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THESIS

THE DESIGN OF A PROTOTYPE PERSONAL COMPUTER DATABASE FOR THE EXPERT SYSTEM ADVISOR FOR AIRCRAFT MAINTENANCE SCHEDULING (ESAAMS)

by

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and
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December, 1991

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The Expert System Advisor for Aircraft Maintenance Scheduling (ESAAMS) was originally proposed in 1985 to assist in the scheduling of maintenance discrepancy repair in the organizational squadron environment. This dynamic environment produces a continuous flow of maintenance documentation from each maintenance action. Presently there exists no single system for the maintenance expert to retrieve this information to assist him, or her, in the critical maintenance decision making process.

This thesis addresses the design of the ESAAMS database which is of paramount importance to the expert system. Research on the use of the Naval Aviation Logistics Data Analysis (NALDA) database for a personal computer-based database is documented. Review of other existing naval aviation database systems are included in this research. Based on interviews with experienced fleet aviation maintenance managers, a prototype database design is produced. This thesis concludes with recommendations for further study based upon the findings of this research.

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The Design of a Prototype Personal Computer Database For The Expert System Advisor for Aircraft Maintenance Scheduling (ESAAMS)

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ABSTRACT

The Expert System Advisor for Aircraft Maintenance Scheduling (ESAAMS) was originally proposed in 1985 to assist in the scheduling of maintenance discrepancy repair in the organizational squadron environment. This dynamic environment produces a continuous flow of maintenance documentation from each maintenance action. Presently there exists no single system for the maintenance expert to retrieve this information to assist him, or her, in the critical maintenance decision making process.

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ACRONYMS AND NOMENCLATURE

4GL	Fourth Generation Language
ADA	A Procedural Language
ADS	Automated Data System
AEMS	Aircraft Engine Maintenance System
AIMD	Aircraft Intermediate Maintenance Department
AMEN	Aircraft Maintenance Engineering System
AMO	Assistant Maintenance Officer
AMPAS	Analytical Maintenance Program Support
ANSI	American National Standardization Institute
ASCII	American Standard
ASO	Aviation Supply Office
ASR	Aircraft Service Record
AV-3M	Aviation Maintenance Material Management
BIT	Built-in Test
BUNO	Bureau Number
BU/SERNO	Bureau Number/Serial Number
CDB	Central Database
CIMP	Corporate Information Management Plan
CNO	Chief of Naval Operations
CODASYL	Conference on Data Systems Languages
CSA	Configuration Status Accounting
D-Level	Depot Level
DBMS	Database Management System

DBTG	Database Task Group
DL/I	Data Language I
DOJ	Deport Originated Jobs
DSF	Data Services Facility
EBCDIC	An IBM Machine Language
ECAMS	Enhanced Comprehensive Asset Management System
EGT	Exhaust Gas Temperature
EMT	Elapsed Maintenance Time
EPU	ECAMS Processing Unit
ESAAMS	Expert System Advisor for Aircraft Maintenance Scheduling
ETR	Engine Transaction Report
FIRAMS	Flight Indicator Recording and Monitoring System
FOJ	Fleet Originated Jobs
GE	General Electric
I-Level	Intermediate Level
ICRL	Individual Component Repair List
IECMS	Inflight Engine Condition Monitoring System
IMA	Intermediate Maintenance Activity
IS	Information System
JCN	Job Control Number
LETR	Last Engine Transaction Report
LSAR	Logistic Support Analysis Record
LUI	Life Used Indices
MAL	Malfunction
MC	Maintenance Chief

MCC	Maintenance Control Chief
MDCS	Maintenance Data Collection System
MDS	Maintenance Data System
MENS	Mission Essential Needs Statement
MHRS	Man Hours
MMCO	Maintenance Material Control Officer
MMP	Monthly Maintenance Plan
MO	Maintenance Officer
MRC	Maintenance Requirement Card
MSDRS	Maintenance Status Display and Recording System
MU	Memory Unit
MV	Multi-Value
NADEP	Naval Aviation Depot
NADIS	Naval Aviation Depot Information System
NADOC	Naval Aviation Depot Operations Center
NALCOMIS	Naval Aviation Logistics Command Management Information System
NALDA	Naval Aviation Logistics Data Analysis
NAMP	Naval Aviation Maintenance Program
NAMO	Naval Aviation Maintenance Office
NAMSO	Naval Aviation Maintenance Support Office
NAVAIR	Naval Air Systems Command
NAVFLIRS	Naval Flight Record Subsystem
NAVMASSO	Navy Management Systems Support Office
NIC	NALDA Interface Computer

NPS	Naval Postgraduate School
NRMM	NALCOMIS Repairables Management Module
NSLC	Naval Supply Logistics Center
O-Level	Organizational Level
OCM	On-Condition Maintenance
OMA	Organizational Maintenance Activity
PC	Personal Computer
PLTS	Parts Life Tracking System
PMR	Periodic Maintenance Requirements
PMS	Planned Maintenance System or Preventive Maintenance System
RCM	Reliability Centered Maintenance
RFI	Ready For Issue
SAF	Support Action Form
SAFE	Structural Appraisal of Fatigue Effects
SCIR	Subsystem Capability and Impact Reporting
SE	Support Equipment
SNT	Serial Number Tracking
SQL	Structured Query Language
SRA	Shop Replaceable Assembly
SRC3M	Scheduled Removal Component Maintenance and Material Management
SSC	Supply Support Center
TD	Technical Directive
TDAIR	Technical Directives Status Account (Aircraft)
TDCGS	Technical Directives Status Account (Components and Support Equipment)

TDENG	Technical Directives Status Account (Engines)
TDHER	Technical Directives Status Account (Historical Engines)
TDHIS	Technical Directives Status Account (Historical Aircraft)
TDSA	Technical Directives Status Account database
TEC	Type Equipment Code
TTM	Tape Transport Magazine
TYCOMS	Type Commanders
VIDS/MAF	Visual Information Display System/Maintenance Action Form
WRA	Weapons Replaceable Assembly
WUC	Work Unit Code

I. INTRODUCTION

A. BACKGROUND

Today's Navy and Marine Corps maintenance managers are faced with systems which are continuously becoming more sophisticated and complicated to maintain. Guided by the Naval Aviation Maintenance Program (NAMP), the maintainer is responsible each day for optimizing the operational availability of his or her assigned assets. To accomplish this monumental task a continuous flow of information must be readily available to him/her to make accurate and timely decisions.

Over the years, access to information has been limited to local records and feedback reports (forwarded from data processing facilities) that are 60 to 90 days old. In today's dynamic maintenance environment this way of doing business is no longer acceptable for the maintenance manager. In an age of automated information systems and real time access to records, a reliable information system is not only possible, but must be made available to maintenance managers.

The Expert System Advisor for Aircraft Maintenance Scheduling (ESAAMS) introduced by McCaffrey [Ref. 1] in 1985, is the key to the way maintenance information can be processed and put to use in the Navy of the 21st century. This system concept incorporates the use of an expert system to use the information generated in the organizational aviation maintenance activity to assist in the scheduling of the daily maintenance workload.

This thesis is a follow-on to research previously conducted which will ultimately produce the personal computer (PC) based ESAAMS system. This research will directly build on the earlier work of McCaffrey [Ref. 1] and Burpo [Ref. 2] and to a lesser extent on the works of Chase [Ref. 3] and Stone [Ref. 4].

B. OBJECTIVES

The objective of this thesis is to review the contents of Naval Aviation Logistics Data Analysis (NALDA) database and other aviation maintenance database systems, and design a PC-based prototype database for ESAAMS using NALDA data. Potential links to other data management systems will also be investigated.

The following primary research questions will be addressed:

- What data contained in the NALDA database system are germane for use in building the ESAAMS main database?
- What uses/benefits would such a database provide an organizational maintenance activity?

Secondary research questions include:

- Are other databases in addition to NALDA required for the proper operation and maximum benefit of ESAAMS?
- What do the "experts" in the aviation maintenance community want from a management information system?

C. SCOPE, LIMITATIONS AND ASSUMPTIONS

Development of the ESAAMS concept is so broad that this thesis will only address issues involving ESAAMS database design. This research concludes with recommendations for future use of the ESAAMS database structure as a standalone DBMS and the future of ESAAMS in general. Design and discussion of other essential components of the ESAAMS system are deferred for future research projects.

User input for this research was conducted in an informal question and answer format. The sample was limited to personnel assigned to the activities addressed below and the interview format was structured to allow a subjective vice objective input. While this form of sampling is not scientific by nature, the authors feel that the views and opinions of those interviewed do reflect some of the primary concerns of the experts assigned within the F/A-18 community. These opinions and views do not necessarily encompass views and opinions from all aviation maintenance communities Navy-wide.

D. RESEARCH METHODOLOGY

Data collection for this project was conducted both on-site and through telephone conversations. Activities contacted include: NAVAIR Program Manager Air 270 (PMA-270); Naval Aviation Maintenance Office (NAMO-42); Commander Strike Fighter Wing Pacific Fleet Code 70; Naval Aviation Maintenance Training Group Detachment (NAMTRAGRUDET) Lemoore, CA; Aviation Intermediate Maintenance Department (AIMD), Naval Air Station Lemoore, CA.; Strike Fighter Squadron 25 (VFA-25); Strike Fighter Squadron 113 (VFA-113); members of the NALDA Users Assistance Group.(NAMO-622C); and a cadre of Aerospace Engineering Duty Officers assigned to the Naval Postgraduate School, Monterey, CA.

A thorough review of current fleet instructions, fleet system proposals and supporting program literature was conducted to provide the most current system and program status. Information assembled includes some yet unpublished research material to reflect the state-of-the-art in current Navy management information system development.

Description of the aviation maintenance process was based on the governing aviation maintenance instructions and the authors' personal experience at three types of Naval aircraft squadrons, and an Aircraft Intermediate Maintenance Department (AIMD).

E. THESIS ORGANIZATION

The remaining chapters of this thesis are as follows:

II. DATABASE SYSTEMS. A general discussion of database and Database Management Systems (DBMS). DBMS concepts and objectives, database models, relationships, and database manipulation are discussed.

III. THE AVIATION MAINTENANCE ENVIRONMENT. A brief description of the Naval Aviation Maintenance Program (NAMP) and how it relates to an Organizational Maintenance Activity (OMA) are discussed. The basic levels of maintenance and maintenance data reporting are examined.

IV. NALDA DATABASES. A look into the NALDA program history, database structure, contents, and applicability to ESAAMS are examined.

V. NON-NALDA DATABASES. An examination of other databases available to the maintenance expert and for possible interface with ESAAMS is conducted. A brief background and future uses for each database system are provided.

VI. MAINTENANCE COMMUNITY USER INPUT. Reactions of experts to the ESAAMS concept and potential uses of the NALDA database are examined.

VII. DATABASE DEVELOPMENT AND PROGRAM DESIGN. Design and construction of a prototype database and DBMS compiled from the NALDA database system is examined.

VIII. CONCLUSIONS AND RECOMMENDATIONS. A summary of research question findings and future concerns/recommendations are provided.

II. THE AVIATION MAINTENANCE ENVIRONMENT

A. INTRODUCTION

Naval Aviation Maintenance is a dynamic and constantly changing field. From a land-based, routine training flight to the high tempo of carrier-based flight operations, the squadron maintenance department is responsible for providing safe, mission capable (MC) aircraft on a continual basis. The success, or failure, of an aviation squadron can, and usually does, rest on the professionalism and expertise of the maintenance department. It is essential that critical decisions are made in a timely, accurate and precise manner. To accomplish this monumental task, the maintenance "expert" must have the right information available in the right place at the right time.

Presently, critical decisions are made under the guidelines of the Naval Aviation Maintenance Program (NAMP) and from a combination of experience, governing instructions, and expert knowledge. This decision making process is applied to every maintenance action. The resulting action is recorded and sent upline as maintenance data. With the vast quantities of data that are transmitted upline each day by every maintenance organization, there remains no single retrieval source for this data to assist the organizational maintenance expert in making day-to-day scheduling decisions. The current information system environment is incapable of producing the types of information needed to optimize squadron mission readiness decisions. An expert system, such as ESAAMS, requires access to this wealth of data available in both the Navy's Aviation Maintenance and Material Management System (AV-3M) and the Naval Aviation Logistics Data Analysis (NALDA) system. Specifically, ESAAMS will require the average elapsed maintenance time to remove and replace a part, and the historical failure rate of a component in relation to other components in an aircraft system.

B. THREE LEVELS OF MAINTENANCE

To fully understand the scope of the NAMP it is important to understand the environment of aviation maintenance. The NAMP objective is "...to achieve and continually improve aviation material readiness...with optimal use of material, manpower, and funds."[Ref. 5: p. 2-1] This objective is translated into a primary philosophy which is to repair equipment at the maintenance level, which ensures optimal economic use of resources.

The NAMP divides aviation maintenance into three distinct levels, each level linked to the other through the Naval Supply System. The three levels of repair are the organizational level (O-level), intermediate level (I-level), and the depot level (D-level).

1. Organizational Level

The organizational level encompasses maintenance traditionally considered to be the most basic and simple tasks required for repair of assigned aviation equipment [Ref. 6: p. 108]. O-level maintenance functions include inspection, servicing, handling, on-equipment corrective and preventive maintenance, technical directive compliance, and administrative record keeping and reporting [Ref. 5: p.3-1]. Truly, the other two levels are of limited value without a properly managed and operated maintenance program at the Organizational Maintenance Activity (OMA). O-level maintenance of assigned equipment is the responsibility of the using or reporting activity. The success of the maintenance effort directly affects aircraft availability and Naval aviation readiness. The importance of a high readiness state cannot be over-emphasized.

2. Intermediate Level

The intermediate level of maintenance concentrates on calibration, repair or replacement of damaged or unserviceable parts, components or assemblies; the manufacture/fabrication of non-available parts; and the provisions for technical assistance to O-level activities. Maintenance is accomplished in an off-equipment environment dealing mainly with major system and sub-system aircraft components. The I-level directly supports the O-level by repairing and then returning parts to the supply system.

3. Depot Level

The third level of repair is preformed at Naval Aviation Depots (NADEP) or by NADEP field teams sent to accomp sh on-site repair. D-level maintenance represents the highest level of repair and accomplishes both in-depth on-equipment and off-equipment repair and modifications. Maintenance at this level consists of major overhaul (rework) or complete re-manufacturing of parts, assemblies, subassemblies, and end-items, including the manufacture, modification, testing, and reclamation of parts as required. [Ref. 7 p.3-2] D-level maintenance supports the other two levels of maintenance directly and through the supply system.

C. THE ORGANIZATIONAL MAINTENANCE ACTIVITY

Our focus in this thesis is on the organizational level or OMA. The most common OMA is the aviation squadron. We will concentrate our attention and research here. Chase [Ref. 3] points out "...the two broad areas of aircraft maintenance are--a Planned Maintenance System (PMS) and a Maintenance Data System (MDS)." Both of which are to "insure the highest state of aircraft readiness and reliability at the lowest cost in men, money, and material." [Ref.8: p. I-3]

In addition to the scheduled requirements, the maintenance manager is faced with a daily array of unscheduled requirements to maintain aircraft availability. This area of aviation maintenance typically absorbs a greater part of the total maintenance time than does scheduled maintenance.

The MDS is a management information system designed to provide statistical data for use at all aviation maintenance and management levels. The system collects data from every maintenance action performed on an aircraft or component of an aircraft or support system. The data also includes input about parts availability and usage, man-hours expended in the repair process, equipment configuration, and flight information.

The system is designed so that each worker, when performing a job, converts a narrative description of the job into codes and enters coded information on standard forms or source documents. These source documents are collected and transmitted to a data services facility (DSF) where information is converted into machine records. The DSF then uses the machine records to produce periodic report listings summarizing the submitted data. These reports are supplied to maintenance supervisors to provide assistance in planning and directing the maintenance effort. [Ref 10: p. 2-1]

1. Planned Maintenance System

The Planned Maintenance System (PMS) is an aircraft-specific maintenance plan which specifies applicable maintenance actions to be performed at predetermined (scheduled) intervals. Contained in a series of publications, it specifies the minimum maintenance that must be accomplished, the scheduled maintenance. [Ref. 3] The publications provide a basis for planning, scheduling, and actual performance of scheduled maintenance requirements. [Ref. 9 pp. 10-21] The PMS is the responsibility of the Maintenance Department within each squadron. Adherence to the PMS optimizes aircraft life and safety of operation during its life cycle. It ensures, when properly conducted, that "all aeronautical equipment receive required servicing, preventive maintenance, and inspection." [Ref. 9: p. 6-5]

2. Maintenance Control

The first principle of maintenance is: ***Maintenance Control must control maintenance!*** While sounding like a play on words, this corollary is the foundation of the success or failure of the entire maintenance program. Maintenance control is the focal point, "control center", of the squadron maintenance program. In this "hub" of the Maintenance Department, the maintenance workload is coordinated and prioritized. Maintenance tasks are then assigned to each supporting work center to fulfill the days requirements. See Figure 2-1 below.

