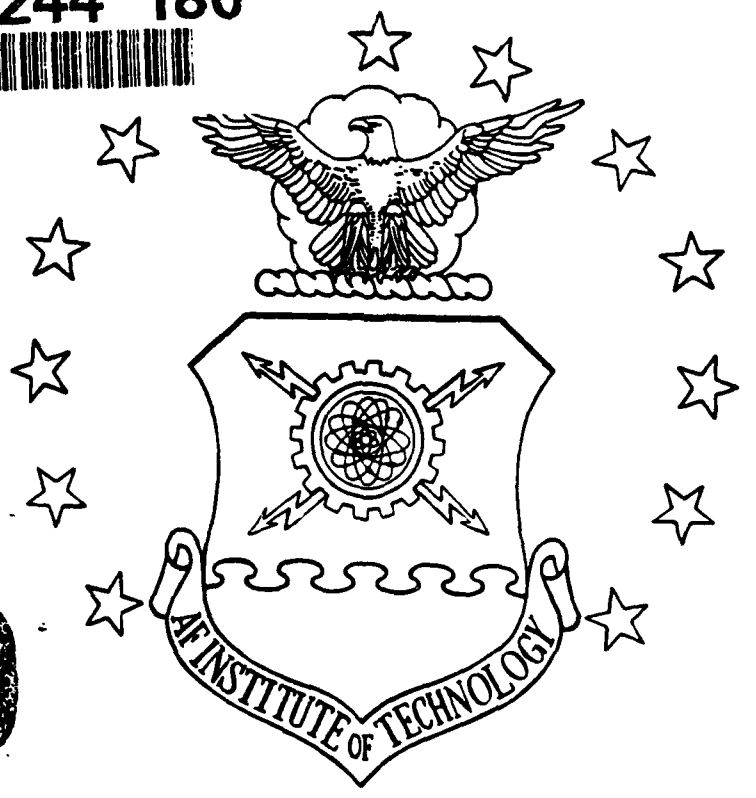

DEPARTMENT OF THE AIR FORCE

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Design and Implementation of a Graphical User Interface and Database Management System for the Saber Wargame

THESIS

Andrew Horton
Captain, USAF

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THESIS

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Captain, USAF

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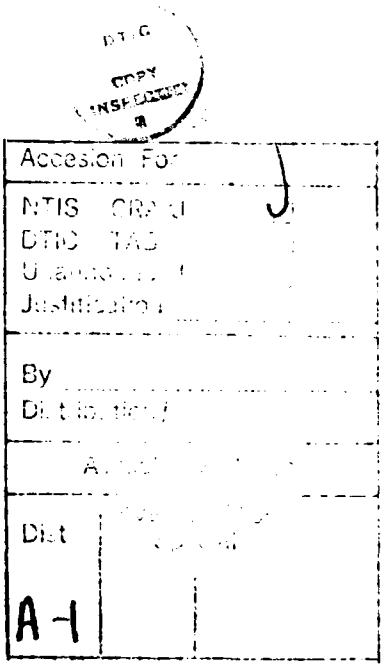

Preface

The goal of this thesis was to design and implement a graphical user interface and database management system for the Saber theater-level wargame. It is a continuation of two previous thesis efforts to develop an integrated wargame to teach tactical employment concepts to future leaders in the United States armed forces.

This thesis documents the methodology, efforts and sofware products produced that went into achieving these goals. My sincere hope is that this work proves beneficial to the Air Force Wargaming Center and the United States Air Force in general.

I thank the Lord Jesus Christ for his grace, love, and countless undeserved blessings. I am deeply indebted to Major Mark Roth, my thesis advisor, for his patience, direction, and invaluable assistance during the development of this thesis effort. I wish to thank the additional members of my thesis committee, Dr. Henry Potoczny and Major Michael Garrambone, for their wisdom and assistance. Special recognition is given to my thesis partners, Captain Gary Klabunde and Captain Christine Sherry, for their patience and effort spent in the completion of this project. I cannot say thank you enough to Arlene and Qiana Bryant for their undying love, selflessness and inspiration. I also thank the entire class of GCS-91D, especially Dennis Rumbley and Tim Jacobs, for their friendship. I must acknowledge my cat, Garfield, who kept me company on the many late evenings I spent burning the midnight oil. Finally, extra-special thanks goes to Yulaunda Abram, my future wife, for her unwavering support, prayers, and understanding during throughout the course of this project.

Andrew Horton

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Abstract

Saber is a theater-level, multi-sided, airpower employment computerized wargame that can be programmed to simulate any combat scenario. The model simulates theater level combat between air and land forces, and takes into account the effects of logistics, resupply, and both theater nuclear and chemical warfare. The major objective of the Saber model is to provide a suitable educational platform to allow users to apply basic, tactical employment concepts to multiple combat units, each having a specialized mission and incorporating every branch of the armed services.

This thesis documents a graphical user interface and data management system that has been developed to execute the Saber theater level wargame simulation. It is a continuation of two previous efforts, and is one component of three thesis efforts designed to develop an integrated, on-line simulation of the Saber theater-level wargame.

Design and Implementation of a Graphical User Interface and Database Management System for the Saber Wargame

I. Introduction

1.1 Overview

Saber is a theater-level, multi-sided, airpower employment computerized wargame that can be programmed to simulate any combat scenario. The model simulates theater level combat between air and land forces, and takes into account the effects of logistics, resupply, and both theater nuclear and chemical warfare. The major objective of the Saber model is to provide a suitable educational platform to allow users to apply basic, tactical employment concepts to multiple combat units, each having a specialized mission, and incorporating every branch of the armed services. (22) This thesis documents the graphical user interface and data management system that has been developed to execute the Saber theater level wargame simulation.

The Saber model was developed by Captain William F. Mann and Captain Marlin A. Ness at the Air Force Institute of Technology for use by the Air Force Wargaming Center at Maxwell AFB, Alabama (22). The game was originally designed to incorporate current USAF and US Army doctrine into a new AirLand theater wargame.

The model currently supports both the land and air aspects of theater warfare, and the model can be extended to incorporate naval operations as well. Air aspects that are modelled include reconnaissance, close air support, interdiction, suppression of enemy air defenses, combat air patrol, and many others (22). Fundamental land missions that are simulated include, among others, exploitation, pursuit, and various offensive and defensive combat movements and postures (25).

1.2 Background

The history of wargames is long. The need for accurate wargames is no secret, and has been extensively documented. Several benefits of realistic computer war simulations include:

- Provide training – Wargames are training platforms that can be used to instruct future leaders in the art of conducting combat operations that encompass a wide variety of scenarios. Lessons learned from mistakes made on a computerized battlefield may eventually save lives on an actual battlefield.
- Save material and manpower – A computer simulation is less expensive to execute than performing an actual theater-level war exercise using real people and equipment. Resources that are used during actual training exercises are also saved. Furthermore, exercise that include real people involve the inherent risk of injuries to personnel or even loss of life.
- Repetition – A computer simulation allows users not only to recreate specific events, but also to explore different outcomes that might occur if the players decide to do things differently.
- Time compression – A battle scenario that spans several days or weeks can be simulated by a computer in a matter of hours.

Further information on the history, benefits, and importance of wargames can be found in (7, 8, 22, 25).

In (25), Marlin Ness described the development of a theater level *land* combat model that incorporated the latest land combat modeling theory, army operating procedures, and tactical and strategic operations of units in the field. The model is a simulation of the doctrinal planning and decision making operations that are conducted at the army group level, providing credible land combat processes, unit movement and attrition, logistics, and intelligence based on player inputs, airland unit interactions and terrain characteristics.

William Mann took the land battle model developed by Ness, redefined the ground combat units, and integrated Air Force doctrine, producing a new model, known as Saber, that incorporated both air and land battles. Saber introduced stochastic attrition between aircraft, ground forces, and theater air defenses by joining together unclassified engineering submodels to gain credible interactions between aggregated entities. The major components of this new model are stochastic attrition, aircraft packages, logistics, intelligence, and nuclear warfare. (22)

Both Mann and Ness dealt primarily with conceptual models of a wargame, concentrating on the playing pieces and the algorithms necessary for a realistic simulation. The scopes of their theses did not contain the development of an appropriate data management

system or user interface for their models. However, they did provide guidelines and insight into how additions to their models could be integrated into a complete package.

Mann defined four areas of player input necessary to implement the Saber theater level wargame. These areas are aircraft beddown, transportation of supplies, instructions to land units, and finally, aircraft and missile missions (22). Each of these areas of input are addressed in this thesis.

1.3 Problem Statement

Modern computerized wargames require a substantial amount of data to be input by the players of the games. The large amount of data that is required as input to a wargame can take a significant amount of time to be entered into a computer. Furthermore, for the game to be as realistic and believable as possible, the instructions supplied to the wargame should be in a format similar to the commands issued during actual armed conflicts. Not only does a large volume of data need to be entered into a computer before a simulation can begin, but the entered data also must be properly tracked and readily available for manipulation. The problem addressed in this thesis is the input and storage of data necessary for proper execution of the Saber theater level wargame.

1.4 Research Objectives and Constraints

After examining various alternatives, and considering the constraints set forth by the sponsor of this thesis, it was determined that the input of data into the wargame could be appropriately handled through the use of a graphical user interface. In addition, it was determined that the management and manipulation of data for the Saber game could best be handled through the use of a database management system. Therefore, the purpose of this thesis effort is to document the design and implementation of a graphical user interface and relational database management system for the Saber theater level computerized wargame. The interface is capable of managing all data entered by the players of the wargame, and the database management system has been designed to allow fast and easy retrieval and manipulation of all data used in the wargame simulation.

The implementation constraints as set forth by the Air Force Wargaming Center were:

1. The interface must allow fast, simple, and user-friendly input of information in a format similar to the commands issued in war.

2. The user interface must be coded using the Open Systems Foundation (OSF) Motif (27) toolkit in conjunction with the *X Window System* (39).
3. All input and wargame data must be stored in flat files that can be accessed by a relational database.
4. The user interface and database implementation must execute on a *Sun 386i* and be transportable to a *Sun Sparc II* or compatible workstation.

1.5 Methodology

The major portion of this thesis effort was to implement a graphical user interface and a database management system (DBMS) for the Saber theater level wargame. The implementation followed these steps described below:

1. Determine all player inputs and database entities necessary to implement the wargame simulation. This was accomplished by reviewing suggested player inputs listed in previous theses (22, 25), and inputs requested in Air Force Wargaming Center requirement documents (10). Reviews were accomplished by the Saber implementation team, which consisted of Major Mark Roth, Major Michael Garrambone, Captain Andrew Horton, Captain Gary Klabunde, and Captain Christine Sherry.
2. Classify related inputs by categories. This was also accomplished by iterative reviews of the Saber implementation team.
3. Construct menu systems that allow input by category. The menu system was constructed to allow related information to be input as a unit.
4. Construct appropriate entity-relationship (ER) diagrams. ER diagrams were constructed to map the relationships between the various entities and attributes used in the Saber model, and to display the overall logical structure of the database. The ER models represent certain constraints to which the contents of the Saber database must conform to. One such constraint is *mapping cardinalities* which express the number of entities to which another entity can be associated via a relationship set. (19)
5. Convert ER diagrams to database relations. For each entity set and for each relationship set in the Saber database, a unique relation table was created which was assigned the name of the corresponding entity set or relationship set. The attributes for each entity correspond to the column names of the relation table. (19)

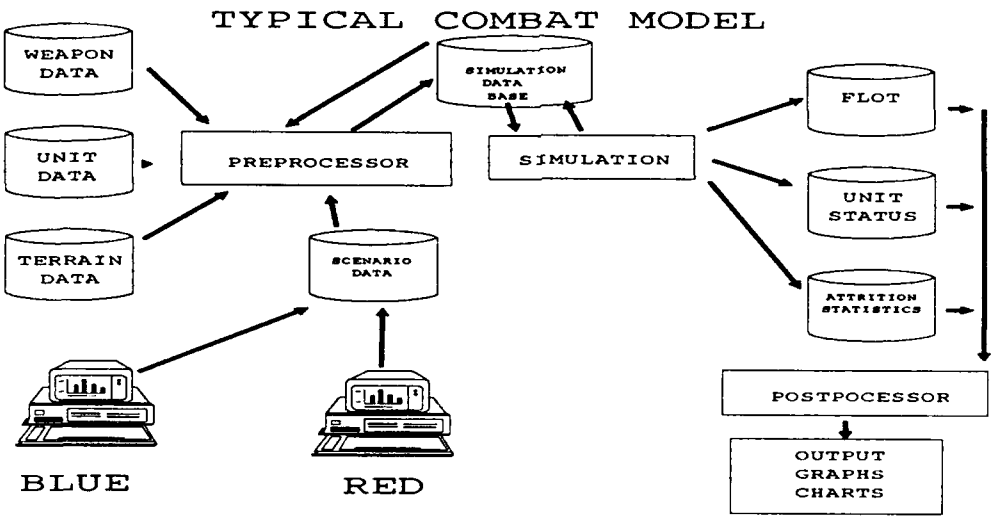

Figure 1. Typical Combat Model (22)

6. Normalize database relations to ensure data integrity. The goal of the Saber relational database design was to generate a set of relation schemes that allow the storage of information without unnecessary redundancy, and also allow for the easy retrieval of the information (19).

1.6 Scope and Limitations

Figure 1 is an illustration of the components necessary to implement a typical combat model simulation. Weapon, unit, terrain, and scenario data are input to a simulation preprocessor, which in turn, provides output to be used by the simulation software. The output from the simulation is sent to a postprocessor that formats output for both printed and terminal displays.

This thesis project developed the user interface, database system, and associated preprocessor software necessary to implement the Saber theater level computerized wargame.

Another thesis project (30) takes values stored in the Saber DBMS, and applies attrition algorithms to simulate battlefield scenarios. A third thesis project (16) processes output from both the Saber DBMS and the simulation results, producing a graphical representation of the theater war events, and documenting the results of battlefield simulations through the generation of various reports in a computer printout format.

Verification and validation of the Saber model is to be accomplished by the Air Force Wargaming Center.

1.7 Materials and Equipment

This thesis effort uses the OSF Motif toolkit along with the *X Window System* in its implementation of the user interface. The Saber data management system was designed and implemented using the *Oracle* (9) relational DBMS. The software generated as a result of this thesis can be executed on both the *Sun 386i*, and on *Sun Sparc II* compatible workstations.

1.8 Outline of Document

The remainder of this thesis is organized into 4 additional chapters. Chapter 2 of this thesis is a summary of previous related research on computerized wargames, and the interfaces and database management systems that are used to implement them. Chapter 3 describes the methodology used in designing the Saber DBMS, and presents a relational system using the *Oracle* DBMS. Chapter 4 defines the implementation of the Saber graphical user interface, and how this interface interacts with the Saber DBMS. Chapter 5 summarizes this thesis effort, gives concluding remarks, and recommends areas of further research.

II. Summary of Current Knowledge

2.1 Overview

This chapter provides an overview of key research in the area of graphical user interfaces and data base management systems as it pertains to computerized versions of wargames. In the sections that follow, the motivation for the development of the Saber wargame is discussed, followed by a brief summary of its historical development. Notable advances in user interface theory are also presented, including a brief survey of computerized wargames and their associated user interface implementations. This chapter then presents a description of the *X Window System*, and how it used in the development of the Saber user interface. Finally, this chapter concludes with a description of relational database design using an object-oriented methodology. This design was used as the foundation for the Saber data management system.

2.2 User Interface Issues

2.2.1 Background of User Interfaces and Their Design. User interface design has been recognized as a critically important part of any software system. Kross (20) provides an excellent summary of the history of user interfaces. In the early days of computers, the only people who interacted with computers were computer programmers. They were usually the only users of the computer system, since the interface consisted of hardware components such as a punch card reader. Today, computers are used by vast numbers of untrained users. This fact has increased the importance of user-friendly interfaces and made it one of the highest concerns of the modern software engineer.

In today's modern computing age, the quality of the user interface is often the yardstick by which an entire system is judged. An interface which is difficult to use can result in a high level of user errors, and may even cause the software system to be discarded, irrespective of the functionality that the system offers (33). Therefore, the interface must be designed with the needs of the user in mind.

2.2.2 User Interface Design Objectives. For most interactive systems, the screen displays are a key component to successful user interface designs. A dense or cluttered display can lead to user errors, and inconsistent formats can inhibit performance and lead to user frustration. (31)

Sommerville (33) listed these three fundamental principles that should be adhered to when user interfaces are designed:

1. **The user interface must be designed to meet the needs and abilities of the individual user.** Users should not be forced to adapt to an interface because it was convenient to implement, or because it was suited to the system designer. To achieve this objective, the users of the Saber wargame from the Air Force Wargaming Center were given periodic prototypes of the Saber user interface as it was incrementally developed. Recommendations from the users were then incorporated into the existing interface.
2. **The user interface must be consistent.** A user interface is deemed consistent when system commands and menus have the same format. A consistent interface means that when a user learns about one command in the interface, the knowledge can then be applied to all other commands within the system.
3. **The user interface should have built-in "help" facilities.** Different levels of help and advice should be available to the user from any point in the system. Help should range from very basic information on how to get started with the system to a full description of system facilities and how to use them.

Sommerville's list is typical of the guidelines set forth in many texts on designing user interfaces. Many of these guidelines, although useful, are sometimes vague. Smith and Mosier (32) made an attempt to overcome this problem. Table 1 is a sample of 162 data display guidelines listed in Smith and Mosier.

The user interface to a computer wargame simulation poses some unique problems. For any model to be believable, the interface must allow player input in a format similar to the commands issued during an actual conflict. Smith (32) proposed the following objectives for the data entry design portion of a user interface:

- **Consistency of data entry transactions.** Related data should be entered in a similar fashion. Furthermore, there should be a single method for entering data. Users should not be forced to switch from one mode of data entry to another.
- **Minimal entry actions by the user.** Users should only have to enter any particular data item once. Programs that require the re-entry of data force the user to duplicate their efforts and increase the possibility of entry errors.

Table 1. Samples of the 162 data display guidelines from Smith and Mosier

Display data to users in a directly useable form; do not make users convert displayed data.
For any particular type of data display, maintain a consistent format from one display to another.
Use short, simple sentences.
Use affirmative statements, rather than negative statements.
Order lists by some logical principle; if no other principle applies, order lists alphabetically.
Left-justify columns of alphabetic data to permit rapid scanning.
In multi-paged displays, label each page to show its relation to the others.
Consider color coding for applications in which users must rapidly distinguish among several categories of data, particularly when the data items are dispersed on the display.
When data display requirements may change, which is often the case, provide some means for users (or a system administrator) to make necessary changes to display functions.

- **Minimal memory load on the user.** Data items should be kept as short as possible. Long data items should be abbreviated or partitioned into shorter groups. For example, a social security number can be entered as three groups, 123-45-6789.
- **Compatibility of data entry with the data display.** User interfaces should have a consistent HOME position, consistent cursor placement, and easy cursor movement between data fields.
- **Flexibility of user control of data entry.** Since data entry requirements often change, some means must be provided for the user or a system administrator to make necessary changes to the data entry functions.

Mann defined four areas of player input necessary to implement the Saber theater level wargame. These areas are aircraft beddown, transportation of supplies, instructions to land units, and finally, aircraft and missile missions (22). Each of these areas of input are addressed in this thesis.

2.3 The X Window System

The design of user interfaces using windowing environments is relatively new in the field of computer science. Windows have the advantage of allowing several pieces of information or documents to be displayed at one time.

Graphical user interfaces that use some type of windowing system are a common feature to many of the current software packages available in today's modern computer age. As a result, users have come to expect all applications they work with to have a professional, user-friendly interface (39). The *X Window System*, or simply X, is one software system that provides the necessary facilities to allow programmers to efficiently develop professional graphical user interfaces (39). A full description of X and its capabilities can be found in (13, 14, 26, 29, 39).

X is a network-transparent window system that enables users to simultaneously run multiple applications in separate windows (29). X was developed in 1984 at the Massachusetts Institute of Technology (MIT) to fulfill the need for a distributed, hardware-independent graphical user interface platform (39). Since its version 10 release in 1986, X has been adopted as a standard by nearly every workstation manufacturer, and should eventually replace or be supported under their proprietary windowing systems(26). One of the requirements for implementing Saber was for the software generated to execute on the *Sun 386i*, and *Sun Sparc II* compatible workstations. Since X software packages can be executed on several different types of incompatible machines, the X Window System has proven to be an appropriate choice for building the graphical user interface for the Saber theater level wargame.

2.4 OSF/Motif

One interface to X is a C language library known as Xlib (39). Although applications can be built in their entirety using Xlib, the Xlib library can be tedious and difficult to use correctly. The window manager conventions alone require the programming of hundreds of lines of code. (39) To make X programming easier and less time consuming, Open Software Foundation (OSF) developed a high-level toolkit known as Motif (27).

Motif allows X programmers to be more productive by hiding many X Windows implementation details from the programmer. With Motif, creating and manipulating windows on a screen is simpler and requires less lines of code to be programmed.

Motif increases user productivity by supplying the user with an application toolkit, a window manager, and a user interface language. The Motif toolkit consists of a set of functions and procedures, known as widgets and gadgets, that provide quick and easy access to the lower levels of the X Window system. The window manager provides for the direct manipulation of graphic objects. The placing and sizing of windows, icon definitions, and communications between different applications are all handled by the window manager. The Motif user interface language, or UIL, is a specification language for describing the initial state of a user interface for a Motif application. The specification describes the objects used in the interface, such as menus, form boxes, labels, and push buttons. The specification also describes which functions are to be called when the interface changes state as a result of user interaction. A detailed description of each of these productivity tools can be found in (27).

2.5 Saber Database Management

2.5.1 Database Management Concerns. The data required to implement Saber will be stored in flat files that can be accessed by a relational database. Database management systems offer a number of major advantages over directly manipulating flat files. Korth (19) and Date (6) present these advantageous of using a DBMS to control data versus using a file-processing system.

- **Data redundancy and inconsistency can be reduced.** Redundancy leads to higher storage and access cost as well as potential data inconsistency. Any particular value of a data item should be stored in one location, if feasible. This can be accomplished through proper normalization of the data items being stored.
- **Data integrity can be maintained.** The values stored in the database must be accurate and must satisfy consistency constraints. For example, the number of aircraft in a strike package can never be a negative number.
- **Multiple users can share data.** A DBMS usually has a built-in mechanism to allow multiple users to access the same data simultaneously without sacrificing data integrity.
- **Standards can be enforced.** A DBMS can aid in ensuring that data items are stored in the proper format. For example, a DBMS can inform the users to input a date in YYMMDD format if they attempt to enter the date in any other format.

- **Security restrictions can be readily applied.** Not every user of Saber should be able to access all the data stored in the Saber DBMS. Since application programs, such as report writers, are added to a system in an ad hoc manner, the use of DBMS can aid in the enforcement of security constraints.

The goal of a DBMS is to provide an environment that is both convenient and efficient to use in retrieving information from and storing information into a database (19).

2.5.2 The ORACLE Database Management System. ORACLE is a relational database system produced by Oracle Corporation of Belmont, California. ORACLE includes a complete set of integrated software productivity tools for application development and data analysis. Versions of ORACLE exist that run on a wide range of machines, from desktop personal computers mainframes. This flexibility allows organizations to use heterogeneous hardware but still operate in a standard software environment for applications. (9) ORACLE has been used for development of the Saber DBMS at the request of the Air Force Wargaming Center. ORACLE provides the following tools for programmers to create and maintain their own applications (9).

- Application Generator and Screen Formatter.
- Report Writer.
- Color Graphics.
- Document Preparation and Text Merging.
- Integrated Data Dictionary.

Each of these tools were used in the development of the Saber DBMS. These software productivity tools are run on both the *Sun 386i* and on *Sun Sparc II* compatible workstations, which are the required hardware platforms for the Saber Theater level wargame. These tools can continue to be used to modify and maintain the Saber DBMS as the need arises.

2.6 User Interface Applications of Existing Wargames

This section presents an overview of theses on user interfaces for wargames, and on the user interfaces that currently exist on computerized versions of wargames.

2.6.1 Theater Analysis Model AirLand Campaign Model. The Theater Analysis Model (TAM) system (11) is a set of wargame models used by the Joint Staff, Politico-Military Assessment Division (PMAD). The TAM system currently consists of four components, specifically, Maritime Campaign, AirLand Campaign, Air Engagement, and Naval Engagement Models. (11) The interface and data management system for the AirLand Campaign Model are reviewed here.

2.6.1.1 TAM AirLand Campaign Model User Interface. The TAM AirLand Campaign Model is a theater level combat simulation between conventional land and air forces. The model provides a highly aggregated view of a broad array of force structures and operational situations. The entire system is hard-coded in Ada to execute on a desktop personal computer. (11)

The interface for the TAM AirLand Campaign model is basically a linked array of 52 different menus arranged hierarchically. Each menu is a single-column list of options. All menus operate in the same fashion:

- Up and down *arrow* keys move the cursor to the next higher or lower line on a menu.
- The *page-up* and *page-down* keys move the cursor up or down one page on menus whose length exceeds the depth of the screen (24 rows).
- The *home* key takes the cursor to the top line in a menu, while the *end* key moves the cursor to the bottom line.
- A menu can be exited by pressing the *escape* key or by selecting the "Quit" option.
- A menu item is selected by placing the cursor on the appropriate line and pressing the space bar. (11)

Selecting a menu item by pressing the space bar can send the user to a sub-menu in the menu hierarchy. The interface does not make use of a pointing device, such as a mouse, to aid the user in navigating through the menu system. Moreover, no windowing of menus has been provided. Since the menu hierarchy goes as far as 10 levels deep, the user can easily lose track of where in the system they are.

2.6.1.2 TAM AirLand Campaign Model Database. Very little information is available on the data management system used by the TAM AirLand Campaign Model. All the data is stored in flat files and can be updated by the user through the menu system.

The database consists of 15 major components, including ground units, aircraft, air units, air bases, areas, targeting, sectors, and special weapons. The data is not actually stored or manipulated by a DBMS such as ORACLE, DB2, or Dbase IV. All data management services, such as retrieval and modification, are coded into the TAM software.

2.6.2 Theater War Exercise. The Theater War Exercise (TWX) is a computer version of a wargame currently played at the U.S. Air War College. TWX is currently supported by the Air Force Wargaming Center.

The game computer interface for the TWX wargame, also known as AGILE, was designed for a player with no previous computer training (1). The Agile interface is form-based, and was designed in a manner that would allow the game users to concentrate on military objectives and strategy, rather than on learning how to use a computer.

The interface to AGILE is similar to the interface used in the TAM AirLand Campaign Model in that it also uses a linked list of menus. The cursor can be moved on any menu with the *arrow* keys or by using the *return* key. The *page-up* and *page-down* keys move the cursor to the top or bottom of a menu, respectively. A menu item is selected by placing the cursor on top of the item, and then hitting function key *F10.* (1)

Data entry is accomplished by the user filling in the blanks of a form displayed on the computer terminal. A form exits for each area of data input necessary to play the wargame, such as aircraft movement, logistics movement, and land unit control. Each form on the screen corresponds to worksheet that the players are required to fill out prior to entering data into the computer. For example, there is a worksheet for augmentation and movement orders, aircraft role change orders, surface and air logistics orders, day and night reconnaissance orders, and battlefield air interdiction orders. Players plan out their missions by filling out these worksheets, and then transfer data from their worksheets to the computer by entering the data on the corresponding computer displayed form.

Selecting a menu item by pressing function key *F10* can send the user to a sub-menu in the menu hierarchy. The interface does not make use of a pointing device, such as a mouse, to aid the user in navigating through the menu system. No windowing of menus has been provided. (1) These problems have led to several efforts to revise the AGILE user interface (20, 38).

2.7 Database Management Systems and Design

A database management system (DBMS) is a collection of interrelated data and the set of programs that can access that data. This collection of data is often referred to as a database (19).

Korth states that the primary goal of a DBMS is to provide an environment that is both *convenient* and *efficient* to use in retrieving information from and storing information into the database.

A database management system is advantageous when large amounts of information have to be manipulated. One primary advantage that a DBMS offers is the concept of data abstraction. Data abstraction is the concept of hiding the user from system level details, such as how data in a database is stored on disk, manipulated, or retrieved. (19) Data abstraction leads to data independence, which frees application programmers from concerns about the physical schema of stored data. Since the user sees data differently than it is stored in the computer, application programs that access the data do not need to be modified whenever the physical organization of the data is changed. (37)

To be successful, a database management system must be skillfully designed and properly implemented (37). As mentioned earlier, data redundancy must be reduced to eliminate the possibility of incurring data inconsistency. Databases can be designed using several methods. Two common approaches to database design are the top-down method and the bottom-up method. The Saber DBMS was implemented using a top-down design, which is described here in detail. A description of bottom-up database design can be found in (19, 37).

2.8 Top Down Database Design Methodology

In the top-down approach to designing a database, the Entity-Relationship (ER) model is used to develop an overall logical structure for a database (37). The ER model is based on a perception of the real world which consists of a set of basic objects called *entities* and *relationships* among these objects (19).

Simply put, an entity is nothing more than a distinct object that can be distinguished from other objects. Each entity is described by a set of attributes, which characterize the properties of the entity. (19) For example, the attributes of an airbase include its *name* and *location.*

Airbases, hexes, land units, and aircraft all represent entities in the Saber database system. A relation is the affiliation, association, or connection between two or more entities. An example of a relationship is the association of an aircraft to the airbase it is assigned to. Two special relationships between entities are *generalization* and *specialization.* Specialization involves adapting or tailoring an entity to a specific function, or supplying the entity with specific characteristics. For example, a helicopter is a specialization of a generic aircraft entity. Generalization is the opposite of specialization. In generalization, specific characteristics of an entity are hidden. (19)

One important constraint in the ER model is *mapping cardinalities* which describe the number of entities from one entity set that can be associated with any given entity in another entity set. There are four types of mapping cardinalities.

- One-to-one relationship, denoted (1:1).
- One-to-many relationship, denoted (1:N).
- Many-to-one relationship, denoted (N:1).
- Many-to-many relationship, denoted (M:N).

A one-to-one relationship states that one entity from one set can be associated with one and only one entity from another set. Considering no land unit can be in more than one place at a time, there is a one-to-one relationship between a land unit and the hex that it resides in. A description of all four types of mapping cardinalities can be found in (19).

All the components of the Entity-Relationship model are illustrated graphically in an ER diagram. An ER diagram consists of the following components:

- Rectangles – Represent entity sets. A double walled rectangle depicts a weak entity.
- Ellipses or Circles – Represent attributes.
- Diamonds – Represent relationships between entities.
- Lines – illustrate the connection between entities and relations, and between entities and their associated attributes. A line between two entities represents an ISA relationship, which depicts a specialization of an entity.

The sequence of operations for top down design are as follows (37):

1. Identify the entities for the enterprise for which the database is being designed.

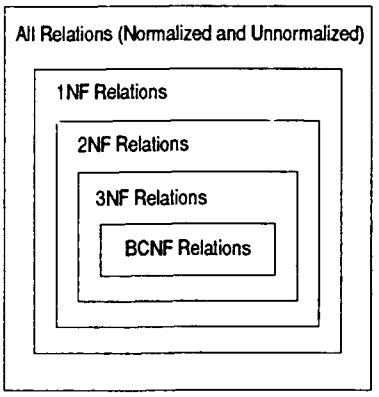

Figure 2. Different Stages of Normal Forms

2. Identify the attributes of each entity.
3. Identify the relationships between entities and sketch the entity-relationship diagram.

2.9 Relational Database Design Considerations

There are several pitfalls of relational database design. The undesirable properties of a poor database design that should be avoided are repetition of information, inability to represent certain information, and loss of information (19). To avoid these problems, all relation tables generated from an ER diagram should be normalized.

Data normalization is accomplished by applying constraints to the relation tables that are known as data dependencies. Data dependencies are used to determine techniques that can be used to decompose tables with a large number of attributes into several relations with a smaller number of attributes. One specific data dependency that is used is called a *functional dependency.* Functional dependencies are expressed by the formula $X \longrightarrow Y$, which states that attribute Y is functionally dependent on attribute X if each value of X can be used to determine the value of attribute Y. Correct application of these dependencies can be used to avoid the three properties of poor database design. (19, 37)

In data normalization, functional dependencies are used to decompose tables into an appropriate *normal form.* A normal form is the degree of data replication and redundancy that exists within a given relation. Normal forms are usually characterized in levels known as first, second, third, and Boyce Codd normal forms (BCNF), as depicted in Figure 2. Certain undesirable features are eliminated from an unnormalized relation as the relation is normalized to successive normal form stages.

Several different approaches can be taken to progress from one normal form stage to the next. "The rules leading to and including third normal form can be summed up in a single statement: Each attribute must be a fact about the key, the whole key, and nothing but the key" (28). Rettig cites these five rules that should be followed for data normalization (28).

1. Eliminate repeating groups. Make a separate relation table for each set of related attributes, and give each table a primary key.
2. Eliminate redundant data. If an attribute depends on only part of a multi-valued key, remove it to a separate table.
3. Eliminate columns not dependent on the primary key. If attributes do not contribute to a description of the key, remove them to a separate table.
4. Isolate independent multiple relationships. No table may contain two or more 1:M or N:M relationships that are not directly related. This applies only to relationships that include one-to-many and many-to-many relationships.
5. Isolate semantically related multiple relationships. There may be practical constraints on information that justify separating logically related many-to-many relations.

