A METHODOLOGY TO DEVELOP INTERACTIVE DECISION SUPPORT SYSTEMS FOR COMPLEX UNITED STATES AIR FORCE LOGISTICS PLANNING

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in Engineering

By

TODD W. KUSTRA
B.S. United States Air Force Academy, 1991

2000
Wright State University

ABSTRACT

Kustra, Todd William. M.S.E., Department of Biomedical, Industrial, and Human Factors Engineering, Wright State University, 2000. *A Methodology to Develop Interactive Decision Support Systems for Complex United States Air Force Logistics Planning.*

Designing effective decision support systems for complex logistics planning is necessarily challenging to accomplish. Only now, with the advent of the Air Expeditionary Force concept of operations and impending advancements in logistics database capabilities, is an effective desktop decision support system for production level supervisors a feasible reality. Several factors including knowledge about resources and requirements, uncertainty, work domain task constraints, and database capabilities influence the decision making process of the logistics professional. To develop effective decision support systems, this research proposed a methodology that incorporates image theoretical constructs, work domain analysis, decision analysis, and knowledge-based heuristical modeling to capture and transform expert mental frameworks into computer-based support systems for supporting daily decision making.

Specifically, this research includes knowledge-based model development and implementation. The model development was based on two components. First, it was based on field study observations and interviews with real-world logisticians at two air bases. Second, it was based on decision making activity analysis using observation and semi-structured interviews with production superintendents of operational F-16 maintenance units at Hill AFB, UT.

Two modes of decision support were instantiated for the task of aircraft selection under the Air Expeditionary Force scenario. One mode simply presented information for supporting decision making, while the other provided more interactive decision support based on the proposed methodology. These systems were evaluated using maintenance personnel from the 445th Air Force Reserve Squadron and Air Force Material Command familiar with the elements of aircraft selection. Results showed that the interactive decision support system significantly decreased

the time to complete the task, but did not conclusively demonstrate performance accuracy improvement or increased confidence in the generated solution. Overall, the results indicated that the methodology developed produced a decision support system that suggests tangible benefit for complex logistics planning in United States Air Force activities.

WRIGHT STATE UNIVERSITY

SCHOOL OF GRADUATE STUDIES

<u>March 15, 2000</u>

I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY Todd William Kustra ENTITLED A Methodology to Develop Interactive Decision Support Systems for Complex United States Air Force Logistics Planning BE ACCEPTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF Master of Science in Engineering.

_____
S. Narayanan, Ph.D., P.E.
Thesis Director

_____
Richard J. Koubek, Ph.D.
Department Chair

Committee on Final Examination

_____
S. Narayanan, Ph.D., P.E.

_____
Richard J. Koubek, Ph.D.

_____
Craig M. Harvey, Ph.D., P.E.

_____
Ling Rothrock, Ph.D.

_____
Joseph F. Thomas, Jr., Ph.D.
Dean, School of Graduate Studies

ABSTRACT

Kustra, Todd William. M.S.E., Department of Biomedical, Industrial, and Human Factors Engineering, Wright State University, 2000. *A Methodology to Develop Interactive Decision Support Systems for Complex United States Air Force Logistics Planning.*

Designing effective decision support systems for complex logistics planning is necessarily challenging to accomplish. Only now, with the advent of the Air Expeditionary Force concept of operations and impending advancements in logistics database capabilities, is an effective desktop decision support system for production level supervisors a feasible reality. Several factors including knowledge about resources and requirements, uncertainty, work domain task constraints, and database capabilities influence the decision making process of the logistics professional. To develop effective decision support systems, this research proposed a methodology that incorporates image theoretical constructs, work domain analysis, decision analysis, and knowledge-based heuristical modeling to capture and transform expert mental frameworks into computer-based support systems for supporting daily decision making.

Specifically, this research includes knowledge-based model development and implementation. The model development was based on two components. First, it was based on field study observations and interviews with real-world logisticians at two air bases. Second, it was based on decision making activity analysis using observation and semi-structured interviews with production superintendents of operational F-16 maintenance units at Hill AFB, UT.

Two modes of decision support were instantiated for the task of aircraft selection under the Air Expeditionary Force scenario. One mode simply presented information for supporting decision making, while the other provided more interactive decision support based on the proposed methodology. These systems were evaluated using maintenance personnel from the 445th Air Force Reserve Squadron and Air Force Material Command familiar with the elements of aircraft selection. Results showed that the interactive decision support system significantly decreased

the time to complete the task, but did not conclusively demonstrate performance accuracy improvement or increased confidence in the generated solution. Overall, the results indicated that the methodology developed produced a decision support system that suggests tangible benefit for complex logistics planning in United States Air Force activities.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

ABBREVIATIONS AND ACRONYMS

ACC	Air Combat Command	**DCC**	Dedicated Crew Chief
AEF	Air Expeditionary Force	**DM**	Decision Maker
AFB	Air Force Base	**DSS**	Decision Support System
AFLIF	Air Force Logistics Information File	**DTC**	Data Transfer Cartridge
AFORMS	Air Force Operations Readiness Management System	**EAF**	Expeditionary Aerospace Force
AI	Artificial Intelligence	**FMC**	Fully Mission Capable
APS	Authoring and Presentation System	**FR/ED**	Fault Reporting/Expert Diagnostic
AWDS	Automated Weather Distribution System	**GA**	Genetic Algorithm
AWN	Automated Weather Network	**IDSS**	Interactive Decision Support System
BLSM	Base-Level System Modernization	**IMIS**	Integrated Maintenance Information System
C2IPS	Command and Control Information Processing System	**IPO**	Information Presentation Only
CAMS	Core Automated Maintenance System	**LOCIS**	Logistics Command and Control Information Support
CAP	Crisis Action Plan	**MCDM**	Multi-Criteria Decision Making
CONUS	Continental United States	**MESL**	Minimum Equipment Subsystems List
D3	Dataset number 3	**MOC**	Maintenance Operations Center
D4	Dataset number 4	**MS**	Maintenance Superintendent

NMC	Non Mission Capable
OAP	Oil Analysis Program
OPTEMPO	Operations Tempo
OS	Operations Squadron
P$_{1-6}$	Position numbers one through six
PMC	Partially Mission Capable
PS	Production Superintendent
PS&D	Plans, Scheduling, and Documentation Branch
SAB	Scientific Advisory Board
SIOP	Single Integrated Operational Plan
SMO	Squadron Maintenance Officer
TAWDS	Transportable Air Weather Distribution System
TCTO	Time Compliance Technical Order
USAF	United States Air Force
UTC	Unit Type Code

1.0   Introduction

1.1 Motivation and Background

With the emergence of ideologically polarized world communities after World War II, the United States Air Force (USAF) has adhered to a Cold War containment policy designed to win large-scale conflicts between major world powers. These policies required enormous investments in standing military forces, intelligence, treaty maintenance, and pre-positioned supplies. With the fall of the Soviet Union, political realities have caught up with ever constricting budgets of the Department of Defense, resulting in the need for a new way of thinking. The challenges faced by today's Air Force are not only from outside powers impinging on vital national interests, but also from within its own organizational structure. Large-scale conflicts require large applications of force, but the low to mid-level crises common to our era require proportionate dispensations of force.   Adhering to Cold War dogma increases the cost and inefficiency of modern forces resulting in an "all-or-nothing" response to global conflicts.   Containment policies have transformed into global engagement policies, which respond to crises before they evolve into larger-scale conflicts. This fundamental shift has resulted in corresponding changes to strategic implementation of force and serious impact to logistics practices and methods.

1.1.1   Fundamental Shift in Air Force Strategy: Expeditionary Aerospace Forces

With the advent of changing world threat conditions, increasing budgetary constraints, and the need for a more responsive, capable logistics capacity, the USAF has embarked on a new course of operations that mark the return to expeditionary, light and lean applications of force. The Focused Logistics operational concept of Joint Vision 2010 (JV2010) and the resulting Global

Engagement: A Vision for the 21st Century Air Force, outline the need for a greater capacity to launch world-wide military actions based from the continental United States (CONUS) instead of the present-day reliance on large-scale forward-basing of supplies and equipment overseas. In order to meet the challenge of multiple low to mid-level crisis response efforts, the Secretary and Chief of Staff of the Air Force commissioned the USAF Scientific Advisory Board to study and make recommendations concerning Air Expeditionary Forces (AEFs). AEFs are defined to be "tailorable and rapidly employable air and space assets that provide the National Command Authority and the theater commanders-in-chief with desired outcomes for a spectrum of missions ranging from humanitarian relief to joint or combined combat operations" (USAF SAB, 1997, p. 1). Under the EAF concept, the Air Force is divided into several Air Expeditionary Forces (AEF), each roughly equivalent in capability, among which deployment responsibilities will be rotated (Tripp et al., 1999). The AEF is a unique, task organized, tailorable warfighting force composed of organic airpower assets capable of supporting operations anywhere in the world (Goodman, 1998). It provides the combatant commanders flexible, rapid response force packages capable of supporting a wide spectrum of operations while reducing the operations tempo (OPTEMPO) for personnel involved (Reid, 1999). This concept requires the ability to deploy and employ quickly, adapt rapidly to changes in the scenario, and sustain operations indefinitely. To meet the demanding timelines, units must be able to deploy and set up logistics production processes quickly. Deploying units will, therefore, have to minimize deployment support. This, in turn, demands the support system be able to ensure the delivery of sufficient resources when needed to sustain operations (Reid, 1999).

1.1.2 Using Computer Aiding as a Performance-Multiplier

The successful employment of crisis action plans (CAP) for logistical operations in support of AEFs depend heavily on the "transition from a situation in which functional stovepipes exchange vital information late in the cycle, if at all, to a collaborative environment supported by tools that facilitate communication and decision making" (USAF SAB, 1997, p. 37). Part of the solution is

the incorporation of joint decision support tools that "will aggregate, categorize, and depict data elements in a format easy to use and understand" (Joint Vision 2010, Focused Logistics, 1995, p. 21). Decision support tools can come in many forms and may be distinguished by their level of interaction with the user. Low-interaction support tools utilize the computer's ability to perform complex mathematical processes in a relatively short period. These low-interaction support tools depend heavily on the ability of the developer to identify and understand the relationships between several objects of interest, expressing them in mathematical arrangements that can be optimized for the best arrangement or combination of objects in the system. Optimized solution generators attempt to take advantage of the computer's ability to evaluate a significantly large number of combinations to arrive at a desirable solution. Pallet optimization routines that generate the best arrangement of objects to be shipped on a pallet exemplify this type of solution generator. Support tools of this nature are necessarily non-transparent to the user and do not offer explanations for the decision rationale. Optimized solutions are best used for complex systems with closed-form analytic solutions where system objectives remain constant. High-interaction support tools rely upon the user's ability to provide necessary processing of information. A system that determines and displays all information relevant to the entire decision process will enable the user to consider or disregard information at their discretion. Strict high-interaction support tools do not attempt to confine the problem area or offer solutions, but leave the user to explore data elements and determine a solution. Current logistics planning tools, such as the Core Automated Maintenance System (CAMS), provide mostly information presentation and as such do not meet the need for decision support tools outlined in Joint Vision 2010. Complexity in U.S. Air Force logistics processes is due in part to the large number and variety of assets within the system as well as dynamic shifts in objectives. Fluid environments manifest in warfare demand decision-support tools that can incorporate changing objectives and complexity. The goal of this study is to develop and apply a methodology to generate an interactive decision support system for a complex logistics-planning problem in U. S. Air Force systems.

1.2   Research Methodology

Research methodology for this study consists of four inter-related steps. The four steps are: information gathering, model development, model application in complex logistical systems, and model evaluation of performance, efficiency, and trust. Information collection was accomplished by reviewing research literature in the subject area, examining prototypical maintenance work situations at a local Air National Guard base, examining regulations and formal instructions developed by the U.S. Air Force, and by conducting interviews with experts at Hill AFB, Utah. User-centered design principles were used to gather information in a bottom-up manner. Creation of the client model involved two components, modeling air base sortie generation and recovery, and capturing the decision process for an instance of common logistical practice. Typical decision practices were evaluated for use based on their applicability to the logistics domain. The prototype model was then validated using field-testing with subject-matter experts. Subject-matter experts were used to gather subjective and objective data for model evaluation. The primary focus of the research was to determine an approach that can be used throughout the logistical community to develop interactive computer-based decision support aids for AEF-related planning and execution.

The remainder of this thesis is as follows. Chapter 2 outlines the literature review of the various phases of this research. Chapter 3 describes the methodology applied to the model development of resource availability for inclusion in deployment activities. Chapter 4 applies the model to the design and evaluation of interactive decision support for logistical processes. Finally, Chapter 5 discusses the contributions and limitations of this study and outlines ideas for future research.

2.0 Related Research

There are several areas that are directly applicable to the development of a systematic decision support methodology in USAF logistics. The first section outlines a traditional generic framework for developing a decision support system. The framework serves to provide an adaptive iterative design template from which to implement decision support ideas. This framework is an important element, necessary for understanding how individual functions relate to the entire system environment and for identifying the user's interaction with system components. The second area outlines research into database technologies. Future database solutions for USAF activities, programs underway and recent attempts to coordinate between a myriad of information systems are discussed with the emphasis on the state of USAF database capabilities and critical shortfalls for current DSS design. The third section reviews system components that make up the model base. The model base outlines various techniques developed to manage and frame the contents of the database. These methods range from strict system-centered analytical tools that limit user involvement to user-centered techniques that maximize flexibility and allow for changing environmental conditions. The fourth and final area discusses the perspective of the user as a fully integrated component within a DSS framework. Using Image theory to discern human operator cognition, this section outlines important implications for DSS design. Image theory is a powerful tool for understanding and reproducing mental representations in which decision-makers comprehend and interact with the system environment (Beach, 1997). Identification of the appropriate user schema is vital to the successful implementation of an interactive decision tool.

2.1 Decision Support Systems (DSS)

Decision support systems change by definition and function across disciplines in such a way that it is necessary to first characterize the nature of decision support systems before moving on to necessary structural features. Steven Alter (1980) examined fifty-six systems, which supported decision-making varying by "degree of action implication of system outputs, i.e., the degree to which the system's output can directly determine the decision." Finding a strict definition difficult to generate, he utilized this sample to develop a set of abstractions describing their characteristics. Characteristics of DSS differ from electronic data processing systems by their emphasis on "increased individual and organizational effectiveness rather than on increased efficiency in processing masses of data" (Alter, 1980, p. 3). Vlatko Ceric (1997) and Sprague (1989) combined the work of Alter (1980) and Keen (1981) with their own work to outline six necessary qualifications for DSSs. Ceric summarized DSS characteristics as being able to:

- "Assist the users in semi-structured decision tasks,

- Support managerial judgment,

- Improve the effectiveness of decision making,

- Be used by non-computer specialists in an interactive manner,

- Combine use of models with data bases, and

- Adapt to the decision-making approach of the user" (Ceric, 1997, p. 251).

The above themes are consistent and widely agreed upon standards for DSS. They are also somewhat ambiguous, qualifying most computer applications in use today as decision support tools of one degree or another. Yet the above list has several aspects important to the adoption of an appropriate logistics DSS framework, namely semi-structured task domains, the ability to perform adaptively to the changing goals and values of the user, and support for managerial judgement.

Ceric, Alter, Keen, and Sprague all agree that semi-structured decision tasks are the environment in which good DSSs thrive. Semi-structured decision tasks are those tasks that "do not display enough structure to list feasible values of parameters...." (Alter, 1980). Multiple criteria decision making (MCDM) proponents further categorize semi-structured decision spaces as having two main problems, not knowing the decision maker (DM) value function and the inability to capture changing DM preferences as the process of analyzing progresses (Kaliszewski, 1998). These problems violate, in spirit if not in fact, the fourth and sixth characteristic in Ceric's list. True interaction and adaptation with the user implies a level of cooperation between DSS components not inherent in current USAF logistics systems (LOCIS, 1997).

Supporting managerial judgment and improving the effectiveness of decision-making relate to the decision space or contextual relationships within an organizational structure. Sprague (1989) theorizes that because, improving performance is the ultimate objective and knowledge workers in an organizational context are the clientele, any DSS framework must be created adjusting for variation among differences in organizational structure. This is not to say that one DSS must accommodate all levels of management only that DSS must consider the relationship the user has with system components within the context of the organization. Herbert Simon (1945) first identified this concept as 'bounded rationality'. Due to limited cognitive capacity, the DM reduces information-processing demands by simplifying problems they encounter. Therefore, any DSS framework must account for the limiting capabilities of the user.

Knowing the characteristics or qualities of DSS enable us to develop a likely generic framework of system components for an appropriate architecture. Watson and Sprague (1989) discuss useful ways of thinking about component parts of a DSS and the relationship among the parts. Suggested components utilize the dialog, data, and models (D, D, M) paradigm. Component architecture is shown in Figure 1.