Maintenance control's responsibility does not apply only to the PMS and unscheduled maintenance. A primary mission of every OMA is to ***meet the daily flight schedule!*** To accomplish this task a combination of variables must be considered:

- Daily flight schedule aircraft requirements
- Scheduled maintenance requirements (calendar/phase inspections, etc.)
- Daily array of unscheduled "gripes" for each aircraft
- Personnel requirements (work center manning, training, etc.)
- Support equipment availability
- Parts availability (repairable/consumable)
- Future command requirements (detachments/deployments)
- Requirements specified by higher authority (inspections, special exercises, technical bulletins/directives)
- Support facility availability (IMA personnel available, holidays, etc.)

All of these variables must fit into a "master schedule" and be precisely coordinated to maximize readiness and aircraft availability. This is maintenance control's biggest task.

This major undertaking is the responsibility of the Maintenance Officer (MO) and his direct subordinates. The master plan, commonly known as the maintenance plan, is normally developed by the senior enlisted member in the maintenance control division, the Maintenance Master (or Senior) Chief (MMC), in concert with the Maintenance/Material Control Officer (MMCO); the Assistant Maintenance Officer(AMO), where personnel or training is involved; and the Maintenance Control Chiefs (MCC). Figure 2-1 depicts the organization of the maintenance department.

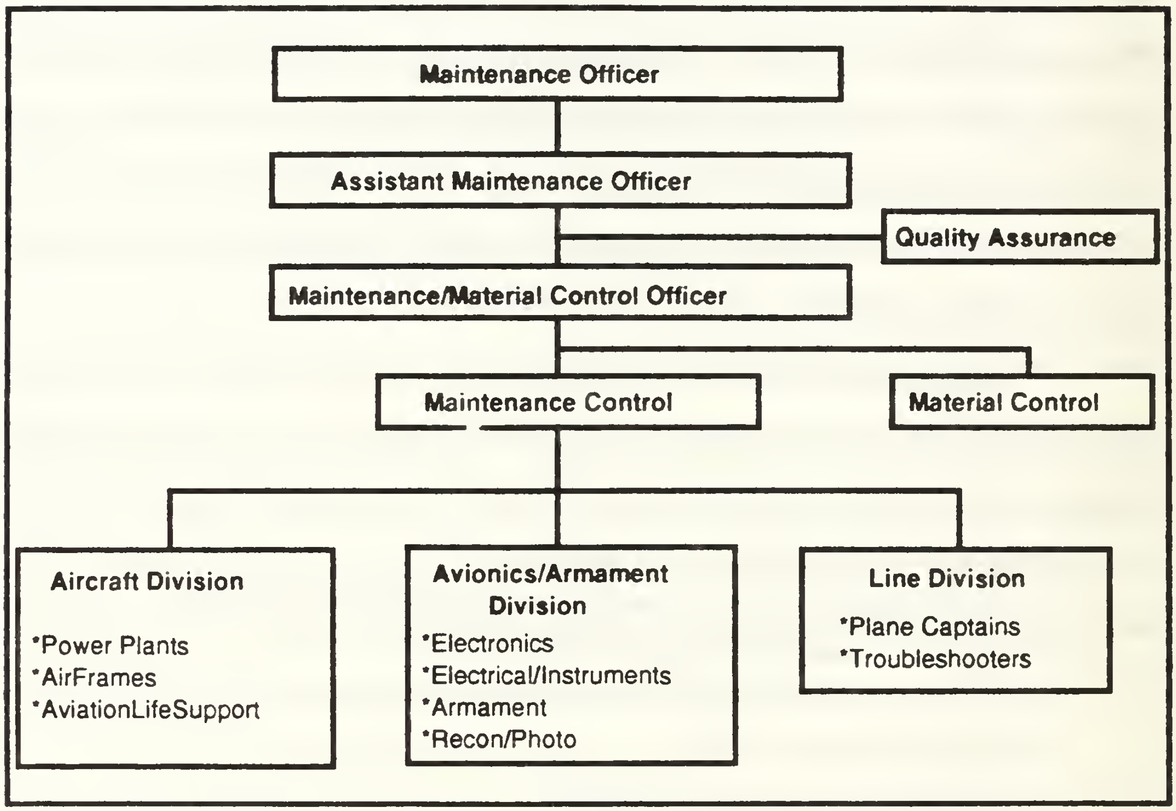

Figure 2-1. OMA Maintenance Department Organization[1]

The Maintenance Master Chief (Senior Chief when no Master Chief is assigned), is the resident enlisted *expert* in maintenance control. It is usually his decision making that sets the pace of the entire maintenance effort. Ideally, the MMC is the most experienced member of the Maintenance Control team and is well versed in every facet of the NAMP and an expert on the type of aircraft being maintained. It is important to assign a capable

[1] Figure 2-1 is an adaptation of Figure 3-3 in Ref. 9: p 3-3.

leader who can maintain the continuity between maintenance control and the maintenance production work centers, which may also have Chief Petty Officers (CPOs) assigned.

Working directly for the MMC are the MCCs who generally manage the "leading edge" or minute-by-minute flow of maintenance. Their decision making process is made in real-time, commonly split second, input from the entire maintenance arena. They put the maintenance plan into effect but must vary their structure as internal and external influences demand.

The Maintenance/Material Control Officer and the Maintenance Master Chief are generally involved with the program in a broad sense. Master scheduling and long range strategic planning typically absorb a large quantity of their time. Deriving and publishing a monthly schedule of maintenance, not surprisingly known as the Monthly Maintenance Plan (MMP), reflects this strategic planning. These two individuals are widely considered to be the *experts* in the maintenance environment. Their combination of maintenance experience, understanding of the NAMP, and knowledge of the aircraft, make them invaluable to the maintenance process.

D. AV-3M REPORTING

The Maintenance Data System and one of its major sub-groups, the Aviation Maintenance and Material Management (AV-3M) System, provides the principal means for the collection of maintenance data. Data is collected from every maintenance action performed on every item of aeronautical equipment processed at the O and I-levels, including some input from D-level actions.

Reporting of maintenance actions accomplished at the O-level is primarily directed into the Naval Aviation Maintenance and Material Management (AV-3M) System by the use of OPNAV Form 4790/60, the Visual Information Display System/Maintenance Action Form (VIDS/MAF) and OPNAV Form 4790/42, Support Action Form (SAF). These documents, (referred to as source documents) are screened for accuracy at the OMA and submitted to the local Data Services Facility (DSF). This is commonly known as the local cycle.[Ref. 10: para 2.1.3]

The source documents are again screened, corrected, and converted into ASCII or EBCDIC machine language at the DSF. When the documents have been verified, the information is transmitted to the Naval Aviation Maintenance Support Office (NAMSO) where it is compiled with input from all other DSFs. NAMSO then provides AV-3M monthly feedback reports to the originating activities. It also sends the data to the Naval Aviation Logistics Data Analysis (NALDA) database. This is the central repository of aviation maintenance data. Figure 2-2 depicts the current AV-3M data flow. The Enhanced Comprehensive Asset Management System (ECAMS) will be discussed in Chapter V. Further discussion of NALDA will be reserved for Chapter IV.

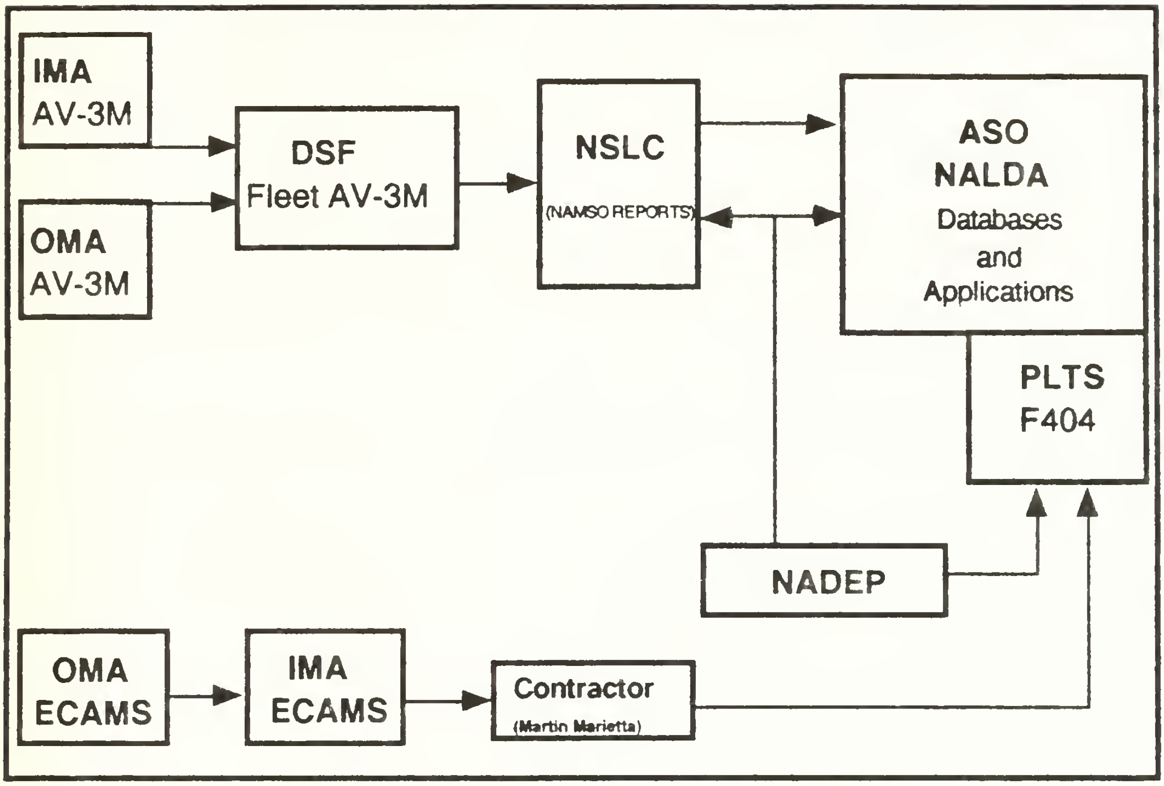

Figure 2-2. Current AV-3M Data Flow

E. SUMMARY

The dynamic environment of naval aviation maintenance requires the maintenance expert to make split-second decisions accurately and with professional confidence. To accomplish this task, he or she must be provided with the right information at the right time in the right place. There is a wealth of historical information available in the NALDA database. The data consists of hundreds of maintenance actions that are accomplished daily, processed for accuracy, and then are transmitted to the main NALDA database. The processing of this data into information, and making it available to the maintenance expert, could be a valuable asset to the planning and scheduling of organizational maintenance. The composition and use of the NALDA database is the subject of the next chapter.

III. DATA BASE SYSTEMS

A. INTRODUCTION

This chapter introduces database and database management system concepts. An expert system, such as ESAAMS, contains a knowledge base, an inference engine, and a user interface. The knowledge base contains the rule base and access to the database. The database is the repository of facts that, together with the rules in the knowledge base, will be used by the inference engine for the expert system. Database management system concepts and objectives, data models, relations, and how data is manipulated to perform required applications, will be discussed.

B. DATABASE TECHNOLOGY

Before the introduction of database concepts, businesses and organizations used *file processing systems* to process records and produce information. These systems stored groups of records in separate files and processed them separately. Although these systems were a great improvement from the laborious manual processing, there are several limitations:

- Data is separated and isolated
- Data is often duplicated
- Application programs are dependent on file formats
- It is difficult to represent complex objects using file processing systems [Ref. 11: p. 7]

To overcome the limitations of file processing systems, database technology was developed. A database is a collection of integrated, shareable, and non-redundant records. These records are interrelated by specific relationships. [Ref. 12: p.5] An integrated database provides an organization with greater access to information, better control and easier program application development. David M. Kroenke and Kathleen A. Dolan define a Database Management System (DBMS) as:

> "...a program (or a set of programs) that allows stored data to be integrated, reduces data duplication, ensures data integrity, eliminates program dependency on file formats, and allows complicated objects to be easily represented and retrieved. Briefly, a DBMS is a software system that is capable of supporting, manipulating, and managing a database."[Ref. 11: p. 9]

C. DATABASE MODELS

There are three basic data models or structures used in Database Management Systems: hierarchical, network, and relational.

1. Hierarchical Model

The hierarchical data model represents data relationships using hierarchies or trees. As Figure 3-1 illustrates, a tree or hierarchy consists of a number of nodes arranged in a top-down sequence. Every node represents a data element. Every node is related to another node at the next higher level. The higher node is called the parent and the nodes below the parent are the children. A child can only have one parent but a parent can have several children. The top-most parent is often labeled the root while the bottom most children are called the leaves (hence, the name TREE). IBM first introduced this structure for use in their *Data Language I (DL/I)* DBMS.

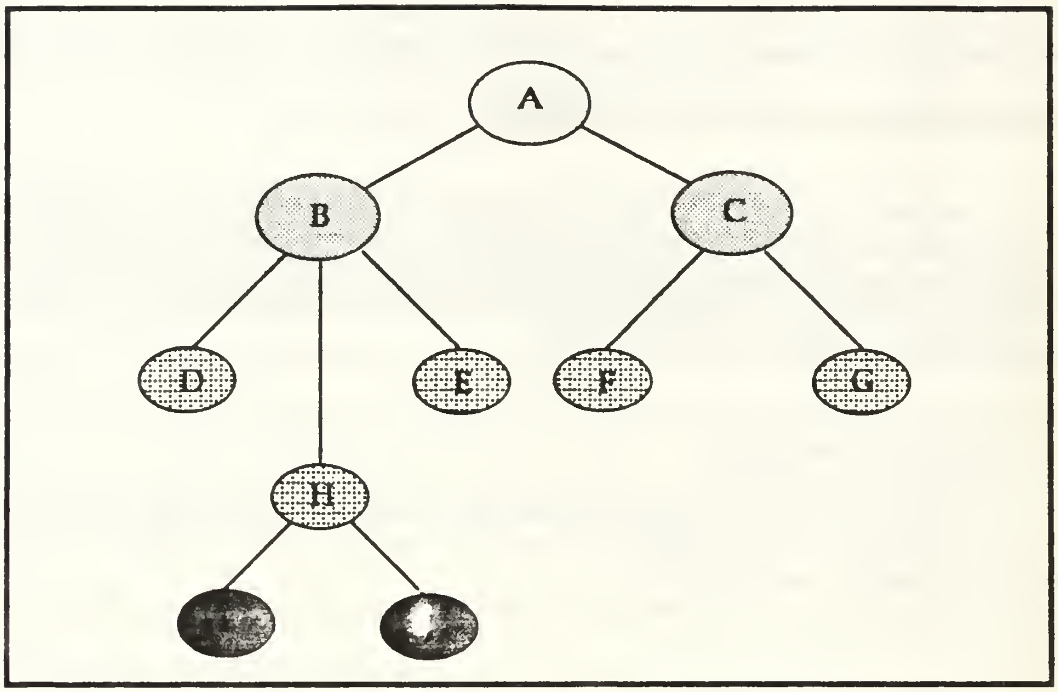

Figure 3-1. Hierarchical Model

2. Network Model

In a network model, the degree of sophistication is carried up to the next level by letting children have more than one parent. The basic hierarchical or tree structure approach is still used. See Figure 3-2. The most widely known network model is the CODASYL DBTG (Conference on Data Systems Languages, Data Base Task Group). The development of CODASYL is very complex. The American National Standardization Institute (ANSI) never adopted CODASYL as a national standard.

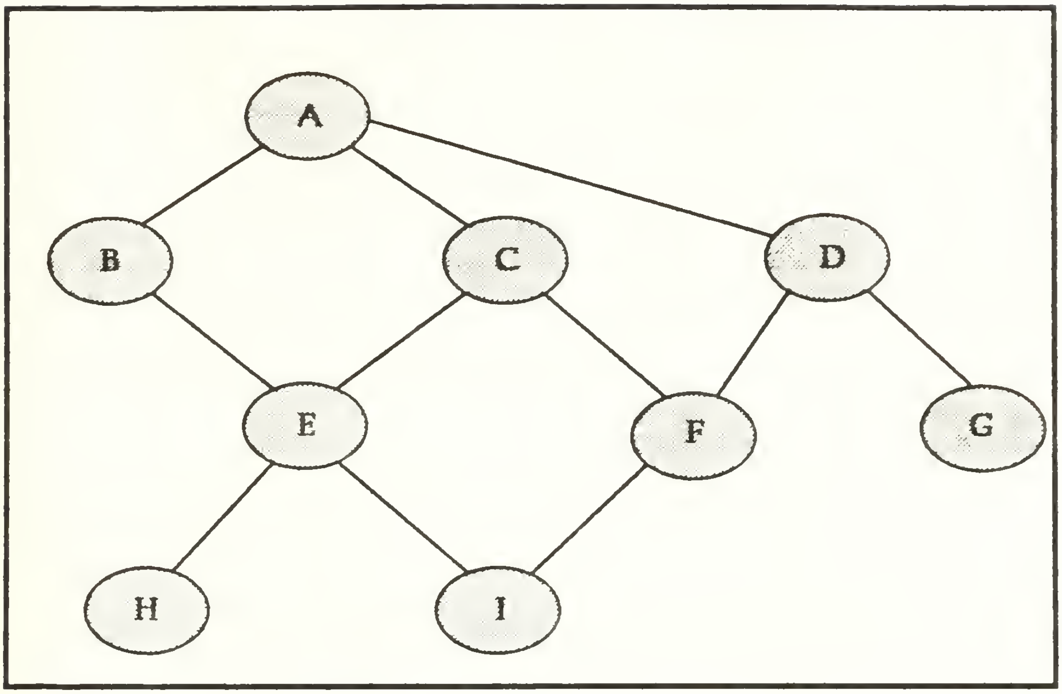

Figure 3-2. Network Model

3. Relational Model

The relational model, with its accompanying SQL (Structured Query Language), was accepted as the national standard by ANSI in 1986.