Normalization of data is used to avoid the pitfalls of bad database design. In summary, normalization ensures that relations are broken into simpler relations in which related data items are grouped, and that duplication of data is kept at a minimum (37).

2.10 Summary

The goal of this chapter was to familiarize the reader with several key topics related to this research. This chapter introduced graphical user interfaces and their implementations in computerized wargames. A relational database design using an object-oriented

methodology was also presented in this chapter. The following chapters describe in detail the implementation of the Saber graphical user interface and database management system.

III. Saber Database Implementation

This chapter gives a description of the process that was followed in implementing the Saber database system. The first step in the design consisted of an analyis of the problem domain to identify all the entities that needed to be modelled. The entities are described in Section 3.1, along with the process that was followed to produce ER diagrams that represented these entities. The second section details the steps taken to convert the Saber ER diagrams to relation tables. The next section is a detailed description of the Saber database tables that were created, and how they are used to store wargame information. Section 3.4 gives a description of the files used to upload and download data from the Oracle database to flat ASCII files. Finally, Section 3.5 discusses verification and validation issues as they relate to the Saber DBMS.

3.1 Saber Top Down Design

The first step in designing the Saber database was identifying all entities (objects) that needed to be modelled. This was accomplished by reviewing objects already identified in previous thesis efforts (22, 25), and in general group meetings of the Saber implementation team. Table 2 is a listing of the major objects identified that were necessary to implement the Saber wargame.

Several objects were also identified as a specialization of these objects. Objects shown in Table 3 on the right hand side of the $\Longrightarrow$ symbol are specializations of the objects on the left.

Grouping objects together produced the generalization objects shown in Table 4. Objects shown on the right hand side of the } symbol are generalizations of the objects listed on the left hand side of the } symbol.

Table 2. Saber Database Objects

Airbase	Aircraft	Aircraft Missions
Aircraft Package	City	Depot
Force	Hex	Hexside Asset (Obstacle)
Land Unit	Play Period	Pipeline
Radar	Railroad	River
Road	Runway	Satellite
Weapons	Weapons Loads	Weather

Table 3. Object Specializations

Land Unit	$\Longrightarrow$ Supply Train
Weapon	$\Longrightarrow$ Surface to Air (S2A) Weapon
Weapon	$\Longrightarrow$ Surface to Surface Missile (SSM)
Weapon	$\Longrightarrow$ Biological or Chemical Weapon
Weapon	$\Longrightarrow$ Nuclear Weapon
Weapon	$\Longrightarrow$ Air to Air (A2A) Weapon
Weapon	$\Longrightarrow$ Air to Ground (A2G) Weapon
Weapon	$\Longrightarrow$ Land Component (Tanks, Armored Vehicles, etc.)
Weapon	$\Longrightarrow$ Base Component
Weapon	$\Longrightarrow$ Radar
Weapons Load	$\Longrightarrow$ Conventional Load
Weapons Load	$\Longrightarrow$ Nuclear Load
Weapons Load	$\Longrightarrow$ Biological or Chemical Load
Hex	$\Longrightarrow$ Ground Level Hex
Hex	$\Longrightarrow$ Air Hex
Hexside Asset (Obstacle)	$\Longrightarrow$ Country Border
Hexside Asset (Obstacle)	$\Longrightarrow$ Coast
Hexside Asset (Obstacle)	$\Longrightarrow$ FEBA (Forward Edge of the Battle Area)

Table 4. Object Generalizations

Hex	Target	Satellite	Asset	Land Unit	Movement Destination
Obstacle		Obstacle		Airbase	
Road		Road		Depot	
Railroad		Railroad		Hex	
Pipeline		Pipeline			
Land Unit		Land Unit			
Airbase		Airbase			
City		City			
Depot		Depot			

The second step in designing the Saber database using the top-down approach was to identify attributes for each of these entities. The complete relational design can be found in Appendix A. Definitions of attributes and the legal range of values they can take on can be found in the Saber Data Dictionary located in Appendix B.

The third step in the design process was to identify the relationships between the entities that were identified, and generate corresponding Entity-Relationship diagrams. The ER diagrams for the Saber database model are shown in Figures 3–7. The attributes associated with entities are normally displayed in an ER diagram in ellipses or circles. To preserve an understanding of how the data is organized, and to prevent the diagrams from being overly cluttered, only attributes that are primary keys to relations have been displayed in these Saber Database ER diagrams.

3.2 Reducing Entity-Relationship Diagram to Relations

The next phase in the Saber database implementation was converting the entities and relations in the Saber ER diagrams into relations. Some entities were directly converted into relations by simply placing their attributes into the columns of a relation. When converting relationships to relations, the primary keys of the entities associated with the relationship were placed in the new relation as attributes, along with any other attributes needed to properly model the depicted relationship. Weak entities were converted to relations using attributes from both the weak entity and its associated strong entity. (37)

Korth describes these two different methods for transforming an ER diagram which includes generalization and specialization to a tabular form. (19)

- Create a relation first for the higher level entity. For each entity that is a specialization of this higher level entity, create a relation which includes a column for each of the descriptive attributes of that entity plus a column for each attribute of the primary key of the high-level entity.
- Instead of creating a relation for the higher level entity, create a relation for each specialized entity which includes a column for each of the descriptive attributes of that entity plus a column for each attribute of the generalized or higher-level entity.

The first method described above was used in converting the ER diagram into relations for entities that were specializations of other entities. This method was selected to minimize the number of attributes in a relation, since each of the higher level entities in

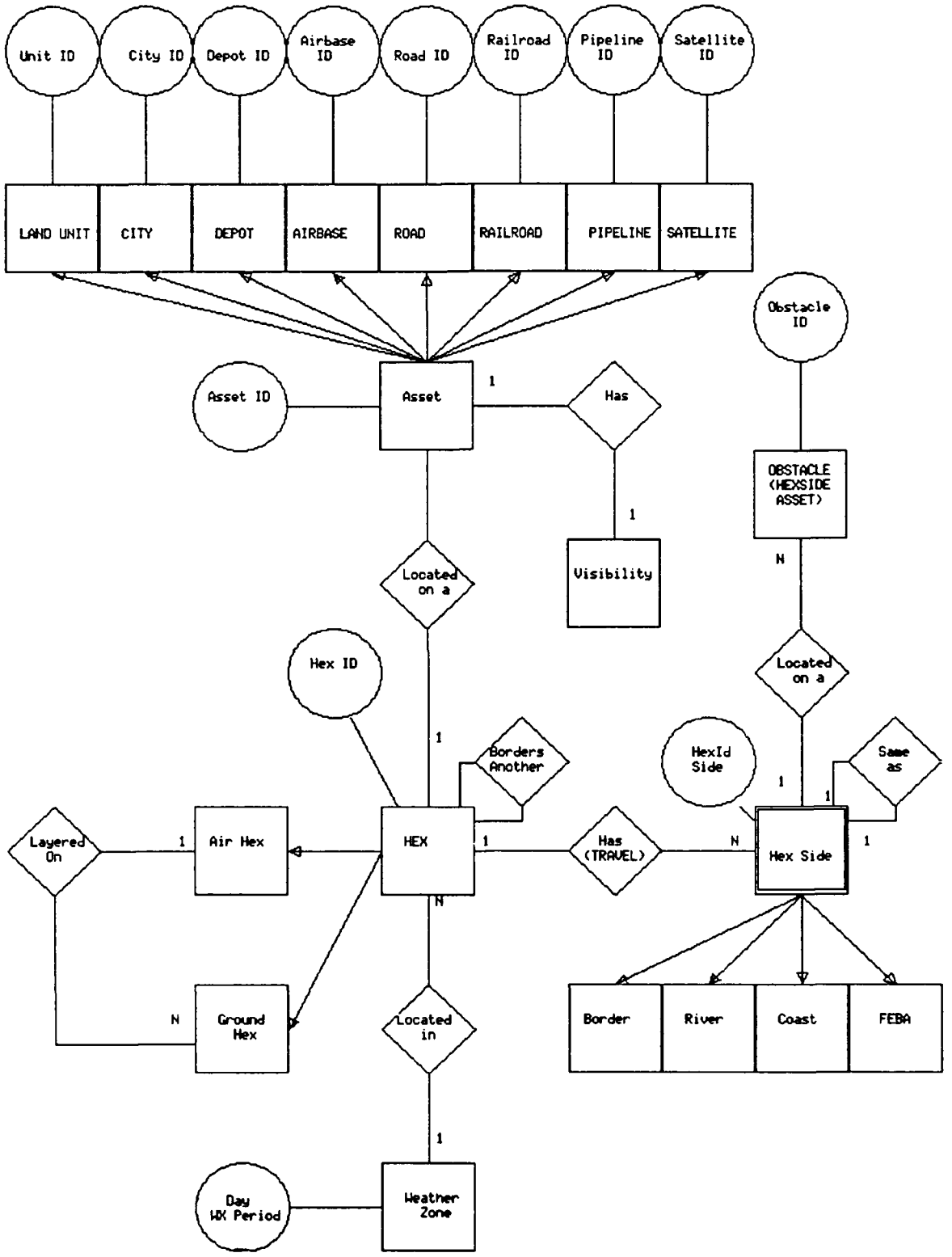

Figure 3. Saber Database ER Diagram (Part 1)

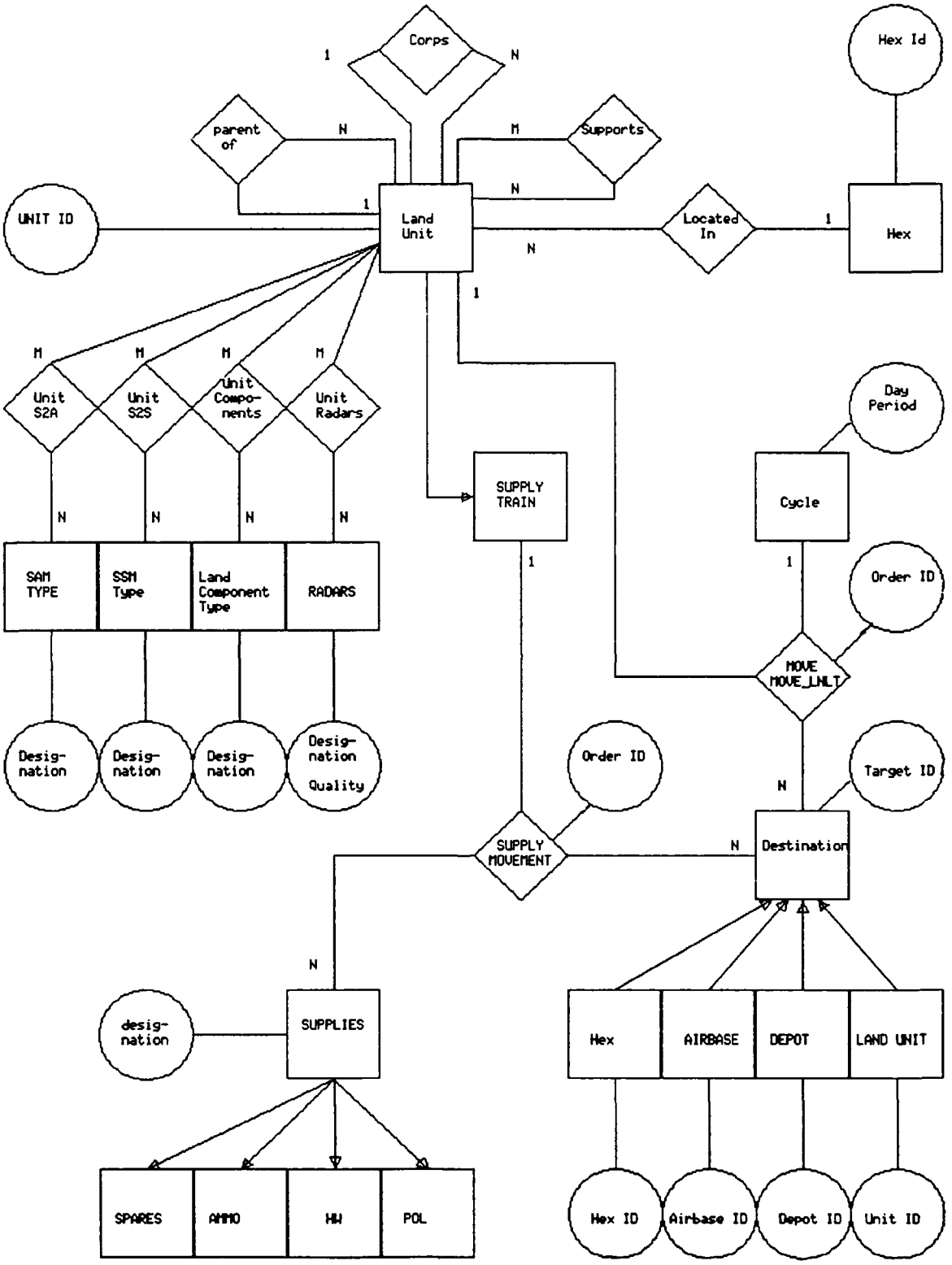

Figure 4. Saber Database ER Diagram (Part 2)

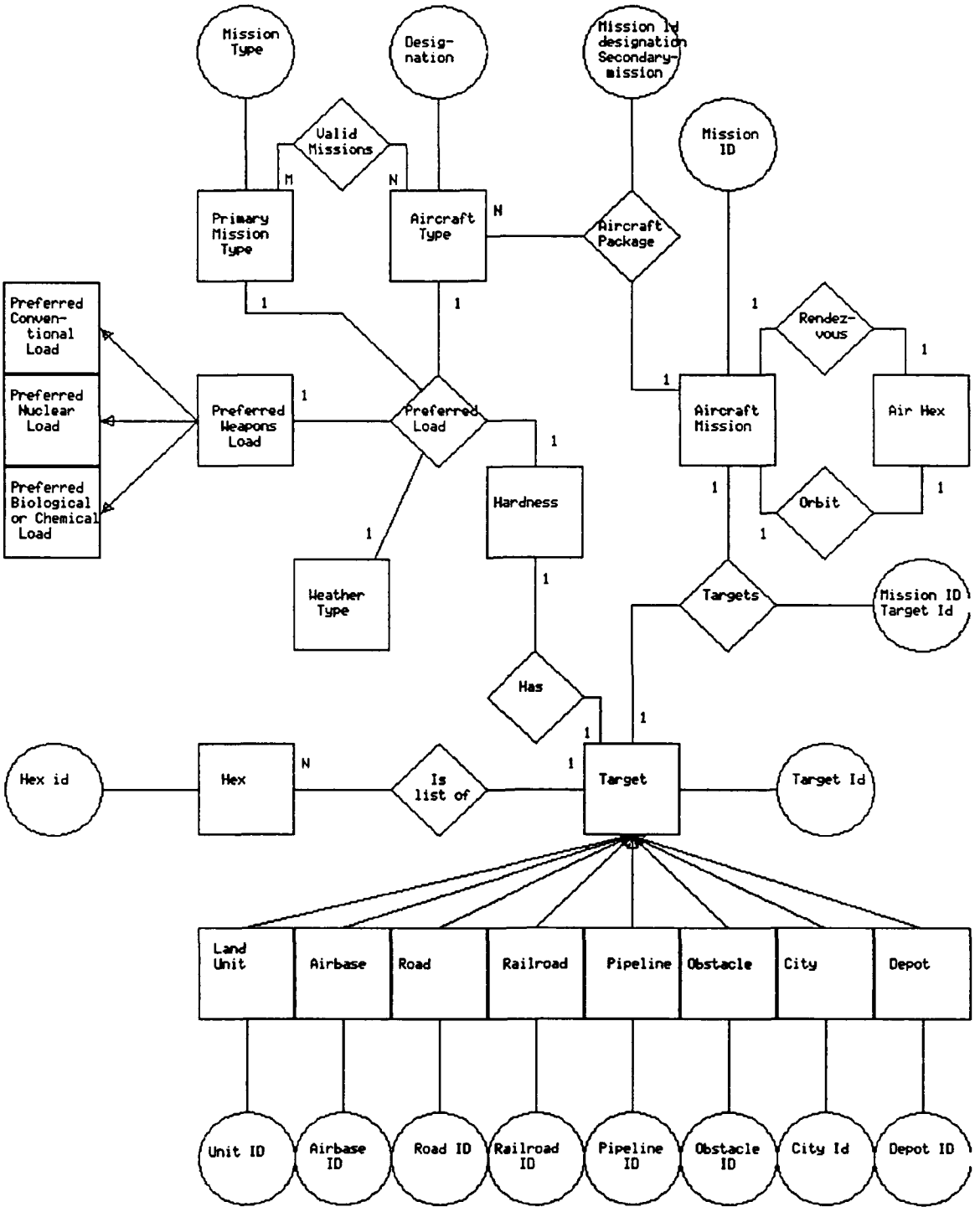

Figure 5. Saber Database ER Diagram (Part 3)

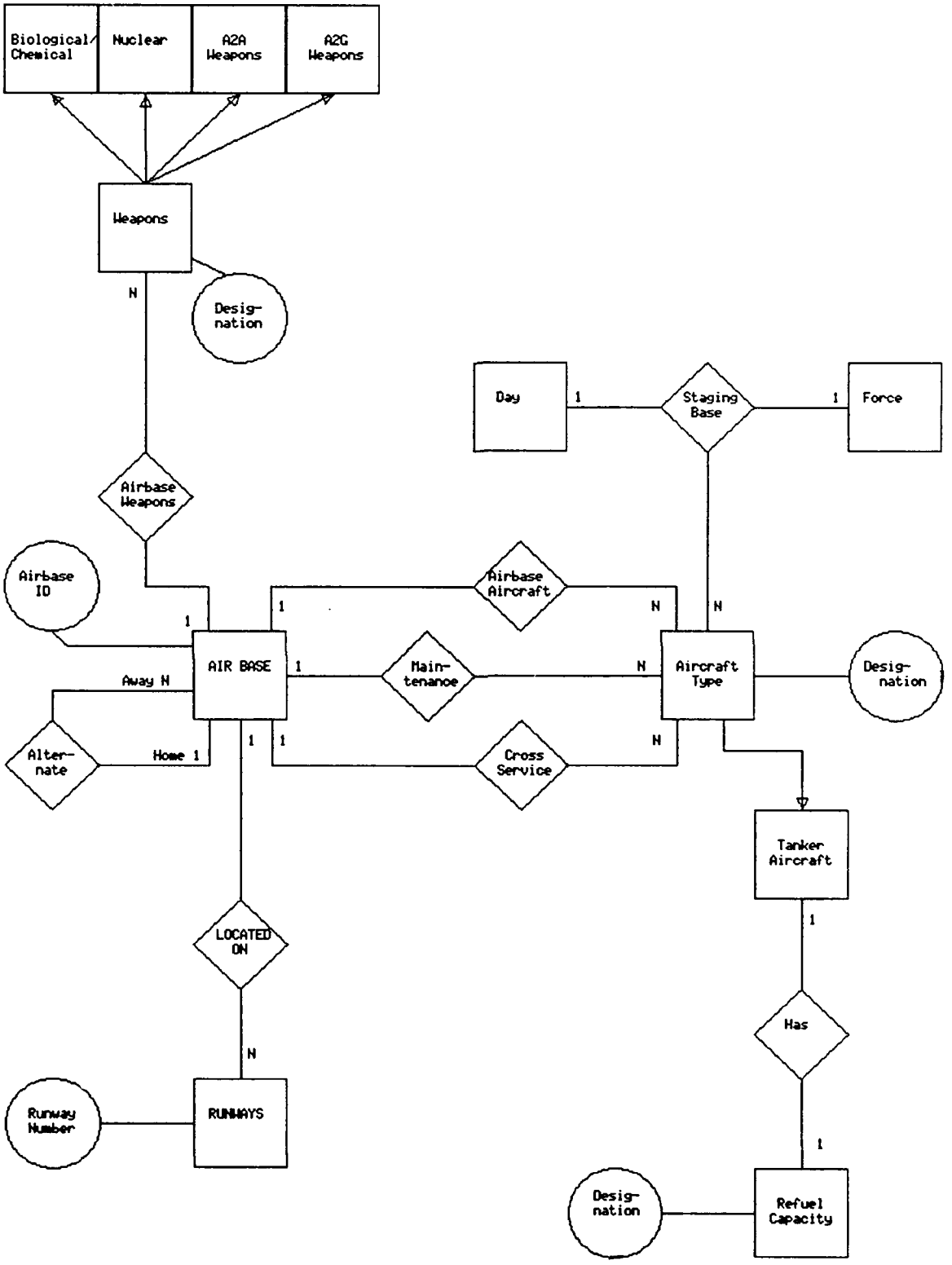

Figure 6. Saber Database ER Diagram (Part 4)

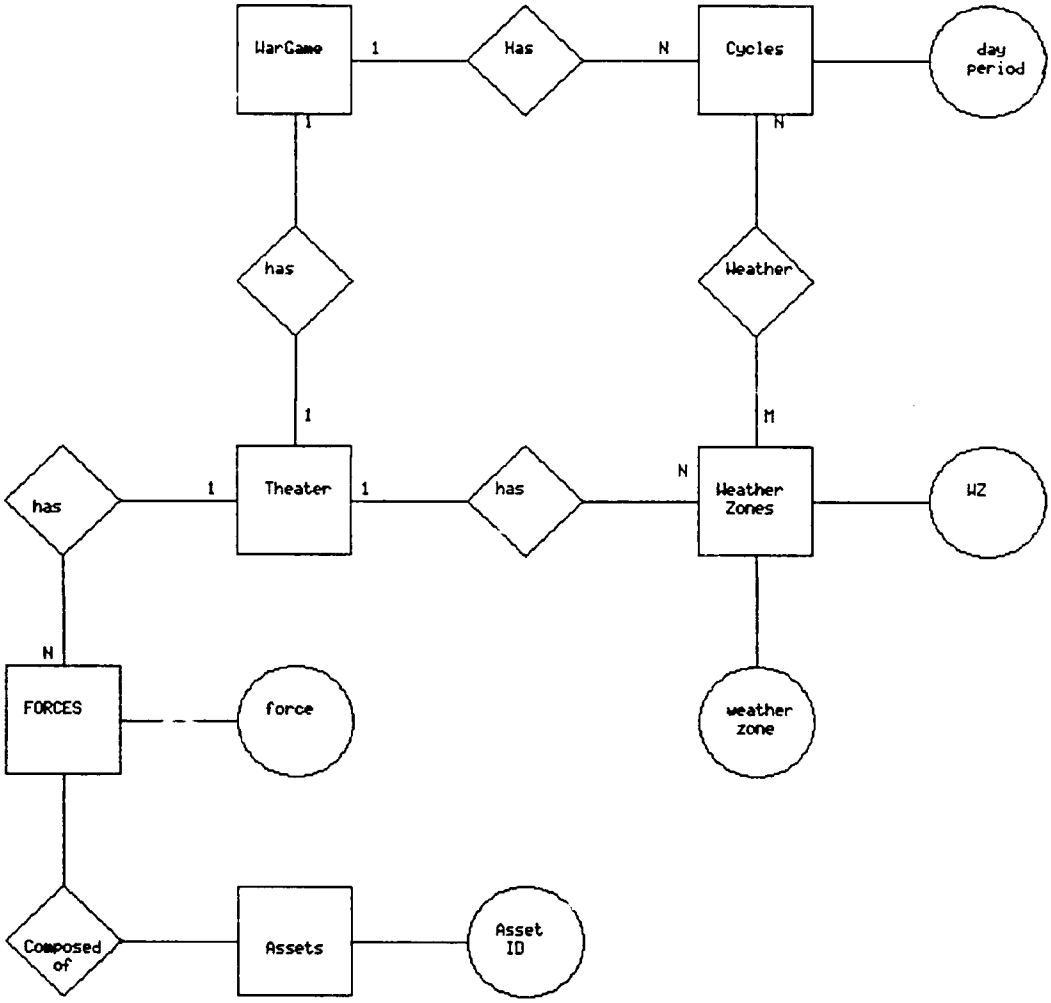

Figure 7. Saber Database ER Diagram (Part 5)

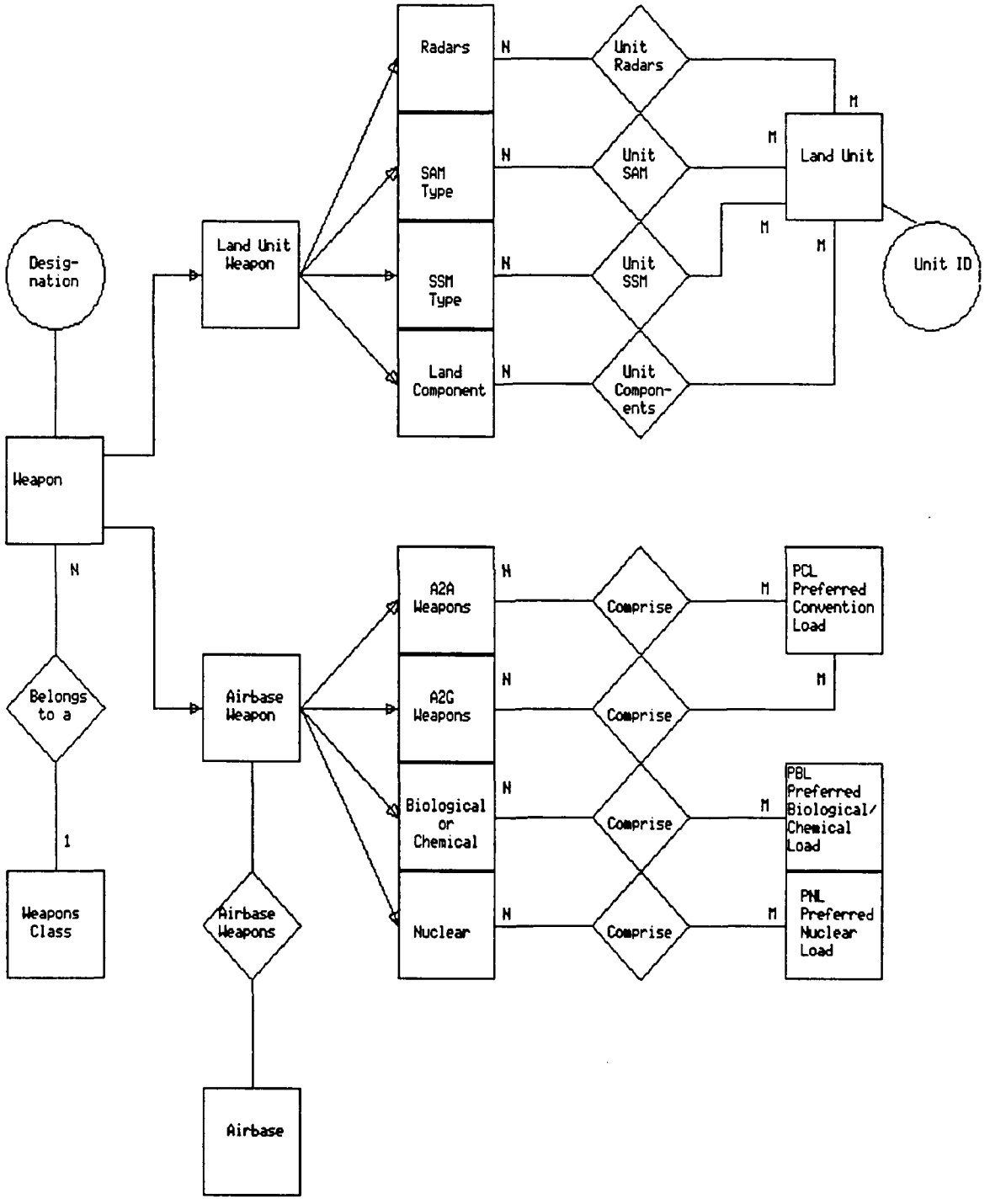

Figure 8. Saber Database ER Diagram (Part 6)

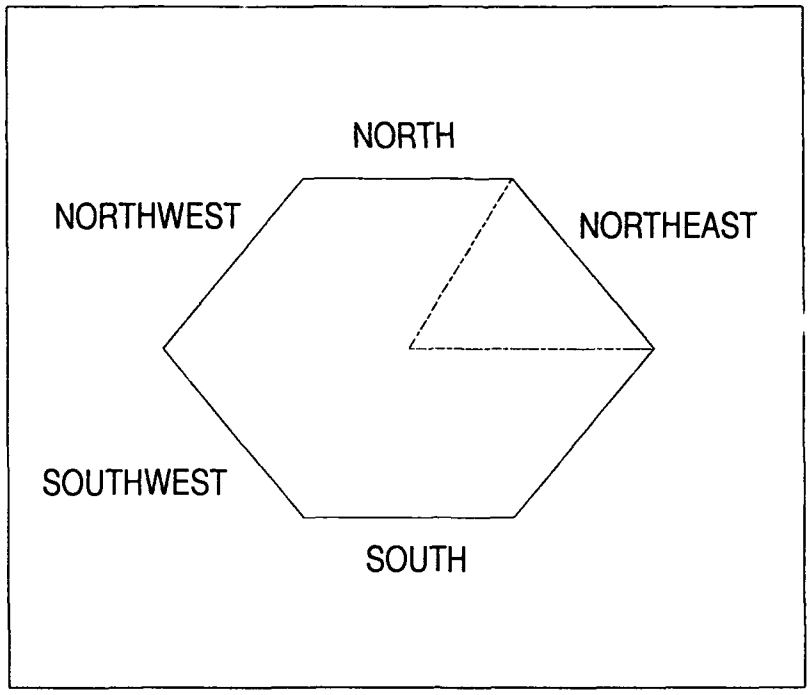

Figure 9. Ground level hex

the Saber model are composed of a large number of attributes, including one relation with over 40 attributes.

3.3 SABER Database Implementation

The following sections detail the specific implementation of the Saber database.

3.3.1 The Hex, Airhex, and Travel Relations. The Saber wargame is similar to many common wargames that use a gameboard in that terrain features are modelled using hexagons (hexes). A typical gameboard wargame usually consists of a terrain map that has been overlaid with grids or hexagons. The hexagonal grid is used to regulate movement and the position of units. (7) Ness gives a discussion on hexagonal terrain model representation in (25).

The Saber wargame also incorporates the concept of air hexes. Air hexes are described by Mann in (22). Basically, an air hex is the aggregation of seven ground level hexes, as shown in Figure 10. Air hexes are stacked six levels deep on top of a ground hex to simulate levels of altitude from ground level to outer space.

