliction of routes could be handled through a networking technique. Both simulation and linear programming would support the user's ability to experiment with the options provided, and offer an optimal or sub-optimal solution.

Early and frequent iteration will produce a quick identification of the decision processes even if the mode base is not incorporated into the system. It is noted [illegible] both the second version of the storyboards and the

AD-A185 234 DESIGN OF A DECISION SUPPORT SYSTEM FOR THE DYNAMIC 2/3
=RETASKING= OF AIR IN.. (U) AIR FORCE INST OF TECH
WRIGHT-PATTERSON AFB OH SCHOOL OF ENGI.. J A SCHOECK
UNCLASSIFIED JUU 87 AFIT/ENS/GST/87M-15 F/G 15/6 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

reconfiguration storyboard would require a model intensive underpinning to produce the graphic and probabilistic requirements necessary to meet the user's needs. However, the design of the DSS should not initially be constrained by any particular set of model requirements. The user should merely inform the designer what is needed in the form of output and storyboards and have the designers supply the necessary model base. The importance of incorporating models into the system is one of the major implementation steps and will afford an expanded view of the problem definition for subsequent iteration and evolution.

Recommendations for Further Research

The identification of the processes by which the FIDO makes the decisions to retask air interdiction assets require prototyping. The need now exists to approach the problem through the implementation of a portion of the system. Attention should be focused on the retasking of BAI aircraft missions at the ASOC level. By initiating a prototype design at the ASOC level, where current retasking requests in the form of air tasking requests originate, strong user interaction and insightful feedback from the organization will allow this research area to expand and to accelerate with the technological growth of the weapon systems.

While this research made advancements in the understanding of the basic approaches to solving a complex problem, a great deal of work remains. Several areas are recommended for further study. They are:

1) Reaccomplish the storyboards with multiple users several times considering the entire system and then implement only what is considered by those users to be the most beneficial contribution to their task <u>now</u>.

2) Examine and develop kill rates per sortie by target and weapons load.

3) Examine and develop partial sortie effectiveness rates considering all those things which prevent a particular sortie from achieving 100% effectiveness by target type, aircraft and weather.

4) Prioritize the retasking triggers (by scenario if necessary).

5) Implement a portion of the system (reconfiguration storyboard) at the squadron level during sortie surge operations.

6) Evaluate and test the system in a command and control exercise such as Blue Flag.

7) Field the system in an operational flying exercise for a period of time. Have multiple exercise participants use the system and provide their inputs and evaluation at Red or Green Flag.

8) Further emphasis is needed in both the area of evaluation criteria and the investigation of more specific model placement within the overall system design.

9) Investigate the retasking of BAI aircraft at the user end of the spectrum by exploring the opportunities presented to an ASOC authorized to retask dedicated BAI ground alert aircraft.

10) The need exists for software designed to facilitate the creative construction of storyboards.

A further description of this point is required. Features which this storyboard software should possess include color, graphics, audio tones, and multi-display windows. Simple overlays including various highlighting modes and the ability to change the speed and intensity of a flashing or blinking display should be provided.

The ability of the user to sit beside the designer during the storyboarding process would greatly enhance process identification. This software could allow users to build and maintain their own storyboards and then have the designers determine the means for arriving at the output.

Additionally, a network of DSS storyboarding machines would enhance user-designer interface. The ability of multiple users to work with a designer through the use of mail and phone facilities would permit rapid sharing of new ideas and concepts, increase the number of iterations of user feedback, and allow for the free flow of suggestions and alterations as the designer introduces them. Simple test case model bases could accompany the software package to allow the user or designer the opportunity to experiment with different model constructs as they apply to the system, expanding the system as it is being designed.

Two important aspects of the adaptive design process require emphasis for future DSS designers. This research would have made a larger contribution if after an initial investigation of the problem area, an immediate selection of one of the subproblems or kernels had been made. Subsequent implementation of the selected kernel would have afforded a stronger anchor point for the overall DSS design rather than the broad, general scope offered in the second version of the storyboards. Thus, the two important aspects of selecting and implementing a small kernel should become the focus of any future research.

Final Conclusion

This thesis has identified that the ATO tasking system in place in NATO ATOCs is not presently capable of directing our future weapon systems and exploiting the increased flexibility which they will provide. The command and control structure in place does not fully utilize the expected inputs which intelligence sensors and fusion centers will be able to produce. The major contribution of this thesis is to show that a design strategy is possible and indicate where the same technological advancements improving our weapon systems can be used to help the FIDO redirect AI assets.

In conclusion, the adaptive design process and the decision support systems methodology works, and works well for problems of seemingly overwhelming size and complexity. The primary advantage of the marriage of the two concepts is the chunking of the problem space to help identify those areas where the greatest impact on specific problem solution can be made with the greatest chance of succeeding.

The future presents a challenge for all: to provide answers to complex problems, which are difficult and vague, and to package those answers for tomorrow's leaders in the most meaningful way possible.

<u>Review of Assumptions</u>

There were three basic premises which were used to develop this thesis. They were devised to help move forward and improve the way we think about the command and control of air interdiction assets, but they often became a driving force and inspiration.

<u>Improvements in Collection</u>. The capability of sensors to identify and categorize both friendly and enemy assets will soon allow the commander a view of the battle as it unfolds. Target prioritization and the fusion of information will permit anticipation of the enemy's next move and his objective, while simultaneously exposing vulnerable areas for exploitation. Effective information management will allow coordination of our actions so that we move at the time and the place where the enemy is most vulnerable.

<u>Improvements in Execution</u>. The weapon systems of the future will have the capability to receive this updated sensor data in a digestible format. With an ability to capture such real time data and display it in a "super cockpit," and with an ability to plan and replan "on the fly," the air interdiction assets will have an increased

flexibility unmatched in modern times. Additionally, defensive systems will allow them to penetrate and operate singly with a reduced need for mutual support.

The Continuous ATO. These improvements in collection and execution would prove useless without a command and control system dedicated to exploiting their by-product of increased flexibility. A push toward the development of a twenty-four hour warfighting attitude and the doctrine to support it is necessary. This effort will insure that the technological advantages which our forces currently possess can best be used and maintained. Immediate tasking and retasking of the AI assets while the tactical situation changes would allow our forces to maintain the initiative.

Observations and Issues

The following topics were selected from the hook book for an expanded explanation. They represent observations and issues which were generated during the detailed work of storyboarding as well as during the less rigorous moments of contemplation on the subject of command and control and the accompanying challenges. These thoughts and ideas are of a more lofty nature, but demand attention. They are the really important issues that arose during this approach to the retasking problem. They were captured and formulated because this approach forced the researcher to spend more time 'up front' investigating the problem.

Where Should We Micro-Manage? Technological advances have produced a tremendous capability and overwhelming number of options for prosecuting the missions assigned to the air interdiction forces supporting the ground commander. Even more exciting are the forecasted capabilities on the drawing board and those already in development. Smart/multiple delivery mode munitions, instantaneous data communications, super cockpits with multiple displays, and improvements in sensor collection have produced an extremely detailed picture of the battle and provided a variety of alternatives toward accomplishing specific mission objectives.

Additionally, the command and control structure has improved its ability to "see" the battle. With vast amounts of information flooding our operational control centers, the commanders will be able to anticipate enemy movements, possess real-time status of friendly forces, and be able to generate and play out different battle strategies before committing resources.

The question arises, where do we want to micro-manage our air interdiction aircraft? There are two extremes. At one end of the spectrum, we can give each aircraft and aircrew a package of information which pertains to their objectives and mission. The last real command we give is "Cleared for take-off." They prosecute the mission on their own with little or no control from the command center. They use their judgment and decision making abilities to analyze the data as presented and 'manage' their aircraft to complete their mission.

The opposite end of the spectrum is the RPV mentality. The aircrew is just along for the ride. Almost all of the decisions and choices are made by the controllers back at home base. These controllers possess the information and overall game plan. As warlords, they micro-manage the practically pilotless aircraft on its mission, 'managing' it during every phase of flight, like a remotely piloted vehicle.

Technology will allow us to proceed in either direction. Presently we have the choice to demand from it one approach or the other. In the not too distant future, however, without selecting a course of action now, technology will dictate the path that we will take.

A choice exists between developing highly automated (RPVs) or deeply human dependent weapon systems (aircrews). A mixture seems the prudent choice. Guidelines are needed with which we can channelize their individual advantages when attacking a target. Is technology closing the time gap to the point where we can act more judiciously with increased flexibility through centralized control AND centralized execution?

Communications vulnerability is the weak link in our command and control structure. The vulnerability of any communications system to a technological breakthrough rendering it useless suggests that we not put all of our decision power at one location with one system and one centralized user. But there is still another insidious danger which makes our system vulnerable to future exploitation -- predictability through structured automation.

An advantage can be gained in any conflict if the enemy becomes predictable. The need exists to insure that our computer dependent command and command control system directs our forces, as viewed from the enemy's perspective, in an unpredictable manner. A crisp, clean and fully automated command system may produce undesirably predictable tactics and strategies.

Humans are better at coping with the unexpected than are computers. War will produce unexpected, unanticipated situations which the programmed computer cannot handle. A human can map previous solutions and experiences through pattern recognition to the new problem domain. We need a human in the loop.

We need a mix of both simple aircraft with the man in charge, complex machines where the man is just along for the ride with limited veto power, and pilotless vehicles for those tasks which can be pre-programmed. At what level then do you aggregate these resources to insure that you gain the synergistic effects which comes with many users saturating a target area simultaneously? Coordination of strike packages for different priority targets will still be required at higher level.

Force technology to give the aircrews the necessary situational information and let the aircrews prosecute the battle. The higher echelon leadership should instill their thoughts, wisdom and desires during the peacetime training exercises. Let the aircrews achieve the mission objectives as they were trained to perform them -- assisted by the technologically advanced equipment.

<u>All Information at All Levels</u>? To what depth of the organization do we want to force our technological advantage? More importantly, what types of information are needed at what levels? Who or what is going to interpret the needs for this information? Does each aircrew member need an airborne DSS to sort the information, generate the alternatives, and choose a course of action? It appears that technological advances are moving us toward a more centralized warfighting strategy. Do we design our weapon systems to meet an anticipated future threat, or do we design them to expand and react to unknowns?

At what level do we decide to micro-manage? Do we make detailed analysis of the situation in the cockpit or do we perform this type of detailed analysis in the command center? Do we make all of the information oriented decisions at the highest level of the organization or do we force the technology to the lowest level? Forcing the information to the lowest level would have us moving toward an even more decentralized execution. The fighting units would be equipped to access the information that previously only command centers possessed. Although the fighting units would possess the information, it does not necessarily mean they have the knowledge to use it to their best advantage.

The choice appears to demand either operating, leading, and managing from a highly centralized perspective or giving the lower echelons the capability to make autonomous decisions in a deeply decentralized command and control structure. Which specific mission areas or tasks require a highly centralized plan or reaction to the enemy's movements?

When the command center knows more than the aircrew in the aircraft, who should make the decision? The aircrew wants the controller or sensor telling them the significant information they need to know. There is a great difference between informing the aircrew of the current situation and directing them how to do it. A training program aimed at the completion of mission objectives should have taught the aircrew how to perform the mission, adapting to the new situation.

For example, a forward air controller (FAC) would suggests ways of attacking a particular target, but it is up to the flight leader to decide what is the best tactic, formation and weapon setting. The FAC acts more in the capacity of an intelligence officer, giving fighters the most current and up to date information possible, and like a range safety officer, insuring that the friendlies are not placed in jeopardy. The flight lead wants to prosecute the mission with his tactics, his aircraft, his weapon load, and his wingman. Some would suggest that the FAC also helps the fighters locate the target. The new generation of sensors and signature related target identification schemes will replace the FAC. A likely adjustment to this improvement in target designation and selection would be to place the FAC onboard the JSTARS aircraft (a giant FAC, data linked to the aircraft through the command center).

It has been said that knowledge is power and information is knowledge, but I am not convinced that information is power. I really believe their is much useless information being collected which dilutes our war fighting capabilities, gives us a false sense of security, detracts from our overall ability to flex and respond in a timely manner, and in general, gets in the way. Everything we collect must have a purpose, right? There must be a statement of need indicating we require this particular piece of information for this purpose. Yet, too often we collect information simply because we have the capability to do so, hoping to fit it into the puzzle and produce a clearer picture, but with little regard to how it might fit or its real value. More time needs to be spent interpreting the information than collecting it.

Who are the real information power brokers in the air interdiction campaign? The command and control structure operates with experienced leaders who must understand the trade off involved between allowing inexperienced aircrew members time to become battle seasoned and learn slowly (aircraft survival) and the need to provide a knockout punch to the enemy (target destruction). There is not going to be one sortie which wins the war, but high value targets destroyed early in the battle will have a greater influence on the overall outcome than those destroyed in the fifth or sixth day of the engagement.

<u>Technology</u> <u>Versus</u> <u>Doctrine</u>: <u>Which</u> <u>is</u> <u>the</u> <u>Driver</u>? What is going to win the next conflict -- bits and bytes, or bullets and bombs? An argument should be made that the real determinant is how we manage these resources. Their relationship to one another through an insightful doctrine will produce victory. Their misuse will produce swift defeat. The doctrine on how we will employ those bits and bytes is sadly lacking at a time when we are becoming more dependent on those same bits and bytes to squeeze more out of the bombs and the bullets. Information doctrine is becoming more significant than the operational doctrine.

Goals drive our decisions based on how we perceive the environment around us. All the intelligence in the world will not help the decision makers if they do not have clear cut goals, established with purpose and supported by doctrine. In the case of retasking air interdiction assets, each FIDO needs clear goals so that he can make the choices necessary to plan the fight.

We are presently building sensors to collect all types of signatures and data. Someone must have a grasp of the overall collection plan. But someone is also needed to insure that the distribution of that information is available to everyone who needs it and that they receive the details in an aggregated format. Decision makers need to receive the information with proper consideration to the importance of one item over another. Training our future leaders requires that they know what kind of information is available so that they are are able to request that information which would most affect their decision processes toward making intelligent judgments and choices among a variety of options.

What will really make our future air interdiction forces powerful will be the command and control structure which we begin to initiate now. What should be the command and control system's capabilities and features? All knowing, all seeing? Let us decide that first using storyboards driven by doctrine, then force our technological industries to focus their attention toward increasing that power.

Once we have used the doctrine and storyboard approach to chart a path down which technology should take the command and control system and the executable weapon systems, it becomes paramount that security of these ideas be maintained. The developed approach must be protected in this era of information wars, because if the contents of the approach were exposed, our efforts would prove more useful to the enemy than to us.

Although every commander places the need for C2 improvements at the top of the list, the reason it remains there is because it is such a difficult a problem to solve for every occasion and circumstance. Commanders are serious about the issue, but too often the emphasis is misplaced. At almost all levels "looks" count. Sometimes only lip service is paid to the depth and guts of the new system while the looks and feel of the system get most of the attention. When a commander is leery of a system is he really worried as much about the accuracy of the system as he may be concerned with the larger issue of an over dependence on a centralized decision structure with no real fall back posture? The concern may be that too much dependence on computers will eventually destroy man's ability to be creative and think.