A relational model conceptually stores data in a way that a user can easily understand and relate to. It was first introduced by E. F. Codd and was derived from the mathematical definition of relations, that is, a relation is a subset of the Cartesian product of its underlying domains. The relational model is based on the concept that data is organized and stored in two-dimensional tables called relations [Ref. 13 p. 131]. The columns are called attributes while the rows are called tuples. A row in a relation or table is like a record with its own characteristics. Figure 3-3 shows a complete example of a relational database organization where one table is called **MAINT_ACTION** and the other is called **INCORPORATED_TD**. In Figure 3-3 , the first row contains a document number called SWP 4826, a maintenance level of 0, a malfunction code of 123, an action taken code of 5, and man-hour reading of 0.5. The columns, called attributes, represent fields or data elements. So in Figure 3-3, the entries under **DOC_NUM** are fields of document numbers, entries under **MAINT_LVL** are fields of maintenance levels, etc. The entire table of rows and columns is roughly the equivalent of a file. A file contains records and records contain fields or data elements. Unlike mathematical relations, however, database relations are time-varying since tuples (rows) may be inserted, deleted, or updated [Ref. 11: p. 186]. In simple terms, we have a file of maintenance actions and another file of incorporated Technical Directives.

Each tuple or row in a relation or table is identified by a *key*. A *key* is a group of one or more attributes that uniquely identifies a row [Ref. 11: p. 139]. Going back to Figure 3-3 once more, the first row of **MAINT_ACTION** can be uniquely identified by the **DOC_NUM** SWP 4826. All the other rows have their own unique **DOC_NUMs**. It is possible that a row can have more than one attribute that can become a *key*. These attributes are called *candidate keys* and they can be composed of a *primary key* and *foreign keys*. A *primary key* is an attribute that can uniquely identify a row or a tuple. A *foreign key* is a *candidate key* that is taken from another table or relation and placed as an attribute (column) in another table in order to form a relationship between the two tables. These keys are selected to uniquely identify the row. In Figure 3-3, the table **INCORPORATED_TD** has two *candidate keys*, namely, **DOC_NUM** and **BASIC_NUM**. **INCORPORATED_TD** is related to **MAINT_ACTION** through **DOC_NUM**. **DOC_NUM** is a *foreign key* to **INCORPORATED_TD** since **BASIC_NUM** can be its *primary key*. It is possible for the *primary key* and *foreign key* to be the same. For instance, in Figure 3-3, **DOC_NUM** can be the *primary key* for both the **INCORPORATED_TD** and **MAINT_ACTION** since it can uniquely identify a row from either table.

MAINT_ACTION

DOC_NUM	MAINT_LVL	MAL_CODE	ACT_TKN	MH
SWP 4826	0	123	5	0.5
SNM 4001	0	295	7	1.5
SWS 5002	I	350	7	2.0
AMP 1001	I	311	7	0.5
AWS 5005	0	070	7	0.5
AGL 4221	O	070	2	1.0

INCORPORATED_TD

DOC_NUM	INT_NUM	AMEND_NUM	KIT_NUM	BASIC_NUM	TD_CODE
SWP 4827	X	0	A1	0050	01
SNM 4101	X	1	A1	0047	02
SWS 5003	X	1	A1	0047	02
AMP 1221	-	2	00	0048	01
AWS 2005	X	0	A2	0049	02
AGL 1121	-	0	A1	0059	01

Figure 3-3. Relational Database Model

4. Normalization

Normalization is the process of gathering data items (or attributes) into relations. The goal of a good logical database design is to represent objects or entities in the database using relations that (1) provide the data needed to construct user objects (or tables) and (2) are robust enough to allow rows to be inserted, deleted, and modified without resulting in inconsistencies or errors in the stored data. [Ref. 11: p. 133-134]

5. Relationships

In order to have an efficient operation for a DBMS, proper data base design is extremely critical. It is necessary to preclude an excessive amount of data redundancy, inadvertent deletion of data, and presence of data anomalies. Correct relationships between entities or objects are imperative to achieve a proper logical design. Relationships between entities can be classified in three ways:

- One-to-one
- One-to-many
- Many-to-many

a. One-to-one Relationships

A one-to-one (1:1) relationship is the simplest form. Given an Object *A* and an Object *B*, a one-to-one relationship exists if *A* contains *B* as a single-valued property (or attribute), and either *B* contains *A* as a single-valued property or *B* does not contain *A*. Hence, there can only be one occurrence for an attribute in an object. The key of one of the relations must be stored as an attribute of the other in order to link them together. [Ref. 11: pp. 169-174]

An example of this kind of relationship can be shown using Appendices A and B. In Appendix A, the table or object **Maintenance_Action** is related one-to-one

(1:1) with the object **Incorporated_TD**. This is denoted by the absence of "mv" or multiple value after object **Incorporated_TD** inside the object **Maintenance_Action**. In other words, for each occurrence of a **Maintenance_Action** there is only one occurrence of **Incorporated_TD**. In Appendix B, the graphical logical representation of the database shows the 1:1 relationship again by the straight line connection between these two objects without the arrow tail. Note in Appendix B that the *primary keys* **JCN** and **WC** of **Maintenance_Action** are used as *foreign keys* for **Incorporated_TD.**

b. One-to-many Relationships

A one-to-many (1:N) relationship occurs when a record of one type is related to potentially many records of another type. [Ref. 11: p. 174). The terms parent and child are sometimes applied to records in one-to-many relationships. The parent record is on the one side of the relationship and the child record is on the many side. The key of the parent relation must be stored as an attribute of the child relation.

Using Appendices A and B to show an example of a one-to-many (1:N) relationship, let's take the objects **End_Item** and **Maintenance_Action**. For every occurrence of an **End_Item** there can be many **Maintenance_Actions**. This follows the same logic in the business environment of aviation maintenance. For every aviation end item, which can be an aircraft system or part, there can be multiple maintenance actions taken. Appendix A shows the 1:N relationship between these two objects by the presence of "mv" after **Maintenance_Action** inside the **End_Item** object. Appendix B shows this relationship once more by the arrow tail symbol on **Maintenance_Action.**

c. Many-to-many Relationships

In a many-to-many (M:N) relationship a record of one type is related to many records of the second type and a record of the second type is related to many records of the first type. Many-to-many relationships cannot be directly represented in relations as one-to-one (1:1) or one-to-many (1:N) relationships because deletion and insertion anomalies will occur in the database. The solution to the problem is to create a third relation that shows the correspondence of the objects. This relation is called an *intersection* relation. Each record in an intersection relation contains the keys of each of the related records in the two relations. [Ref. 11: pp. 178-183]

Appendices A and B don't show a many-to-many relationship. To show an example of a many-to-many relationship, let us take two imaginary objects called **Personnel** and **Squadron**. Aviation personnel can belong to many squadrons (maybe not at the same time) and a squadron can have many personnel. Since these two objects are both multi-valued, in order to create a database relationship an *intersection* object must be created. This object can be called **Squadron_Personnel** and will contain the keys of each of the objects.

D. WHY CHOOSE A RELATIONAL DATABASE MODEL FOR ESAAMS?

As mentioned earlier, a relational database is stored conceptually in a way the user can understand and access directly. Relations, being two-dimensional tables, are easier to comprehend and deal with by non-programming oriented users. Users are presented with a single and consistent data model or structure. There is no need for concern on the 1:N versus the M:N relationships as in the hierarchical and network models. The relationships are stored in the data themselves.

There is more data independence, flexibility, database processing power, and security in a relational model. The model permits relational completeness that can be transparent to a non-technical user. It also facilitates good database design. Potential aviation maintenance users will be able to comprehend the database structure better when designed in the relational model vice a hierarchical or network model.

Unlike other database structures, relational databases make ad hoc queries possible. Ad hoc means unpredicted. Other database models are not structured to answer unpredicted questions easily. [Ref. 5: p. 296] The ability to ask ad hoc questions is essential for a decision support system. ESAAMS can best benefit from a relational DBMS.

E. STRUCTURED QUERY LANGUAGE

The *de facto* language used in relational data manipulation is SQL (Structured Query Language). SQL is a transform-oriented relational language. SQL provides a language to transform input into desired output via relations. [Ref. 11: p. 321] SQL is not a procedural language like ADA, Pascal, or C. It is a fourth-generation (4GL) data access language that allows usage between different computers. Until now, transferring data from one computer to another proved difficult because each computer had its own data sublanguage. With SQL and its simple query/update language, data transfer between micros, minis and mainframes can be facilitated with ease. It is employed only to access data from a database and manipulate it. SQL can be embedded in application programs.

F. SUMMARY

The ESAAMS expert system needs a database to provide information. An efficient database model is essential for the optimal interaction between the database and the expert system.

Three database models were discussed in this chapter to show the different methods for constructing the database schema. The relational database is the model that this thesis will use for the design and construction of the ESAAMS Database Management System. Several applications that can be used by aviation maintenance managers will be generated to show proper functioning of the DBMS.

IV. NALDA DATABASES

A. INTRODUCTION

The NALDA databases are uniquely qualified to serve as a foundation for essential ESAAMS information [Ref. 2: p.49]. Because NALDA is the central repository of data for the naval aviation logistics and maintenance community, Burpo (1990) concluded to use the NALDA databases, sometimes called the NALDA data bank, for the development of ESAAMS. This chapter will cover NALDA's program history, databases and their contents, and applicability to ESAAMS.

B. BACKGROUND

The Naval Aviation Logistics Data Analysis (NALDA) system evolved from the need for improved data analysis capabilities to support growth in sophistication and complexity of Naval air weapons and associated support systems. Its primary objective is to (support) centralized logistics data analysis. [Ref. 14: p.1] It also provides the capability to accommodate upline reporting requirements as set forth in the Maintenance Data System (MDS) program of the NAMP. The upline reporting is used to transport all maintenance data and information from the OMAs, IMAs, and NADEPs to a central repository of data for later retrieval.

The NALDA system is a centralized, integrated and uniform data bank providing storage, retrieval and analysis capability. It is configured in a hierarchical database structure using the Systems 2000 (S2K), developed by MRI (Intel) Systems Corporation of Austin, Texas, in the early 1970s, as its Database Management System. It can be used, in an interactive manner, through remote terminals in support of the naval aviation logistics community [Ref. 14: p. 1].

In the early 1970s, there were hosts of uncoordinated and separate databases and data systems in the aviation logistics community. In 1975, the NALDA Automated Data System (ADS) Development Plan was formulated. In May of 1976, The Assistant Secretary of the Navy (Financial Management) approved the phased development of NALDA. NALDA became operational in the early 1980s. Figure 4-1 shows the NALDA 2010 Structure -- the envisioned NALDA future organization structure.

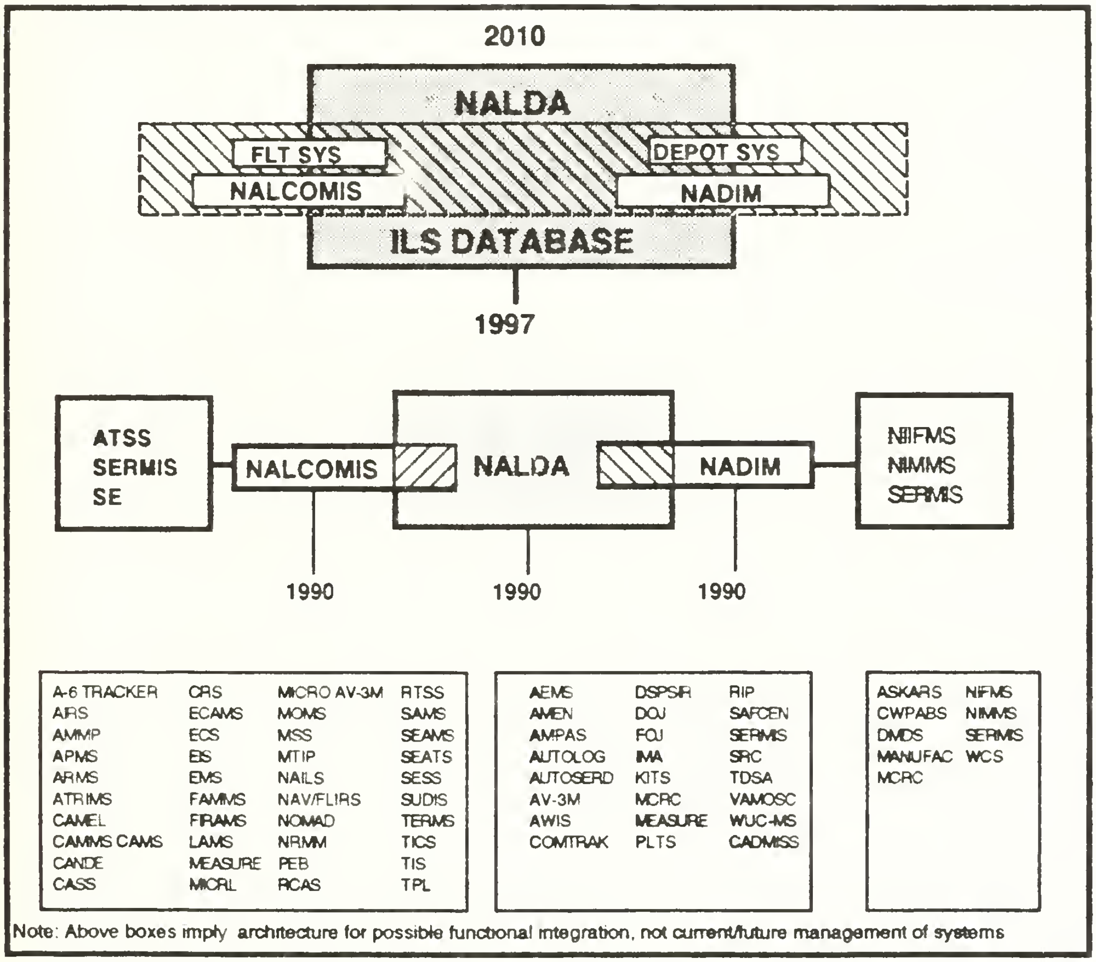

Figure 4-1. Current and Proposed Future NALDA Structure [Ref. 14]

1. Phase One Development:

NALDA's Phase One goal was the integration of three existing logistics data systems: the Analytical Maintenance Program Analysis Support (AMPAS) System, Aircraft Maintenance Engineering (AMEN) System, and the Technical Directive Status Accounting (TDSA) System. Phase One development also sought the creation of an intensified maintenance data analysis capability. [Ref. 15: p.87] NALDA's target user community includes:

- All Navy and Marine Corps Aviation Headquarters
- Field Activities
- Type Commanders (TYCOMS)
- Fleet Activities (Intermediate Activities and above)

A very noticeable omission from the targeted user community are the Organizational Maintenance Activities (OMA). Ironically, the originators of the data, at present, receive little direct benefit from the NALDA database system. With ESAAMS, NALDA will be able to expand its services directly to the organizations that provide the bulk of the upline data. NALDA Phase One currently provides the following:

- A Corporate Aviation Maintenance and Material Management database with on-line interactive access Navy-wide;
- Data analysis capability to perform Reliability Centered Maintenance (RCM);
- Technical Directive Status Accounting (TDSA);
- Consolidation of the two original major NAVAIR Information Systems -- AMPAS and AMEN.

2. Phase Two Development:

Phase Two NALDA objectives are expansions on Phase One and are an opportunity to make significant life cycle cost reductions while incorporating needed readiness improvements. Development started in early 1985 and is on-going with a targeted full deployment date in late 1995.

Redundancy exists in the current aviation maintenance data collection system. AV-3M data is collected at the various levels of maintenance, processed and sent to NAMSO, Chesapeake, VA. At the same time, the same maintenance data is sent to the NALDA database system located at ASO, Philadelphia, PA. Realizing this redundancy, the CNO has directed NALDA to be the Navy's central upline logistics data system. The program management team at NAMO has undertaken the AV-3M/NALDA merger. At this writing, the program merger is on-going and is projected for completion in 1997. This merger will do much to solve the redundancy problem and also greatly expedite the on-line query process.