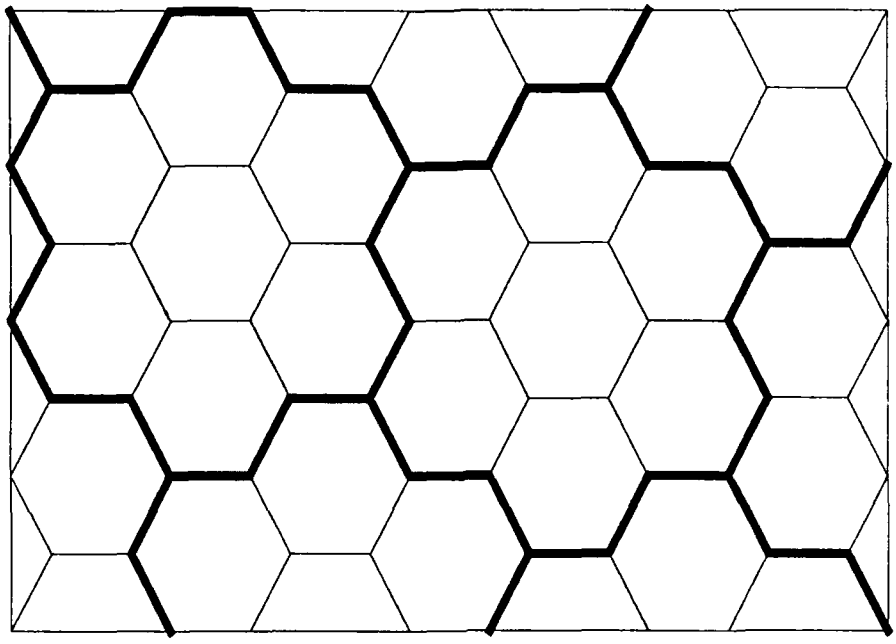

Figure 10. Airhex Grid

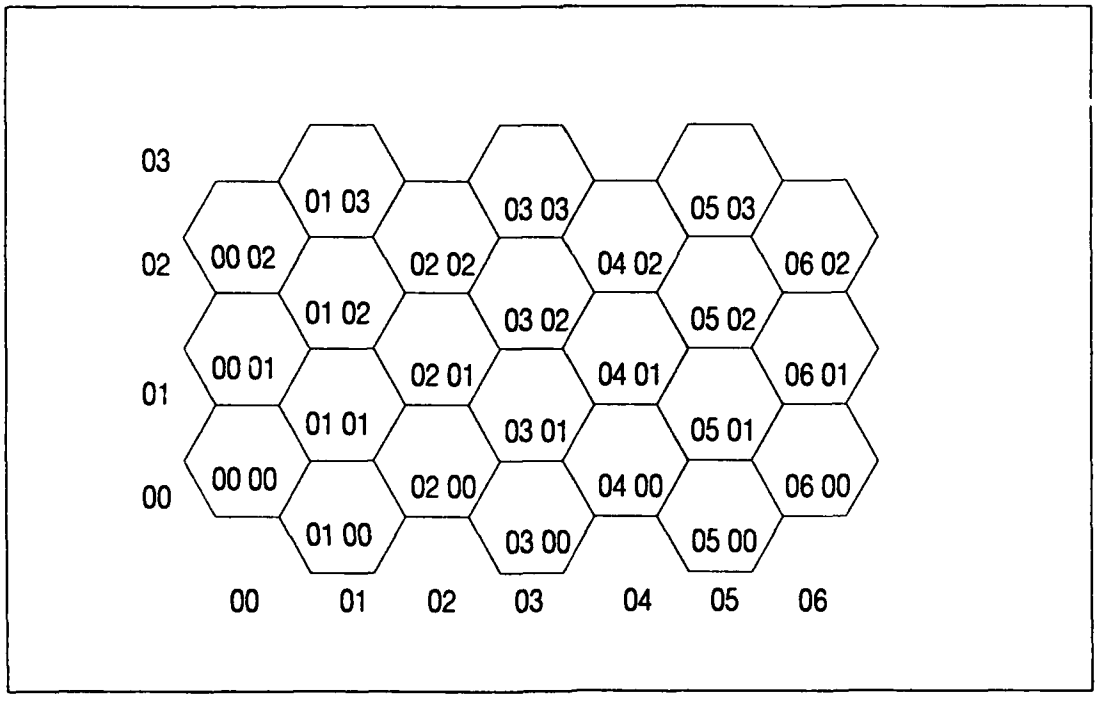

Figure 11. Saber Ground Level Hex Grid System

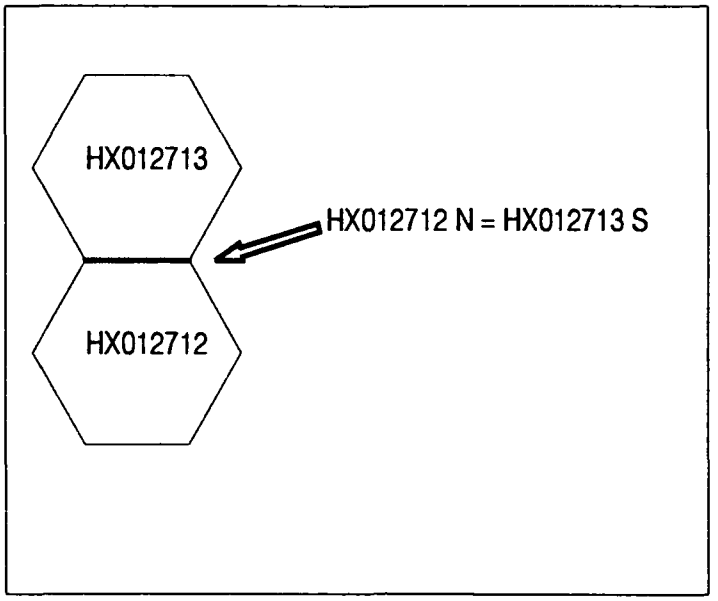

Figure 12. Neighbor ID

The Saber model uses a ground level hex with vertices (points) that are oriented in an east-west direction, as shown in Figure 9. The hex relation is the foundation for the entire Saber computerized wargame. Most entities in the wargame can be mapped to a hex position. Ground level hexes are labeled in accordance with an X-Y coordinate system, in that the hex closest to a point of origin (for a given theater) is given a hex location of (0,0). Hexes are labelled sequentially from the hex at location(0,0), or in other words, from left to right and from bottom to top. The ground hex location due north of the origin hex has an X-coordinate of 0 and a Y-coordinate of 1. Figure 11 depicts the Saber basic hexagonal coordinate system and its numbering scheme.

Each hex is uniquely identified by the *hex_id* attribute. A complete definition of this attribute can be found in Appendix B. The attribute is a character string of length eight. The first two characters are the letters *HX*. The last six characters in the hex_id attribute are used for the Saber hexagonal coordinate system. The first two digits identify the level of the hex, 01 for a ground level hex, and 02–07 for an air hex. The second set of two digits are the X-axis coordinate, and the final set of two digits are the Y-axis coordinate. Figure 12 shows two adjacent ground level hexes labeled with their hex_id identifiers. HX012712 identifies the hex as a ground level hex at level 01 with a X-axis coordinate of 27 and Y-axis coordinate of 12.

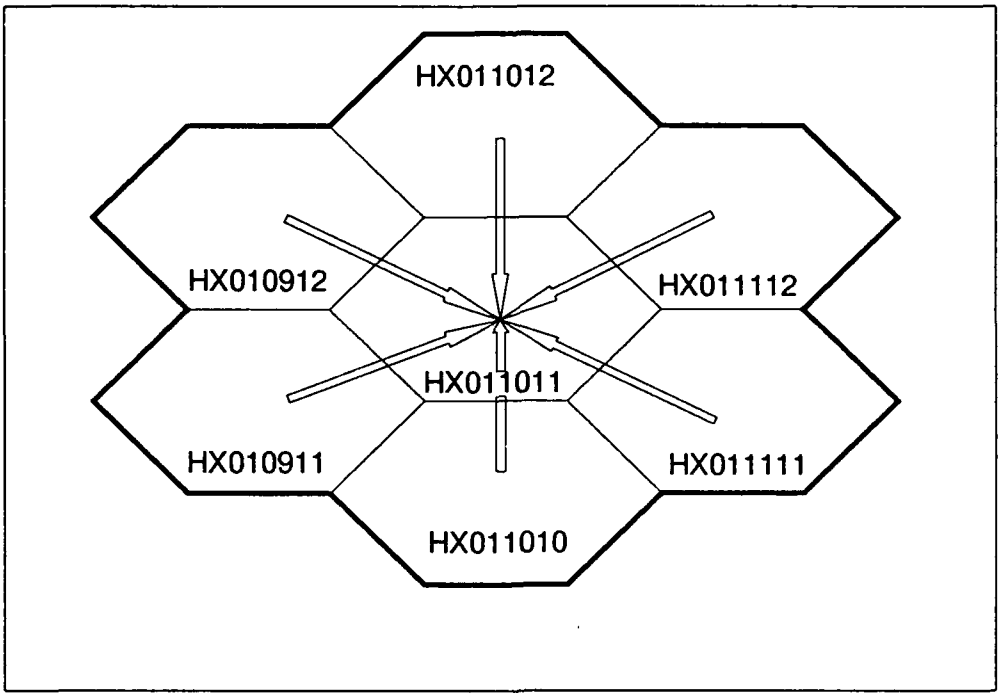

Figure 13. Center Hex

Each ground hex has an airhex that is located directly above it. Figure 13 shows seven ground hexes with an airhex superimposed on the outside border. Each hex points to the center hex that is located directly under the center of the airhex. The *center* attribute is the hex_id of this centrally located ground hex. The hex_id of the airhexes located over this center hex each have the same X-axis coordinate and Y-axis coordinate as the center hex. The airhex at level 03 for the example given in Figure 13 would be labelled with a hex_id of HX031011.

Other significant attributes of the hex relation are *force, country, terrain, forest,* and weather zone, *wz* . Each of these attributes are used in mapping the geographical characteristics of the theater. For example, the terrain attribute describes the topography of the territory in the hex, which can be used in determine a detrimental effect upon troop movements and combat. The remaining attributes (*ec, intel_index, cpo, cpi,* and *persistence_time*) are all computed by the simulation, and are used for efficiency in executing the simulation. These values are read into the simulation at the start of a session, rather than being computed.

The airhex entity is actually a specialization of the hex entity, retaining only the hex_id, wz, and persistence_time attributes. The *trafficability* attribute was added to compensate for mountains that might extend up into the lower levels of the airhexes. Aircraft flying through airhexes with a trafficability value other than *excellent* are subject to a time delay penalty. For example, aircraft flying through a hex with a trafficability of *excellent* are assessed no time delays, while an airhex with a trafficability of *fair* are assessed a time delay equivalent to 20 minutes.

The *travel* relation stores information on the amount of time it would take a land unit to travel from the center of a hex to one of its borders. The key to the relation is a combination of the hex_id identifier and its directional hexside (North, Northeast, etc.). Each hex is divided into six pie pieces, formed by connecting opposite hex vertices with a line. Figure 9 shows a ground level hex with the northeast pie piece highlighted. Each pie piece within a hex has its own *pie trafficability* value. Hexes that have a mountain terrain are given pie trafficability values of *poor* or *very poor* for all six pie pieces. A road that bisects a pie piece can upgrade or improve the pie trafficability of a hex pie piece to a more suitable (*fair–excellent*) condition for travel.

In addition to *hex_id, hexside, and pie_trafficability*, the travel relation also has an attribute named *neighbor_id.* Data normalization requires the minimization of data redundancy. Figure 12 depicts two adjacent hexes, and emphasizes that these two hexes share a common border. The north border of Hex HX012712 is identical to the south border of Hex HX012713. Figure 14 shows a bridge that is shared between hexes HX012414 and HX012413. Data integrity insists that the bridge be stored only once in the database, to prevent one hex showing one-half of a bridge and the adjacent hex showing nothing. To achieve this data integrity, the attribute neighbor_id was introduced. In this example, the south side of HX012414 and the north side of HX012413 are both mapped to one neighbor_id. This neighbor_id in turn is then used to identify the location of the bridge. The location of the bridge is consequently stored in one place in the database.

3.3.2 The Assets Entity and Asset Visibility. As mentioned in the previous section, the hex relation is the foundation for the entire the Saber computerized wargame. Almost every entity within the Saber model can be directly mapped to a hex position. Table 4 lists the entities that are assets, or entities that can be mapped to a hex position. The assets entity is depicted in Figure 3. Each asset depicted in Figure 3 was converted into a relation.

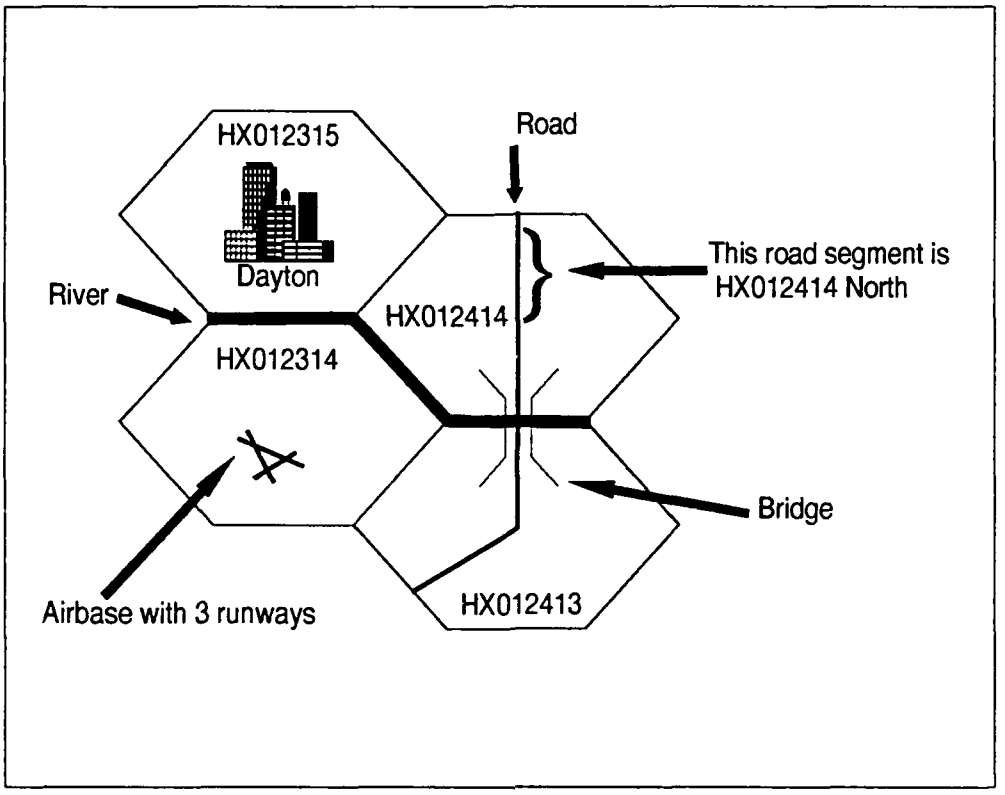

Figure 14. Hex Assets

Any given hex can be home to multiple assets. The *assets* to *hex* relationship is N:1, or any individual asset can only reside in one hex location at any given time. Taking advantage of this mapping cardinality, an attribute (either *hex_id*, or its alias, *location*), was added to each asset relation to store the current position of the asset. This was accomplished rather than creating a table that combines the keys of the hex relation and the keys to various asset relations.

Figure 3 also shows that each asset has associated with it a visibility. An asset is *visible* if the enemy has knowledge of it through intelligence. Since a 1:1 mapping cardinality exists between an asset and its visibility, an attribute, *vis_to_enemy*, was added to each relation that was derived from an asset entity. The vis_to_enemy attribute stores whether an asset will be displayed on the computer terminal to *enemy* forces. The *visibility* relation defines the *vis_to_enemy* attribute. Further explanation of the visibility relation can be found in Appendix A and B.

Table 5. Hexside_Assets Relation

neighbor_id	*obstacle_id*	obstacle	difficulty	vis_to_enemy
NB000331	OB000001	BRIDGE	VG	RBXXXXXX

3.3.3 Hexside Assets Relation. The *Hexside Assets* relation stores information on obstacles that are located on the borders between hexes. It is used in determining any penalty that might be involved when moving from one hex to another hex. Every obstacle in the game can be targeted, and is given a unique identifier. This identifier, *obstacle_id*, is the primary key for the relation.

The obstacle type is stored in the *obstacle* attribute. Examples of obstacles are bridges and minefields. The *difficulty* attribute is used to assess any penalty or benefit that will be experienced in traversing the obstacle. A bridge typically has a difficulty of *VG* (Very Good), indicating that there is no detrimental effect of crossing from one hex to another across a bridge. A minefield might have a difficulty value of *poor*. This value can be used to determine the amount of casualties a unit crossing the minefield might incur.

The neighbor_id attribute is used in the hex_side relation to record the location of the obstacle, and the vis_to_enemy attribute is used to determine what forces the obstacle's location will be reported to. Given the bridge in Figure 14, a sample tuple in the hexside_assets relation appears in Table 5.

3.3.4 Roads, Railroads, and Pipelines. Roads, railroads, and pipelines are stored in the Saber database in segments. Each segment is identified as starting from the center of hex and connecting radially outward to the center of a hexside. Therefore, the key to these relations are the *hex_id* and *hexside* attributes. Figure 14 shows a road of four segments that runs north-south through hex HX012414 and then curves to bisect the southwestern side of hex HX012413. The identifiers for these four segments would be:

HX012414 North
HX012414 South
HX012413 North
HX012413 Southwest

All three of these relations contain a respective segment identifier and the attributes *name* and *flow*. The name attribute is used to identify multiple segments that are related.

Table 6. The Roads Relation

road_id	hex_id	hexside	name	road_size	flow
RD008001	HX012414	N	ROUTE_1	HIGHWAY	YES
RD008002	HX012414	S	ROUTE_1	HIGHWAY	YES
RD008003	HX012413	N	ROUTE_1	HIGHWAY	YES
RD008004	HX012413	SW	ROUTE_1	ROAD	YES

For example, *Highway I-675* might be the name used to identify all road segments in the theater of operations that make up the highway.

Bottlenecks and chokepoints for transportation are a common target in modern warfare. The segment identifier allows each segment of a road, railroad, or pipeline to be individually targeted. The flow attribute describes whether a particular segment is usable. A flow value of *yes* delineates that the segment has not been bombed or destroyed, while a flow value of *no* means that significant damage has occurred to the segment in question, and that it cannot be used for transportation.

In addition to the attributes already mentioned, the *roads* relation has the attribute *road_size*, and the *pipelines* relation has the attribute *product*. Road_size is a description of the width of the road segment. For example, a highway segment is wider than an average street segment, allowing greater mobility for the land units using the highway segment. Using the road segments illustrated in Figure 14, a sample Roads relation appears in Table 6.

3.3.5 FEBA, Borders, Coasts, and Rivers. The entities *FEBA*, *Borders*, *Coasts*, and *Rivers* are all specializations (*ISA relationship*) of a hex side, and they are uniquely identified by their associated *neighbor_id* attribute (see Figure 3). All of these relations are graphically displayed as falling directly on a hex side.

The FEBA relation is a list of hex borders that designates the forward edge of the battle area line which separates one fighting force from another. The borders relation lists the boundaries between different countries, and the coast relation lists the boundary between land and bodies of water. The rivers relation has one attribute in addition to the *neighbor_id* identifier. The rivers relation includes the attribute *river_size* which describes the depth or size of the river segment located on the hex.

Table 7. The City Relation

city_id	*location*	name	urban	capital	population
CY010200	HX012315	DAYTON	2	NO	563000

3.3.6 The City Relation. Figure 3 shows the city entity as a target located on a hex. Cities can be used in a wargame to achieve several different effects. For example, a city can be used:

- to slow or extend troop movements.
- to prolong the amount of time required to capture a hex (from door-to-door fighting).
- as a source for logistical supplies.
- as a geographical landmark.
- as a counter-asset target.

The city entity from Figure 3 was translated directly into the *city* relation. The primary key of the city relation is the attribute *city_id.* In addition to the primary key, the city relation contains one foreign key, *location* and four descriptive attributes, *name, urban, capital,* and *population.*

The location attribute is an alias of the hex_id attribute of the hex relation. *Location* contains the hex_id identifier of the hex that the city is located in, and acts as a foreign key to the *hex* relation. The name attribute holds the name of the city. The urban attribute is a factor used to portray the physical dimension or size of a city. The capital attribute is descriptive field that specifies whether a city is a country capital. Finally, the population attribute is the quantity of people that inhabit the city. Given the sample city in Figure 14, a sample tuple in the city relation is shown in Table 7.

In this example, Dayton is located in hex HX012315, has a population of 563,000, and is uniquely identified by the city_id CY010200. Furthermore, it has an urban physical size value of two, and it is not the capital of its country.

3.3.7 The Weather and Cycle Relations. Figure 3 shows that every hex is located in a distinct weather zone, and each weather zone has its own weather. A weather zone attribute, *wz*, was added to the hex relation to model this relationship.

Table 8. The Weather Relation

wz	*day*	*wx_period*	forecast_good	forecast_fair	actual_wx
1	1	1	60	30	GD
2	1	1	20	50	POOR
3	1	1	100	0	GD
4	1	1	20	20	FAIR
1	1	2	50	30	FAIR
2	1	2	30	45	FAIR
3	1	2	100	0	GD
4	1	2	20	20	FAIR

Weather in the Saber theater-level wargame can take on values of *good, fair*, and *poor*. Good weather allows land units to have good visibility, uninhibited detection of enemy units, and unhindered movement during travel. A sample of the weather relation appears in Table 8.

The key to the weather relation is a combination of the *wz, day*, and *wx_period* attributes. The attribute *wz* is the weather zone, *day* is the game session day, and *wx_period* is the weather period, which is a multiple of the game period. The combination of these attributes allows weather to be controlled separately in each weather zone, with changes as frequent as the weather period changes.

The remaining three attributes are *forecast_good* (the percent chance probability of having *good* weather), *forecast_fair* (the percent chance probability of having *fair* weather), and *actual_wx* (the actual weather in the weather zone for the associated weather period). The first tuple in the relation shows a 60% of *good* weather, a 30% chance of *fair* weather, and by default, a 10% chance of *poor* weather. The actual weather can be determined by random number generator that produces numbers between 0 and 100, and comparing this number to the following chart.

test condition	actual weather is
random number $\leq$ forecast_good	GD
forecast_good $<$ random number $\leq$ forecast_good + forecast_fair	FAIR
random number $>$ forecast_good + forecast_fair	POOR

In addition to weather, darkness may also prohibit the flying of certain types of aircraft and prohibit the effective use of certain anti-aircraft systems. The *cycles* relation correlates the session periods with daytime or nighttime.

Table 9. The Cycle Relation

cycle	*period*
DAY	1
DAY	2
DAY	3
DAY	4
NIGHT	5
NIGHT	6
NIGHT	7
NIGHT	8

This sample *cycles* relation in Table 9 shows that session periods one through four all occur during daytime, while periods five through eight appear between dusk and dawn.

3.3.8 The Airbase and Depot Relations. The airbase and depot relations store information on airbases and depots. Depots are similar to airbases. However, combat missions cannot be flown from a depot. Two separate relations are used to store airbase and depot information, rather than one, as a matter of convenience for the Saber simulation software.

All bases in the Saber model have an identity, situational awareness, resources, and weapons (22). According to Mann, situation awareness of an airbase is the cognitive ability of a base to determine if it has been attacked or how much intelligence to report after being reconnoitered (22). The key to the airbase relation is the *airbase_id* attribute. The attributes *abbrev_designator* (abbreviated designator) and *full_designator* can also be used to uniquely identify an airbase. However, airbase_id is used as the foreign key in the *airbase_aircraft* and *airbase_weapons* relation to link these resources to an airbase.

The hex that the base is located in is the *location* attribute. The size of an airbase is stored in the *length* and *width* attributes. The *weather_minimum* attribute describes the worst weather condition that the base can endure and still be used to fly aircraft missions.

The *max_ramp_space* attribute stores the maximum ramp space that is available at the base to park aircraft. This value is used to limit the number of aircraft that can be located at a particular base. Each aircraft type has a ramp space factor. This aircraft ramp space factor multiplied the number of aircraft at the base determines the amount of ramp space that has been used by the airbase.

The base resources include POL (petroleum, oil and lubricants), ammunition, maintenance equipment, and spare parts. POL is stored in two attributes, *pol_hard_store*, which

Table 10. Weapon Specialization Relation Names

Weapons Specialization	Relation Name
Surface-To-Air	S2A_Weapons
Surface-To-Surface	S2S_Weapons
Air-To-Air	A2A_Weapons
Biological/Chemical	Chemical
Air-To-Ground	A2G_Weapons
Nuclear	Nuclear
Land Component	Land_Component_Type
Base_Component	Base_Component_Type
Radar	Radars

is the amount of POL in hardened storage, and *pol_soft_store*, which is all POL on the base not in hardened storage facilities. *Spare_parts* stores the amount of aircraft spare parts located on a base, and *shelters* is the number of hardened aircraft shelters the base has available. *Maint_personnel* is the quantity of maintenance personnel available to maintain aircraft returning from a mission. *EOD_Crews* and *RRR_Crews* are the number of explosive ordinance disposal and rapid runway repair personnel.

Depots differ from airbases in two primary ways; Depots do not have runways, and combat missions cannot be flown from a depot.

3.3.9 Weapons and the Weapons_Class Relation. The *weapons* entity is depicted in Figures 6 and 8. Table 3 shows that the weapon entity has been specialized as surface-to-air, surface-to-surface, air-to-air, air-to-ground, land component, base component, radar, biological, and chemical weapons. Each of these specializations were converted to a relation, as shown in Table 10.

Each weapon relation uses the *designation* attribute to uniquely identify weapons. Each relation also contains descriptive attributes specific to the type of weapon being modelled. For example, the *SAM_type* relation contains only attributes that specifically describe surface-to-air missiles, such as range, while the *chemical* relation has attributes distinctive to chemical and biological weapons, such as *lethality* and *persistence_time*.

Figure 8 shows that nuclear, chemical, air-to-air, and air-to-ground weapons are weapons that are associated with an airbase. Combining *airbase_id*, the primary key of the airbase relation, and *designation*, the primary key to the weapons relations, produces the airbase_weapons relation.

Table 11. Sample Weapons_Class Relation

designation	relation
AIM9L	A2A_Weapons
CM432	Chemical
SA9	S2A_Weapons

Figures 4 and 8 show the relationships between land units and weapons. The *radars, sam_type, ssm_type*, and *land_component* entities were converted to relations with *designation* as the primary key. The *unit_radars, unit_sam, unit_ssm*, and *unit_components* relations associate their respective entities to the land_unit entity by combining the designation attribute with *unit_id*, the primary key of the land_unit relation.

Figure 8 also shows that each weapon belongs to a unique weapons class. The weapons_class entity was converted to the *weapons_class* relation, with the designation attribute as the primary key. Table 11 is a sample of the weapons_class relation.

3.3.10 Aircraft Type. Figure 5 shows the *aircraft_type* entity. A relation of the same name was given to model this entity. The aircraft_type relation stores aircraft capability ratings, or numerical evaluations of an aircraft's effectiveness in performing various missions. The primary key to the aircraft_type relation is the designation attribute. Aircraft within the Saber model are instantiations of an aircraft_type. The designation for an aircraft is also used to determine the preferred weapons load (see Section 3.3.14).

As mentioned earlier, the aircraft_type relation contains numerical evaluations of an aircraft's potential capability to accomplish certain missions. The attribute *a2a_rating* represents the air-to-air dogfighting ability of an aircraft type, while *a2g_rating* portrays the air-to-ground surface strike ability of an aircraft. *Loiter_time* is the amount of time an aircraft can linger over a target, *radius* stands for normal combat radius, *max_speed* represents the maximum speed of an aircraft, and *min_runway* is the minimum runway length the aircraft type needs to take off or land.

In addition to these attributes, the aircraft_type relation contains, among others, descriptive attributes for an aircraft's capability to operate at night, and to operate in adverse weather. A full description of these attributes is given in Appendices A and B.

3.3.11 Runways, Airbase Aircraft, Airbase Weapons, and Cross Servicing. Figure 6 shows the relationship between an airbase, its runways, its assigned aircraft, the types of

Table 12. The Airbase_Aircraft and Airbase_Weapons Relations

AIRBASE_AIRCRAFT

airbase_id	*designation*	weapon_count
AB001234	F15A	24
AB001234	F15E	13
AB001234	FB111	55
AB001234	A10	17

AIRBASE_WEAPONS

airbase_id	*designation*	weapon_count
AB001234	AIM9L	175
AB001234	AIM7	102
AB001234	MK500	760
AB001234	ALCM	50

aircraft it can service, and its stockpile of weapons. The *airbase_id* attribute is the foreign key that is used to tie the *runways, cross_service, alternate_bases, airbase_aircraft,* and *airbase_weapons* relations to the airbase relation.

Figure 8 shows that nuclear, chemical, air-to-air, and air-to-ground weapons are weapons that are associated with an airbase. Combining *airbase_id*, the primary key of the airbase relation, and *designation*, the primary key to the weapons relations, produces the airbase_weapons relation. Similarly, combining *airbase_id* from the airbase relation and *designation* from the aircraft_type relation produces the airbase_aircraft relation.

The *airbase_aircraft* and *airbase_weapons* relations are equivalent in their composition, having the attributes *airbase_id, designation*, and *weapon_count. Designation* is the alphanumeric designation of the aircraft or weapon system, and *weapon_count* simply is the weapon quantity. Figure 14 depicts an airbase with three runways in hex HX012314. Given an airbase_id of AB001234, sample relations for the amount of aircraft and weapons at an airbase are depicted in Table 12. These two relations show that airbase AB001234 has 24 FB111 aircraft and 175 AIM9L missiles, along with a host of other resources.

Whereas the airbase_aircraft relation stores the quantity of aircraft at an airbase, the *cross_service* relation shows whether an aircraft can fly combat missions (C) from the airbase, be serviced (B) at the airbase, or neither (N). The *service_type* attribute replaces *weapon_count* in the cross_service relation. The cross_service relation appears in Table 13.

Table 13. The Cross_Service Relation

airbase_id	*designation*	service_type
AB001234	F15A	C
AB001234	F15E	C
AB001234	FB111	B
AB001234	A10	C

Table 14. The Runways Relation

airbase_id	*runway*	difficulty	current_length	max_length
AB001234	1	EXC	7500	10000
AB001234	2	GD	5000	5000
AB001234	3	POOR	12000	12000

The *runways* relation has five attributes: *airbase_id, runway, difficulty, current_length,* and *max_length. Runway* is the runway identifier for the base. The *difficulty* attribute is a measure of the hardness of the runway. A difficulty value of EXC (Excellent) can take a significant amount of bomb damage before it is rendered unusable, while a runway with a POOR difficulty might be rendered unusable after one bomb hit. Damage to a runway is measured by the runway's length. An undamaged runway has a *current_length* equivalent to the runway's normal length, which is stored in the *max_length* attribute. As a runway sustains bomb damage, the *current_length* is shortened. For an aircraft to use a runway, the runway must meet or exceed the minimum runway (*min_runway*) length needed by the aircraft. An airbase that has suffered significant damage to its runways is rendered unusable once the current_length of all of its runways have been shortened beyond the min_runway length point of the aircraft that are based at the airbase. A sample runways relation for the airbase depicted in Figure 14 is shown in Table 14. This relation reveals that this airbase has received bomb damage to runway number 1, having a current length equal to 75% of its original length.

The *alternate_bases* relation also uses *airbase_id* as its foreign key. Each airbase has associated with it a number of bases that have been designated as alternates. Aircraft returning from a mission that find the base they originated from unusable due to enemy air strikes will be directed to one of their alternate airbases. The alternate_bases relation contains two attributes, *airbase_id*, and *alternate_id.* The airbase_id is the identifier for the host airbase, and the alternate_id is the airbase_id of an alternate airfield. A sample

Table 15. The Alternate_Airbase Relation

airbase_id	*alternate_id*
AB001234	AB000001
AB001234	AB001342
AB000122	AB001234

Table 16. Saber Mission Matrix

Primary Missions	Secondary Missions					Targets	
	ESCORT	CAP	SEAD	EC	REFUEL	Strike	Area
Offensive Counter Air (OCA)	X		X	X	X	X	
Fighter Sweep (FS)			X	X	X		X
Combat Air Patrol (CAP)			X	X	X		X
Defensive Counter Air (DCA)							X
Air Interdiction (AI)	X		X	X	X	X	
Battlefield Air Interdiction (BAI)	X		X	X	X	X	
Close Air Support (CAS)		X	X	X	X	X	
Reconnaissance (RECCE)	X		X	X	X	X	X
SEAD	X			X	X	X	X
Electronic Combat (EC)	X		X	X	X	X	X
Command and Control (CC)	X		X		X		X
Nuclear (NUKE)	X		X	X	X	X	
Chemical (CHEM)	X		X	X	X	X	X

relation appears in Table 15. This relations shows that airbase AB001234 has two alternate airbases. Furthermore, this relation shows that airbase AB001234 is also the designated alternate airbase for the airbase with airbase_id AB000122.

3.3.12 Aircraft Missions, Aircraft Packages, Targets. Figure 5 illustrates the relationship between aircraft, aircraft packages, missions, and targets. The aircraft_mission and aircraft_package entities, and the targets relationship were converted into Saber relations, each including the common attribute *mission_id.*

The aircraft_mission relation stores information on aircraft missions. The primary key of the aircraft_mission relation is *mission_id.* Aircraft packages are formed to conduct aircraft missions. An aircraft package in the Saber model is composed of aircraft flying a primary mission and may include separate aircraft flying a number of secondary support missions. Aircraft package data is stored in the aircraft_package relation. The key to the aircraft_package relation is the mission identifier (mission_id), the aircraft type (designation) flying the mission, and the primary or secondary mission type of the aircraft (ac_mission). Each aircraft mission has a target. The target entity from Figure 5 is a generalization of other objects in the Saber model, such as a road or an airbase. The *targets* relation associates these targets with a particular mission. This relation has two attributes, mission_id and target_id, which is a union of the primary key of the aircraft_mission relation and the primary key of the target relation (Land_Unit, Airbase, Roads, etc.).

Table 17. The Aircraft_Mission, Aircraft_Package, and Targets Relations

AIRCRAFT_MISSION (*subset*)

mission_id	mission_type	class	rendezvous_hex	rqst_day on_target	rqst_prd on_targ	priority
MS000001	CAS	CONV	HX031226	2	3	1
MS000002	RECCE	CONV	HX042128	3	1	2

AIRCRAFT_PACKAGE

mission_id	*designation*	*ac_mission*	requested_ac
MS000001	A10A	PRIMARY	4
MS000001	F15E	ESCORT	2
MS000001	EF111	EC	1
MS000002	RF4R	PRIMARY	2
MS000002	KC135	REFUEL	1

TARGETS

mission_id	*target_id*
MS000001	AB022212
MS000002	HX010101
MS000002	HX010102
MS000002	HX010103

The primary Air Force missions modelled in Saber are shown in Table 16 along with the possible secondary missions that can accompany the primary mission. These mission types are defined in Mann (22). The primary mission type is stored in the *mission_type* attribute of the aircraft_mission relation. Furthermore, missions can be prioritized, with the mission priority value stored in the *priority* attribute.

All missions in the Saber model are either strike missions or area missions. Area missions target one or more hex locations. Strike missions target specific objects, such as a land unit, an airbase, or a bridge. The two far right columns in Table 16 show which missions are area missions, strike missions, or both.

The *class* attribute records whether a mission is conventional, biological, chemical, or nuclear in nature. The attributes *rqst_prd_on_target* and *rqst_day_on_target* are used to store the period and day the user has requested a mission to hit its target.