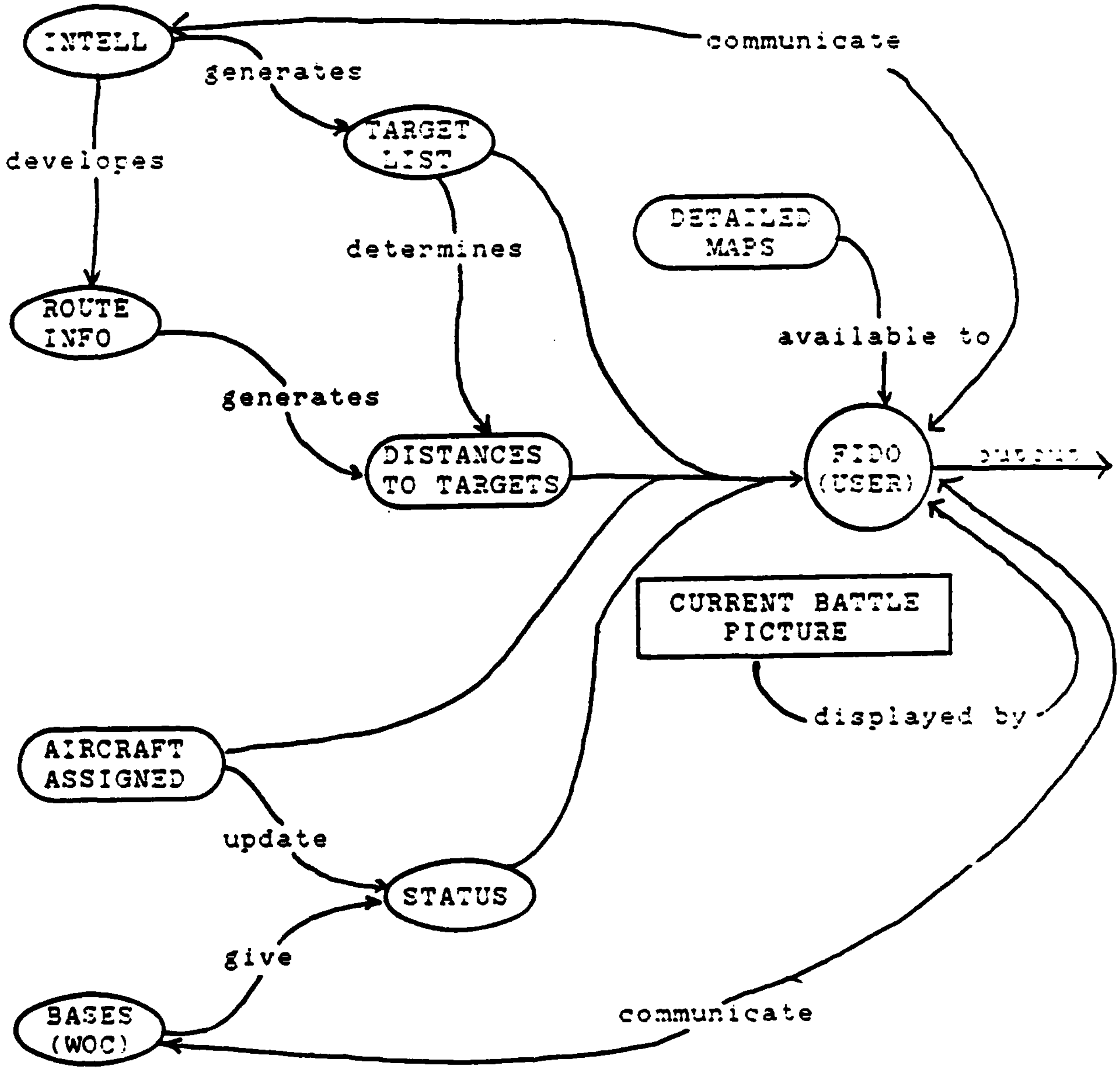
We presently fight the air interdiction battle using a preplanned mentality and a twenty-four hour cycle. This preplanning cuts deeply into the flexibility afforded immediate tasking of our resources. Our AI campaign should no longer revolve around a 24 hour game plan. Technology will let us reduce the planning time, deconflict the assets, increase the responsiveness of our forces, and in the long run, keep our aircrews and aircraft continuously flying.

A new concept for conducting the air interdiction campaign is needed. CAAP, the Continuous Application of Air Power, would use new technologies in order to make the enemy react to our initiatives. CAAP is envisioned as an extension to the RAAP concept, the Rapid Application of Air Power, viewed from the bomb and bullet rather than the bit and byte perspective. RAAP can determine from the intelligence sources where and when to attack the enemy (bits and bytes), while the operation centers would use CAAP to designate how and with what our forces should attack (bombs and bullets). These concepts are desperately needed as our command and control decision time cycle decreases in direct relation to the ability of technology to increase the flexibility and responsiveness of our air interdiction forces.

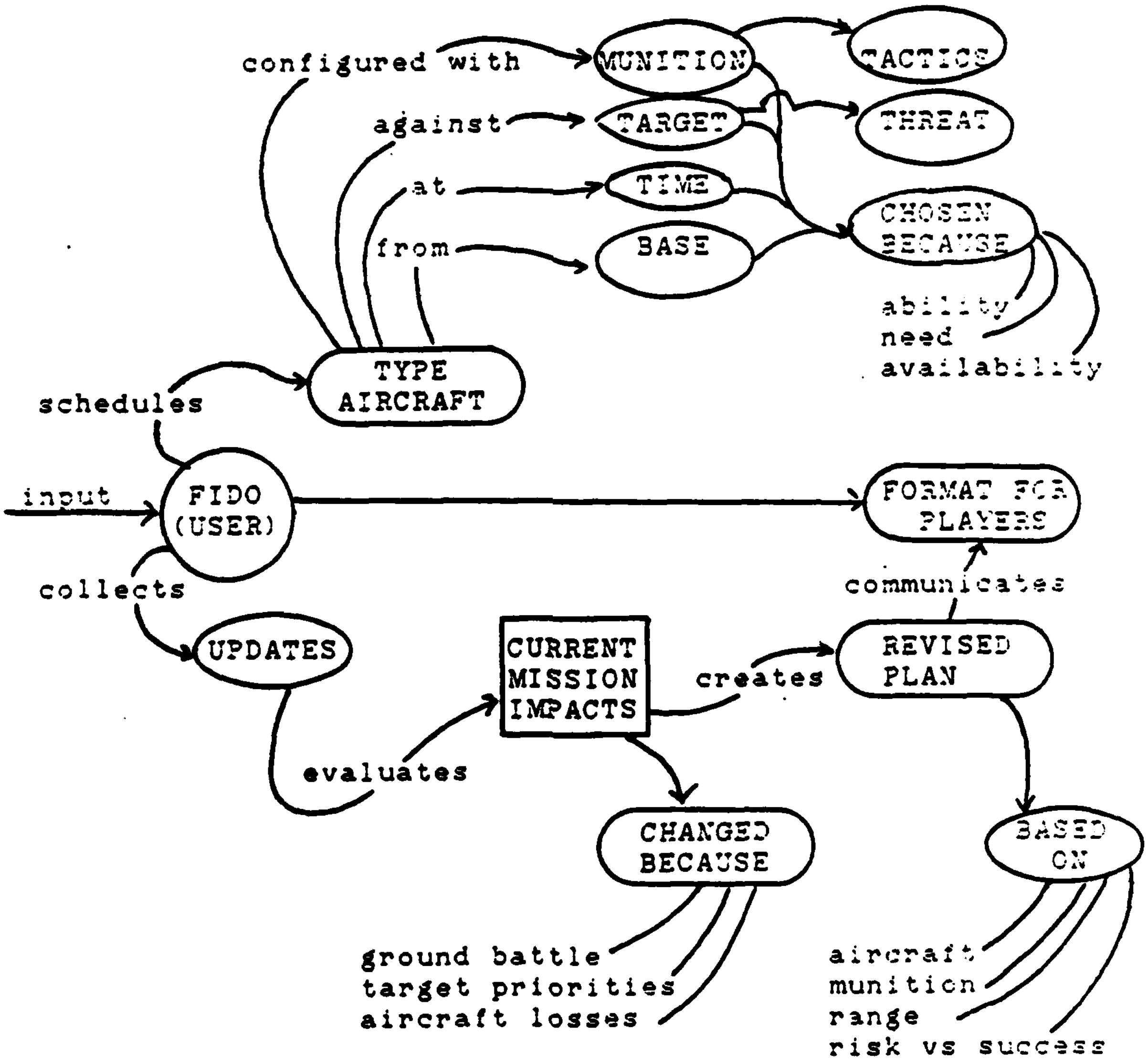
Appendix A: Concept Maps and Matrix

This appendix contains the concept maps for the FIDO retasking problem as explained in Chapter IV. An additional concept map for the reconfiguration of the air interdiction aircraft is also presented. The concept matrix which was developed simultaneously with the reconfiguration concept map is provided with an explanation of its use.

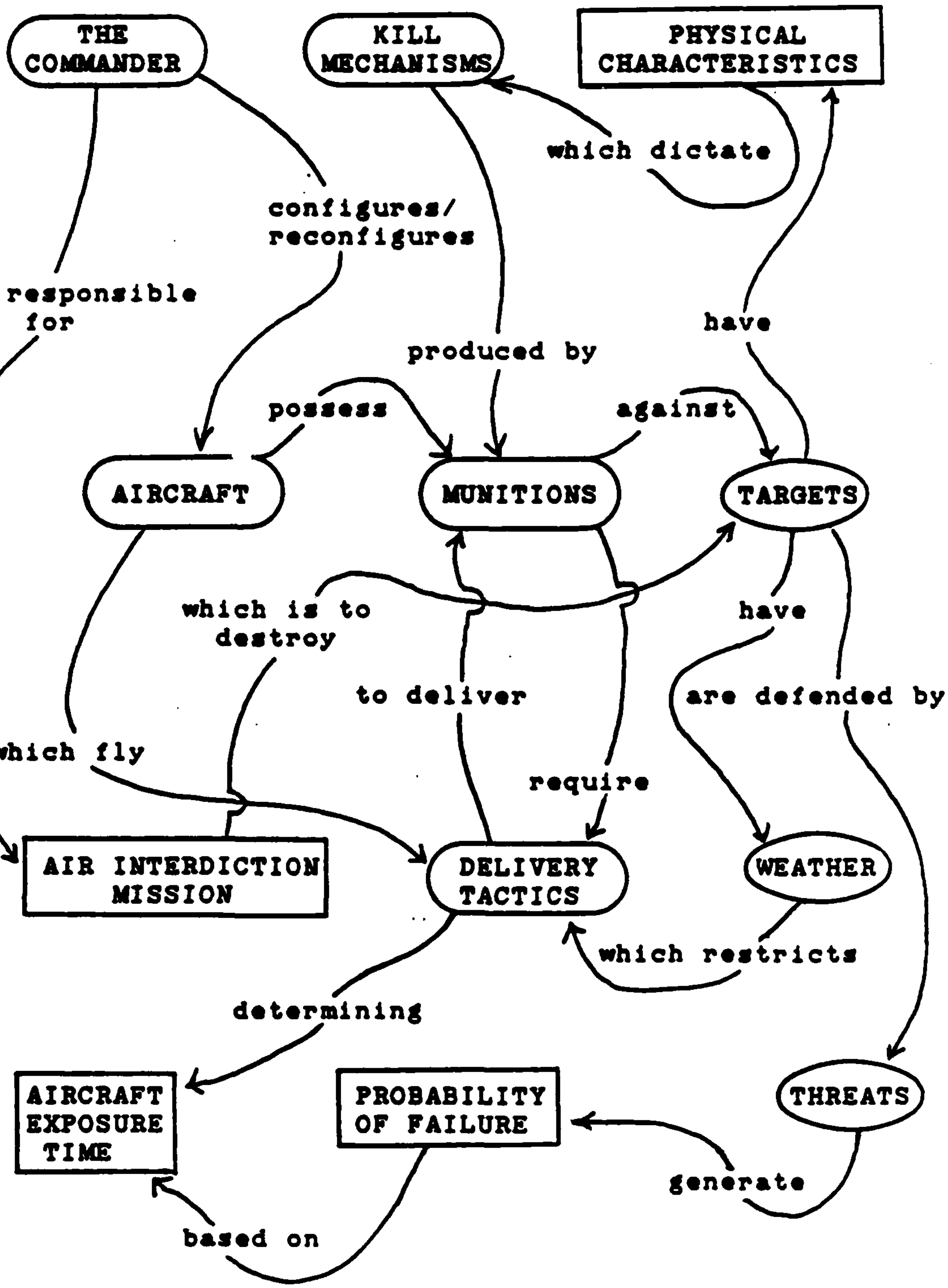
Concept Map -- FIDO Input



Concept Map -- FIDO Output



RECONFIGURATION CONCEPT MAP



Reconfiguration Concept Matrix

LEFT COL. AFFECTS TOP ROW	AIRCRAFT	MUNITION	TACTIC	TARGET	THREAT
AIRCRAFT	N/A	limits the type and quantity and the delivery accuracy	limits the type	acquires this has accuarcy versus this	is exposed to this engaged by this
MUNITION	is carried and delivered by this	N/A	restrict this requires certain delivery mode or signatur	sometime picks up target signa- ture	deli- very accur- acy, track time avail.
TACTIC	is limited by type of this and positions this for delivery	is dictated by the type of this	N/A	position aircraft to acquire this	exposes the aircrft to this
TARGET	is engaged by this	is damaged or not damaged by this	is acquired during this	N/A	is defend- ed by this
THREAT	engages this	dictates the delivery mode of this	dictates the ex- posure time	defends this	N/A

Explanation of Concept Matrix

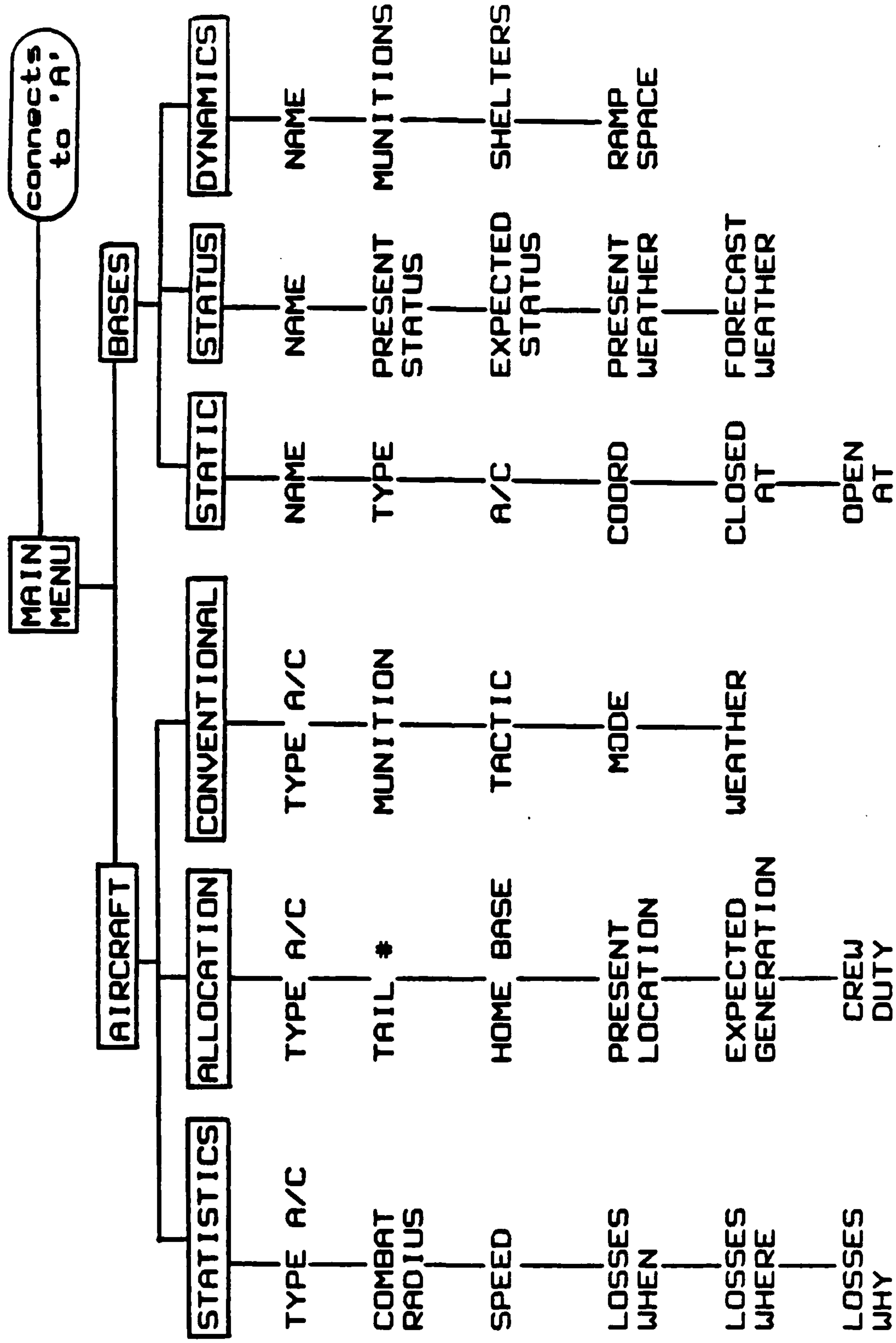
The concept matrix is useful for enumerating those key elements which may have surfaced during the development of the concept map or the building of the storyboards. The user lists the key elements across the top and down the left side of the matrix. The user then examines each block to determine the relationships between the two elements by beginning on the left hand column and asking in what manner the element on the left affects each element across the top row. Obviously the diagonal does not apply. It cannot be assumed that the matrix is symmetric, for two elements may have completely different ways of interacting with each other. Studying the elements separately from each viewpoint offers the user an uncluttered approach which may assist in breaking the problem into smaller, more meaningful subproblems or kernels.