Objectives for Phase II include the following:

- Merger of common AV-3M functions supported by the Naval Sea Logistics Center (NSLC) and NALDA to eliminate redundancy;
- Addition of other logistics data like the Logistics Support Analysis Record (LSAR) and Configuration Status Accounting/Serial Number Tracking (CSA/SNT);
- Consolidation of other logistics information systems (ISs) to follow the OP-51 Functional Sponsor Plan (FSP) directing NALDA to be the Navy's central upline logistics data system;
- Improve user-friendliness by the introduction of relational DBMS.

C. NALDA SUBSYSTEMS AND DATABASES

The current Phase One NALDA operational system covers a whole spectrum of different subsystems and databases to provide system users with information to solve problems and make informed decisions. To date there are some 25 databases. Some of the more prominent databases are listed below.

- Fleet Originated Jobs (FOJ) database: the principal repository of reported maintenance data from all OMAs, IMAs and Depots. There is one FOJ database for each aircraft type/model, plus additional databases for Support Equipment (SE), training devices, and other end items identified by a Type Equipment Code (TEC).
- AMPAS system database: to implement and sustain the Phased Maintenance Program. This database became the vehicle for providing the analysis procedures and techniques needed by Naval Air Systems Command Engineering Support Office engineers, analyst managers and type commanders.

- AMEN database: developed from the FOJ database to provide in-house logistics managers, engineers, and others throughout the logistics community with an effective tool to identify and resolve aviation logistics problems.
- TDSA system database: an automated accounting system designed to store, maintain, and disseminate information concerning the status of Technical Directives.
- Depot Originated Jobs (DOJ) database: a database to track maintenance actions collected by the Depot Maintenance Data Collection System and originated at the depots.
- Intermediate Maintenance Activity (IMA) Analysis database: contains summary data that enables analysis of the production effort at the intermediate level of maintenance and at an Aircraft Intermediate Maintenance Department (AIMD) for identified items.
- Present Maintenance Requirements (PMR) database: not yet completed. Will contain data describing scheduled maintenance requirements at the O- and I-levels.
- Training database: identical to FOJ except for the different values in the schema records. Data in this system pertains to training devices and equipment.
- Aircraft Engine Maintenance System (AEMS) database: contains information derived from the Aircraft Engine Management System (AEMS) data system. This database consists of two separate and independent data systems, one containing propulsion system data and one containing propulsion system module information. The system contains data from the Engine Transaction Report (ETR) and calculated data such as turn-around time, operating hours, etc.
- Last Engine Transaction Report (LETR) database: contains information from AEMS.
- Aircraft/Equipment Summary Reports database: contains summary information identical to data reported in AV-3M information reports.
- Non-Maintenance Job Control Number Supply database: contains information identical to AV-3M information reports.
- Scheduled Removal Component database: contains information from Scheduled Removal Component (SRC), Assembly Service Record (ASR), Module Service Record (MSR) and Equipment History Forms (EHF) which are collected at the Scheduled Removal Component Central repository.
- Master Index of Repairables database: contains item identification, evolution, applications, projected workload, modification and life limited replacement requirements information as applicable for each repair item.
- Individual Component Repair List (ICRL) database: contains data which depicts the level of repair capability for each repairable at each Intermediate Maintenance Activity. Fully compatible with IMA Analysis database.
- Code translation database: contains various translation codes; such as Work Unit Code (WUC), Type Equipment Code (TEC), and Malfunction Code (MAL), utilized in NALDA databases. [Ref. 14: p.2-3]

D. DATABASE FOR THE OMA AND ESAAMS --THE FOJ DATABASE

Burpo (1990) asserted that the most likely database for ESAAMS is the FOJ database. This conclusion was based from his interviews with different NALDA users. Research in this thesis has uncovered other NALDA databases that are also useful to the OMA maintenance expert. Their potential for inclusion into the PC-based expert system will be evaluated and discussed fully in the next section.

The FOJ database stands to be the most logical and usable database for OMA use. Chapter II, Section D discussed how data from the OMAs is sent upline using the the AV-3M reporting system of the MDS. All this data ends up in the NALDA FOJ database schema. All data taken from the VIDS/MAFs, training reports, safety-engineering investigations, and depot summaries end up in the FOJ database. Hence, any historical maintenance record of an aircraft or an aircraft system can be found in this single NALDA database.

The database itself is enormous and not all data are germane to a maintenance manager. The challenge, therefore, is to identify and extract the relevant data from the mainframe hierarchical DBMS of NALDA and transfer them to a PC-based relational DBMS for use by maintenance planners and ESAAMS.

E. ANALYSIS OF OTHER NALDA DATABASES

The feasibility study conducted by Burpo, [Ref. 2], concludes that the FOJ database is the most useful for application to ESAAMS because it contains elements necessary to assist in the scheduling of maintenance. As pointed out, the NALDA system consists of many databases each containing specific data. The question, from a maintainer's stand point must be raised: Do any of these other databases hold information which can be effectively used at the O-level? Care must be exercised when examining the contents of a database.

One must not conclude just because it contains known useful data for the OMA, that the data is also usable for ESAAMS.

Of the 16 databases listed above, only four contain specific data the authors feel is germane to the OMA effort and therefore potentially of value to the ESAAMS database. Many of the other databases contain data that is a duplicate of data already included in the FOJ database and are not considered. The four useful databases are discussed below.

1. AMPAS

The Analytical Maintenance Program Analysis Support (AMPAS) system was designed to provide a group of analysis procedures/techniques to NESC Engineers/NAVAIR managers through a series of reports to solve day-to-day logistic and management problems. The database is massive and encompasses two major subdivisions: the Depot Maintenance Data Sub-System (DMDS) and the Maintenance Data Sub-System (MDS). The MDS is further divided into three subcategories consisting of the Sub-System Capability and Impact Report (SCIR) system, the Maintenance Data Reporting (MDR), and 3M Flight Data Reporting for aircraft utilization. [Ref. 16: p. 2]

The AMPAS database contains information from all three levels of maintenance. Much of the data from the most recent 18 months is identical to data in the FOJ database. In addition, it also contains a flight file (aircraft usage), depot and support equipment (SE) information. This database also functions as an archive of maintenance information. Data for all type of Naval aircraft are available from January of 1980 to the present. This data can be readily retrieved for the user without going to the archives. Data on aircraft prior to 1980 is available by special request. The database is updated monthly but still suffers from a 60-90 day delay for processing through the data collection network.

As mentioned, data contained in the AMPAS database reflects the same data in the FOJ database specifically pertaining to the O-Level. The maintenance manager can use this database to retrieve data which is more than 18 months old. For example, trend analysis of EMT on a specific system can be conducted to reflect any changes, positive or negative, over the life span of a weapon system.

While very useful historical information is available in the AMPAS system, the processes of converting ten years of data, stored in a hierarchical structure, to a relational database structure would be time prohibitive. Conversion time not withstanding, physical storage space in a PC-based system could not possibly handle this quantity of information on a stand-alone basis without an expensive, large capacity hard disk drive upgrade. Information required from AMPAS should therefore be accessed through normal query methods by certified NALDA users

2. TDSA

The Technical Directives Status Account (TDSA) databases contain data describing attributes of Naval Air Systems Command (NAVAIR) Technical Directives (TD). The primary function is to store, maintain, and disseminate information concerning the status of TDs. There is a TDSA database for aircraft (TDAIR), an engine database (TDENG), and one for components and support equipment (TDCGS). The databases contain detailed inventory records for all TDs reflecting the incorporated/not incorporated status of applicable TDs. Historical databases are also maintained for TDs affecting aircraft (TDHIS), engines (TDHER) and component/support equipment (TDHCG).[Ref. 17: p 1]

In this research, the chosen aircraft (F/A-18) has seen a multitude of TDs issued for update and modification. From the aircraft inception, TD tracking has been one of the most time and labor intensive functions of the Maintenance Control staff. Some OMAs have even set up separate sub-work centers to manage TDs. The importance of properly tracking the incorporation of TDs makes this data extremely important to the safety and operation of the aircraft. While every OMA maintains a separate file of source documentation concerning TDs, the authors find this database information important as a cross check and management tool.

TD data is not solely contained in the TDSA databases, the FOJ databases also contain data, reported on the VIDS/MAF, concerning the incorporation of TDs. This data will be available through the FOJ-derived database, which is the primary focus of this research. The TDSA database, much like the AMPAS database, is a historical archive of data and contains data beyond the most recent 18 months as is the case with the FOJ database.

The O-Level maintenance manager has the same opportunity to conduct trend analysis as was the case with the AMPAS database. In this case, the TDSA enables him, or her, to look back farther than the most recent 18 months for specific information pertaining to technical directives. The NALDA Users Group, upon request, can furnish any batch report on any TD incorporation and aircraft/engine configuration.

3. Present Maintenance Requirements (PMR) Database

The PMR database will contain data describing scheduled maintenance requirements derived from the Maintenance Requirements Cards (MRC) decks [Ref. 18: Sec V, p. 40]. MRC decks contain the step-by-step maintenance actions of the PMS program. This database will be updated periodically to reflect changes in maintenance requirements or errors in the initial requirements recorded in the MRC decks. A database containing this information is a major step in the automation of the PMS program. It provides the OMA with an on-line system of scheduled maintenance requirement information. The maintenance manager can verify his on hand type-aircraft MRC contents with the data in the PMR to ensure accuracy. This database, while not available until the late 1990s, will be extremely valuable in establishing the ESAAMS rule base and future validation processes since it contains all scheduled maintenance requirements. To date, PMR databases are only available for the F-14 and A-7E MRC decks. As of this writing there is no target date mentioned for fleet-wide completion.

4. Scheduled Removal Component (SRC) Database

The SRC database contains information archived by part number, including data provided by the depots. Each record is included in the database with an indicator identifying the most current data for a component by part number and serial number. The record includes data concerning installations, removals, overhauls, repairs, and technical directive compliance.

A sub-database to this system is the SRC3M database. This database contains data generated from the FOJ history files as recorded in the main SRC database.

This data set is considered by the authors to be historical and therefore, not of immediate use in a day-to-day maintenance environment. This system is considered to be a valuable data source when researching a specific component for rework or installation history. In the case of a component failing at a higher than normal rate, this information would be useful to initiate research and trend analysis. The authors believe that this form of information would be best served at the I-level, the supporting Supply department or at the depot, where most rework is accomplished and inventoried. Value to the OMA is perceived as useful, at most, in the case of SRC validation, which is generally considered an IMA process and is not considered pertinent to the maintenance scheduling process.

F. SUMMARY

The NALDA system is a centralized, integrated and uniform data bank providing storage, retrieval and analysis capability that can be used in an interactive manner, through remote terminals in support of Naval Aviation Logistics community. The system provides a blanket of coverage throughout the field of aviation maintenance and is one of the main repositories for all data generated at the three levels of maintenance.

A very noticeable omission from the target user community for NALDA are the Organizational Maintenance Activities (OMAs). The NALDA databases are uniquely qualified to serve as the foundation for ESAAMS in the OMA. With ESAAMS, NALDA will be able to expand its services directly to the organizations that provide the bulk of the upline data.

The current Phase One NALDA operational system covers a whole spectrum of different subsystems and databases to provide system users with information to solve problems and make informed decisions. Burpo (1990) asserted that the most likely database for ESAAMS is the FOJ database. The FOJ database stands to be the most logical and usable database for OMA use since it is one of the main repositories for AV-3M upline data. Four additional databases from the NALDA system contain specific data the authors feel are germane to the OMA effort and therefore may provide some utility for ESAAMS. They are: AMPAS, TDSA, PMR, and SRC databases.

While no amount of data will help the maintenance program if it is not processed into information and used, this research has found that there is a wealth of data available, which is applicable to O-level maintenance planning. The only investment necessary is the training of a qualified user to extract data from the current NALDA system. ESAAMS will greatly expedite this process through on-line access to pertinent NALDA data **when it is required**.

The NALDA database is not the only source of data available to the OMA user. Two non-NALDA programs currently hold an important link to the success of ESAAMS. They will be the subject of the next chapter.

V. NON-NALDA DATABASES

A. INTRODUCTION

In this chapter we will examine other databases available to the maintenance expert. While these systems are not currently planned for linkage to this project's database, the authors feel that the future will see close interaction between these systems and an expert system such as ESAAMS. We have chosen two systems which are in operation but are not currently directly linked to the NALDA system. The Enhanced Comprehensive Asset Management System (ECAMS) and The Naval Aviation Logistics Command Management Information System (NALCOMIS) will be examined. A brief background of each system will be provided followed by future uses for each.

In this thesis we are focusing our attention on database construction of a generic DBMS from NALDA databases. As previously mentioned, research for this project involved the F/A-18 *Hornet* aircraft and Strike Fighter Squadron OMAs. The Hornet weapons system was developed to include several state-of-the-art subsystems to assist in the accomplishment of aircraft maintenance. One of these subsystems is ECAMS. ECAMS is unique to the F/A-18 aircraft.

B. THE ENHANCED COMPREHENSIVE ASSET MANAGEMENT SYSTEM

ECAMS is an on-line, interactive, computerized monitoring and data management system which is, as stated in Ref. 19 (p 1-1):

> "...designed to support the Reliability Centered Maintenance/On-Condition Maintenance philosophy for the F/A-18 aircraft and F404-GE-400 turbofan engine. Reliability Centered Maintenance (RCM) is maintenance which enables equipment to perform its task with a specific probability of success at the lowest possible total cost for system operation and support of its life cycle. On-Condition Maintenance (OCM) is based on replacement of aircraft and engine components and the performance of

scheduled maintenance only when necessary to preclude operational failures or degradation of weapon system performance."

The ECAMS system is intended to facilitate efficient, timely, and cost effective aircraft maintenance while ensuring high levels of aircraft reliability [Ref. 20: WP 002 00 p. 4].

1. The F/A-18 *Hornet* Aircraft

To fully understand the ECAMS system, a brief description of the major weapon system must be made. The F/A-18 *Hornet* aircraft was designed to fulfill both the light attack and fighter/intercept missions in a single weapon system base, as demanded by Naval Aviation. The aircraft was procured as a replacement for the aging A-7 *Corsair II* attack aircraft and the F-4 *Phantom II* fighter aircraft. McDonnell Aircraft (prime contractor) and General Electric (gas turbine engine division) teamed to produce this twin engine "strike-fighter," which entered the fleet in the early 1980s.

The engine selected for the F/A-18 is the General Electric (GE) F-404 turbofan engine. The F-404 reflects the current state-of-the-art *modular* engine design vice conventional designs in which the engine is a complete end item, which can only be broken down into component parts. Modular design divides the engine into separate components or *modules* which can be removed and repaired separately from the end item. This affords the intermediate maintenance activity the option of removing the defective module(s), replacing it (them) with RFI or ready for issue module(s), then repairing the defective module separately from the main engine assembly. This expedites engine repair turn-around time and returns critically needed assets to the supply inventory. Earlier called the "augmented turbofan," the engine is also installed in the F-117A Stealth Fighter and several retrofit types of aircraft around the world.

Unique to the F/A-18 is the process of accounting for the life of component parts[2]. Instead of the traditional flight hour accounting used to determine part life limits in most naval aircraft, the Hornet system measures the useful life of component parts, especially critical engine components, as a function of the environment in which the part is used. For example, the severity of engine internal operating environment is measured in terms of power cycles and resultant internal engine temperature and speed variations. Several parameters, called Life Used Indices (LUI), have been developed to measure operating severity and are automatically recorded by installed systems. [Ref. 19: p. 1-4]

Performance data is recorded on the aircraft by the Maintenance Status Display and Recording System (MSDRS) Tape Transport Magazine (TTM), for F/A-18A/B aircraft and Flight Indicator Recording and Monitoring System (FIRAMS) Memory Unit (MU) for F/A-18C/D aircraft. Engine and airframe operational status are continuously monitored by MSDRS or FIRAMS for unit failures. If failure is detected, the mission computer will activate the TTM/MU to record significant maintenance data and selected tactical/inflight information. This data can be used by maintenance experts in the OMA to troubleshoot and fault isolate applicable systems. [Ref. 19: p. 1-1]

2. The ECAMS Data Processing System

Upon completion of a flight, data must be downloaded from the aircraft before it is accessible to the maintenance crew. The TTM/MU is removed from the aircraft and brought to the ECAMS Ground Station, sometimes referred to as the ECAMS Processing Unit (EPU), where the data is extracted. The EPU enables the processing and storage of the performance data. During the process, the data is augmented with other information pertinent to the flight data from the aircraft. This data is manually entered by maintenance

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[2] The Navy is currently developing systems similar to ECAMS in the F-14 A+/D program. Other ECAMS-like systems will be used in future aircraft development.

control personnel and include selected elements from the VIDS/MAF and other control documents relating to the flight. The EPU supports organizational maintenance requirements in the following ways: maintenance fault isolation of selected avionic and non-avionic systems, F-404 engine exceedances, engine performance data and selected life limited components usage data.