Depending on its mission, an aircraft package can either attack its target and immediately return home, or it can loiter over its target for an extended period of time. Aircraft packages flying DCA or CAP missions can loiter over their target. The loiter airhex location is stored in attribute *orbit_location*. For these aircraft missions that can loiter over

Table 18. The Valid_AC_Missions Relation

designation	*mission_type*
RF4R	RECCE
EF111	EC
KC135	REFUEL
F15A	OCA
F15A	FS
F15A	CAP
F15A	AI
F15A	BAI
F15A	SEAD

their target, the *rqst_return_period* and *rqst_return_day* attributes store the session period and day that the user wants the aircraft flying the mission to return to their home airbase.

Table 17 shows a sample *subset* of the aircraft_mission relation, a sample aircraft_package relation, and the targets relation. The aircraft_mission table reveals that mission MS000001 is a priority one, conventional, close air support mission, with aircraft that will rendezvous in airhex HX031226, and with a proposed strike at its target in period three of day two. Examining the aircraft_package relation discloses that the user has requested that this close air support (CAS) mission be flown using four A10A aircraft, with two F15E aircraft as escorts, and one EF111 flying in an electronic countermeasure role. Table 16 shows that CAS missions are strike missions, having a specific object as a target. The target of the mission is shown in the targets relation as an airbase with airbase_id AB022212.

Table 17 also shows that mission MS000002 is an area reconnaissance mission flown by two RF4R aircraft, with a KC135 available for refueling. The priority is two, and the area to be reconnoitered is three ground hex locations with hex_id identifiers of HX010101, HX010102, and HX010103.

Figure 5 shows that each aircraft type has associated valid mission types. This restriction is placed on the types of aircraft that can be used to conduct the *primary* aircraft mission. For example, aircraft designated as refuelers cannot fly the primary mission of close air support, and cargo aircraft are restricted from flying fighter sweep, electronic combat, or air interdiction missions. The valid_ac_missions relation of Figure 5 was converted into the Saber relation of the same name.

Table 18 gives sample values for the *valid_ac_missions* relation. The example data shows that RF4R aircraft are limited to a reconnaissance (RECCE) role, EF111 aircraft

Table 19. The Hardness Relation

target_type	hardness
AIRCRAFT	SOFT
HARD_STORE	HARD
LAND_UNIT	SOFT

are limited to electronic combat (EC) role, and KC135 aircraft can only perform in a refueling role. However, the table also shows that F15A aircraft can fly in different roles, such as offensive counter air or air interdiction.

3.3.13 Target Hardness. Figure 5 illustrates that every target has a individual *hardness* associated with it. The hardness entity was translated into the *hardness* relation.

The hardness relation has two attributes, *target_type*, and target *hardness*. Target_type is a description of the target. Target hardness can take on a value of *soft, medium* or hard. Soft targets are targets in the open, such as a land unit in the open desert. Hard targets are usually associated with underground or reinforced bunkers.

The sample relation given in Table 19 shows that aircraft and land units are soft targets, while HARD_STORE (hardened POL storage facility) is recorded as a hard target. Hard targets are more difficult to destroy than soft or medium targets, often requiring the use of specialized, high-accuracy, and high-explosive weapons. In the Saber model, both surface-to-surface and air-to-ground weapons have separate capabilities (probabilities) for destroying soft, medium, and hard targets.

Table 20. Weapons_Load Relation

load_id	*designation*	weapon_count
WL000001	NULL	0
WL000002	AIM9L	4
WL000002	AIM7	2
WL000002	GBU10	4
WL000003	M2000	6
WL000003	AGM65	4

3.3.14 Preferred Weapons Loads. Each aircraft flying a mission is equipped with a compliment of weapons known as a weapons load. Depending on the aircraft mission, a weapons load can contain conventional, biological, chemical, or nuclear weapons.

Table 20 is a sample of the weapons_load relation. This relation has three attributes, *load_id, designation* and *weapon_count.* The load_id attribute is used to collectively group weapons, the designation attribute is the designation of the weapon, and the weapon_count attribute is the quantity of the weapon.

Table 20 depicts three different weapons loads. Weapons load WL000001 is empty, or contains no weapons. Weapons load WL000002 consists of four AIM9L Sidewinder missiles and two AIM7 Sparrow missiles. Weapons load WL000003 incorporates six M2000 2000 lb. pound freefall bombs and four AGM65 Maverick air-to-surface missiles.

Figure 6 shows how a weapons load relates to aircraft flying an aircraft mission. Five items determine what weapons load an aircraft will be loaded with to fly a mission.

1. Mission class – conventional, biological, chemical, or nuclear.
2. Mission type – CAP, CAS, SEAD, RECCE, etc.
3. Weather (WX) at the target – good, fair, or poor.
4. Hardness of the target – soft, medium, or hard.
5. Aircraft designation – F15, Mig 27, KC135, etc.

Weapons loads are divided by mission class. Conventional weapons load are stored in the *PCL* (Preferred Conventional Load) relation, nuclear loads are stored in the *PNL* (Preferred Nuclear Load) relation, and both biological and chemical loads are stores in the *PBL* (Preferred Biological/Chemical Load) relation. All three of these relations are similar in their composition, having identical attributes.

Table 21 represents a sample PCL relation. This table shows that an A10A aircraft flying a CAS mission against a medium hard target in fair weather carries weapons load WL000003 (six M2000 2000 lb. free fall bombs and four AGM65 Maverick Missiles). Given good weather and a *soft* target, the table shows that EF111, RF4R, and KC135 aircraft carry no weapons.

Taken together, the relations in Tables 17, 20, and 21 are used to determine what weapons are used by aircraft flying a mission.

Table 21. PCL – Preferred Conventional Load Relation

wx	*designation*	*mission_type*	*hardness*	load_id
FAIR	A10A	CAS	MED	WL000003
FAIR	F15E	ESCORT	MED	WL000002
GD	EF111	EC	SOFT	WL000001
GD	RF4R	RECCE	SOFT	WL000001
GD	KC135	REFUEL	SOFT	WL000001

3.3.15 The Staging Base Relation. Staging bases are the area of entry for new aircraft, and are *located* in an area exempt from hostile attacks. (22) Figure 6 depicts the *staging base* relation associating an airbase, aircraft, and days. This relationship was converted into the *staging_base* relation shown with example values in Table 22.

The staging_base relation has four attributes, *day, designation, force*, and *quantity.* The *day* attribute signifies the game session day that the aircraft are available for entry into the simulation, *designation* is the alphanumeric designation of the aircraft, *force* is the color designator of the destination armed forces (RED, BLUE, etc.), and *quantity* is the number of aircraft available for entry.

The values in Table 22 show 22 F15A aircraft are available for entry to the blue player on day 1, while only 14 are available for entry to the red player. The last tuple shows 7 SU25D aircraft are available for entry on day 3 to the red player.

3.3.16 Land Units. Figure 4 shows the *land unit* entity and its relationships with other objects in the Saber model. The land unit entity was directly converted to the *land_unit* relation, with *unit_id* as the primary key.

Figure 4 shows that a land unit is located in a hex. To model this 1:1 relationship, the *location* attribute was added to the land_unit relation to store the hex_id of the hex that the land unit is located in. Figure 4 also shows that a land unit can be the parent of

Table 22. The Staging_Base Relation

day	*designation*	*force*	quantity
1	F15A	BLUE	22
1	F15A	RED	14
3	SU25D	RED	7

another land unit, and that each land unit is a member of another land unit, known as a corps. Again, these relationships are 1:1, allowing an attribute to be added to land_unit relation to model the relationship. The *parent_unit* attribute is used to store the unit_id of the parent land unit, or the next land unit up in the chain of command, and the *corps_id* attribute stores the unit_id of the corps that the unit is part of.

A land unit can support multiple land units, as shown by the *unit supports* relation in Figure 4. This relationship was transformed into the *unit_supports* relation. The unit_supports relation has three attributes, *unit_id, unit_supported*, and *percent*. Unit_id is the identifier of the supporting unit. *Unit_supported_id* is an alias for unit_id, and is the identifier of the unit receiving support. *Percent* is the amount of support a unit provides expressed as a percentage. Table 23 is sample of the unit_supports relation. This examples shows that land unit LU000001 provides 50% percent support to units LU000002 and LU000003, whereas LU000003 provides 100% support to land unit LU000004.

The *land_unit* relation stores all information pertinent to ground units. In addition to the primary key, unit_id, each tuple in the land_unit relation can be uniquely identified by the attributes *abbrev_designator* (abbreviated designator), and *full_designator*.

Divisions are the basic land unit of the Saber wargame. Figure 15 is an example structure of the US Army 3rd Corps. This structure shows the 3rd Corps is composed of the 1st Calvary Division and the 35th Mechanized Division. The 1st Calvary Division is an aggregation of the 101st Air Assault Brigade and the 18 Infantry Brigade.

In this example, The 3rd Corps is the parent unit of the 1st Calvary Division and the 35th Mechanized Division. The attribute *unit_type* is an abbreviation for the unit's structure (armored division, infantry brigade, calvary). A *subset* of the land_unit relation showing the attributes described previously appears in Table 24.

The land_unit relation contains many other attributes in addition to those already mentioned. The recent Persian Gulf conflict demonstrated that certain units, such as the Iraqi Republican Guard, are better equipped and better trained than other units.

Table 23. Unit_Supports Relation

unit_id	*unit_supported_id*	percent
LU000001	LU000002	50.0
LU000001	LU000003	50.0
LU000003	LU000004	100.0

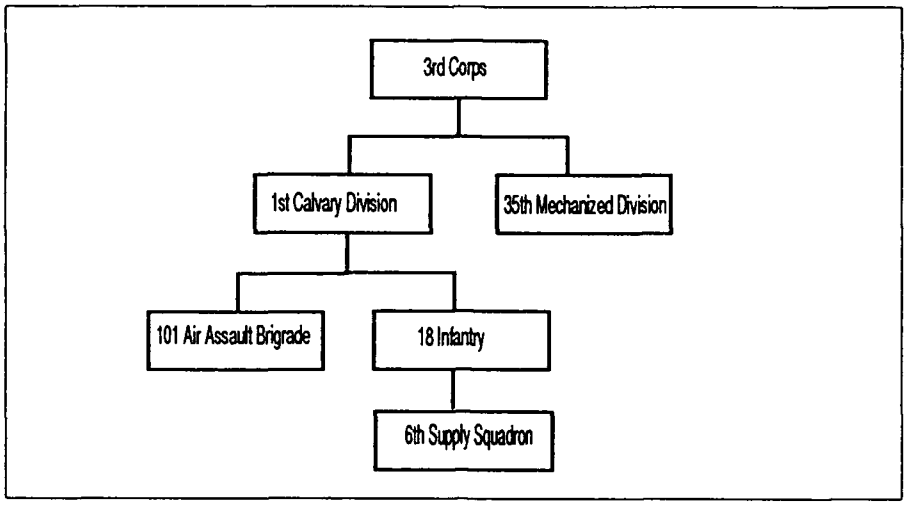

Figure 15. Land Unit Hierarchy Chart

Table 24. Subset of the Land Unit Relation

unit_id	country	corps_id	parent_unit	unit_type	abbrev_designator	full_designator
LU000001	US	LU000001	LU000001	INF	3RD_CORP	3RD CORPS
LU000002	US	LU000001	LU000001	CALDV	1CALVDIV	1ST CALVARY DIVISION
LU000003	US	LU000001	LU000001	ARMDV	35MECDIV	35TH MECHANIZED DIVISION
LU000004	US	LU000001	LU000002	AVN	101AASLT	101 AIR ASSAULT BRIGADE
LU000005	US	LU000001	LU000002	INFBR	18INFBRG	18 INFANTRY BRIGADE
LU000006	US	LU000001	LU000005	INFBR	6SUPPSQ	6TH SUPPLY SQUADRON

Troop_quality allows land units to have varying levels of skill or will to fight. The *combat_power* of a land unit is computed from the weapons it possesses. This value is used in conflict resolution. Closely associated with comat_power is the *breakpoint* attribute, which basically is a "chicken factor" index. A land_unit will automatically begin retreating when its combat_power deteriorates below its breakpoint value.

The *intel_filter* and *intel_index* attributes can be used to determine the amount of reliable intelligence data that a unit can report or receive. The land_unit relation contains many other attributes, all of which are described in Appendices A and B.

Table 25. Sample Move Relation

order_id	unit_id	day	period	target_id	army_mission_type
OR000001	LU000002	1	2	HX010102	ATK
OR000002	LU000003	1	2	HX010103	ATK
OR000003	LU000003	2	1	LU000001	MOVE
OR000004	LU000006	2	2	LU000001	MOVE
OR000005	LU000006	3	1	AB001234	MOVE

3.3.17 Land Unit Movement. Figure 4 shows that a land unit can move every *day* and *period* from its current location to the location of an airbase, depot, hex, or other land unit. The *move* Entity was translated into two similar relations, *move* and *move_lnlt*. These relations inherit the primary keys of the land unit, destination, and cycle entities. The move relation contains land movement orders to be executed at the day and time specified. The move_lnlt (leave no later than) relation contains orders that can override orders in the move relation. This feature is useful in redirecting land units that get *bogged* down performing their primary mission movements.

The destination of a land movement can be the location of an airbase, depot, land unit, or ground hex. Given an airbase or depot as a destination, a land unit travels to the hex position that the airbase or depot is located on. Given a target land unit as a destination, the moving land unit should attempt to follow the movement of the target land unit. A sample move relation is shown in Table 25.

The data in Table 25 defines five separate land movements. Each movement is given a unique order identifier, *order id*, which serves as the primary key for the move and move_lnlt relations. The first tuple, or movement order (OR000001), in Table 25 states that LU000002 (1st Calvary Division in these examples) should attempt to attack (ATK) hex location HX010102 on day 1, period 2. During this same time frame, LU000003 (35th Mechanized Division) should attack the adjacent hex, HX010103. Order OR000003 states that on day 2, period 3, the 35th Mechanized Division should cease attacks, and move to the location currently occupied by the 3rd Corps, LU000001. Order OR000004 states that the 6th Supply Squadron, LU000006, should also move to join with the 3rd Corps, LU000001. The final tuple instructs the 6th Supply Squadron to travel to airbase AB001234.

3.3.18 Supply Trains and Supply Movement. Figure 4 depicts the *supply train* entity as a specialization of a land unit that moves supplies (aircraft spare parts, ammunition,

Table 26. Supply_Movement Relation

order_id	*designation*	deliver_qty
OR000004	POL	400
OR000004	HW	75
OR000005	SPARES	527

hardware, and POL) from its current location to a destination. The destination can be an airbase, a depot, or another land unit.

A supply train land unit retains all the attributes of a regular land unit, and adds a few more. However, the *supply_train* relation contains only *unit_id*, the primary key of the land_unit relation, and attributes that pertain to the movement of supplies. One of these attributes is *total_capacity*, which defines the maximum cargo capacity of the supply train. Other attributes define the amount of supplies that supply train is carrying.

The *supply movement* relation pictured in Figure 4 was transformed into a relation table of the same name. This relation contains the quantity and list of supplies to be delivered to the destination. Table 26 shows the supply_movement relation with sample data.

The key to the supply_movement relation is a combination of the order_id and designation attributes. The order_id attribute is the link that connects the supplies being moved to the supply train and its destination. The order_id attribute is used to match related information between the move relation, Table 25, and the supply_movement relation, Table 26. Entering both relations where the order_id is OR000004 reveals that land unit LU000006 (6th Supply Squadron) will attempt to deliver 400 units of POL and 75 units of HW (hardware) to LU000001 (3rd Corps). The last tuple in both relations indicates that the 6th Supply Squadron will endeavor to deliver 527 units of SPARES to airbase AB001234.

3.3.19 Satellites. The *satellites* entity of Figure 3 was translated directly into the *satellites* relation. *Satellite_id* is the primary key to the satellites relation. Every satellite in the Saber model is individually tracked. The satellites relation stores primarily descriptive information on a satellite, such as satellite type, orbit type, and direction of movement. All satellites are located in air hex level seven.

3.4 Database Uploading and Downloading

An issue surrounding the design of the Saber theater level wargame was hardware portability. A goal of the implementation program was to allow Saber to be executed on as many different hardware platforms as possible by not tieing it to any specific application program. Therefore, Saber uses the Oracle RDBMS as a repository of data only. Saber operates totally on data stored in ASCII flat files. This section describes the design and implementation of the programs that download data from Oracle to ASCII flat files, and from ASCII flat files to the Oracle RDBMS.

3.4.1 ASCII Flat File Format. The structure of Saber ASCII data files is straightforward, and is in format that resembles the relations. Columns represent attributes. Every tuple is a complete record in a corresponding relation, with each tuple placed on its own line, separated from other tuples in the relation by a carriage return. Attributes in the Saber DBMS are defined as one of three data types: character string, integer, or decimal (floating point). All character string data entries are in uppercase letters only. Appendix B lists each attribute data type and column width. Attributes that are characters strings are preceded by one blank space, while integer and decimal attributes are preceded by two blank spaces. The second blank space that proceeds numeric values is reserved by the Oracle DBMS for a minus (−) sign for negative values. However, all numeric values in the Saber DBMS are non-negative, causing a second blank to be output before each numeric value.

All numeric values, whether integer or decimal, are formatted right-justified, with leading zeros displayed. The column width of an attribute of type integer can vary from one to eight digits. All decimal-type attributes are formatted with a column width of 10 characters. These 10 characters are composed of 5 digits with leading zeros followed by the decimal point followed by 4 significant digits with trailing zeros.

In addition to the data, each ASCII dump file contains two header lines. The first header line contains the name of the file. The second line is used for column headings. The column headings are the first characters of the attribute name up to the length of column width. Column headings longer than the formatted column width are truncated to the length of the column width. For example, the *designation* attribute has a column width of 5 characters, so its column heading in a dump file would be truncated to *desig*.

Table 27. A2A_Weapons Relation and Attribute Format

A2A_Weapons Relation

designation	force	full_designator	range	sspk
AIM7	BLUE	AIM-7 SPARROW A2A MISSILE	00000025	00000.7500
AIM9L	BLUE	AIM-9L SIDEWINDER A2A MISSILE	00000050	00000.9000

A2A_Weapons Attributes

attribute	format(length)
designation	CHARACTER(5)
force	CHARACTER(7)
full_designator	CHARACTER(30)
range	INTEGER(8)
sspk	DECIMAL(5.4)

An example of the flat file format is given here using the A2A_Weapons relation. Table 27 shows a sample of the A2A_Weapons relation, alogn with its attributes as defined in Appendix A.

The sample values shown in Figure 27 would produce an ASCII dump of

```
a2a_weapons.dat
desig  force     full_designator                  range      sspk
AIM7   BLUE      AIM-7 SPARROW A2A MISSILE        00000025   00000.7500
AIM9L␣BLUE   ␣AIM-9L SIDEWINDER A2A MISSILE  ␣␣00000050␣␣00000.9000
  5      7                30 characters            8 digits     10
```

where ␣ represents a blank space between data values.

3.4.2 Downloading Oracle Relations to ASCII. Data stored in Oracle relations are downloaded using Oracle Structured Query Language (SQL) commands. Figure 16 shows the code required to download the A2A_WEAPONS relation. This code, as well as code for every Saber relation, was automatically generated by a program that referenced values in the Saber data dictionary.

The first line designates the filename to which the data will be dumped. The lines that begin with the word COLUMN are used to format the data and define column headings. The actual SQL commands used to dump data from Oracle are

```
SELECT *
FROM <RELATION NAME>
```

```
SPOOL a2a_weapons.two
COLUMN designation HEADING desig FORMAT A5
COLUMN force HEADING force FORMAT A7
COLUMN full_designator HEADING full_designator FORMAT A30
COLUMN range HEADING range FORMAT 09999999
COLUMN sspk HEADING sspk FORMAT 09999.9999
SET SPACE 1
SET UNDERLINE OFF
SET TERM OFF
SET PAGESIZE 7000
SET LINESIZE 71
SELECT *
FROM A2A_WEAPONS;
SPOOL OFF
SET TERM ON
EXIT
```

Figure 16. SQL*Plus Download Code for A2A_Weapons Relation

which selects every attribute and tuple in the relation. The remaining commands in Figure 16 are used in formatting the dump files, and are fully explained and documented in (4, 5).

*3.4.3 Upioading ASCII Files into Oracle with SQL*Loader.* Two methods for uploading ASCII files into Oracle were looked at for this project. The first was to write an input program in Ada using the Oracle Pro*Ada precompiler program (17). The second was to use Oracle SQL*Loader (24), which is simply a tool for loading data in external files into Oracle database relations.

The first approach had several disadvantages. First a large Ada program would be required that matched every column in each flat file to its corresponding relation and attribute in Oracle. Another disadvantage would occur in maintaining the database. Every time a change to the Saber DBMS would occur, this program would have to be rewritten, recompiled, and tested for accuracy. SQL*Loader was chosen because it was fast, simple to use, and it avoided the problems associated with using Pro*Ada.

SQL*Loader is a tool for moving data from external files into relations in an ORACLE database. It has many of the same features as the DB2 Load Utility from IBM Corporation. Also included are several other features that extend its power and versatility above the DB2 Load Utility. During its execution, SQL*Loader produces a detailed *log file* with

```
---
---  a2a_weapons.ctl     Upload File
---
LOAD DATA
INFILE /saber/dat/a2a_weapons.dat
INTO TABLE A2A_WEAPONS
(designation          POSITION(01:05) CHAR,
 force                POSITION(07:13) CHAR,
 full_designator      POSITION(15:44) CHAR,
 range                POSITION(47:54) INTEGER EXTERNAL,
 sspk                 POSITION(57:66) DECIMAL EXTERNAL)
```

Figure 17. Sample Control File for A2A_Weapons Relation

statistics about the uploaded data, a *bad file* (records rejected because of incorrect data), and a *discard file* (record that did not meet the upload selection criteria). These three files are particularly useful in pinpointing any anomalies present in the data. (24)

SQL*Loader uses as input a file called the *control file*, which contains a description of the data to be loaded. The control file describes:

- the names of the data files
- the format of the data files
- the data fields in those files
- how to load the data into relations (which relations and columns should be loaded).

Each relation uses its own control file. The control files for the Saber DBMS were automatically generated from a program that referenced the Saber data dictionary. A change in a relation definition merely requires the control file generation program to be re-executed to produce new and accurate upload control files. Figure 17 shows a sample SQL*Loader control file for the a2a_weapons relation. SQL*Loader is *not* case-sensitive. The first three lines are comments. This example shows the full path name of the a2a_weapons data file as the source file, and specifies that the data should be loaded into the Oracle a2a_weapons relation. To use SQL*Loader, the relations to receive the data must already exist in an Oracle database. These relations may contain data, or they may be empty.

The attributes of the relation are listed between matching parenthesis. The POSITION keyword is followed by the attributes starting and ending column number. These

column specifications are enclosed in another set of parenthesis. For this example, the ASCII data file has the attribute *designation* in positions 1–4. The full_designator attribute starts in column 15 and ends in column 44.

Files are uploaded using the following command:

```
sqlload userid/password filename
```

where `filename` is the name of the control file. Saber DBMS control files are named after their respective relation name, followed by a ".ctl" extension. A batch file containing a sqlload statement for each relation can be used to collectively upload all flat files at one time.

Before the data can be uploaded into Oracle, the first two header lines from the data file must be stripped off. The two header lines are removed using the unix stream editor *sed* (23). Appendix C contains the batch file used to upload ASCII files into Oracle.

3.5 Database Verification

Verification and validation of data within a wargaming simulation is an area of critical importance. For a simulation to be realistic, it must mimic actual scenarios with some degree of precision. Regression tests using historical data are often used to fine tune the accuracy of a data model. However, tweaking of numbers within a system can lead to confusion if changes in data values are not properly documented.

Validation questions that often arise with current wargames are along the lines of:

- Where did these numeric values come from?
- What was used to calculate a unit's firepower or combat power?
- Why is one weapon system rated better than another?

The very nature of simulations, coupled with speed and space constraints, can often lead to data aggregation. However, to properly validate a model, the component values of aggregated data must remain distinct. For example, a land unit firepower score of 255.123 provides little information to someone validating a wargame model. However, computing a firepower score of 255.123 from a *given* formula that took as inputs, 45 M1 tanks, 23 armored personnel carriers, 13 105mm self propelled howitzers, and 4 Phoenix surface-to-air missile batteries, provides a substantially greater amount of information than a simple raw score. Furthermore, providing descriptive characteristics of each individual weapon

Table 28. Surface-to-Surface Missile Relation

designation	class	lethal_area	cep	pk_hard	pk_med	pk_soft	min_range	max_range
SCUD	CONV	20	5.25	0.20	0.50	0.75	123	1234

can simplify the verification and validation process. The Saber DBMS design is unique among existing wargames in that all firepower scores can be computed directly from the amount and quality of weapons that an army possesses.

Individual characteristics of every major weapon system can be modelled in the Saber DBMS. Where possible, individual characteristics of weapons systems were kept distinct and not aggregated into an overall capability rating. A subset of the surface-to-surface (S2S) missiles relation is shown in Table 28. The single tuple shows sample data for a *scud* missile. Rather than giving the missile a lump sum capability rating, the characteristics of the missile is divided into multiple components. The missile's lethal area, circular error of probability (cep), and the probability of destroying hard, medium, and soft targets are stored in the Saber DBMS. Furthermore, both the minimum and maximum effective range of the missile are also stored. The overall capability of the weapon is a combination of the individual properties. A similar breakdown occurs for each weapon type stored in the Saber DBMS.

Although subjectivity in number values cannot be eliminated from a simulation, proper documentation of the origin of the numbers used within a simulation is a necessity for program validation and verification. Where possible, numeric capability ratings for weapons systems were provided by Dunnigan in (8). Dunnigan is an expert acknowledged by military circles in the wargaming arena. For example, the minimum and maximum range of surface-to-air missiles were listed in (8). Jane's Information Group, producers of the familiar "Jane's All the World's Aircraft," was an alternative source of weapon capabilities, to include preferred conventional loads for aircraft. (3, 35, 36). Additional weapon capabilities were also taken from (15, 18).

3.6 Summary

This chapter described the design and implementation of the Saber DBMS. The system was designed to ease validation and verification of the overall simulation model.

Entity-Relationship diagrams of the Saber model were constructed, iteratively refined, and then decomposed into relations. Normalization of relations was accomplished to BCNF level.

The Saber DBMS uses Oracle as a data repository. Data stored in Oracle relations are downloaded into flat ASCII files using a combination of Structured Query Language statements and unix stream editing utilities. Data is uploaded from flat ASCII files via the Oracle SQL*Loader utility.

The design of the Saber DBMS is unique from other similar applications in that individual characteristics of individual weapon types are stored. These component values are then aggregated to combine firepower and combat power ratings. This system simplifies data verification and validation, and may prove to be beneficial in fine-tuning the overall simulation.

IV. Saber User Interface Implementation

4.1 Overview

This chapter is a description of the unique, original design of the Saber graphical user-interface (GUI), and its implementation. The chapter begins with background information on the Saber interface, which is then followed by principles used in the design and implementation of the Saber interface. The next section presents a brief description of the user interface design. The third section is a synopsis of the four areas of user input defined by Mann (22). This chapter ends with a summary of the user interface design and implementation.

The purpose of the user interface is to provide a human interface to the Saber computer simulation program by applying computer graphics techniques. These graphical techniques, often referred to as a visual interface, have found widespread applications in man-machine interaction.

The viability of applying a graphical user interface to the Saber is based upon three factors:

1. The inexperienced or casual user of such a complex application as Saber does not have or maintain the necessary skills to efficiently utilize the application (21).
2. Military workloads and complexity of computer hardware and wargaming systems often preclude familiarity with system interfaces (34).
3. The progress and proliferation of high order, user interface programming languages have promoted the use of GUIs, and have reduced the level of effort required to produce sufficient and suitable interfaces tailored to specific applications.

New users to wargame simulations are inundated with a variety of obstacles, including unfamiliar hardware and cryptic command structures, as well as a wide variety of wargaming software systems. In many cases, in-depth training is required before a wargaming session can commence, which consumes valuable time, resources, and money (34). The Saber graphical user interface was designed with the goals of allowing fast, easy data entry for experienced users, without sacrificing user-friendliness for new and inexperienced users.

The design goals of the Saber graphical user interface were:

- Fast, easy data entry for experienced users, without sacrificing user-friendliness for new and inexperienced users.
- Minimize user training requirements through the use of standardized input screens based on a common template.
- Provide an interface that requires minimal use of external documentation.
- Recognition of information, not recall, is all that is required to properly utilize the interface.
- Enjoyment in using the system.

4.2 Methodology

The technology to support graphical interfaces has advanced to the point where most users have come to expect to be able to sit down at a computer and properly execute a software program with minimal or no references to program documentation. The mouse, keyboard, high-resolution monitor, and printer are the common elements in microcomputing that are utilized to enter and extract data from computer systems. Users no longer are satisfied with traditional direct command entry or menu selection by keyboard, but prefer to *point* to a graphically depicted list of possible choices, and click a mouse for selection.

Apple Computer has developed two helpful sets of principles for the developers of user interface applications (34). These principles were based on extensive research with the purpose of assisting developers in generating user-friendly interfaces. The following general design principles were used in the design and implementation of the Saber user interface:

1. *Metaphors from the real world.* Plain and concrete metaphors from the real world were used, allowing users to apply their expectations to the computer environment. Visual effects to support the metaphor were used wherever possible. Most computer users are not experts, but have direct experience in their immediate world. Using familiar concepts makes users feel comfortable. Figure 18 is a sample list of icons that can be used to represent four areas of player input in the Saber model.
2. *Direct manipulation.* Direct manipulation was used to give users a sense of control over the activities of the computer. Direct manipulation is based on the fact that people exert physical actions that result in physical feedback. Therefore, moving the

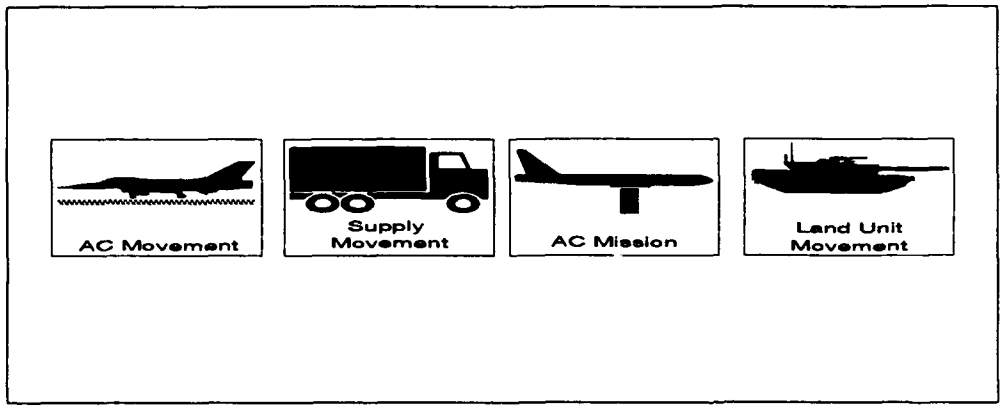

Figure 18. Sample User Input Icons

mouse results in a corresponding movements of the cursor or pointer, and clicking on icons or buttons results in associated actions.

3. *See-and-point.* All possible alternatives were presented on the screen to the user. This allows the user to see-and-point, rather than remember-and-type. Recognition, not recall, was a fundamental goal in the design of the interface. There is no need for the user to remember what the computer already knows. This also removes the burden of learning and recalling cryptic or complex command structures, allowing the user to concentrate on the actual task of entering wargaming data. Recognition, rather than recall is all that is required to successfully operate the Saber GUI.

4. *Consistency.* Each user interface screen is consistent in content, layout, and operation. Once a user is accustomed to entering data on one input screen, the same skills can be used to enter dissimilar data on other input screens. Similar buttons on different areas of the user interface behave in a similar fashion, leaving no surprises for the user.

5. *Forgiveness.* Even proficient and experienced users make mistakes. The Saber GUI was designed to be as forgiving as possible when mistakes occur. Provided documentation is often bypassed by users, which directly leads to a form of exploration. Saber users can learn by doing. To support this, naive or inattentive users are provided warnings before making unrecoverable mistakes.