7

Data Base						Model Base

Figure structure:

Data Base

Transaction Data:
- Aircraft Status
- Flying Schedule
- Operational Supply
- Personnel
- Other

- Other Internal Data
- Document Based Data
- External Data

Database Management System (e.g. CAMS) ←

Model Base Management System →

Model Base
- Strategic Models
- Tactical Models
- Operational Models
- Model Building Blocks and Subroutines

Dialog/Interface

Decision Maker

Figure 1: A Generic Logistics DSS Framework adapted from Decision Support Systems: Putting Theory into Practice (p. 108), by R. H. Sprague and H. J. Watson, 1989, Englewood Cliffs, NJ: Prentice Hall. Copyright 1989 by Prentice Hall. Reprinted with permission.

Figure 1 shows the identity and relationships between the three major components of a DSS, database, model base, and dialog, as they relate to the DM. Information is made available through the database, interpreted to support particular decision spaces in the model base, and presented to the user in the dialog or interface. Not shown in the figure is the knowledge base or

what the user knows about the decision and about how to use the DSS. In USAF logistics this information is largely treated as though it comes from outside the DSS environment and is not traditionally included as a formal part of the system.

2.2   Database in Context

According to Captain R. Cardona (personal communication, September 9, 1999), an F-16 maintenance officer working for the Air Force Research Laboratory, the database in Figure 1, within the context of USAF logistics systems, is comprised of an enormous amount of individual items. Examples of relevant data include information concerning the status of spare parts, personnel, individual activities in progress, fuel, ammunition, maintenance, planning and scheduling, resource amount and availability, facilities, and managerial policy and direction. These data groupings interact in such a way that it is difficult to separate each database one from another. To demonstrate this and to decrease the amount of confusion in explanation, this research focuses on front-line maintenance units that are responsible for the sortie generation of aircraft in a fighter squadron. It is also helpful to note that each of these databases can significantly differ based on the type of aircraft or weapon system for which an individual unit is responsible. For example a General Dynamics F-16 requires different parts, specialists, documentation, fuel, ammunition, and scheduling, than does a Republic A-10. This information can be found by consulting the millions of pages of documentation associated with the individual aircraft. This factor causes difficulty when each of the individual weapon systems do not have standardized information processing systems to manage the data. The following paragraphs in this section depict current USAF research enabling real-time update of the database and interaction among the various database components.

In December 1995, the Air Force Armstrong Laboratory in concert with Paperless Acquisition Initiative published a document outlining the requirements for the Logistics Command and Control Information Support (LOCIS) project. This project proposed to "assess the information

9

requirements, flow, and use of current logistics management and technical systems"(LOCIS, 1995, p. 1). The purpose of the research was to determine the "need for, and feasibility of, conducting a research and development (R&D) project that would investigate better ways to improve the timeliness and understandability of logistics information as it feeds a wing's command and control process" (LOCIS, 1995, p.1). When viewing the USAF logistics community informational data reservoirs as the database component in Sprague's DSS framework, three of the six major findings of the study directly portray the current state of the component for DSS use.

1. "There are numerous interface problems between logistics automated systems. Most of the systems currently used do not have basic clipboard cut and paste capabilities that users expect. [This bullet is seemingly two distinct problems, (1) computer databases are unable to communicate with each other due to different formats, and (2) older computer systems do not meet with current expectations in user-interface design]

2. There is an inordinate amount of "fat finger" data collection occurring within all units. In many cases information is double and triple entered. It is so time consuming and inconvenient that data is either not input or is not accurate.

3. Information presented to decision-makers is unintegrated, not current, not accurate and not easily understood. The telephone and radio net are still the most commonly used systems for passing important logistics information during normal, contingency or deployment operations" (LOCIS, 1995, p.5-7).

These findings spawned efforts to revisit and renew research in the area to enable real-time and accurate information. One such effort was the Integrated Maintenance Information System (IMIS). IMIS demonstrated the "capability to access and integrate maintenance information from multiple sources and present the information to technicians through a rugged, hand-held computer (Link, Von Holle, and Mason, 1987, p.1)." IMIS enabled workers at the lowest levels to directly input work order data to a central information database updated in real-time. IMIS also

10

incorporated an Authoring and Presentation System (APS). APS demonstrated the use of a "neutral" database, independent of the computer system that is used to display the information. Information entered by the user is encoded independent of the output format and thus can overcome the differing format issues associated with legacy presentation systems. IMIS proved so successful that an F-16 system was developed by Lockheed to service the F-16C/D Block 40/42 aircraft. The system, originally called the F-16 Fault Reporting/Expert Diagnostic (FR/ED) System, is "designed to take manual input or to electronically download maintenance data from the Data Transfer Cartridge (DTC), installed in the aircraft by the pilot prior to flight (LOCIS, 1995, pg. 37)." Lockheed, simultaneous with their development of the F-22 aircraft, is also developing a comparable fully integrated maintenance information system.

Other current programs designed to increase the availability and usefulness of real-time and historical data are:

- Air Force Logistics Information File (AFLIF),
- Air Force Operations Readiness Management System (AFORMS),
- Automated Weather Network (AWN),
- Automated Weather Distribution System (AWDS),
- Transportable Air Weather Distribution System (TAWDS),
- Base-Level System Modernization (BLSM),
- Command and Control Information Processing System (C2IPS), and the
- Core Automated Maintenance System (CAMS).

These systems represent a determined attempt by the USAF to overcome current shortcomings in transparency and availability of needed information. Though it is important to note that (1) the needed transparency and availability are not far enough in development to be useful even in a worker-level maintenance DSS, and (2) user expectations and interactions with system components are largely ignored.

2.3   Model Base Development

Models are defined depending on their purpose, treatment of randomness, and generality of application. Banks, Carson, and Nelson (1996) define a model to be a representation of a system for the purpose of studying the system. This definition can be further refined for this paper, as a representation of a system for the purpose of supporting decision-making. This is a very broad definition and can apply to a wide range of techniques that make up the model base. Sprague (1989) states that models used for DSS can have one of two purposes, optimization or description. Optimization models provide information about points of maximization or minimization. Optimization is a prescriptive modeling technique that compares and evaluates decision-making based on some identifiable normative standard. Beach (1997) states that, "With the possible exception of structural modeling, the emphasis in most work on decision making has been on prescribing what should be done rather than on describing what decision makers actually do and certainly not on diagnosis or implementation" (p.5). As a result the cognitive process is evaluated based on how well it conformed to some prescriptive, optimized models rather than the other way around. Descriptive models do not take liberties with ascribing a best solution, but only describe the system's behavior; not suggesting optimizing conditions. Considering Popken's (1992) assessment, that in logistical systems high levels of complexity and entity interactions as well as uncertainty make strict analytical solutions intractable, prescriptive techniques may be unfounded.

Models can also vary in terms of generality of application. Personnel needing decision support are actors within the framework of the organization, and as such DSS should reflect changes in organizational hierarchy. Organizational officials at the strategic-level determine objectives, policies, and disposition of resources. "Strategic models tend to be broad in scope with many variables expressed in compressed, aggregate form (Sprague and Watson, 1989, p.)." The decisions require larger amounts of information from outside the organization and project over a greater time period. In contrast, the lowest levels, or operational level, tend to require short-term,

internally generated information. To support these activities researchers have generated several techniques to assist the user in devising better solutions, these include but are not limited to artificial intelligence, genetic algorithms, heuristics and expert systems.

2.3.1 Artificial Intelligence (AI)

Artificial intelligence is the field whose goal is to automate the knowledge process of human users through the use of information or knowledge representations (Chang, 1985). AI exists in many forms and is often used in the study of mental faculties through the use of computational models (Charniak and McDermott, 1984). AI is based on the idea that mental processes can be thought of in some level as a kind of mathematical, statistical or logical computation and as such has greatly increased understanding about how human operators cogitate. It is important to note, however, that even though AI has its basis in human cognition, "it is not committed to any particular way of producing the results (and in particular, the methods may not be exactly those that people use)" (Charniak and McDermott, 1984, p. 7). AI systems use various methods to obtain their results. Problem solving is accomplished using symbolic representations instead of numerical methods as the basic unit of computation. These symbolic units are utilized in algorithmic frames so that the incremental steps followed by the program are influenced by the particular problem being presented. Typical AI problem-solving methods include: dependency directed backtracking, problem decomposition, generate and test, heuristic search, logical deduction, and meta-reasoning. Traditional applications of AI include search methods, robotic control, natural language processing, speech processing, strategic game playing, and pictorial information processing. Even though AI has progressed geometrically over the past 30 years, Chang (1985) states that several problems, typically involving massive amounts of data, remain to be solved and advances in computing processing power should facilitate the usefulness and power of AI systems. In problems where massive data processing is imperative, these advances have made AI more accessible and practical, however, processing speed has not solved all difficulties, especially involving interactive human decision-making systems.

13

Acquired influences on human decision-making can be broken down into two parts, absolute information and relative information (Kaliszewski, 2000, p. 162). Absolute information is information about values of separate criteria. Relative information is information about criteria values relative changes when moving away from a given decision along a feasible direction. Relative information causes problems for AI researchers in that "the decision maker (DM) value function is usually not known, [and] DM preferences change as the process of analysing a decision problem progresses" (Kaliszewski, 2000, p. 162). Several methods are available to address this problem, two of which are Genetic Algorithms (GA), and Expert Systems.

2.3.2 Genetic Algorithms (GA)

Genetic algorithms are a part of evolutionary computing, which is a rapidly growing area of artificial intelligence. GA originates in the biological evolutionary concept. Each input is represented as a symbolic representation called a chromosome. In biology, chromosomes combine during reproduction in such a way that errors can occur causing mutation. In nature, the degree to which a combination survives can be termed its "fitness." In GA, fitness values are assigned to each new combination of chromosome pairs and tested to determine the feasibility within the domain. Often the fitness value is evaluated using a multi-objective fitness function that reflects different conflicting, quantifiable system goals and requirements such as minimizing cost or maximizing resource utilization (Schneider, 1998; Narayanan et al, 1999). GAs are used most effectively when no "best" answer or condition is known and when the search for a desired outcome is very complicated (Obitko, 1998). GA searches come from the range of all possible solutions and as such can consume a great deal of time and are not useful for time-critical solutions (Obitko, 1998). AEF requirements state the need for logistics planning to be completed within 24 hours of the notice for deployment and as such can be considered time-critical. GA might become more useful to the logistics community with the advent of more powerful computer hardware, but remains an unrealistic expectation for a current DSS application.

2.3.3 Expert Systems

"Expert systems, or knowledge-based systems, are programs that reproduce the behavior of a human expert within a narrow domain of knowledge" (Widman et al, 1989, p. 9). Expert systems usually consist of an inference engine and a knowledge base. Inference engines contain the control structure that enables the program to use the knowledge base. Knowledge base is that information captured from the expert decision-maker for use processing decisions. The knowledge base is typically expressed using production rules or frames (Widman et al, 1989). Production rules represent knowledge as a series of "if-then-else" conditional operators. These operators reflect an "informal estimate of the probability that the conclusion is true if the premises of the rule are met" (Widman et al, 1989). Production rules add to the modularity, uniformity, and naturalness of the model, but also detract from the program efficiency. Information framing deals with the expert's ability to extract a certain order or mental model from a situation (Beach, 1997). Representing an expert's knowledge framework is accomplished using values or procedures stored in a series that together reflect the expert frame. The framework is not interactive and relies heavily on captured knowledge representations that do not readily accommodate change. In real-life, frames are dynamic. They are continually generated and updated by the expert in such a way that criteria have been developed to help decide whether a particular area of knowledge is suitable for development of an expert system (Walters et al, 1988):

- The knowledge required is well defined.

- There exist people who are acknowledged experts in the area.

- The experts can find high-quality solutions to a typical problem in minutes or hours, while non-experts cannot achieve equally good solution or require much more time to do so.

- A timely solution of the problem has high value.

- There is little or no requirement for commonsense reasoning.

- The knowledge base is stable.

15

The knowledge domain described above is well characterized in the military logistics arena. Countless regulation manuals and continual job training help define the knowledge necessary for every specialty in logistics. Personnel are evaluated using graduated training scales and experience levels. For example, USAF military enlisted members are characterized as apprentices, journeyman, craftsman, or supervisors. This knowledge hierarchy enables the researcher to readily identify 'supervisors' as the acknowledged experts in each logistics career field. These supervisors are available in relative abundance and can be interviewed and observed as needed. Consistent with the logistics domain, supervisors practice and work under the strictest time pressures in response to military crises all over the world. In essence, expert knowledge-based systems appear to be useful for military logistical applications, though no current USAF system could be found.

With the identification of domain experts, it is important to identify a theory of decision making that enables researchers to capture and understand the user's decision-making schema. This schema or frame is utilized to develop the expert knowledge base for the model and characterizes the necessary interaction with the user. Image theory provides a useful paradigm for this purpose.

2.4   Image Theory

2.4.1 Background

In order to adequately cover the topic of Image theory it is important to start with the two precursor theories from which it derived, prescriptive theory and behavioral theory. Prescriptive theory is founded on directing decision making toward some normative ideal and determining what should be done instead of what is actually being done. Even though proponents of the theory often used language that implied that prescriptive theory paralleled the cognitive process,

16

the logic of prescriptive models need not conform to that standard (Beach, 1997). Behavior that conformed to the models was considered rational, and behavior that did not conform was judged irrational. Behavioral decision theory started as a study of the degree to which unaided human decision-making conforms to the processes and output of prescriptive decision theory. Decision-making was looked at as a risk analysis or risk avoidance problem. Theorists evaluated through experimentation the conditions under which a DM would gamble on a difficult outcome and what were the strategies involved in creating a balance between payoff and loss. Image theory deviates from both prescriptive and behavioral decision theory in its almost exclusive focus on how decisions are actually made (Beach, 1997). Theorists of this approach use observation to diagnose and decompose decision-making paradigms.

2.4.2 Constructing the DM Frame

Beach outlines Image theory in the following way (refer to Figure 3): "in a nutshell, decision makers use their store of knowledge (images) to set standards that guide decisions about what to do (goals) and about how to do it (plans)" (Beach, 1997, p. 164). Decision-makers evaluate the progression of a plan by continually evaluating it against the goal to determine acceptability. Likewise, any goals or plans not conforming to the standards are eliminated from consideration.

Images are further defined in three categories, value images, trajectory images, and strategic images. Value images refer to the DM's internal principles and ethics. These images determine the rules that govern the DM's behavior within an organization and with the world. Trajectory images refer to the DM's life goals, work goals, and in general the direction of a personal agenda. Image theory does not assume a motivated operator acting in the best interest of the organization alone, but further differentiates between levels of motivation. The third image, strategic, anticipates the outcome of trajectory images and serves to resolve conflicts between internal images and goals. Cognitive dissonance, the conflict between a person's actions and beliefs

17

would be an issue resolved by the strategic image. Framing is the process of searching the constituent parts of the three images to find details relevant to a particular problem. This frame is

Figure 2: The framing of images from The Psychology of Decision Making: People in Organizations (p. 166), by L. R. Beach, 1997, Thousand Oaks, CA: Sage Publications, Inc. Copyright 1997 by Sage Publications, Inc. Reprinted with permission.

then used to adopt a choice strategy or make decisions. Choice strategies can be thought of as progressing along a continuum of cost or difficulty. Strategies range from guessing (Nonanalytic strategies) to exhaustive aided analytic strategies. Unaided analytic strategies or learned procedures would fall in the middle of the cost scale. Aided analytic strategies might include artificial intelligence techniques that fully explore the solution set while taking valuable time to complete the analysis. The two types of decisions in Image theory are the adoption decisions and the progress decisions. Adoption decisions "are about whether to add new goals to the trajectory image or new plans to the strategic image" (Beach, 1997, p. 168). Progress decisions determine whether a plan (or choice strategy) is progressing toward the fulfillment of its goal. Two types of decision mechanisms, compatibility tests and profitability tests process these two types of decisions. Compatibility tests screen (similar to satisficing) options based on the quality of the decision. If the decision has violations of standard above a threshold level it is effectively incompatible with the standards outlined by the choice strategy derived from the three images. Compatibility tests weight the competing decisions for evaluation. Should any decisions survive the parsing process in the compatibility test, the profitability test determines which is best based on quantity of the outcomes associated with the options, or the net expected gain. The net expected gain represents the difference between the subjective cost or difficulty and the expected outcome utility.

2.4.3 Image Theory Application to DSS

Image theory provides researchers with three important elements necessary for inclusion in a logistical decision support system: (1) support for choice strategies identified as necessary to the individual decision task, (2) support for interactive compatibility tests, and (3) support for interactive profitability tests. Images developed by the domain expert form to create a sequential iterative process for completing particular tasks. These tasks are to be identified using a descriptive human-centered approach instead of using a top-down, normative prescription of some ideal process. The identified process should allow the user to interactively perform parsing

19

tasks (compatibility tests) as well as interactive benefit analysis (profitability tests). Compatibility screening relies on some absolute rejection threshold to determine which items under consideration survive. Profitability screening, on the other hand, is not a single decision mechanism but a collective term for the individual's repertory of strategies for making choices and the mechanism for selecting one of those strategies for use on a particular choice (Beach, 1997, p. 170). The rejection threshold and repertory of strategies can be identified by experimentation, observation, or interview. Inclusion of these three elements facilitates the user's natural inclination toward determining the correct solution and as such will simplify the decision-making process.