Data is transmitted upline from the EPU via a telecommunications network, which links the organizational sites, intermediate sites, and the Parts Life Tracking System (PLTS) Central Data Base (CDB) using the NALDA Interface Computer (NIC). OMA data is transmitted daily to the IMA for networking to the CDB. Shipboard data is forwarded to NALDA via PLTS tapes.

3. OMA Reports

a. Structural Appraisal of Fatigue Effects (SAFE) Program

The F/A-18 Structural Life Tracking system represents the Navy's first advanced development effort to access an entire fleet's airframe fatigue life. [Ref. 19: p. 1-4] Squadrons generate fatigue data through the EPU. Data is compiled and reported back to the OMAs as a SAFE fatigue report published quarterly by NADC. This information is available to the OMA to track fatigue life limit and inflight loading of all assigned airframes.

b. Inflight Engine Condition Monitoring System (IECMS) Reports

IECMS Reports are engine status reports used to track engine life cycle usage, and to record engine event data. An engine event is an occurrence of any of the following conditions on either engine: overspeed, abnormal inlet temperature, high Exhaust Gas Temperature (EGT), flameout, or abnormal oil pressure. [Ref. 20: WP 004 00 p. 2] Use of the reports are valuable in the diagnosis of engine problems which could ultimately result in an engine change.

c. Engine PLTS Reports

The F-404 engine contains forty-five (45) components, which are tracked in the PLTS. Twenty-four (24) of these components are life limited parts. It is imperative that modules and other major assemblies are tracked to follow the life limited parts within these assemblies.[Ref. 20: WP 005 00 p. 2] Prior to extended deployments at the O-level, knowledge of engine components life limits becomes a major planning tool to access engine needs during the deployment. This information can eliminate high time engine changes during deployment and aid in the determination of stock levels in ship's supply.

d. Avionics Built-In-Test (BIT) Recording Reports

Avionics BIT recording reports are systems status reports that can be used to determine system operation and provide fault analysis. BIT reports can provide information isolating failure information down to the subassembly or Shop Removable Assembly (SRA). An SRA is a system component, commonly a circuit card or small component, within a major system component or Weapon Removable Assembly (WRA). The components are nomally changed at the IMA.

C. NALCOMIS

The Naval Aviation Logistics Command Management Information System (NALCOMIS) manages, tracks, and reports on aircraft maintenance and material management requirements throughout the Navy and Marine Corps. The system is defined as a fully integrated computer system that provides local managers with a tool, which will aid them in their day-to-day management decisions affecting their assigned aircraft and equipment. [Ref. 21: p. 2-1]

1. Background

The AV-3M system was developed in 1964 to automate data collection of 3M source data to upline activities. Summary reports were also provided back to squadron activities on a monthly basis. [Ref. 21: p. 2-1] The AV-3M system provided effective validation of source documentation and upline reporting but did not provide this information to reporting activities in a timely manner. As a result of this shortcoming, the NALCOMIS concept was born.

The NALCOMIS Mission Element Need Statement (MENS) of 1984 identified three major deficiencies within the OMAs, IMAs, and the Supply Support Centers (SSC). These deficiencies were: lack of real-time management information, a difficult data collection process, and inadequate up-line information reporting. [Ref. 22: p. 1]

The principal objective of NALCOMIS is to automate the NAMP business functions throughout Navy and Marine Corps aviation maintenance activities, and to implement a standardized management system that will have a measurable, positive impact on aircraft weapon system readiness.

2. Three Phases of NALCOMIS

Introduced in three phases, the current implementation plan reflects complete site implementation by the year 1997.

a. Phase I

Phase I, implemented at the IMA level, provided a first look at key-entered demand and status data and reduction of the common paper traffic associated with repair functions. Called NRMM for NALCOMIS Repairables Management Module, the system provided limited functionality and served as an intermediate step toward implementation of Phase II. Information was provided on demand (screen-driven) and through batch reports reflecting component status within the repair process.

b. Phase II

Phase II implements full functionality of NALCOMIS operations at the IMA and SCC. Unlike NRMM, Phase II makes provision for on-line source data entry/validation and local up-line reporting of AV-3M data through batch reports and magnetic media, interactive interfacing through supply information systems, and management information to the IMA in areas of personnel management, technical publications, equipment, and configuration control. [Ref. 22: p. 3]

c. *Phase III*

Phase III, or NALCOMIS OMA, is currently being implemented at chosen sites throughout Navy and Marine Corps OMA activities. This implementation represents the first release of Phase III technology and will be evaluated at these *alpha* sites prior to complete implementation in OMAs fleet-wide.

Phase III provides full functionality of NALCOMIS at the OMA. The systems designed to provide on-line processing of all maintenance, flight, and supply information which supports aircraft mission capability. The on-line processing features support immediate intra- and inter- organizational communication of maintenance action initiation, approval, priority assignment, work status, and material requirements information.[Ref. 21: p. 3-2]

Data loaded into the system and electronic interfaces with other automated systems allows aviation maintenance managers to monitor and analyze logistics, supportability, readiness, flight safety, configuration management, and other critical parameters. This information, when applied to NAMP principles, forms the foundation for a sound maintenance program.

The system, when fully implemented, will consist of nine subsystems supported by the NALCOMIS OMA database. (See Figure 5-1) The system includes:

1. Database Administration Subsystem --provides the baseline data for the squadron, system security, and data tables.
2. Flight Subsystem --collects and processes flight related data.
3. Maintenance Subsystem --collects and processes maintenance-related data.

4. Logs and Records Subsystem --provides the ability to establish and maintain configuration profiles on aircraft, engines, modules, and components assigned to the squadron.

5. Personnel Subsystem --automates many of the administrative functions associated with personnel management including the maintenance of military manning authorization and manning information.

6. Data Analysis Subsystem --provides the squadron's AV-3M analyst the ability to review and correct each flight and maintenance record prior to submission into the AV-3M system

7. Technical Publications Subsystem --provides the ability to manage the squadron's assigned aeronautical technical publications.

8. Reports Subsystem --provides the ability for a squadron to select and execute NALCOMIS OMA reports.

9. System Administration Utility --provides the ability to the squadron's NALCOMIS system administrator to maintain the squadrons NALCOMIS system.

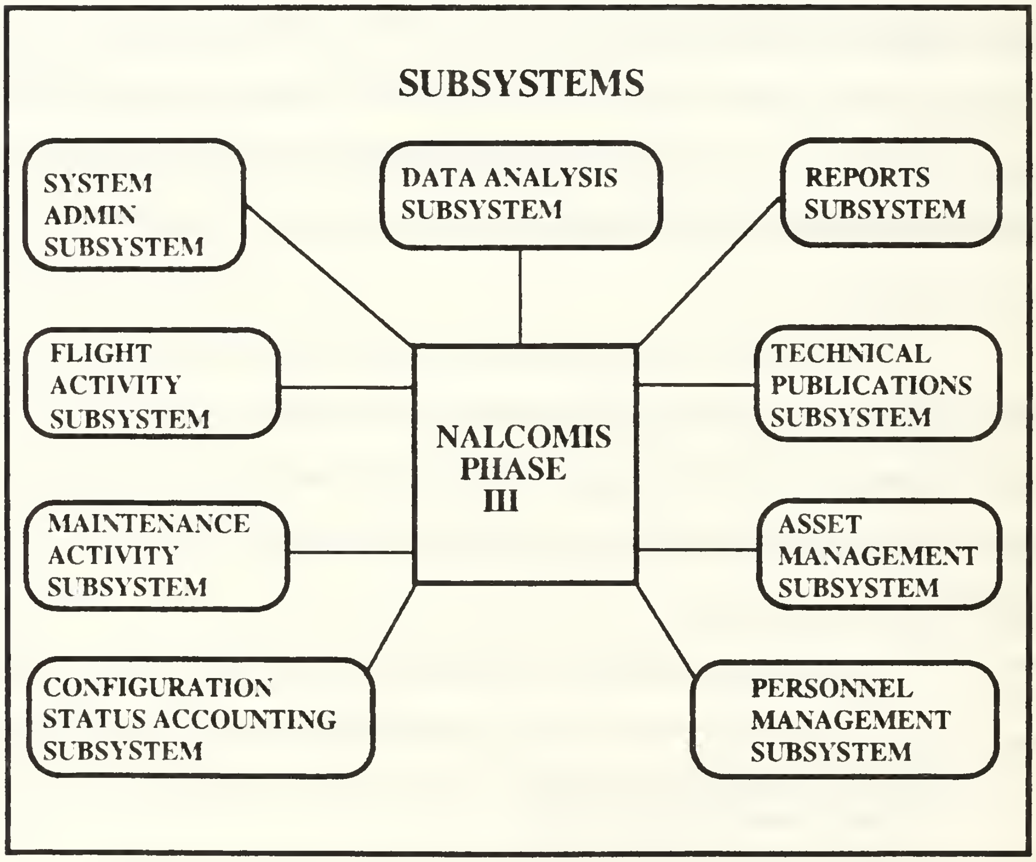

Figure 5-1. NALCOMIS Phase III Subsystems

Ref. 22 lists the following qualitative benefits of Phase III:

- Improved Management Information to Local Squadron Managers
- Improved Aircraft Material Readiness
- Improved Accuracy of Aircraft/Engine Configuration
- Improved Maintenance through Automated Tracking of Aircraft and Support Equipment Scheduled Maintenance
- Improved Management Information through Timely Automated Data From Squadrons Detachments with PC-Based NALCOMIS System
- Improved Standard Asset Management at OMA
- Improved Data Collection and Accuracy
- Improved Pilot/Aircrew Flight Data Reporting/Record keeping
- Elimination of 3M Source Document Key Entry at Supporting DSF
- Improved Standardization of Maintenance Administration

D. SUMMARY

Data management in the OMA is of paramount importance to the success of the maintenance program. Data is collected during the flight and throughout the maintenance process by various methods and transferred into the AV-3M system or similar databases. Currently there are limited ways to retrieve this data for use at the O-level.

The Enhanced Comprehensive Asset Management System (ECAMS) was developed as an on-line, interactive, computerized monitoring and data management system in support of the F/A-18 *Hornet* aircraft. The F/A-18 concept, in concert with ECAMS, incorporated a new way of measuring the useful life of component parts using parameters called Life Used Indices (LUIs). The LUI concept takes into consideration more of the flight characteristic variables than do conventional flight hour measurement methods used on most naval aircraft. ECAMS provides maintenance experts real-time data to evaluate, troubleshoot, and fault isolate conditions occurring outside acceptable parameters.

The Naval Aviation Logistics Command Management Information System (NALCOMIS) is a CNO-backed initiative to provide an automated method of providing AV-3M information back to the reporting activities in a timely manner. Three deficiencies were noted in the NALCOMIS Mission Elements Need Statement (MENS) of 1984. They were: lack of real-time management information, difficult data collection processes, and inadequate upline information reporting. NALCOMIS addresses these issues and automates NAMP business functions throughout the Navy and Marine Corps.

NALCOMIS was implemented in three stages with current focus on the OMA (Phase III). Phase III provides full functionality of NALCOMIS to the OMA and consists of nine subsystems. Each of the subsystems provides a different measure of functionality to the OMA. When fully implemented the system should provide improved management information to OMA experts including real-time information retrieval capability.

The future of automated data management should find ECAMS, or a form thereof, and NALCOMIS providing necessary information in a timely and accurate manner to the maintenance expert. Incorporation of this technology, with improved decision making tools, hold the key to improved aircraft material readiness and efficient use of funding. Conclusions and recommendations for the future of these two systems will be discussed in later chapters.

VI. USER INPUT

A. INTRODUCTION

The idea of developing an expert system advisor for the aviation maintenance community was introduced by the authors to U.S. Navy and U.S. Marine Corps aviation maintenance personnel at NAS Lemoore, CA. The idea was presented to both senior enlisted and experienced aviation maintenance officers. The presentation and interviews were conducted in two fleet aviation squadrons, VFA-25 and VFA-113; and then with the *experts* on the staff of the Naval Aviation Maintenance Training Group Detachment (NAMTRAGRUDET), Lemoore.

Interviews in the two fleet squadrons were conducted on a one-to-one basis with key officer personnel in the maintenance department. The authors found the informal interview process allowed "uninhibited" information flow in which the interviewees felt free to express opinions and make suggestions about the NALDA system and the ESAAMS concept in general.

Interviews at NAMTRAGRUDET were conducted in an open forum format. The main group consisted of 20 senior enlisted maintenance experts from various type-aircraft backgrounds. The concept was briefly introduced and explained by the authors followed by an informal question/answer period in which opinions and views of NALDA and ESAAMS were discussed. The authors were available for the remainder of the day for one-on-one interviews with selected personnel.

Reactions to the concept were varied, ranging from total acceptance to total pessimism and doubt. This was expected. This form of research was chosen to facilitate a bottom-up approach to pool the experts' knowledge vice a top-down, closed environment, model. During the interviews, it was noted by most of the personnel that this strategy was the only way to <u>successfully</u> produce the system.

This kind of end-user involvement is what most information systems developers encourage when developing new IS software. Involving the user is a logical and important step in the analysis and development of any information system. In the final analysis, if users cannot understand the system, it won't be utilized or in some cases, the user will employ other means to avoid system utilization.

As mentioned above, this form of information gathering is not scientific by nature and is from a limited sample. But it does offer some insight to the views of maintenance personnel assigned within the F/A-18 community. The opinions expressed by the personnel interviewed do not necessarily reflect either the F/A-18 or the Navy-wide aviation maintenance community's views of the subject. They do, however, serve as important information for the design of a maintenance related DBMS. For it is user input which will make this or any system a viable decision making tool.

The results of the interviews and comments about the use of the NALDA database for ESAAMS are summarized below.

B. INTERVIEW INFORMATION

1. Scheduled Maintenance

As pointed out by McCutcheon [Ref. 23: p.33], data in the NALDA database routinely suffers from a 60 to 90 day lag. This time lag limits usefulness of the data. One possible use of the NALDA database in its current configuration involves scheduled maintenance. Using historical records of elapsed maintenance times, scheduling of required aircraft inspections can be prioritized.

Figure 6-1 shows the proposed data flow after the AV-3M/NALDA merger, currently in work. One of the obvious benefits from this merger will be much more rapid transmission of data to the NALDA database and reduction of the time lag. Some expected estimates, post-merger, put the future time lag at no more the 20 to 30 days. The merger and implementation of NALCOMIS OMA greatly expedites the MDS cycle virtually eliminating any retrieval or accuracy problems due to a time lag.

Scheduled maintenance was one of the common areas of focus throughout the interviews. A majority of the experts interviewed agreed that a NALDA-derived system for scheduled maintenance is feasible.

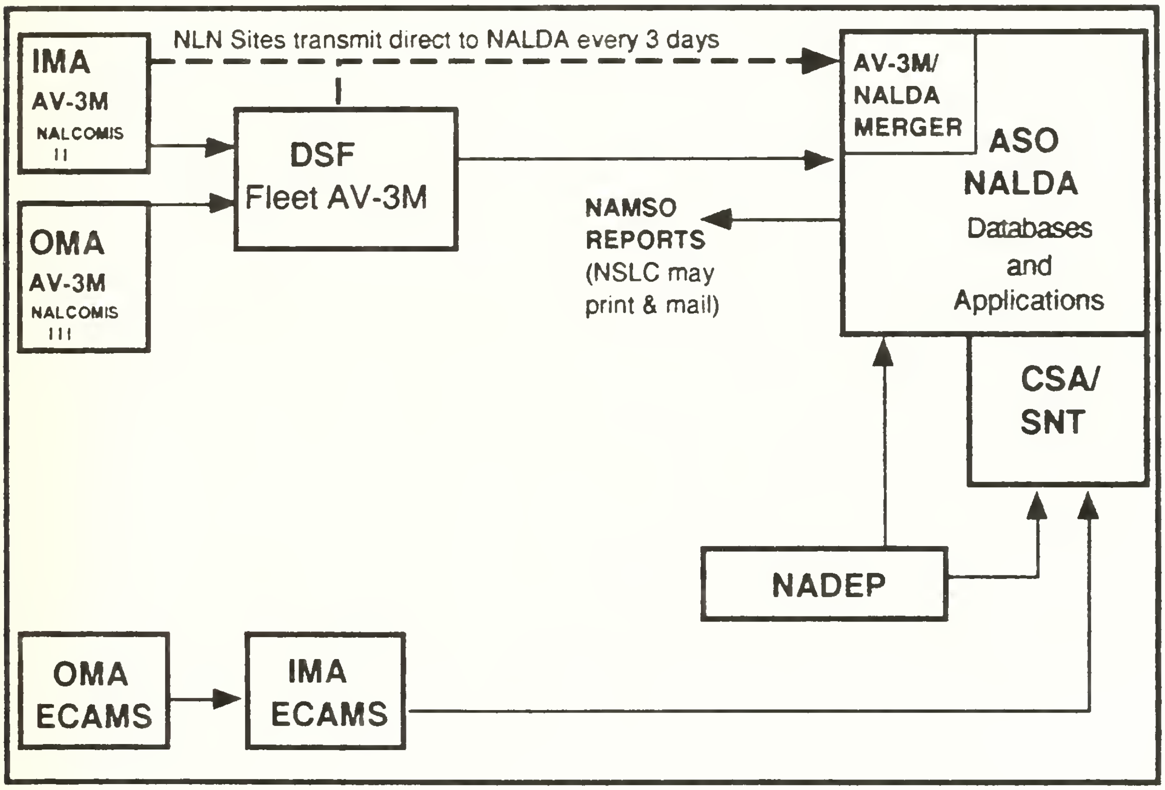

Figure 6-1. Proposed AV-3M Data Flow

Another closely related area involves the construction of the Monthly Maintenance Plan (MMP). Scheduled inspections are required at various times in the maintenance cycle of every aircraft. These inspections are required either by the passage of time or by the accumulation of flight hours.[3] The maintenance planner must compile these requirements and schedule them into a systematic format to accomplish inspections as required. Historical information can assist in planning when to accomplish a specific inspection within the "window," or acceptable time frame, of the inspection. Once again, elapsed maintenance time is an important variable. Using EMT the maintenance planner gains insight into how many man hours a typical maintenance procedure may consume. When dealing with scheduled maintenance, workloads can be prioritized to conform to available maintenance time, i.e., per shift or work day. For example, if several aircraft require scheduled maintenance, and there is a requirement for a large number of aircraft to be mission capable the next day, the maintenance planner can draw EMT information from historical files to prioritize tasks to optimize aircraft availability for the next day. In other words, perform those scheduled maintenance tasks which provide the maximum number of "up" aircraft.