6. *Feedback and Dialogue.* A goal of the Saber interface design was to keep the user informed. Feedback to user input is immediate and clear through the use of *command*

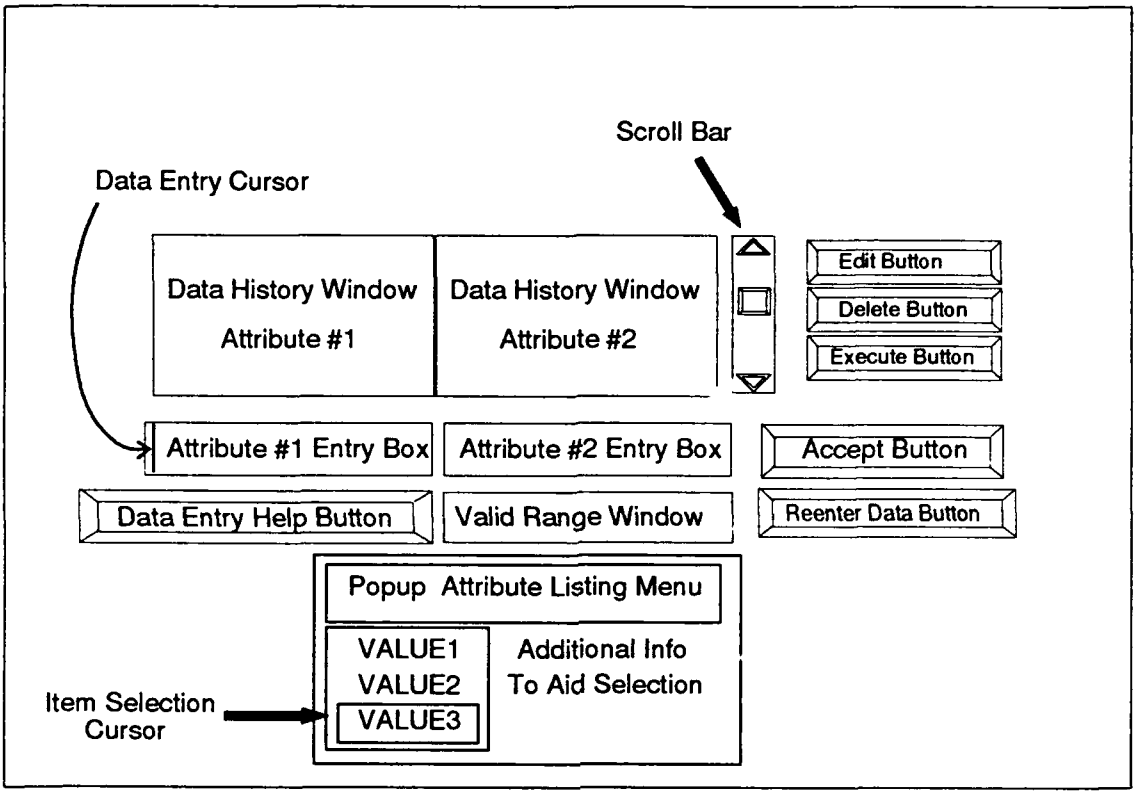

Figure 19. User Interface Template

history windows, warning message windows, and error message windows. Data entered by the user is echoed to the user, allowing the user to be constantly aware of the progress of operations. If operations cannot be completed, a brief, direct explanation is given to the user.

7. *Perceived stability.* Users feel comfortable in an environment that remains familiar and understandable, rather than one that changes randomly. Saber provides a sense of stability through consistency, and by maintaining a small number of objects and actions, each having a clear purpose.

8. *Aesthetic integrity.* A visually confusing or unattractive display detracts from the effectiveness of human-computer interactions. A design target of the Saber GUI was to make similar items appear similar, and different items to appear different. Furthermore, users have a limited ability to control the appearance and location of input screens.

4.3 Saber User Interface Design

The Saber data input interface was designed for users having multiple levels of expertise. Fast direct input is available for proficient and experienced users in a format similar to entry forms supplied by common data base management applications. Varying levels of (see-and-point) input selection also is available for beginning and novice users.

Figure 19 shows the template used in the design of Saber data input screens. The use of a single template for all input screens allows consistency and familiarity to be programmed into the interface. The skills necessary to adequately operate on one data input screen can be applied to operate all data input screens. An additional goal of the Saber GUI was to use keyboard keys in a manner consistent with their use in word processing applications. The <Backspace> and <Del> key can be used to delete unwanted characters, and the arrow keys can be used for cursor movement.

Each data input screen appears in its own window and is activated by selecting a controlling icon, such as those shown in Figure 18. This property provides flexibility to the Saber interface by allowing a user to provide input to multiple areas of the wargame concurrently, with each area of user input in its own window.

4.3.1 Data Input. A DBMS entry forms usually consists of a fill-in-the-blanks template on the computer screen that allows fast input of data items through direct keyboard entry. The middle of Figure 19 resembles a DBMS data entry form. The template requires the user to enter two different data items. The two fill-in-the-blanks input fields, *attribute #1 entry box,* and *attribute #2 entry box*, are shown in the center of the figure. Upon entering a data entry window, the user is automatically placed the attribute #1 entry box, although the user can choose the input field they want to type into by pointing to a field, and then clicking the select button on the mouse. An I-shaped data entry cursor blinks in the box to mark the typing position. Characters can be typed directly from the keyboard into the attribute entry box. Hitting the <Return> key enters the information into the computer, and moves the cursor to the next attribute input field. This method allows familiar data to be entered into the computer quickly, as they would if they were being input in a DBMS application.

4.3.2 Help Facilities. Immediately below the input field for attribute #1 is a *data entry help button* designed for new and inexperienced users. Selecting the help button provides a pop-up menu which indexes alternative value selection options. Values can

be selected from a list of all the available values with the keyboard or mouse, and their selection will automatically be entered in the attribute input field. For example, selecting the data entry help button in Figure 19 produces a pop-up attribute list of three values that attribute #1 can assume.

In addition to a listing of the available values that an attribute can assume, the values of certain attributes can be displayed graphically in a separate window. The user selects the value by clicking the mouse over the symbol that represents the desired data value. The purpose behind listing all available values is to place an emphasis on recognition, and not recollection of information. The interface is designed to aid the user in any way possible, permitting the user to focus on the wargame application.

4.3.3 Feedback, Dialogue, and Warning Messages. Several events occur once an item is entered into an input field:

1. Error Checking – All items entered are immediately verified as to their validity. Users are notified of input errors, and the I-shaped cursor is once again placed in the input field.

2. Error Correction – All items entered are automatically converted to uppercase. Furthermore, any illegal characters that could not possibly be part of a valid input string, such as a space, ampersand, or apostrophe, are automatically removed by the interface. The modified input string is then checked for validity against a list of all possible values.

   Figure 20 shows valid input strings for a text input field designed to accept airbase identifier input. The input field in Figure 20 will accept either the abbreviated designator, *abbrev_designator*, or some form of the *airbase_id* attribute. In this example, the abbrev_designator has a value of *TAEGU* and the airbase_id attribute has a value of *AB000800*. Each of the entries in Figure 20 are automatically corrected by the user interface without an error message being generated. This allows the user to continue typing input without interruption and without having to delete illegal characters. Figure 20 also shows sample input strings accepted for aircraft designation entries.

   A modified input string without invalid characters that does not match any valid value can be input to a spell checking routine to further assist the user. For example, an input of *Eegle* would automatically be corrected to *EAGLE* without generating an error message, and without requiring the user to edit the input data. These forms of error correction maximize the rate of data entry from the keyboard.

AB000800	F15A
800	f15a
AB800	f,'15a
gNXv 800	Eagle
⊔8⊔⊔00'	Ea g l e;
&%8*⊔0 d0	
taeGU	
TAEGU	

Figure 20. Valid Entries for Airbase Identification and Aircraft Designation.

3. Input History – Once a valid input has been entered into an input field, the input is echoed in the data history window above the input field. This provides immediate feedback, notifying the user of valid input, and allowing the user to trace the history of data properly entered into the computer system. The Saber data history window is superior to DBMS form entry in that all the data previously entered into the computer is readily visible for confirmation, whereas DBMS form entry usually *blanks out* all the input fields when a record of information is entered.
4. Cursor Movement – Entry of valid data item moves the I-shaped data entry cursor into the next input field. This allows data to be entered quickly and efficiently without unnecessary cursor movements.

After the last data input field has been entered, the cursor moves to the *accept* button located to the right of last input field. Clicking the accept button (or hitting the <Return> Key) signifies to the computer that user is satisfied with the text as entered in the input fields. The *Cancel* button allows the user to edit data in the attribute input fields, placing the I-shaped cursor back in the left-most input field.

Warning and error messages are an integral component of the Saber user interface, and appear in pop-up windows as required to notify users of a particular situation. Figure 21 depicts a sample of a warning dialogue window. Informative messages appear in the top portion of the window, and confirmation, cancel, and help selections appear in the lower half of the window. Warning and error dialogue windows provide immediate and clear feedback, which achieves the goal of keeping the user informed.

4.3.4 Forgiveness. To the right of the scroll bar is a menu that allows users to update data previously saved in the data history window. Data entered into the data

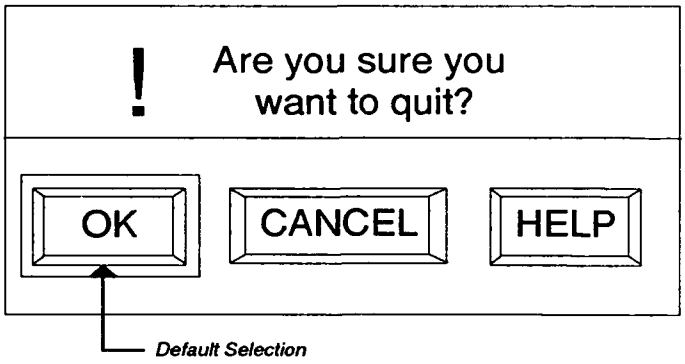

Figure 21. Sample Warning Dialogue Window

history windows does not immediately affect the simulation, but is stored separately until the user selects the *Execute* option. Selecting the *Execute* option results in all data entered to be executed and applied to the simulation. The scroll bar can be used to highlight a particular tuple of entered information for update. Once a row of data has been selected, the *Edit* option permits users to revise the data. Similarly, the *Delete* option enables users to delete a tuple of data, after verification that this what the user actually intends to do. These options provide maximum flexibility in allowing users to recover from input errors.

4.3.5 Error Prevention. The valid values of certain attributes often depend on the values of other attributes previously entered. Choices that have become invalid or unavailable are greyed out, and set insensitive to both keyboard and mouse input. This method is used to prevent user errors.

4.4 Saber User Interface Implementation – User Input

The Saber model requires four areas of user input: aircraft movement, land unit instructions, transportation of supplies, and aircraft missions. A full description of these input areas can be found in Mann (22). This section illustrates how data for these four areas are incorporated into the Saber model.

4.4.1 Aircraft Movement. Aircraft movement is the deployment of aircraft from one airbase to another airbase within the theater of operations. Aircraft movement inputs

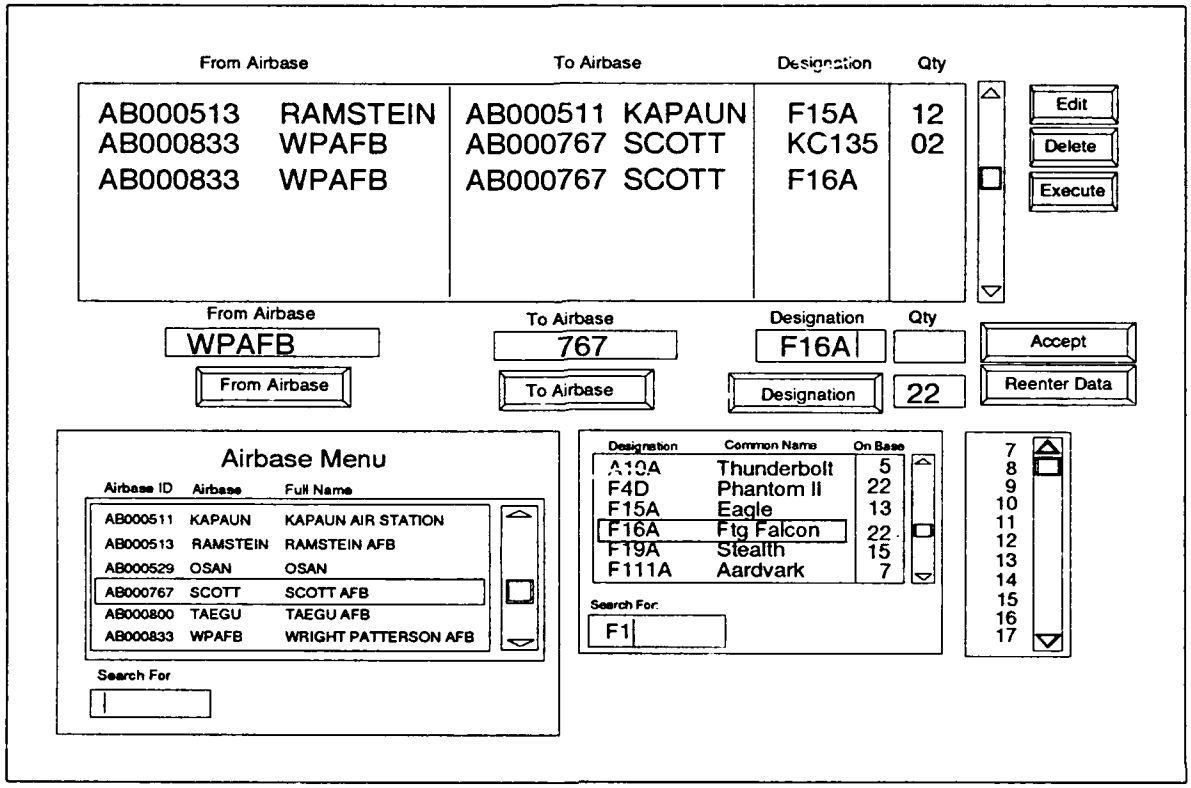

Figure 22. Aircraft Movement Data Entry Template

are provided by users on a daily basis, and are carried out instantaneously, before the next simulation period is executed. Therefore, they are not stored in the Saber DBMS.

The interface screen for aircraft movement is shown in Figure 22. This input screen is based on the user interface template shown in Figure 19. The movement of aircraft requires four separate data entries, the losing airbase, the gaining airbase, the aircraft designation, and the quantity of aircraft to be moved.

The proceses for entering data to identify both the losing and gaining airbase are identical. The airbase can be identified by *either* entering the 8 character abbreviated designator attribute (*abbrev_designator*) from the airbase relation described in Section 3.3.8, or entering the digits of the *airbase_id*. Accepting both categories of input provides flexibility by permitting the user to choose an entry mode suited to his experience level. Furthermore, the data history windows display both the airbase_id and abbrev_designator attributes side-by-side to assist the user in verifying that intended data was entered and recognized by the computer.

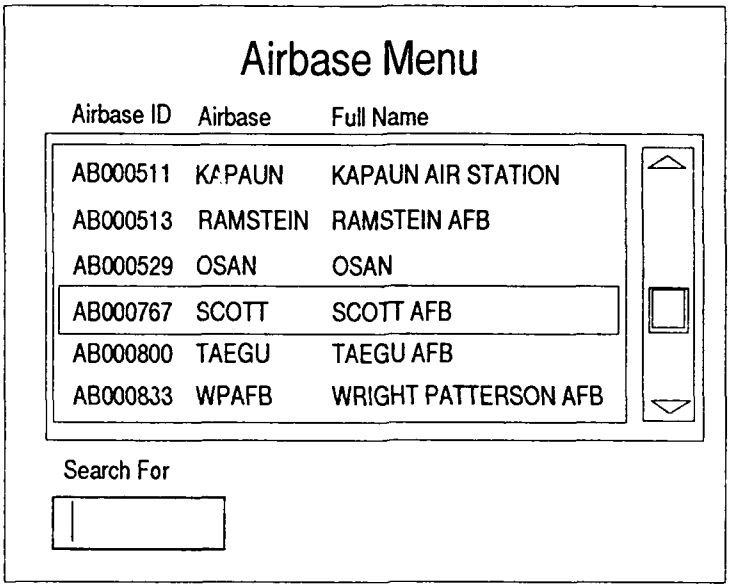

Figure 23. Airbase Listing Selection

The aircraft movement entry screen shown in Figure 22 illustrates both categories of data in the attribute entry fields. The first data entry field is shown accepting the value *WPAFB*, the abbreviated designator value for the airbase with airbase_id AB000833. The second data entry field is depicted as accepting the numeric value 767. This value is converted into the 8 character airbase_id, AB000767. The data history window shows both AB000767 and its associated abbrev_designator value, *SCOTT*.

Clicking on the airbase *help* button displays a pop-up menu soliciting the user to select from a listing of airbases as shown in Figure 23, or select from a graphical display of airbases, as depicted in Figure 24. Figure 24 displays airbases with the Saber airbase icon developed by Klabunde (16). Designating an airbase from the graphical display is accomplished by positioning the mouse cursor over the desired airbase symbol and clicking the mouse select button. A similar graphical representation can be used to select and display land units, targets, hex locations, and airhex locations.

In addition to airbase entries, the aircraft movement data entry screen requires the designation and quantity of aircraft to be moved. The airbase list is static, meaning the available list of values never changes. However, the list of available aircraft at a base is dynamic. Aircraft can leave a base in 3 ways:

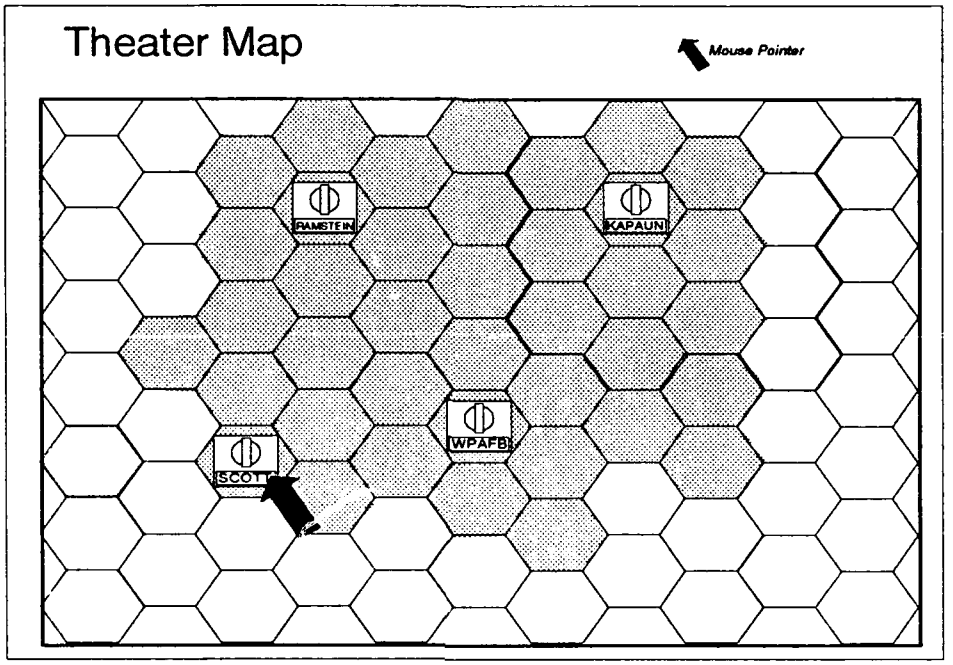

Figure 24. Airbase Graphical Selection

- User specifically requests transfer.
- Aircraft on a mission are destroyed.
- Aircraft get rerouted to alternate airfields due to damage at the home airbase.

Aircraft can arrive on a base from 3 sources.

- Staging Base.
- Transferred from another base.
- An airbase which has designated the gaining base as an alternate airfield.

Since the quantity and types of aircraft available at an airbase is dynamic, the aircraft selection list that is displayed by clicking on the designation *help* button must also be dynamic. Furthermore, not all aircraft can be serviced at every base. Therefore any list of aircraft presented in a help list should not identify aircraft that the gaining airbase cannot service. The cross_service relation described in Table 13 lists the only types of aircraft that can be serviced at any given airbase. In Figure 22, the designation help button has been

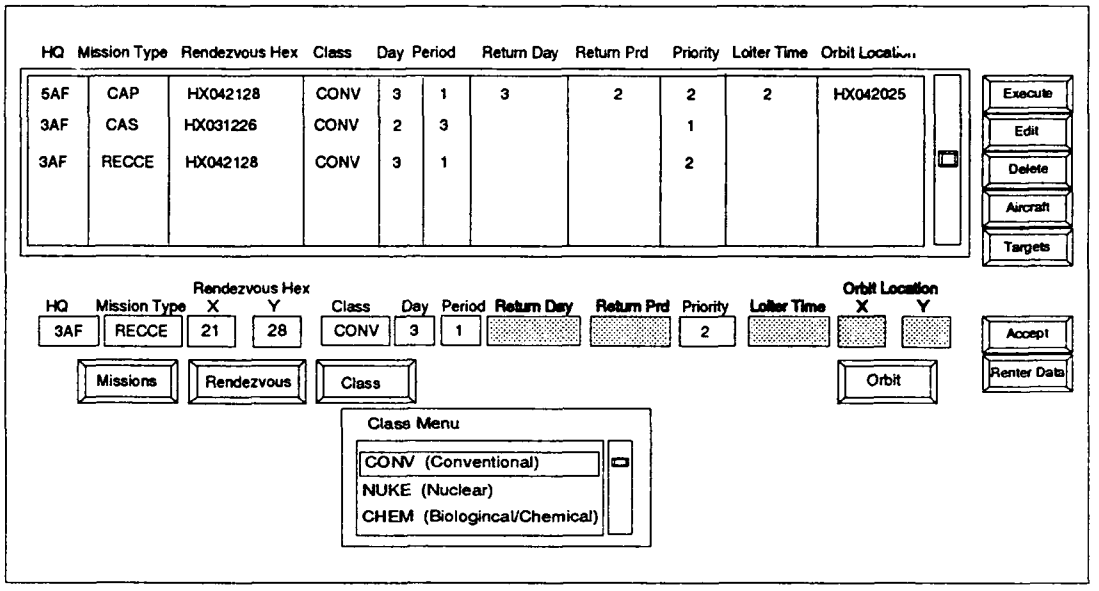

Figure 25. Aircraft Mission Selection List

selected and the aircraft help window has appeared to assist the user. The only aircraft displayed on the help list are those that currently are on the losing base and that also can be serviced at the gaining base. This aim of this feature is to prevent or reduce user input errors to a minimum. Invalid input results in a error message to the user.

Error checking is also accomplished in the aircraft quantity input field, which is labeled *qty*. The interface checks the number of aircraft requested for transfer against the quantity of aircraft currently available on the base, to ensure that a sufficient quantity or aircraft exists. If a sufficient quantity does not exist, an appropriate warning message is displayed.

4.4.2 Land Unit Instructions. Whereas aircraft movement instructions must be input on the day of the movement, instructions for troop movements can be programmed in advance. Furthermore, orders given to land units are executed during the simulation, and not prior to a simulation session.

Orders to troop movements are stored in the move and move_lnlt relations. These relations were described in Section 3.3.17, with a sample of the move relation given as

Table 25. All the attributes of the move relation must be supplied by the user, except *order_id*, which is internally computed by the Saber program.

The interface screen to the move relation uses the user interface template of Figure 19. Land unit_id entry is analogous to airbase_id entry in that land units can be input by entering the units abbreviated designator, *abbrev_designator*, or by entering the digits of the unit_id. Land units can be selected from a list of available unit names, or from a graphical display of land unit icons, similar to the airbase symbols depicted in Figure 24.

Destination hex locations can be entered by two methods. The X and Y-coordinate can by entered into a text input field, or the appropriate hex can be selected with the cursor from a graphical theater-level map.

4.4.3 Transportation of Supplies. Logistics is the third area of user input in the Saber model. Movements of supplies can be made between airbases, depots, and land units. Aircraft spare parts, designated *spares*, and POL are resources used to resupply airbases, while POL, hardware, and ammunition are supplies used to resupply land units. Supply units are moved by units designated as supply_trains. The supply_movement relation depicted in Table 26, the move relation, and the supply_train relation are used to track the movement of supplies.

The input required from the user is a combination of the move and the supply_movement relation. The user interface screen for supply movement is an instantiation of the user interface template shown in Figure 19.

Supply trains are used for logistics transfer in the Saber model, and their movement is controlled during execution of the Saber simulation. In addition, units can be created by the user to transfer supplies between airbases, which are processed ahead of the simulation cycle. This feature is provided as a menu option on the supply movement data entry screen.

4.4.4 Aircraft Mission Input. The aircraft mission relation was described in Section 3.3.12. The aircraft mission data entry screen is shown as Figure 25. It is an instantiation of the user interface template that has been tailored specifically to accept Saber aircraft mission inputs.

All attributes in the aircraft mission input screen are *not* necessarily required entries. Required inputs depend on the mission type. Upon selection of an aircraft mission,

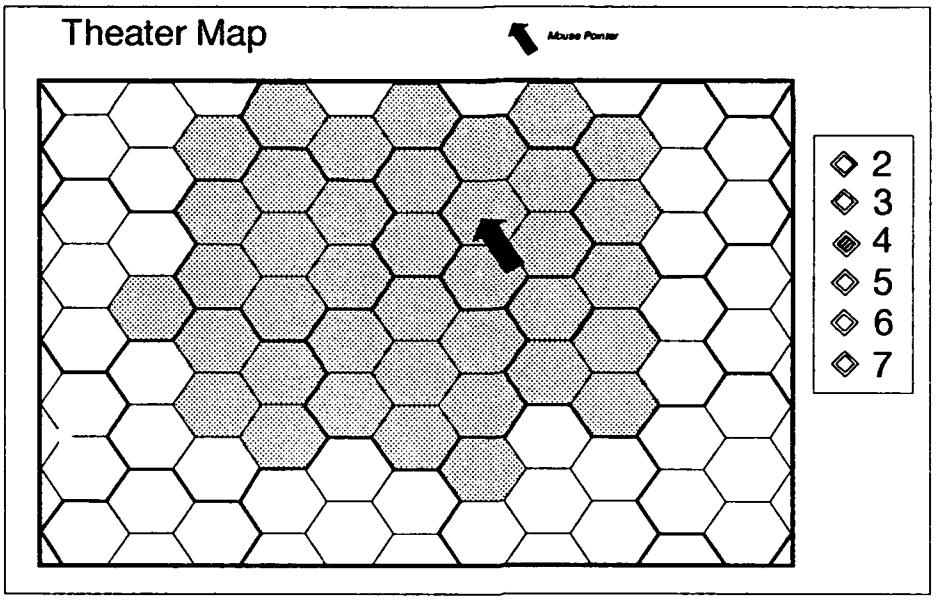

Figure 26. Airhex Selection

attributes that are not required are greyed out, and their input fields are rendered insensitive to keyboard and mouse input. The example in Figure 25 shows that CAP (combat air patrol) missions require entry of each input field, whereas CAS (close air support) and RECCE (reconnaissance) missions do not require input of the *return day, return prd, loiter time,* or *orbit location* attributes. Consequently, these four attributes are shown with their input fields greyed out. After the *period* attribute has been entered, the cursor automatically bypasses all greyed out attributes, and data entry continues in the next required input field, *priority*. This method of error prevention benefits the user not only by eliminating improper inputs, but also by eliminating cursor travel through unrequired input fields. Figure 3.3.12 shows a pop-up help window that is displayed upon selection of the mission *class* help key. The class of a mission can be conventional, nuclear, or biological/chemical. A help key is also provided for selection of the primary aircraft mission type, and for selection of the mission rendezvous hex and orbit location. Both the rendezvous hex and orbit location are airhexes. A graphical display for airhex selection is shown in Figure 26. Selection of an airhex using a graphical theater level display is accomplished by clicking the mouse cursor in the desired airhex. The display of Figure 26 also provides a facility to select the airhex level.

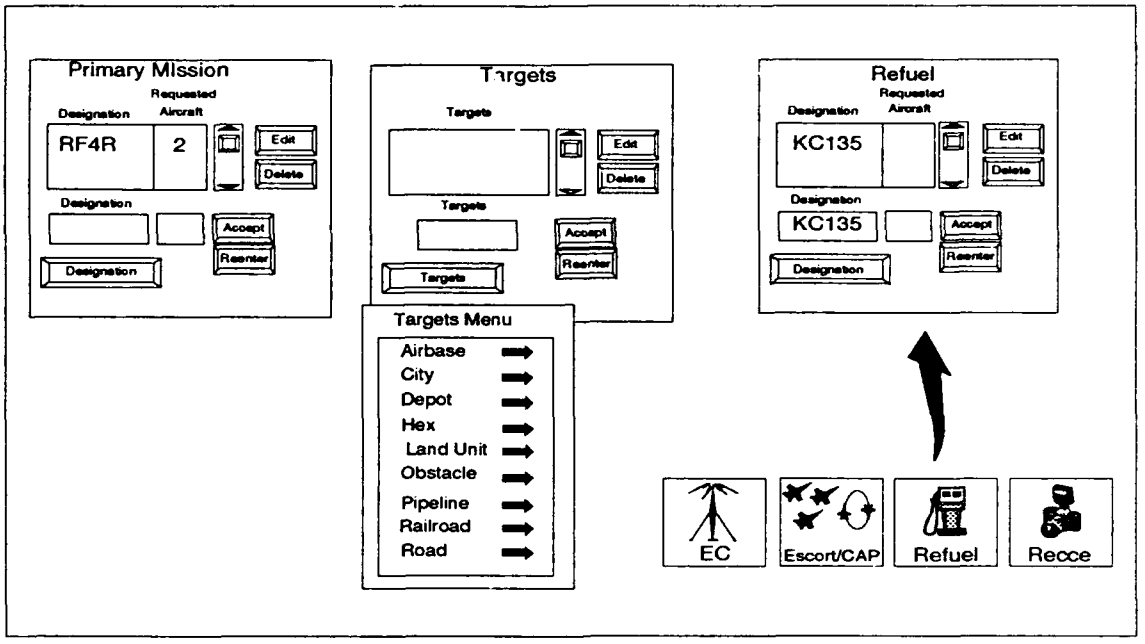

Figure 27. Aircraft Package and Targets Interface Screen

Associated with each aircraft mission is the aircraft package that flies the mission, and the target of the mission. After a line of valid mission input has been entered, and the *accept* button selected, a window requesting the aircraft package and target information for the mission is opened, as shown in Figure 27.

Figure 27 shows one window open for input of the aircraft flying the primary portion of the mission. A second window is used for entering mission target data. The target *help* button has been depressed, revealing the pop-up help menu which lists the different types of targets available in the Saber model. Table 16 describes five secondary missions that are flown in an aircraft package in support of the primary mission. These missions are CAP, EC, ESCORT, REFUEL, and SEAD. However, CAP and ESCORT missions are mutually exclusive, meaning that aircraft cannot perform in both of these two secondary mission roles in the same aircraft package. The mission matrix pictured in Table 16 defines secondary missions that can accompany a particular primary mission type. The lower right hand corner of Figure 27 is a display of four icons, each of which can be used to open a window for input of aircraft flying secondary missions in support of the primary missions. The arrow shown in this figure is used to simulate the generation of the *Refuel* data entry

window from selection of the refuel icon. Normally, icons disappear when the window it controls is opened. However, the refuel icon is shown here for illustrative purposes only.

CAP and ESCORT missions are mutually exclusive. Therefore, one icon can be used to control both types of input. Only windows to secondary missions that will used in a particular aircraft package need to be opened by the user. Therefore, placing secondary missions in separate windows reduces screen clutter, and allows the user to customize the layout of the aircraft package input screen.

Two additional buttons not found in the user interface template appear in the aircraft mission input screen. These buttons, labeled *aircraft* and *target*, appear with the data history *delete* and *edit* buttons, and are used to update the aircraft packages and targets of a previously entered mission input tuple that appears in the data history window.

4.5 X Window Implementation

The Saber user interface was implemented using the X Window System and Motif. Motif is a graphical interface, a style guide for providing application consistency, a programmer's toolkit library, and a window manager (12). Several sources of documentation cover both the Motif toolkit and the X Window system, including (2, 12, 13, 29, 39).

The use of Motif to implement the Saber user interface was a design constraint, as indicated in Section 1.4. However, there are several advantages for using Motif and X-Windows as the interface platform for the Saber Wargame.

1. Motif provides a standard interface with a consistent look and feel. Users can spend less time learning new Motif applications, since the knowledge of using one Motif application can be transferred to other applications.
2. Motif provides a very high-level object-oriented library. Extremely complex graphical programs can be generated with a very small amount of code. The Motif toolkit allows the reuse of functions specified in the toolkit, consequently saving program development time and effort.
3. Motif is based upon X Windows, which has been adopted as one computer industry standard, and allows programs to be executed on a variety of different platforms. (12)

The Motif programmers library consists of a variety of *widgets*. A widget is an object that provides a user interface abstraction (12). Definitions of widgets are not described in

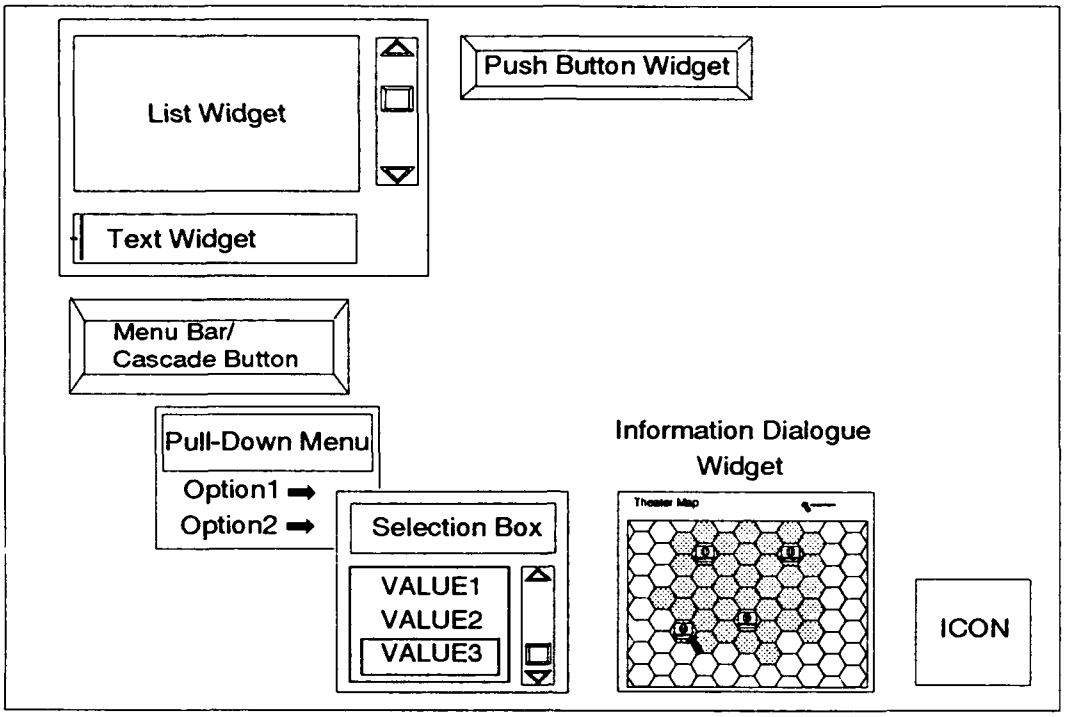

Figure 28. Motif Widgets Used in the Saber GUI

this thesis, but can be found in (2, 12, 13, 29, 39). Instead, the widgets that were used to implement the various components of the Saber GUI are listed.