2.5   Summary

In this chapter several important points are highlighted. First, current systems based on traditional DSS frameworks consider the user's knowledge and experience as a component outside of the system environment with the database, model base, and interface operating without regard to the user's values, goals, and organizational function. Second, there is a need to limit human-centered uncertainty by using support systems based on descriptive human-centered design principles rather than prescriptive techniques. Finally, knowledge-based methods that apply expert interviews and scientific observation to develop modeling content introduce an attractive alternative when combined with the image theoretic approach. This methodology presents an appropriate solution generator in time critical, stable tasks typified by USAF logistics.

In this thesis, a methodology was developed to determine an approach that can be used throughout the logistical community to develop interactive computer-based decision support aids for AEF-related planning and execution. The next chapter describes the expert model development and application of the methodology to an AEF-related task.

3.0 Research Methodology

3.1 Introduction

This thesis developed a human-centered image theoretic methodology as an iterative design approach to the development of a logistics DSS. The research methodology consisted of two major phases: knowledge-based model development and implementation. Model development examined prototypical situations to extract a suitable mental schema allowing sufficiently general application to individual problems. The mental schema for the model development was based on two major components: (1) work domain analysis using open-ended interviews and observations at the Springfield, OH Air National Guard Base and at the ACC Logistics Readiness Training Center at Hill AFB, UT, and (2) decision making activity analysis using observation and semi-structured interviews with Production Superintendents of operational F-16 maintenance units at Hill AFB, UT. Implementation of the model was accomplished using Sun Microsystems's object-oriented programming language Java to develop a PC-based desktop DSS.

3.2 Model Development

Model development utilized work domain analysis techniques to elicit an appropriate representation of a work domain that is useful for system design and analysis. The objective is not to represent the actual interaction among the various system components for a specific situation, but to produce a generalized representation of the work domain in terms of functions, activities, and trajectory (Rasmussen, 1994). These elements comprise the environment in which the human operator conducts business within the organization. By identifying these elements, a task-specific DSS can be implemented that is independent of the various image states, types of
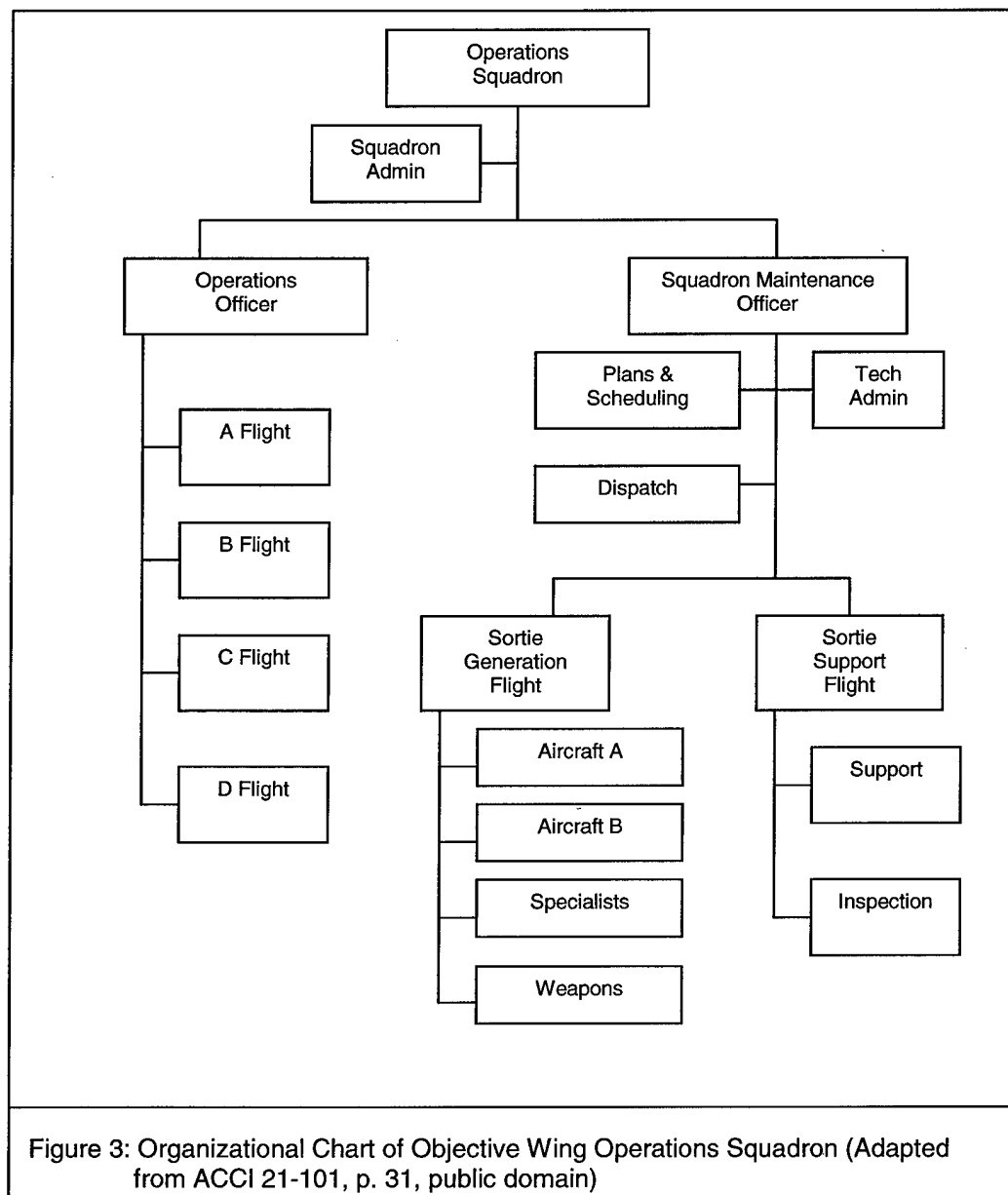
21

decisions, and tests conducted by the human operator as outlined by Image Theory. Analysis is accomplished by identifying three levels of abstraction, general work activities and functions, problem specific processes and activities, and individual task decision-making activities.

3.2.1 General Work Activities and Functions

The decision-makers relative placement and function within the organization, relationship to other intra-organizational entities, and direction from higher echelons heavily influence the development of a knowledge-based model of decision making. This section outlines the work activities and functions of an Operations Squadron maintenance unit that are typical of the Objective Wing Structure in USAF Air Combat Command (ACC). The denotation of activity or function at this level of abstraction is independent of the underlying processes involved as well as their physical implementation.

The Objective Wing concept is a decentralized structure designed to maximize mission effectiveness by anticipating a combat environment characterized by deployed USAF flying units producing sustained aircraft sortie rates under hostile fire conditions (ACCI 21-101). In order to achieve decentralization, the organization further subdivides maintenance organizations into on-equipment sortie production (Operations) and off-equipment support (Logistics). These designations do not delineate between logistical and non-logistical operations, but rather identify broad categories of functional concentrations. For example, maintenance units exist within the Operations Group and also in the Logistics Group. Maintenance units that repair and maintain individual aircraft systems are located in the Logistics Group and generally concentrate on those activities that require higher expertise with individual system components. Operations Group maintenance units are responsible for the day-to-day planning, scheduling, repairing, inspecting, and documenting of aircraft in coordination with the flying component resident in the Operations Squadron (OS). Repair actions beyond the capabilities of the Operations Maintenance unit are handled by the Logistics Group. The overarching goal of both groups is the same, however,

enabling safe, consistent and reliable operation of aircraft for the purpose of accomplishing a specified mission. The Operations Squadron organizational chart is depicted in Figure 4 and should be used as each maintenance-related activity and function is explained. Relevant structural activities and functions include the Squadron Maintenance Officer, Squadron PS&D, the Maintenance Operations Center (MOC), and elements of the Sortie Generation Flight.

```
                          ┌──────────────┐
                          │  Operations  │
                          │   Squadron   │
                          └──────────────┘
              ┌──────────────┐
              │   Squadron   │
              │    Admin     │
              └──────────────┘

      ┌──────────────┐            ┌──────────────────────┐
      │  Operations  │            │ Squadron Maintenance │
      │   Officer    │            │       Officer        │
      └──────────────┘            └──────────────────────┘
                              ┌──────────────┐   ┌──────────┐
                              │   Plans &    │   │   Tech   │
    ┌──────────┐              │  Scheduling  │   │  Admin   │
    │ A Flight │              └──────────────┘   └──────────┘
    └──────────┘              ┌──────────────┐
                              │   Dispatch   │
    ┌──────────┐              └──────────────┘
    │ B Flight │
    └──────────┘        ┌──────────────┐        ┌──────────────┐
                        │    Sortie    │        │    Sortie    │
    ┌──────────┐        │  Generation  │        │   Support    │
    │ C Flight │        │    Flight    │        │    Flight    │
    └──────────┘        └──────────────┘        └──────────────┘
                          ┌──────────────┐
                          │  Aircraft A  │        ┌──────────┐
    ┌──────────┐          └──────────────┘        │ Support  │
    │ D Flight │          ┌──────────────┐        └──────────┘
    └──────────┘          │  Aircraft B  │
                          └──────────────┘
                          ┌──────────────┐        ┌──────────┐
                          │ Specialists  │        │Inspection│
                          └──────────────┘        └──────────┘
                          ┌──────────────┐
                          │   Weapons    │
                          └──────────────┘
```

Figure 3: Organizational Chart of Objective Wing Operations Squadron (Adapted from ACCI 21-101, p. 31, public domain)

23

The Squadron Maintenance Officer (SMO) is responsible to the Operations Squadron Commander for maintenance production as outlined in ACCI 21-101, Section 2.6. The SMO, assisted by the Maintenance Superintendent (MS), manages resources necessary to accomplish the mission. The SMO and the Operations Officer serve as the liaison between the needs of the OS flying components and the OS maintenance components. The needs of the flying components include successfully achieving flying hour goals and maintaining current pilot qualification in the mission design series. The needs of the maintenance component include time, personnel, resources, and facilities to inspect, document, and repair aircraft for routine operations. Coordination is a key element to the smooth function of flying operations and as such the SMO and MS spend a great deal of time meeting with cross-functional areas to resolve personnel, supply and production issues. The SMO and MS perform the following functions as outlined by ACCI 21-101:

- Designate Maintenance Flight Commanders/ Chiefs.
- Implement Monthly Maintenance Plans.
- Monitor Dedicated Crew Chief (DCC) Program and certifies the Aircraft Dedicated Crew Chief in writing.
- Ensure personnel are qualified to support OS tasking.
- Establish procedures for the Structural Integrity Program.
- Periodically review CAMS data.
- Publish procedures covering storage, control and handling of starter cartridges to meet daily alert, training, and single integrated operations plan (SIOP) requirements.
- Ensure assigned personnel understand the purpose of AF Form 2409, General Sequence Action Schedule.
- Monitor oil analysis program (OAP) status.

The Squadron Maintenance Plans, Scheduling and Documentation (OS PS&D) Section reports directly to the SMO/ Superintendent, and is the focal point for all squadron maintenance planning. OS PS&D performs all scheduling duties for assigned aircraft, and maintains a liaison between the squadron, operations support squadron PS&D, and the Logistics Group Mission Analysis Section (LSS/EM). The planning process, at the squadron level, is a consolidated task involving all squadron supervisors. Automated data collection products, like CAMS, are used to forecast, schedule, and monitor completion of squadron aircraft hourly inspections, special inspections, technical orders, and replacement of time change items. OS PS&D responsibilities as outlined by ACCI 21-101 include:

- Plan and schedule the use of squadron aircraft to meet flying requirements.
- Conduct unit pre-dock and attend daily maintenance meetings.
- Perform the PS&D portion of aircraft document reviews.
- Initiate and maintains folders for applicable TCTOs.
- Ensure major maintenance support requirements are loaded into CAMS.
- Maintain aircraft historical documents.
- Compute OS Maintenance Planning Effectiveness and forwards data to analysis section.
- Attend various meetings that ensure proper coordination.

The Maintenance Operations Center (MOC) monitors sortie production, maintenance production, and execution of the flying and maintenance schedules provided by the PS&D Section. The MOC sets priorities for their respective production efforts to meet mission requirements. Priorities are set for activities such as fuel or calibration docks, wash racks, and dispatched specialists from the maintenance squadron. The exchange of information between squadrons and the MOC must be in sufficient detail to allow the MOC to comply with reporting requirements and to identify potential problems. MOC responsibilities as outlined in ACCI 21-101 include:

- Maintain visual aids that show the status and location of each aircraft on station, maintained, or supported by the Wing.

- Ensure aircraft status is properly reported and maintained.

- Coordinate and monitor the progress of Aircraft Functional Check Flights.

- Inform affected activities of changes in priorities, plans, and schedules.

- Coordinate changes to the flying schedule.

- Coordinate munitions delivery priorities.

- Select tail numbers of aircraft needed for contingency operations.

- Other coordinating activities.

The Sortie Generation Flight normally consists of Aircraft, Specialist, and Weapons sections. The flight is responsible to the SMO for ensuring sufficient numbers and specialties of personnel are available to support the production effort. Aircraft sections are comprised of dedicated crew chiefs, assistant crew chiefs, and aircraft technicians. Aircraft sections are the primary work centers responsible for maintaining the assigned aircraft. Common aircraft section tasks are servicing scheduled and unscheduled maintenance, pre-flights, basic post-flights, home station checks, and launch and recovery of aircraft. The Specialist section includes dedicated technicians that perform on-aircraft repairs; troubleshooting, component removal/replacement and aircraft ground handling. The Weapons section performs the loading and maintenance of weapons onto the aircraft.

The Production Superintendent (PS) is also resident in the Sortie Generation Flight and is the focal point and coordinator for maintenance production decisions within the squadron. The PS is a key figure in achieving sortie generation goals and directives and as such makes daily decisions that enable the squadron to successfully implement AEF directives regarding deployment of forces, personnel, and resources to employment locations. For the purpose of this thesis, the PS functions as the designated decision-maker for the individual decision task

examined by the interactive DSS. ACCI 21-101 section 7.8 outlines the PS responsibilities as follows:

- Directs the maintenance effort using resources from Sortie Generation and Sortie Support Flights.

- Is involved in developing and implementing the Monthly and Weekly Maintenance Plans, ensuring resources are available to meet these plans.

- Serves as the squadron point of contact for all decisions relating to squadron maintenance production.

- Coordinates with other squadron PS for squadron to squadron support.

- Attends Daily Maintenance Meeting.

- Knows the status of assigned aircraft.

- Knows the actions required under unit SIOP/ Contingency Plans

- Directs aircraft generation flow

- Coordinates with the MOC for support required outside their control.

- Advises the MOC of conditions that may disrupt orderly, controlled execution of the Maintenance Plan.

In this section, individuals and organizational entities were discussed to provide a functional representation of the organizational environment in which the Production Supervisor (PS) conducts business. Utilizing organizational resources to gather, update, and interact with pertinent resources; the PS derives images that correspond to Image Theory values, trajectory, and strategic direction. Directives received from higher organizational components, like the Operations Squadron (OS) through the Squadron Maintenance Officer (SMO), coupled with the sphere of authority and responsibility outlined by pertinent regulations make up the PS non-physical constraints to decision making. The tangible realities, limiting factors of personnel, resource allocation, facilities, and aircraft limitations produce the physical constraints to the sortie production decision space. Production Superintendents, thus constrained, make adoption

decisions and progress decisions using appropriate image theoretical tests (Compatibility and Profitability) to generate aircraft maintenance production.

3.2.2 Processes and Activities (Sortie Generation)

The process and activities associated with sortie generation define the properties necessary and sufficient for control of physical work activities and use of aircraft to perform the mission. Discussed in this section is the iterative process of coordinating activities between the various OS components to achieve the organizational objective. This section examines the work environment from the perspective of system output extracted from procedural utilization of the previously discussed functional elements of the OS. Significant processes and activities include, but are not limited to, Aircraft Scheduling, Aircraft Status Reporting, and Flight Line Maintenance processes (see Figure 4). These processes transfer the direction from higher headquarters into the day-to-day activity of a flying unit and provide feedback to upper management. The following paragraphs depict the basic processes resulting in sustainable sortie production.