The FOJ database contains this data. Automation of some of the squadron MMP can be performed by a DBMS on a stand-alone PC using this data at the OMA.

2. Unscheduled Maintenance

Unscheduled maintenance is a dynamic process requiring access to information, which is as current as possible. The NALDA time lag becomes a limiting factor in this environment. Application of data in this situation is limited to trend analysis usage. Our interviews also revealed other information needs of the *experts.* To a person, a common theme became obvious: What the maintenance controller needs most is a tool, with <u>instantaneous</u> access to current data, to make the correct decisions in this dynamic environment. The current NALDA structure cannot support this need nor was it ever

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[3] In most aircraft, flight hours are used to track the relative age and use of certain critical parts. As mentioned, the F/A-18 aircraft system uses LUIs to track the life, and to determine when certain inspections are required, for a number of critical parts in the PLTS program.

designed to. *Real time* computing is a necessity in the aviation maintenance environment. The combination of NALDA database use and NALCOMIS OMA should provide the access necessary to enable a real time or near real time environment.

3. Real Time Computing

If on-line and real time computing is available in the maintenance environment, the maintenance manager can improve decision making capability quantifiably. The speed in which the environment changes becomes a limiting factor. Automation can put the right information in the right place at the right time, and speed. Unfortunately, the present NALDA database system alone cannot support this type of real time access. To accomplish this desired product, linkage to a MIS, like NALCOMIS, is necessary.

4. NALDA Data Use

As pointed out by McCutcheon [Ref. 23: pp. 46-48], NALDA data does not enjoy wide usage in the OMA. For various reasons, whether they are unaware of data existence or it is just used for historical data retrieval, OMA managers don't regularly use NALDA data. The AV-3M monthly summary does receive limited use, but rarely are real-time decisions made using this form of data.

The experts also questioned the necessity and application of NALDA data. Their views seemed to be consistent with those found in McCutcheon's (1989) interviews.

5. NALDA Accuracy

Another area of concern expressed by the experts was the accuracy of NALDA data. It is a widely known but little discussed fact that a squadron is graded on readiness numbers obtained from the data submitted into the system. The AV-3M system was never designed for this purpose. Before data is released into "the system" it is thoroughly screened, "scrubbed," for any bit of information which could be detrimental to the squadron's chance in competing for the various awards given on an annual basis.

Information is also "looked at" during inspections and is used as a grading criterion when trying to separate the "best" squadron from the others, in some higher commands.

The accuracy of the data is therefore questionable in most maintainer's minds. Burpo [Ref. 2: pp. 37-41] poses the question of data accuracy and concludes that a "data fudging" occurs on a frequent basis. Burpo continues, citing several additional reasons for the inaccuracy of NALDA data. The authors and the experts interviewed agree, from their experience with fleet inputs, that there is a "fudge factor" used especially in the Subsystem Capability Impact Reporting (SCIR) system.

6. What about NALCOMIS?

NALCOMIS Phase II is gaining rapid acceptance from the users interviewed. Much of this stems from the system's capabilities to provide on-line and almost real time computing.

NALCOMIS Phase III, or NALCOMIS OMA, can provide the on-line real time computing needed by O-level managers. Data can be provided upline and downline from the network with connections to supply databases and other maintenance information databases. NALCOMIS OMA will also be the AV-3M reporting vehicle and, thus, will contain all squadron VIDS/MAF and Naval Flight Record Subsystem (NAVFLIRS) input, the very sources of data required by the maintenance manager.

7. User-Friendly System

Any information system that is to be introduced must be designed with the KISS[4] principle in mind. This statement was echoed by all senior enlisted personnel interviewed. There is no need to expend energy developing a system people find too complicated to operate and, therefore, won't use!

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[4] KISS: Military slang for Keep It Simple, Stupid.

To satisfy this need, complete interaction with the user during the design phase is essential. They alone are the people who will use and benefit from the IS.

8. Other Findings

The experts were generally in favor of a system designed to help the maintenance program operate more smoothly. Other ideas include:

- Daily schedule of events including maintenance priorities, personnel manning requirements, non-maintenance related events, etc.
- Cannibalization tracking
- Part tracking through the repair system (would require link to I-level)
- Link to the supply system part expeditor. Would provide continuous update of part availability.
- Scheduled Removal Components (SRC) scheduling. (requires real time link)
- Location specific parts/equipment requirements. Would allow squadrons to obtain information on part/equipment requirements for geographical-specific detachments/deployments. (i.e., cold weather vs. warm weather operations)
- Phase maintenance kit tracking
- Special inspection tracking (i.e., hard landings, engine over speed/over temp, etc.)
- Inventory tracking. Aircraft, engine accessories, system integrity, classified communications equipment, and other reportable equipment.

The information presented above indicates a deep rooted interest by some fleet experts for a better information retrieval and management system. NALCOMIS OMA will provide the capability for many of the experts needs. No single system, one which can accomplish <u>all</u> maintenance management needs, is planned for the foreseeable future.

C. SUMMARY

The intended users for ESAAMS were very direct and forthright with their comments on the proposed system. There were three immediate uses that most could see for the NALDA database, namely, scheduled maintenance, failure rate information and trend analysis. While this was a common thread, it was not the primary desire for what they really want or expect from a DBMS or expert system. On-line and real time computing are what is desired and needed. Users want *instantaneous* access to *current* data to help manage the demands of a dynamic environment. The authors agree that this is the direction of the future. The last chapters will deal with a prototype design of an ESAAMS DBMS.

VII. DBMS PROTOTYPE DESIGN

A. INTRODUCTION

This chapter will discuss the design process of the ESAAMS Database Management System. As mentioned in Chapter III, a DBMS stores, retrieves, and updates data. For the ESAAMS DBMS, the data will come from the NALDA FOJ database which is determined by the authors as the most useful database for an OMA maintenance manager. The FOJ database contains a large volume of data that it can easily overload the capacity of a 200 megabyte PC hard disk drive. Hence, the prototype database design for this thesis will only consider data applicable to a single aviation squadron. With an evolutionary prototype ESAAMS DBMS in mind, careful consideration into the modularity of the database design is undertaken. Starting small with a single squadron, the prototype database design can be expanded to a larger organization like an Air Wing or a Fleet Command. The only limitation that the authors see right now is the micro-computer hard disk drive capacity. The data extracted from the NALDA database for this thesis is for VFA-25, an F/A-18 squadron based at NAS Lemoore, CA.

Conversion from a hierarchical database model to a relational database model is needed in order to take advantage of the powerful 4th generation language (4GL), SQL, for use by squadron personnel. As mentioned in Chapter III, use of SQL makes ad hoc queries of the database possible and, therefore, provides a wide range of flexibility for the maintenance manager to manipulate the database for decision support.

The DBMS design process will cover four phases: definition, requirement, evaluation, and design. Implementation of the prototype design, using ORACLE® RDBMS software will not be covered in this thesis. A separate User's Manual, software application package, and demonstration database will be available in April, 1992 through the thesis advisor at Naval Postgraduate School, Monterey, CA.

B. DEFINITION PHASE

The ultimate goal of this continuing research on ESAAMS is to develop an expert system advisor for the OMA maintenance manager. It is mentioned in Chapter III that a knowledge base that accesses a database containing historical data, for a particular model aircraft, is an integral part of this expert system. This database contains all domain facts that the expert system can use. The creation of a DBMS, as a module of ESAAMS, will enable the maintenance managers to view data, analyze trends, print reports and perform limited what-if decision queries.

1. Scope

Optimally, use of the entire NALDA database would have been needed in order to cover all aspects of maintenance in naval aviation and provide the maintenance manager with the plethora of information he requires. However, the NALDA FOJ database can be sufficient to perform scheduling, trending, and analyzing. Chapter IV covers the NALDA databases and the contents of the FOJ database.

Extraction of data from the hierarchical NALDA FOJ database into the relational database of ESAAMS can be performed by pulling out attributes from the FOJ schema. These attributes are grouped together to form the entities or objects that will make the relational database. In other words, the extracted attributes will be constructed into a flat spreadsheet-like table, then transferred to the corresponding relational table of the ESAAMS DBMS. Extracted data from NALDA will be in ASCII format and transferred in batch via the floppy disk medium. The ORACLE® SQL Loader utility tool will be used for the data transfer. This method of constructing the relational database from a hierarchical database is the simplest and most feasible way of transformation without creating numerous anomalies in the system. Current field research is still underway in the transformation of entire hierarchical databases into relational databases [Ref. 24].

2. Feasibility

The method of extracting data from a hierarchical database by creating flat file tables and then transforming into a relational database is feasible. The process itself is simple but careful consideration into the design of the relational tables is paramount in order to avoid anomalies in the resulting relational database. [Ref. 24]

C. REQUIREMENTS PHASE

Potential users from VFA-25 and Senior Enlisted Personnel from NAMTRAGRUDET, NAS Lemoore, CA were interviewed. Chapter VI contains some of their maintenance management needs that can be fulfilled by this prototype DBMS. The NALCOMIS OMA, when fully operational, will be a better source of data for maintenance management because of its real time capability. With the 60 to 90 day time lag that is inherent in the NALDA data, all potential users conclusively stated that the most probable use for the extracted data is for historical-type knowledge. Potential applications can include:

- **Historical Failure Report** - this report records historical failure rate of systems identified by Work Unit Codes. For a selected WUC, the maintenance manager can get an idea of the failure rates of specific systems or subsystems historically. This is a very important application for ESAAMS. For this thesis, only the F/A-18 aircraft for VFA-25 will be covered. As the database is expanded, other aircraft type and squadrons can be queried.

- **Average Elapsed Maintenance Time Report** - this report shows the average elapsed maintenance times (EMT) of systems or subsystems identified by WUC for a specific action taken (AT) code. For example, an action taken code of "R", which means remove and replace, is used when a component is removed due to a suspected malfunction and the same or like component is reinstalled. This gives a maintenance manager an idea of how much time to allocate for a specific maintenance action. This information can be very valuable for ESAAMS.
- **High Manhour Consumer Report** - this report can aid the maintenance manager in identifying problem areas in aircraft maintenance as evidenced by manhour consumption. This report can be queried according to aircraft Bureau Number (BUNO), aircraft system or subsystem as identified by WUC. Top manhour consumers can be identified immediately by aircraft identification then by system WUCs and subsystem WUCs. Analysis of this report can show maintenance managers of potential problems to specific aircraft or systems/subsystems.

A very limited application can be supported by this stand-alone database because of the time lag. Yet, for applications that are not considered dynamic, that is, not requiring real time data. the DBMS can be used.

Figure 7-1 shows the data flow diagram of the prototype DBMS. Updating of data is only done in batch mode on a monthly frequency, which corresponds with the update of data in the mainframe NALDA database. Once data has been transferred from the NALDA database to the ESAAMS relational database, applications can be generated by using the SQL language for *ad-hoc* queries or the programmed reports.

1. Database Objects

Five *objects* are designed for this prototype database. An *object* is a named collection of properties that sufficiently describes an entity in the user's work environment [Ref. 11: p. 90]. Appendix A shows the construction of these five objects. *Object* diagrams summarize the knowledge of the *objects* and present them visually and unambiguously [Ref. 11: p.91]. Appendix C contains *object* specifications and *domain* definition for the database.

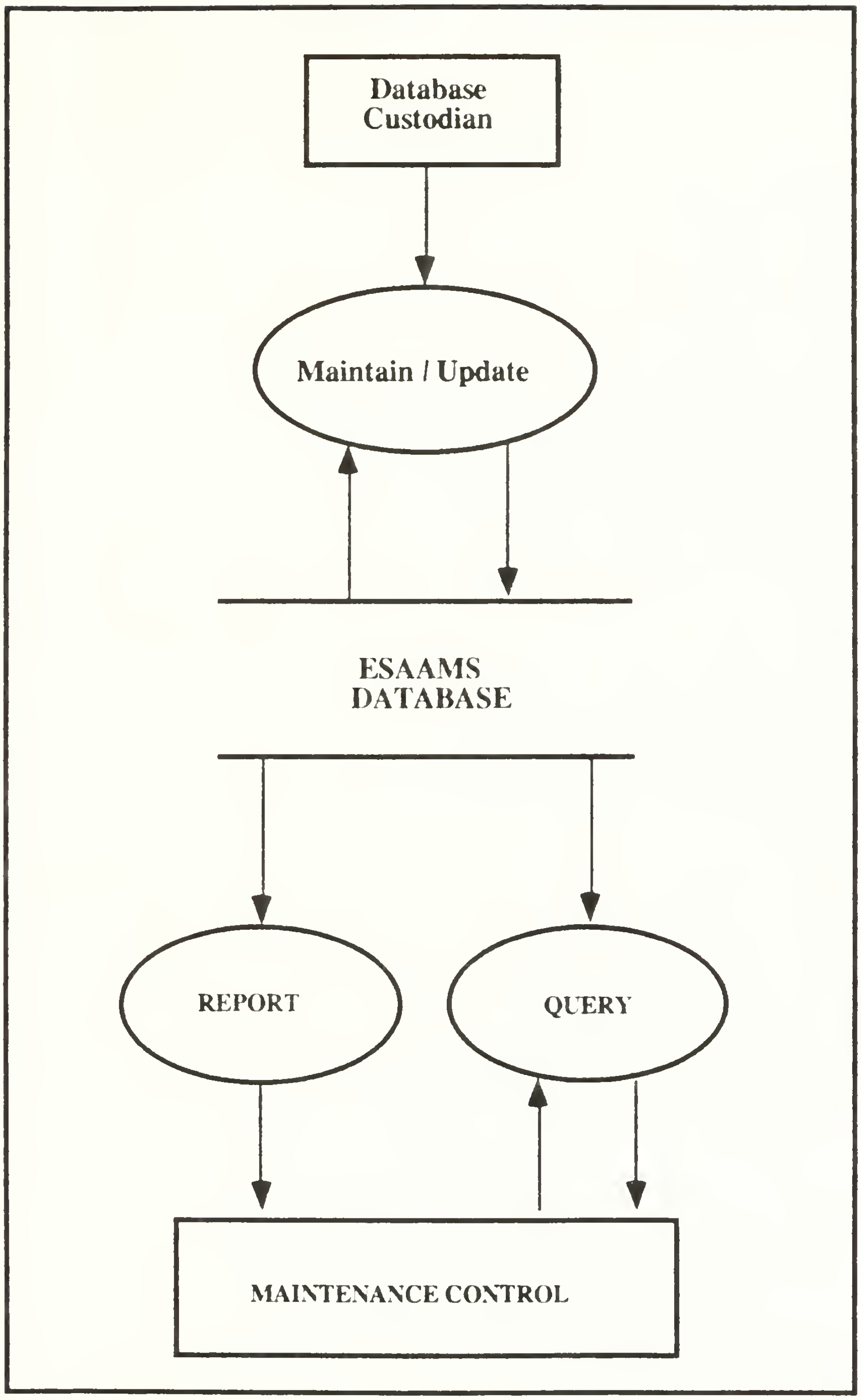


Figure 7-1. Dataflow Diagram

a. Maintenance_Action

This object describes data which is primarily documented in the completed VIDS/MAF. It contains attributes like *elapsed maintenance time (EMT), action taken code, work unit code (WUC),* etc. There are a total of 18 properties in **Maintenance_Action.** Fifteen are *non-object* properties and three are *object* properties. An *object* property is a characteristic of the entity that is another *object* [Ref. 11: p. 91].

b. End_Item

End_Item contains *type equipment code (TEC)* as reported in record type "A" of the VIDS/MAF, record type "7B" or record type "79." Aircraft end item and program (parts) end items are both contained in this *object*. There are six **End-Item** properties, four *non-object* and two *object* properties.

c. Equipment_Summary

Equipment_Summary contains availability and utilization data for aircraft and training devices as reported on record type "79." Mission capability hours whether *FMC, PMC, or NMC* per aircraft are contained in this *object*. Total flight hours and number of flights are also included here. **Equipment-Summary** contains 14 properties with 13 *non-object* properties and one *object* property.

d. Incorporated_TD

Incorporated_TD contains data pertinent to an individual technical directive incorporation as reported on record type "F" of the VIDS/MAF. Technical Directives are always used during any maintenance evolution because they contain the latest technical changes that must be followed before any given part or equipment is worked on or operated.. There are eight properties for **Incorporated_TD** with seven *non-object* and one *object* property.

e. *Job_ID*

Job_ID contains the *job control number (JCN)* that OMAs assign to their maintenance action. This is used to track maintenance actions and identifies the organization performing the maintenance. **Job_ID** contains six *non-object* properties and one *object* property.