Figure 28 shows the Motif widgets that were used in the implementation of the Saber GUI. Each input screen is an instantiation of the Motif form widget. These composite widgets contain basic widgets, placed in a form layout format.

Attribute entry fields are instantiated using the Motif text widget. Text widget allow information to be typed in via the keyboard. Text widgets allow the usual editing functions to be performed on the text entered. Furthermore, text widgets support the selection of text with the mouse to delete, copy, or move text. Text can be any length. (2) However, the size of the text fields in the Saber GUI are set to a length equal to the attribute length.

The Motif list widget is used to implement data history windows. The number of visible items can be specified, which determines the size of the list widget. (2)

Push button widgets simulate the behavior of actual or physical push buttons on the screen. If the mouse button is pressed inside the button window, the button will darken, and the shading will make it appear as if the button is actually depressed. These push

button widgets are used in the Saber GUI to access pop-up help menus, and to perform operations, such as editing and deleting data. (2)

Help menus in the Saber GUI are normally implemented using cascade buttons and pull-down menus. Pull-down help menus are activated by pressing the cascade button widget associated with the help menu bar. Cascade buttons in the menu bar are similar to push buttons, except that they do not normally display a shadow. When the cascade button is depressed, its shading changes, and its associated pull-down menu is displayed. (2)

Motif list widgets are used to select one or more strings from an arbitrary list of items. Scrolled list widgets and selection box widgets are specializations of the list widget. These widgets are used in Saber to display to the user all of his possible choices.

Graphical displays were implemented with an information dialogue widget. These high-level widgets are actually aggregations of several smaller level widgets. These graphical selection widgets were developed and documented by Klabunde in (16).

Finally, icons are used in the Saber GUI in a standardized manner consistent to their use in common graphical user interface applications. Icons are used in the control of opening and closing windows.

4.6 Summary

The Saber graphical user interface has been designed to accommodate users with different levels of computer expertise. Fast keyboard entry in a format similar to DBMS entry forms is provided for experienced users, while selection lists and graphical displays are used to assist novice and inexperienced users of the Saber wargame.

The design goals of the Saber graphical user interface were:

- Fast, easy data entry for experienced users, without sacrificing user-friendliness for new and inexperienced users.
- Minimize user training requirements through the use of standardized input screens based on a common template.
- Provide an interface that requires minimal use of external documentation.
- Recognition of information, not recall, is all that is required to properly utilize the interface.

- Enjoyment in using the system.

These goals were accomplished using various techniques. Both error prevention and error checking are extensively used in the interface implementation to assist the user by minimizing user input errors. Multiple see-and-point selection techniques were incorporated to facilitate information recognition. Furthermore, the use of windows for each data input screen permits users to customize the interface to suit their particular expertise level.

The unique feature of the Saber GUI is its use of data history windows. This feature is advantageous over normal DBMS form entry in that it allows the user to immediately observe and readily manipulate data entered into the computer.

This combination of error prevention, information recognition, standardized interface template, and data history windows provide a unique, user-friendly system that not only requires minimal start-up training, but is also enjoyable to use.

V. Summary and Conclusions

5.1 Summary of Work

This thesis effort resulted in the design and implementation of a graphical user interface and a database management system for the Saber theater-level wargame. Development of the user interface consisted of generating an interface design, and then implementing this design using the Motif toolkit to X Window System.

Development of the Saber database management system consisted of analyzing the problem domain to determine objects and the relationships between those objects, construction of Entity-Relationship diagrams that modelled the objects, decomposing these diagrams into relations, normalizing the relations into Boyce-Codd Normal Form, and finally, entering a large volume of actual data into the newly created database. The Saber model uses the Oracle DBMS as a data repository.

To properly interface the Saber DBMS with other components of the Saber wargame, such as the user interface, the simulation, and the graphical post-processor, programs were developed to download data stored in Oracle relations to ASCII data files, and to upload ASCII files back into Oracle relations. The Saber model operates exclusively on data stored in ASCII flat files.

The Saber DBMS is unique in that is was designed to simplify verification and validation efforts. Relations exist to properly model every major weapon system. This allows all firepower scores to be computed from the quantity and quality of the weapons systems possessed by a combatant. Finally, data values were taken from documented sources.

The Saber GUI has been designed to accommodate users with different levels of computer expertise. The interface is user-friendly, and allows fast and efficient entry of wargame commands in a format similar to orders issued during combat. Moreover, the interface allows the system to be used with minimal training, and minimal reliance on external documentation. Recognition, rather than recall, is all that is necessary to properly operate this application.

The Saber GUI is unique from other wargame interfaces in its use of data history windows. This feature provides immediate feedback to the user, and maximizes flexibility by allowing users to easily review and modify input.

5.2 *Recommendations for Future Work*

The design of the Saber DBMS allows it to be easily expanded. The current wargame models the airland battle. It follows then that a naval component can be added to provide an inclusive sea/land/air scenario. Furthermore, consideration should be given to properly modelling the addition of outer space to the Saber model. Currently, the database has a relation that covers only the tracking of satellites. However, research in the area of the Strategic Defense Initiative (star wars) can be used to expand the Saber DBMS to incorporate an outer space scenario.

The Saber hexagonal grid system currently covers a 100x100 hexagon playing area due to the fact that X and Y coordinates are limited to a two digit number. Programming a global coordinate system is an area of future research that can be considered. This research should be part of the development of an overall scenario development tool that can be used to customize data values within the Saber DBMS so that it can accurately model any situation on any part of the globe.

5.3 *Conclusion*

This thesis documented the design and implementation of a graphical user interface and database management system for the Saber theater-level wargame. These efforts are only one component of an expandable, yet integrated system, designed to educate the military leaders of tomorrow.

Appendix A. *Saber Relation Tables Dictionary*

A.1 Dictionary Description

This relations in this dictionary were derived from the SABER entity relationship diagrams, and through iterative design discussions of the Saber implementation team. The dictionary entries are described as follows:

Index – The primary key for the relation. This key is the minimum combination of attributes necessary to uniquely identify a tuple in the relation. The plus sign (+) is the logical AND operator. For example, and index value of *airbase_id + designation* denotes that the combination of both attributes is necessary to uniquely identify a tuple in the relation.

Secondary Relations – A listing of relations that are directly referenced to or by the given relation. For example, the *airbase_id* of the **RUNWAYS** relation directly references the same attribute in the *AIRBASE* relation.

Reference – The acceptable value of an attribute often *must* appear as a value in another relation. For example, the value for the attribute *alternate_id* in the **ALTERNATE_BASES** relation must appear as the value of an *airbase_id* in the **AIRBASE** relation. This is described with the notation *airbase_id@AIRBASE*, signifying that the value of the attribute must be a subset of the values given for the *airbase_id* attribute of the **AIRBASE** relation.

Alternate Index – A secondary key that can be used instead of the primary key (Index) to access tuples in the relation.

A.2 Relation Table Dictionary

A2A_WEAPONS Air-to-Air missiles and their characteristics.
Index: designation.

ATTRIBUTES	FORMAT
designation	CHARACTER(5)
force	CHARACTER(7)
full_designator	CHARACTER(30)
range	INTEGER(8)
sspk	DECIMAL(5.4)

A2G_WEAPONS Air-to-ground weapons and their characteristics.
Index: designation.
Secondary Relations: AIRBASE_WEAPONS, PBL, PCL, PNL.

ATTRIBUTES	FORMAT
designation	CHARACTER(5)
force	CHARACTER(7)
full_designator	CHARACTER(30)
radius	INTEGER(8)
cep	DECIMAL(5.4)
pk_hard	DECIMAL(5.4)
pk_med	DECIMAL(5.4)
pk_soft	DECIMAL(5.4)

ABBREVIATIONS Abbreviations and definitions for the the two letter prefix of identifiers.
Index: code, or symbol.

ATTRIBUTES	FORMAT
code	CHARACTER(2)
symbol	CHARACTER(12)

AIRBASE Airbase relation.

Index: airbase_id.

Secondary Relations: AIRBASE_AIRCRAFT, AIRBASE_WEAPONS, ALTERNATE_BASES, CROSS_SERVICE, RUNWAYS.

ATTRIBUTES	FORMAT
airbase_id	CHARACTER(8)
full_designator	CHARACTER(30)
abbrev_designator	CHARACTER(8)
command	CHARACTER(15)
country	CHARACTER(4)
location	CHARACTER(8)
future_location	CHARACTER(8)
hq	CHARACTER(5)
length	INTEGER(8)
width	INTEGER(8)
weather_minimum	CHARACTER(4)
base_mission	CHARACTER(6)
max_ramp_space	INTEGER(8)
ramp_avail	INTEGER(8)
intel_index	DECIMAL(5.4)
enemy_mines	INTEGER(8)
mopp_posture	INTEGER(1)
status	CHARACTER(7)
pol_soft_store	INTEGER(8)
pol_hard_store	INTEGER(8)
max_pol_hard	INTEGER(8)
max_pol_soft	INTEGER(8)
maint_personnel	INTEGER(8)
maint_hrs_accum	INTEGER(8)
maint_equip	INTEGER(8)
spare_parts	INTEGER(8)
shelters	INTEGER(8)
eod_crews	INTEGER(8)
rrr_crews	INTEGER(8)
vis_to_enemy	CHARACTER(8)

AIRBASE_AIRCRAFT The number and type of aircraft that are located on an airbase.
Index: airbase_id + designation.

ATTRIBUTES	FORMAT
airbase_id	CHARACTER(8)
designation	CHARACTER(5)
weapon_count	INTEGER(8)

AIRBASE_WEAPONS The bombs and missiles that are located on a particular airbase.
Index: airbase_id + designation.

ATTRIBUTES	FORMAT
airbase_id	CHARACTER(8)
designation	CHARACTER(5)
weapon_count	INTEGER(8)

AIRCRAFT_MISSION Aircraft Missions.
Index: mission_id.
Secondary Relations: AIRCRAFT_PACKAGE, TARGETS.

ATTRIBUTES	FORMAT
mission_id	CHARACTER(8)
force	CHARACTER(7)
hq	CHARACTER(5)
mission_type	CHARACTER(8)
rendezvous_hex	CHARACTER(8)
class	CHARACTER(4)
rqst_prd_on_targ	INTEGER(2)
rqst_day_on_targ	INTEGER(2)
actual_start_prd	INTEGER(2)
actual_start_day	INTEGER(2)
loiter_time	INTEGER(4)
rqst_return_prd	INTEGER(2)
rqst_return_day	INTEGER(2)
actual_return_prd	INTEGER(2)
actual_return_day	INTEGER(2)
priority	INTEGER(4)
activated	CHARACTER(3)
ineffective_reason	CHARACTER(4)
orbit_location	CHARACTER(8)

AIRCRAFT_PACKAGE The number and types of aircraft that compose a specific mission.
Index: ac_mission + designation + mission_id.

ATTRIBUTES	FORMAT
mission_id	CHARACTER(8)
designation	CHARACTER(5)
ac_mission	CHARACTER(7)
requested_ac	INTEGER(8)

AIRCRAFT_TYPE The characteristics of individual aircraft types.
Index: designation.
Secondary Relations: AIRBASE_AIRCRAFT, AIRCRAFT_PACKAGE, CROSS_SERVICE, MAINTENANCE, PBL, PCL, PNL, REFUEL_CAPACITY.

ATTRIBUTES	FORMAT
designation	CHARACTER(5)
force	CHARACTER(7)
common_name	CHARACTER(12)
night_capability	DECIMAL(5.4)
wx_capability	CHARACTER(4)
sorties_week	INTEGER(8)
ac_size	INTEGER(8)
search	INTEGER(8)
ec	INTEGER(8)
max_speed	INTEGER(8)
radius	INTEGER(8)
loiter_time	INTEGER(4)
cargo	INTEGER(8)
recon_ability	DECIMAL(5.4)
refuelable	CHARACTER(3)
maintain_dist	CHARACTER(10)
maintain_mean	INTEGER(4)
maintain_standev	INTEGER(4)
spare_parts	INTEGER(8)
pol_usage_rate	DECIMAL(5.4)
ramp_space	INTEGER(8)
min_runway	INTEGER(8)
a2a_rating	INTEGER(8)
a2g_rating	INTEGER(8)
max_hex	INTEGER(2)

AIRHEX Relation stores information on all air hex locations, from level 2 to level 7.
Index: hex_id

ATTRIBUTES	FORMAT
hex_id	CHARACTER(8)
wz	INTEGER(4)
persistence_time	INTEGER(4)
trafficability	CHARACTER(4)

ALTERNATE_BASES Listing of the alternate airbases that an aircraft can fly to in case its home base is destroyed while it is flying its mission.
Index: airbase_id + alternate_id.

ATTRIBUTES	FORMAT
airbase_id	CHARACTER(8)
alternate_id	CHARACTER(8)

APPORTIONMENT The apportionment of aircraft by mission for each session day and period.
Index: day + force + mission_type + period.

ATTRIBUTES	FORMAT
mission_type	CHARACTER(8)
day	INTEGER(2)
period	INTEGER(2)
force	CHARACTER(7)
projected	INTEGER(8)
actual	INTEGER(8)

BASE_COMPONENT_TYPE The lenght, width, and target weight of components that make up an airbase, such as shelters and POL storage facilities.
Index: designation.

ATTRIBUTES	FORMAT
designation	CHARACTER(5)
target_wgt	INTEGER(8)
length	INTEGER(8)
width	INTEGER(8)

BORDERS The list of hex borders that constitute the border between separate countries.
Index: neighbor_id
Reference: neighbor_id@TRAVEL.

ATTRIBUTES	FORMAT
neighbor_id	CHARACTER(8)

CARGO_CAPACITY The cargo capacity of vehicles and trains.
Index: vehicle.

ATTRIBUTES	FORMAT
vehicle	CHARACTER(12)
capacity	INTEGER(8)

CHEMICAL Chemical Weapons.
Index: designation.
Secondary Relation: PCL.

ATTRIBUTES	FORMAT
designation	CHARACTER(5)
name	CHARACTER(12)
force	CHARACTER(7)
persistence_time	INTEGER(4)
lethality	INTEGER(4)
cep	DECIMAL(5.4)

CITY A description of the cities in the given theater of operations.
Index: city_id.

ATTRIBUTES	FORMAT
city_id	CHARACTER(8)
location	CHARACTER(8)
name	CHARACTER(12)
urban	INTEGER(1)
capital	CHARACTER(3)
population	INTEGER(8)

COASTS A list of hex borders that constitute the boundary between land and bodies of water.
Index: neighbor_id.
Reference: neighbor_id@TRAVEL.

ATTRIBUTES	FORMAT
neighbor_id	CHARACTER(8)

CODES This relation matches the 6 digit number to its appropriate two letter prefix. The id numbers of one code should not overlap with the id numbers of a different code.
Index: id.

ATTRIBUTES	FORMAT
id	INTEGER(6)
code	CHARACTER(2)

CROSS_SERVICE This relation shows what types of aircraft can be based at or fly missions from a particular airbase, and what type of aircraft service is available at the airbase.
Index: airbase_id + designation.
airbase_id@AIRBASE.

ATTRIBUTES	FORMAT
airbase_id	CHARACTER(8)
designation	CHARACTER(5)
service_type	CHARACTER(1)

DEPOT Depots.
Index: depot_id.

ATTRIBUTES	FORMAT
depot_id	CHARACTER(8)
full_designator	CHARACTER(30)
abbrev_designator	CHARACTER(8)
command	CHARACTER(15)
country	CHARACTER(4)
location	CHARACTER(8)
future_location	CHARACTER(8)
hq	CHARACTER(5)
length	INTEGER(8)
width	INTEGER(8)
weather_minimum	CHARACTER(4)
base_mission	CHARACTER(6)
max_ramp_space	INTEGER(8)
ramp_avail	INTEGER(8)
intel_index	DECIMAL(5.4)
enemy_mines	INTEGER(8)
mopp_posture	INTEGER(1)
status	CHARACTER(7)
pol_soft_store	INTEGER(8)
pol_hard_store	INTEGER(8)
max_pol_hard	INTEGER(8)
max_pol_soft	INTEGER(8)
maint_personnel	INTEGER(8)
maint_hrs_accum	INTEGER(8)
maint_equip	INTEGER(8)
spare_parts	INTEGER(8)
shelters	INTEGER(8)
eod_crews	INTEGER(8)
rrr_crews	INTEGER(8)
vis_to_enemy	CHARACTER(8)

FEBA The list of hex borders that constitute the forward edge of the battle area.
Index: neighbor_id.
Reference: neighbor_id@TRAVEL.

ATTRIBUTES	FORMAT
neighbor_id	CHARACTER(8)

FLOAT_CONSTANTS Float constant names, values, and their associated unit of measure.
Index: constant.

ATTRIBUTES	FORMAT
constant	CHARACTER(20)
value	DECIMAL(5.4)
units	CHARACTER(20)

FORCES This relations associates which countries in the theater are neutral, which are red players, and which are blue players.
Index: country.

ATTRIBUTES	FORMAT
country	CHARACTER(4)
force	CHARACTER(7)

HARDNESS Target Hardness.
Index: target_type.

ATTRIBUTES	FORMAT
target_type	CHARACTER(15)
hardness	CHARACTER(4)

HEX Relation that stores all information on each ground hex location.
Index: hex_id.

ATTRIBUTES	FORMAT
hex_id	CHARACTER(8)
center_hex	CHARACTER(8)
force	CHARACTER(7)
country	CHARACTER(4)
ec	INTEGER(8)
wz	INTEGER(4)
intel_index	DECIMAL(5.4)
cpo	DECIMAL(5.4)
cpi	DECIMAL(5.4)
terrain	CHARACTER(8)
forest	INTEGER(1)
persistence_time	INTEGER(4)

HEXSIDE_ASSETS The obstacles that are located on hex borders.
Index: obstacle_id.

ATTRIBUTES	FORMAT
neighbor_id	CHARACTER(8)
obstacle_id	CHARACTER(8)
obstacle	CHARACTER(9)
difficulty	CHARACTER(4)
vis_to_enemy	CHARACTER(8)

INTEGER_CONSTANTS Integer constants names, values, and their associated units of measure.
Index: constant.

ATTRIBUTES	FORMAT
constant	CHARACTER(20)
value	DECIMAL(5.4)
units	CHARACTER(20)

LAND_COMPONENT_TYPE This relation stores the characteristics of different land unit weapons and components, such as tanks and Bradley fighting vehicles.
Index: designation.
Secondary Relations: UNIT_COMPONENTS

ATTRIBUTES	FORMAT
designation	CHARACTER(5)
force	CHARACTER(7)
full_designator	CHARACTER(30)
ammo_usage_rate	DECIMAL(5.4)
hw_usage_rate	DECIMAL(5.4)
pol_usage_rate	DECIMAL(5.4)
target_wgt	INTEGER(8)
firepower	DECIMAL(5.4)
length	INTEGER(8)
width	INTEGER(8)

LAND_UNIT A ground army unit.
Index: unit_id.

ATTRIBUTES	FORMAT
unit_id	CHARACTER(8)
country	CHARACTER(4)
corps_id	CHARACTER(8)
parent_unit	CHARACTER(8)
unit_size	INTEGER(8)
full_designator	CHARACTER(30)
abbrev_designator	CHARACTER(8)
unit_type	CHARACTER(5)
location	CHARACTER(8)
combat_power	DECIMAL(5.4)
firepower	DECIMAL(5.4)
troop_quality	INTEGER(4)
msn_eff_day	INTEGER(2)
region	CHARACTER(6)
groundspeed	INTEGER(4)
intel_index	DECIMAL(5.4)
intel_filter	DECIMAL(5.4)
mopp_posture	INTEGER(1)
attrition	DECIMAL(5.4)
breakpoint	INTEGER(8)
grid_time	DECIMAL(5.4)
total_pol	INTEGER(8)
pol_resupply_pct	DECIMAL(5.4)
pol_usage_rate	DECIMAL(5.4)
total_ammo	INTEGER(8)
ammo_resupply_pct	DECIMAL(5.4)
ammo_usage_rate	DECIMAL(5.4)
total_hardware	INTEGER(8)
hw_resupply_pct	DECIMAL(5.4)
hw_usage_rate	DECIMAL(5.4)
fuel_trucks	INTEGER(8)
ammo_trucks	INTEGER(8)
water	INTEGER(8)
water_percent	DECIMAL(5.4)
water_trucks	INTEGER(8)
engineers	INTEGER(8)
eng_vehicles	INTEGER(8)
status	CHARACTER(7)
day_last_intelled	INTEGER(2)
prd_last_intelled	INTEGER(2)
loc_last_intelled	CHARACTER(8)
vis_to_enemy	CHARACTER(8)

MAINTENANCE This relation stores information on the maintenance hours required by aircraft returning from a mission. The maintenance time main_time must expire before the aircraft can fly another mission.
Index: airbase_id + designation + maint_time + quantity + start_time.

ATTRIBUTES	FORMAT
airbase_id	CHARACTER(8)
designation	CHARACTER(5)
quantity	INTEGER(8)
maint_time	INTEGER(4)
start_time	INTEGER(4)

MOVE This relation stores the orders for land unit to move to a given hex location, move to a given target, or move to another land unit.
Index: order_id.
Reference: unit_id@LAND_UNIT.
Alternate_index: unit_id + day + period.

ATTRIBUTES	FORMAT
order_id	CHARACTER(8)
unit_id	CHARACTER(8)
day	INTEGER(2)
period	INTEGER(2)
target_id	CHARACTER(8)
army_mission_type	CHARACTER(4)

MOVE_LNLT Move, Leave No Later Than. A land unit will follow the orders in this relation in lieu of orders found in the MOVE relation.
Index: order_id.
Reference: unit_id@LAND_UNIT.
Alternate_index: unit_id + day + period.

ATTRIBUTES	FORMAT
order_id	CHARACTER(8)
unit_id	CHARACTER(8)
day	INTEGER(2)
period	INTEGER(2)
target_id	CHARACTER(8)
army_mission_type	CHARACTER(4)

NUCLEAR Nuclear Weapons.
Index: designation.
Secondary Relation: PCL.

ATTRIBUTES	FORMAT
designation	CHARACTER(5)
name	CHARACTER(12)
yield	INTEGER(4)
force	CHARACTER(7)
cep	DECIMAL(5.4)
persistence_time	INTEGER(4)

PBL Preferred Biological/Chemical Load. This relation associates aircraft with a weapons load based on the hardness of the target and the weather at the target location.
Index: designation + hardness + mission_type + wx.
Secondary_Relations: WEAPONS_LOAD.

ATTRIBUTES	FORMAT
wx	CHARACTER(4)
designation	CHARACTER(5)
mission_type	CHARACTER(8)
load_id	CHARACTER(8)

PCL Preferred Conventional Load. This relation associates aircraft with a weapons load based on the hardness of the target and the weather at the target location.
Index: designation + hardness + mission_type + wx.
Secondary_Relations: WEAPONS_LOAD.

ATTRIBUTES	FORMAT
wx	CHARACTER(4)
designation	CHARACTER(5)
mission_type	CHARACTER(8)
hardness	CHARACTER(4)
load_id	CHARACTER(8)

PIPELINES Pipeline segments, the product they carry, and whether the segment is can be used to transport a product.
Index: pipeline_id.
Alternate_index : hex_id + hexside.

ATTRIBUTES	FORMAT
pipeline_id	CHARACTER(8)
hex_id	CHARACTER(8)
hexside	CHARACTER(2)
product	CHARACTER(12)
name	CHARACTER(12)
flow	CHARACTER(3)

PNL Preferred Nuclear Load. This relation associates aircraft with a weapons load based on the hardness of the target and the weather at the target location.
Index: designation + hardness + mission_type + wx.
Secondary_Relations: WEAPONS_LOAD.

ATTRIBUTES	FORMAT
wx	CHARACTER(4)
designation	CHARACTER(5)
mission_type	CHARACTER(8)
load_id	CHARACTER(8)

RADARS The number, quality, and type of surface-to-air missile radars and the units they belong to.
Index: quality + radar_type + unit_id.

ATTRIBUTES	FORMAT
unit_id	CHARACTER(8)
radar_type	CHARACTER(3)
quality	DECIMAL(5.4)
quantity	INTEGER(8)

RAILROADS Railroad segments, and whether they can be used to move supplies.
Index: railroad_id.
Alternate_index: hex_id + hexside.

ATTRIBUTES	FORMAT
railroad_id	CHARACTER(8)
hex_id	CHARACTER(8)
hexside	CHARACTER(2)
name	CHARACTER(12)
flow	CHARACTER(3)

REFUEL_CAPACITY This relation store the fuel capacity of tanker aircraft.
Index: designation.

ATTRIBUTES	FORMAT
designation	CHARACTER(5)
capacity	INTEGER(8)

RIVERS A listing of the hex borders that constitute river or stream segments.
Index: neighbor_id.
Reference: neighbor_id@TRAVEL.

ATTRIBUTES	FORMAT
neighbor_id	CHARACTER(8)
river_size	CHARACTER(6)

ROADS Road and highway segments, and whether travel can be performed on the road segment.
Index: road_id.
Alternate_index : hex_id + hexside.

ATTRIBUTES	FORMAT
road_id	CHARACTER(8)
hex_id	CHARACTER(8)
hexside	CHARACTER(2)
name	CHARACTER(12)
road_size	CHARACTER(7)
flow	CHARACTER(3)

RUNWAYS The runways located on an airbase. The current and the maximum length of a runway is tracked, along with the difficulty of destroying a particular runway due to its construction only.
Index: airbase_id + runway.
Reference: airbase_id@AIRBASE.

ATTRIBUTES	FORMAT
airbase_id	CHARACTER(8)
runway	INTEGER(2)
difficulty	CHARACTER(4)
current_length	INTEGER(8)
max_length	INTEGER(8)

SAM_TYPE Surface-to-air missile types and their characteristics.
Index: designation.
Secondary Relations: UNIT_G2A, UNIT_LAUNCHERS.

ATTRIBUTES	FORMAT
designation	CHARACTER(5)
force	CHARACTER(7)
full_designator	CHARACTER(30)
class	CHARACTER(4)
slow_high	INTEGER(4)
slow_low	INTEGER(4)
fast_high	INTEGER(4)
fast_low	INTEGER(4)
sspk	DECIMAL(5.4)
range2	INTEGER(8)
range3	INTEGER(8)
range4	INTEGER(8)
range5	INTEGER(8)
range6	INTEGER(8)
range7	INTEGER(8)
radar2	INTEGER(8)
radar3	INTEGER(8)
radar4	INTEGER(8)
radar5	INTEGER(8)
radar6	INTEGER(8)
radar7	INTEGER(8)
rnds_per_launcher	INTEGER(4)
reload_time	INTEGER(4)
weather_minimum	CHARACTER(4)

SATELLITES The position , type, and status of orbiting satellites.
Index: satellite_id.

ATTRIBUTES	FORMAT
satellite_id	CHARACTER(8)
name	CHARACTER(12)
force	CHARACTER(7)
location	CHARACTER(8)
sat_type	CHARACTER(4)
status	CHARACTER(7)
speed	INTEGER(8)
direction	CHARACTER(2)
orbit	CHARACTER(10)
delay	INTEGER(4)

SSM_TYPE Surface-to-surface missiles and their characteristics.
Index: designation.
Secondary Relations: UNIT_G2A, UNIT_LAUNCHERS.

ATTRIBUTES	FORMAT
designation	CHARACTER(5)
force	CHARACTER(7)
full_designator	CHARACTER(30)
class	CHARACTER(4)
lethal_area	INTEGER(8)
cep	DECIMAL(5.4)
pk_hard	DECIMAL(5.4)
pk_med	DECIMAL(5.4)
pk_soft	DECIMAL(5.4)
min_range	INTEGER(8)
max_range	INTEGER(8)
rnds_per_launcher	INTEGER(4)
reload_time	INTEGER(4)

SUPPLY_MOVEMENT This relation details the quantity of supplies that a SUPPLY_TRAIN land unit is to deliver to its destination.
Index: designation + order_id + unit_id.

ATTRIBUTES	FORMAT
order_id	CHARACTER(8)
designation	CHARACTER(5)
deliver_qty	INTEGER(8)

SUPPLY_TRAIN Supply Train. All supply train units are land units from the LAND_UNIT relation. The SUPPLY_TRAIN relation shows the additional characters of a supply train that ordinary land units do not have.
Index: unit_id@LAND_UNIT.
Secondary Relations: MOVE, MOVE_LNLT, SUPPLY_MOVEMENT.

ATTRIBUTES	FORMAT
unit_id	CHARACTER(8)
capacity	INTEGER(8)
in_use	CHARACTER(3)
supply_type	CHARACTER(3)
trans_mode	CHARACTER(8)
total_pol	INTEGER(8)
total_ammo	INTEGER(8)
total_hardware	INTEGER(8)
spare_parts	INTEGER(8)

TARGETS The targets of missions.
Index: mission_id + target_id.

ATTRIBUTES	FORMAT
mission_id	CHARACTER(8)
target_id	CHARACTER(8)

TRAVEL This table associates common hex borders to a single neighbor_id, and stores the trafficability of a hex pie piece (see pie_trafficability).
Index: hex_id + hexside
Reference: hex_id@HEX.

ATTRIBUTES	FORMAT
hex_id	CHARACTER(8)
hexside	CHARACTER(2)
neighbor_id	CHARACTER(8)
pie_trafficability	CHARACTER(4)

UNIT_COMPONENTS The tanks and fighting vehicles that are owned by a land unit that are used in computing the unit's combat power.
Index: unit_id + designation.
Reference: unit_id@UNIT.

ATTRIBUTES	FORMAT
unit_id	CHARACTER(8)
designation	CHARACTER(5)
weapon_count	INTEGER(8)

UNIT_S2A The surface-to-air weapons owned by a land unit.
Index: unit_id + designation.
Reference: unit_id@UNIT.

ATTRIBUTES	FORMAT
unit_id	CHARACTER(8)
designation	CHARACTER(5)
weapon_count	INTEGER(8)

UNIT_SUPPORTS This relation shows which land units support other land units, and how much support they give is expressed as a percentage.
Index: unit_id + unit_supported_id.
Reference: Both unit_id and unit_supported_id must be a unit_id in the LAND_UNIT relation.

ATTRIBUTES	FORMAT
unit_id	CHARACTER(8)
unit_supported_id	CHARACTER(8)
percent	DECIMAL(5.4)

VISIBILITY Relation associates force colors with a character string position.
Index: position, or force.

ATTRIBUTES	FORMAT
char_pos	INTEGER(1)
force	CHARACTER(7)

WEAPONS_CLASS The relation tells what relation stores the characteristics of a weapon type.
Index: designation.

ATTRIBUTES	FORMAT
designation	CHARACTER(5)
relation	CHARACTER(20)

WEAPONS_LOAD This relation associates aircraft types with standard weapon loads.
Index: designation + load_id.
Reference: PBL, PCL, PNL.

ATTRIBUTES	FORMAT
load_id	CHARACTER(8)
designation	CHARACTER(5)
weapon_count	INTEGER(8)

WEATHER This relation stores the weather conditions in each zone of the theater for the duration of the game scenario.
Index: day + wx_period + wz.
Secondary Relations: AIRHEX, HEX, PBL, PCL, PNL.

ATTRIBUTES	FORMAT
wz	INTEGER(4)
day	INTEGER(2)
wx_period	INTEGER(2)
forecast_good	INTEGER(3)
forecast_fair	INTEGER(3)
actual_wx	CHARACTER(4)

Appendix B. *Saber Data Attributes Dictionary*

B.1 Dictionary Description

This attributes in this dictionary were derived from the SABER entity relationship diagrams, and through iterative design discussions of the Saber implementation team. The dictionary entries are described as follows:

Where Used – The relation table names that the entry is an attribute in.

Type – The ADA data type of the attribute entry, followed by the length of the data type in parenthesis. For Examples,

- INTEGER(8) – An integer value with 8 digits.
- CHAR(4) – A character string 4 characters in length.
- FLOAT(5.4) – A real number or floating point value that consists of 5 digits before the decimal point, and 4 digits following the decimal point.