As an example from the reconfiguration matrix, the AIRCRAFT "limits the type of" TACTIC, based on its speed and maneuverability, while the TACTIC "positions the AIRCRAFT for delivery" of the munition. Thus, each element viewed separately suggests different levels of importance when addressing the question of reconfiguration of AI aircraft.

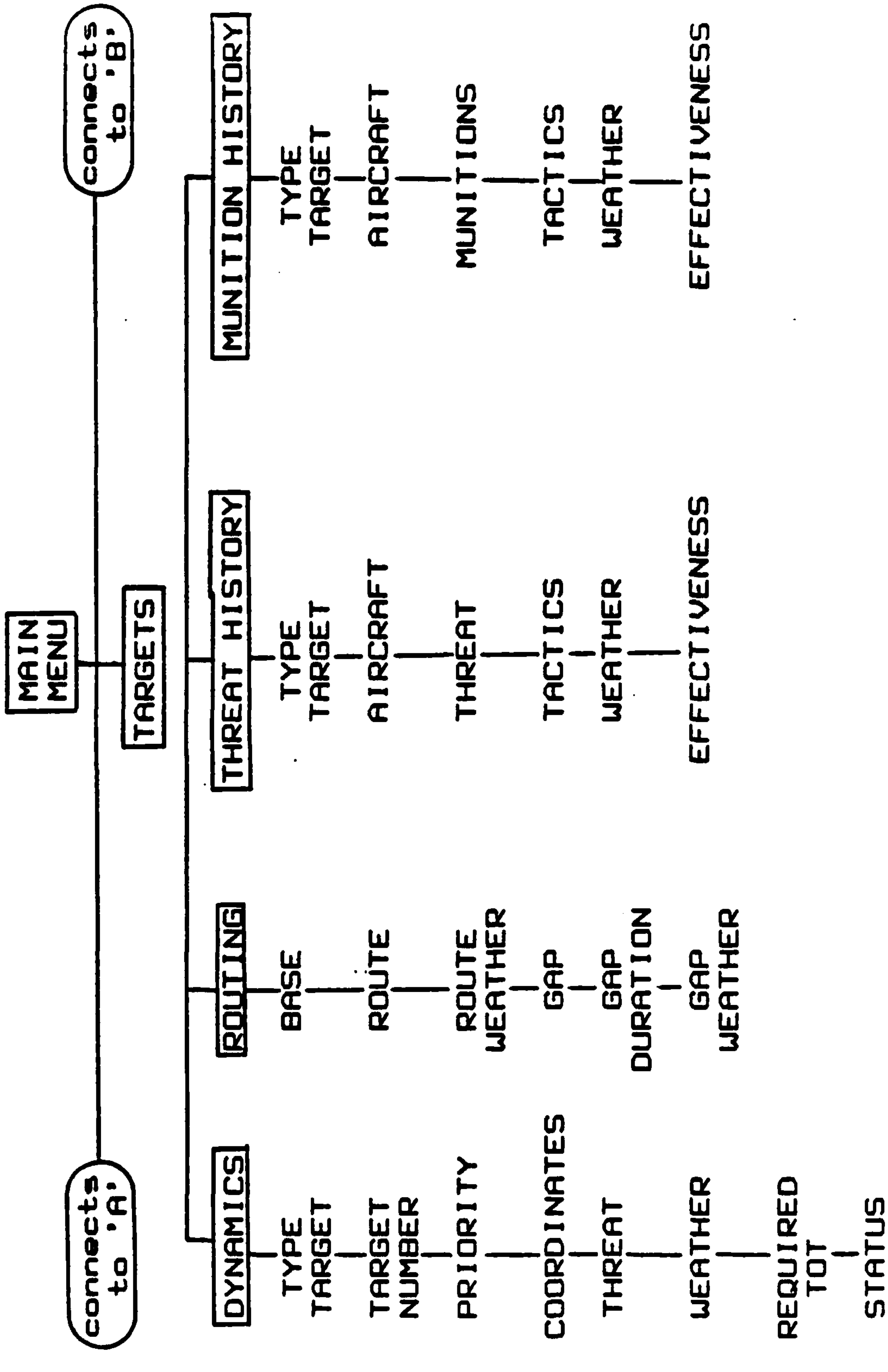
Appendix B: Feature Chart

This appendix contains the feature chart hierarchy which was used to develop the first version of the storyboards. The chart is presented on three pages and requires connection at the A and B points to produce a single diagram. Although the main menu block appears on each page, the chart was designed for use with only one main menu.

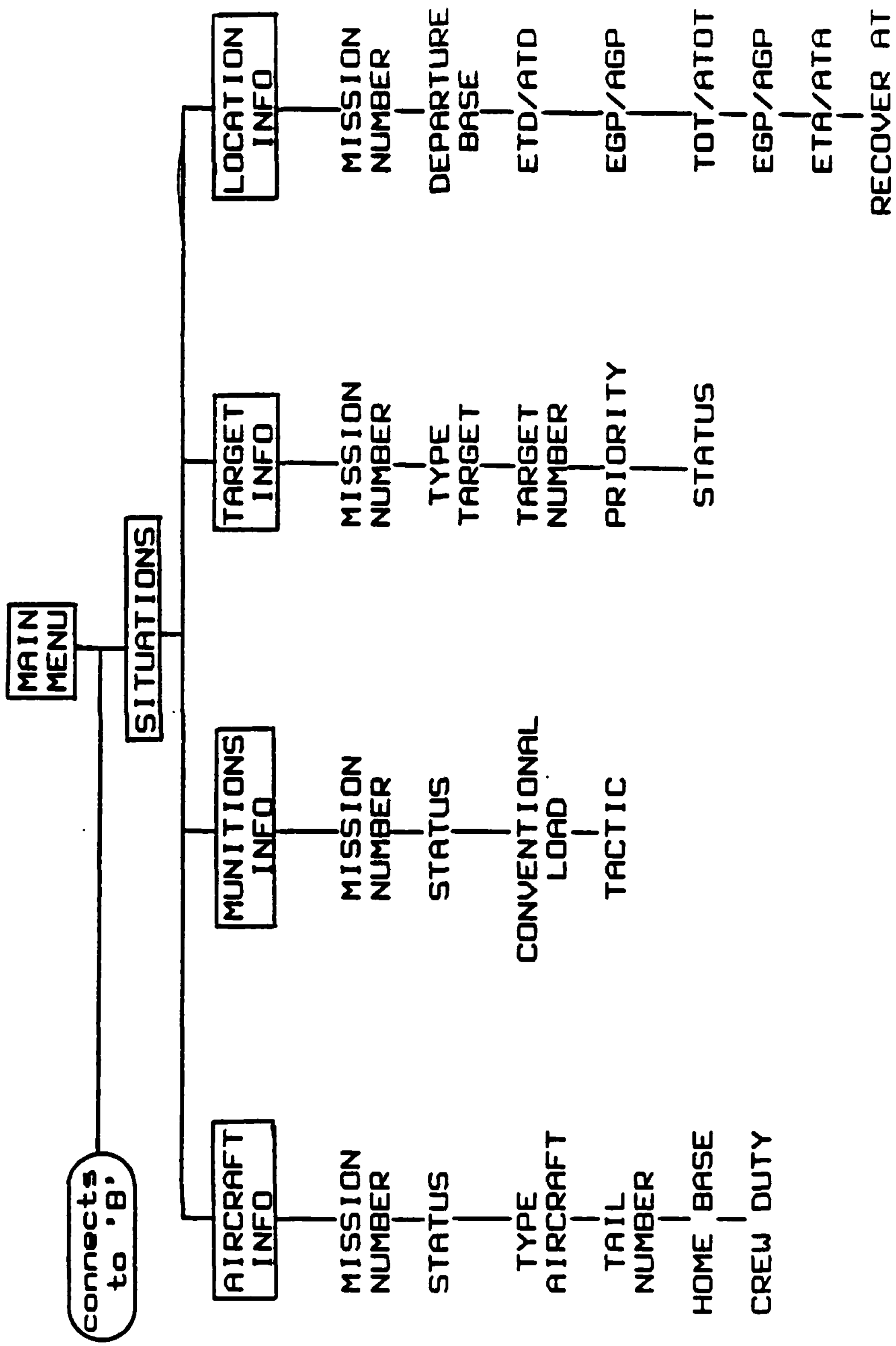
Feature Chart Hierarchy (Part 1 of 3)



Feature Chart Hierarchy (Part 2 of 3)



__Feature Chart Hierarchy__ (Part 3 of 3)



Appendix C: STORYBOARDS -- VERSION 1.0

This appendix contains the first version of the storyboards. The master menu is provided as the first representation and each display provides a sub-menu for operation on selected data elements within that display. A narrative explaining each storyboard is also provided.

Master Menu

```
*************************************************************
*                                                           *
*              DYNAMIC AIR INTERDICTION                     *
*                     RETASKER                              *
*                                                           *
*                                                           *
*                   MASTER MENU                             *
*                   ===========                             *
*              --> AIRCRAFT                                 *
*                                                           *
*                  BASES                                    *
*                                                           *
*                  TARGETS                                  *
*                                                           *
*                  SITUATIONS                               *
*                                                           *
*                                                           *
*===========================================================*
* 1-HLP | 2-MENU | 3-NOTE | 4-SAVE | 5-PRNT | 6-SORT | 7-SRCH | 8-EDT | 9-QUIT*
*-------+--------+--------+--------+--------+--------+--------+-------+------*
* TIME  |  DATE  |    "ERROR MESSAGE"       |    MENU TITLE   |  10-TRANSMIT *
*************************************************************
```

Master Menu

1 - Depends on the screen display and the cursor position. Invokes master HeLP menu by category.

2 - Returns you to previous master MENU in the hierarchy.

3 - Opens a window on the display and allows the user to make a NOTE; scratch pad which prompts for file name and saves it.

4 - Prompts user for specific file name, then SAVEs screen display or window note. Allows user to file note with other displays.

5 - PRiNTs screen display or file desired.

6 - Prompts user for criteria, then SORTs operating file.

7 - Prompts user for SeaRCH criteria, then locates data elements.

8 - Used to enter or EDiT data on situation displays or files.

9 - QUIT returns operating system to ready state. Prompts user to ensure user wishes to depart system.

10 - Allows user to highlight data for TRANSMI(T)ssion to Wing Operations Centers and/or to Air Support Operations Centers.

TIME - running clock in zulu.

DATE - MM-DD-YY.

"ERROR MESSAGES" - Tell the user he cannot perform certain functions. Audio beep indicates invalid key.

MENU TITLE - Descriptive name of the current display.

--> Arrow moved by cursor controls to select and reverse highlight desired category. Carriage return moves user to that menu. Function keys work on the selected item.

Aircraft Statistics

```
********************************************************************************
*                                                   | --> STATISTICS           *
*                                                   |     ALLOCATION           *
*                                                   |     CONVENTIONAL LOAD    *
*                                                   +--------------------------*
*                                                                              *
*                                                                              *
*                COMBAT                          HISTORICAL LOSSES             *
*     TYPE       RADIUS      SPEED      WHEN          WHERE          REASON    *
*     ====       ======      =====      ====          =====          ======    *
*     F-44        600         550                                              *
*     A-19        300         350                                              *
*     F-32        500         450                                              *
*                                                                              *
*                                                                              *
*                                                                              *
*                                                                              *
*==============================================================================*
* 1-HLP | 2-MENU | 3-NOTE | 4-SAVE | 5-PRNT | 6-SORT | 7-SRCH | 8-EDT | 9-QUIT*
*-------+--------+--------+--------+--------+--------+--------+-------+-------*
* TIME  |  DATE  |      "ERROR MESSAGE"     |      AIRCRAFT   |  10-TRANSMIT  *
********************************************************************************
```

Aircraft Statistics

This display contains information on each TYPE of aircraft. The information is of a permanent or prior day nature. The model base would use the SPEED (knots) and RADIUS (nm) for the calculation of mission range feasibilities. The decision maker will review this periodically to observe the loss rates being experienced by the air interdiction forces and why. Thus, feedback is provided to the different FIDOs and they can quickly receive a "how goes it" when starting their individual shifts. The FIDO would use historical data to aid in determining if a retasking option is wise based on previous aircraft experience either in certain target areas or against certain threats. The REASON column would contain the threat which defeated the aircraft.

The sub-menus are indicated in the upper right hand corner and can be selected with the cursor control. They reflect the general hierarchy of the DSS.

Aircraft Allocation

The purpose of this display is to allow the WOCs to communicate their anticipated aircraft and crew status to the FIDO. The decision maker can refer to this display when he needs to know when, where and what aircraft will next be available for tasking. New aircraft may be allocated to the

```
****************************************************************************
*                                                      !    STATISTICS      *
*                                                      ! --> ALLOCATION     *
*                                                      !    CONVENTIONAL LOAD *
*                                                      +--------------------*
*                                                                           *
*                 TAIL     HOME     PRESENT      EXPECTED                   *
*    TYPE      NUMBER / BASE      LOCATION    GENERATION      CREW DUTY     *
*    ====      =============      ========    ==========      =========     *
*    F-44          70626 AA          AA          1400            8:30       *
*    F-32          69724 BB          DD          1420            6:16       *
*    F-32          72928 DD          CC          1450            7:19       *
*    A-19          70898 RR          RR          1500            8:10       *
*                                                                           *
*                                                                           *
*                                                                           *
*                                                                           *
*===========================================================================*
* 1-HLP ! 2-MENU ! 3-NOTE ! 4-SAVE ! 5-PRNT ! 6-SORT ! 7-SRCH ! 8-EDT ! 9-QUIT*
*-------+--------+--------+--------+--------+--------+--------+-------+------*
* 1220  !  DATE  !      "ERROR MESSAGE"     !     AIRCRAFT    !  10-TRANSMIT  *
****************************************************************************
```

FIDO by the warlord from other mission areas based on intelligence information, by new aircraft arriving in theater, or by cancellation of previous missions for dual role aircraft. For all such displays, the titles of the columns remain fixed and the data may be scrolled and scanned manually beneath them.

The aircraft on this display have not been tasked. The crew duty assumption is twelve hours and is used to ensure the aircraft recover at home base for crew changes. The crew duty time is the remaining time available once the aircraft is generated. Note that the generation time is sorted chronologically. There is another DSS which is determining which aircraft and how many are being roled to the air interdiction mission from the theater air order of battle.

Type - Self Explanatory

Tail Number/Home Base - 5 Digit number and two characters designating the aircraft's home base. FIDO needs this info to insure aircrew recovers at home base for replacement crew.

Location - Where the aircraft is currently being generated. It could be at the MOB, FOL, DET, or Home Station.

Generation - Expected time when aircraft can crank and go. Maintenance ready time, but untasked. An airframe ready time with crew. Note that the times are arranged by earliest expected time. Generally, these aircraft were hard broke. Anything greater than 24 hours estimated time in commission will not show.

Crew Duty - Assumed 12 hours for this problem. Clock begins on crew when they show for duty. Adjusted to the generation time, the column of numbers does not move. It reflects a crew available duty time when the aircraft is generated. Fido must get aircraft and crew to home station for crew change.

Aircraft Conventional Load

```
*************************************************************************
*                                                   !     STATISTICS       *
*                                                   !     ALLOCATION       *
*                                                   ! --> CONVENTIONAL LOAD *
*                                                   +----------------------*
*                                                                          *
*                                                                          *
*                                    AIRCRAFT   WEAPON                     *
*    TYPE        MUNITION              TACTIC / MODE            WX MINS    *
*    ====        ========              =============            =======    *
*    F-44         500 LB               TOSS / LASER GUIDED      8000 / 6   *
*    F-44        2000 LB              LEVEL / TV GUIDED          600 / 2   *
*    A-19        MAVERICK              BUMP / IR GUIDED         2000 / 5   *
*    A-19        ROCKEYE                POP / FREE FALL         2000 / 3   *
*    F-32         500 LB             HI ALT / TV GLIDE         10000 / 7   *
*    F-32     HYPER VEL RKTS           BUMP / FWD FIRING        1500 / 3   *
*                                                                          *
*==========================================================================*
* 1-HLP ! 2-MENU ! 3-NOTE ! 4-SAVE ! 5-PRNT ! 6-SORT ! 7-SRCH ! 8-EDT ! 9-QUIT*
*-------+--------+--------+--------+--------+--------+--------+-------+------*
* TIME  !  DATE  !      "ERROR MESSAGE"     !     AIRCRAFT    !  10-TRANSMIT *
*************************************************************************
```

Aircraft Conventional Load

This display would provide the permanent information on the aircraft assigned to the air interdiction role. This exhaustive list would contain, by aircraft type, the munitions each aircraft could carry. Standard self-defense munitions would not be shown. This display shows how each aircraft is capable of delivering the munitions. The data would be drawn from JMEMs. Some aircraft are capable of delivering the same munition but with different tactics and different terminal guidance modes. In either case, each delivery tactic requires certain minimum weather conditions so that the munition can be effectively employed. The weather minimums are listed by ceiling and visibility in feet and nautical miles. They can be changed to meters and kilometers for the European scenario. The need exists in a conflict to have standard type conventional loads for each aircraft (number and type). This would be accomplished in the weaponeering section of the DSS. During the weaponeering portion of the tasking process, the system would filter choices and provide only those options which are compatible for the given weather, type aircraft, and the munition available.