Appendix B shows the *Object* diagrams and Appendix C contains *Object* specifications and domain definitions for this database. *Object* diagrams summarize the knowledge of the *objects* and present them visually and unambiguously [Ref. 11: p.91].

2. Methodology

The *Objects* formulated for this database are output-driven (i.e., derived from intended applications). The authors' interview with domain "experts" resulted in several applications that can be developed by the database. Although these applications are limited in scope, as far as optimality of usage in aviation maintenance, they show that the DBMS can be used for the ESAAMS system. Information derived from the VIDS/MAF is most relevant for any maintenance manager, therefore, the formulation of these objects concentrated on the data recorded from the VIDS/MAF.

D. EVALUATION

The evaluation phase of any system development consists of three tasks. First, alternative application system architectures are identified. Second, the feasibility of the application is reassessed now that the requirements are known in more detail and the basic alternative solutions have been specified. And third, all user requirements are reevaluated within the context of each possible solution. [Ref. 11: p. 78]

More comments on this section will be provided in the concluding chapter of this thesis.

E. DESIGN

The design phase includes the logical database design and the applications design. A graphical representation is presented in Appendix B.

1. Logical Database Design

a. Relationship between parent End_Item and siblings Maintenance_Action and Equipment_Summary

The **End_Item**, uniquely identified by *TEC (Type Equipment Code)* and *BUNO*, may have a number of **Maintenance_Action** and **Equipment_Summary**. **End_Item** has a one-to-many (1:N) optional relationship with either **Maintenance_Actions** and **Equipment_Summary** objects. *TEC* and *BUNO* are foreign keys to both **Maintenance_Action** and **Equipment_Summary**. *JCN* and *WC* are the primary keys for **Maintenance_Action**, while *BUNO* and *YYMM-ES* are the primary keys for **Equipment_Summary**.

b. Relationship between parent Maintenance_Action and sibling Incorporated_TD

The **Maintenance_Action**, uniquely identified by JCN and WC, has a one-to-one and optional relationship with **Incorporated_TD**. But the reverse is a mandatory relationship. In other words, a given **Maintenance_Action** does not necessarily have to have an **Incorporated_TD** but for each occurrence of an

Incorporated_TD a Maintenance_Action must be present. JCN and WC are foreign keys to **Incorporated_TD** with TD_Num and JCN, as primary keys.

c. Relationship between parent Job_ID and sibling Maintenance_Action

Maintenance_Action and **Job_ID** are related one-to-many (1:N). A **Maintenance_Action** must have (mandatory) one **Job_ID** but a **Job_ID** is only optionally related to **Maintenance_Action**. WUC and WC are **Job_ID**'s primary keys. **Maintenance_Action** will contain WUC and WC as foreign keys.

There is no relationship between **Maintenance_Action** and **Equipment_Summary**.

2. Application Design

The application output (i.e., reports and forms) will be developed using ORACLE® RDBMS Version 6 software. Use of ORACLE® is necessary because NEXPERT OBJECT®, the target expert shell software for ESAAMS development, interacts with the ORACLE® RDBMS.

User-friendliness of the system is of utmost importance. To allow users to control and direct applications, menus will be used instead of commands. An attempt to incorporate the use of "mouse" environment will be pursued.

Menu logic and materialization will not be included in this thesis. These will be covered fully in a separate User's Manual.

Appendix D contains prototype samples of reports desired for this DBMS as discussed in section C of this chapter. These reports will be produced by the ESAAMS DBMS.

F. SUMMARY

A DBMS is a software program that manipulates data in the database to produce results that a user requires for his business or work. In this chapter, a walkthrough of how the prototype ESAAMS DBMS will be designed has been covered. Numerous challenges abound in the transformation of a hierarchical database model to a relational database model. The planning and design of correct objects or entities and their attributes and understanding of how the business of aviation maintenance is performed is important to the logical presentation of the whole database.

A DBMS is only useful if it satisfies the needs of the users. This satisfaction can be derived if the system is easy to use, the system produces the right results and it meets the constraints that the users have in performing their business.

VIII. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

A. SUMMARY

To keep pace with the sophisticated and advanced technology of today's aircraft and weapon systems, maintenance managers must have the tools, information, and data available to make accurate, knowledgeable, and expert decisions. The management tools and data support systems must be equally as sophisticated as the equipment they support but designed and constructed with a user interface which is a tool and not a hindrance to the process.

A wealth of data is generated daily at all levels of maintenance. This data has been meticulously sorted and stored in various major databases throughout the Naval MDS. The problem does not lie with the quantity of data available to the maintenance manager but, the **accessibility** to this data and the transformation of this data into useful information. Present organizational maintenance management information systems simply do not have the capability to provide usable data at the time and in the form required to make accurate and timely decisions. The question presented to major project managers and the general focus of this research is on how to get information to the manager, in a timely and usable format, to assist in the critical decision making process. The introduction of NALCOMIS OMA will be the first significant step to satisfying this need.

The NALDA database system contains the information necessary for decision making but suffers from an inherent time lag of 60 to 90 days. Access to the system can only be accomplished by on-line query or telephone requests to the user assistance group. While both of these vehicles are productive ways to access information, they do not provide sufficient focus on the OMA. However, historical failure information and elapsed maintenance time are useful information.

The purpose of this thesis was to identify the applicable data contained in the NALDA databases and design a user-friendly PC-based database for use with ESAAMS. A relational database constructed from the hierarchical structure of NALDA is one answer to providing NALDA data access to the OMA. Design, analysis and potential use of this database concept for ESAAMS has been provided in this thesis. The authors have also introduced the concept to the user maintenance professionals. Their opinions on aviation maintenance community information needs substantiate the focus of this research.

The primary research questions addressed were:

- What data contained in the NALDA database system are germane for use in building the ESAAMS main database?
- What uses/benefits would such a database provide an organizational maintenance activity?

Secondary questions that evolved from the research focus were:

- Are other databases in addition to NALDA required for the proper operation and maximum benefit of ESAAMS?
- What do the "experts" in the aviation maintenance community want from a management information system?

B. CONCLUSIONS

What data contained in the NALDA database system are germane for use in building the ESAAMS main database?

The NALDA database contains voluminous amounts of data which includes information necessary to assist the maintenance expert to make more informed decisions. It contains all resource data entered daily on the VIDS/MAF, which is the primary source of information required by the maintenance manager. As discussed in Chapter IV, the NALDA FOJ database contains all the data germane for use in building the ESAAMS main database. However, the time lag between a maintenance action reported at the O-Level and its availability for data retrieval from the NALDA system limits the utility of this database. This research has concluded that a stand-alone database management system using only the data contained in the NALDA database systems will have limited use and cannot support the **total** maintenance decision making process required in a dynamic aviation environment.

The NALDA system is frequently used in the IMA to track the history of parts and assemblies throughout the maintenance/operation cycle. This level of maintenance tends to be not as dynamic as the O-level. The problem is that the NALDA system, in its present form, lacks real time capability.

What uses/benefits would such a database provide an organizational maintenance activity?

Access to real time information is the main desire that all maintenance managers have voiced in order to support the fast-paced evolution of aircraft maintenance. A specifically designed, stand-alone database like the one proposed in this thesis, will provide the OMA with a means of retrieving historical and trend data to assist the maintenance scheduling task. In the event of any communications failure or if communications are unavailable to the host system, this PC-based database can provide some of the needed data for decision support. The construction of the ESAAMS database from NALDA data is an important interim step toward accomplishment of the aviation maintenance information needs of the future.

While the uses and benefits of a stand-alone system are limited and consume significant time, effort, and cost to produce, the construction of this prototype database is feasible and will achieve some benefit to the maintenance expert. This concept was explored, not only to provide short term benefit to the maintenance manager, but, to evaluate the design and project requirements for ESAAMS in the long run.

Are other databases in addition to NALDA required for the proper operation and maximum benefit of ESAAMS?

This research has continually stressed the need for a real time capability, by any aviation maintenance information system, to enable maintenance managers to make real time decisions. The NAVAIR 2010 Plan for total information systems (Figure 4-1 on page 24) involves the NALDA/NALCOMIS/NADIM interrelation. NALDA will become the central database. This system design will enable the transmission and retrieval of *real time* data to and from any potential user.

NALCOMIS Phase III becomes the central player in this schema because it provides the necessary hardware to support the system at the OMA. Also, the NALCOMIS network provides the necessary links and protocols. Real time data management can be achieved using the NALCOMIS Phase III interface.

NALCOMIS OMA in its optimal form, with ESAAMS as a subsystem application, will eliminate the inherent data time lag of the current NALDA system. Current source data will be available locally, in addition to access to the NALDA historical files. This combination eliminates any time lag in the retrieval and use of maintenance data. This corresponds directly with the preferences stated by the maintenance experts interviewed.

What do the "experts" in the aviation maintenance community want from a management information system?

Chapter VI discussed what some experts in the aviation maintenance community wanted from a management information system. They are:

- User friendliness
- Instantaneous access to data

- Real time computing
- Single-system architecture (like NALCOMIS)

Whatever information system is deployed for fleet use, a *real time* link to the aviation maintenance data collection system should exist. To omit this feature will severely limit the utility of the system and decision support for the maintenance manager of the future.

C. RECOMMENDATIONS

Based upon research conducted in this thesis and the conclusions offered in the previous section, the following recommendations are offered:

- Currently, OMA community knowledge of the NALDA system and its use is limited. Every OMA should qualify a NALDA user for access to any NALDA database. This could be tied to the Data Analyst schooling providing an extra two weeks of instruction for NALDA use. This information returned to the squadron would fill the void now present in many organizations where little, if any, knowledge of the NALDA program exists.Presently there exists no direct access from OMA to NALDA except through IMA facilities. The NAVAIR 2010 structure which links together the NALCOMIS/NALDA/NADIM systems should provide access at the OMA to facilitate on-line query capability. (See Figure 6-1 on p. 48)
- Remove the policy of grading activities on aircraft readiness statistics which are derived from maintenance data input. This will encourage activities to report more accurate data and not promote "scrubbing" to improve readiness statistics as is the current practice. The quality of data contained in the various databases should improve quantifiably, thus allowing a more realistic picture when studying trends from the databases.
- Link ECAMS and NALCOMIS OMA directly at the O-level to eliminate processing time and allow local use of the information on one system. The ECAMS system, or version thereof, is currently being implemented in several aircraft types. This rich source of data must be made available to the maintenance manager on the same *real time* basis as NALCOMIS information. This implementation would allow processing of data on a single system hardware suite vice the current two system setup.
- Tie-in ESAAMS as a subsystem application to NALCOMIS OMA (see Figure 8-1).The authors believe that an expert advisory system can be designed and made to interface with the proposed NALCOMIS OMA structure. To facilitate this linkage, the structure of the NALCOMIS/NALDA database must be a functional, relational database structure. Such a change in database structure is currently in development at NAMO. Further research into the feasibility of such a link should be studied. This supports the original ESAAMS concept as envisioned by McCaffrey (1985).

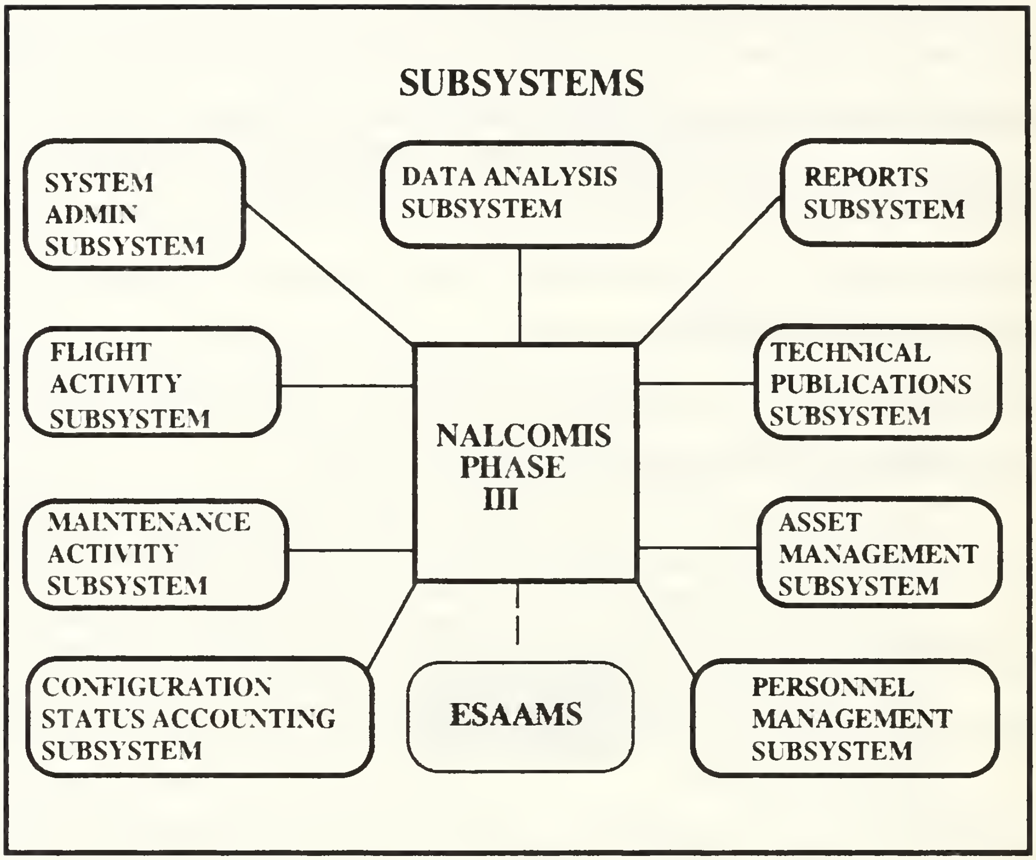
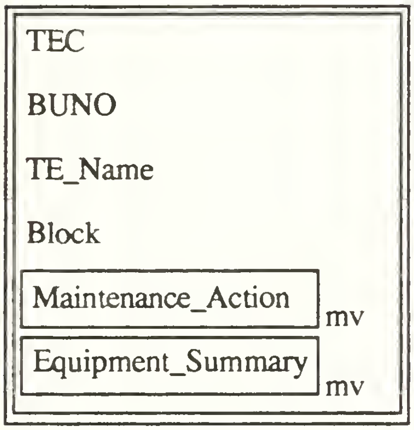


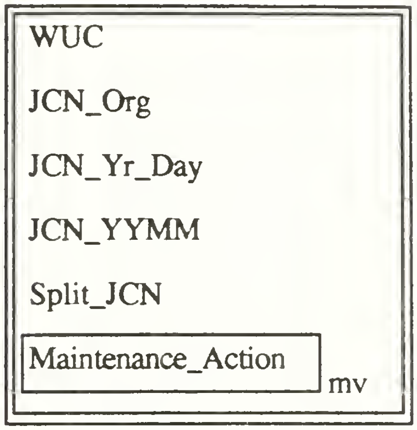
Figure 8-1. NALCOMIS Phase III with ESAAMS