Values – The Range of legal values that an attribute can take on. For descriptive fields, sample values are given as examples.

Alias – An alternative name for an attribute. Relations do not allow multiple attributes with identical names. Therefore, attributes must be renamed if two similar attributes must appear in the same relation. For example, the **ALTERNATE_BASES** relation uses the *airbase_id* attribute for both the host base and the bases that are the alternate bases. The *airbase_id* that identifies the alternate bases is renamed with the alias of *alternate_id.*

Composition – A description of the components that make up an attribute. For example, the attribute *hex_id* is composed of a two letter identifier 'HX' followed by a 6 digit number.

Reference – The acceptable value of an attribute often *must* appear as a value in another relation. For example, the value for the attribute *alternate_id* in the **ALTERNATE_BASES** relation must appear as the value of an *airbase_id* in the **AIRBASE** relation. This is described with the notation *airbase_id@AIRBASE*, signifying that the value of the attribute must be a subset of the values given for the *airbase_id* attribute of the **AIRBASE** relation.

B.2 Saber Data Attributes

a2a_rating The air to air combat (dogfight) rating of an aircraft type.
Where Used: AIRCRAFT_TYPE.
Type: INTEGER(8).
Values: 0-99,999,999.
Source: (8:page 164) Ftr Capability Rating

a2g_rating The air to ground attack rating of an aircraft type. The ability of an aircraft to accurately attack ground targets.
Where Used: AIRCRAFT_TYPE.
Type: INTEGER(8).
Values: 0-99,999,999
Source: (8:page 164) Atk Capability Rating

abbrev_designator An 8 character abbreviation of the full_designator field.
Where Used: AIRBASE, DEPOT, LAND_UNIT.
Type: CHAR(8).
Values: Example: *101MID* for 101 MECHANIZED INFANTRY DIVISION.

ac_mission The support mission of aircraft within an aircraft mission package.
Where Used: AIRCRAFT_PACKAGE.
Type: CHAR(7).
Values: CAP, EC, ESCORT, PRIMARY, REFUEL, SEAD.

ac_size The size of an aircraft.
Where Used: AIRCRAFT_TYPE.
Type: INTEGER(8).
Values: 0-99,999,999.
Source: (15:pp 160-207) Dimension: length * span.

activated Boolean variable that describes whether a requested aircraft mission was activated.
Where Used: AIRCRAFT_MISSION.
Type: CHAR(3).
Values: NO, YES.

actual Actual apportionment of aircraft.
Where Used: APPORTIONMENT.
Type: INTEGER(8).
Values: 0-99,999,999.

actual_return_day The actual session day that an aircraft mission returned to its airbase.
Where Used: AIRCRAFT_MISSION.
Type: INTEGER(2).
Values: 0-num_periods.

actual_return_prd The actual period that an aircraft mission returned to its airbase.
Where Used: AIRCRAFT_MISSION.
Type: INTEGER(2).
Values: 0–num_days.

actual_start_day The actual day that an aircraft mission hit its target.
Where Used: AIRCRAFT_MISSION.
Type: INTEGER(2).
Values: 0–num_days.

actual_start_prd The actual period that an aircraft mission hit its target.
Where Used: AIRCRAFT_MISSION.
Type: INTEGER(2).
Values: 0–num_days.

actual_wx The actual weather that is occuring within a weather zone.
Where Used: WEATHER.
Type: CHAR(4).
Values: FAIR, GD, POOR.

airbase_id The unique identifier of an airbase asset.
Where Used: AIRBASE, AIRBASE_AIRCRAFT, AIRBASE_WEAPONS, ALTERNATE_BASES, CROSS_SERVICE, MAINTENANCE, RUNWAYS.
Type: CHAR(8).
Values: AB000001–AB009999
Alias: target_id.
Composition: Two letter identifier 'AB' followed by a 6 digit number. Airbases are numbered sequentially.

alternate_id The airbase_id of an alternate airbase.
Where Used: ALTERNATE_BASES.
Type: CHAR(8).
Values: Same as airbase_id.
Composition: Same as airbase_id.
Reference: airbase_id@AIRBASE.

ammo_resupply_pct The percentage of ammunition that get resupplied to a unit.
Where Used: LAND_UNIT.
Type: FLOAT(5.4)
Values: 0.0–100.0000 (percent).

ammo_trucks The number of ammunition trucks owned by a particular land unit.
Where Used: LAND_UNIT.
Type: INTEGER(8).
Values: 0-99,999,999.

ammo_usage_rate The amount of ammunition a unit uses on a daily basis.
Where Used: LAND_COMPONENT_TYPE, LAND_UNIT.
Type: FLOAT(5.4)
Values: 0.0-99999.9999 (tons/day).
(8:pp 82, 87, 464) Rounds on board, Divisional Supply Requirements.

army_mission_type The mission of land unit. (attack, defend, move)
Where Used: MOVE, MOVE_LNLT.
Type: CHAR(4).
Values: ATK, DEF, MOVE, SPT, WTD.

attrition Unit attrition.
Where Used: LAND_UNIT.
Type: FLOAT(5.4).
Values: Computed by simulation.

base_mission The mission of an airbase (Deploy, Not Applicable) .
Where Used: AIRBASE, DEPOT.
Type: CHAR(6).
Values: DEPLOY, NA.

breakpoint The minimum combat_power level that a land_unit must sustain in order to engage in battles. When the combat_power of a unit drops below its breakpoint level, the unit automatically begins to retreat.
Where Used: LAND_UNIT.
Type: INTEGER(8).

capacity The cargo capacity of vehicles and trains, and the fuel capacity of tanker aircraft (tons).
Where Used: CARGO_CAPACITY, REFUEL_CAPACITY, SUPPLY_TRAIN.
Type: INTEGER(8).
Values: 0–99,999,999 (tons).
Source: (35) Trucks - Max Load; (8:page 466) Vehicle - Load; (8:page 552) Tanker - In Flight Refueling.

capital Boolean variable that describes whether a city is a capital of a country.
Where Used: CITY.
Type: CHAR(3)
Values: YES, NO.

cargo The cargo capacity of an aircraft.
Where Used: AIRCRAFT_TYPE.
Type: INTEGER(8).
Values: 0–99,999,999 (tons).
Source: (15:pp 550-551) Payload.

center_hex The air hex located directly over the associated ground hex_id.
Where Used: HEX.
Type: CHAR(8).
Values: HX010000–HX079999.
Alias: center_hex, location, orbit_location, rendezvous_hex.
COMP: Two letter identifier 'HX' followed by 6 digit number. The first two digits are the hex level. The second set of two digits are the X-coordinate index, and the last set of two digits are the Y-coordinate index.
Reference: hex_id@HEX.

cep Circular error of probability.
Where Used: A2G_WEAPONS, CHEMICAL, NUCLEAR, SSM_TYPE.
Type: FLOAT(5.4)
Values: 0.0–99999.9999 (meters)
Source: (8:page 440) CEP

char_pos The position within the character string field *visibility*.
Where Used: VISIBILITY.
Type: INTEGER(1).
Values: 0–8.

city_id Unique identifier for a city.
Where Used: CITY.
Type: CHAR(8).
Values: CY000001-CY009999.
Composition: Two letter identifier 'CY' followed by a 6 digit number. Cities are numbered sequentially.

class The class of weapon. (Conventional, Chemical/Biological, or Nuclear).
Where Used: AIRCRAFT_MISSION, WEAPON_CLASS, SAM_TYPE, SSM_TYPE.
Type: CHAR(4).
Values: CHEM, CONV, NUKE.

code Two letter abbreviation used with identifiers.
Where Used: ABBREVIATIONS, CODES.
Type: CHAR(2).
Values: AB, CY, DP, HX, OB, LU, MS, NB, PI, RD, RR, ST, SU, WL.

combat_power Combat power.
Where Used: LAND_UNIT.
Type: FLOAT(5.4)

command The air force command that operates an airbase.
Where Used: AIRBASE, DEPOT.
Type: CHAR(15).
Values: Examples: *USAFE, MAC, PACAF, SAC, TAC)*

common_name The Nato common name of a weapon or aircraft.
Where Used: AIRCRAFT_TYPE, A2A_WEAPONS, A2G_WEAPONS, LAND_COMPONENT_TYPE, SAM_TYPE, SSM_TYPE.
Type: CHAR(12).
Values: Example: *EAGLE, FOXBAT, SCUD.*

constant The name of a program constant or database constant.
Where Used: FLOAT_CONSTANTS, INTEGER_CONSTANTS.
Type: CHAR(20).

corps_id Corps identifier. The identifier of the corps land unit.
Where Used: LAND_UNIT.
Type: CHAR(8).
Values: LU000001-LU999999.
Composition: Same as unit_id. Two letter identifier 'LU' followed by a 6 digit number.
Reference: unit_id@LAND_UNIT. Each corps_id must appear as an unit_id in the LAND_UNIT relation.

country The country a ground hex is located in, or the country that owns a particular asset.
Where Used: AIRBASE, DEPOT, FORCES, HEX, LAND_UNIT.
Type: CHAR(4).
Values: NK (North Korea), SK (South Korea), USSR, USA, etc.

cpi Combat Power In. The firepower that is being projected into a particular ground level hex.
Where Used: HEX.
Type: FLOAT(5.4)
Values: Computed from units and weapons.

cpo Combat Power Out. The firepower that is being projected out of a particular ground level hex.
Where Used: HEX.
Type: FLOAT(5.4)
Values: Computed from units and weapons.

current_length The current length of a runway.
Where Used: RUNWAYS.
Type: INTEGER(8)
Values: 0–99,999 (meters).

cycle Attribute records whether a session period occurs during the day or during the night.
Where Used: CYCLE.
Type: CHAR(5).
Values: DAY, NIGHT.

day The session day.
Where Used: APPORTIONMENT, MOVE, MOVE_LNIT, STAGING_BASE, WEATHER.
Type: INTEGER(2).
Values: 0–99.
Alias: rqst_day on_target, actual_start_day, rqst_return_day, actual_return_day.

day_last_intelled The last day intelligence was performed on a unit.
Where Used: LAND_UNIT.
Type: INTEGER(2).
Values: 0–maxdays.

delay The time delay required by a satellite from the time of its launching to the time is operational in orbit. (days)
Where Used: SATELLITES.
Type: INTEGER(4).
Values: 0–365.

deliver_qty Deliver quantity. The quantity of a weapon that a supply train should deliver to its destination unit or airbase.
Where Used: SUPPLY_MOVEMENT.
Type: INTEGER(8).
Values: 0-99,999,999 (tons).

depot_id Unique identifier for a depot.
Where Used: DEPOT.
Type: CHAR(8).
Values: DP000001-DP009999.
Composition: Two letter identifier 'DP' followed by a 6 digit number. Depots are numbered sequentially.

designation The alphanumeric designation of a weapon type.
Where Used: AIRBASE_AIRCRAFT, AIRBASE_WEAPONS, AIRCRAFT_TYPE, A2A_WEAPONS, A2G_WEAPONS, CHEMICAL, CROSS_SERVICE, MAINTENANCE, NUCLEAR, PBL, P L, PNL, REFUEL_CAPACITY, SAM_TYPE, SSM_TYPE, SUPPLY_MOVEMENT, UNIT_COMPONENTS, UNIT_S2A, UNIT_S2S, VALID_AC_MISSIONS.
Type: CHAR(5).
Values: Example *F15A, EF111, SA-6, BMP.*
USED (cont.): AIRCRAFT PACKAGE, BASE_COMPONENT_TYPE, LAND_COMPONENT_TYPE, STAGING_BASE, WEAPONS_CLASS, WEAPONS_LOAD.
Source: TWX.

difficulty Difficulty level.
Where Used: HEXSIDE_ASSETS, RUNWAYS.
Type: CHAR(4).
Values: EXC, VG, GD, FAIR, POOR, VP (Excellent – Very Poor).

direction The current direction of travel.
Where Used: SATELLITES.
Type: CHAR(2).
Values: N, NE, SE, S, SW, NW (North, Northeast, etc.)

ec Electronic Countermeasure.
Where Used: HEX, AIRCRAFT_TYPE.
Type: INTEGER(8).
Values: 0-99.
Source: (8:page 164) EC.

enemy_mines The number of enemy mines that have been dropped on an airbase.
Where Used: AIRBASE, DEPOT.
Type: INTEGER(8).
Values: 0–99,999,999.

eng_vehicles The number of engineer vehicles.
Where Used: LAND_UNIT.
Type: INTEGER(8).
Values: 0-99,999,999.

engineers The number of engineers in a unit.
Where Used: LAND_UNIT.
Type: INTEGER(8).
Values: 0-99,999,999.

eod_crews The number of explosive ordinance crews at an airbase or depot.
Where Used: AIRBASE, DEPOT.
Type: INTEGER(8).
Values: 0–99,999,999.

fast_high Air Defense Artillery value for a fast moving attack aircraft with high probability, from Mann p. 138.
Where Used: SAM_TYPE.
Type: INTEGER(4).
Values: 0-9999.
Source: (22:page 138).

fast_low Air Defense Artillery value for a fast moving attack aircraft with low probability, from Mann p. 138.
Where Used: SAM_TYPE.
Type: INTEGER(4).
Values: 0-9999.
Source: (22:page 138).

firepower The firepower of a unit.
Where Used: LAND_COMPONENT_TYPE, LAND_UNIT.
Type: FLOAT(5.4)
Values: Computed from the weapons owned by a unit.

flow Boolean variable that describes whether traffic can flow along a railroad, road, or pipeline segment.
Where Used: RAILROADS, ROADS, PIPELINES.
Type: CHAR(3).
Values: NO, YES.

force The color designation of a player.
Where Used: AIRCRAFT_MISSION, APPORTIONMENT, A2A_WEAPONS, A2G_WEAPONS, FORCES, HEX, NUCLEAR, SAM_TYPE, SATELLITES, STAGING_BASE, SSM_TYPE, VISIBILITY.
Type: CHAR(7).
Values: RED, BLUE, NEUTRAL, etc.

forecast_fair The probability of having fair weather, expressed as a percentage.
Where Used: WEATHER.
Type: INTEGER(3)
Values: 0–100 (percent).

forecast_good The probability of having good weather, expressed as a percentage.
Where Used: WEATHER.
Type: INTEGER(3).
Values: 0–100 (percent).

forest The amount of forestation of a ground hex.
Where Used: HEX.
Type: INTEGER(1).
Values: 0–3.
Source : Topography Map.

from_airbase_id The asset_id of the airbase that is the source of inter-airbase aircraft movements.
Where Used: AC_MOVEMENT.
Type: CHAR(8).
Values: Same as airbase_id.
Alias: airbase_id@AIRBASE.

fuel_trucks The amount of fuel trucks in a land unit.
Where Used: LAND_UNIT.
Type: INTEGER(8).
Values: 0-99,999,999.

full_designator The full alphanumeric designation of weapon or land unit.
Where Used: A2A_WEAPONS, A2G_WEAPONS, AIRBASE, DEPOT, LAND_COMPONENT_TYPE, LAND_COMPONENT_TYPE, SAM_TYPE, SSM_TYPE, Type: CHAR(30).
Values: Example: *101 Mechanized Infantry Division.*
Source: TWX.

future_location The future location of an airbase.
Where Used: AIRBASE, DEPOT.
Type: CHAR(8).
Values: Same as hex_id.
Alias: hex_id, location.
Reference: hex_id@HEX.

grid_time The amount of time needed for a unit to finish crossing a ground hex at a time when a session ended.
Where Used: LAND_UNIT.
Type: FLOAT(5.4)

groundspeed The top speed that a land unit can move across a land hex.
Where Used: LAND_UNIT.
Type: INTEGER(4).
Values: 0-9999 (km/hr).

hardness The hardness of a target type.
Where Used: HARDNESS.
Type: CHAR(4).
Values: HARD, MED, SOFT.

hex_id Unique hex identifier.
Where Used: HEX, AIRHEX, TRAVEL, ROADS, RAILROADS, PIPELINES.
Type: CHAR(8).
Values: HX010000–HX079999
Alias: center_hex, location, orbit_location, rendezvous_hex.
Composition: Two letter identifier 'HX' followed by a 6 digit number. The first two digits are the hex level, 01 to 07. The second set of two digits are the X-coordinate index, and the last set of two digits are the Y-coordinate index.
Source: Topography map with hex grid overlay.

hexside The identifier which designates the side of a hex.
Where Used: PIPELINES, RAILROADS, ROADS, TRAVEL.
Type: CHAR(2).
Values: N, NE,SE, S, SW, NW (NORTH, NORTHEAST, etc.)

hq The command headquarters of an airbase.
Where Used: AIRBASE, AIRCRAFT_MISSION, DEPOT.
Type: CHAR(5).
Values: Examples: *10_AF, 15_AF.*

hw_resupply_pct Hardware resupply percent.
Where Used: LAND_UNIT.
Type: FLOAT(5.4)
Values: 0.0-100.0000

hw_usage_rate The amount of hardware used by a unit on a daily basis.
Where Used: LAND_COMPONENT_TYPE, LAND_UNIT.
Type: FLOAT(5.4)
Values: 0-99,999 (tons/day).
Source: (8:page 464) Divisional Daily Supply Requirements.

id Identifier. The 6 digit number used in 8 character identifiers.
Where Used: CODES.
Type: INTEGER(6).
Values: 1-999999.

in_use Boolean variable that describes whether a supply train is currently in use or not.
Where Used: SUPPLY_TRAIN.
Type: CHAR(3).
Values: NO, YES.

ineffective_reason The reason an aircraft mission was aborted or ineffective. (Abort, Preventive Maintenance, Jettisoned Weapons, and Weather).
Where Used: AIRCRAFT_MISSION.
Type: CHAR(4).
Values: ABRT, PMS, JETT, WX.

intel_filter Intelligence Filter. The amount of intelligence or reconnaissance information that accurately reaches a unit.
Where Used: LAND_UNIT.
Type: FLOAT(5.4).

intel_index Intelligence Index.
Where Used: HEX, LAND_UNIT, AIRBASE, DEPOT, SUPPLY_TRAIN.
Type: FLOAT(5.4)

launcher_qty The quantity of missile launchers for a particular missile.
Where Used: UNIT_S2A, UNIT_S2S.
Type: INTEGER(8).
Values: 0–99,999,999.

length The measure of the length of a object.
Where Used: AIRBASE, BASE_COMPONENT_TYPE, DEPOT, LAND_COMPONENT_TYPE, WEIGHT.
Type: INTEGER(8).
Values: 0-99,999,999 (meters).
Source: (3) Length; (35) Length

lethal_area The lethal blast radius of a surface-to-surface missile.
Where Used: SSM_TYPE.
Type: INTEGER(8).
Values: 0–99,999,999 (meters).
Source: (22:page 112) Lethal Area.

lethality The lethality of a chemical weapon.
Where Used: CHEMICAL.
Type: INTEGER(4).
Values: 0-9999.
Source: (8:page 416) Harass/Kill and Time to Take Effect value.

load_id Weapons load identifier.
Where Used: PBL, PCL, PNL, WEAPONS_LOAD.
Type: CHAR(8).
Values: WL000001–WL009999.
Composition: Two letter identifier 'WL' followed by a 6 digit number. Weapons loads are numbered sequentially.

loc_last_intelled The hex_id (location) of a land unit at the time it had any reconaissance performed on it.
Where Used: LAND_UNIT.
Type: CHAR(8).
Values: HX010000-HX019999.
Alias: hex_id.
Reference: hex_id@HEX.

location The identifier of the hex that an asset is located in.
Where Used: AIRBASE, CITY, DEPOT, LAND_UNIT, SATELLITES, SUPPLY_TRAIN.
Type: CHAR(8).
Values: HX010101-HX019999.
Alias: hex_id, center_hex, orbit_location, rendezvous_hex.
Two letter identifier 'HX' followed by a 6 digit number. The first two digits are 01 for hex level one. The second set of two digits are the X-coordinate index, and the last set of two digits are the Y-coordinate index.
Reference: hex_id.

loiter_time The length of time an aircraft can circle over a battle area, or the requested amount of time that an aircraft package should loiter over its target.
Where Used: AIRCRAFT_MISSION, AIRCRAFT_TYPE.
Type: INTEGER(4).
Values: 0-9999 (hours).

maint_equip Maintenance equipment located on an airbase.
Where Used: AIRBASE, DEPOT.
Type: INTEGER(8).
Values: 0–99,999,999.

maint_hrs_accum The number of maintenance hours accumulated at an airbase.
Where Used: AIRBASE, DEPOT.
Type: INTEGER(8).
Values: 0–99,999,999.

maint_personnel The number of maintenance personnel at an airbase to repair aircraft.
Where Used: AIRBASE, DEPOT.
Type: INTEGER(8).
Values: 0–99,999,999.

maint_time The maintenance time required by aircraft returning from a mission.
Where Used: MAINTENANCE.
Type: INTEGER(4).
Values: 0-9999 (hours).

maintain_dist Maintenance distribution type for an aircraft type.
Where Used: AIRCRAFT_TYPE.
Type: CHAR(10).
Values: NORMAL, POISSON, UNIFORM.

maintain_mean The mean (average) of the maintenance distribution.
Where Used: AIRCRAFT_TYPE.
Type: INTEGER(4).
Values: 0-99 (hours).

maintain_standev The standard deviation of the aircraft maintenance distribution.
Where Used: AIRCRAFT_TYPE.
Type: INTEGER(4).
Values: 0-99 (hours).

max_hex The maximum hex level (altitude) that an aircraft can fly in.
Where Used: AIRCRAFT_TYPE.
Type: INTEGER(2).
Values: 02–07.
Source: (15:pp 160–270) Normal operational ceiling.

max_length The original length of a runway.
Where Used: RUNWAYS.
Type: INTEGER(8).
Values: 0–99,999 (meters).

max_pol_hard The maximum amount of petroleum, oil, and lubricants (pol) that can be stored at an airbase or depot.
Where Used: AIRBASE, DEPOT.
Type: INTEGER(8).
Values: 0–99,999,999 (tons).

max_pol_soft The maximum amount of petroleum, oil, and lubricants (pol) that can be stored in soft storage at an airbase of depot.
Where Used: AIRBASE, DEPOT.
Type: INTEGER(8).
Values: 0–99,999,999 (tons).

max_ramp_space The maximum ramp space at an airbase for parking aircraft.
Where Used: AIRBASE, DEPOT.
Type: INTEGER(8).
Values: 0-99,999,999.
Source: TWX.

max_range The maximum range a surface to surface missile can fly.
Where Used: SSM_TYPE.
Type: INTEGER(8).
Values: 0–99,999,999 (km).
Source: (18) Max Range.

max_speed The maximum speed an aircraft can fly. (km/hr)
Where Used: AIRCRAFT_TYPE.
Type: INTEGER(8).
Values: 0–00009999 (km/hr).
Source: (8:page 164) Max Speed.

min_range The minimum effective range that a surface to surface missile can be used to hit a target. (kilometers) Where Used: SSM_TYPE.
Type: INTEGER(8).
Values: 0–99,999,999 (km).
Source: (18) Min Range.

min_runway The minimum runway length needed by an aircraft type to take off and fly a mission.
Where Used: AIRCRAFT_TYPE.
Type: INTEGER(8).
Values: 0-99,999 (meters).

missile_qty The quantity of a particular missile designation.
Where Used: UNIT_S2A, UNIT_S2S.
Type: INTEGER(8).
Values: 0–99,999,999.

mission_id Unique aircraft mission identifier.
Where Used: AIRCRAFT_MISSION, AIRCRAFT_PACKAGE, TARGETS.
Type: CHAR(8).
Values: MS000001–MS009999.
Composition: Two letter identifier 'MS' followed by a 6 digit number. Aircraft missions are numbered sequentially.

mission_type The primary aircraft mission type.
Where Used: AIRCRAFT_MISSION, PBL, PCL, PNL.
Type: CHAR(8).
Values: AI, BAI, CAP, CAS, C2, DCA, EC, MISSILE, OCA, RECCE, RESERVE, SAT, SEAD.

mopp_posture Mopp posture.
Where Used: AIRBASE, DEPOT, LAND_UNIT.
Type: INTEGER(1).
Values: 0-4.

msn_eff_day Mission effectiveness day - the day that a land unit becomes active in a given session.
Where Used: LAND_UNIT.
Type: INTEGER(2).
Values: 0-max_periods.

name Descriptive name of an asset.
Where Used: CHEMICAL, PIPELINES, RAILROADS, ROADS, SATELLITES.
Type: CHAR(12).
Values: *Route_1, I-675.*

neighbor_id Unique hexside label that identifies the common border between two ground hexes.
Where Used: BORDERS, COASTS, FEBA, RIVERS, TRAVEL.
Type: CHAR(8).
Values: NB000001-NB999999.
Two letter identifier 'NB' followed by a 6 digit number. The hex borders are numbered sequentially starting with 1.

night_capability The percentage of an aircraft's full capability that can be used at night.
Where Used: AIRCRAFT_TYPE.
Type: FLOAT(5.4)
Values: 0.00-100.00 (percent).
Source: TWX.

obstacle A hex border obstacle.
Where Used: HEXSIDE_ASSETS.
Type: CHAR(9).
Values: BRIDGE, IMPASS, LOGISTICS, MINE, MMADE.

obstacle_id Unique label for a hex border obstacle. The obstacle type, such as BRIDGE or MINEFIELD, is found in the obstacle attribute.
Where Used: HEXSIDE_ASSETS.
Type: CHAR(8).
Values: OB000001-OB999999.
Two letter identifier 'OB' followed by a 6 digit number. Obstacles are numbered sequentially from 1.

orbit Satellite orbit type (Geosynchronous or Geostationary).
Where Used: SATELLITES.
Type: CHAR(10).
Values: GEOSTATION, GEOSYNCH.

orbit_location The air hex location that an aircraft mission should center its orbit in.
Where Used: AIRCRAFT_MISSION.
Type: CHAR(8).
Values: Same as hex_id@AIRHEX.
Alias: hex_id @ AIRHEX.

order_id Land movement order identifier.
Where Used: MOVE, MOVE_LNLT, SUPPLY_MOVEMENT.
Type: CHAR(8).
Values: OR000001-OR009999.
Composition: Two letter identifier 'OR' followed by a 6 digit number. Orders are numbered sequentially.

parent_unit The identifier of the parent land unit.
Where Used: LAND_UNIT.
Type: CHAR(8).
Values: LU00001-LU999999.
Alias: UNIT_ID, CORPS_ID.
Composition: Same as unit_id. Two letter identifier 'LU' followed by a 6 digit number.
Reference: unit_id@LAND_UNIT. - All parent units must be found as a unit_id in the LAND_UNIT relation.

percent The percentage of support one unit gives another.
Where Used: UNIT_SUPPORTS.
Type: FLOAT(5.4)
Values: 0.0–100.0000 (percent)

period The session period.
Where Used: APPORTIONMENT, CYCLE, MOVE, MOVE_LNLT.
Type: INTEGER(2).
Values: 1-24.
Alias: actual_start_prd, actual_return_prd, rqst_prd_on_targ, rqst_return_prd.

persistence_time The remaining time a hex feels the effects of a nuclear or a chemical weapons attack.
Where Used: AIRHEX, CHEMICAL, HEX, NUCLEAR.
Type: INTEGER(4).
Values: 0-9999 (hours).

pie_trafficability The difficulty of travel between the center of a ground hex and a hex side.
Where Used: TRAVEL.
Type: CHAR(4).
Values: EXC, VG, GD, FAIR, POOR, VP (Excellent - Very Poor).

pipeline_id Unique identifier for a pipeline segment.
Where Used: PIPELINES.
Type: CHAR(8).
Values: PI000001-PI999999.
Composition: Two letter identifier 'PI' followed by a 6 digit number. The pipeline segments are numbered sequentially.

pk_hard The probability of destroying a hardened target with a direct hit.
Where Used: A2G_WEAPONS, SSM_TYPE.
Type: FLOAT(5.4)
Values: 0.0–100.0 (percent).
Source: (22:page 112) PK Hard.

pk_med The probability of destroying a medium-hardened target with a direct hit.
Where Used: A2G_WEAPONS, SSM_TYPE.
Type: FLOAT(5.4)
Values: 0.0–100.0 (percent).
Source: (22:page 112) PK Med.

pk_soft The probability of destroying an unhardened target with a direct hit.
Where Used: A2G_WEAPONS, SSM_TYPE.
Type: FLOAT(5.4)
Values: 0.0–100.0 (percent).
Source: (22:page 112) PK Soft.

pol_hard_store The amount of petroleum, oil, and lubricants in hardened storage.
Where Used: AIRBASE, DEPOT.
Type: INTEGER(8).
Values: 0–99,999,999 (tons).

pol_resupply_pct Petroleum, oil, and resupply percentage.
Where Used. LAND_UNIT.
Type: FLOAT(5.4)
Values: 0.0 -100.0 (percent).

pol_soft_store The amount of petroleum, oil, and lubricants in soft storage.
Where Used: AIRBASE, DEPOT.
Type: INTEGER(8).
Values: 0–99,999,999 (tons).

pol_usage_rate The amount of total_pol (petroleum, oil, and lubricants) that a unit used during a day.
Where Used: AIRCRAFT_TYPE, LAND_COMPONENT_TYPE, LAND_UNIT.
Type: FLOAT(5.4)
Values: 0.0-99999.9999 (tons/day)

population The population of a city.
Where Used: CITY.
Type: INTEGER(8).
Values: 0-99,999,999.

prd_last_intelled The last session period that intelligence was performed on a unit.
Where Used: LAND_UNIT.
Type: INTEGER(2).
Values: 0–max_periods.

priority Aircraft mission priority.
Where Used: AIRCRAFT_MISSION.
Type: INTEGER(4).
Values: 0–9999.

product The product carried by a pipeline.
Where Used: PIPELINES.
Type: CHAR(12).
Values: OIL, WATER, etc.

projected Projected apportionment of aircraft.
Where Used: APPORTIONMENT.
Type: INTEGER(8).
Values: 0–99,999,999.

quality The quality of a radar system.
Where Used: RADARS.
Type: FLOAT(5.4)
Values: 0–2.0

quantity Quantity.
Where Used: AC_MOVEMENT, MAINTENANCE, RADARS, STAGING_BASE.
Type: INTEGER(8).
Values: 0–99,999,999.

radar2 The ability of a surface-to-air missile radar system to acquire and track targets flying in air hex level 2.
Where Used: SAM_TYPE.
Type: INTEGER(8).
Values: 0–99,999,999.

radar3 The ability of a surface-to-air missile radar system to acquire and track targets flying in air hex level 3.
Where Used: SAM_TYPE.
Type: INTEGER(8).
Values: 0–99,999,999.

radar4 The ability of a surface-to-air missile radar system to acquire and track targets flying in air hex level 4.
Where Used: SAM_TYPE.
Type: INTEGER(8).
Values: 0–99,999,999.

radar5 The ability of a surface-to-air missile radar system to acquire and track targets flying in air hex level 5.
Where Used: SAM_TYPE.
Type: INTEGER(8).
Values: 0–99,999,999.

radar6 The ability of a surface-to-air missile radar system to acquire and track targets flying in air hex level 6.
Where Used: SAM_TYPE.
Type: INTEGER(8).
Values: 0–99,999,999.

radar7 The ability of a surface-to-air missile radar system to acquire and track targets flying in air hex level 7.
Where Used: SAM_TYPE.
Type: INTEGER(8).
Values: 0–99,999,999.

radar_type The type of radar used with surface to air missile systems. (Acquisition or Radar Fire Control).
Where Used: RADARS.
Type: CHAR(3).
Values: ACQ, RFC.

radius The maximum distance an aircraft can fly unrefueled in AIRCRAFT_TYPE, and the explosive radius of an air-to-ground weapon on A2G_WEAPONS.
Where Used: AIRCRAFT_TYPE, A2G_WEAPONS.
Type: INTEGER(8).
Values: 0-99,999
Source: (15:pp 160–270) Normal unrefuel range – Aircraft Type.

railroad_id Unique identifier of a railroad seqment.
Where Used: RAILROADS.
Type: CHAR(8).
Values: RR000001-RR999999.
Composition: Two letter identifier 'RR' followed by a 6 digit number. The railroad segments are numbered sequentially.

ramp_avail The amount of ramp space currently available at an airbase.
Where Used: AIRBASE, DEPOT.
Type: INTEGER(8).
Values: 0–99,999,999.
Source: TWX.

ramp_space The amount of ramp space taken up by an aircraft type.
Where Used: AIRCRAFT_TYPE.
Type: INTEGER(8).
Values: 0–9999
Source: TWX.

range The range of an air-to-air missile.
Where Used: A2A_WEAPONS.
Type: INTEGER(8).
Values: 0–99,999,999 (km).
Source: (8:page 174) Range.

range2 The range of a surface-to-air missile that is fired at a target flying in air hex level 2.
Where Used: SAM_TYPE.
Type: INTEGER(8).
Values: 0-99,999,999 (km).
Source: (8:page 174) Range value adjusted using trigonometry.

range3 The range of a surface-to-air missile that is fired at a target flying in air hex level 3.
Where Used: SAM_TYPE.
Type: INTEGER(8).
Values: 0-99,999,999 (km).
Source: (8:page 174) Range value adjusted using trigonometry.