Figure 4: Significant Maintenance Processes

28
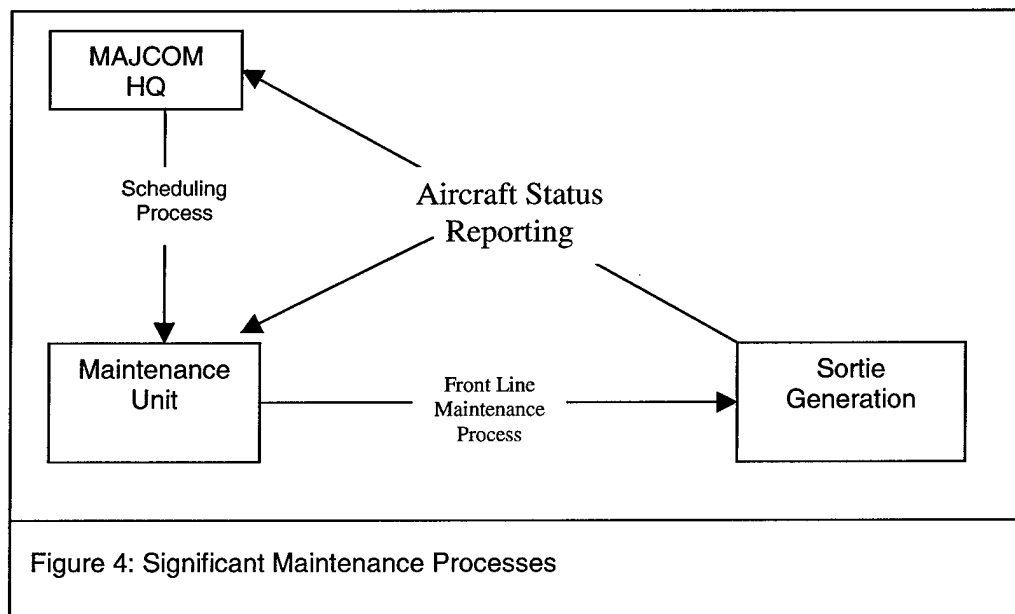
Flying and Maintenance Scheduling is the process of enacting the Flying Hour Allocation program through the planning cycles of operations and maintenance quarterly, monthly, and weekly schedules. Flying hour goals and directives are distributed to the individual unit through the USAF Major Command Headquarters. These directives include the required flying hours, sorties/missions, flying days in each month, known and projected special mission requirements, configuration/munitions requirements, and aircraft/aircrew alert requirements. These parameters are used to generate annual allocations of flying hours and utilization rates to the individual flying squadrons. Principle areas of concern are mission accomplishment and improved efficiency.

Flying squadron input is used to generate the maintenance planning cycle. The maintenance planning cycle ensures the proper and effective use of maintenance resources. Long range planning of this sort is needed to arrange quarterly flying hour programs, TCTO programs, depot inspections, phase inspections, scheduled exercises, and deployments. Scheduling and planning of activity results in general operating parameters that maintenance assets use to determine the day-to-day work associated with the unit. These measures of performance and measures of effectiveness represent the guiding force for sortie production and supervision in an attempt to limit the complexity and uncertainty associated with logistical processes.

Limiting uncertainty does not guarantee its absence and supervisors must maintain close scrutiny on operations and aircraft status. To accomplish necessary feedback the Aircraft Status and Reporting process is used. Aircraft status is depicted using a code assigned to a specific aircraft that shows its mission capability rating. The current state of aircraft subsystems is compared to the Minimum Equipment Subsystems List (MESL) to determine the combat capability of the asset. The MESL lists all the systems and subsystems needed for full mission performance and outlines a unit's specifically assigned wartime, training, and test missions and the systems and subsystems that must be working for a unit to accomplish those missions. Aircraft are given a code depicting aircraft status as follows:

- **Fully Mission Capable (FMC):** All systems, subsystems, and components listed in the Full System List (FSL) column are fully functional.

- **Partially Mission Capable (PMC):** One or more systems, subsystems, or components are not working and the aircraft can perform some but not all of its basic missions.

- **Non-Mission Capable (NMC):** Aircraft is incapable of performing any of its basic missions as outlined in the MESL.

Production Superintendents often broaden the scope of aircraft status to include the aircraft state (configuration, fuel, weapons, location, etc.) at a point in time. This definition reflects changes brought on by the Flight Line Maintenance process, but is a less formal definition and is not part of the Aircraft Status and Reporting procedure.

The Flight Line Maintenance process is designed to maintain a level of aircraft readiness at some point beyond aircrew and operational requirements and to provide combat ready aircraft for surge capacity and mobility commitments. Its objective is to provide safe, flyable aircraft, in the proper configuration, when and where needed to satisfy aircrew training and operational mission requirements. During this process, maintenance personnel make preparations for landing, park the aircraft, debrief the aircrew, perform post-flight inspections, work in-flight discrepancies, schedule maintenance actions, and prepare for the next mission. All actions are documented and are posted to the aircraft information system's database.

In this section, processes are defined that translate directives into squadron activities (Aircraft Scheduling), provide feedback and accountability in the form of documentation (Aircraft Reporting), and produce aircraft missions (Sortie Production) through the system environment. Various elements of each of these processes are used by all members of the organization to elicit the desired response, sustainable sortie generation. The next section describes how an

individual decision task is examined to determine the needs of the decision-maker within the system environment.

3.2.3 Decision Making Activity Analysis (Deployment Aircraft Selection Task)

One prototypical production task, choosing which aircraft should be deployed as a part of an AEF rotational cycle, was chosen from the core Production Superintendent's responsibilities to demonstrate the decision-making activity endemic to the Sortie Generation domain under the new AEF concept of operations. The deployment of tailored Unit Type Codes (UTC) for AEF deployment is novel in that traditional deployment encompassed the entire squadron and not just partial representation of the unit. Now, six aircraft may be chosen to deploy, whereas previous deployments included all mission capable aircraft in the squadron. Squadron personnel must prepare and perform all planning activity within a 24-hour period after notification.

Interviews identified two types of choice strategies dependent upon duration and utilization of aircraft while on deployment. Choice strategy 1 was used to select six aircraft for deployment if phase inspections were not expected to be performed at the contingency location. Subject matter experts utilized this strategy if the expected total time of aircraft flight operations was 100 hours or less. Choice strategy 2 was used if aircraft utilization at the deployment location suggested that phase inspections would be performed during deployment. Only choice strategy 1 was incorporated into the decision support system due to the expectation that AEF deployments would be rapid response, short duration actions designed to expedite operations and holding actions before the arrival of more permanent forces. The emphasis being on speed and projection of force instead of on full-scale large deployments. The interactive decision support system used computer suggestions to portray the choice strategy to the user.

Eight evaluative subtasks were identified for choice strategy 1 and listed in Table 1. These subtasks were analyzed to determine the rejection threshold and the variables associated with

31

the profitability tests. Decision tasks served to first eliminate aircraft from consideration that did not meet specified criteria (Compatibility Test) and second, choose the best-suited aircraft based on subjective expected utility (Profitability Test). Compatibility tests performed by the Production Superintendent remove aircraft when the numbers of violations in aircraft mission capability, repair history, and Phase inspection times are above the minimum threshold values for the strategy being used. Profitability tests performed include critiquing aircraft based on scheduled maintenance, outstanding unscheduled maintenance, time to Phase inspection, aircraft configuration, and aircraft location.

During the mission capability or aircraft status compatibility test, the Production Superintendent excludes all aircraft from consideration that are designated NMC or PMC if at least 12 aircraft remain to pass to the next compatibility test. NMC or PMC aircraft are not likely to change status within the 24-hour planning deadline called for by AEF requirements. Aircraft are also eliminated based on repair history considerations associated with the remaining aircraft. An aircraft that has a history of repeat/recurring problems may not be able to successfully execute a transatlantic crossing or fulfill its mission once at the employment location. Repeat/recurring maintenance actions that have no known explanation do not effect the mission capability rating of an aircraft if the problem is not currently present, but must be considered likely to effect wartime efforts if the problem is in a critical system. This characteristic is commonly referred to as the aircraft's 'personality' and denotes the increased likelihood of specific maintenance actions due to prior repairs and factory defects. The complexity and interrelation of aircraft subsystems prohibits the detection and repair of all system failures and must not be ignored.

Evaluation	Evaluation Order	Decision Type	Test Type	Information Requirements
Aircraft Status	1	Adoption Decision	Compatibility Test	Mission Capability Rating, Aircraft History
Phase #1	2	Adoption Decision	Compatibility Test	Time until Phase Inspection, Phase Month, Conflicting Activities
Scheduled MX	3	Adoption Decision	Profitability Test	All known scheduled maintenance actions for the period of the deployment
Unscheduled MX	4	Adoption Decision	Profitability Test	Outstanding repair actions, time to complete repairs, impact of repair actions
Phase #2	5	Adoption Decision	Profitability Test	Time to Phase Inspection
Aircraft Configuration	6	Adoption Decision	Profitability Test	Current configuration of aircraft
Aircraft Location	7	Adoption Decision	Profitability Test	Location of aircraft relative to the airfield
Monitor Goal State	Continuous	Progress Decision	Compatibility Test	Mission update

Table 1: Identification of subtasks.

The Phase Inspection compatibility test takes into account the time remaining before an aircraft is due for major scrutiny (300 hours of flight time), taking it off the list of available assets. If an aircraft comes due for Phase inspection while on deployment, the aircraft is not available to be used for combat missions and must be held until maintenance personnel can fit the inspection into an already crowded schedule. Therefore the rejection threshold for this test is the expected total number of hours aircraft are needed to fly during deployment. If aircraft are deployed for an extended period of time Phase inspection cannot be avoided, but every effort is made to reduce the workload of maintenance personnel while on deployment. Phase inspection cycles are generally displayed on a Phase Flow chart depicting in descending order the tail number of aircraft by time remaining until inspection is due. A line is drawn showing the ideal graduated descent enabling aircraft to enter Phase incrementally. Incremental entry into Phase enables sufficient aircraft to remain in service to accomplish mission requirements. Decision-makers, at this stage, generally eliminate from consideration any aircraft that is due for Phase inspection within flight time allotted for the deployment. Remaining aircraft are included for consideration in the next stage of profitability tests. If the number of aircraft surviving the two compatibility tests is less than the number of aircraft needed for deployment the current choice strategy is abandoned and a new strategy adopted.

33

The first profitability test conducted by Production Superintendents is a review of the importance, frequency, and density of scheduled maintenance items to be performed on the aircraft. Examples of common aircraft scheduled maintenance items include wash and corrosion control checks, 10 hour throttle grip/flame sensor inspection, 50 hour miniforce check, 25 hour borescope inspection, and 50 hour borescope inspection of aircraft blade retainer. Scheduled inspections vary between aircraft mission design series and are determined by specifications provided by the manufacturer. Regular inspections enable the safe and reliable operation of aircraft and enable long service life. Aircraft due for major inspections of critical systems are ranked higher in importance than inspections involving non-critical systems. Importance of aircraft scheduled events were rated by subject matter experts for this particular task to reflect the impact the item would have on deployment sortie generation. Rated items were categorized into three-color codes, red (High Importance), blue (Medium Importance) and green (Low Importance). Time to conduct the inspection and equipment involved in the process are also major considerations. The decision-maker utilizes the aircraft schedule provided by PS&D section to make the assessment, rank ordering aircraft from best to worst.

Unscheduled maintenance review refers to the evaluation of aircraft based on broken, cracked, or out of limit components found during inspection or reported by pilots. Aircraft sent on deployment should necessarily be as free of problems as possible. Therefore, a thorough review of outstanding repairs is necessary. Aircraft are ranked, from best to worst, based on the time to repair the item and the manpower necessary to complete the work order. Repairs to non-mission essential components, regardless of the time and manpower needs, are ranked lower than mission essential component repairs.

Phase inspection times are re-evaluated in the next stage to determine aircraft that have more time until inspection is due. Aircraft with that will not come due for inspection within the time frame of the deployment are ranked higher than are those requiring more immediate attention.

34

Aircraft best meeting this need are located from left to right on the Phase Flow chart and are easily identified. Any times that are over the projected deployment time satisfy the requirement, but those aircraft with greater time until inspection are better due to unforeseen occurrences that might effect the duration an aircraft remains in theater.

Next, aircraft configuration is evaluated to determine those aircraft meeting the mission configuration requirement before deployment. Configuration refers to the presence or lack of armaments, weapons, or specific mission systems on the airframe. For example, if aircraft are needed for overseas deployment, wing tanks are used to extend the range an aircraft can fly. If wing tanks are already present on the airframe, less time is needed to configure the aircraft for duty. The decision-maker ranks aircraft based on the time and effort necessary to reconfigure aircraft for duty.

Also, aircraft are evaluated to determine the most expedient airfield location for preflight activities and launch. Aircraft requiring loading of armaments must comply with regulations concerning distance from critical facilities and other assets in the event of emergency. Similarly, aircraft requiring fuel need to be away from sensitive areas. With larger airframes, movement on the airfield can be extremely difficult due to space limitations and availability of equipment used in the transfer. Smaller airframes, like the F-16, are more readily accommodated. Aircraft are rank-ordered by least effort to comply with regulation limits during preflight and launch activities.

Finally, decision-makers continually evaluate the progressive creation of the available aircraft list. A comparison of current decision progress against the internal image constituents (value, trajectory, and strategic images) impacts the determination of satisfactory progress. In general, this relates to the trust decision-makers have in the process utilized to make the decision and the efficacy of the projected outcome. Solution sets not conforming to internal measures of validity and confidence will not be accepted and initiate a new approach to the problem.

35

Categorizing the identity, decision type, and test type of subtasks enable the development of a semi-structured model-based environment for implementation. In the next section, decision subtasks and image theoretical characterizations are combined to form a knowledge-based model of aircraft selection.

3.3   Model Implementation

A combination pictorial and spreadsheet-based interface is commonly used in many electronic information systems to present information and collect user input. Users consult the spreadsheet-based information presented by scrolling through lists of information, selecting control nodes leading to other pages, and by evaluating forms or figures displayed on the screen. User input is accomplished by inserting aircraft tail numbers into an exclusionary list for compatibility tests and an ordered list for profitability tests. Implementation of Image theoretical decision structures are accommodated by utilizing a structured interactive approach limiting the user to the specified sequence of events and types of decisions, but not limiting the input within the eight identified decision subtasks. Adoption decisions are assisted employing user-input text fields to either exclude aircraft from a list or rank aircraft in an ordered list. Progress decisions are accommodated using a feedback mechanism displaying a cumulative rank ordered list of aircraft as the decision process proceeds. Users can effectively account for changes to internal image states by overriding computer suggestions at any point. Figures 5-13 display screen captures of the individual decision screens directly corresponding to the seven discrete decision subtasks. Users are asked to perform the aircraft selection task within the context of a deployment-based scenario. Scenario instructions are listed in Table 2 and displayed to the user in Figure 5.

36

Scenario: You are the Production Superintendent of a maintenance squadron that provides maintenance support for 18, F-16 block 50 aircraft. You have been tasked by your supervisor to assess the current inventory of aircraft in your squadron and decide which six aircraft should be sent to support an AEF deployment to Aljaber, Kuwait. Upon arrival at the deployment destination the aircraft will be used to provide 100 hours of air-to-air coverage to on-going operations in the area.

Use the program's step-by-step instructions and the information provided to select six aircraft from your squadron to support the AEF directive. These steps will guide you through an expert-derived process to find the best aircraft in the squadron to send on deployment. Any questions should be directed to the experimenter. You may practice as many times as necessary, until you feel comfortable enough to complete the task. When you are ready to attempt a timed trial, inform the experimenter and he will help you begin. Timing of the task begins when the first screen is displayed. Thank you for your participation.

Table 2: Scenario-based Instructions.

3.3.1 Compatibility Tests

The first identified compatibility test is based on aircraft status information. Figure 6 displays the information provided to the user for this purpose. Shown on screen is pertinent data necessary to determine the true mission capability of all squadron aircraft. Users peruse the spreadsheet and activate the aircraft history screen by left clicking on the individual aircraft repair history field. Once aircraft have been identified that do not meet minimum criteria, the user selects the correct aircraft tail number from the list and moves it to the box provided for exclusion. A computer suggestion box is provided illustrating the model's selection of aircraft for exclusion. Users signify agreement or disagreement by entering only those aircraft tail numbers into the exclusion field. The process progresses to the next screen when the NEXT button is selected. Only user-input values are incorporated into the remainder of the program and any user-excluded tail numbers are eliminated from consideration for the duration of the program.
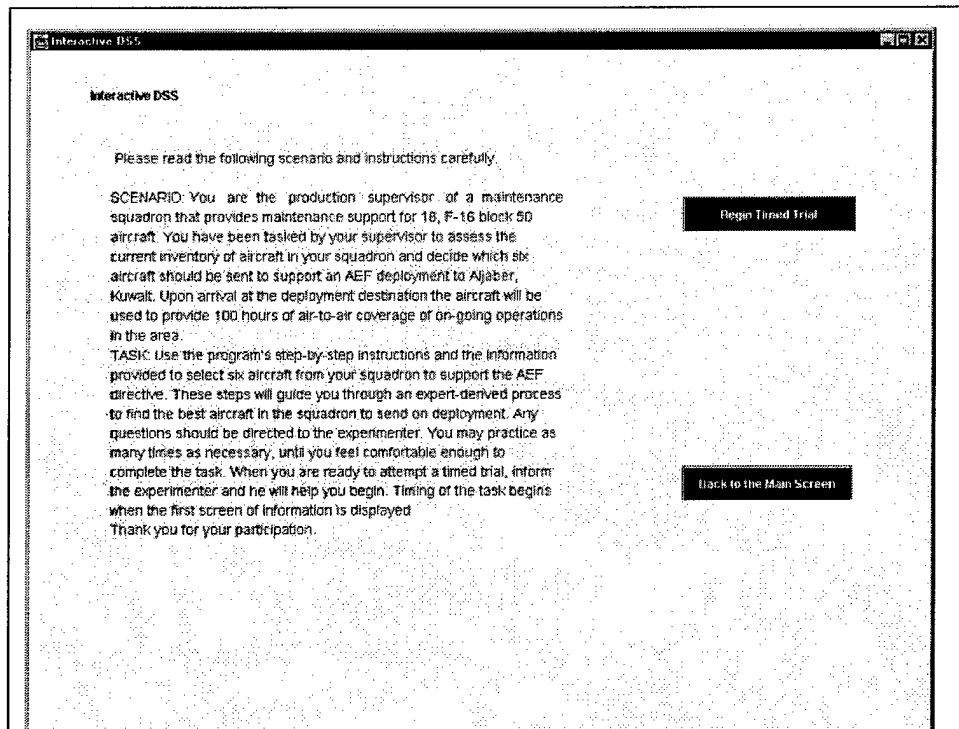
Figure 5: DSS Introductory screen displaying instructions.