APPENDIX A. OBJECT DIAGRAMS

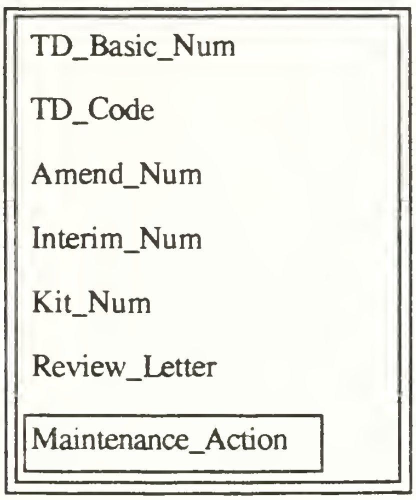
END_ITEM



JOB_ID



Incorporated_TD



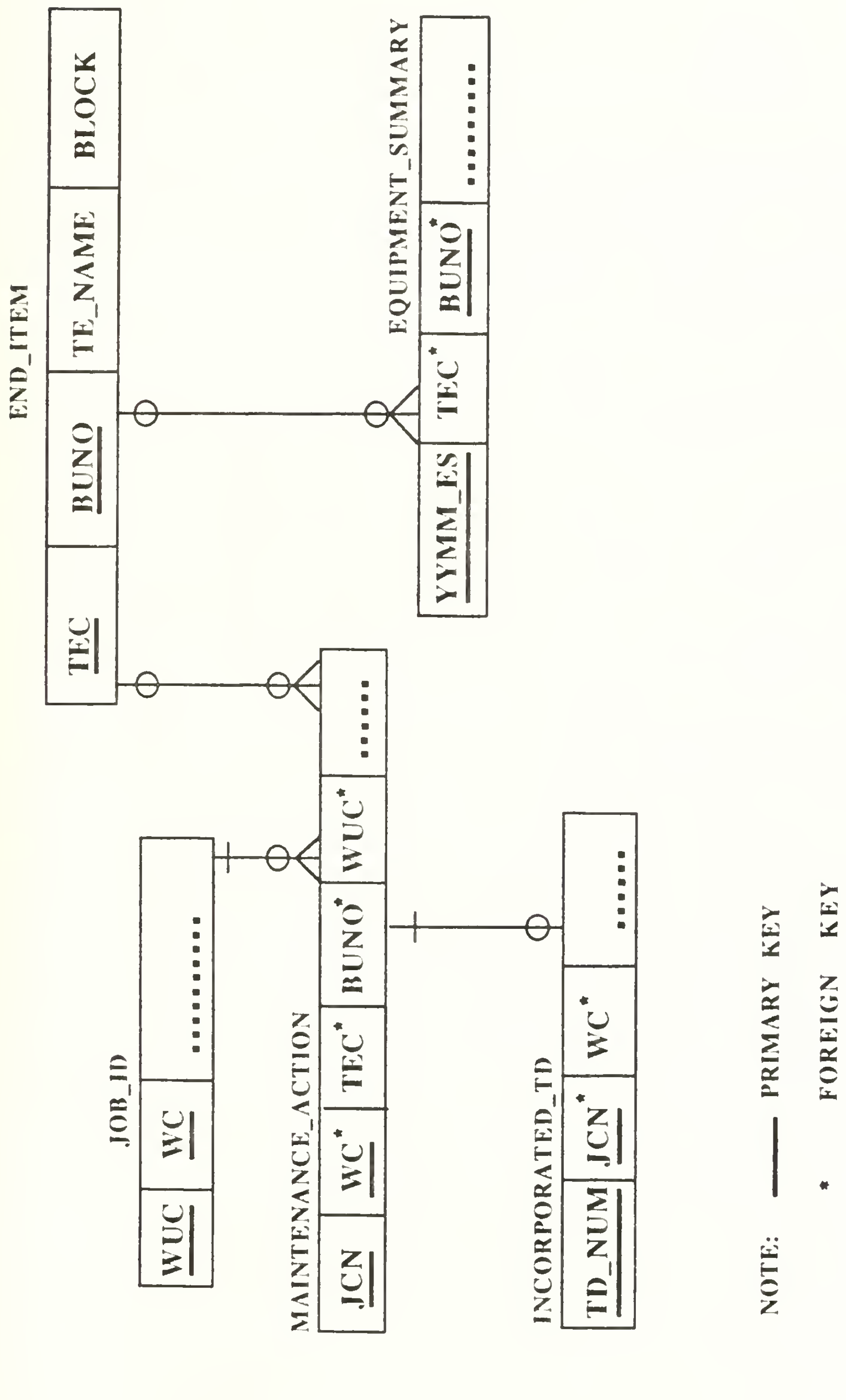
Maintenance_Action

JCN
WC
Action_Taken_Code
AWM_Days
AWP_Days
EMT
WUC
Maint_Hrs
Malfunction_Code
Num_Items
Recd_to_Comp_Days
Recd_to_Inwork_Days
Transaction_Code
Type_Maintenance
When_Discovered
End_Item
[Incorporated_TD]
[Job_ID]

Equipment_Summary

FMCM
FMCS
NMCS
NMCM
NMCU
OPC
PMCM
PMCS
Ship_Flight
Ship_Flight_Hrs
Total_Flight_Hrs
Total_Flights
YYMM_ES
[End_Item]

APPENDIX B. ENTITY RELATION DIAGRAM



APPENDIX C: OBJECT SPECIFICATIONS AND DEFINITIONS

I. OBJECT DEFINITIONS

A.END_ITEM

TEC; Type Equipment Name
BUNO; Aircraft Bureau Number
TE_Name; Type Equipment Name
Block; Equipment Production Block
Maintenance_Action; Maintenance_Action object; MV;
SUBSET [Julian Control Number, Work Center]
Equipment_Summary; Equipment_Summary object; MV;
SUBSET [BUNO, Year-Month of Equipment Summary]

B. MAINTENANCE_ACTION

JCN; Julian Date Control Number
WC; Work Center Number
Action_Taken_Code; Maintenance Code for Action Taken
AWM_Days; Days Awaiting Maintenance
AWP_Days; Days Awaiting Parts
EMT; Elapsed Maintenance Time
WUC; Work Unit Code
Maint_Hrs; Maintenance Hours Performed
Malfunction_Code; Maintenance Malfunction Code
Num_Items; Number of Items Processed
Recd_to_Comp_Day; Days from Receipt to Completion
Recd_to_Inwork_Day; Days from Receipt to Inwork

Transaction_Code; Maintenance Transaction Code

Type_Maintenance; Maintenance Type

When_Discovered; Maintenance Code for When Discovered

End_Item; End_Item object; SUBSET [TE_Name, TEC, BUNO]

Incorporated_TD; Incorporated_TD object; MV; SUBSET [TD_Basic_Num]

Job_ID; Job_ID object;

C.EQUIPMENT_SUMMARY

FMCM; Full Mission Capable Maintenance Hours

FMCS; Full Mission Capable Supply Hours

NMCS; Not Mission Capable Supply Hours

NMCM; Not Mission Capable Maintenance Hours

NMCMU; Not Mission Capable Maintenance Unscheduled Hours

OPC; Optimum Performance Capable Hours

PMCM; Partial Mission Capable Maintenance Hours

PMCS; Partial Mission Capable Supply Hours

Ship_Flight; Number of Ship Operational Flight

Ship_Flight_Hours; Ship Operational Flight Hours

Total_Flight; Total Number of Flights

Total_Flight_Hours; Total Number of Flight Hours

YYMM_ES; Year and Month of Equipment Summary

End_Item; End_item object; SUBSET [BUNO, TEC, TE_Name]

D. JOB_ID

WUC; Job Work Unit Code
JCN_Org; Job JCN Maintenance Organization Code
JCN_Yr_Day; Job JCN Year and Day
JCN_YYMM; J0b JCN Year and Month
JCN_Split; Job Split Numbered JCNs
Maintenance_Action; Maintenance_Action object; MV;
SUBSET [JCN, WC]

E. INCORPORATED_TD

TD_Basic_Num; Technical Directive Basic Number
TD_Code; Technical Directive Code
Amend_Num; Technical Directive Amendment Number
Interim_Num; Technical Directiv Interim Number
Kit_Num; Technical Directive Kit Number
Review_Letter; Technical Directive Review Letter
Maintenance_Action; Maintenance_Action object;
SUBSET [JCN, WC]

II. DOMAIN DEFINITIONS

A. END ITEM

1. **TEC** - Type Equipment Code - identifies a complete End_Item.
   Text 4
2. **TE_NAME** - Type of Equipment name - identifies Type/Model/Series of Equipment.
   Text 12
3. **Block** - Production Block - identifier assigned by manufacturer to indicate aircraft that have been configured identically.
   Text 3

4. **BUNO** - Bureau Number - alphanumeric identifier for aircraft or equipment.
Text 6

B. EQUIPMENT SUMMARY

1. **FMCM** - Full Mission Capable Maintenance Hours - hours during a reporting period that equipment is full mission capable but not optimum performance capable, because of maintenance requirements existing on theinoperable subsystems.
Numeric 3

2. **FMCS** - Full Mission Capable Supply Hours - hours during a reporting period that equipment is full mission capable but not optimum performance capable, because maintenance required to clear the discrepancy cannot continue due to a supply shortage.
Numeric 3

3. **NMCS** - Not Mission Capable Supply Hours - hours during the reporting period that equipment is not capable of performing any of its missions because maintenance required to clear the discrepancy could not continue due to a supply shortage.
Numeric 3

4. **NMCMS** - Not Mission Capable Maintenance Scheduled Hours - hours during reporting period that equipment is not capable of performing any of its missions due to scheduled maintenance requirements.
Numeric 3

5. **NMCMU** - Not Mission Capable Maintenance Unscheduled Hours - hours during reporting period that equipment is not capable of performing any of its missions because of unscheduled maintenance requirements.
Numeric 3

6. **OPC** - Optimum Performance Capable Hours - hours during reporting period that equipment is in optimum performance capability status.
Numeric 3

7. **PMCM** - Partial Mission Capable Maintenance Hours - hours during reporting period that equipment is capable of performing at least one but not all of its missions because of maintenance requirements existing on the inoperable subsystems.

Numeric 3

8. **PMCS** - Partial Mission Capable Supply Hours - hours during reporting period that equipment is capable of performing at least one but not all of its missions because maintenance cannot continue due to supply shortage.

Numeric 3

9. **Ship_Flight** - The number of individual ship operation flights that an aircraft has accumulated during the reporting period.

Numeric 3

10. **Ship_Flight_Hrs** - Portion of the total flight hours, rounded to the nearest whole number, accumulated on an aircraft while involved with ship operations during the reporting period. This includes all flight hours for flights that originate, terminate or involve a ship (i.e., a flight originates at a shore station, flies to a ship, lands and takes off to shore), and will be reported as ship operations.

Numeric 3

11. **Total_Flight_Hrs** - Number of flying hours, rounded to the nearest whole number, accumulated on an aircraft, during the reporting period.

Numeric 3

12. **Total_Flights** - Number of individual flights that an aircraft has accumulated during the reporting period.

Numeric 3

13. **YYMM_ES** - Year and month for which the equipment summary record was generated.

Numeric 4

C. INCORPORATED_TD

1. **TD_Basic_Num** - Technical Directive Basic Number - number assigned by Naval Air Technical Services Facility (NATSF) to identify the Technical Directive which has been approved by the Change Control Board. Numbers are assigned sequentially from 0001 by the Technical Directive Code within the aircraft type model.

Text 4

2. **TD_Code** - Technical Directive Code - code identifying a type of Technical Directive and system to which it is applicable.

Text 2

3. **Amend_Num** - Amendment number - identifies the document that clarifies, corrects, adds to, deletes from, makes minor changes in requirements to, or cancels an existing Technical Directive.

Text 1

4. **Interim_Num** - Interim Number - code indicating that the Technical Directive is an interim change.

Text 1

5. **Kit_Num** - Kit Number - alphanumeric character that identifies a particular kit associated with a particular Technical Directive.

Text 2

6. **Review_Letter** - Character that identifies the revision number of the Technical Directive. The character identifier is blank if the Technical Directive is not a revision.

Text 1

D. Job_ID

1. **WUC** - Work Unit Code - alphanumeric code that identifies the component or end item on which maintenance was performed.

Text 7

2. **JCN_Org** - Job Control Number Organization - alphanumeric code that identifies the organization that originated the Job Control Number.

Text 3

3. **JCN_Yr_Day** - Job Control Number Julian Year Day - the Julian date (YYDD) that the JCN was initiated.

Numeric 5

4. **JCN_YYMM** - Job Control Number Julian Year Month - the Julian date in year and month (YYMM) that the JCN was initiated.

Numeric 4

5. **Split_JCN** - Split Job Control Number - identifies multiple jobs, identifiable as separate valid transactions which are reported with the same JCN. When multiples occur, split_JCN is valued in each multiple job in the sequence A to Z, 0 to 9.

Text 1

E. Maintenance Action

1. **Action_Taken_Code** - code indicating action taken in performance of a maintenance action. I.E., repair, corrosion prevention, etc.

Text 1

2. **AWM_Days** - Awaiting Maintenance days - total number of days a job was in an awaiting maintenance status. Awaiting maintenance status is a summary of all statuses having a status of 0 through 9 associated with a single

Numeric 4

Number of decimal 1

3. **AWP_Days** - Awaiting Parts Days - total number of days a job was in an awaiting parts status. Awaiting parts status is defined as a summary of all statuses with a job status of "S" for a single maintenance action.

Numeric 4

Number of Decimal 1

4. **EMT** - Elapsed Maintenance Time - total elapsed clock hours for "in work" time.

Numeric 5

Number of Decimal 1

5. **WUC** - Work Unit Code -alphanumeric code that identifies the component or end item on which maintenance was performed.

Text 7

6. **Maint_Hours** - Maintenance Manhours - total number of manhours spent performing a maintenance action.

Numeric 5

Number of Decimal 1

7. **Malfunction Code** - Code describing the malfunction which necessitated the maintenance action.

Numeric 3

8. **Num_Items** - Number of Items processed - total number of items processed as a result of the maintenance action.

Numeric 2

9. **Recd_to_Comp_Day** - Receipt to completion day - total number of days from received day and time to the completion data and time.

Numeric 4

Number of Decimal 1

10. **Recd_to_In_work_Day** - Receipt to In-work day - total number of days from the received date and time to the In-work date and time.

Numeric 4

Number of Decimal 1

11. **Transaction_Code** - code indicating the type of maintenance data reported. I.E., on equipment work, inventory, etc.

Numeric 2

12. **Type_Maintenance** - Type of maintenance code - code indicating the type of maintenance performed. I.E., scheduled maintenance, unscheduled maintenance, etc.

Text 1

13. **When _Discovered** - When discovered code - code indicating when the discrepancy was discovered. I.E., in-flight, pre-flight, etc.

Text 1

14. **WC** - Work Center - code identifying the work center that performed the maintenance action.

Text 3

15. **JCN** - Job Control Number - the alphanumeric characters assigned to specific maintenance requirement utilized for maintenance action tracking.

Text - 11

APPENDIX D. SAMPLE REPORTS/FORMS

HISTORICAL FAILURE REPORT

EXAMPLE: 1

ORG CODE: AC3 **or ALL NAV** ____

TEC AMAF **TMS** F/A-18 C

SYST WUC: 56000

WUC	FAILURES/100FHRS
56450	5.6
5645R	0.1
56X2A	4.5
56X2800	4.2
56X20	21.6
56X2800	5.4
56X2830	4.6
56X2840	0.2
56X2860	0.8
56X2870	1.4
56X2880	4.3
56X2890	3.5
•	
•	
•	

AVERAGE ELAPSED MAINT TIME

EXAMPLE: 2

ORG CODE: AC3 **or ALL NAV**

TEC AMAF **TMS** F/A-18 C

WUC	ACT TKN	AVG EMT
11000	R	18.9
11110	R	6.9
1111100	R	1.5
1111110	R	0.5
1111111	R	1.6
1111200	R	11.8
1111211	R	4.2
1111212	R	10.6
1111213	R	8.6
1111214	R	21.2
1111215	R	11.6
1111216	R	3.6
1111300	R	8.2
•		
•		
•		

EXAMPLE: 3a HIGH MANHOUR CONSUMERS

BY: BUNO __x__ SYSTEM ____ SUBSYSTEM ______

INC DATES 1001 TO 1031

BUNO	1 WUC	EMT	2 WUC	EMT	3 WUC	EMT	TOT EMT
162003	13000	128.0	45310	116.5	56X2800	98.4	425.6
162010	13000	118.9	56X2800	102.6	57D9501	65.2	389.6
162011	56X2800	106.5	13000	102.8	653A300	58.8	346.2
162001	56X2800	98.6	13000	78.4	57D9501	43.6	298.6
162015	45310	112.3	56X2800	100.9	13000	75.4	286.5

EXAMPLE: 3b

HIGH MANHOUR CONSUMERS

BY: BUNO ____ SYSTEM x SUBSYSTEM ______

INC DATES 1001 TO 1031

SYST WUC: 71000

1WUC	EMT	2 WUC	EMT	3 WUC	EMT	4WUC	EMT
713V0	123.6	716J0	113.5	71E10	98.6	71Y90	86.2

EXAMPLE: 3c HIGH MANHOUR CONSUMERS

BY: BUNO ____ SYSTEM ____ SUBSYSTEM X

INC DATES: 1001 TO 1031

SUBSYST WUC: 71D10

1WUC	EMT	2 WUC	EMT	3 WUC	EMT	4WUC	EMT
71D110	123.6	71D1210	113.5	71D1120	98.6	71D1213	86.2

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