range4 The range of a surface-to-air missile that is fired at a target flying in air hex level 4.
Where Used: SAM_TYPE.
Type: INTEGER(8).
Values: 0-99,999,999 (km).
Source: (8:page 174) Range value adjusted using trigonometry.

range5 The range of a surface-to-air missile that is fired at a target flying in air hex level 5.
Where Used: SAM_TYPE.
Type: INTEGER(8).
Values: 0-99,999,999 (km).
Source: (8:page 174) Range value adjusted using trigonometry.

range6 The range of a surface-to-air missile that is fired at a target flying in air hex level 6.
Where Used: SAM_TYPE.
Type: INTEGER(8).
Values: 0-99,999,999 (km).
Source: (8:page 174) Range value adjusted using trigonometry.

range7 The range of a surface-to-air missile that is fired at a target flying in air hex level 7.
Where Used: SAM_TYPE.
Type: INTEGER(8).
Values: 0-99,999,999 (km).
Source: (8:page 174) Range value adjusted using trigonometry.

recon_ability The reconaissance ability of an aircraft.
Where Used: AIRCRAFT_TYPE.
Type: FLOAT(5.4)
Values: 0-100.00

refuelable Boolean variable which indicates whether an aircraft type can be refueled in flight.
Where Used: AIRCRAFT_TYPE.
Type: CHAR(3).
Values: NO, YES.

region The region of a hex that a land unit is located in.
Where Used: LAND_UNIT.
Type: CHAR(6).
Values: CENTER, BORDER.

relation The relation table name that contains the type information for a particular weapon.
Where Used: WEAPONS_CLASS.
Type: CHAR(20).
Values: A2A_WEAPONS, A2G_WEAPONS, CHEMICAL, NUCLEAR, SAM_TYPE, SSM_TYPE, COMPONENT_TYPE.

reload_time The minimum time necessary to reload a missile launcher after a missile has been fired.
Where Used: SAM_TYPE, SSM_TYPE.
Type: INTEGER(4).
Values: 0–9999 .

rendezvous_hex The air hex that the aircraft flying a combined mission come together at.
Where Used: AIRCRAFT_MISSION.
Type: CHAR(8).
Values: Example: *HX030452*.
Alias: hex_id@AIRHEX.
Composition: Same as hex_id@AIRHEX.
Reference: hex_id@AIRHEX.

requested_ac The quantity of an aircraft type that the user has requested to fly in an aircraft mission.
Where Used: AIRCRAFT_PACKAGE.
Type: INTEGER(8).
Values: 0-99,999,999.

river_size The width of a river segment.
Where Used: RIVERS.
Type: CHAR(6).
Values: RIVER, STREAM.

rnds_per_launcher Missile rounds per launcher. The number of missile rounds that are normally loaded on a single launching platform.
Where Used: SAM_TYPE, SSM_TYPE.
Type: INTEGER(4).
Values: 0-9999.
Source: (8:page 190) Missiles Barrels.

road_id Unique identifier of road segment.
Where Used: ROADS.
Type: CHAR(8). Values: RD000001-RD999999.
Composition: Two letter identifier 'RD' followed by a 6 digit number. The road segments are numbered sequentially.

road_size The width of a road_segment.
Where Used: ROADS.
Type: CHAR(7).
Values: HIGHWAY, ROAD.

rqst_day_on_targ The requested day that an aircraft mission should hit its target.
Where Used: AIRCRAFT_MISSION.
Type: INTEGER(2).
Values: 0–num_days.

rqst_prd_on_targ The requested period that an aircraft mission should hit its target.
Where Used: AIRCRAFT_MISSION.
Type: INTEGER(2).
Values: 0–num_periods.

rqst_return_day The requested day that an aircraft mission should return to its airbase.
Where Used: AIRCRAFT_MISSION.
Type: INTEGER(2).
Values: 0–num_days.

rqst_return_prd The requested period that an aircraft mission should return to its airbase.
Where Used: AIRCRAFT_MISSION.
Type: INTEGER(2).
Values: 0–num_periods.

rrr_crews The number of rapid runway repair crews available at an airbase.
Where Used: AIRBASE, DEPOT.
Type: INTEGER(8).
Values: 0–99,999,999.

runway The runway identifier at an airbase.
Where Used: RUNWAYS.
Type: INTEGER(2).
Values: 0-99.

sat_type Satellite type.
Where Used: SATELLITES.
Type: CHAR(4).
Values: ASAT, NAV.

satellite_id Unique identifier for a satellite. Every satellite is individually tracked.
Where Used: SATELLITES.
Type: CHAR(8).
Values: ST000001-ST009999.
Composition: Two letter identifier 'ST' followed by a 6 digit number. Satellites are numbered sequentially.

search The diameter of the sensor's detection area in kilometers.
Where Used: AIRCRAFT_TYPE.
Type: INTEGER(8).
Values: 0-99,999,999 (km).
Source: (22:page 110) Search.

service_type The types of aircraft services supported at an airbase.
Where Used: CROSS_SERVICE.
Type: CHAR(1).
Values: B, C, N.
Source: TWX.

shelters The number of shelters at an airbase or depot.
Where Used: AIRBASE, DEPOT.
Type: INTEGER(8).
Values: 0–99,999,999.

slow_high Air Defense Artillery value for a slow moving attack aircraft with high probability, from Mann p. 138.
Where Used: SAM_TYPE.
Type: INTEGER(4).
Values: 0-9999. Source: (22:page 137).

slow_low Air Defense Artillery value for a slow moving attack aircraft with low probability, from Mann p. 138.
Where Used: SAM_TYPE.
Type: INTEGER(4).
Values: 0-9999. Source: (22:page 137).

sorties_week Maximum aircraft sorties that can be flown by an aircraft per week.
Where Used: AIRCRAFT_TYPE.
Type: INTEGER(8).
Values: 0–99,999,999 (sorties/week).
Source: TWX; (8:page 164) Srt Capability Ratings.

spare_parts The amount of spare airplane parts at an airbase, or the number of spare parts required by an aircraft type.
Where Used: AIRBASE, AIRCRAFT_TYPE, DEPOT, SUPPLY_TRAIN.
Type: INTEGER(8).
Values: 0–99,999,999 (tons).
Source: TWX.

speed The speed of a satellite.
Where Used: SATELLITES.
Type: INTEGER(8).
Values: 0–99,999,999 (km/hr).

sspk Single shot probability of a kill.
Where Used: A2A_WEAPONS, SAM_TYPE.
Type: FLOAT(5.4)
Values: 0.0–100.0 (percent).
Source: (8:page 190) Effectiveness; (22:page 112) PK Air.

start_time The maintenance start time for aircraft that have returned from a mission.
Where Used: MAINTENANCE.
Type: INTEGER(4).
Values: 0–9999.

status The status of asset.
Where Used: AIRBASE, DEPOT, LAND_UNIT, SATELLITE.
Type: CHAR(7).
Values: ACTIVE, GROUND, INACTIVE, OVERRUN.

supply_type Supply train type. Predirect supply trains (PST) can be used multiple times, whereas the assets of a regular supply train (ST) become part of the unit that is being supplied. ST type trains get absorbed (disappear) into the unit they are supplying.
Where Used: SUPPLY_TRAIN.
Type: CHAR(3).
Values: PST, ST.

symbol The full length description of the two letter character code used with identifiers.
Where Used: ABBREVIATIONS.
Type: CHAR(12).
Values: AIRBASE, CITY, DEPOT, HEX, OBSTACLE, LAND_UNIT, MISSION, NEIGHBOR, PIPELINE, ROAD, RAILROAD, SATELLITE, SEA_UNIT, WEAPONS_LOAD.

target_id The unique identifier of a target. This could be a hex_id or an asset identifier.
Where Used: MOVE, MOVE_LNLT, SUPPLY_MOVEMENT, TARGETS.
Type: CHAR(8).
Composition: Two letter identifier followed by a 6 digit number.
Reference: hex_id, unit_id, airbase_id, depot_id, obstacle_id, city_id, pipeline_id, railroad_id, road_id.

target_type The alphanumeric description of a target.
Where Used: HARDNESS.
Type: CHAR(15).
Values: Examples: *AIRBASE, AIRCRAFT, HARD_STORE*

target_wgt Target weight.
Where Used: BASE_COMPONENT_TYPE, LAND_COMPONENT_TYPE.
Type: INTEGER(8).
Values: 0–99,999,999.
(22:page 158)

terrain The terrain of a ground hex.
Where Used: HEX.
Type: CHAR(8).
Values: DESERT, GREEN, HILL, MOUNTAIN, OCEAN.
Source: Topography map with hex grid overlay.

to_airbase_id The asset_id of the airbase that is the destination of inter-airbase aircraft movements.
Where Used: AC_MOVEMENT.
Type: CHAR(8).
Values: Same as airbase_id.
Alias: airbase_id@AIRBASE.

total_ammo Total ammunition.
Where Used: LAND_UNIT, SUPPLY_TRAIN.
Type: INTEGER(8).
Values: 0-99,999,999 (tons).

total_hardware The amount of hardware.
Where Used: LAND_UNIT, SUPPLY_TRAIN.
Type: INTEGER(8).
Values: 0-99,999,999 (tons).

total_pol The total amount of petroleum, oil, and lubricants.
Where Used: LAND_UNIT, SUPPLY_TRAIN.
Type: INTEGER(8).
Values: 0–99,999,999 (tons).

trafficability The trafficability of an airhex. Mountains or obstacles extending up into an airhex are used to add a time delay penalty to aircraft flying through a hex. The lower the trafficability, the longer the delay.
Where Used: AIRHEX.
Type: CHAR(4).
Values: EXC, VG, GOOD, FAIR, POOR, VP (Excellent - Very Poor).

trans_mode Supply train transportation mode (AIRCRAFT, TRAIN, or TRUCK).
Where Used: SUPPLY_TRAIN.
Type: CHAR(8).
Values: AIRCRAFT, TRAIN, TRUCK.

troop_quality The experience, leadership, and fighting skill of a land unit.
Where Used: LAND_UNIT.
Type: INTEGER(4).
Values: 0-9999.

unit_id Unique identifier for a land unit.
Where Used: LAND_UNIT, MOVE, MOVE_LNLT, RADARS, SUPPLY_MOVEMENT, SUPPLY_TRAI UNIT_COMPONENTS, UNIT_S2A, UNIT_S2S, UNIT_SUPPORTS.
Type: CHAR(8)
Values: LU000001-LU999999.
Alias: Target_id@MOVE, Target_id@MOVE_LNLT, unit_supported_id@UNIT_SUPPORTS.
Composition: Two letter identifier 'LU' followed by a 6 digit number. Land units are numbered sequentially.

unit_size The size of land unit.
Where Used: LAND_UNIT.
Type: INTEGER(8).
Values: 0-999999.

unit_supported_id The unit_id of a unit that is supported by another land unit.
Where Used: UNIT_SUPPORTS.
Type: CHAR(8).
Values: same as unit_id.
Alias: unit_id@LAND_UNIT.
Composition: Same as unit_id.
Reference: unit_id@LAND_UNIT.

unit_type Land unit type description.
Where Used: LAND_UNIT.
Type: CHAR(5).
Values: ADA, ADACO, ADAHQ, ADARG, AF, ARM, AVN, C3, CAV, DEPOT, ENG, FA, FABA, FABR, INF, INFBR, INFDV, MI, MIBR, MIDV, SF, SPT, SHIP, UNK.

units The unit of measure used in constants.
Where Used: FLOAT_CONSTANTS, INTEGER_CONSTANTS.
Type: CHAR(20).
Values: Example: *km/hr* (for speed).

urban Urbanization – The size of city.
Where Used: CITY.
Type: INTEGER(1).
Values: 1–3 (Town – Metropolis).

value The numeric value of a constant.
Where Used: FLOAT_CONSTANTS, INTEGER_CONSTANTS.
Type: FLOAT(5.4), INTEGER(8).

vehicle Vehicle Type. Where Used: CARGO_CAPACITY.
Type: CHAR(12).
Values: AMMO_TRAIN, AMMO_TRUCK, FUEL_TRAIN, FUEL_TRUCK, WATER_TRAIN, WATER_TRUCK.

vis_to_enemy Visibility to the enemy. Boolean field which describes whether an asset will appear on the computer of a player that is not the player which owns the particular asset. An R indicates the asset will appear on red computers, and a *B* for Blue computers.
Where Used: HEXSIDE_ASSETS, LAND_UNIT, AIRBASE, DEPOT.
Type: CHAR(8).
Values: Example *RBXXXXXX*. (An *X* indicates the asset is not visible to the color that corresponds to the position in the string.

water The amount of water owned by a particular unit.
Where Used: LAND_UNIT.
Type: INTEGER(8).
Values: 0-99,999,999 (tons).

water_percent The percentage of water used by a unit on a daily basis.
Where Used: LAND_UNIT.
Type: FLOAT(5.4)
Values: 0.0-100.0 (percent).

water_trucks The number of water trucks owned by a unit.
Where Used: LAND_UNIT.
Type: INTEGER(8).
Values: 0-99,999,999.

weapon_count The number of weapons. Where Used: AIRBASE_AIRCRAFT, AIRBASE_WEAPONS, UNIT_COMPONENTS, WEAPONS_LOAD.
Type: INTEGER(8).
Values: 0–99,999,999.

weather_minimum The minimum amount of weather necessary at an airbase in order to fly any missions with planes that would originate from that airbase.
Where Used: AIRBASE, DEPOT.
Type: CHAR(4).
Values: EXC, VG, GD, FAIR, POOR, VP.
Reference: actual_wx@WEATHER.

width The width of an object.
Where Used: AIRBASE, BASE_COMPONENT_TYPE, DEPOT, LAND_COMPONENT_TYPE, WEIGHT.
Type: INTEGER(8).
Values: 0-99,999,999 (meters).

wx Weather condition. The weather condition that occurs at the target location.
Where Used: PBL, PCL, PNL.
Type: CHAR(4).
Values: FAIR, GD, POOR.

wx_capability The minimum weather conditions that an aircraft type can fly a mission in.
Where Used: AIRCRAFT_TYPE.
Type: CHAR(4).
Values: EXC, VG, GD, FAIR, POOR, VP (Excellent - Very Poor).

wx_period The weather period. The weather period is the smallest period of time in which weather conditions are tracked. The wx_period is a multiple of the session period.
Where Used: WEATHER.
Type: INTEGER(2).
Values: 0-99.

wz Weather zone.
Where Used: WEATHER.
Type: INTEGER(4).
Values: 1-9999.

yield The yield of a nuclear weapon (Megatons).
Where Used: NUCLEAR.
Type: INTEGER(4).
Values: 0-9999 (kilotons).
Source: (8:page 440) Warhead Yeild.

Appendix C. *Saber Upload Flat Files to Oracle Program*

This program takes ASCII flat files, strips of any header lines, removes blank lines, and then imports the data into the Saber DBMS.

```
#!/bin/sh
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" hex.dat                > hex.two
sqlload saber/saber hex
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" airhex.dat             > airhex.two
sqlload saber/saber airhex
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" visibility.dat         > visibility.two
sqlload saber/saber visibility
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" travel.dat             > travel.two
sqlload saber/saber travel
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" hexside_assets.dat     > hexside_assets.two
sqlload saber/saber hexside_assets
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" feba.dat               > feba.two
sqlload saber/saber feba
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" borders.dat            > borders.two
sqlload saber/saber borders
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" coasts.dat             > coasts.two
sqlload saber/saber coasts
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" rivers.dat             > rivers.two
sqlload saber/saber rivers
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" abbreviations.dat      > abbreviations.two
sqlload saber/saber abbreviations
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" codes.dat              > codes.two
sqlload saber/saber codes
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" roads.dat              > roads.two
sqlload saber/saber roads
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" railroads.dat          > railroads.two
sqlload saber/saber railroads
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" pipelines.dat          > pipelines.two
sqlload saber/saber pipelines
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" land_unit.dat          > land_unit.two
sqlload saber/saber land_unit
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" unit_supports.dat      > unit_supports.two
sqlload saber/saber unit_supports
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" cargo_capacity.dat     > cargo_capacity.two
sqlload saber/saber cargo_capacity
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" move.dat               > move.two
sqlload saber/saber move
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" move_lnlt.dat          > move_lnlt.two
sqlload saber/saber move_lnlt
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" airbase.dat            > airbase.two
sqlload saber/saber airbase
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" depot.dat              > depot.two
sqlload saber/saber depot
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" runways.dat            > runways.two
```

```
sqlload saber/saber runways
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" cross_service.dat       > cross_service.two
sqlload saber/saber cross_service
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" alternate_bases.dat     > alternate_bases.two
sqlload saber/saber alternate_bases
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" hardness.dat            > hardness.two
sqlload saber/saber hardness
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" land_component_type.dat > land_component_type.two
sqlload saber/saber land_component_type
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" base_component_type.dat > base_component_type.two
sqlload saber/saber base_component_type
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" airbase_aircraft.dat    > airbase_aircraft.two
sqlload saber/saber airbase_aircraft
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" airbase_weapons.dat     > airbase_weapons.two
sqlload saber/saber airbase_weapons
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" unit_s2a.dat            > unit_s2a.two
sqlload saber/saber unit_s2a
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" unit_s2s.dat            > unit_s2s.two
sqlload saber/saber unit_s2s
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" unit_components.dat     > unit_components.two
sqlload saber/saber unit_components
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" weather.dat             > weather.two
sqlload saber/saber weather
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" city.dat                > city.two
sqlload saber/saber city
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" aircraft_type.dat       > aircraft_type.two
sqlload saber/saber aircraft_type
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" refuel_capacity.dat     > refuel_capacity.two
sqlload saber/saber refuel_capacity
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" ssm_type.dat            > ssm_type.two
sqlload saber/saber ssm_type
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" radars.dat              > radars.two
sqlload saber/saber radars
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" sam_type.dat            > sam_type.two
sqlload saber/saber sam_type
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" supply_train.dat        > supply_train.two
sqlload saber/saber supply_train
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" supply_movement.dat     > supply_movement.two
sqlload saber/saber supply_movement
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" aircraft_mission.dat    > aircraft_mission.two
sqlload saber/saber aircraft_mission
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" aircraft_package.dat    > aircraft_package.two
sqlload saber/saber aircraft_package
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" targets.dat             > targets.two
sqlload saber/saber targets
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" maintenance.dat         > maintenance.two
sqlload saber/saber maintenance
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" weapons_class.dat       > weapons_class.two
sqlload saber/saber weapons_class
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" a2a_weapons.dat         > a2a_weapons.two
sqlload saber/saber a2a_weapons
```

```
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" a2g_weapons.dat        > a2g_weapons.two
sqlload saber/saber a2g_weapons
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" pcl.dat               > pcl.two
sqlload saber/saber pcl
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" pbl.dat               > pbl.two
sqlload saber/saber pbl
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" pnl.dat               > pnl.two
sqlload saber/saber pnl
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" weapons_load.dat      > weapons_load.two
sqlload saber/saber weapons_load
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" satellites.dat        > satellites.two
sqlload saber/saber satellites
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" apportionment.dat     > apportionment.two
sqlload saber/saber apportionment
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" chemical.dat          > chemical.two
sqlload saber/saber chemical
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" nuclear.dat           > nuclear.two
sqlload saber/saber nuclear
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" forces.dat            > forces.two
sqlload saber/saber forces
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" integer_constants.dat > integer_constants.two
sqlload saber/saber integer_constants
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" float_constants.dat   > float_constants.two
sqlload saber/saber float_constants
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" cycle.dat             > cycle.two
sqlload saber/saber cycle
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" valid_ac_missions.dat > valid_ac_missions.two
sqlload saber/saber valid_ac_missions
sed -e "/.dat/d" -e "/^[ ]*$/d" -e "/[a-z]/d" staging_base.dat      > staging_base.two
sqlload saber/saber staging_base
rm *.two
```

Appendix D. *Saber User Interface Input Screens*

This Appendix contains the design of a user interface screen developed for the four areas of input in the Saber wargame.

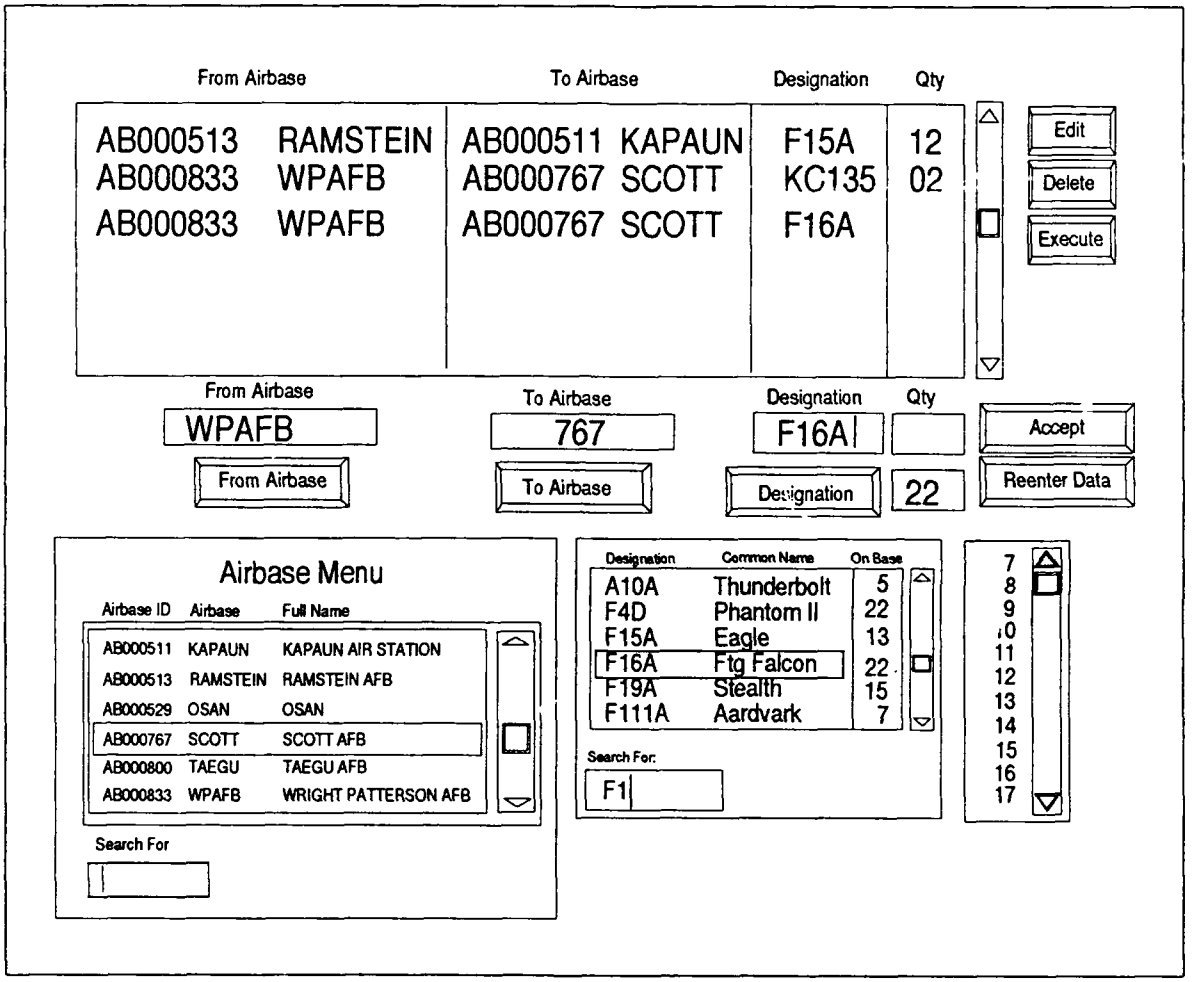

Figure 29. Aircraft Movement Data Entry Template

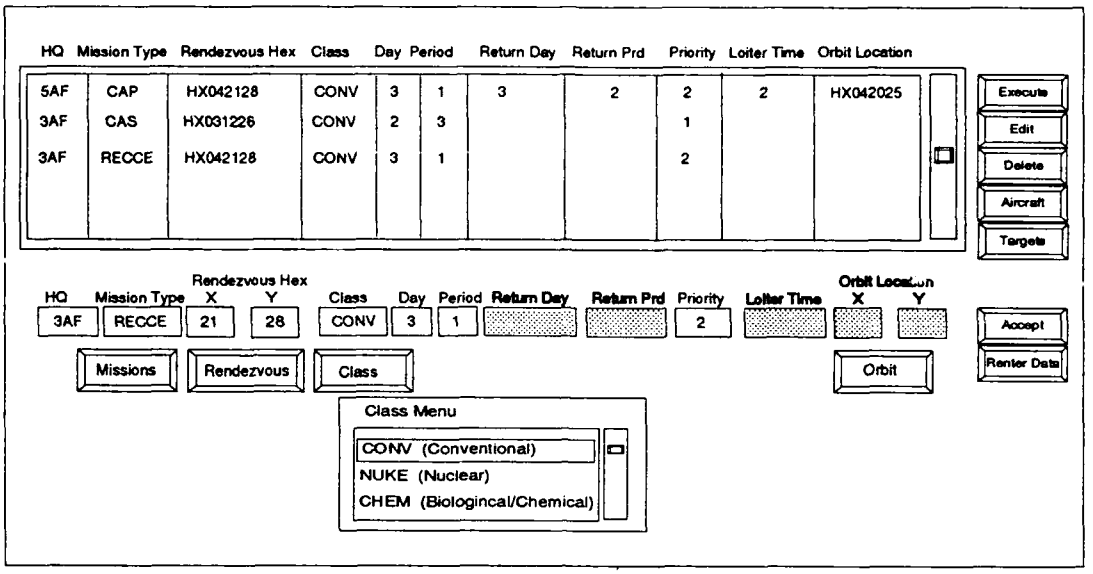

Figure 30. Aircraft Mission Interface Screen

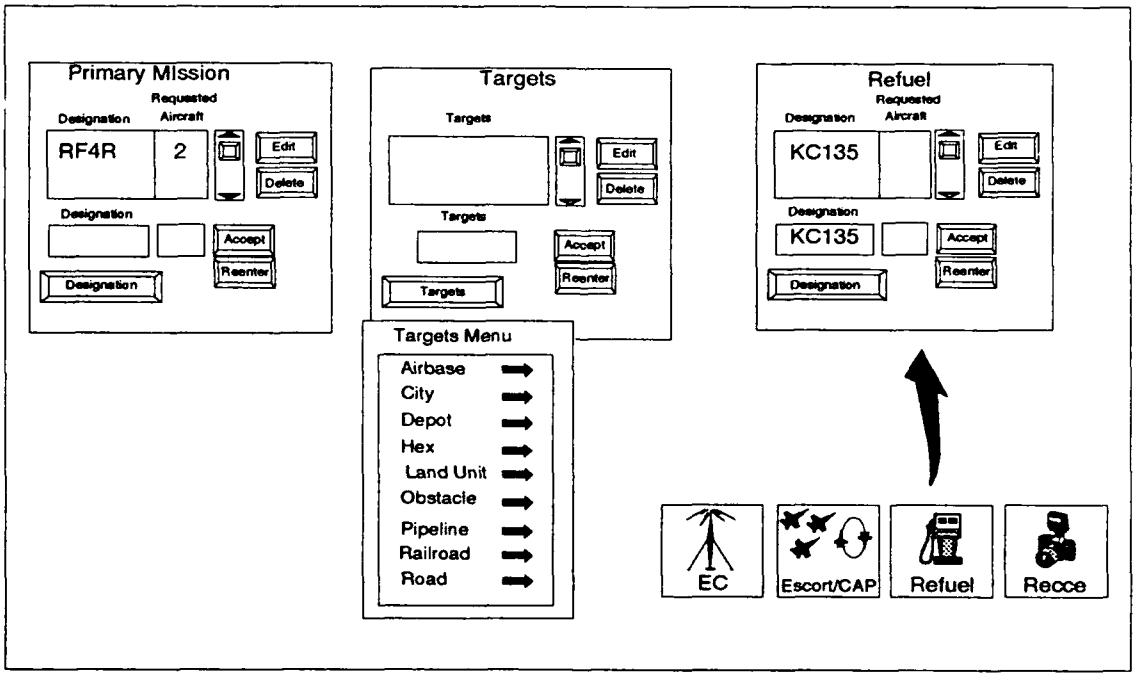

Figure 31. Aircraft Package and Targets Interface Screen

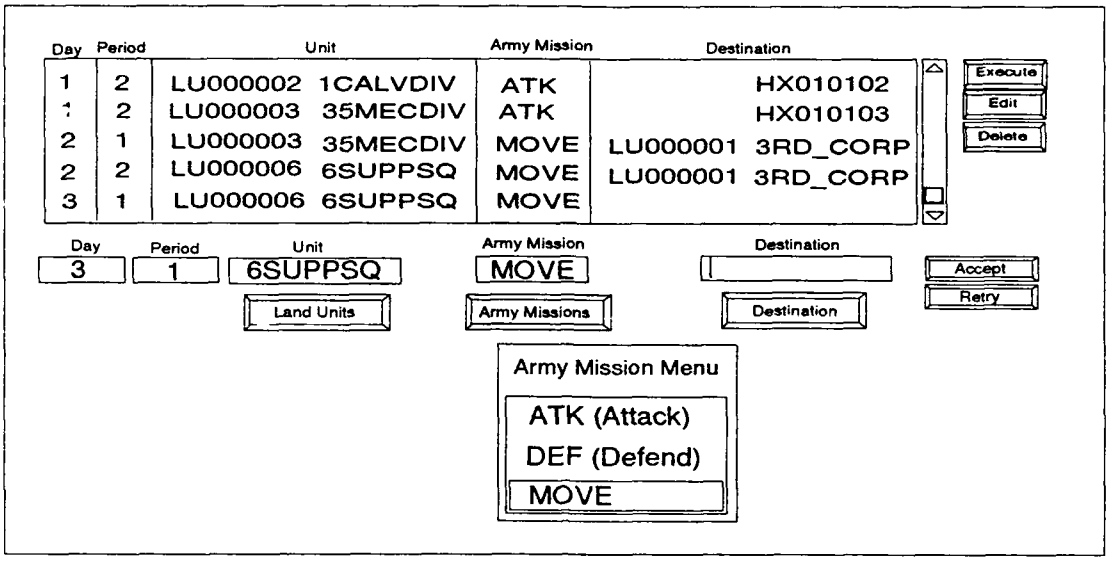

Figure 32. Land Unit Movement Interface Screen

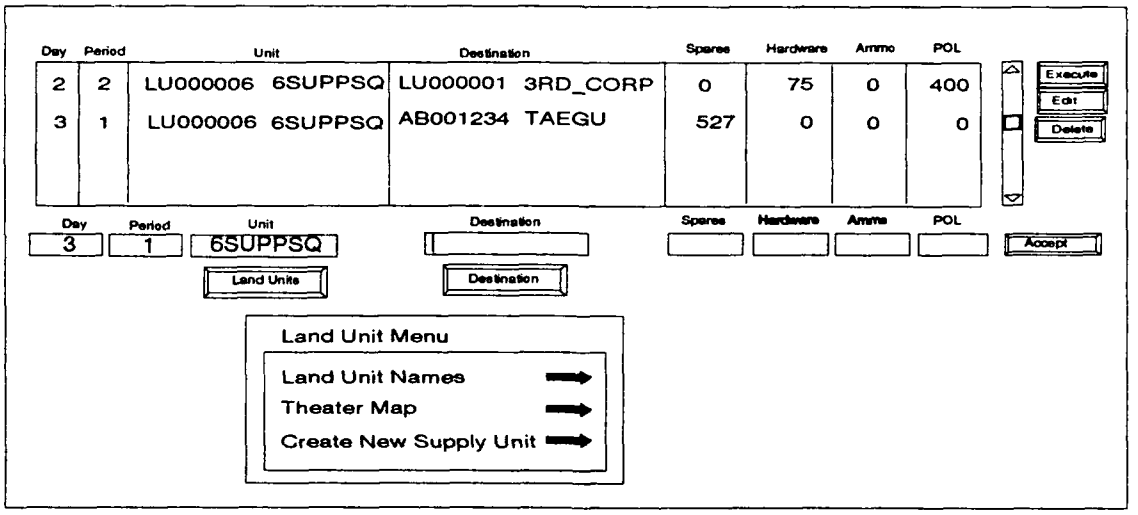

Figure 33. Supply Movement Interface Screen

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December 1991 Master's Thesis

Design and Implementation of a Graphical User Interface and a Database Management System for the Saber Wargame

Andrew M. Horton, Captain, USAF

Air Force Institute of Technology, WPAFB OH 45433-6583

AFIT/GCS/ENG/91D-08

Air Force Wargaming Center, Maxwell AFB, AL 36112-5532

Abstract

Saber is a theater-level, multi-sided, airpower employment computerized wargame that can be programmed to simulate any combat scenario. The model simulates theater level combat between air and land forces, and takes into account the effects of logistics, resupply, and both theater nuclear and chemical warfare. The major objective of the Saber model is to provide a suitable educational platform to allow users to apply basic, tactical employment concepts to multiple combat units, each having a specialized mission, and incorporating every branch of the armed services.

This thesis documents a graphical user interface and data management system that has been developed to execute the Saber theater level wargame simulation. It is a continuation of two previous efforts, and is one component of three thesis efforts designed to develop an integrated, on-line simulation of the Saber theater-level wargame.

Database Management System, User Interface, Wargame 152

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