Figure 6: Aircraft Status screen.

The next compatibility test involves removal of aircraft due to low Phase inspection times. Figure 7 displays the screen capture for this subtask. The computer-generated suggestion removes aircraft from the working list of available aircraft if the time-to-Phase value is less than 40 hours. Users may signify their approval or disapproval of computer suggestions by selecting aircraft tail numbers from the spreadsheet and including them in the text box for removal. Aircraft are removed from the available aircraft list when the NEXT button is activated.
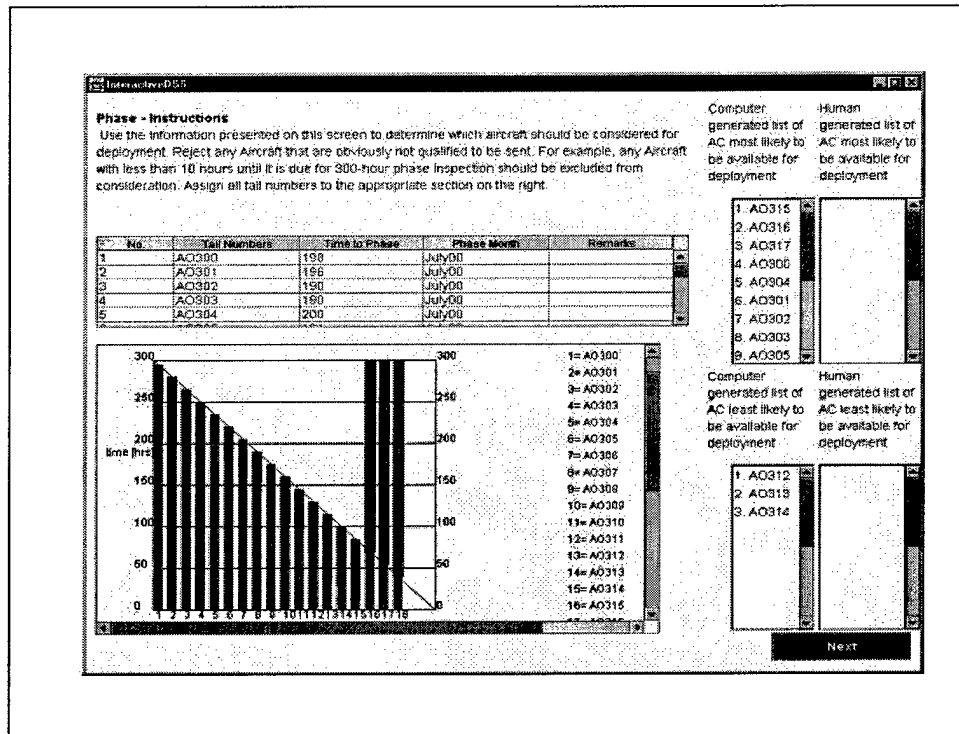
Figure 7: Phase Inspection screen #1.

3.3.2 Profitability Tests

The first profitability test utilizes information concerning schedule maintenance actions. Figure 8 displays the information screen for this subtask. Users compare the list of available aircraft against the density and importance of scheduled maintenance items over the duration of the deployment period. Items are color coded to represent various importance ratings from mandatory actions (red) to less important actions (green). The user is asked to rank order the aircraft tail numbers from best to worst in the text field provided. Data entry is accomplished by selecting a tail number from the list and moving it to the appropriate column. Computer suggestions are provided in the left-most column. The subtask is completed when the user activates the NEXT button.
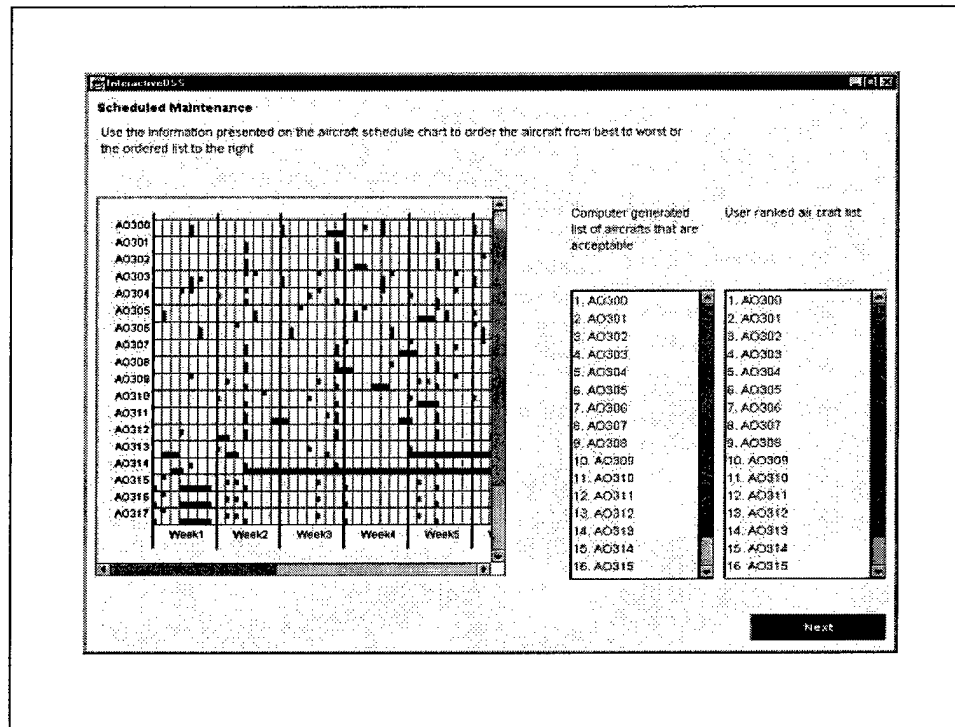
Figure 8: Scheduled Maintenance screen.

Outstanding unscheduled maintenance items are evaluated by utilizing aircraft history records and time-to-complete projections. Figure 9 displays the information screen for this subtask. Aircraft are rank-ordered based on the severity of the outstanding repair action, the time-to-complete, and the impact repair will have on the deployed mission. Users are tasked to provide an ordered list common to all profitability test subtasks. The subtask ends when the user activates the NEXT button.
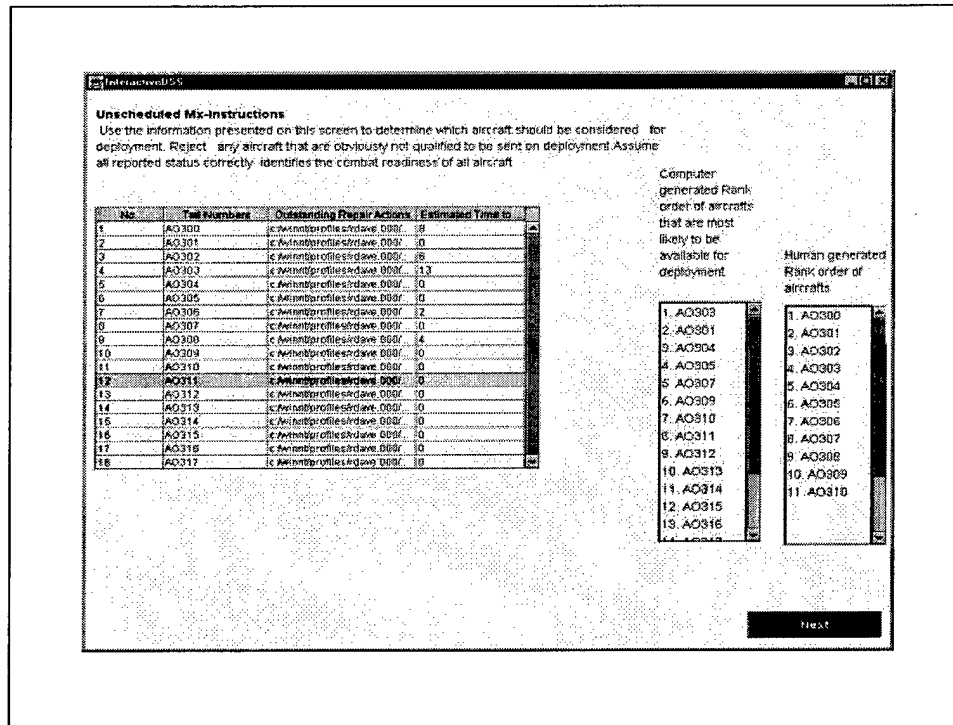
Figure 9: Unscheduled Maintenance screen.

Figure 10 displays the screen utilized for the second Phase inspection evaluation. Users rank-order aircraft tail numbers based on the time-to-Phase values provided in the accompanying chart. Aircraft with larger times-to-Phase are generally considered better than those aircraft with less time due before major inspection. A second computer generated list is provided on this screen representing the cumulative rank ordering of available aircraft. Previous to this screen cumulative progress was only identified by inclusion of the aircraft for consideration. At this stage two screens (Scheduled and Unscheduled Maintenance) of rank ordered data are available to construct the cumulative rank ordering of aircraft. Displaying cumulative feedback of on-going processes fulfills the progress decision requirement for users to be cognizant of advancing solutions. Aircraft tail numbers are ordered and the subtask ends when the user activates the NEXT button.
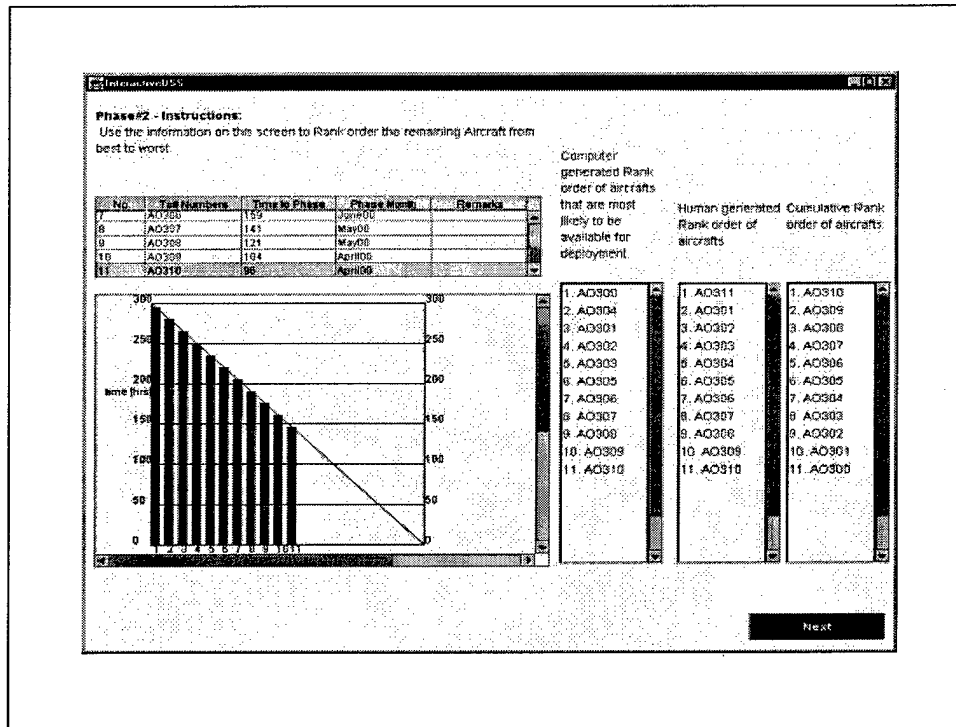
Figure 10: Phase Inspection screen #2.

The final two subtasks, Aircraft Configuration and Aircraft Location, are evaluated in the next two screens shown in Figures 11 and 12. Aircraft configuration and location data is evaluated to determine which aircraft require the most time and effort to make ready for departure. Locations of individual aircraft are shown in relation to other aircraft, facilities, and known hazards. Aircraft are rank-ordered and values are submitted by activating the NEXT button. Figure 13 displays the cumulative list and allows the user a final time to alter the solution set. Baring any further alteration, the entire task is complete and the user is provided with a list of aircraft tail numbers rank-ordered from best to worst for use choosing aircraft for the specified deployment.
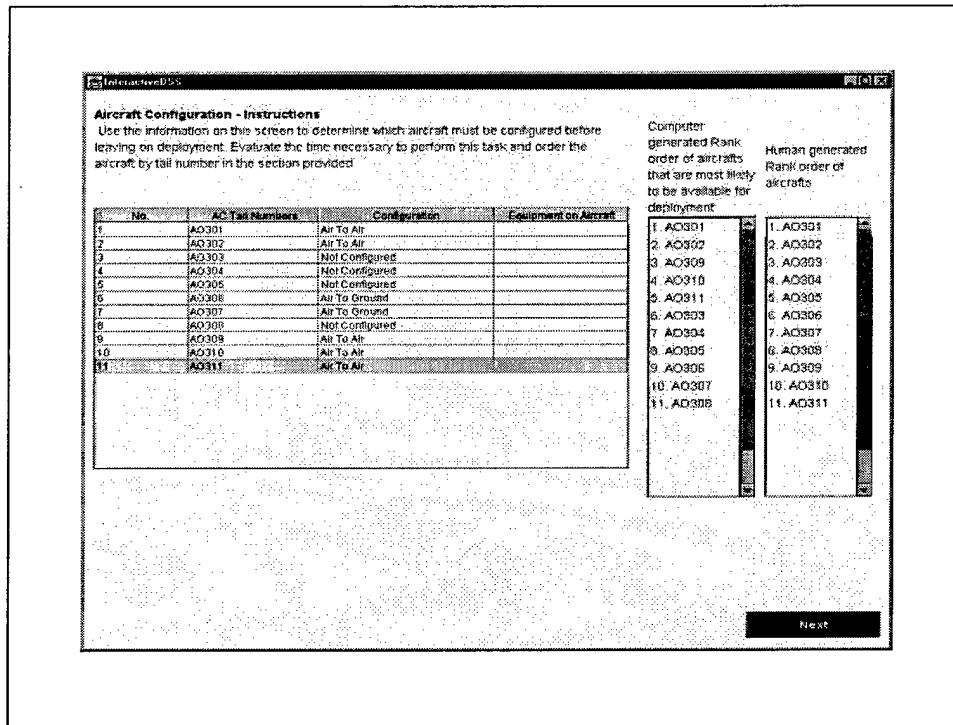
Figure 11: Aircraft Configuration screen.
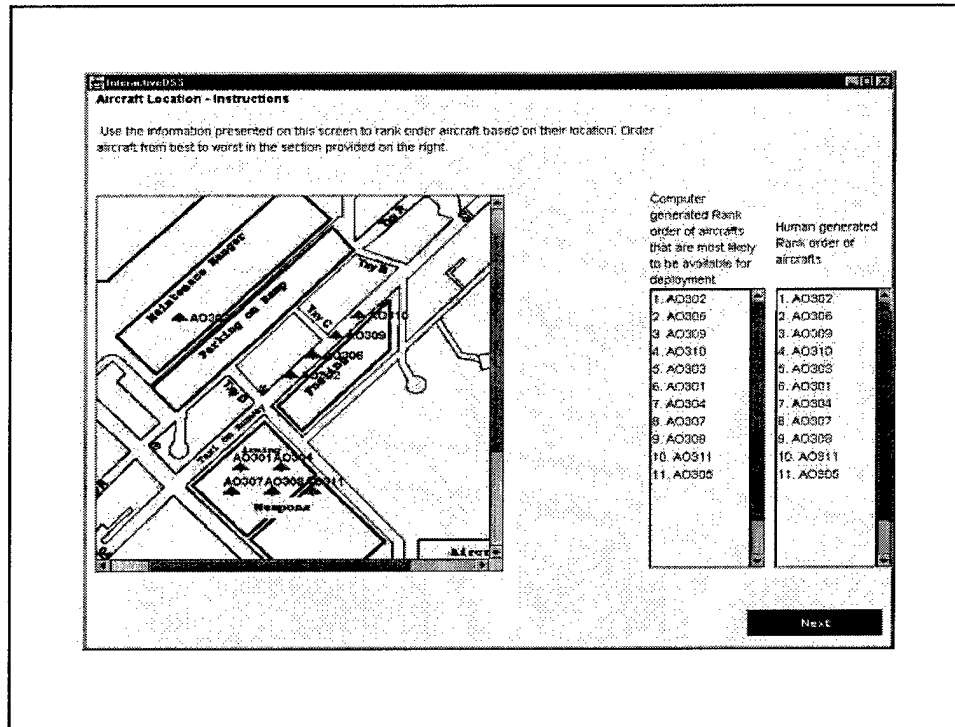
Figure 12: Aircraft Location screen.
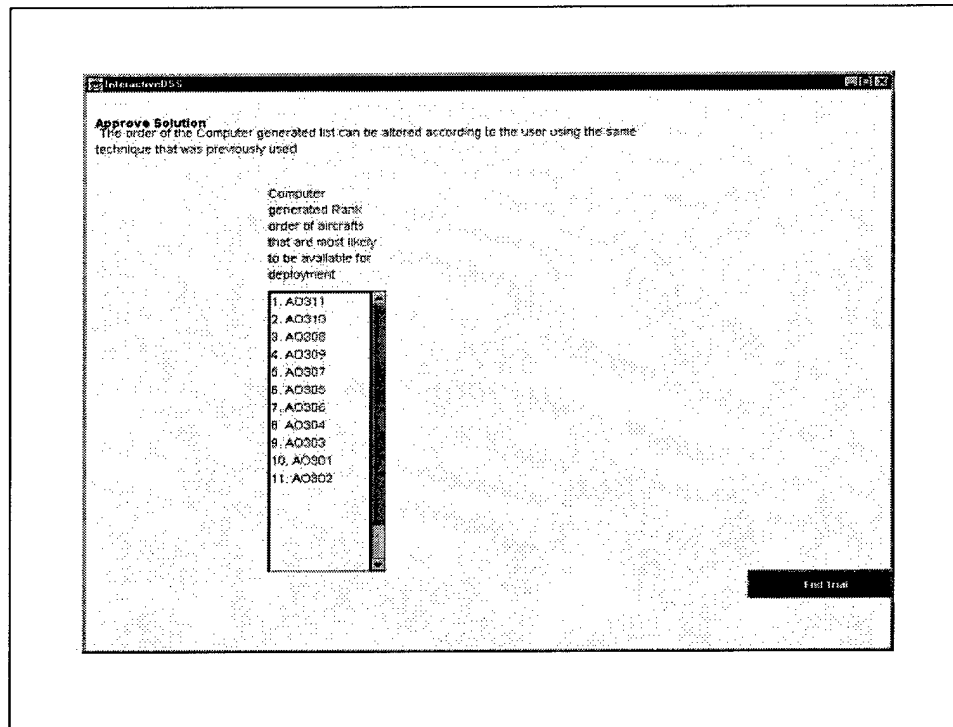
Figure 13: Approve Solution screen.