<u>TACTICS</u>: Maneuver from a position of ingress, (altitude, ground track, speed), to a delivery point (altitude, angle, speed, slant range) from which the aircrew can acquire the target or the weapon can acquire the guidance signature. Minimize exposure time, maximize surprise and tracking time for delivery accuracy.

MODE:

GUIDED: Laser, TV, IR, fire and forget, deliver and track.

UNGUIDED: Gravity (free fall), Forward Firing (stand off).

Base Static

This display would show the permanent information about each base that is usable by the air interdiction aircraft. Most of the data elements are self explanatory. The coordinates are in latitude and longitude. The history column (date/zulu time) would reflect the last five days of activity at that base. It would collect the information from the dynamic base display as input from the WOCs. The FIDO would use this display when choosing in flight diverts for the assets. If the historical data indicates frequent closures, then the choice as a divert base may require a different option.

Base Status

Although the data on this display appears to be only weather related, the status of the base may very well be determined by the enemy. The data would be color coded to the NATO standard weather codes. To indicate a status change as a result of enemy attack, that particular base and its status line would begin flashing. The ceiling and visibility data are in feet and nm. The times are date/clock times in zulu. The FIDO would use this to

Base Static

```
*****************************************************************************
*                                                        | --> STATIC       *
*                                                        |     STATUS       *
*                                                        |     DYNAMICS     *
*                                                        +------------------*
*                                                                           *
*                                                   HISTORY                 *
*  NAME   TYPE    AIRCRAFT        COORD        CLOSED    FROM    TO         *
*  ====   ====    ========        =====        ======================       *
*   AA     MOB      F-32       52:43/30:19     12/1220    13/0600           *
*   DB     FOL    A-19/F-44    50:23/21:34     15/1609    15/1800           *
*   RR     COB      A-19       49:42/20:44     13/0400    13/1450           *
*                                                                           *
*===========================================================================*
* 1-HLP | 2-MENU | 3-NOTE | 4-SAVE | 5-PRNT | 6-SORT | 7-SRCH | 8-EDT | 9-QUIT*
*-------+--------+--------+--------+--------+--------+--------+-------+------*
* TIME  |  DATE  |     "ERROR MESSAGE"      |      BASES      | 10-TRANSMIT   *
*****************************************************************************
```

Base Status

```
| --> STATIC
|     STATUS
|     DYNAMICS
+---------------

         PRESENT     EXPECTED          PRESENT     FORECAST
NAME     STATUS      STATUS            WEATHER     WEATHER
====     ======      ======            =======     =======
 AA      CLOSED      OPEN @ 12/1220     100/1      12/1200 1000/3
 DB      OPEN        OPEN              1500/4      12/2000 1000/3
 RR      OPEN        CLOSE @ 12/1030   1000/5      12/1030  200/1

1-HLP | 2-MENU | 3-NOTE | 4-SAVE | 5-PRNT | 6-SORT | 7-SRCH | 8-EDT | 9-QUIT
1005 |03-12-87|   "ERROR MESSAGE"   |   BASES   |  10-TRANSMIT
```

determine if assets at a particular base are available for tasking based on the two most significant restrictive factors, weather and attack condition.

Base Dynamics

This display, updated by the WOCs, does not contain all of the combat essential items which a base must possess to operate under wartime conditions. The assumption is that there is a logistics DSS supporting the ATOC as well. The FIDO does not need the LOX or POL statistics. He needs to know if the base is operating, shown on the STATUS display. That display, tied to a logistical DSS "watch dog", allows the FIDO to assume that the base has the maintenance and sortie generating capacity. The ramp and shelter columns are updated by the WOCs in the SITUATION portion of this DSS. In other words, if the FIDO diverts an aircraft from recovering at RR to divert to DB, then the airbase capacity numbers of this dynamic display would be incremented and decremented automatically as the retasking occurs.

The shelter size of each base is designed for the aircraft assigned to that location. The ramp space size is determined by the largest of the air interdiction aircraft, so these figures may be conservative. The WOCs would update the list for battle damage, but the basic premise is that these shelters, parking spots, and munitions are untasked, available resources. Any other limiting factors on the

Base Dynamics

```
*****************************************************************
*                                                 !    STATIC   *
*                                                 !    STATUS   *
*                                                 ! --> DYNAMICS*
*                                                 +-------------*
*                                                               *
*                                                               *
*  NAME        MUNITIONS           SHELTERS        RAMP SPACE   *
*  ====        =========           ========        ==========   *
*   AA       230 MAVERICK             25               14       *
*   AA      2000 500 LB               --               --       *
*   RR       560 ROCKEYE              12               23       *
*   RR      1300 HPV ROCKETS          --               --       *
*   DB      1400 2000 LB              17                8       *
*   DB       480 500 LB               --               --       *
*                                                               *
*                                                               *
*===============================================================*
* 1-HLP ! 2-MENU ! 3-NOTE ! 4-SAVE ! 5-PRNT ! 6-SORT ! 7-SRCH ! 8-EDT ! 9-QUIT*
*-------+--------+--------+--------+--------+--------+--------+-------+-------*
* TIME  !  DATE  !     "ERROR MESSAGE"      !      BASES      !  10-TRANSMIT  *
*****************************************************************
```

bases would be contained in another specific DSS, such as the logistics or maintenance systems. The FIDO is directing the AI campaign and would rely on these other DSS to support his role of using the assets to execute the air interdiction campaign. The munitions column gives the FIDO a feel for the available munitions at a particular location, although the weaponeering system and logistics network would be more concerned with the actual accounting of individual items.

Target Dynamics

The purpose of this display is to provide the FIDO with target specific information of a changeable nature. The information is provided from intelligence sources including active and passive sensors, aircrew debriefs and ground forces battle information. Targets displayed would require no pre-attack coordination with the ground commander, as they would be of the BAI or AI variety and deconflicted from friendly troops by time or space. The TYPE and reference NUMBER of the target are provided as well as a priority assigned by the intelligence target nomination branch. The COORDinates are given in latitude and longitude figures but could be converted to UTM coordinates rather easily. The THREAT would represent those surface to air threats which would be a factor in the target area during weapon delivery.

Target Dynamics

```
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
x                                                  | --> DYNAMICS          x
x                                                  |     ROUTING           x
x                                                  |     HISTORY-THREAT    x
x                                                  |     HISTORY-MUNITION  x
x                                                  +-----------------------x
x                                                                          x
x TYPE   NUMBER   PRIORITY   COORD     THREAT   WEATHER   REQ'D TOT   STATUS x
x ====   ======   ========   =====     ======   =======   =========   ====== x
x ARMOR   23          53   54:45/21:23 SA-8      BLUE   21/1400-1500  TASKED x
x                                                                          x
x                                                                          x
x                                                                          x
x                                                                          x
x                                                                          x
x                                                                          x
x==========================================================================x
x 1-HLP | 2-MENU | 3-NOTE | 4-SAVE | 5-PRNT | 6-SORT | 7-SRCH | 8-EDT | 9-QUITx
x-------+--------+--------+--------+--------+--------+--------+-------+------x
x TIME  |  DATE  |     "ERROR MESSAGE"      |       TARGETS   |  10-TRANSMIT  x
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

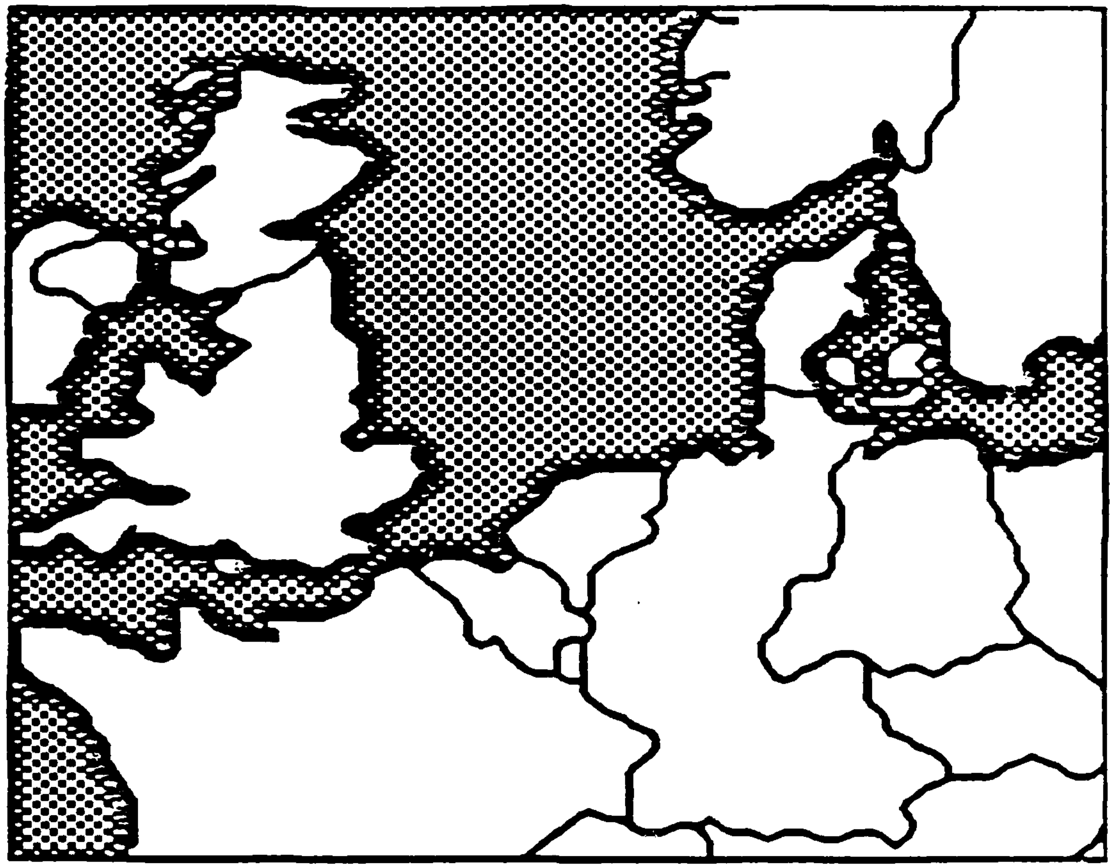
Specific location of the threat sites would be available through the graphic display module and a back up data storyboard. Because of the lack of physical observation, the WEATHER in the target area would be provided through the use of NATO weather schemes, which could be updated by aircrews returning from the area. The weather would be the worst expected for the TOT and would be input by the weather section of the command center The REQ'D TOT is given in date/zulu and is based on intelligence sources best guess of the duration of stay at a particular location for semi-mobile targets, the army's need to remove the target, and, in some cases, the coordination and deconfliction of target engagements by multiple modes (artillery, rockets, friendly movements, special forces).

The status represents where in the FIDO assignment process the target stands. The different categories include: UNTASKED -- no assets assigned, TASKED -- assets assigned, AIRBORNE -- AI assets enroute, ENGAGED -- AI assets attacking, REPORT -- Intelligence is waiting for a report on the mission so as to determine the level of destruction, change the target priority, or update any other item on the target list.

Target Dynamics Map

The purpose of this display is permit the FIDO to graphically view the dynamics of specific targets as displayed in the TARGET DYNAMICS storyboard. Using a color coded map to depict terrain, the map display could be expanded or reduced to fit the user's need for detailed representation of a particular situation or area. The features on the map itself would be removable by selecting or deselecting several overlays of data. This representation of targets would include threats in the form of rings. A selected ingress altitude could be selected to show how terrain and radar coverage would increase or decrease threat intensity. Although these specifics would be more useful to the aircrew, from a planners point of view there is a need to know what the target and threat environment looks like before committing forces. The entire display could be rotated to show the features of the target area from a point in space. Threats would be displayed as domes and terrain features would be depicted along the route. Again this detailed target area analysis is more appropriate for the aircrew in planning their final attack.

Target Dynamics and Routing Map



Target Routing

```
*****************************************************************************
*                                                  :     DYNAMICS          *
*                                                  :  --> ROUTING           *
*                                                  :     HISTORY-THREAT    *
*                                                  :     HISTORY-MUNITION  *
*                                                  +-----------------------*
*                                                                           *
*                          ROUTE                                    GAP     *
*  BASE      ROUTE        WEATHER        GAP           GAP TIME    WEATHER  *
*  ====      =====        =======        ===           ========    =======  *
*   RR       17/140        BLUE      A/54:30-55:04   12/1500-1600   GREEN   *
*   RR       23/167        YELLOW    B/49:23-50:45   12/1300-1400   YELLOW  *
*   AA       14/97         YELLOW    A/54:30-55:04   12/1500-1600   GREEN   *
*   AA       43/125        RED       B/49:23-50:45   12/1300-1400   YELLOW  *
*   DB       21/78         GREEN     A/54:30-55:04   12/1500-1600   GREEN   *
*   DB       47/83         GREEN     B/49:23-50:45   12/1300-1400   YELLOW  *
*                                                                           *
*===========================================================================*
* 1-HLP : 2-MENU : 3-NOTE : 4-SAVE : 5-PRNT : 6-SORT : 7-SRCH : 8-EDT : 9-QUIT*
*-------+--------+--------+--------+--------+--------+--------+-------+-----*
* TIME  :  DATE  :      "ERROR MESSAGE"       :    TARGETS     : 10-TRANSMIT *
*****************************************************************************
```

Target Routing

There are several other decision support systems within the command and control unit at the ATOCs. Some of them would generate the overall electronic support measures (ESM) packages. Another would be generating the target priorities and TOTs, such as an intelligence DSS which would fuse the sensor data. A similar ground battle manager located at the ASOC is monitoring the flow of the battle. Again, these other systems would be supporting the FIDOs who would make the decisions necessary to get the munitions on the targets. This particular display shows the routing from the AI bases to the gaps in the FEBA. The route includes a number which the individual squadrons would have and which could be preprogrammed into the navigational system on future aircraft. The distance in nautical miles is also included in the route information.

The weather information, although more conducive to a map display, is color coded to NATO standards. The weather would maintain the detailed weather maps in a separate DSS. The gaps are indicated by a single letter. The coordinates are displayed and the gap, or "gate," is the line drawn between coordinates intercepting the FEBA. It could be given in two coordinates and the gap would be the line connecting that set of coordinates. Color coding the gaps would create a less cluttered display. The route distance drives the takeoff time which must be early enough to make the gaps, meet the TOTs and return. The gap time is displayed by date/time.

Target Routing Map

This display, similar to the Target Dynamics Map demands a more graphic display. Color coding would be used to display the weather across the entire battle area. The map may be exploded to examine specific areas of interest. The gap information would be displayed in the form of icons or graphical funnels, and would be highlighted with an expected duration time, fed to the system by the ESM DSS. The bases would also be inserted on the map with the routes of flight to the different gaps overlayed on the map. The FIDO would use this information to help filter missions which are infeasible due to weather or aircraft range.

This map display could actually become the shell from which all other displays are generated. Nearly every item discussed to this point as well as those requiring further attention could be annotated on a map. The ability of the FIDO to use a graphical representation enables him to continue his decision process without the interruption due to trying to interpret raw data. The idea is that the FIDO could draw from his experience as an aircrew member more readily when he is using something with which he is already comfortable, a map and a joy stick or mouse for cursor control. Commands are needed to allow the FIDO to switch not merely from storyboard to storyboard, but to switch from overlay to overlay.

The FIDO should have the means to remove information from the display which may clutter or confuse his task and distract his decision process. Linked to real time intelligence data and sources, using a voice command synthesizer to 'display threats' and other options, and with a computer 'mouse' for designating and requesting more detailed information in a data format window (or second display monitor), this representation becomes his grease board, his note pad, his planning tool, his feasibility checker, his message format and transmission station, his eyes on the battle, his instantaneous feedback when an aircraft is removed from the system. Each base would exhibit a queue of aircraft which are being generated and awaiting new tasks. He would follow their mission and once airborne communicate to them any changes to their initial tasking.

Target History - Threat

The information on this display is a combination of the enumerated capabilities of each aircraft to deliver weapons in a specific delivery pattern with specific weather against a specific target. The display information is historical in the sense that during the conflict, intelligence would be updating this previously 'predicted game plan' via mission

Target History - Threat