3.4   Summary

In this chapter, a methodology was outlined to develop a knowledge-based model using work domain analysis techniques and implemented in a decision support framework for use in a maintenance organization. One continuous and seven discrete subtasks were found corresponding to an Image theoretical expression of a Production Superintendent's choice strategy. Identification and elaboration of this framework led to the representation of the process by means of adoption and progress decisions. Relevant subtasks were further categorized by types of decision tests performed and were adapted to support the overarching decision process. The resulting decision support system will be tested in the following chapter.

4.0 Evaluation

In order to evaluate the DSS generated by the research methodology, a real-time database capability was needed to simulate the environmental conditions of near-term Air Force database systems. Simulated real-time data was used for two purposes, realism and bias prevention. For the purposes of this thesis, near-term database capabilities are assumed to exist. Real-time database systems behave differently from current systems in that they provide more accurate, timely, and reliable information. Inclusion of the simulated real-time database removes those tasks from consideration that are performed merely to compensate for limiting factors associated with poor database capability. Inclusion of the simulated data also serves to remove prior knowledge of aircraft history from hindering evaluation of the DSS. Air Force maintenance personnel are a highly cohesive and integrated work force. It is not unreasonable to assume that subjects drawn from this group may have prior knowledge of existing aircraft used in any current squadron. Personnel are moved periodically from base to base, operate in close proximity and coordination with other maintenance units, and communicate freely across squadrons to solve complex issues. Creation of a squadron of aircraft, flown in simulation for several months, effectively generates a completely new set of aircraft data.

Major features of the air base simulation infrastructure include a random number generator, a statistical distribution calculator, an event calendar, simulation clock, failure generator, and main simulation loop. The failure generator incorporated major inspection cycles, unscheduled failures to system components, aborted sorties due to weather and scheduling conflicts, and delays due to part unavailability, manning difficulties, and mission restrictions. The assignment of the simulation was to generate as many sorties as possible while conforming to realistic limitations. Typical restrictions included a five-day flying schedule, and a 10-hour flying day. Aircraft were flown for 18 weeks to fully develop the repair histories and establish a "personality" pattern for each individual aircraft. Generated aircraft datasets were eliminated from use if flight time was

low and unscheduled maintenance actions were not uniformly distributed. The simulation shared major components with the JADIS architecture for logistics simulation as outlined by Narayanan, et al (1997).

Exploration of DSS efficacy consisted of drawing comparisons between the effectiveness of an Information-Presentation-Only tool and the Interactive DSS tool. The first section outlines the rationale behind the use of an Information-Presentation-Only tool. The remaining sections discuss experimental procedures for evaluating the Interactive DSS.

4.1   Information-Presentation-Only Tool

Utilization of an Information-Presentation-Only (IPO) tool as a substitute for data collection in an actual aircraft squadron is necessary to eliminate confounding variability due to user data collection and user prior knowledge. Users frequently collect aircraft data for the selection task by personal communication with pertinent organizational elements (LOCIS, 1995). Collection times may vary due to collection method, interfering tasks, process deficiencies, and prior knowledge of aircraft conditions. It becomes increasingly difficult to separate task performance from non-essential variability in actual field conditions. For these reasons, an IPO collection tool was constructed to provide more realistic baseline measurements.

The IPO tool consists of a series of informational screens with an accompanying 'scratch pad' that serves as an external memory storage device. The scratch pad is a blank list, ordered from one to eighteen. This list is external to the informational screens in that it is always visually present as the user navigates through the screens. The user interacts with the information screens by freely selecting the tabs associated with each of the screens. Users annotate aircraft tail numbers to the scratch pad by selecting an individual tail number from the information screen and assigning it to a list position on the scratch pad. Users navigate through the information compiling and amending the aircraft list and finish the task by selecting the END button. IPO

screens are comprised of Phase Info, Aircraft Status, Scheduled Maintenance, and Location of Jets.

The Phase Info screen depicted in Figure 14 utilizes the standard Phase Flow diagram and typical Phase-related data generally employed by maintenance personnel. Data includes aircraft tail number, number of hours until Phase inspection is due, projected Phase month aircraft should become unavailable due to Phase, fleet time for the entire squadron, and annotated remarks concerning special aircraft scheduled deployments, exercises, or training.
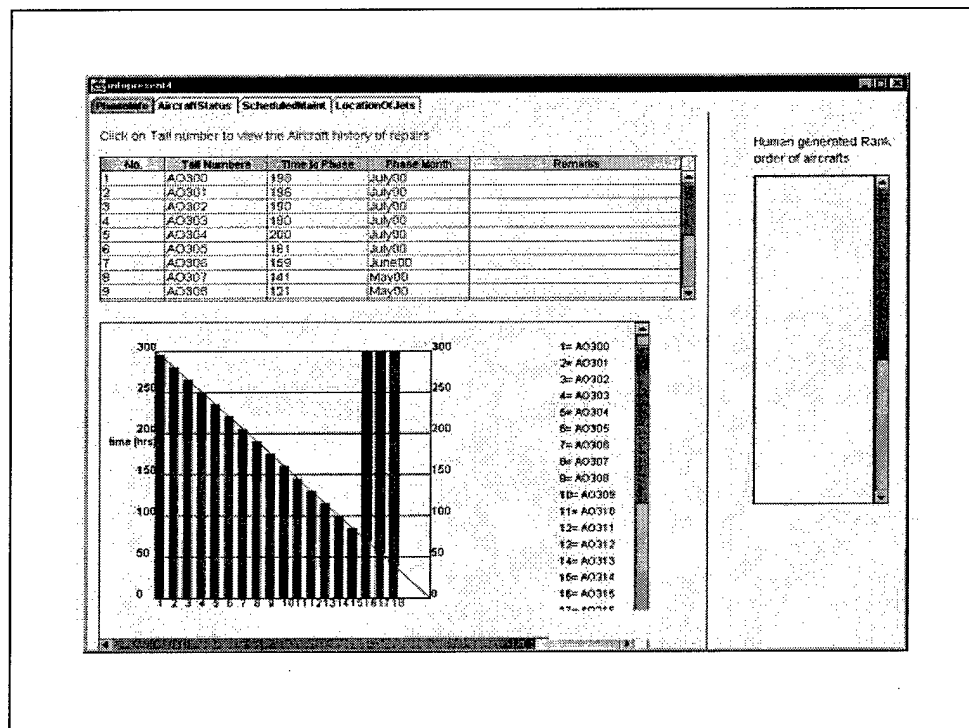
Figure 14: IPO Phase Info information screen.

The Aircraft Status screen shown in Figure 15 combines elements of four categories of information: status, configuration, aircraft history, and unscheduled maintenance. Status, as discussed in the previous chapter, relates to the mission capability of an individual aircraft. Since it is assumed that real-time data is available, status refers to the actual condition of the combat capability of the aircraft and not the frequently inaccurate listed condition due to reporting latency.

49

Similarly, aircraft configuration, history, and unscheduled maintenance items accurately reflect current aircraft state.

Figure 15: IPO Aircraft Status information screen.

The Scheduled Maintenance information screen depicted in Figure 16 allows the user to view aircraft maintenance schedules in Gantt chart format for a period of one quarter year of squadron operation. The chart is viewed by using the scroll bar to access out-of-limit representations in the viewing area. Identical to the Interactive DSS, the chart is color coded to represent importance rating for varying levels of scheduled inspections and processes. Red indicates important inspections possibly interfering with aircraft use in deployment operations. Yellow indicates moderate task importance. Green indicates scheduled tasks that can possibly be delayed or have limited impact on an aircraft's deployment availability.

50
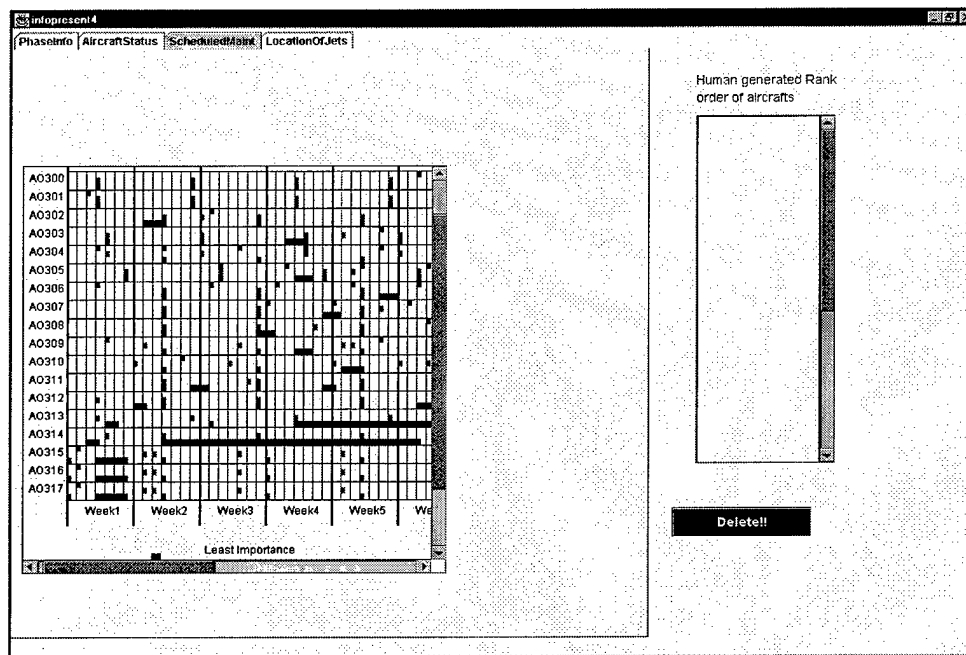
Figure 16: IPO scheduled maintenance screen.
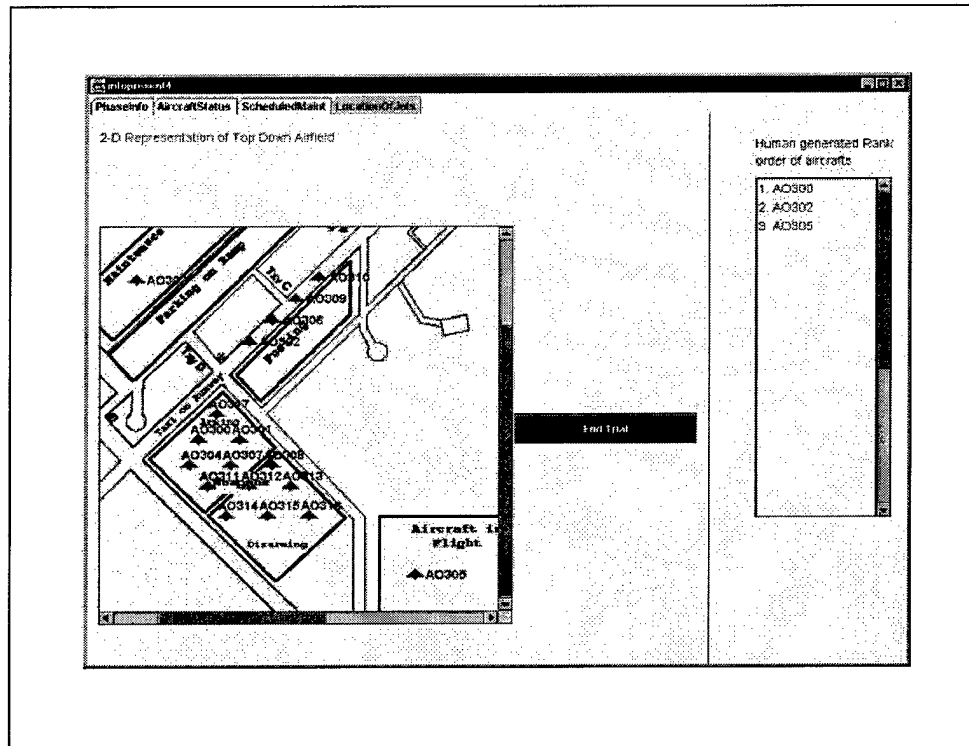
Figure 17: IPO Location of Jets information screen.

Figure 17 displays the last screen, Location of Jets. This screen is consulted to determine aircraft location relative to pertinent airfield features. Aircraft locations are depicted in green with tail numbers listed in red. Aircraft in flight are listed in a special section of the display as well as aircraft residing in one of the hangers.

When all aircraft have been assigned to a location on the scratch pad's ordered list and the END TRIAL button is activated, data collection is complete and the time-to-complete-task and ordered list are saved to a text file for later examination. Differences between the two presentation methods, IPO and IDSS are highlighted in Table 3 and show the inclusion or exclusion of the identified image theoretical constructs identified in the choice strategy.

	IDSS	IPO
Compatibility Test		
Aircraft Status	Suggested removal of aircraft if: • FMC status is violated	
Phase Inspection #1	Color coding of deviations from standard Suggested removal of aircraft if: • Time until Phase is less than expected deployment duration	Color coding of deviations from standard
Profitability Test		
Scheduled Maintenance	Color coding of importance rating Aircraft ranked based upon: Σ(importance rating)x(duration)x (frequency)	Color coding of importance rating
Unscheduled Maintenance	Aircraft ranked based upon: • Lowest time to complete repairs	
Phase Inspection #2	Color coding of deviations from standard Aircraft ranked based upon • Highest time until due for phase inspection	Color coding of deviations from standard
Configuration	Aircraft ranked based upon: • Lowest time to achieve desired configuration	
Location	Graphical map of airfield with positions listed Aircraft ranked based upon: • Lowest time to achieve desired location on ramp	Graphical map of airfield with positions listed
Process Constraints	Enforced step-by-step process	None

Table 2: Procedural, graphical, and computer-aided suggestions for each presentation method.

4.2 Experimental Design

4.2.1 Hypothesis

There are three hypotheses evaluated in this experiment. First, the IDSS presentation method provides better performance environment than the IPO presentation method. Second, the IDSS

presentation method yields a faster time to complete the task than does the IPO presentation method. Thirdly, the IDSS presentation method produces a higher subjective confidence in the generated solution.

4.2.2 Variables

Independent variables include the presentation method (IDSS and IPO) and the aircraft data set (D3 and D4). Associated with these variables are three dependent variables: performance, time-to-complete, and user confidence.

4.2.3 Equipment

The experiment was administered at the 445th Air Force Reserve Generation Flight and the Air Force Material Command Headquarters building, both located at Wright-Patterson AFB in Dayton, Ohio using a Micron Pentium II laptop computer. A 15 inch integrated color monitor attached to the laptop was used at 1024x768 pixels. The Interactive DSS and IPO test conditions were written in Java version 1.2, and executed in a Windows 98 environment. Program input was accomplished using a computer mouse and keyboard.

4.2.3 Subjects

The subject pool for this experiment consisted of maintenance personnel from the 445th Air Force Reserve Squadron and Air Force Material Command familiar with elements of the selection task. All 12 subjects were military AFRES or active duty personnel with over 10 years flight line experience. No subject had any physical impairment that might degrade performance with a color monitor, keyboard, or mouse. No subject was compensated for his or her time. Subjects consisted of one female and 11 male personnel.

4.2.5 Design and Procedure

Subjects participated in a two-factor crossed experiment (Presentation Method and Aircraft Data Set) with two treatments in each factor. Repeated measures were used on one factor (Presentation Method). Order of presentation for the two factors utilized a randomized design. In this experiment the Interactive DSS and IPO were evaluated by comparing three criteria, time-to-complete, percent of ordered responses that correctly identified the "ideal" rank order established by a committee of experts, and subjective confidence ratings. See Table 3 for design clarification.

Subject	Presentation Order	
	First	Second
1	Dataset 3, IDSS	Dataset 4, IPO
2	Dataset 3, IDSS	Dataset 4, IPO
3	Dataset 3, IDSS	Dataset 4, IPO
4	Dataset 3, IPO	Dataset 4, IDSS
5	Dataset 3, IPO	Dataset 4, IDSS
6	Dataset 3, IPO	Dataset 4, IDSS
7	Dataset 4, IDSS	Dataset 3, IPO
8	Dataset 4, IDSS	Dataset 3, IPO
9	Dataset 4, IDSS	Dataset 3, IPO
10	Dataset 4, IPO	Dataset 3, IDSS
11	Dataset 4, IPO	Dataset 3, IDSS
12	Dataset 4, IPO	Dataset 3, IDSS

Table 4: Presentation order of treatments to subjects before randomization.

The experiment consisted of four phases: experiment introduction, presentation method practice trials, data collection trials, and post-experimental questionnaire. Experiment introduction was used to obtain the participant's signature on the consent form (see Appendix A), acclimate the subject to the testing environment, and a written explanation of the task and scenario. Practice trials were conducted for each of the two presentation methods using a practice aircraft dataset. Subjects were allowed to practice until comfortable with the task and experimental environment. After training, subjects began the data collection trials presenting the experimental factors using counter-balanced design in Table 3. At the conclusion of the data collection trials, subjects were asked to fill out the post-experimental questionnaire (see Appendix B).

4.3 Evaluation of Performance

An independent committee of three maintenance Production Superintendents from the F-16 System Program Office at Wright-Patterson AFB rank ordered subject raw position scores to determine a relative performance ranking. Committee members performed the aircraft selection task using the IPO for each aircraft dataset and used their responses as the ideal rank order of aircraft within the dataset (See Appendix D). After comparing the respondent's rank ordered performance list to the rank ordered list of the committee, a relative ranking of subject responses was derived. Relative rank orders were listed from one to twenty-four (number of subjects multiplied by two presentation conditions a piece), with one representing the best matching solution to the committee and twenty-four representing the least correct solution set.

4.4 Evaluation of Time to Complete the Task

Times to complete the task were evaluated using a One-Way ANOVA to test the hypothesis that the mean time using the IDSS was less than that for the IPO condition, or H_1: $\mu_{IPO(D)} > \mu_{IDSS(D)}$, where μ is the mean time to complete the task per each condition and D represents the aircraft dataset used during the trial.

4.5 Evaluation of Post-Experimental Questionnaire

Post-experimental questionnaire responses were categorized by experience, subjective confidence rating, and write-in comments. Experience items reflected whether or not a subject had previous familiarity with individual aspects of the aircraft selection task. Responses were used to determine the level to which subjects could comprehend and express knowledgeable opinions on the information format and content of the presentation method. Subjective confidence ratings were collected using a series of fourteen questions eliciting preferences about assurance in the generated solutions. Each question used a seven-point scale to determine the level to which the presentation method better expressed the users point of view. Write-in comments were expressed in the blank spaces provided.

5.0 Results

5.1 Performance Analysis

Performance data from the experiment were assessed using the non-parametric Kruskal-Wallis Test to evaluate the hypotheses, H_0: $\mu_{IDSS} = \mu_{IPO}$, where μ indicates the mean rank ordered response of all subjects using the designated presentation method. The Kruskal-Wallis test statistic (K=.021332) proved to be less than the $X^2_{(.01,1)}$ of 6.637. Therefore, H_o cannot be rejected indicating no significant difference between the subject IDSS solutions and the subject IPO solutions at an alpha of .01.

5.2 Time to Complete Analysis

Using a One-Way ANOVA, analysis of time to complete data indicate that when presented first, the IDSS condition significantly (1-tail significance = .048) improved timed performance at an alpha of .05. Mean difference in time to complete the task was 670.67 seconds. When presented second, the IDSS did not show a significant difference in time to complete, but did show practical improvement by 112.5 seconds over the IPO condition. Further analysis using One-Sample T-Tests for IDSS first presentation order and IDSS second presentation order did not indicate significant differences between the two test conditions for either criterion, but generally indicated that the IDSS took less time with mean –257 seconds and mean = -527 seconds respectively.

5.3 Subjective Questionnaire Analysis

Subjective questionnaires were utilized to examine the experience level of subjects, perception of confidence, and written comments. Subject experience level is depicted in Table 7 and indicates a strong majority felt they had experience with five of the eight areas (strong = 80% or above), and a simple majority stated experience in seven of the eight areas. Areas listed in this section pertain to major maintenance activities relating to the experimental task or are skill items that aid

57

in the use of maintenance computer products. It is unclear, however, how all subjects can be experienced in the use a computer program (Question 6) when not all subject have used a computer to process information (Question 5).

Experience and Familiarity with:	Subjects Responding "Yes" (%)
1. Choosing aircraft for deployment or special duty	58.3
2. Scheduling aircraft for repair and inspection	41.6
3. Determining priority of repair actions	66.6
4. Serving as part of a deployed maintenance unit	91.6
5. Using a computer to process information	91.6
6. Using a CAMS-like computer program to keep track of aircraft data	100
7. Viewing and assessing the impact of aircraft repair histories	83.3
8. Determining if an aircraft is combat ready	91.6

Table 5: Subjective responses to experience questions

Subjective confidence responses were used to derive a measure of inter-rater reliability using the Coefficient Alpha test. The test indicated an appropriately level of internal consistency (.9697) to use the questionnaire. Reliability Analysis is listed in Table 8.

	Mean	Std. Dev.	Cases	Alpha if item deleted
Q16	4.1667	1.9924	12	.9616
Q17	4.25	2.1794	12	.9609
Q18	4.0	2.0	12	.9618
Q19	4.25	2.3404	12	.9645
Q20	5.0	2.1742	12	.9651
Q21	4.5	2.4309	12	.9645
Q22	2.1667	1.1146	12	.9747
Q29	3.25	1.3568	12	.9686
Coefficient Alpha	.9697			

Table 6: Reliability Analysis for Confidence Related Questions.

User responses to the subjective confidence portion of the questionnaire indicate no preference for one presentation method over another (mean = 3.833, with 4.0 being a neutral response). Only one question was individually suggestive (Q22), indicating that the IPO condition allowed greater freedom to explore the information thoroughly. All other response means were centrally distributed and did not strongly indicate confidence in one presentation method over another.

Written comments typically involved three areas, the scenario, the display format, and substantive information related material. Written comments are listed in Appendix C and were generally positive in nature. Comments generally favored the concept of a decision support system for maintenance especially as a loose association of relevant informational components, or as a training aid.

5.4   Discussion

The first hypothesis for the experiment was that the mean expert committee rating for the IDSS condition is significantly better than the equivalent statistic for the IPO condition. This would imply that a better decision is made with the use a decision support using an image theoretic system constraining the user so that each identified subgoal is considered in a manner more closely related to user image states, adoption criterion, and expert framing. The second hypothesis stated that the IDSS condition would allow users to accomplish the task significantly

faster than the IPO condition. Thirdly, the IDSS presentation method produces a higher subjective confidence in the generated solution. The following subsections discuss the hypotheses and the independent variables.

5.4.1 Performance Hypothesis

The performance hypothesis is not supported by the research. The results show that the IDSS produced a committee ranking that was not significantly different than did the IPO. Verbal and written responses on the post-questionnaire indicate that lack of confidence in the solution process as well as interface problems may have constrained the ability of users to interact effectively within the system. While most respondents liked the computer suggested input, it may be the case that the method for generating computer suggestions be made visible to the user.

5.4.2 Time to Complete Hypothesis

The time to complete hypothesis was supported for the first order of presentation. IDSS Subjects completed the task on average 38% more quickly than the IPO condition. Both presentation methods during the second testing session tended to have more lengthy times to complete. This may have been due to fatigue or other confounding factors. There was evidence that would suggest shorter IDSS completion times for the second presentation period, but the differences proved not to be statistically significant. It may be the case that the difference in completion times for the second testing period were of practical significance differing on average 8.3%.

5.4.3 Confidence Rating

The hypothesis involving the confidence of users towards the generated solution was not supported by the research. Subjects proved to be indifferent in terms of confidence towards either the presentation method or the solutions generated. Mean response indicated 3.8 on a seven-point scale with one indicating strong IPO confidence and seven indicating strong IDSS confidence. Subjects expressed reluctance to commit to a firm opinion of confidence due to concern that the decision support system was not in its final version, interface problems

60

decreased the ability to fully explore the system, and aircraft data and scheduled maintenance items were not detailed enough to permit precise evaluation during the task. Though subjects detailed their partiality to decision support features such as computer suggestions and guidance, color coding, and desktop convenience, these favorable responses did not reflect in confidence ratings.

6.0 Conclusions

6.1 Contributions of the Research

This thesis made practical contributions to information systems research by outlining a methodology for creating decision support systems in complex logistics planning. Contributions include uncovering decision support needs for the organizational strata of front line supervisors, applying current naturalistic decision theory to the logistics arena, and defining a level of interaction between the decision maker and the decision support system that accommodates subgoal variation while maintaining the structure of the knowledge-based framework.

Use of Image theory to identify decision activity greatly increased the level of detail and understanding of the decision process of Production Superintendents. Standard methods for identifying decision subtasks do not necessarily direct the method in which those tasks will be incorporated into the decision support system. Uncovering the image states of the subject matter experts led to the acquisition of two types of decision strategies. These decision strategies, once identified, not only changed the order of presentation, but highlighted significant structural changes to the algorithms used in providing computer-aided suggestions to the user.

Decision support needs for line supervisors in logistics have been largely deferred in favor of high visibility management where the informational needs are more globally oriented, integrating vast amounts of data combined with uncertainty and a heterogeneous perspective (Vicente, 1999). Lower levels of management have different needs for decision support than upper level managers, but remain just as dependent on informational computer support. Large problem spaces, even at the squadron level complicate the thorough examination of data and hinder the process of shortfall identification, repeat or recurring problem analysis, and determination of system patterns on which quality decision making depends. Impactful decision support

incorporating satisficing heuristics may enable a more direct and immediate application of supervision on the production of aircraft sortie generation and on overall squadron production.

Application of current naturalistic decision theory to the logistics arena provides a human-centered perspective that takes advantage of the organic teleological processes inherent in human mental schemas. Providing information constrained to fit these processes allow decision makers more direct application of pertinent information to affect the generated solution within the context of the knowledge-based framework. Formalization of the decision makers natural choice strategies to evaluate decisions based on compatibility and profitability, adoption or progression, abbreviates the decision process reducing internal complexity and confusion, thereby reducing decision time.

The third contribution of the research is the further clarification of the role of humans in the human-machine system. By defining a level of interaction between the user and the decision support system, image states and goal directed behavior inherent to logistics organizations can be applied to the decision process while taking advantage of computer processing speed to identify patterns, process heuristics, and make computations. Subgoals can be evaluated visually, using the computer to display graphical representations of information patterns while leaving the option to examine the data individually. Progress towards a realistic, useful generated solution can be monitored, assessed, and altered, allowing the decision maker to review the solution's compatibility with projected needs.

In the experiment, the Interactive Decision Support System (IDSS) suggested that greater speed can be realized in the decision process. This thesis anticipated an increase in performance, confidence, and trust in the generated solution, which did not materialize in the study. Due to the low number of participants, only general conclusions can be drawn from the research to include a suggested increase in solution generation time using the decision support system.

6.2   Limitations of the Study

There were several limitations of the study that included small size and experience variation of subject population, lack of expected user-input capability, display format issues, and dissimilar aircraft datasets.   These limitations in design represented a significant stumbling block for participants in the study and for meaningful evaluation of the data.

First, the number of subjects in the experiment needs to be increased for a more statistically significant relationship to exist. Although statistically significant results were found at an alpha of .05 for time to complete analysis, the low number of subjects would suggest that an alpha of .01 would strengthen any argument for the decision support system. Also, it is possible that the mixture of active duty and reserve component personnel were too dissimilar to be compared easily. Reserve personnel largely incorporate ex-active duty personnel, and as such show a great increase in the total time serving in a maintenance specialty. While at first glance this factor suggests that the more experience in maintenance the better, it may not be true. Unfortunately, significant differences occur in the practice of maintenance between the two groups. Active duty personnel move from base to base over the course of their career and do not serve a single squadron for very long. Reserve personnel serve in the same squadron for long periods of time and do not experience the problems associated with moving. It is possible that reserve personnel do not have enough experience assessing a group of aircraft that is new to them. The low turnover of aircraft and personnel in Reserve squadrons implies a decrease in the ability to articulate and thoroughly evaluate aircraft history data.

Second, lack of program functionality that the majority of computer users have come to rely upon was missing or ineffective in the IDSS and IPO programs. Such functions as "point-and-click" and "drag-and-drop" were not available to the user. Users adapted to the input method with a significant amount of complaint using a modified method of selection of aircraft tail number and selection of position reference to assign tail numbers to the appropriate positions. Assignment to the scratch pad was a little tricky and required some skill to use. Practice with the system

64

modified this factor, but remained a difficulty throughout the experiment. Also, problematic were the occasional overlapping of data on the aircraft location diagram. Overlapping tail numbers, while not prohibitive, possibly added time to the search for tail numbers of interest, especially if the user did not expand the display to its full size. Subjects were also unhappy that they needed to scroll through data to view the contents. Frequent remarks were made about the display graphics not fitting in their entirety on the display surface.

Lastly, a more thorough examination of the aircraft datasets was warranted. The time-to-complete data and the performance data suggest that the two datasets may have been unequal in difficulty. An aircraft dataset that had a greater number of aircraft that were mission ready and capable of deployment would add to the difficulty of selecting between them. Future evaluations should include datasets that more closely resembled one another in their complexity level.

7.0 References

1   Alter, S. L. (1980). Decision Support Systems: Current Practice and Continuing Challenges. Reading, MA: Addison-Wesley Publishing Company.

2   Banks, J., and Carson, J.S. II. (1996). Discrete-Event System Simulation (2nd ed.). New Jersey: Prentice-Hall International Series in Industrial and Systems Engineering.

3   Beach L. R. (1997). The Psychology of Decision Making: People in Organizations. Thousand Oaks, CA: Sage Publications Series in Foundations for Organizational Science.

4   Ceric, V. (1997). Visual Interactive Modeling and Simulation as a Decision Support in Railway Transport Logistic Operations. Mathematics and Computers in Simulation, 44, 251-261.

5   Chang, C. L. (1985). Introduction to Artificial Intelligence Techniques. Austin, TX: JMA Press Inc.

6   Charniak, E., McDermott, D. (1984). Introduction to Artificial Intelligence. Reading, MA: Addison-Wesley Publishing Company.

7   Goodman, Glen W. Jr., "An Expeditionary Aerospace Force", Armed Forces Journal International, Aug 1998, Vol. 136.

8   Headquarters US Air Force Air Combat Command (ACC/LGQP). (1998). US Air Force Air Combat Command Instructions (ACCI 21-101): Objective Wing Aircraft Maintenance. HQ ACC/LGQP 130 Douglas Street, STE 210, Langley AFB VA 23665-2791.

9   Headquarters US Air Force. (1996). Global Engagement: A Vision for the 21st Century Air Force. (http://www.af-future.hq.af.mil/21/indext.htm).

Washington DC: U.S. Government Printing Office.

10   Headquarters US Air Force. (1998). US Air Force Instructions (AFI 21-103ACCSUP1): Supplement 1. Pentagon, Washington D.C. 20330-1670. p. 101-104.

11   Joint Chiefs of Staff. (1995). Joint Vision 2010. (ADA311168). Washington DC: Defense Technical Information Center, 8725 John J. Kingman Rd. STE 0944, Ft. Belvoir, VA 22060-6218.

12   Kaliszewski, I. (2000). Using Trade-off Information in Decision Making Algorithms. Computers & Operations Research, 27, 161-182.

13   Keen, P. G. W. (1981). Decision Support Systems: A Research Perspective. Decision Support Systems: Issues and Challenges. Oxford, England: Pergamon Press.

14   Link, W. R., Von Holle, J. C., & Mason, D. (1987). Integrated Maintenance Information System (IMIS): A Maintenance Information Delivery Concept (AFHRL Publication No. AFHRL-TP-87-27). Interim Report. Air Force Systems Command, Brooks AFB, TX.