```
***********************************************************************************
*                                                    :     DYNAMICS               *
*                                                    :     ROUTING                *
*                                                    : --> HISTORY-THREAT         *
*                                                    :     HISTORY-MUNITION       *
*                                                    +----------------------------*
*                                                                                 *
*  TYPE TARGET   AIRCRAFT    THREAT    TACTICS    WEATHER    EFFECTIVENESS        *
*  ===========   ========    ======    =======    =======    =============        *
*    ARMOR         F-44       SA-8     POP-UP      BLUE           75%             *
*    ARMOR         F-32       SA-13    LEVEL       YELLOW         50%             *
*                                                                                 *
*                                                                                 *
*                                                                                 *
*                                                                                 *
*                                                                                 *
*                                                                                 *
*=================================================================================*
* 1-HLP : 2-MENU : 3-NOTE : 4-SAVE : 5-PRNT : 6-SORT : 7-SRCH : 8-EDT : 9-QUIT*
*-------+--------+--------+--------+--------+--------+--------+-------+--------*
* TIME  :  DATE  :       "ERROR MESSAGE"    :        TARGETS       :  10-TRANSMIT *
***********************************************************************************
```

results. Thus, the FIDO has a means, as do the aircrews at the unit level, to receive feedback on their delivery accuracy. For instance, training scenarios at Red Flag or Maple Flag may have indicated high success rates for F-44 aircraft performing level passes on armor. During the conflict, this high effectiveness level may actually be much lower because of changes in enemy tactics or other battle field factors.

This is one of the first displays to marry the target and aircraft information. Although not munition specific, the level of effectiveness is driven by exposure time to the threat based on a tactical maneuver. The TARGET TYPE, AIRCRAFT, and WEATHER categories are self explanatory. The THREAT is that which is defending the target during the attack TACTICS being performed by the aircraft. These TACTICS are restricted by weather, are specific for aircraft and munitions, and determine the amount of exposure time to the threat. Looking at it from another viewpoint, how capable is the threat of defending the target against certain aircraft employing certain tactics. The next display looks at it from the point of view of the munition -- how capable is the munition of hitting and damaging a specific type target when delivered by a specific aircraft using a specific delivery tactic. The EFFECTIVENESS of the tactic versus the threat predicts that three of four F-44 aircraft will survive and be able to egress the target area by employing a level delivery under weather condition blue against armor units defended by the threat displayed.

Target History - Munition

This display specifically details the effectiveness of a particular weapon against a particular target. The enumeration of each type of munition for each aircraft flying the tactic specified is matched against a target with a specific weather condition to produce an effectiveness for that particular sortie. As with the Target History - Threat display, this munitions oriented display is historical, with a game plan developed through exercises and results from previous conflicts. During the actual conflict, intelligence sources would recompute effectiveness based on actual occurrences and engagements. The TARGET TYPE, AIRCRAFT and WEATHER categories are self explanatory. The threat is not included in this display, as this information is based on a sterile environment in which the primary concern is operating the aircraft in the given weather conditions. The MUNITIONS and TACTICS for each aircraft are maintained in their individual aircraft data structures. The EFFECTIVENESS is an indication of how well the aircraft can acquire the target or the munition tracking signature and how accurately with the munition specific kill mechanism he can engage the target.

Target History - Munition

```
**************************************************************************
*                                                 :     DYNAMICS           *
*                                                 :     ROUTING            *
*                                                 :     HISTORY-THREAT     *
*                                                 : --> HISTORY-MUNITION   *
*                                                 +------------------------*
*                                                                          *
*  TYPE TARGET    AIRCRAFT    MUNITIONS   TACTICS    WEATHER   EFFECTIVENESS *
*  ===========    ========    =========   =======    =======   ============= *
*     ARMOR         F-44        MK-82     POP-UP      BLUE          66%      *
*     ARMOR         F-32        MK-20     LEVEL       YELLOW        45%      *
*                                                                          *
*==========================================================================*
* 1-HLP : 2-MENU : 3-NOTE : 4-SAVE : 5-PRNT : 6-SORT : 7-SRCH : 8-EDT : 9-QUIT*
*-------+--------+--------+--------+--------+--------+--------+--------------*
* TIME  :  DATE  :      "ERROR MESSAGE"      :      TARGETS    :  10-TRANSMIT *
**************************************************************************
```

For instance, approximately one of every two sorties flying with MK-20s using level deliveries in yellow weather will acquire, deliver and destroy the armor. Initial investigation indicates that a primary scheduling kernel process involves the decision of the trade off between the risk to the aircraft versus the assurance of a desired level of target destruction.

Situation Aircraft Info

This display gives the STATUS of the tasked MISSION # by aircraft TYPE, TAIL # (the specific airframe identifier and future direct communications address), aircraft HOME BASE, and a countdown clock of the available CREW DUTY time available in hours and minutes. The purpose of this display is to allow the FIDO to 'see' by aircraft type the number and associated time remaining on each asset. Can he afford to divert an aircraft which is returning from a mission? Can he divert an aircraft and mission # which is not engaged to fulfill another target or mission requirement?

This display, then, permits the FIDO to see which of his allocated resources have already been tasked. Its counterpart display is the Aircraft AI Allocation, which shows untasked airframes. All of the aircraft allocated to the AI FIDO by higher headquarters will thus be displayed on one of these two representations, and no single aircraft can be on both displays simultaneously. The aircraft depicted,

```
*****************************************************************************
*                                                  ! --> AIRCRAFT INFO     *
*                                                  !     MUNITIONS INFO    *
*                                                  !     TARGET INFO       *
*                                                  !     LOCATION INFO     *
*                                                  +-----------------------*
*                                                                          *
*  MISSION #    STATUS     TYPE        TAIL # / HOME BASE    CREW DUTY     *
*  =========    ======     ====        ==================    =========     *
*   21 1545     AIRBORNE   F-32            70625 AA             6:45       *
*   21 1435     ENGAGED    F-44            70674 RR             3:56       *
*   21 3453     TASKED     A-19            68929 BB             2:34       *
*                                                                          *
*                                                                          *
*                                                                          *
*                                                                          *
*                                                                          *
*==========================================================================*
* 1-HLP ! 2-MENU ! 3-NOTE ! 4-SAVE ! 5-PRNT ! 6-SORT ! 7-SRCH ! 8-EDT ! 9-QUIT*
*-------+--------+--------+--------+--------+--------+--------+-------+-------*
* TIME  !  DATE  !     "ERROR MESSAGE"      !     SITUATIONS  !  10-TRANSMIT *
*****************************************************************************
```

and married with their mission #s, both preplanned and immediate, are in effect, 'in the barrel' if they are on this display. They are 'in the holding pattern' if they are on the Aircraft AI Allocation display.

The highest priority for the FIDO lies with his airborne assets, for they are vulnerable, using up resources (fuel), and are the most available assets for making a contribution to the overall battle. Some typical scenarios which may occur include target changes (due to weather, movement, destruction, priority change), configuration changes (due to jettison of munitions when engaged by an airborne adversary), or range restrictions (due to diverts or route changes because of new gaps). All of these would require the FIDO to retask the airborne assets.

MISSION # -- date/discrete number.

STATUS -- TASKED; have received their orders but are not airborne.
AIRBORNE; have launched and have not reached their initial point (IP) for final run-in.
ENGAGED; attacking their target within their TOT.
REPORT; returning to base/reporting to intel on mission.

Note that these same status keywords were used in the Target Dynamics display. The data displayed is real-time, not planned.

Situation Munition Info

```
*****************************************************************
*                                           !     AIRCRAFT INFO  *
*                                           ! --> MUNITIONS INFO *
*                                           !     TARGET INFO    *
*                                           !     LOCATION INFO  *
*                                           +--------------------*
*                                                                *
*    MISSION #       STATUS        CONV LOAD         TACTIC      *
*    =========       ======        =========         ======      *
*     21 3454        ENGAGED        MK-82            POP-UP      *
*     21 1345        AIRBORNE       MK-20            LEVEL       *
*                                                                *
*                                                                *
*                                                                *
*                                                                *
*                                                                *
*================================================================*
* 1-HLP ! 2-MENU ! 3-NOTE ! 4-SAVE ! 5-PRNT ! 6-SORT ! 7-SRCH ! 8-EDT ! 9-QUIT*
*-------+--------+--------+--------+--------+--------+--------+-------+-------*
* TIME  !  DATE  !     "ERROR MESSAGE"     !    SITUATIONS    !  10-TRANSMIT  *
*****************************************************************
```

Situation Munition Info

The purpose of this display is to provide the FIDO with tasked munition information (i.e., assigned a MISSION #). Knowing that a certain high priority, untasked target has just been identified, and that this target requires a quick response with a particular munition and the proper kill mechanism, the FIDO can search this display for the timely information required. He then can make the necessary changes to the mission # to redirect the aircraft to the new target. Additionally, threat updates may dictate new or more conservative tactics or the need to knock out a target may require a more aggressive tactic. With this display, the FIDO can visualize which mission numbers are available for immediate retasking. Thus, the process identified earlier as the trade off of aircraft risk versus mission success can be examined on the munition/tactic level solely by exploring the options with what is tasked and available now.

Situation Target Info

The purpose of this screen representation is to display the critical in-progress targets which have been tasked. The FIDO can look at this information and determine which targets by priority have been tasked. This allows him to evaluate where the emphasis, by priority, should be placed

Situation Target Info

```
*************************************************************************
*                                                 :    AIRCRAFT INFO    *
*                                                 :    MUNITIONS INFO   *
*                                                 : --> TARGET INFO     *
*                                                 :    LOCATION INFO    *
*                                                 +---------------------*
*                                                                       *
*    MISSION #      TYPE        TARGET #      PRIORITY       STATUS     *
*    =========      ====        ========      ========       ======     *
*     21 3454      ARMOR           23            53          ENGAGED    *
*     21 1243      ROADWAY         47           128          AIRBORNE   *
*     21 1376      C3 BUNKER       69            14          TASKED     *
*                                                                       *
*                                                                       *
*                                                                       *
*                                                                       *
*=======================================================================*
* 1-HLP : 2-MENU : 3-NOTE : 4-SAVE : 5-PRNT : 6-SORT : 7-SRCH : 8-EDT : 9-QUIT*
*-------+--------+--------+--------+--------+--------+--------+-------+--------*
* TIME  :  DATE  :      "ERROR MESSAGE"     :   SITUATIONS    :  10-TRANSMIT  *
*************************************************************************
```

in future retasking efforts. As with the other situation displays (munitions, aircraft and location), this target information focuses the FIDOs attention on the targets themselves. By comparing this listing with the total target base nominated by intelligence sources, the FIDO can examine where his emphasis should be placed during his tour of duty. The MISSION #s would be arranged so that the top most are those targets which are engaged, and which he can do little about, those targets which have aircraft enroute to them (airborne), and those targets which have been tasked but for which aircraft are not yet airborne. The targets which have been engaged will not appear on the display, as the FIDO must wait for the intelligence update on that particular target array, unless multiple sorties have been tasked against that particular target.

Situation Location Info

Similar to a scheduling grease board, this display tracks the airborne phase of the missions. A time oriented display arranged chronologically by earliest TOT first, this display allows the FIDO to search and find missions which are ahead or behind schedule, missions which could be diverted because they are in the early phases of mission prosecution, or returning missions which require a divert because their recovery base is under attack. The basic hierarchy of this display then follows the status given in

Situation Location Info

```
**********************************************************************
*                                                 :     AIRCRAFT INFO   *
*                                                 :     MUNITIONS INFO  *
*                                                 :     TARGET INFO     *
*                                                 : --> LOCATION INFO   *
*                                                 +---------------------*
*                                                                       *
*  MISSION #  DPRT  ETD/ATD    EGP/AGP    TOT/ATOT   EGP/AGP    ETA/ATA   RCVR *
*  =========  ====  =======    =======    ========   =======    =======   ==== *
*   21 3445    AA   1220/1224  1240/1244  1300/1310  1330/1340  1405/      BB  *
*   21 3496    BB   1300/1255  1340/1342  1400/      1415/      1436/      CC  *
*   21 2356    AA   1330/1345  1400/      1430/      1500/      1530/      AA  *
*                                                                       *
*                                                                       *
*                                                                       *
*                                                                       *
*                                                                       *
*=======================================================================*
* 1-HLP : 2-MENU : 3-NOTE : 4-SAVE : 5-PRNT : 6-SORT : 7-SRCH : 8-EDT : 9-QUIT*
*-------+--------+--------+--------+--------+--------+--------+-------+-------*
* 1346  : 21 MAR :     "ERROR MESSAGE"      :    SITUATIONS     :  10-TRANSMIT  *
**********************************************************************
```

previous displays from top to bottom line: Report, Engaged, Airborne, and Tasked.

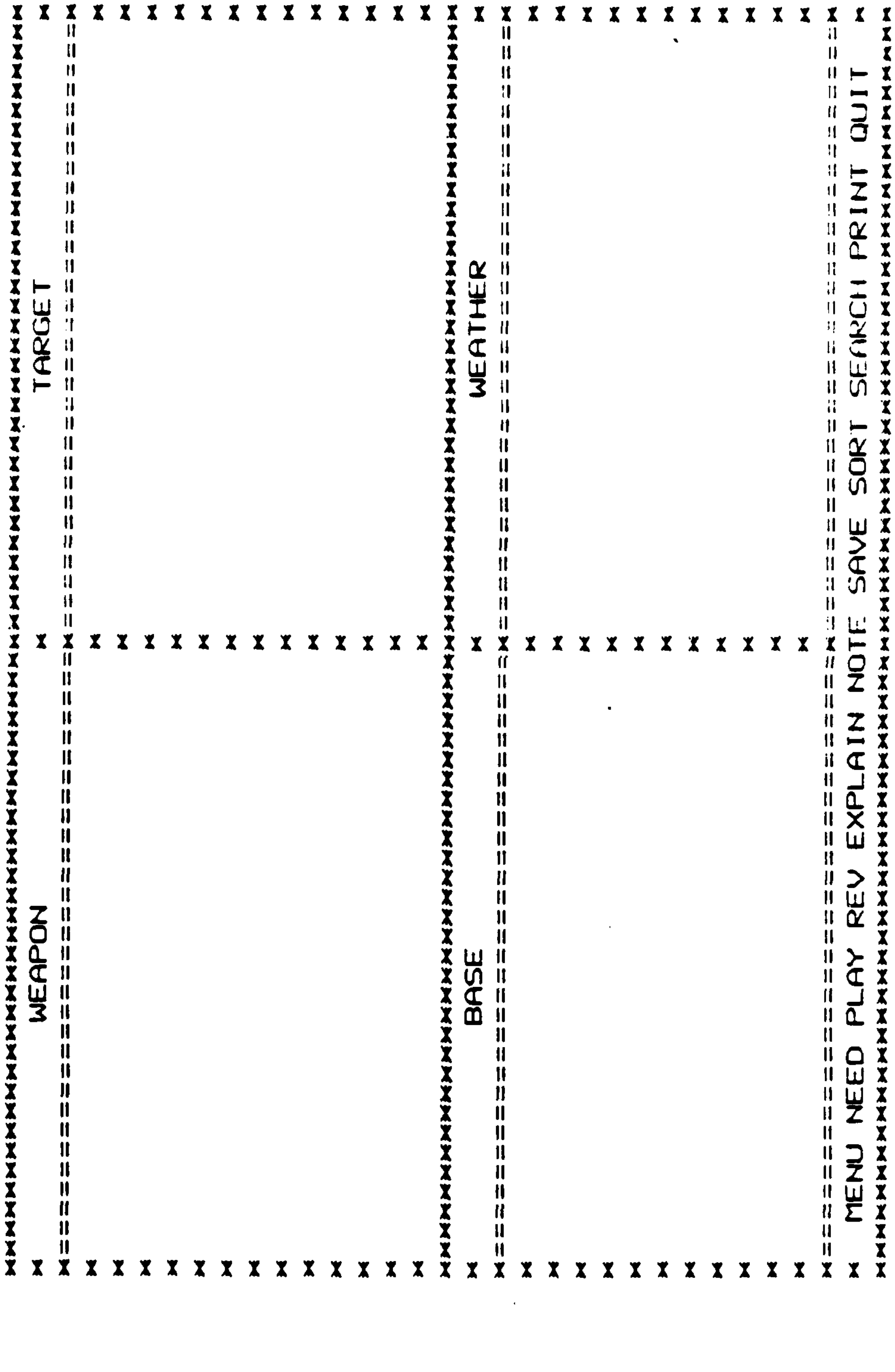
The times are zulu and would be color coded so that any actual time which is beyond the estimated would be colored yellow. If it was determined that a mission is being delayed beyond the point of making a gap time or TOT, then the entire line would appear in shades of red, blinking to inform the FIDO that a revision is necessary. DPRT and RCVR are the departure and recovery bases, with their associated lines of estimated and actual departure and arrival times. For this display, the missions which have landed are removed from this display and returned to the Aircraft AI Allocation Display or removed from the AI DSS and re-roled to another DSS (CAS, Counter-air). The TOTs are assumed to be 20 minute windows for this DSS and the Gap duration is assumed to be 60 minutes. The TOT column is thus the ± 10 point, while the EGP/AGP are the estimated and actual gap times.

The purpose of maintaining this information is that the FIDO is provided with information on his assets. The critical issue is which mission number is about to enter the battle? Of all the aircraft and mission number matches which he has formed, what phase of flight are they in? For example, a higher priority target has just been identified and must be destroyed; which aircraft can be retasked so as to engage that target? Weather is down or an attack is in progress at another base, which aircraft needs to be notified, where does the FIDO divert them so as to permit a rapid turn time for the next sortie?

Appendix D: Storyboards -- Version 2.0

This appendix contains a second version of the retasking storyboards. The emphasis here was placed solely on the retasking triggers to force development of the kernel process of retasking. The base opening and closing triggers were used to demonstrate the construction of the front end process by which the FIDO would make the decisions to retask his assets. A retasking template and the six displays used as the front end for retasking the AI assets due to a base closure because of weather are provided. A narrative explaining each display is also provided.

Retasking Template



Retasking Template

This template shows the four windows or frames which constitute the basic design for the remaining six displays. They depict the four retasking triggers which were identified following the creation of the first version of the storyboards.

Weather Down at a Base

Display 1. This series of three displays highlights the process which the FIDO would use if the weather was deteriorating and forcing a retasking posture. This particular display triggers the FIDO with the weather frame, "Weather is down at Base X." The critical element and concern of the FIDO becomes the airborne assets tasked to recover at Base X and possible divert locations. The Weapon Status window would offer those aircraft which are returning (inbound) from missions to Base X.

The Target window offers outbound aircraft, still proceeding on their missions. These aircraft may have to abort their missions because of the increased flying time associated with the divert. They become the second priority after the inbound aircraft. Aircraft are listed by flying time remaining. Bases are listed by closest to Base X. The aircraft in the Target window are listed by those which will

Weather Down at a Base -- Display 1

WEAPON
: REQUIRED DIVERTS :

MSN #	A/C	ETA X	ETA	LOIT
43B6	F-44	+15	+10/Q	+30
62A9	F-19	+30	+35/V	+45

TARGET
: AIRBORNE TASKED LAND X :

MSN #	A/C	PHASE	LOIT
24C6	F-32	ENG	1+10
13M7	F-19	ING	1+40

BASE
: DIVERTS AVAILABLE :

CLOSEST	SHEL	RAMP	MUNI
Q	12	13	GREEN
V	0	5	RED
W	16	16	YELLOW

WEATHER

DOWN AT BASE 'X'

UNTIL 1200Z

CURRENT: FOG, VIS = 1/8 MILE

FORECAST: 1200Z, 1500/3

next become inbound to Base X, in other words, closest to their TOTs.

Display 2. The commander wants to get his aircraft on the ground and turned as quickly as possible. He also wants to make sure that airborne weapon systems that are loaded and tasked have an opportunity to make an impact by completing their mission. The trade off is evaluated in each case using this screen display. Using a matching program from the model base, the weapons requiring diverts and divert bases available are graphically displayed. The FIDO can then run this graphic to show the aircraft (arrows) making the necessary route changes and landing at the divert bases. This "play" feature would have a speed control, freeze feature and playback capability.

What does the model consider? These questions would be checked by the model base:

1) Are there any aircraft with no place to go? (no open bases within range, indicated by blinking arrow.)

2) Are there any aircraft with only one base available? (send them)

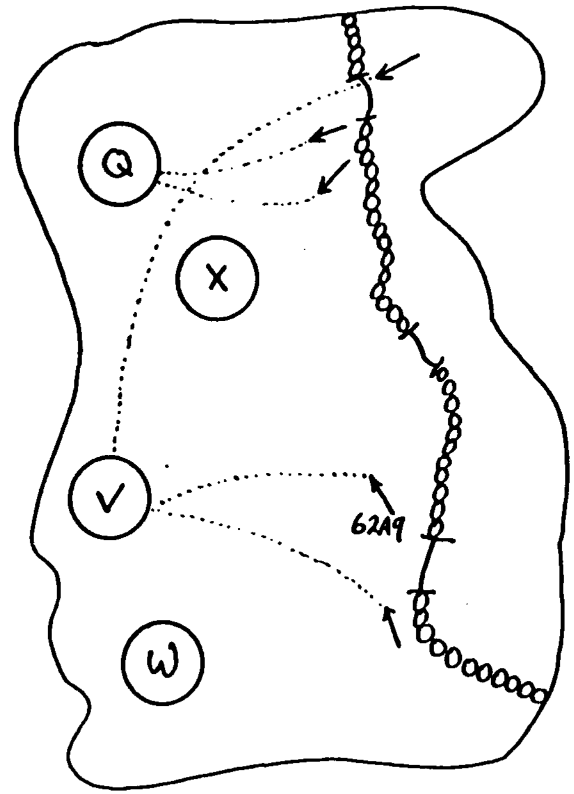
3) Of the other aircraft inbound:
   a) send to base with shelters and munitions.
   b) send to base with space and munitions.
   c) send to base w/o shelters or space but munitions (and wait).
   d) send to base without either and wait.

4) Try to spread aircraft out, don't divert all to a single base.

Weather Down at a Base -- Display 2

PLAY WEAPON-BASE

| INBOUND DIVERTS |



FLAG TARGET

| AIRBORNE RECALL/RETARGET |

MSN #	A/C	PHASE	LOIT
13C6	F-44	OUT	1+35

<< OR >>

NONE

WEATHER

DOWN AT BASE 'X'

UNTIL 1200Z

CURRENT: FOG, VIS = 1/8 MILE

FORECAST: 1200Z, 1500/3

After partitioning the inbound aircraft, attention is directed to the target frame of Display 2. This frame depicts those aircraft which must abort their missions to insure that they can return to a divert field. The commander says use them, so a model is called upon to perform the following functions:

1) Determine new targets, which reduce in-flight time and are within range of the aircraft.

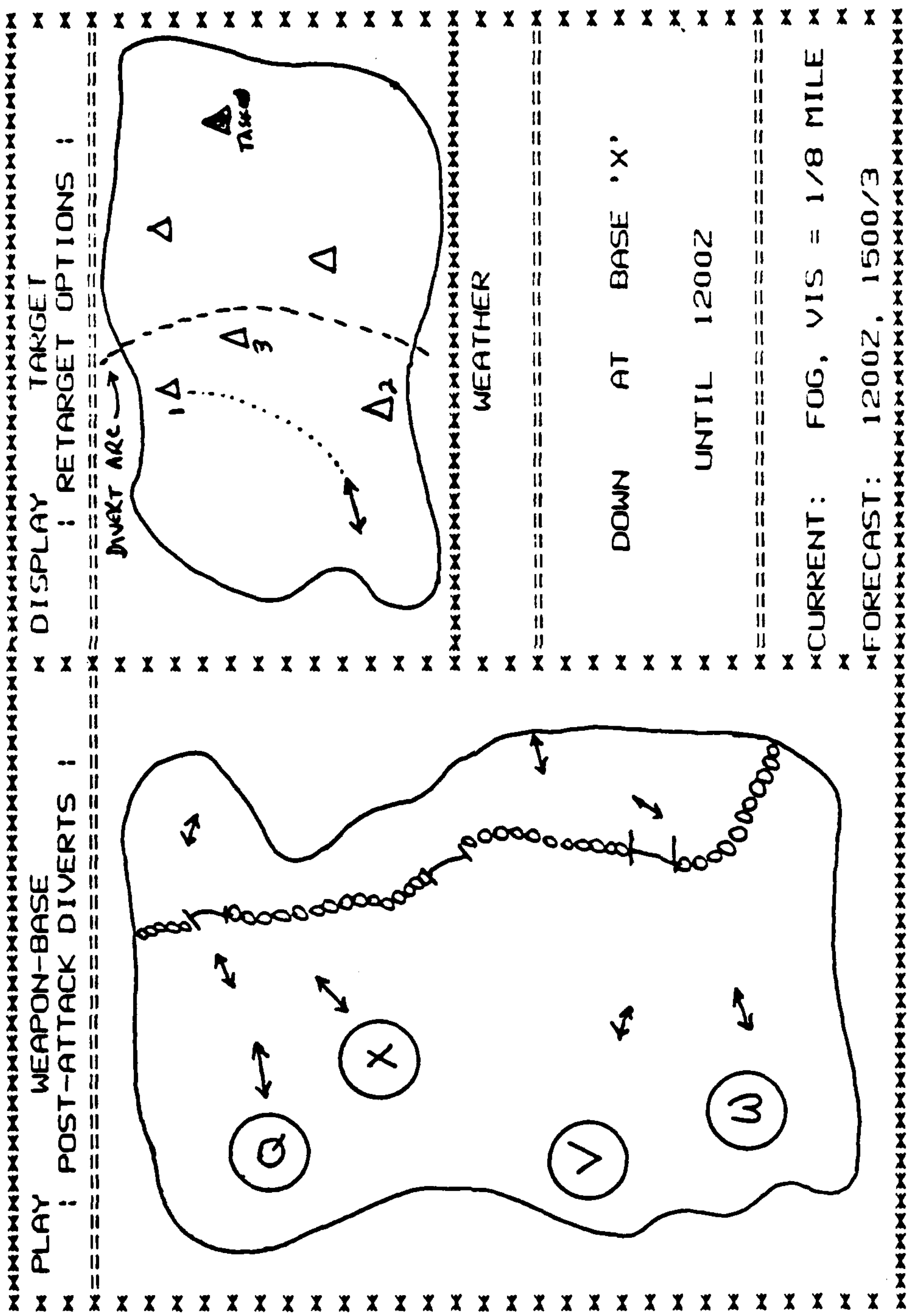
2) Match and filter weapons (the aircraft and munition pair) and check their suitability with the target nomination listing.

3) Retarget that aircraft and display with the set of post attack aircraft and the target priorities.

An important consideration is that the bases are changing their capabilities to handle aircraft continuously because of other outbound missions and recoveries. The need exists, as mentioned in Chapter VI, to provide the FIDO with the most current and reliable information as possible.

Display 3. This display continues to focus on the trigger of the Base X closing due to weather. It captures the retasking of the those aircraft which have not completed their missions. The left side of the display shows a map of the bases, with a graphical representation of the FEBA, gaps in the FEBA and the aircraft (double-headed arrows to indicate pre-attack phase). Similar to the inbound aircraft divert scheme, the FIDO can play the scenario by running the divert model. Two further considerations, the egress route and the penetration gap closest to the divert fields, become

Weather Down at a Base -- Display 3



important factors. A particular aircraft may require a change in the routing and exit gap.

From Display 2 it was determined that because of Base X closing, a mission is in jeopardy of having no divert field if it continues on its mission to attack the original target. This FIDO display shows the aircraft position in relation to the original target, an arc representing the maximum distance for possible diverts, and selected targets short of the arc.

The idea is that based on the aircraft's munition load and capability, the current aircraft position, the constrained range arc, as well as the possible new targets relative priorities, the FIDO would be offered options for retargeting the mission. The mouse control would allow the FIDO to designate on any item displayed and have its details appear in the weather window.

Whether an airfield attack, the weather, or a facilities degradation requires restricted handling of aircraft at a base, these three displays allow the FIDO to work the problem, uncluttered by stacks of data. Instead, aided by the model base, the basic algorithms with which he must be familiar, the FIDO is offered alternatives which he can evaluate and select.

Two important areas are directly affected by the weather deteriorating at a base: targets are now uncovered because sorties which were tasked cannot depart, and it may require a retasking and reconfiguration of aircraft at other bases due to changes in the available target listing and priorities.

Weather at a Base Improves

Display 1. If the retasking trigger (opportunity) shows that the weather is up at Base X, then this display would indicate the new resources that are now available for use in the Base window, what new assets are available in the Weapon window, and what current Targets are uncovered. The Base information would automatically update the data base structure. Although it is not necessarily needed by the FIDO at this point in time, it is displayed as a mind jogger to show him if the base is saturated with aircraft or low on resources. In the same regard, if the weather is good, then how good it is really does not matter at the moment. So both the Weather and the Base windows can be removed from the display.

The retasking process involves handling those missions which have been generated and configured. The commander wants them to make an impact and make one now. The other assets at the base which have not been configured or tasked are not a retasking problem, but are being handled by the "super FIDO". The issue of taking the sorties that were tasked (loaded, mission number, TOT, target, recovery base), and changing their loads prior to retasking would be handled by the reconfiguration DSS. The retasking of these assets most importantly would include new targets and revised TOTs. Tasking them with new targets and TOTs becomes the FIDO's number one priority.

Weather at a Base Improves -- Display 1

WEAPON
¦ TASKED AT X ¦

A/C	LOAD	ETD
F-44	3	1220
F-19	6	1225
F-19	6	1230
F-19	5	1245

TARGET
¦ UNTASKED ¦

PRI	TYPE	TOT
34	C2 BUNK	1300
76	ARMOR	1320

BASE 'X'

SHEL	RAMP	MUNI
13	25	GREEN

WEATHER

IS UP AT BASE 'X'

CURRENT: GREEN

FORECAST: BLUE

It is desired to have a good enough weather forecast so that a gradual retasking of the aircraft can be accomplished. However the aircraft may be waiting in their shelters or on the ramp, configured, crews close at hand with an out-of-date tasking, waiting for new direction.

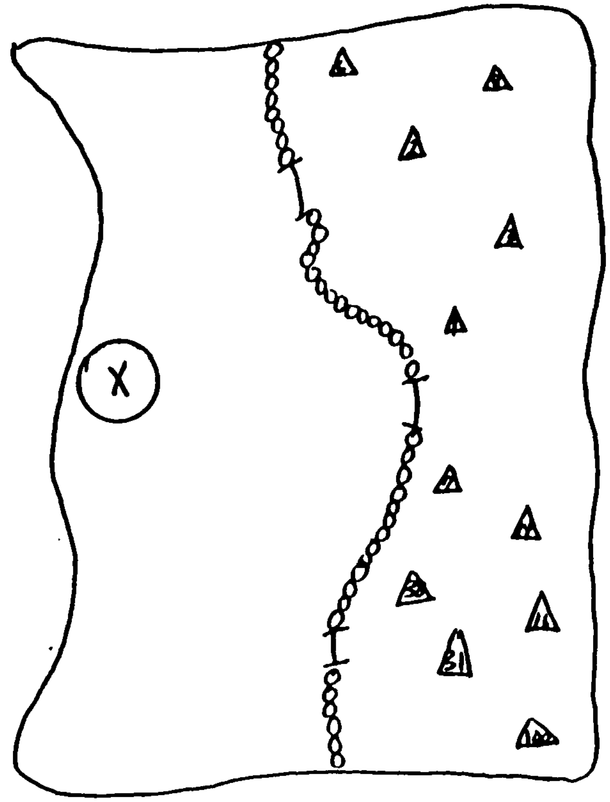
Display 2. This display shows the removal of the Base and the Weather windows, and the expanded Weapon and Target frames. The weapon section contains the information on those aircraft at Base X which now require retasking because the weather has improved. There may be more than one type of aircraft at the base due to previous diverts, but the WOC has reported the following: type aircraft with former mission numbers, present configuration and home base (for crew change purposes).

Depending how good the weather forecast has been will determine how many prior 'good' taskings have been accomplished to meet that forecast. Depending how long the base has been closed, this list may be short or long. The FIDO has his assets which require retasking and he has his display of the targets within the region that are untasked. He can now have the model base do a matching and observe the assets from the weapon list deleted and their mission numbers appear at the target locations with a TOT tag. The targets are represented by triangles and they contain their individual priority.

Weather at a Base Improves -- Display 2

WEAPON ! TASKED AT X !			
MSN #	A/C	LOAD	ETD
34T3	F-44	3	1220
22F6	F-19	6	1225
13A7	F-19	6	1230
45Q2	F-19	5	1245

TARGET
! UNTASKED !



Display 3. The last display offers the FIDO a plan. It has taken the aircraft-munition combination and the prioritized target listing, and assigned those mission numbers which required retasking a new target and TOT. The model asks these types of questions when filtering and matching:

1) Is the munition the aircraft is configured with capable of delivering a certain level of destruction against the target?

2) Is the target within range of the target based on transit corridors and ESM penetration gaps?

3) Is the mission feasible time-wise (responsive to the TOT)?

The system would display the reasons why selections were made or not made when the particular data field is designated with the mouse control. For example, mission # 16T5 is not retasked because of the explanation given in the box in the bottom left hand corner. If the FIDO is interested in a higher priority target which is not covered, then possible explanations could range from "no suitable munition available" to "threat level too high for current assets available -- suppression required."

The key to the explain facility would be the simultaneous generation of recommended alternatives. Even though the system has offered the complete retasking solution, the plan can be still be altered. The FIDO can experiment with each uncovered target and move missions around the target display with the mouse control. The system would explain why this change of plans would be

Weather at a Base Improves -- Display 3

WEAPON
: TASKED AT X :
: WITHOUT TARGETS :

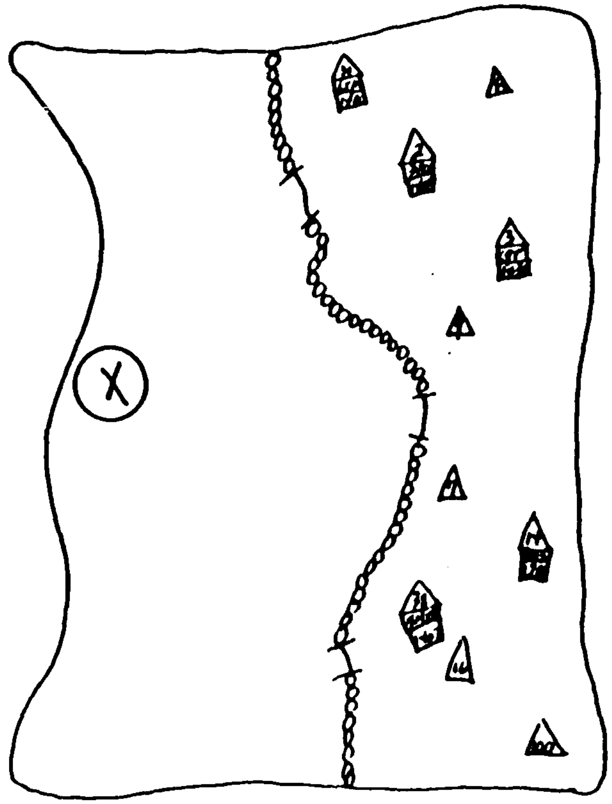
MSN #	A/C	LOAD	ETD
16T5 ↑	F-44	3	1220

EXPLANATION: MSN # 16T5

There are no targets which can be effectively engaged with this munition load.

RECOMMEND: Reconfigure or Hold

TARGET
: RETASKED/UNTASKED :



infeasible or less desirable. The system would still allow the FIDO to modify the system's retasking.

A function key is envisioned which is called the "I need ..." command. During the process the FIDO discovers that there is an aircraft with an unsuitable weapons load for the present target array. The function would allow him to request a compatible target for the configuration which the aircraft currently possesses. A search through the target list does not currently uncover a compatible target, so the FIDO essentially "back orders" a target. He can also establish a time limit for this process so that he can hold the aircraft for a certain time, if a target does not appear, then the aircraft is referred to the reconfiguration DSS.

This display would also incorporate a play function with a simulation program to see in advance how well the retasking plan would work. A series of these plans could be generated so as to discover what trends may be causing one set of plans to fail while a separate set seems to be working.

Conclusion

The six storyboards represent a selection of two of the triggers, a setback and an opportunity, which make up the front end design of the retasking DSS. They walk the FIDO through the process of retasking AI assets in a dynamic environment. The displays and supporting models offer assistance to the FIDO in the form of generating alternatives which he can evaluate and then select.

Similar displays can be created for the remaining triggers, but it was determined that these six displays capture the key representations and processes required to retask a mission. A continuous match/rematch/match process becomes the key kernel as the availability of weapon systems increases or decreases, or as targets become more lucrative or disappear. The weather and base triggers determine changes to the target and weapon availability directly.

Appendix E: Reconfiguration Storyboard

This appendix contains a single storyboard for capturing the key elements involved with the reconfiguration of air interdiction aircraft. The emphasis with this display is to allow the user to experiment with the tradeoffs involved in the reconfiguration problem without having to switch among different displays. A master menu is not provided as this representation is envisioned as a supportive tool for the overall process of allocating the AI assets. A narrative explaining the potential uses of the storyboard is provided.

```
************************************* A - 7 ***************************************
*                                    =====                                          *
*        TARGET:  C3 BUNKER                                   WEATHER:  1500/3      *
*        ======                                               =======               *
*                 +----------+                                                      *
*      MUNITION:  |MAVERICK|   ROCKETS     20MM      500LB     2000LB               *
*      ========   +----------+                                                      *
*                                                                                   *
*   DESTRUCTION:  >>>>>>>>>>>>>>>>>>>>>> 58%          75%          100%             *
*   ===========                                                                     *
*===================================================================================
*                                                                                   *
*        THREAT:     3/SA-6          2/SA-11          2/ZSU 23-4                    *
*        ======                                                                     *
*                                  +----------+                                     *
*       TACTICS:    POP-UPS    LEVEL   |STANDOFF|   HI-DRAGS   PRECISION GUIDED     *
*       =======                    +----------+                                     *
*                                                                                   *
*      SURVIVAL:  >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>> 79%     90%     100%       *
*      ========                                                                     *
*===================================================================================
*  1-HELP|2-AIRCRAFT MENU|3-NOTE|4-SAVE|5-PRINT|6-PUT NOTE ON|7-QUIT|8-EDIT        *
*************************************************************************************
```

Reconfiguration Storyboard Explanation

The tactical aircraft assigned to perform the mission of air interdiction are capable of attacking various targets with a wide assortment of conventional munitions. Each munition is designed to produce a particular kill mechanism and each is designed for delivery from specific weapons delivery tactics. Free fall (bombs, dispensers), forward firing (projectiles, rockets), and precision guided (TV maverick, laser) munitions are they major categories of tactical ordnance. Self protection configurations such as chaff, flares, ECM pods, and air-to-air missiles were considered standard aircraft loads for this investigation.

The command and control questions addressed in the development of this storyboard were:

1) When and how does the commander of air interdiction assets decide to reconfigure his aircraft?

2) Fundamentally, what are the underlying processes by which the commander formulates his judgment to reconfigure?

3) How does he make his choice on the specific aircraft munition loads to be used?

This single display would use a mouse control to allow movement within the display and permit designation of the different data fields. Developed from the concept map located in Appendix A, each field would be backed up by a series of different element types, such as the set of aircraft assigned to the air interdiction mission. The user could activate one of the data blocks using the mouse, and toggle through the set of elements for that particular field.

This storyboard would display the updates based on the newly selected data point, whether it is the threat, target, or tactic. The decision maker can literally start from any given data element as the anchor position, and experiment with the other fields while monitoring the percentages for aircraft survival and target destruction. The target would come packaged with the threat and weather information from intelligence sources.

As with the aircraft type the target types are stored in a data base and the decision maker can cycle through them. As he does so, the weather will be displayed for that target. If a delivery tactic is selected which violates the weather criteria for that tactic, then the weather category and numbers will flash as well as the tactic selected, indicating that an invalid delivery tactic for the given conditions has been selected. The target type will also eliminate any munition which is totally ineffective against a particular target and not permit display of that weapon.

The user could also drive the sliding bars with the tailing percentages to certain levels and the model base backing up the representation would offer solutions in the form of the best available configuration for a particular aircraft and the given threat and weather conditions. The use of a single display would provide tighter control and less interference with the experimentation of the scenarios and the decision processes involved with the final reconfiguration selection.

Most of the function keys are self-explanatory:

1 - HELP...On-line documentation.
2 - AIRCRAFT MENU...Assets available.
3 - NOTE...A scratchpad, window to jot notes.
4 - SAVE...Preserve a screen display.
5 - PRINT...Print display.
6 - PUT NOTE...Attach a note to another display.
7 - QUIT...Leave the display.
8 - EDIT...Change input.

The development of this storyboard has produced some insight into this complex problem. The commander must make the decision to reconfigure when the threat or weather force a change in tactics. The overall ground battle situation may dictate an increase in the commander's requirement to destroy targets, thus increasing his risk taking posture. An increased emphasis on the design of cockpit selectable munitions to permit different delivery modes is needed. The weather usually won't cause aircraft losses during a conflict, but poor tactics against even a mediocre threat will.

In summary then, the commander must make the decision to reconfigure when:

1) The threat changes the tactic.
2) The battle changes the risk taking posture.
3) The target changes.
4) The munitions available change.
5) The weather changes the tactic.

Appendix F: Hook Book

The following ideas/thoughts represent this researcher's notepad. The ideas have been gathered during the evolutionary process and two iterative designs of the retasking storyboards. The ideas have been organized by similar topical areas as closely as possible, and where feasible, a capsule paragraph is offered as an expanded explanation of the topic. Although some of these ideas may not be practical and others may not be possible, they are still offered in hopes of preventing future DSS designers from "re-thinking" the problem, and possibly help generate newer ideas and insights.

Decision Support Systems in General

The hook book became the futuristic, 'I want this for a storyboard.' The hook book will drive the requirements, it tells the builders what the user wants, indicates what they need, how they might want it displayed, and captures other sub-problems which the user and the designer may end up dealing with.

Adaptive design works well for problem definition because it is more responsive to user needs, and that's what the users want. They will not wait, they'll do there own programming, because they have that power to do so.

The closer this research came to completion, the more ideas and entries were made in the hook book.

A key seems to be to find an organizational or procedural mechanism to allow 'bottom up' adaptive design of DSS to interface with the 'top down' design of the major data providing systems currently planned or in existence.

Dynamic programming and decision analysis would allow for the sequential optimization of the processes and permit alternative selection through multi-criteria decision making in the form of discovering the impacts of decisions.

If all of the organizational people are keeping hook books, and you have a meeting where all come to a meeting armed with the collections of ideas, a powerful brainstorming session could result with all participants feeding off one another.

Users need a specific test plan which they can employ in the operational environment. This is a crucial evaluation hurdle which when overcome leads to more specific requirements definition and the evolutionary creation of follow-on capability.

Adaptive design is discovering from experimentation through system design.

Users are oftentimes not smart enough to define their own requirements.

Need a simulation (scenario) builder.

What is the one thing we can do for the user using automation?

If you are going to build an ES you have to have an expert, don't you need the same if you are going to build a DSS?

In the adaptive design process there is no real end goal, while a specific prototype of a system will have an end goal for the systems requirements.

The range to a given target set based on the route of flight and the penetration gap is a constraint.

The 'what if' nature of the hook book makes it an important design tool even by itself.

Maintain data integrity---lose an aircraft? Remove it from everywhere within the system, but record the historical reasons for the loss.

Never, under any circumstances close out your hook book. When you think you've filled it up, another idea will occur. Like the DSS itself, the hook book is never complete, but unlike the DSS, many hook book items outgrow their system in importance and contributions.

A DSS is not strapped to a 300 page book of specifications. There is no need to use the complete memory capacity of the cray computers in the initial design process.

Don't let technology get ahead of the expert, let the expert remain in charge.

Use the evolutionary approach so that we learn as we grow.

For now use automation for functional areas, automating the simplest manual information. Really need now to see that the right information is in the right form and gets to the right place at the right time.

A DSS is designed to provide memory aids rather than mere storage facilities for information. These memory aids are provided to assist the process of making a decision without interfering with the decision process itself.

To make the DSS sensitive to the user's needs a linear programming sensitivity analysis model could allow the FIDO to experiment and watch the impact of different decisions.

Make it sensitive to determine how the decision varies in its importance of evaluating different criteria. A simulation model would analyze the outcomes to determine statistically where the biggest punch could be administered with the highest degree of certainty of mission success.

This DSS should provide the support required to jog the memory with appropriate heuristics vice requiring the user to stop working and search for the information needed to continue.

The challenge which a DSS can meet is to provide answers to complex problems.

DSS have refocused research and the attention away from the study of models to the study of the problems those models are designed to solve.

The need for user interface -- Because DSS are predicated on the importance of the users and what they need, put the ultimate user first ... the guy in the cockpit.

Storyboards

One stop shopping with the menu key, use it to go to any display without going through a lengthy list of menus.

Need feature to deal with maps which permit the user to expand or explode the maps to view details or large scale implications of decisions.

Storyboarding helps you develop requirements even if technology is not present.

This (f)orm or (p)rint vice this function key approach (1-form 2-print) for storyboards. Should make both varieties available and let the user decide which is better suited.

For simplicity, reduce everything to a common denominator, i.e., sorties "I have 54 F-44 POL sorties remaining."

Instrument approach facilities for a base are definitely part of their status.

When the pressure of time exists, the user needs interactive communication with a system which saves time.

What generated ideas for the hook book? In my case, the storyboarding process.

The reconfiguration DSS -- supply a graphic picture of the aircraft with pylons ... too specific?

Spoken commands, high speed simulations for planning and "what if" exercises, plus a capability to communicate through both audio and visual media.

Pictures, graphics and maps, 3-D precise views of the battle field from any angle.

Process

The danger of automation is the loss of the rational behind the decision process and the interrelationships used to capture the rational behind the planning. A way to avoid this ... the managers are the planners.

Think in terms of processes about the individual data bases versus descriptors of the system.

Pretend the munition is the most important thing, track each and every one of these.

Command and Control

A parallel system and operator is needed to run an identical DSS with a back up simulation driver running at several times the speed of the real time system so that the FIDO can use the simulation driver information to anticipate, analyze and evaluate the expected results of his selections and taskings. With this ability to play out selected options, the FIDO can get smart and avoid dumb mistakes.

Just like flexibility is the key to airpower, anticipation is the key to command and control power. So the command center needs weather, intelligence and disaster preparedness folks to make good forecasts which will allow the FIDO to task before setbacks force him to react.

Warlord has the big picture with map displays. The FIDO is sweating the details and needs more specifics to ask/retask, might tie into map displays quite often.

The communications problem is HUGE!!! There is presently extreme difficulty in communicating the retasking message to the AI assets.

Who has the real decision power and influence?

Decentralize during design by giving the DSS to the guy at the lowest level. The results will be better information on the needs of the end users, more rapid execution, and the workers will then demand the technology, instead of having the system hidden in the command center.

What are the relations between data and information? Just because someone has the information, it does not mean that they have the expertise or knowledge to make a decision. Merely possessing the information does not give the person the "power" to make a decision.

The flexibility to cope with change, that's the beauty of the adaptive, iterative, rapid prototype approach. Interesting point, I was working on a project designed to increase the flexibility for the command and control system and the air interdiction assets, using a flexible approach. The more dynamic a problem area, the more an adaptive approach design applies.

This tool will definitely reduce time required to retask air interdiction aircraft, but more importantly, increase the effectiveness of our AI assets by increasing their flexibility.

This command and control DSS should be of such size as to allow airborne employment aboard an E-3A, AWACS or an ABCCC C-130 (Portability).

Someday airborne diverts of our air interdiction assets will be possible both in terms of communications and pilot workload. This DSS is trying to capture the essence of those futuristic capabilities by examining the command and control structure which is needed to use that mission capability effectively.

Continue to think dynamic with last minute changes to target, munitions, base, and aircraft, even though at the present time we cannot react or flex quite that quickly.

The air tasking message is not responsive enough ... there must be a better way to treat the rapid retasking!

The ATM is the vehicle by which the ATOC tasks a wing to fly an immediate mission or change a previously preplanned mission. Couldn't the ATOC send out a selection of priority targets, and the WOCs send back the targets they are going after. Is this workable? Does it improve the overall effectiveness of our assets or does it just streamline a command and control process?

ATM is not responsive enough ... burst communications, digitally transmitted.

Just like there is a bone yard for aircraft we have retired, we need a place to retire our older command and control system components.

What's the back up to JSTARS?

The ground control unit (ATOC) and the control unit in the air (ABCCC) need to know what the other is doing.

Real time information on the enemy and the friendly forces is a must if we are going to rely on these systems to work.

Automatically produce and communicate the responsive retasking orders. Automatic blending and correlation of the sensor and intelligence data will give the commander real time situational awareness.

Repetitive performance of the command and control options.

Survivability, flexibility and mobility of the dispersed computer and data resources. Such redundancy would allow us to fight to the last computer.

Eliminate the dreaded information overload through computer systems and afford us the ability to manage and to execute the war with a skeleton command and control crew. In the end, put more people back in operations.

The FIDO

What are the most time consuming, tedious tasks which the FIDO performs?

FIDO becomes a higher ranked person with all of these decision tools and increased responsibility freeing the lieutenants for flying.

Try to recover the aircraft to their home station at the end of a duty day, otherwise the aircraft cannot be turned with a crew change.

Does the FIDO really need to know 'why' things have caused a retasking? Or just that they have changed.

Peacetime training at Blue Flag is a must for future FIDOs who will be using more complex equipment and have more responsibility than just counting beans! Need to identify those who have completed the training, so they can be assigned to the FIDO role when the conflict begins.

Generally, it will take more time to reconfigure an aircraft than it will to find a new target for that mission.

The FIDO tasks ...
- Divert people to bases, targets.
- Reconfigure munition loads.
- Select aircraft from a base dependent on....
- Cover high priority targets.
- Insure aircraft survival.
- Keep the aircraft flying.
- Get aircraft to home base at the end of the duty day.

What is the FIDO's goal? Who is the Super FIDO?

Use conventional loads instead of quantities of munitions to free the FIDO for retasking the weapon systems capabilities versus the ordnance availabilities.

The FIDO could take the default assume position. The assets are there to further the fight for flexibility, so give the FIDO the freedom to do almost anything in the system design and then let the system tell him he can't perform a certain retasking for a given situation and set of circumstances.

Set up several FIDOs with the retasking DSS working the AI problem, tied to the same data bases and have a 'boss' (commander) monitor the big picture, approving and disapproving the FIDOs' retasking efforts.

Feedback to the FIDO ... is he informed as to whether he is meeting, exceeding, or falling short of the command and control goals and objectives?

Behavior modification? What is the discipline required of a FIDO. Who makes the best fighter duty officer? Is there a 'Top FIDO'? What are the suggested mechanisms for training and motivating an augmentee who doesn't want to be in the command center, but instead wants to be flying?

Get ahead of the war! Tell the WOCs to tell the munitions crews in advance as the aircraft are returning from a sortie what to expect to load.

What are the FIDO's marching orders from the warlord?

What does the command structure really want the FIDO to be responsible for? What are the commander's guidelines and how does he communicate these to the FIDO?

Find out if aircraft are returning with ordnance. Get a faster turn if they still have munitions; give them priority for fuel.

Operational Procedures

Just because the weather deteriorates in a target area, it doesn't always mean a restriction. A thick overcast may offer just the protection the air to ground assets need to hide from the higher flying air to air threat. Likewise, bad weather at our bases would mean temporary immunity from some air attacks.

The weather is an all pervasive factor in the design. It can close or open target areas, and ground or free weapon systems, just as it opens or closes bases. Likewise it can affect routes and FEBA gaps.

The FIDO should not be 'flight following' the mission like an air traffic controller, but should be actively involved with the immediacy of the situation.

Night fighting capabilities mean a twenty-four hour war with a big thirst for immediate everything, continuous flow tasking.

What basing concept do you use? Get as close as you can to the FEBA, be in jeopardy of constant attack, but be able to exert more pressure by flying more sorties because you are closer to the battle. Or position yourself far enough away to protect your assets, hit the targets fewer times, but probably generate sorties without too much harassment.

Technology will increase the flexibility of our aircraft to the point where the dependency on the large package or gorilla philosophy will be an inflexible, constraining option.

Some other DSS is doing the gross apportionment of aircraft for the different mission roles, i.e., CAS, OCA

For the FEBA penetration, use one gap for penetration and a different gap for egress. Can we deconflict the missions at the gaps by time? Probably a luxury, what can the ESM folks support?

Ineffective missions or missions without a possibility of success waste resources (POL and ordnance) and compete for precious shelter and ramp space.

How long should the FIDO spend on one problem before handling another setback or crisis?

Will it come down to launch everything as soon as you can and we will task them enroute? If so, the reconfiguration kernel becomes the most significant, because that is the last thing you have control over before you launch, unless of course we possess multi-mode weapons.

Deep Interdiction versus Battlefield Air Interdiction. The discriminator is type of target (position and time to enter battle). These two missions are really divided by our capabilities to plan and execute. Technology is giving us the tools to do magnificent things in the area of planning and execution, and thus these missions will tend to blend as one. The threat especially will force the discriminators to vanish.

What is the expected allocation of assets to the AI mission? A completely different problem than the FIDO has, but if the apportionment of aircraft to the AI mission is slim, how does that impact the AI commander's approach to using those assets?

Has compartmentalization of information on the operational side of our forces restricted our growth? A unit with a new, improved capacity tends to possess the 'greater than thou' syndrome. New units are built by cadres of individuals who sometimes think they have enough good ideas because they have good people working the problems. The most insignificant individual to the mission may, in the end, have the greatest contribution through the most unique insight, from the most diverse viewpoint, and sometimes from the most inconspicuous position. The point is, operational units are hurt at both ends of the spectrum; the new unit doesn't get the fresh ideas and the older units don't get the feedback on the new technologies to help them increase their skill levels with older equipment. The technological advances which we are making will tend to lead us to more compartmentalization of information, a danger to the operators who need to know what sister units are doing, and how they can fight together.

Intelligence

As one target is added or subtracted the rest of the targets change their priority ... so too for the changes in the ground war, these changes influence the importance of hitting certain targets.

A target may become more lucrative because the suppression assets have defeated a portion of the enemy's defensive system.

If the enemy is devoting a considerable amount of their air defense resources to protect a given target, does that portray their perspective of increased value for that target?

When does the commander in a conflict need the information? At least as it happens, but preferably with some degree of certainty, before it happens!!!

Target priority is not just ordered. It must have a weight factor attached to it, so that the first and third targets can be separated out by how many more times important the first is versus the second or the third target.

Data fusion generates a target base through sensor data and knowledge of the enemy's movements.

The best decision aid for the commander is good information, accurate and timely.

Intelligence and all their sensors are constantly updating the target listing and threat intensity. How often? What sources are they using?

Friendly situation values are needed to determine areas of influence, critical events, expected enemy reactions on the ground.

Assist the commander in determining high payoff targets and attack them in priority. This priority should be based on interest, doctrine, the situation, target weighting.

Just as we task intelligence to gather information via recce sorties for target pictures, there should be an intelligence "grocery list" which a crew could go to (on a micro in the squadron, of course) to select other Essential Elements of Information they might require for their mission.

Technology

Target acquisition may be the toughest part of the delivery equation, so the emphasis should be placed on improving the ability to acquire the targets with pre-flight intelligence products or through the capture of the target signatures in the final phases of weapon delivery.

Too many command and control systems are not healthy, and may complicate matters. It is important to incorporate new command and control systems simultaneously with the introduction of new weapon system capability.

Try building an aircraft based on the command, control, and communications system we want to use for it and the doctrine we want both to support. Start thinking of the weapon system from these two perspectives up front, C3 and doctrine.

Biggest stumbling block, the communications problem

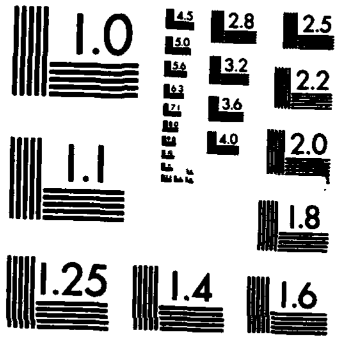
Technology will reduce dependence on airborne [illegible] support.

Technology has the ability to reinforce [illegible] individual as he goes through the decis[illegible]

Doctrine

Does new equipment really generate [illegible]

AD-A185 234 DESIGN OF A DECISION SUPPORT SYSTEM FOR THE DYNAMIC 3/3
=RETASKING= OF AIR IN (U) AIR FORCE INST OF TECH
WRIGHT-PATTERSON AFB OH SCHOOL OF ENGI J A SCHOECK
UNCLASSIFIED JUU 87 AFIT/ENS/GST/87M-15 F/G 15/6 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

What is the organizational resistance? Who and where? It's not just U.S., what about the approaches different NATO forces have toward the command and control of their assets.

How many aircraft are we willing to lose to destroy a given target? How do you measure the cost versus benefit?

If an advantage in the command and control arena can be capitalized on, then force the technology to respond to our needs instead of having technology drive our doctrine.

The increased responsibility presented to the FIDO by using the retasking DSS will also mean an increased influence on the outcome of the battle. Is he becoming more accountable for mission failures?

Further Study

How do you select the right user? Sometimes its the guy with all of the instinct and no set pattern to performing his tasks. Unfortunately, instincts tend to fail with little or no warning, so some type of system should back up those instinctive decision making processes which a leader has often developed through his personal experience.

With the increased sortie rates associated with twenty-four hour operations, manpower adjustments are required for both operations and maintenance.

Organizations always change slower than individuals or technology. Is that good or bad? The damper effect of the system.

How do you get an expert system to represent the time crunch of making pressure type decisions? Lock the system if a time period exceeded?

Need to be assigning value to second echelon targets. The Army may be the candidate to nominate such a value, as depending on where, when and who they are fighting, their status will determine which targets require higher priorities. The value of an enemy ground target in the second echelon is much more likely to be influenced by the status of the ground war than the status of the air war, especially in this age of jointness and interoperability.

For the concept matrix located in Appendix A, to determine mission success, i.e., target destroyed, aircraft survives, what are the most significant blocks? Can I rank these in importance to achieve mission success?

Regarding the retasking triggers, how can we turn our setbacks into opportunities?

Future investigation is required in the area of marginal triggers, where the weather is marginal, the weapons are operating in a degraded capacity, the bases are operating in a restricted mode, or the weather conditions are marginal.

Another DSS for maintenance turn times. A logistics DSS for base mission essentials, i.e. POL, LOX. Upload times for certain standard conventional loads and munitions. A network of DSS, for each functional area.

What things can be changed with the smallest impact versus the greatest impact on the mission?

Does a dynamic DSS need a warm up period like SLAM? This is a dynamic model and so we need to begin with the war already in progress for evaluation purposes.

How do you measure delay of second echelon forces?

What is the minimum message needed by the aircrew for mid-flight diverts?

A connection is necessary between this retasking DSS and the squadron route planning aids and the threat penetration analysis aids, because that's the next thing the crew would do with the new tasking information, begin planning the route and target area tactics.

When is the air threat too intensive to proceed on the mission?

What is the present cut-off time a crew can accept changes and still proceed? The response would be, 'It depends...' Depends on what? The nature of the change ... timing is everything.

The rules of engagement (ROE), often politically driven, are a big factor in how we conduct a war plan. Investigate an ROE advisor. Too much or too complicated of an ROE will restrict our forces.

Future Issues

Advantage, technology could permit combining the WOC and ATOC duties to free up flyers. Disadvantage, too much centralization.

Capture the target area with a video or movie picture scheme so that the aircrew can view the area like a security guard monitors TV screens for security purposes, but also like a surgeon uses fiber optics to view the detail of an operation from different angles.

Do we actually lose our flexibility because in the heat of battle we cannot change our computer programs and software fast enough to keep up with the changing conditions or false preconceived ideas of how the enemy reacts?

How many data links do you want between your command center and the aircraft? Here's an absurd one; takeoff times are sent to the command centers by burst communications which automatically updates the flight following data base when the gear handle is raised.

Duplicate the aircrew heads up displays on a monitor in the command center as is done at Red Flag with the airborne instrumentation packages. The command center then can "dial up" any tail number and observe vital telemetry information.

Single ship missions flying different routes would stretch defenses, decrease predictability, and stretch defenses.

Display an ever shrinking circle on the aircraft video maps showing an overlay indicating distance he can fly from present position based on fuel remaining. Show the same information on the FIDO's divert display.

Assume maintenance crews can cross service aircraft from other bases ... a capability which not all bases or crews might have, but which would allow a tremendous degree of flexibility for the FIDO, "You go to base Y, they can turn you."

Would the FIDO prefer maximum flexibility from the aircrew and AI assets, as if he were flying the jets in a video game (ultimate centralized control), or treating them as super cruise missiles with which he could communicate and change their mission profile, dialing warhead effects? Feasible? Appropriate?

How do you transition to the new technology and keep from reducing your operational effectiveness during the "learning curve"?

How about the most experienced aircrew for the most difficult mission? Track number of sorties each aircrew member has had in theater. Who are the "Top Guns?"

This aid is not designed for today's aircraft or weapon systems, but instead for those of 1995 and beyond equipped with artificial intelligence applications and JTIDS technology.

Deception and misinformation -- who will perform these tasks to protect our command and control structure?

Secondary targets, if not provided and mission not retasked, what are the fall-back orders?

This whole process is so communications dependent. How can it work in a comm-out mode? Command and control is useless if you can't issue executable orders to meet your objectives.

With the increase in computer assisted devices, how will the leaders of tomorrow gain personal experience in making tough decisions? Twenty iterations from now, how will we capture a decision process which the user describes as, "Well, I hit this button, then move the cursor here, then deselect the mouse...." Why do you do it that way? Same old answer as today, "I don't know, but it gives me an answer," but a different reason -- lack of experience and thought on dealing with the decision process because of lack of experience forming a decision process of his own.

<u>Other</u>

How much information is enough? How much is available?

Too many changes, although trying to make things as perfect as they can be and seemingly making the system more flexible, may actually hurt the overall effectiveness of the assets.

Who has the information and who has the expertise and who has the assets? The ATOC has the high level information and planning expertise, the WOC has the most current information on the assets, the aircrews have the most expertise and have the weapons and "pickle" buttons.

Attempt to find the least expensive sorties to cover a specified target with a given aimpoint and set of weaponeering options.

The services tend to waste money on "eye wash and glitter."

DSS + ES = DSES (Decision Support Expert Systems). Combine the power and advantages of the two ... DSS unstructured problems, what does the user want? Give the user what he wants using Storyboard Software and Expert Tools to derive alternative plans of action using rules. The obstacle for command and control systems is generating, testing and selecting alternatives.

Pilot workload ... single-seat versus aircrew versus pilot associate versus type mission aircraft. Have technology reduce the workload, but not restrict the control and the options for the pilot.

Many of these hook book items could be consolidated, many of them could be placed under more than one topic area, some of them could be expanded to three page papers, some of them constitute research topics by themselves.

How often should you aggregate your hook book as I did in this last appendix? More and more items were entered during this categorization process than expected. Suggest that once the items have been organized, avoid the tendency to have your hook list arranged by topical area. If you do, the tendency will be try and pigeon hole each item in an original topic area which may not help you gain new insights in subsequent reorganizations, an important step in the process. Within each topic area presented, further sub-topics should be established and items grouped accordingly.

ESM assets do their own thing. With help from suppression assets, they together work to roll back the SAMs and AAA to allow for FEBA penetration, opening gaps to second echelon target areas.

How close can the ground war get to our forward operating locations (FOLs) before we have to cease flying operations?

Compare the tasking of large scale packages from past Red Flag exercises, matching tactics to threat and munitions with delivery accuracy to expected target damage.

How much air cover do we have for interdiction missions? Is that the best way to use our air to air assets, to protect our air to ground assets?

Alert aircraft -- ground and air. Tanker consideration to maintain airborne alert AI aircraft during critical enemy movements where even more responsiveness is required to gain and maintain the initiative.

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Vita

James Albert Schoeck was born on 28 March 1952 in St. Louis, Missouri. He graduated from St. Louis University High School in 1970 and attended the United States Air Force Academy, Colorado, from which he received the degree of Bachelor of Science in Engineering Mechanics in June 1974. He received a commission in the United States Air Force, entered active duty in June 1974 and attended Undergraduate Helicopter Training (UHT) at Fort Rucker, Alabama. Upon graduation he attended CH-53C Combat Crew Training at Hill AFB, Utah. He then completed an overseas tour at Sembach AB, Germany, performing duties as a CH-53C Flight Examiner. Following completion of Squadron Officers School at Maxwell AFB, Alabama, in December 1979, he was assigned to Grand Forks AFB, North Dakota. There he was the HH-1H detachment operations officer until January 1981 at which time he entered fixed wing conversion training at Sheppard AFB, Texas. Upon completion of fixed wing training, he attended upgrade training in the A-10A at Davis-Monthan AFB, Arizona, graduating in October 1983. Assigned to the 353 TFS, Myrtle Beach AFB, South Carolina, he performed duties as an A-10A Flight Commander, Instructor Pilot, and squadron scheduler until entering the School of Engineering, Air Force Institute of Technology, Wright-Patterson AFB, in August 1985.

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