15   Logistics Command and Control Information Support (LOCIS) Final. (1995). Paperless Acquisition Initiative. Prepared for Department of the Air Force, Armstrong Laboratory, Operations Logistics Branch (HRGO). Contract No.: GS-35F-4131D. Delivery Order No.: F19628-96-F-0432.

16   Logistics Command and Control Information Support (LOCIS) Strategic Planning: Requirements Identification Phase. (1997). Paperless Acquisition Initiative. Prepared for Department of the Air Force, Armstrong Laboratory, Operations Logistics Branch (HRGO). Contract No.: GS-35F-4131D. Delivery Order No.: F19628-96-F-0432.

17   Narayanan, S., Schneider, N. L., & Patel, C. (1999). Application of Genetic Algorithms to Airbase Logistics Planning. Proceedings of the 1999 IEEE Midnight-Sun Workshop on Soft Computing Methods in Industrial

Applications. Kuusomo, Finland.

18   Narayanan, S., Schneider, N. L., Patel, C., Reddy, N., Carrico, T. M., &
        DiPasquale, J. (1997). An Object-Based Architecture for Developing
        Interactive Simulations using Java. ISSN 0037-5497. Simulation Councils,
        Inc. Simulation 69:3, 153-171.

19   Obitko, Marek. (1998). Introduction to Genetic Algorithms.
        http://cs.felk.cvut.cz/~xobitko/ga/menu.html. Czech Technical University
        Web Sight.

20   Popken, D. A. (1992).   An object-oriented simulation environment for
        airbase simulation. Simulation. 59(5), 328-338.

21   Rasmussen, J., Pejtersen, A. M., Goodstein, L. P. (1994). Cognitive
        Systems Engineering. ISBN: 0-471-01-198-3. New York: John Wiley &
        Sons.

22   Reid, John R. (1999). The USAF Aerospace Expeditionary Force: Flying
        into the 21st Century. Newport, Naval War College (NWC) (AD-A363209).

23   Schneider, N. L. (1998). Integrating Genetic Algorithms with Interactive
        Simulation for Repair-Time Analysis in Air Force Logistics. Master's Thesis.
        Wright State University, OH.

24   Simon, H. A. (1945). Administrative Behavior. New York: Macmillan.

25   Sprague, R. J., Jr., Watson H. J. (Eds.). (1989). Decision Support Systems:
        Putting Theory into Practice. Englewood Cliffs, NJ: Prentice Hall.

26   Tripp, Robert S., Galway, Lionel A., Ramey, Timothy L., Killingsworth, Paul
        S., Drew, John G., & Fair, Chris C. (1999). Strategic EAF Planning:
        Expeditionary Airpower, Part 2. Air Force Journal of Logistics, XXIII, No. 3.
        2-7.

27   United States Air Force Scientific Advisory Board. (1997). United States Air
        Force Expeditionary Forces: Volume 1 Summary (SAB-TR-97-01).
        Pentagon, Washington D.C. 20330-1670.

28   US Air Force Air Combat Command Logistics Readiness Training Center. (1999). ACC Flight line Maintenance Officer Course Study Guide. Hill AFB UT.

29   Vicente, Kim J. (1999). Cognitive Work Analysis: Toward Safe, Productive, and Healthy Computer-Based Work. New Jersey: Lawrence Erlbaum Associates, Publishers.

30   Walters J. and Neilsen, N. R. (1988). Crafting Knowledge-based Systems. Wiley, New York.

31   Widman, L. E., Loparo, K. A., & Nielson, N. R. (1989). Artificial Intelligence, Simulation, and Modeling. New York: John Wiley & Sons.

APPENDIX A

Informed Consent Document

Interactive Maintenance Decision Support System

This signed consent is to certify my willingness to participate in this research study. The purpose of this study is to determine the effectiveness of an interactive decision support system based on expert knowledge-based framework. The tasks are structured to emulate the way an expert may perform selection of aircraft to be included on a deployment. I am being asked to participate as a maintenance user of the decision support system, selecting aircraft from my unit to be used in a combined AEF deployment force, with little or no prior knowledge required of the system.

I will be trained to use the decision support system, and how to use the interface to support successful completion of the tasks. I understand that I must complete a practice trial in order to begin the actual experimental trials. After training I will be asked to make decisions based on information provided by the computer information system. The average time required will be between 30 minutes to 1 hour.

During the qualifying test and the experimental trials I will be using a Windows based interface to seek the information mentioned in the tasks. I understand that I must have experience using a mouse and keyboard, be an experienced maintenance professional, and have experience with the CAMS system to participate, and I will be trained in all other aspects of the task.

After performing the selection task, I will be asked to fill out a questionnaire (Approx 10 minutes long) that asks me to rate relevant items about the display and model.

The results of this study may be used to help determine the efficiency of using Image Theory to emulate the decision process in interactive maintenance computer products in the future.

There is very minimal risk that I might experience fatigue, stress, or headaches from using the interface. This risk should be no more than playing a video game.

Any information about me obtained from this study will be kept strictly confidential. No names or other such personal identifiers will be used on the surveys or linked to the surveys. Subject identification numbers will be used to link performance data to survey data. Performance data will be securely located on the principal investigator's personal computer, which is password protected. I will not be identified in any report or publication.

I acknowledge that this study has been explained to me, and that the principal investigator has discussed the possible risks. I certify that I have been given the opportunity to have all of my questions regarding this study answered.

I am free to refuse to participate in this study, or to withdraw at any time. My decision to participate or to not participate will not adversely affect me in any way.

My signature below means that I have freely agreed to participate in this investigational study.

APPENDIX B

Post Experimental Subjective Questionnaire

Subject Number: _____   Date: _____

1. What is your gender?   M   F

2. I have had _____ years of experience in the maintenance career field.

3. Do you have visual impairment such that you would not be able to view a standard 15-inch color monitor to perform a computer-based task?   Y   N

4. Do you have experience:
4A.   Choosing aircraft for deployment or special duty?   Y   N
4B.   Scheduling aircraft for repair and inspection?   Y   N
4C.   Determining priority of repair actions?   Y   N
4D.   Serving as part of a deployed maintenance unit?   Y   N
4E.   Using a computer to process information?   Y   N
4F.   Using a CAMS-like computer program to keep track of aircraft data?   Y   N
4G.   Viewing and assessing the impact of aircraft repair histories?   Y   N
4H.   Determining if an aircraft is combat ready?   Y   N

5. Did the Information-Presentation-Only (IPO) computer program adequately reflect the following:
5A.   Aircraft Status   Y   N
5B.   Aircraft Repair History   Y   N
5C.   Scheduled Maintenance Items   Y   N
5D.   Unscheduled Maintenance Items   Y   N
5E.   Aircraft Location   Y   N
5F.   Aircraft Configuration   Y   N
5G.   Phase Inspection Information   Y   N

5H. If you circled 'N' in any of the above section 4 items, please explain what was lacking in the space provided.

_____
_____
_____
_____
_____
_____

6. For the IPO tool only, was there information that was necessary to choose aircraft for deployment that was not provided within the context of the mission scenario?   Y   N

If you selected 'Y', please explain the needed items in the space provided?

_____
_____
_____
_____

7. For the IPO: rate the confidence you have that the solution you generated is correct
(Very Low Confidence)-1   2   3   4   5   6   7-(Very High Confidence)

8. Did the expert knowledge-based Interactive Decision Support System (IDSS) provide better understanding than the IPO when compiling the recommended aircraft list?
                                                                Y   N

9. Did the expert knowledge-based IDSS provide all the necessary information to perform the task?
     Y   N

If not, provide examples in the space below:

_____
_____
_____
_____
_____

10. For the expert knowledge-based IDSS: were computer suggestions helpful in performing the task?
     Y   N

11. For the expert knowledge-based IDSS: rate the confidence you have that the solution you generated is correct (Very Low Confidence)-1   2   3   4   5   6   7-(Very High Confidence)

12. Do you prefer to generate the aircraft list yourself or have the computer help you with suggestions?
          Generate the list myself   I like the computer suggestions   Doesn't matter to me

13. Did the guidance provided by the expert knowledge-based IDSS help you or hinder the process?
          Help   Hinder

14. Which tool would you prefer for selecting aircraft for deployment?   IDSS   IPO   Neither

15. Please provide CONSTRUCTIVE comments to the experiment staff on how to improve the tools in the future.

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

_____
_____
_____
_____
_____
_____
_____

Definitely the IPO	IPO Mostly	IPO Marginally	Neutral Response	Marginally IDSS	IDSS Mostly	Definitely the IDSS
---------1---------	---------2---------	---------3---------	---------4---------	---------5---------	---------6---------	---------7---------

Use the scale above, rate the test conditions based on the following:

16. Produced a solution that I feel comfortable using in the field.   1—2—3—4—5—6—7
17. Allowed me to make a better decision.   1—2—3—4—5—6—7
18. Allowed me to fully comprehend the aircraft information.   1—2—3—4—5—6—7
19. Increased my understanding of the aircraft fleet status.   1—2—3—4—5—6—7
20. Increased my understanding of my own decision process.   1—2—3—4—5—6—7
21. Increased my trust in the final decision.   1—2—3—4—5—6—7
22. Provided more freedom to explore the information thoroughly.   1—2—3—4—5—6—7
23. Inhibited my ability to understand the aircraft fleet status.   1—2—3—4—5—6—7
24. Inhibited my understanding of my own decision process.   1—2—3—4—5—6—7
25. Produced a solution that I would not use.   1—2—3—4—5—6—7
26. Prevented me from full comprehension of the aircraft information   1—2—3—4—5—6—7
27. Inhibited my freedom to explore the information thoroughly   1—2—3—4—5—6—7
28. Prevented me from making a good decision.   1—2—3—4—5—6—7
29. Disrupted the process I prefer to use.   1—2—3—4—5—6—7

APPENDIX C

WRITTEN COMMENTS

Subject	Comments
1.	Tasking to choose deployment aircraft and schedule aircraft for repair and inspection was done at a higher level
2.	The small red blocks [in the scheduled inspection frame] didn't tell what the aircraft is going to be down for
3.	Tail numbers overlap and cannot be read
4.	Could not find aircraft 317 on last page
	Would like to see the information displayed by aircraft tail number, as an option.
	The reason for my low confidence was a programming difficulty. It would not select and move tail numbers properly
5.	Need WUCs [Work Unit Codes]
	Need to have in the scenario the number of weeks deployed so you could compare like information on the schedule
6.	Make program more user friendly, i.e. click and drag, etc.
7.	I preferred the IPO only because it was confusing to look back and forth between two sets of number lists to make comparisons
8.	A very good training and time to train in use and implementation. We at the Maint. Level get the one class and do it syndrome without allowing for time to build confidence for use.
10.	Unable to see scheduled maintenance tasks. On repair history chart could not scroll down.
	Need to display upcoming inspection requirements

11.	On aircraft status, I would have an ETIC associated with PMC/NMC
	On history, it was confusing as to what discrepancy currently exists
	On Sch. Maint., put how long until the work is complete
	Window displaying phase time is too small and required me to scroll back and forth to find the data.
12.	On Sch Maint., items were only displayed as bars on a chart; would need to know what the bars represented
	Need better explanation of corrective actions on USM
	Need to know specific equipment installed on aircraft
	Need to know if ferry time is to be included or excluded from 100 hour requirement.
	What will the projected UTE rate be at the deployment location
	What will the average sortie duration (ASD) be while deployed
	Not enough detail on the scheduled maintenance chart
	Some information is confusing
	Operations variables such as average sortie duration, mission variation requirements and etc. Should also be available.
	I like the idea of a Wizard or help mate to make decisions. It would be better if all the information was available on one screen and I could pick and choose which information to inflate for closer inspection. The computer suggestions were very helpful and should be provided when asked. I favor a combination of the two different conditions so that I can freely explore the information while also getting some computer help.

APPENDIX D

Expert Ranking of Subject Responses

Table of Responses for Squadron 3 (Database 3)

Exp Rank	2	8	3	9	1	11	12	6	4	10	7	5
Subjects	1	2	3	4	5	6	7	8	9	10	11	12
Subj. Order												
1	AO317	AO315	AO316	AO316	AO317	AO314	AO313	AO317	AO315	AO317	AO315	AO316
2	AO301	AO316	AO317	AO317	AO316	AO312	AO300	AO301	AO316	AO315	AO316	AO315
3	AO314	AO313	AO313	AO315	AO301	AO313	AO303	AO300	AO313	AO301	AO313	AO313
4	AO303	AO311	AO315	AO314	AO315	AO301	AO315	AO314	AO317	AO316	AO311	AO317
5	AO313	AO317	AO314	AO313	AO302	AO317	AO316	AO315	AO311	AO302	AO317	AO311
6	AO312	AO314	AO312	AO312	AO300	AO311	AO317	AO302	AO314	AO314	AO314	AO314
7	AO315	AO312	AO302	AO301	AO314	AO302	AO309	AO315	AO312	AO300	AO312	AO312
8	AO316	AO302	AO300	AO311	AO313	AO300	AO304	AO316	AO302	AO313	AO302	AO302
9	AO302	AO303	AO301	AO303	AO312	AO315	AO310	AO313	AO300	AO312	AO303	AO300
10	AO300	AO300		AO302	AO311	AO316	AO306	AO311	AO301	AO311	AO300	AO301
11	AO311	AO301		AO300	AO303	AO307	AO311	AO312		AO307	AO301	
12	AO310			AO310	AO310	AO308	AO305	AO307		AO309		
13	AO307			AO307	AO307	AO309	AO314	AO310		AO308		
14	AO306			AO309	AO309	AO303	AO312	AO309		AO304		
15	AO309			AO308	AO308	AO310	AO308	AO308		AO305		
16	AO308			AO304	AO304	AO306	AO307	AO304		AO306		
17	AO305			AO305	AO305	AO305	AO302	AO305		AO303		
18	AO304			AO306	AO306	AO304	AO301	AO306		AO310		

Table of responses for Squadron 4 (Dataset 4)

Expert Ranking	4	11	12	7	9	2	5	3	10	8	6	1
Subjects												
Subj Order	1	2	3	4	5	6	7	8	9	10	11	12
1	AO313	AO315	AO315	AO313	AO315	AO313	AO316	AO313	AO316	AO316	AO303	AO317
2	AO316	AO312	AO302	AO311	AO316	AO316	AO302	AO316	AO302	AO311	AO315	AO316
3	AO315	AO303	AO303	AO315	AO313	AO311	AO303	AO311	AO303	AO315	AO301	AO302
4	AO301	AO316	AO317	AO316	AO311	AO315	AO315	AO315	AO301	AO301	AO302	AO303
5	AO302	AO311	AO314	AO312	AO317	AO301	AO301	AO301	AO315	AO312	AO316	AO315
6	AO312	AO300	AO316	AO302	AO314	AO312	AO312	AO312	AO312	AO302	AO312	AO310
7	AO303	AO302	AO301	AO303	AO312	AO302	AO311	AO302	AO317	AO300	AO313	AO314
8		AO301	AO312	AO301	AO302	AO303	AO313	AO303	AO314	AO303	AO311	AO312
9		AO306	AO313	AO309	AO303		AO317		AO313		AO317	AO300
10		AO307	AO311		AO300		AO314		AO311		AO314	AO311
11		AO308	AO310		AO301		AO310		AO300		AO300	AO313
12		AO309	AO300				AO300		AO310		AO304	AO310
13		AO304	AO309				AO304		AO308		AO305	AO304
14		AO305	AO308				AO305		AO305		AO307	AO305
15		AO313	AO307				AO306		AO306		AO306	AO306
16		AO310	AO306				AO307		AO307		AO308	AO307
17		AO314	AO305				AO308		AO309		AO309	AO308
18		AO317	AO304				AO309		AO304		AO310	AO309

Expert Committee Ideal Rank Order of Aircraft Within Dataset

Order	Dataset 3	Dataset 4
1	A0317	A0301
2	A0302	A0313
3	A0301	A0302
4	A0315	A0316
5	A0314	A0311
6	A0313	A0310
7	A0312	A0312
8	A0303	A0317
9	A0300	A0315
10	A0316	
11	A0311	

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	22.Aug.00	THESIS

4. TITLE AND SUBTITLE
A METHODOLOGY TO DEVELOP INTERACTIVE DECISION SUPPORT
SYSTEMS FOR COMPLEX UNITED STATES AIR FORCE LOGISTICS
PLANNING

5. FUNDING NUMBERS

6. AUTHOR(S)
CAPT KUSTRA TODD W

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
WRIGHT STATE UNIVERSITY

8. PERFORMING ORGANIZATION REPORT NUMBER

CY00356

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
THE DEPARTMENT OF THE AIR FORCE
AFIT/CIA, BLDG 125
2950 P STREET
WPAFB OH 45433

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION AVAILABILITY STATEMENT
Unlimited distribution
In Accordance With AFI 35-205/AFIT Sup 1

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

DISTRIBUTION STATEMENT A
Approved for Public Release
Distribution Unlimited

20000831 092

14. SUBJECT TERMS

15. NUMBER OF PAGES
79

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT