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INTEGRATED MAINTENANCE INFORMATION SYSTEM (IMIS) FINAL PROGRAM REPORT VOLUME 2: PROGRAM METHODOLOGY

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Volume 2 of the IMIS Final Program Report discusses the three phases of the IMIS program: Requirements Analysis; System Design and Development; and Demonstration System Fabrication and Field Evaluation. Main objectives of the Requirements Analysis phase were to: (1) identify and analyze the functional, informational, and human-computer interface requirements for an IMIS in the Air Force maintenance environment; (2) develop a system architecture which supported those requirements; and (3) develop system functional requirements specifications. Primary products of the Requirements Analysis were the IMIS Architecture and the System/Segment Specification. During System Design and Development, a subset of IMIS requirements was selected for implementation and demonstration. Upon completion of the IMIS demonstration system, hardware and software were installed and field tested at Luke Air Force Base, Arizona. Objectives of the field evaluation were to: (1) test the IMIS concept under realistic operational conditions, (2) evaluate IMIS effectiveness in supporting the unit maintenance mission, (3) demonstrate the technical advantages of IMIS over the current system, and (4) identify strengths and weaknesses of the demonstration system which could be used in refining requirements for a production implementation.

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PREFACE

Program Methodology is the second volume in the three-volume IMIS Final Program Report. The IMIS program was conducted in three phases: Requirements Analysis; System Design and Development; and Demonstration System Fabrication and Field Evaluation. Main objectives of the Requirements Analysis phase were to: (1) identify and analyze the functional, informational, and human-computer interface requirements for an IMIS in the Air Force maintenance environment; (2) develop a system architecture which supported those requirements; and (3) develop system functional requirements specifications. Primary products of the Requirements Analysis were the IMIS Architecture and the System/Segment Specification. During System Design and Development, a subset of IMIS requirements was selected for implementation and demonstration. Upon completion of the IMIS demonstration system, hardware and software were installed and field tested at Luke Air Force Base, Arizona. Objectives of the field evaluation were to: (1) test the IMIS concept under realistic operational conditions, (2) evaluate IMIS effectiveness in supporting the unit maintenance mission, (3) demonstrate the technical advantages of IMIS over the current system, and (4) identify strengths and weaknesses of the demonstration system which could be used in refining requirements for a production implementation.

INTEGRATED MAINTENANCE INFORMATION SYSTEM (IMIS) PROGRAM METHODOLOGY

INTRODUCTION

The Air Force has developed and is continuing to develop several computer systems to support organizational-level (O-Level) maintenance. Unless planned integration occurs, the Air Force of the future will have multiple computer systems in use simultaneously, causing confusion as a result of incompatible hardware, data requirements, user interfaces, and expertise required to operate and maintain the systems. These deficiencies can cause improper weapon system maintenance, potentially leading to weapon system malfunctions, equipment damage or loss, or personnel injury. This degradation in weapon system and unit readiness limits the ability of combat organizations to accomplish their assigned missions.

The Integrated Maintenance Information System (IMIS) is a proof of concept program to integrate all maintenance information. It is the tool to access, from all available sources, information required to support maintenance, then integrate, format, and present that data for use by maintenance personnel. By integrating the information from the maintenance support systems currently in use and providing a standard mechanism for accessing and presenting that information, IMIS can eliminate the need for maintenance personnel to learn the unique operations of and interact with multiple systems.

Background

Since 1976, the Armstrong Laboratory Logistics Research Division (AL/HRG) has conducted several research and development (R&D) projects to develop the technology for the presentation of technical data on an automated system. From 1976 through 1988, these efforts included two feasibility studies, the development of two prototype systems to support intermediate-level (I-Level) maintenance, and the development of a portable computer system for presentation of technical data for on-equipment maintenance. The scope of these efforts involved performing laboratory studies to develop the required technologies, as well as testing the prototype systems under realistic field conditions to ensure the systems satisfactorily met the needs of the users.

AL/HRG's efforts demonstrated that the presentation of maintenance technical data on a computer-based system was feasible and that an automated system had the potential to improve performance and reduce the costs of maintaining the Air Force technical order (TO) system. In addition, effective user interface (UI) techniques, data presentation techniques, and draft specifications for computer hardware and software were developed.

In addition to demonstrating the benefits of an automated data presentation system, these studies also pointed out the need for a more comprehensive system to make maintenance information available to Air Force maintenance personnel, not just the technician. The lessons learned from these efforts played a major role in developing the IMIS Operational Concept Document (OCD), which formed the basis of the IMIS program.

Scope

The overall scope of the IMIS program involved several different thrusts: to identify and define the requirements for an IMIS; to develop specifications which document those requirements; to design and develop a demonstration system capable of supporting the essential IMIS requirements; to evaluate the IMIS concept and requirements using the demonstration system; and to finalize the IMIS specifications, incorporating the results of the tests, demonstrations, and evaluations conducted. The structure of the program was intended to satisfy each of these major thrusts, as well as to allow maximum application of information gained during each phase to subsequent phases.

Purpose

The objective of the IMIS system was to improve the capabilities of aircraft (A/C) maintenance organizations by providing Air Force personnel an effective maintenance information system. The improved information system would increase the performance capabilities of the maintenance personnel, resulting in an increased sortie generation capability. Specific objectives for IMIS were identified in the OCD. These objectives are as follows.

a. Integrate multiple maintenance information sources into a single easy-to-use information system.

b. Tailor information to meet the specific needs of the task and the technician.

c. Provide on-the-job training aid for new systems and proficiency training on existing systems.

d. Eliminate time-consuming paperwork and tasks through automation.

e. Improve on-A/C diagnostics and reduce “Can Not Duplicates” (CNDs) and “Retest OKs” (RTOKs).

f. Improve the quality of maintenance performance by taking advantage of the computer’s ability to interact with the technician.

g. Maximize the utilization of available manpower resources by providing information in standard, generic formats independent of the subsystem and supporting general technical capabilities at various skill levels.

h. Improve the maintenance capability for dispersed operations by packaging the needed maintenance information into a highly portable, deployable system.

i. Provide the capability to support maintenance performance in future scenarios of consolidated specialties.

Although many of these objectives focus on the maintenance technician, the goal of IMIS is to enhance the performance of all maintenance personnel, regardless of their role in the maintenance process. By allowing easy access to current maintenance information, IMIS would enable all maintenance personnel, including technicians, managers, and support personnel, to make more informed decisions, thereby improving the maintenance process and increasing the availability and mission readiness of the weapon systems.

Content of Final Program Report

This Final Program Report consists of three volumes. Volume 1, the Executive Summary, contains a high-level summary of the objectives, methodology, results, conclusions, and recommendations of the entire program. Volume 2 provides an overview of the methodology used to satisfy the objectives of the IMIS program. This includes information on the requirements analysis conducted in Phases I and II, the hardware and software design activities in Phases II and III, and the system integration and field test activities of Phase III. Volume 3 contains the results and conclusions of each of the field tests conducted at Luke Air Force Base (AFB), along with recommendations based on lessons learned from all phases of the program. It also discusses strategies for further implementation of an IMIS system.

PROGRAM OVERVIEW

The IMIS program was conducted in three phases, beginning in November 1988. The following sections provide an overview of the organizations involved in the program and their responsibilities, as well as a high-level schedule and description of the three program phases.

Program Team Organization and Responsibilities

AL/HRG, the Logistics Research Division of Armstrong Laboratory at Wright-Patterson AFB, was the program customer. As the customer, AL/HRG was involved in all aspects of the program and oversaw the design and development of the system through the review of the appropriate documentation and design review materials, as well as by conducting additional integration testing. AL/HRG also was responsible for planning and conducting each field test.

GDE Systems, Inc., in San Diego, California (formerly General Dynamics Electronics Division), the prime contractor, had overall responsibility for managing program activities. GDE Systems was responsible for the hardware and software development, as well as system integration and test prior to the field tests. GDE Systems also supported the field tests by providing personnel as members of the evaluation teams and to perform system support and maintenance.

Softech, Inc., in Dayton, Ohio, was a subcontractor to GDE Systems in the early stages of the program. Softech assisted in base visits, requirements analysis for the IMIS Architecture (IMISA), and generation of the preliminary system and software specifications.

Systems Control Technology, Inc. (SCT), in Palo Alto, California, was a subcontractor to GDE Systems during the design and implementation phases of the program. SCT developed the interface to the Core Automated Maintenance System (CAMS) and assisted with integrating that software into the IMIS system prior to demonstration.

Applied Science Associates, Inc. (ASA), in Butler, Pennsylvania, was a subcontractor to GDE Systems. ASA assisted in base visits, participated in the development of the human engineering requirements, and reviewed the human engineering aspects of the system design and development. ASA also assisted in the development and administration of the training program, as well as the planning and execution of the field tests.

Lockheed Fort Worth Company (LFWC) of Fort Worth, Texas (formerly General Dynamics Fort Worth Division), had a separate contract with the F-16 System Program Office (SPO) to provide software for authoring and presenting electronic TO data, and to author the TO data for five F-16 subsystems in support of the IMIS contract.

NCI Information Systems, Inc. (NCI), in Dayton, Ohio, was a contractor to AL/HRG. NCI enhanced the electronic TO data developed by LFWC and maintained that data throughout the field tests. NCI also provided maintenance and diagnostics expertise in their participation in the field tests.

Program Schedule

The IMIS program was conducted in three phases: Requirements Analysis, System Design and Development, and Demonstration System Fabrication and Field Evaluation. Figure 1 shows a high-level schedule for each phase, including significant milestones. Figure 2 shows the key IMIS activities and products of those activities in the three phases. The following sections discuss the tasks performed in each phase.

Phase I: Requirements Analysis

The main objectives of the Requirements Analysis phase were: to identify and analyze the functional, informational, and human-computer interface requirements for an IMIS in the Air Force maintenance environment; to develop a system architecture which supported those requirements; and to develop system functional requirements specifications. One critical task in support of the requirements analysis was to interview maintenance personnel at several bases.

The primary products of Phase I were the IMISA, developed using a structured analysis methodology, and the System/Segment Specification (SSS), which documents the IMIS system requirements. This information was reviewed at the System Requirements Review at the end of Phase I.

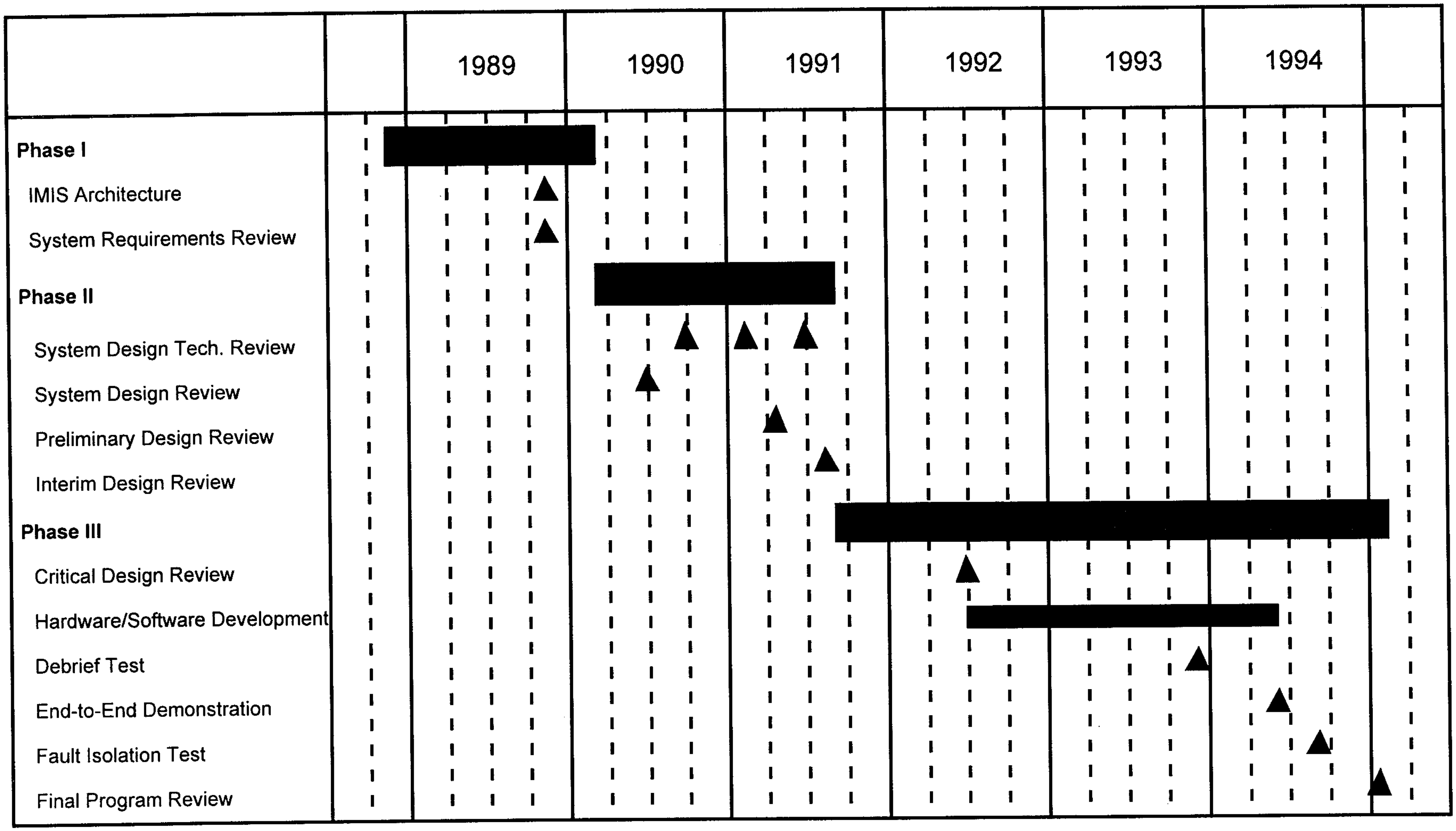


Figure 1.
IMIS Program Schedule

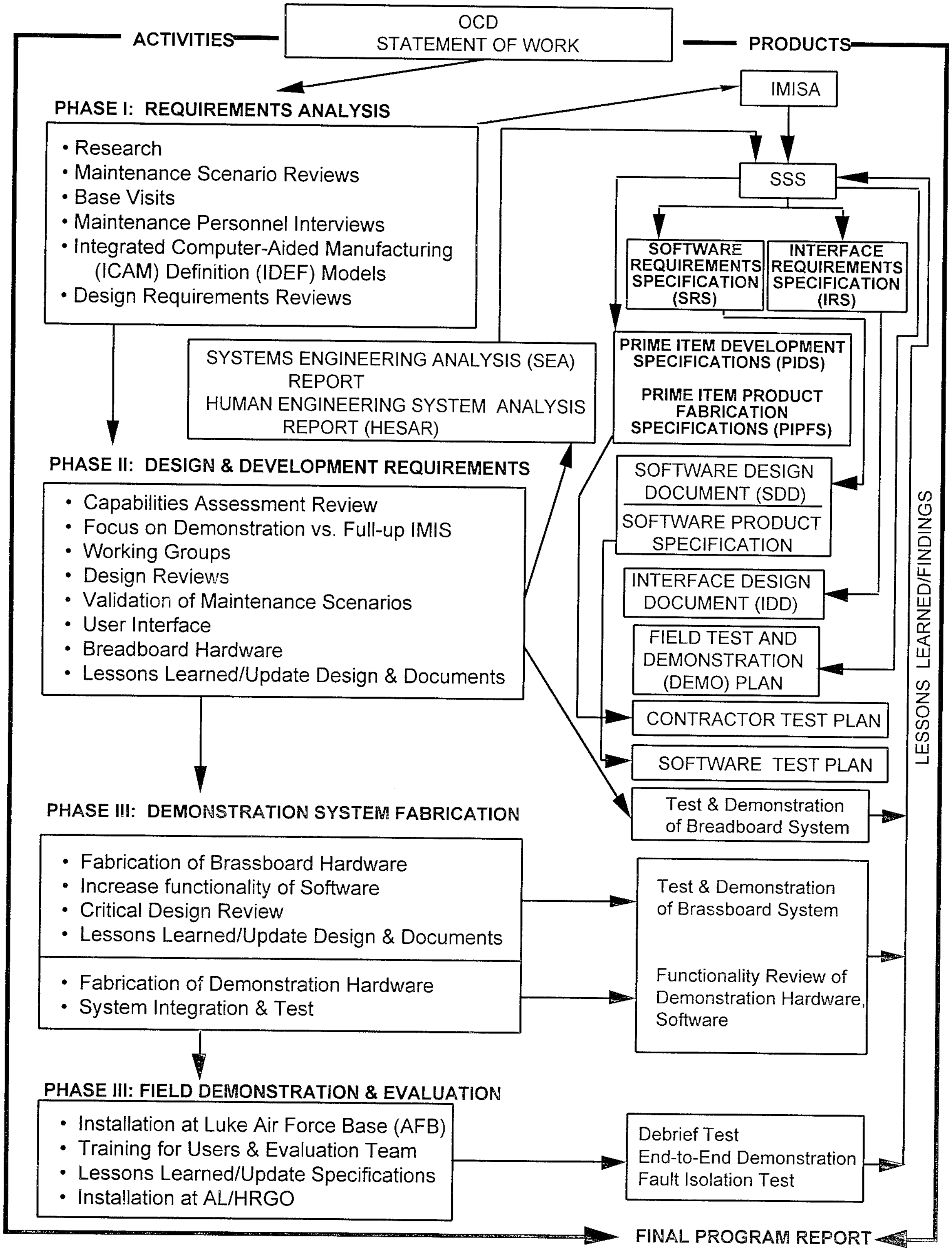


Figure 2. IMIS Phases I - III Key Activities and Products

Phase II: System Design and Development

After the desired IMIS capabilities of a full implementation were defined, the program activities shifted to the development of the demonstration system. During this phase, a subset of the IMIS requirements was selected for implementation and demonstration. Following the successful completion of the System Design Review and the Preliminary Design Review, efforts were concentrated on developing a breadboard system for demonstration at the Interim Design Review. The Interim Design Review and Breadboard Demonstration marked the end of Phase II.

Phase III: Demonstration System Fabrication and Field Evaluation

The main objective early in Phase III was the fabrication and testing of a brassboard system for demonstration at the Critical Design Review (CDR). Based on lessons learned from the Breadboard and Brassboard demonstrations, the final software and hardware designs for the demonstration system were approved. The demonstration hardware and software were developed in accordance with these approved designs. Extensive system integration and testing were conducted in preparation for the field tests. Additionally, plans for conducting the field evaluations and for training personnel to support the field tests were developed.

After the installation, integration, and testing of the demonstration system was completed, three field tests were conducted: the Debrief Test, the End-to-End Demonstration, and the Fault Isolation Test. Results of these tests and of the entire program were discussed at the Final Program Review and are documented in this Final Program Report.

REQUIREMENTS ANALYSIS

It is critical on any program to identify clearly the requirements as early as possible. For IMIS, this process began with the analysis and modeling of the maintenance environment and continued with a structured methodology for defining the resulting architecture. Once the complete set of requirements for a full implementation of an IMIS system had been developed, the process of selecting specific requirements to be implemented in the demonstration system was initiated. This section documents the comprehensive requirements analysis methodology which was used to define the IMIS demonstration requirements and to determine the architecture which satisfies those requirements.

Maintenance Process Analysis

A structured, comprehensive analysis of the maintenance process was necessary for the IMIS system to be acceptable to the maintenance user and to provide the Air Force with accurate information regarding the benefits of the IMIS concept. The early direct involvement with and feedback from the ultimate users of the system, accomplished through extensive interviews conducted at various AFBs, was key to enhancing the usability and the user's acceptance of the system. By supplementing the information gathered from interviews with a structured methodology for modeling the maintenance environment, the maintenance process analysis was further improved. The following subsections describe the details of the process and the analysis.

Base Visits

The objective of the base visits was to interview a large number of maintenance personnel who perform a wide range of duties and functions within the maintenance environment. Data gathered during these interviews was used to support the modeling of the maintenance environment and the definition of requirements for the system architecture. From this in-depth understanding of the existing maintenance environment, including its strengths and weaknesses, IMIS was designed to maximize system effectiveness and user acceptance. Experience has shown that no single person possesses full knowledge of the entire maintenance process in accurate detail. By interviewing many maintenance personnel at several bases, a better understanding of the process and its requirements was gained. More than 400 maintenance personnel, covering 29 different Air Force Specialty Codes (AFSCs) and numerous duty titles, were interviewed at the following Tactical Air Command (TAC) and United States Air Forces – Europe (USAFE) bases in 1989:

Langley AFB, VA
Homestead AFB, FL
Hahn Air Base (AB), Federal Republic of Germany (FRG)
Spangdahlem AB, FRG
Sembach AB, FRG
Leipheim AB, FRG
Ramstein AB, FRG
Moody AFB, GA
Shaw AFB, SC

In addition, interviews were also conducted at Gunter AFB (the Standard Systems Center [SSC] at Gunter is responsible for the development and maintenance of CAMS and the Standard Base Supply System [SBSS]). Through extensive interaction with CAMS and SBSS personnel, the IMIS team obtained interface information and other technical data for each of these maintenance support systems.

Interviews with the A/C maintenance personnel were voluntary and anonymous. They were conducted in accordance with paragraph 30 of Air Force Regulation (AFR) 12-35 and in compliance with the Privacy Act of 1974. As an aid in gathering and categorizing information, a strawman model was developed to describe the maintenance tasks performed by these personnel between the end of one mission and the beginning of the next. The activities described in this model, derived from Air Combat Command (ACC) Regulation 66-5 and coordinated with subject matter experts from the maintenance community, included: obtain A/C status, allocate resources, troubleshoot A/C, order parts, repair A/C, and perform standard service.

The questionnaires used in these interviews were designed to extract data from maintenance personnel in a manner that would lend itself to the subsequent modeling process.

The questionnaires covered all aspects of the six activities described in the strawman model. For each activity, the technician was asked to describe the tasks performed, the sequencing and dependencies of these tasks, how the tasks are initiated and completed, the results of the tasks, data needed to perform the task, and how that data is accessed or provided.

Maintenance Environment Modeling Methodology

The information collected during the data gathering interviews was analyzed and used to model the maintenance process. Figure 3 shows the collected data was used as a direct input to the model. Audio tapes of the interviews were used to augment the data collected via notes. Air Force forms and other materials which identified the data requirements for the maintenance process were also used to develop the model.

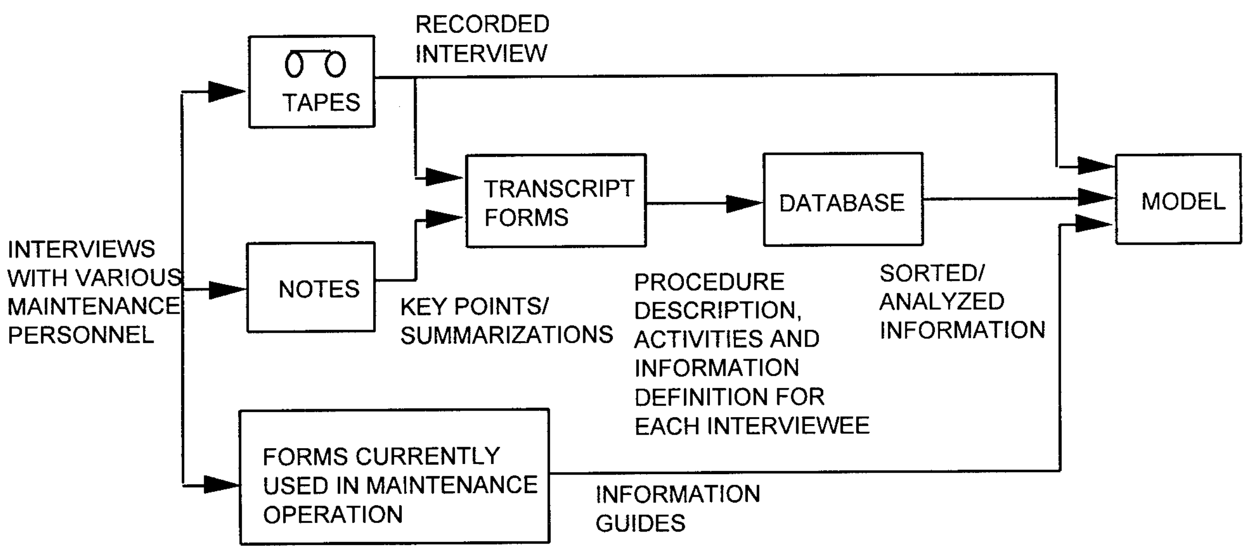


Figure 3. Maintenance Environment Modeling Methodology

This database of information was then used to develop the model of the existing maintenance environment. Although this process was straightforward, it was not just a reorganization of the data in the database into a graphic form. The process of developing a model from raw data requires the introduction of engineering knowledge because the data is usually based on an "organizational" look of a given process, not a "functional" look. However, the organizational look is required to allow the model to be validated by the user.

The first step of the modeling activity was to define the purpose and viewpoint of the model. The purpose of this model is to provide a means of logically illustrating, documenting, and communicating the functional activities and informational relationships associated with the maintenance performed on an A/C. The viewpoint of the model was defined to be the O-Level, I-Level, and depot-level maintenance personnel and staff personnel.

The top-level model was developed, taking the purpose and viewpoint into account. The top level model comprised maintenance that is performed at the O-Level, I-Level, and depot level. The primary emphasis was on the O-Level, which focuses on performing maintenance on the flight line. However, there were interfaces between the O-Level and I-Level critical to the maintenance process that needed to be identified. Also included were base-level management functions performed by personnel on the staff for the Deputy Commander for Maintenance (DCM). As a result, this model includes decompositions of the O-Level, I-Level, and staff functions.

Extensive verification and validation of the model were performed, including internal verification by different organizations with varied experience and backgrounds in maintenance, as well as validation with the user. The validation of the model with the user achieved two important objectives: to develop a more accurate model, and to elicit user input and contributions to the modeling effort. The models were presented to several functional work groups, each consisting of maintenance personnel with the same job title. Any discrepancies identified during the validation were used to update the model.

IMIS Architecture Definition

The methodology described in the previous paragraph to model the existing maintenance environment used a structured analysis method based on Integrated Computer-Aided Manufacturing (ICAM) Definition (IDEF), a methodology that is used to model system planning, requirements analysis, and system design. This methodology, and all the models developed using this methodology, is described in the following subsections, to show how the IMISA was defined.

IDEF Methodology

The IMIS IDEF models consist of a set of related diagrams which are organized in a top-down manner and are representative of the tactical A/C maintenance environment. Transferring user needs into system requirements cannot be done in a single-step process. Consequently, a framework for organizing various viewpoints needed to develop the IMISA and its requirements was used. The Control Architecture (CA) is a process-versus-information (activity) model that describes the user's view of the maintenance environment and the user's information needs. The Information Architecture (IA) is a data model which reorganizes the information derived from the CA Model into logical structures. The Computer Systems Architecture (CSA) takes the information-processing requirements defined in the IA and the information-handling requirements defined in the CA and, by relating them to a set of system processes, defines system requirements such as storage type, storage size, display type, user interfaces, and other hardware and software requirements. Relative to the A/C maintenance environment, the CA defines the maintenance functions, the IA defines the information relationships, and the CSA defines the information-handling requirements of the maintenance process.

The modeling process described starts with the user in the "AS-IS" world. The "AS-IS" world is represented by the existing Air Force maintenance procedures as determined by the onsite interviews and data collection processes. The resulting requirements are those for a system that works in the current maintenance environment. The maintenance model, described in the subsection entitled "Maintenance Environment Modeling Methodology," is actually the CA "AS-IS" model. To take on the problem of resolving "AS-IS" versus "TO-BE" requirements with available data, a threaded modeling approach was used. In this approach, the designer alternately uses both the "AS-IS" models and the "TO-BE" models to derive the IMISA. A set of projected assumptions was derived that was used to extrapolate the CA "AS-IS" model into a CA "TO-BE" model. The corresponding IA and CSA "TO-BE" models were developed using the same systematic approach that was used to build the "AS-IS" set.

IMIS Architecture (IMISA)

After all the modeling activities had been completed, the comprehensive requirements for an IMISA that represents both the present and future functional characteristics were documented in the IMISA, Contract Data Requirements List (CDRL) 13. The IMISA consists of the IMIS architectural requirements based on the analyses and results of the base visits, interviews, maintenance scenarios, maintenance task timelines, and modeling efforts. This document contains complete documentation of the IDEF modeling guidelines, the interview materials for the data gathering trips, and information from each of the six models (CA "AS-IS," IA "AS-IS," CSA "AS-IS," CA "TO-BE," IA "TO-BE," and CSA "TO-BE").

System/Segment Specification (SSS)

The SSS, CDRL 14, establishes the system definition, performance, design, development, and test requirements for a full implementation of an IMIS. Requirements in the SSS were derived primarily from the interviews conducted with maintenance technicians and managers in developing the IMISA. Additional sources included the IMIS OCD, the Advanced Tactical Fighter (ATF) Integrated Maintenance System (AIMS) Concept Document, the Modular Avionics Systems Architecture (MASA) Support Requirements Document, and information from previous Air Force projects.

The requirements listed in the SSS are directly traceable to these sources. Requirements derived from the models trace to actual interviews. This traceability is essential to the evolution of IMIS in that, as changes and improvements are discussed, the models and underlying interviews can provide an understanding of their possible impacts on the overall maintenance process.

The SSS has been updated throughout the life of the IMIS program to reflect changes to the Air Force organization, changes to the maintenance environment, and lessons learned during the design, development, and evaluation of the demonstration IMIS.

Systems Engineering Analysis (SEA) Report

During Phase II, several systems engineering analyses were conducted to identify and evaluate the baseline characteristics, requirements, and constraints of a system which meets the functional requirements specified in the IMIS OCD, the IMISA, and the SSS. The results of these analyses are summarized in the following subsections. Detailed results are documented in the SEA Report, CDRL 19.

Survivability/Vulnerability Study

The Survivability/Vulnerability Study identified the threat environment for Maintenance Data Base (MDB) interfaces and for an IMIS-internal Local Area Network (LAN). The threats analyzed include non-nuclear threats (such as conventional arms, electronic warfare, directed energy, jamming, and chemical/biological substances) and nuclear threat effects (such as electromagnetic pulse, radiation, and shock). These threats were analyzed by tailoring the Data Link Vulnerability Assessment (DVAL) and Network Communications Vulnerability Assessment (NCVA) methodologies specifically to the IMIS system.

Various network designs were evaluated against the physical destruction threat, and it was found that redundancy of communication links and workstations will allow increased survival probabilities in the event of an attack.

The greatest nuclear threat was determined to be from the high-altitude electromagnetic pulse (HEMP) effect. Nuclear detonations at high altitudes as far away as several thousand miles will generate electromagnetic pulses which can induce large currents in power lines, signal lines, radio frequency (RF) antennas, and grounding systems. This can damage electrical and electronic components; microprocessor-based equipment is particularly vulnerable to damage.

A significant, specific threat from biological, chemical, and directed energy (e.g., lasers) weapons was not considered to be feasible for a support system such as IMIS.

Hardware Technology Studies

Five trade studies were performed to investigate alternative technologies and designs for various components of IMIS. These trade studies evaluated batteries, mass storage devices, displays, and microprocessors for the Portable Maintenance Aid (PMA), as well as an investigation into the configuration for an aircraft-mounted Aircraft Interface Panel (AIP).

PMA Battery Study. The PMA battery study identified the characteristics desired of the PMA battery. It was determined that the PMA battery should be safe, rechargeable, small, and lightweight. The PMA battery should also have extremely high energy and power capacities and should operate well over a wide temperature range. The study concluded that high capacity requires greater size and weight, and that the temperature range required for the PMA is greater than can be supported by currently available technology. The Nickel-Cadmium (NiCad) battery provided many desirable characteristics and was selected for the IMIS PMA.

PMA Mass Storage Study. The PMA mass storage study identified available and developmental mass data memory technologies and assessed their respective characteristics in terms of applicability to an IMIS PMA. Mass memory approaches and device types examined include magnetic media, optical media, and semiconductor types. The requirements for the PMA mass storage device include: large storage capacity, high speed, high reliability, small physical size, low weight, low power dissipation, and removable hard drive. Miniature hard disk drives provide most of these characteristics, but the mechanical moving parts design introduced reliability concerns. This information was used in selecting a removable memory module for the PMA.

PMA Display Study. The PMA display study identified and investigated available and developmental display technologies and assessed their respective characteristics in terms of satisfying IMIS display requirements. Major technology types evaluated include: cathode ray tubes (CRTs), vacuum fluorescent displays, liquid crystal displays (LCDs), light-emitting diodes (LEDs), electroluminescent (EL) displays, and plasma displays. None of the available technologies completely satisfy all the desired characteristics of the PMA display. LCDs are nearly satisfactory but have limited ranges of both operating and storage temperatures. This information was used in selecting a display for the PMA.

PMA Processor Study. The PMA processor study specified and identified the most suitable processor unit for the IMIS PMA. Size, power consumption, system compatibility, performance, and technology maturity were used as discriminators in evaluating the available microprocessors. This information was used in selecting a processor for the PMA.

Aircraft Interface Panel (AIP) Study. This study was conducted by General Dynamics Fort Worth Division, now LFWC, to define the requirements for an on-board AIP. This study identified the optimal mix of IMIS functions to be performed on the A/C and on the ground, with little or no impact to A/C performance (including weight, power, and space requirements). The study further defined functional and physical requirements for a generic AIP in the form of a requirements specification.

Electromagnetic Compatibility/Electromagnetic Interface Study

A preliminary analysis of the Electromagnetic Compatibility (EMC) requirements of IMIS was performed, using Military Standard 461 (MIL-STD-461) as a guideline. IMIS can be designated as Class A1, equipment and subsystems installed aboard an A/C, including associated ground support equipment. Each hardware segment was further identified as a subclass within Class A1, according to application environment. The AIP is intended to be installed on the A/C and was therefore designated as Class A1b. The PMA is considered aerospace ground equipment required for the checkout and launch of the A/C, including electronic test and support equipment, and was designated as Class A1c. The MIW is installed in ground facilities and was designated as Class A1h.

Security Requirements Study

The security requirements study addressed the IMIS security requirements for the Trusted Computer System, the Network Trusted Computing System, and the Trusted Data Base Management System partitions of IMIS in accordance with AFR 205-16. Fundamental computer security requirements, including policies regarding the access to classified information, access control labels, identification of authorized users, and the recording of audit information, were defined. This study also provided a risk analysis to identify threats and vulnerabilities, existing protective measures, and gaps or weaknesses requiring additional or alternative protection.

Mission and Support System Definition Study

The Mission and Support System Definition study was conducted by performing three Logistic Support Analysis (LSA) tasks, in accordance with MIL-STD-1388-1A: Task 201, Use Study; Task 202, Mission Hardware, Software, and Support System Standardization; and Task 203, Comparative Analysis.

The LSA Task 201 provided the basis for all logistics planning and readiness analysis of IMIS, identifying how, when, and where IMIS will be used. The study considered various mobility requirements, deployment scenarios, and operating environments which influence the design process, describing the worst-case scenarios for its intended use and focusing on tradeoffs between operational performance and supportability-related design features. Identifying operational characteristics relevant to the design for supportability allows shortfalls to be addressed early in the design process.

LSA Task 202 resulted in the development of system design criteria that maximize the use of existing and planned logistics support. It also provided support-related input to mission hardware and software standardization efforts, including a preliminary software life-cycle support analysis.

The purpose of LSA Task 203 was to capitalize on information and experience gained from previously developed systems in identifying supportability, cost, and readiness issues that need to be addressed by IMIS. The current method for performing maintenance was used as the Baseline Comparison System (BCS) in analyzing the maintenance downtime, active maintenance time, logistics delay time, and administrative delay time. This information illustrated the impact of IMIS on the maintenance operation.

IMIS Simulation

A simulation of the entire operational maintenance environment at the O-Level was developed using the IDEF TO-BE CA as the initial, high-level model of IMIS. This included the pre-flight inspections, A/C flying times, A/C shutdown and pilot debrief, thru-flight and post-flight inspections, scheduled maintenance, and opening/closing work orders. This simulation tool can support the following systems engineering studies: workload studies, in which the queues and waiting times are examined to identify any overused system components; resource studies, in which the quantities of maintenance personnel and equipment are varied to determine the optimal levels needed to support a given deployment scenario; and sensitivity studies, in which probabilities and task times are varied to evaluate the robustness of the system design.

Identification of Demonstration Requirements

The SSS forms the basis for the requirements for a full implementation of IMIS. Developing a demonstration system which meets all these requirements would exceed the schedule and financial constraints for the program. Consequently, an approach for identifying specific functions and requirements to be implemented and demonstrated was developed.

The total set of requirements identified in the SSS provided the foundation for selecting the demonstration requirements. During a series of reviews between May 1990 and March 1991, these requirements were prioritized and categorized for consideration during the demonstrations. An initial prioritization of the capabilities categorized the requirements as mandatory, desirable, or not required for demonstration. Detailed descriptions of each mandatory and desirable capability were then generated and used for further assessment.

As a parallel effort, this set of requirements was reviewed by the Maintenance Review Panel (MRP). The MRP was composed of base-level aircraft maintenance personnel and several members of the IMIS team, both government and contractor personnel, who have Air Force maintenance experience. The charter of the MRP was to serve as an additional independent check to ensure that the focus of the IMIS program remains on its ultimate end users, the maintenance personnel. Subsequent to these reviews, a preliminary set of demonstration requirements was approved and documented in the first draft of the Field Test and Demonstration Plan, CDRL 18.

The final step in identifying demonstration requirements occurred between February and April 1994, when the End-to-End Demonstration was defined. Capabilities required to demonstrate the end-to-end flow of a task within the maintenance environment were documented in a detailed scenario. Following MRP review and approval of this end-to-end scenario, the preliminary set of demonstration requirements was then updated to reflect the deletion of requirements not needed for any of the field tests (Debrief Test, End-to-End Demonstration, and Fault Isolation Test).

The demonstration requirements identified through this process are shown in Table 1. This table lists each requirement number, the applicable SSS paragraph, and the requirement text. Additional information regarding the interpretation of, implementation of, and assumptions relating to each requirement can be found in Appendix B of the IMIS Field Test and Demonstration Plan, CDRL 18.

Table 1. Demonstration Requirements

Rqmt. No	SSS Paragraph No.	Requirement Text
8	3.2.1.1.1.1-b 3.2.1.1.1.2-a	Open Work Orders
9	3.2.1.1.1.2-a.1	Assign Job Control Number (JCN)
10	3.2.1.1.1.2-a.2	Get work order information from databases
11	3.2.1.1.1.2-a.3	Enter work order entries from Menu Choices
12	3.2.1.1.1.2-b.1	Access CAMS (or use technical data to determine resource requirements)
16	3.2.1.1.1.2-c.1	Establish Work Center Event (WCE)
18	3.2.1.1.1.2-c.2.b	Notify roving truck of new WCE
19	3.2.1.1.1.2-c.3	Identify and correlate PMA with specific individual or function
22	3.2.1.1.1.2-e.1.a	Establish Initial A/C Condition code
23	3.2.1.1.1.2-e.1.b	Establish Initial A/C Status using Minimum Essential Subsystem List (MESL)
25	3.2.1.1.1.2-f.1	Maintain mission status of work orders
27	3.2.1.1.1.2-g.1.a	Notify maintenance managers of status changes
29	3.2.1.1.1.2-g.2	Indicate the change in status through audio or visual alerts
30	3.2.1.1.1.2-g.3	Require operator response to the alert (prompt for recognition of status change)
31	3.2.1.1.1.2-g.4	Notify appropriate Crew Chief and Specialist Dispatch of status change
32	3.2.1.1.1.3-a	Display A/C history data
33	3.2.1.1.1.3-b	Display data regarding systems reported as deficient (discrepant)
34	3.2.1.1.1.3-d	Identify if the reported discrepancies are repeat or recurring
35	3.2.1.1.1.3-e	Assist in determining required maintenance by comparison of similar histories
37	3.2.1.1.1.4-a.3	Accept A/C system data manually to augment automatic process
40	3.2.1.1.1.4-b	Interrogate systems for specific conditions or additional diagnostic information
41	3.2.1.1.1.4-c	Accumulate and store all reported data with the repair work order
42.A	3.2.1.1.1.4-d.3	Analyze discrepancies, sortie/flight data, and A/C and system conditions
43	3.2.1.1.1.4-d.4	Access A/C history to compare & present information from previous flights
46	3.2.1.1.1.4-d.7	Present debrief questions and query for responses
47	3.2.1.1.1.4-d.8	Accept responses from debrief questions
48	3.2.1.1.1.4-d.9	If additional info is needed, modify debrief questions based on responses
59	3.2.1.1.2.3-a	Present TO inspection procedures
64	3.2.1.1.2.3-e	Verify sign off authority of inspector
65	3.2.1.1.2.3-f	Deny unauthorized sign off of inspection

Table 1. Continued

Rqmt. No	SSS Paragraph No.	Requirement Text
66	3.2.1.1.1.3.1	Provide access to scheduled flying and maintenance information for an A/C
69	3.2.1.1.1.4.1-a.1	Set initial A/C status from pilot call-in, using the MESL
70	3.2.1.1.1.4.1-a.2	Auto update initial A/C status based on debrief and initial inspect
71	3.2.1.1.1.4.1-b	Present updated status to maintenance managers for approval/modification
72	3.2.1.1.1.4.2	Control A/C status revisions
76	3.2.1.1.1.4.3	Update estimated time in commission (ETIC) based on new information
93	3.2.1.1.1.7.1-a	Interactively and automatically record data from maintenance actions
94	3.2.1.1.1.7.1-b	Automatically attach standard narratives
95	3.2.1.1.1.7.1-c	Allow manual entry of narrative data
96	3.2.1.1.1.7.1-d	Obtain information such as name, AFSC, etc. , from login & personnel files
97	3.2.1.1.1.7.1-e	Prompt technician for additional information needed
99	3.2.1.1.1.7.2-a	Check validity of data entered by technician
101	3.2.1.1.1.7.2-c	Reject and display incorrect data entries
102	3.2.1.1.1.7.3-a	Compile maintenance data
103	3.2.1.1.1.7.3-b	Transmit maintenance data to work centers and external MDBs
104	3.2.1.1.2.1.1-a	Accept input of information on assigned A/C
108	3.2.1.1.2.1.1-d	Collect A/C status for each A/C
109	3.2.1.1.2.1.1-e	Collect A/C ETIC for each A/C
110	3.2.1.1.2.1.1-f	Review A/C status when work order status changes
122	3.2.1.1.2.2.3-a	Monitor availability of specialists by AFSC
123	3.2.1.1.2.2.3-b	Monitor location of specialists
124	3.2.1.1.2.2.3-c	Monitor task qualification of specialists
162	3.2.1.1.2.3.3.b	Disseminate A/C priority & configuration changes to maintenance personnel
163	3.2.1.1.2.3.4-a	Update flying and maintenance schedule
164	3.2.1.1.2.3.4-c	Obtain approval of flying schedule changes
165	3.2.1.1.2.3.4-d	Distribute approved flying schedules
176	3.2.1.1.2.4.1-c.1.a)	Provide status of in-progress maintenance to production managers
177	3.2.1.1.2.4.1-c.1.b)	Provide status of personnel assigned to A/C to production managers
182	3.2.1.1.2.4.1-c.3	Allow data search for more details of current status
199	3.2.1.1.2.4.3-a	Track maintenance personnel assigned to weapon systems
201	3.2.1.1.2.4.3-c	Coordinate with Maintenance Operations Center (MOC) to update work status

Table 1. Continued

Rqmt. No	SSS Paragraph No.	Requirement Text
208	3.2.1.1.2.5.1-b	Obtain qualifications of specialists
209	3.2.1.1.2.5.1-c	Allow approval of recommended specialist assignment
210	3.2.1.1.2.5.1-d	Allow alternative specialist assignment
230	3.2.1.1.2.5.5-a	Convey work order to technician
232	3.2.1.1.3.1.1	Provide maintenance personnel access to discrepancy history
235	3.2.1.1.3.1.3	Provide interactive troubleshooting guidance
236	3.2.1.1.3.1.3	Provide maintenance action recommendations
237	3.2.1.1.3.1.3-a.1	Analyze information for fault isolation
238	3.2.1.1.3.1.3-a.2	Provide maintenance action recommendation based on fault isolation
246	3.2.1.1.3.1.3-a.7.a)	Evaluate time to perform fault isolation
247	3.2.1.1.3.1.3-a.7.c)	Evaluate parts availability
248	3.2.1.1.3.1.3-a.7.d)	Evaluate Mean Time Between Failures (MTBF)
249	3.2.1.1.3.1.3-a.7.e)	Evaluate probable cause of failure
250	3.2.1.1.3.1.3-a.7	Recommend test sequence based on evaluation
251	3.2.1.1.3.1.3-a.8	Provide reasoning for recommending test sequence
253	3.2.1.1.3.1.3-b.1	Present theory of operations data upon request
255	3.2.1.1.3.1.3-c.1	Display graphics of A/C system exonerated w/respect to discrepancy
256	3.2.1.1.3.1.3-c.2	Present components and test points involved in troubleshooting
257	3.2.1.1.3.1.3-c.3	Present weapon system/asset subsystems or components
258	3.2.1.1.3.1.3-d	Interpret module Built-In-Test (BIT) results without removing module
299	3.2.1.1.3.1.5-a	Record troubleshooting data
301	3.2.1.1.3.1.5-b.2	Transmit troubleshooting data to MDBs
302	3.2.1.1.3.1.5-c	Store troubleshooting data
306	3.2.1.1.3.2.2-a.1	Provide access to supply information
309	3.2.1.1.3.2.2-a.3	Process inventory requests for parts availability
311	3.2.1.1.3.2.2-b.1.a)	Identify the required part by number
312	3.2.1.1.3.2.2-b.1.c)	Identify the required part by nomenclature
313	3.2.1.1.3.2.2-b.1.b)	Identify the required part by Work Unit Code (WUC)
314	3.2.1.1.3.2.2-d	Identify the part in an electronic Illustrated Parts Breakdown (IPB)
315	3.2.1.1.3.2.2-e	Identify the part using results of fault isolation
316	3.2.1.1.3.2.2-b.2	Verify part by displaying illustration

Table 1. Continued

Rqmt. No	SSS Paragraph No.	Requirement Text
318	3.2.1.1.3.2.2-b.4	Identify necessary bench stock/hardware
319	3.2.1.1.3.2.2-b.6	Verify correct part with technician
320	3.2.1.1.3.2.2-b.6	Forward parts request to SBSS
321	3.2.1.1.3.2.2-b.7	Accept/Present SBSS acknowledgment of ordered part
324	3.2.1.1.3.2.2-c.1	Verify technicians authorization to order parts
325	3.2.1.1.3.2.2-c.2	Prompt technician for information required for authorization approval
326	3.2.1.1.3.2.2-c.3	Route ordering information to verifier
327	3.2.1.1.3.2.2-c.4	Notify parts orderer of unvalidated order
328	3.2.1.1.3.2.2-c.5	Notify orderer of SBSS rejection
330	3.2.1.1.3.2.2-c.8	Assist in correcting rejected part orders
331	3.2.1.1.3.2.2-d.1	Display due-out release messages from SBSS
337	3.2.1.1.3.3.1-a.1	Select and display technical data
338	3.2.1.1.3.3.1-a.1	Adjust TO data for skill level
340	3.2.1.1.3.3.1-a.2	Provide status updates and maintenance discrepancies
356	3.2.1.1.3.3.3	Record data accumulated as result of repair/maintenance action
366	3.2.1.1.3.5.1-a	Present and sequence applicable TO data
367	3.2.1.1.3.5.1-b	Accept CALS Type B or Type C compatible data
368	3.2.1.1.3.5.1-d	Provide TO data for PMA use
369	3.2.1.1.3.5.1-e	Query tech in case of insufficient TO data in IMIS
370	3.2.1.1.3.5.1-c	Reformat Type C TO data
371	3.2.1.1.3.5.1-f	Provide supplemental TO data
372	3.2.1.1.3.5.1-g	Accept TO updates
373	3.2.1.1.3.5.1.b	Manage currency of data in PMA
375	3.2.1.1.3.5.2-a.1	Adapt technical data to skill level
376	3.2.1.1.3.5.2-a.2	Adapt TOs to A/C configuration
377	3.2.1.1.3.5.2-a.3	Adapt TOs to A/C discrepancy situation
378	3.2.1.1.3.5.2-b	Provide increased detail upon request
379	3.2.1.1.3.5.2-c	Prevent inexperienced technicians from choosing displays with little detail
380	3.2.1.1.3.5.3-a	Present job-related information according to technicians selection
381	3.2.1.1.3.5.3-b	Display related data from other sources within same TO
385	3.2.1.1.3.5.3-f	Present TO warnings and alerts

Table 1. Continued

Rqmt. No	SSS Paragraph No.	Requirement Text
387	3.2.1.1.3.5.3-h	Adapt format to the display device
388	3.2.1.1.3.5.3-i	Track and record all TO steps taken during a job
518	3.2.1.1.5.1.1-a	Provide familiarization training in the use of IMIS
521	3.2.1.1.5.1.1-d.1	Provide overview information of IMIS
522	3.2.1.1.5.1.1-d.2	Provide hardware and software information
523	3.2.1.1.5.1.1-d.3	Provide training tutorials on how to operate IMIS
524	3.2.1.1.5.1.1-e	Provide context-sensitive on-line help instructions in the use of IMIS
583	3.2.1.1.6.1.1-a.1	Initiate system coldstart
584	3.2.1.1.6.1.1-a.2	Load system files
585	3.2.1.1.6.1.1-a.3	Configure system components
586	3.2.1.1.6.1.1-b.1	Initiate Maintenance Information Workstation (MIW) coldstart
587	3.2.1.1.6.1.1-b.2	Load MIW system files
588	3.2.1.1.6.1.1-b.3	Prompt operator for PMA information
589	3.2.1.1.6.1.1-b.4	Provide listing of associated PMAs
590	3.2.1.1.6.1.1-c.1	Provide PMA system files in PMAs
591	3.2.1.1.6.1.1-c.2	Load installation data in PMA
592	3.2.1.1.6.1.1-c.2	Load configuration data in PMA
593	3.2.1.1.6.1.1-c.3	PMA establish communication with MIW
596	3.2.1.1.6.1.2-a.1	Initiate MIW warmstart
597	3.2.1.1.6.1.2-a.2	Reload MIW system files
598	3.2.1.1.6.1.2-a.3	Reconfigure MIW with PMA Identifications (IDs)
599	3.2.1.1.6.1.2-b.1.a)	Reload PMA system files
600	3.2.1.1.6.1.2-b.1.b)	Reload PMA-specific files
601	3.2.1.1.6.1.2-b.1.c)	Reload system configuration data
602	3.2.1.1.6.1.2-b.1.d)	Reload TO and applications data
603	3.2.1.1.6.1.2-b.2	Reestablish communications with MIW
605	3.2.1.1.6.2.2-a	Automatically obtain data from best source
606	3.2.1.1.6.2.2-b	Reformat accessed data as necessary
607	3.2.1.1.6.2.3-a	Automatically extract data to send to MDBs
608	3.2.1.1.6.2.3-b	Automatically compile and reformat data to send to MDBs
609	3.2.1.1.6.2.3-c	Send data to appropriate MDBs

Table 1. Continued

Rqmt. No	SSS Paragraph No.	Requirement Text
610	3.2.1.1.6.2.4-a	Detect if MDBs are off line
611	3.2.1.1.6.2.4-b	Retain collected data if MDB is off line
612	3.2.1.1.6.2.4-c	Inform operator of off-line MDB
619	3.2.1.1.6.3.1-b.1	Self-test of PMA functional sections
621	3.2.1.1.6.3.1-b.3	Test PMA interfaces
625	3.2.1.1.6.3.1-c.4	Initiate self-test of MIW
626	3.2.1.1.6.3.1-c.6	Interpret MIW self-test results
627	3.2.1.1.6.3.1-c.5	Display MIW self-test results
630	3.2.1.1.6.3.1-c.4.c)	MIW self-test to include test of all interfaces
631	3.2.1.1.6.3.1-c.7	Save MIW self-test discrepancies for which maintenance can be deferred
647	3.2.1.1.6.4.1-a	Configure IMIS to work within the specific base maintenance environment
648	3.2.1.1.6.4.1-b	Load base-dependent data in IMIS
649	3.2.1.1.6.4.1-c	Establish communication interfaces
651	3.2.1.1.6.5.1-a	Control access to IMIS resources
652	3.2.1.1.6.5.1-b	Limit number of unsuccessful attempts to access IMIS
654	3.2.1.1.6.5.2-a	Collect personal user data at user log-in
655	3.2.1.1.6.5.2-b	Maintain user data for use by all subroutines
656	3.2.1.1.6.6.1-a	Convert TO data from Content Data Model (CDM) to run-time format
657	3.2.1.1.6.6.1-b	Store and manage converted TO data
658	3.2.1.1.6.6.2-a	Provide English type query language
660	3.2.1.1.6.6.3	IMIS to have database of user profiles
661	3.2.1.1.6.6.3-a	Each IMIS user to have one modifiable record in personnel database
662	3.2.1.1.6.6.3-c	Personnel database to include password
667	3.2.1.1.6.7	Include a generic text editor for user note generation
670	3.2.1.1.6.8	Allow user to retrieve maintenance instructions faster than paper medium
671	3.2.1.1.6.8.1-b	Allow user to move forward thru data, in sequence
672	3.2.1.1.6.8.1-c	Allow user to move backward thru previous screens
673	3.2.1.1.6.8.1-c	Allow user to view previous screen
674	3.2.1.1.6.8.1-d	Allow user to return to original screen in sequence
675	3.2.1.1.6.8.2-a	Select data related to information viewed
676	3.2.1.1.6.8.2-b	Allow multiple methods of data access

Table 1. Continued

Rqmt. No	SSS Paragraph No.	Requirement Text
677	3.2.1.1.6.8.2-c	Present options for data display via hierarchical menus
678	3.2.1.1.6.8.2-d	Display cross-referenced information
679	3.2.1.1.6.8.2-e	Return to screen prior to requesting cross-referenced information
681	3.2.1.1.6.8.2-g	Display list of available information
684	3.2.1.1.6.8.3-b	Allow user to quit or exit the system or data presentation
685	3.2.1.1.6.9-a	Require minimum inputs
686	3.2.1.1.6.9-b	Data input via function keys
687	3.2.1.1.6.9-c	Display function key options
688	3.2.1.1.6.9-d	Support and display user-controlled cursor movement
689	3.2.1.1.6.9-f	Provide a Select capability for user selection of functions
690	3.2.1.1.6.9-g	Echo user alphanumeric input
692	3.2.1.1.6.10-a	Display initiation of process
693	3.2.1.1.6.10-a	Display termination of process
694	3.2.1.1.6.10-b	Display process and expected duration
695	3.2.1.1.6.10-c	Display success of the process
696	3.2.1.1.6.10-c	Display success of the transaction
697	3.2.1.1.6.11-a	Support a display function
698	3.2.1.1.6.11-b	Support different user groups
699	3.2.1.1.6.11-c	Present consistent data format within and across IMIS segments
700	3.2.1.1.6.11-e	Present TO data by expertise levels
701	3.2.1.1.6.11-g	Support zoom and/or scroll functions
702	3.2.1.1.6.12-a	User cancellation or modification of process
703	3.2.1.1.6.12-b.1	Delete function for correction of errors
704	3.2.1.1.6.12-b.2	Undo function for correction of errors
706	3.2.1.1.6.12-b.4	Overwrite function for correction of entered data
707	3.2.1.1.6.13-a	Provide context-sensitive help on the use of IMIS
708	3.2.1.1.6.14.1-a	Notify MIWs of system termination
710	3.2.1.1.6.14.1-b	Support saving of all working files
711	3.2.1.1.6.14.1-c	Terminate all internal processes
712	3.2.1.1.6.14.1-d	Terminate IMIS
713	3.2.1.1.6.14.1-d	Restart required to resume operation

Table 1. Concluded

Rqmt. No	SSS Paragraph No.	Requirement Text
714	3.2.1.1.6.14.2	Initiate termination of MIW
715	3.2.1.1.6.14.2-a	Notify all operators in communication with MIW of termination
716	3.2.1.1.6.14.2-b	Close and save all MIW work files
718	3.2.1.1.6.14.2-e	Shut down the MIW
719	3.2.1.1.6.14.3-a	Close and save all working files for the PMA
720	3.2.1.1.6.14.3-b	Terminate active internal PMA processes
721	3.2.1.1.6.14.3-c	Notify MIW operators of shutdown
722	3.2.1.1.6.14.3-d	Shut down the PMA

Selection of Demonstration Subsystems

To demonstrate the IMIS concept most effectively, enough TO data would need to be authored in an electronic format to support a completely paperless demonstration. This would require the authoring of the Fault Reporting Manual (FRM); Fault Isolation (FI) Manuals; job guides; general system information (theory of operation); Illustrated Parts Breakdowns (IPBs); pre-, post-, and thru-flight inspection procedures; and any second-level references to other TO data found in the FI manuals and job guides, to include wiring diagrams and schematics.

To provide this data for all F-16 subsystems was clearly too large and costly a task. The Statement of Work initially limited the demonstration to five subsystems: two avionics systems, one hydraulic system, one engine subsystem, and one environmental system. Also, in planning for an unconstrained demonstration in which IMIS would be used to maintain operational A/C and correct real discrepancies, it was believed that selecting subsystems with the highest failure rates in these categories would provide the most opportunities to collect information for subsequent analysis.

The Fire Control Radar (FCR) and Head-Up Display (HUD) were selected as the two avionics systems because of their high failure rates. Both of these systems, however, are located on the MIL-STD-1553 D-MUX bus, which is accessed through the Fire Control Computer (FCC), also called the General Avionics Computer (GAC), behind a large panel. Accessing the 1553 D-MUX bus was not feasible for the unconstrained demonstration, because of both the time required to remove the panel and the risk of damage in the process of disconnecting and reconnecting electrical connectors. A better solution for retrieving information directly from the A/C via the 1553 MUX buses would be to access the A-MUX and B-MUX buses. Upon further evaluation, the Inertial Navigation Set (INS) subsystem was selected to replace the engine subsystem. As a result, the following five subsystems were identified for the demonstrations:

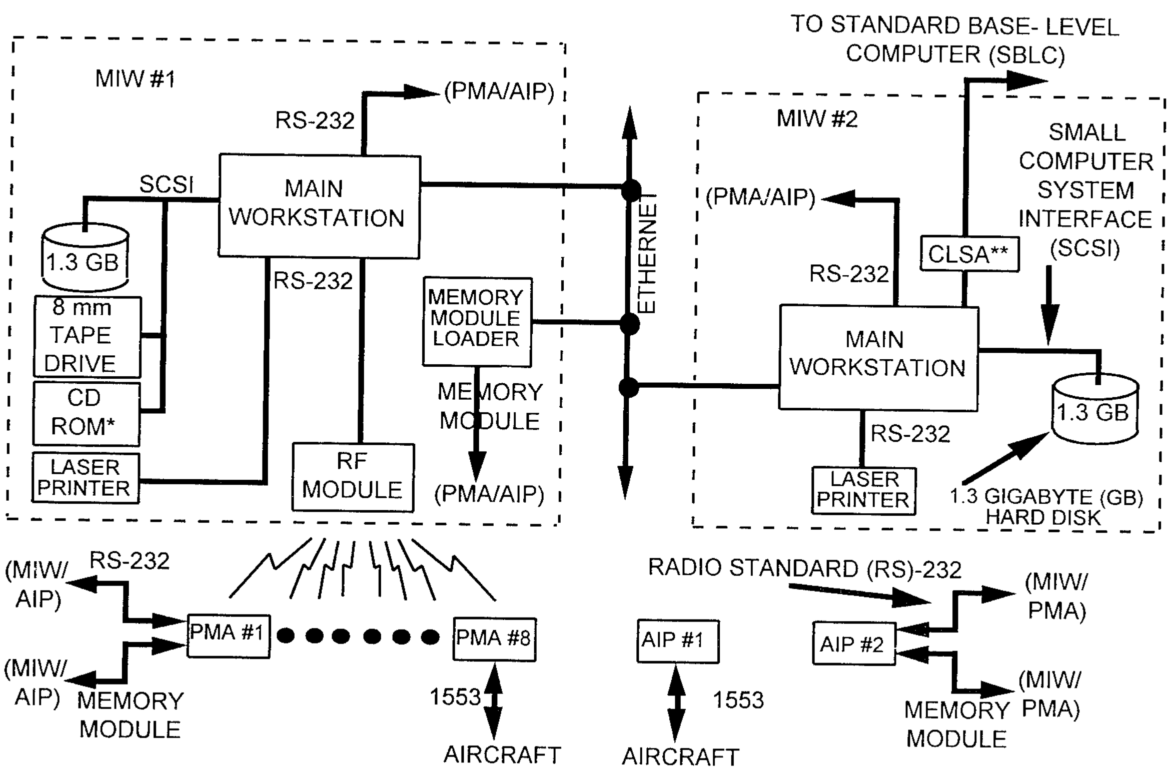
Fire Control Radar (Work Unit Code (WUC) 74A00)
Head-Up Display (WUC 74B00)

Inertial Navigation Set (WUC 74D00)
Hydraulic Power Supply (WUC 45A00)
Cabin Pressurization (WUC 41B00)

The ease of simulating and inserting faults via breakout boxes was considered in the selection of subsystems for the Fault Isolation Test. Consequently, the FCR, HUD, and INS subsystems were selected. A complete description of the faults used during the Fault Isolation Test can be found in the section of this volume entitled, "Fault Isolation Test."

HARDWARE DESIGN

The requirements analysis described in the preceding section identified the key requirements to be supported by the IMIS demonstration system. The IMIS hardware needed to provide access to external databases, portable devices for use on the flightline, and the capability to communicate maintenance data and maintenance decisions to all affected personnel. The optimal IMIS configuration therefore consists of three system segments: the Maintenance Information Workstation (MIW), the PMA, and the AIP. Figure 4 depicts the configuration of the IMIS demonstration system as installed at Luke AFB. A third MIW was added to the network to support integration and demonstration activities.



* CD ROM => COMPACT DISK READ-ONLY MEMORY
** CLSA => COMPUTER LOGICS SYNCHRONOUS ADAPTER

Figure 4. IMIS Configuration

The MIW segment provides an interface to the external data systems and to the PMA. The MIW automatically retrieves the information needed to perform MIW functions from the external sources and provides the capability to transmit data to these external sources. The MIW provides data to the PMA to support the PMA functional requirements, both at the beginning of a task (by preparing a cartridge) and during a task (by sending data and messages over the RF link). The MIW also serves as a user station for personnel who do not perform their main tasks on the flightline (e.g., maintenance debriefers and Maintenance Operations Center [MOC] personnel).

The PMA segment provides an interface for all flightline personnel, both technicians and managers, to the other IMIS segments. The PMA is used by managers to monitor A/C status, personnel assignments, and flying and maintenance schedules. The PMA is used by the technicians to open and close work orders, to perform diagnostics, and to display TOs. The PMA transmits collected data to the MIW for storage, dissemination to other personnel, and/or forwarding to external databases, as required.

The AIP segment, in a full IMIS implementation, provides the interface between the PMA and on-board diagnostic computer system. For the IMIS demonstration, the AIP was a portable mockup used to demonstrate potential applications for the AIP.

The way in which the IMIS segments must interface with one another was also considered. Each segment provides multiple methods for interfacing with the others to ensure that critical data can be distributed throughout the system. Figure 5 provides an overview of the interfaces between the three IMIS hardware segments, as well as the external interfaces with the F-16 A/C (via the 1553 bus) and the legacy databases (via the Standard Base-Level Computer [SBLC]).

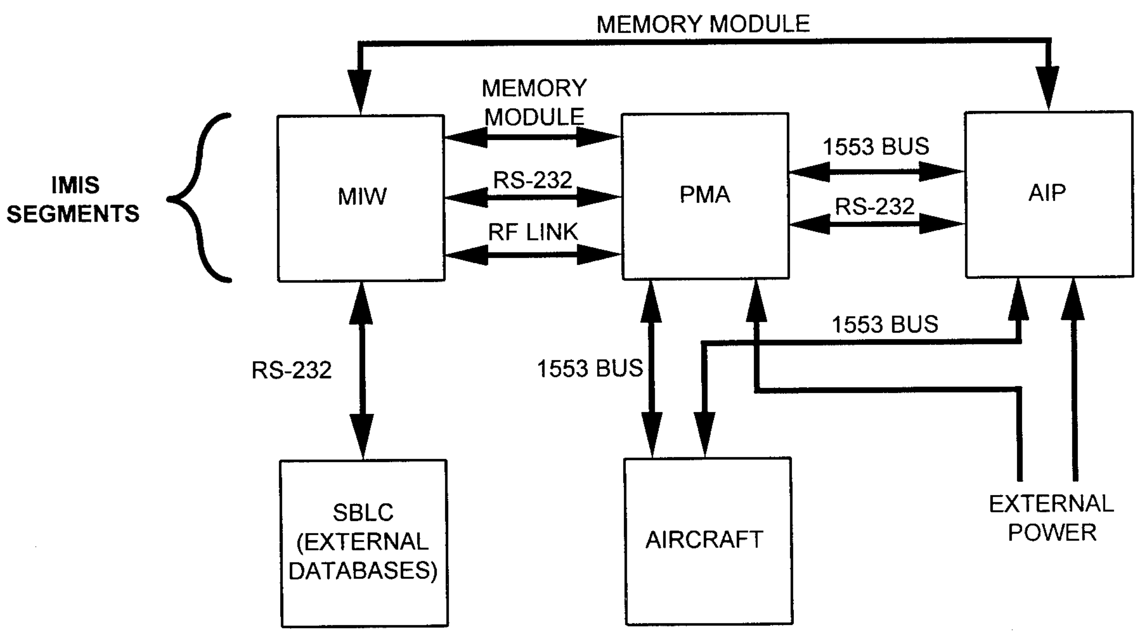


Figure 5. IMIS Segment Interfaces

The following subsections document the hardware design of the IMIS demonstration hardware. Additional detail regarding the hardware requirements and design can be found in the Prime Item Development Specifications (PIDS), CDRL 22, and the Prime Item Product Fabrication Specifications (PIPFS), CDRL 23.

Maintenance Information Workstation (MIW)

The MIW communicates with external information systems and other IMIS segments to provide an integrated source of information for all maintenance personnel. When selecting the hardware for the demonstration system, a trade study was performed to identify the commercial equipment which could support the functional requirements and contractual requirements within the cost constraints. Included in the list of functional requirements were performance, off-the-shelf applicability, expandability and upgrades, software availability, and programmatics, such as cost, schedule, familiarity, and availability. Figure 6 shows the hardware components selected for the MIW as a result of this trade study, their interconnection, and the connection to other IMIS segments, as well as to systems outside IMIS.

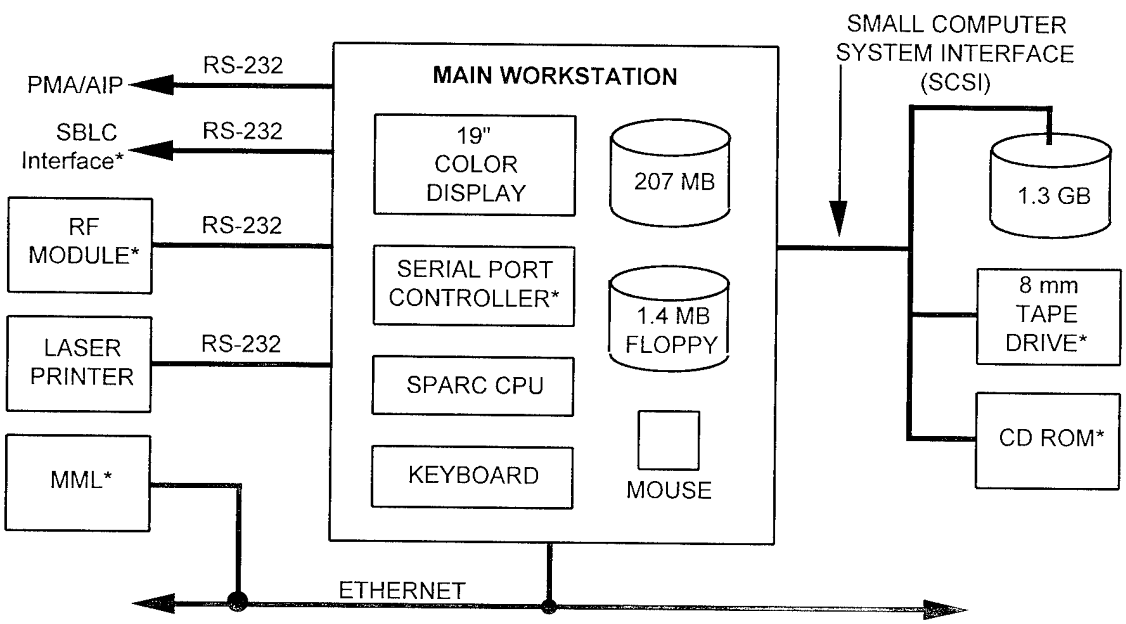


Figure 6. MIW Segment Interfaces

The workstation consists of a Sun SPARCstation 2 Central Processing Unit (CPU), a 19-inch (48.3-centimeter) color display, keyboard, mouse, an internal 1.44 megabyte (MB) 3.5-inch (8.9-centimeter) floppy disk drive, and a 207-MB internal Winchester disk drive. Interfaces external to the main workstation include external disk storage systems which provide 1.3 gigabytes (GB) of storage space, an 8-mm tape drive, a laser printer, and a Compact Disk Read-Only Memory (CD ROM). The network connection between the MIWs allows these devices to be accessed and controlled from any MIW.

Electronic communications between the MIW and the LAN are provided by an Ethernet connection. This allows the MIWs to communicate with one another, to communicate with the Memory Module Loader (MML), and to be connected to any other computer system with a compatible Ethernet interface.

An RF link provides the interface between the MIW and PMA segments. The MIW interface to the RF module is through the Radio Standard (RS)-232 compatible serial ports. The PMA and MIW segments are also able to communicate via an RS-232 interface. The link was primarily for use during development but is available to serve as an alternate means of MIW-to-PMA communications.

The MIW has the capability, via the MML, to download data to and upload data from a PMA memory module, which contains 340 MB of non-volatile storage. The 486-based MML is connected to the MIW network. The MML provides a gateway between the central database, which exists in the SunOS environment, and the local subset of the central database created for each PMA or AIP, which exists in the Santa Cruz Operation (SCO) UNIX environment.

The MIW communicates with the SBLC via an RS-232 interface. This connection is routed through the Computer Logics Synchronous Adaptor (CLSA) device and a series of 9600-baud modems which send data to and receive data from the Unisys mainframe housing CAMS.

Portable Maintenance Aid (PMA)

The PMA collects, processes, and integrates the data entered directly or received through interfaces with the MIW and the AIP. The PMA provides the maintenance technician detailed information regarding maintenance tasks while on the flightline. The technician, through keyboard control and displayed instructions, uses the PMA to diagnose maintenance faults. The PMA can communicate with the MIW to order parts and report status.

The original PMA was based on a standard commercial laptop computer attached to an external chassis which would provide the RF and 1553 interfaces. The work performed in Phases I and II showed that this approach would not result in the best demonstration of the IMIS capabilities. Therefore, a trade study was performed to find the best solution. The PMA Trade Study compared many alternatives, some based on commercial off-the-shelf (COTS) equipment and others representing new design options.

In support of the study, data was gathered regarding the human factors considerations of the PMA device. Mock-ups of proposed PMA chassis designs were presented to personnel at Edwards AFB, and the information collected was considered in the trade study. The findings of the Edwards AFB demonstrations show that the new PMA case design allows the unit to be lifted, held, carried, and used in a way which works well at and around the flight line. The resulting PMA design, including the visual displays, keypads, and controls, uses the applicable human engineering standards of MIL-STD-1472 as guidelines. The anthropometric and human performance aspects of the PMA design were considered throughout the PMA development to optimize man-machine interface effectiveness and minimize training requirements. The PMA chassis is shown in Figure 7.

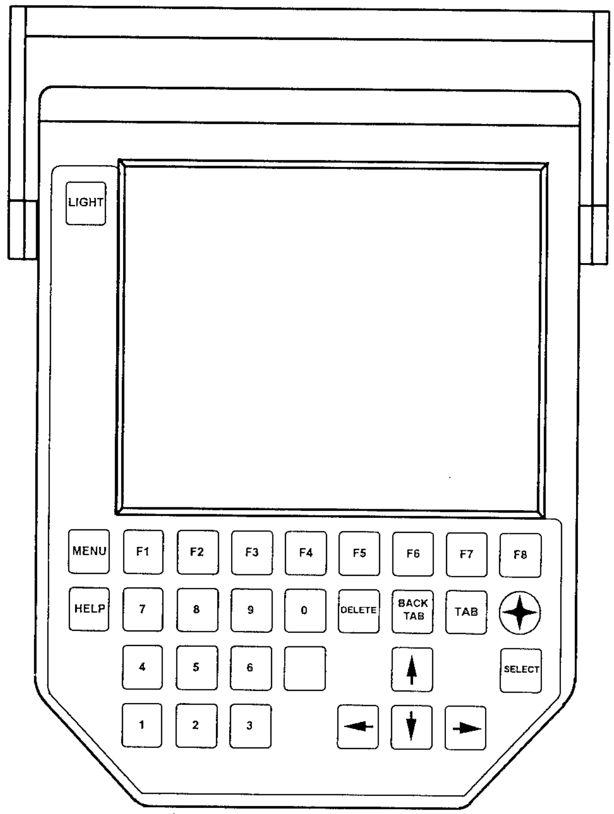
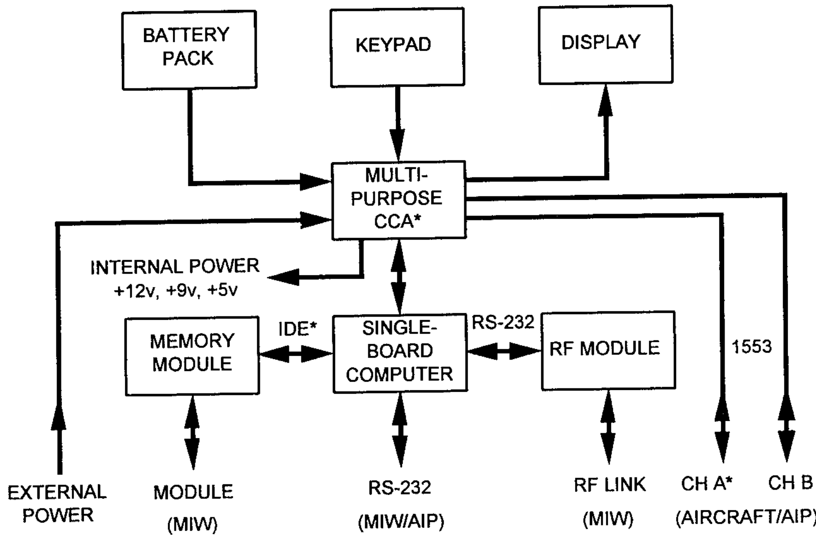


Figure 7. PMA Chassis

The PMA's internal and external interfaces are shown in Figure 8 along with the PMA's major components.

The CPU is a 33-megahertz (MHz), 80486DX-based, single-board computer. In addition to the basic computer capability, the single-board computer provides a Video Graphics Array (VGA) video output, two serial ports, one parallel port, a hard disk interface, a PC-AT bus expansion interface, and a total of 32 MB of random access memory (RAM). The original design called for a 20-MHz, 80386SX-based CPU with 4 MB of RAM. Early testing showed that the computations performed while executing the diagnostics algorithms and other functions required additional speed and memory. The upgraded CPU and memory provide significant improvements to the PMA's performance.

The display is a 640-x-480 VGA, transflective LCD unit. The display can be viewed in direct sunlight without the use of a backlight or in darkness with a backlight. The backlight is integrated into the display module.



* ACRONYMS:
CCA => CIRCUIT CARD ASSEMBLY
IDE => INTELLIGENT DRIVE ELECTRONICS
CH A => CHANNEL A

Figure 8. PMA Segment Interfaces

The PMA uses a non-volatile memory module, which is programmed by a MML connected to the MIW. This memory module's contents include TO data, as well as fault isolation and diagnostics data for the selected subsystem. The memory module in the original design provided 60 MB of storage. As technology matured, the mass storage capacity grew to the 340 MB hard drive used in the PMA tested.

Communication between the PMA and MIW is accomplished through an RF link. The RF module provides spread spectrum communications over the frequency range from 902 MHz to 928 MHz. The frequency used at Luke AFB was 906 MHz. The RF module provides four independent channels and individual receiver addressing. The RF modules operate in a packetized mode such that radio control, data, and status messages are passed between the computer and RF module over the same interface.

The keypad is a matrix of membrane switches which provide the primary UI to the PMA. These switches provide tactile feedback and are resistant to jet fuel and most other solvents.

The battery module is a rechargeable NiCad battery pack. This unit provides a nominal 7.2-volt direct current (DC) output for use by the PMA. In addition, the battery pack provides a temperature-sensor output for use during quick charge. The PMA may also be operated from an external power source.

Aircraft Interface Panel (AIP)

The AIP was designed as a laboratory demonstration unit which demonstrated the capability to communicate A/C information to the PMA. The 1553 Avionics Self-Test Bus is used for this communication, and the AIP is able to send data to and receive data from the PMA via this bus. The AIP uses a removable non-volatile Memory Module, identical to that used on the PMA, to hold its data files and software. This memory module's contents include TO data as well as fault isolation and diagnostics data for the A/C. The goal of the demonstration AIP design was to represent, as closely as possible, an actual AIP that would be embedded in an A/C.

When these requirements were delineated, it was noted that the demonstration AIP required functionality which was very similar to that of the PMA. As a result, the AIP used the internal components of the PMA to the extent possible. With the exception of the RF modem (required on the PMA but not on the AIP), the internal electronics of the two devices were identical, as is shown in Figure 9.

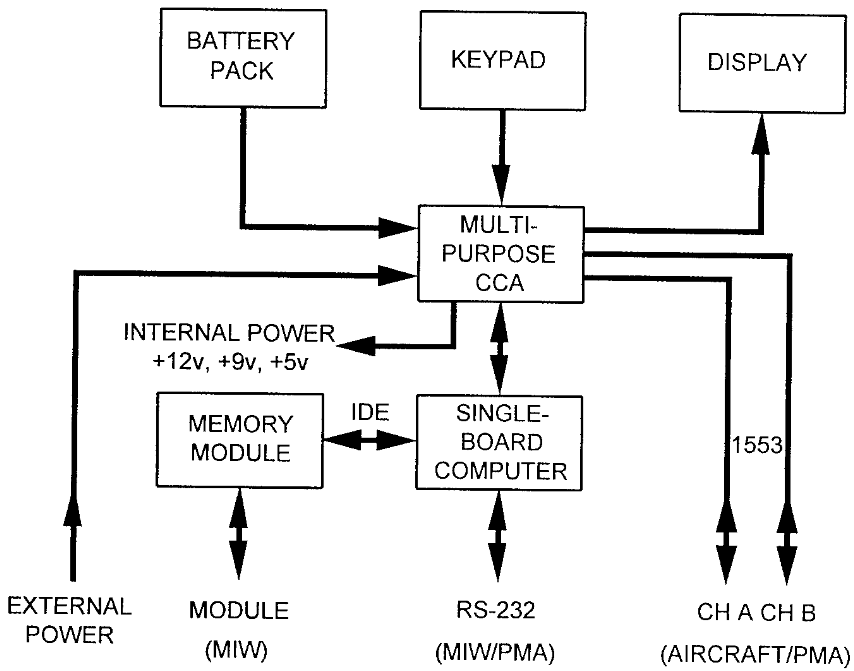


Figure 9. AIP Segment Interfaces

Since the AIP was a functional mockup of a device which would eventually be installed on an A/C, its chassis design was quite different from that of the PMA. The AIP was housed in a metal chassis which gave the appearance of a line replaceable unit (LRU). Handles were placed on the front to allow for easy removal and replacement. Figure 10 shows a rough outline of the front panel of the AIP.

SOFTWARE DESIGN

The IMIS is an integrated, user-oriented system that improves the effectiveness and efficiency of the O-Level maintenance personnel who maintain and support selected F-16 C/D

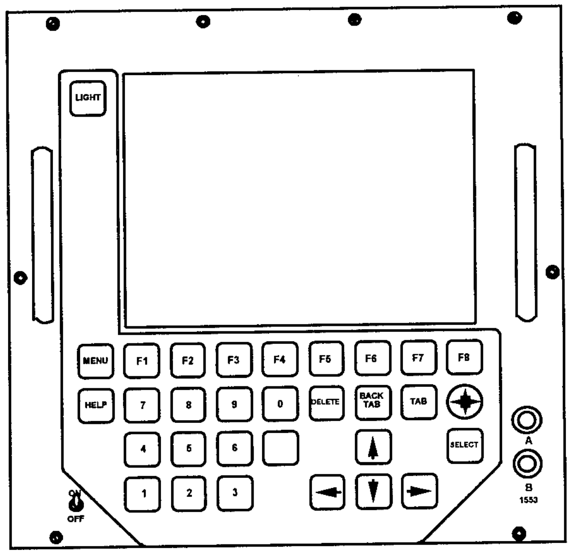


Figure 10. AIP Front Panel

Block 40/42 A/C subsystems. The IMIS software has been designed to support the complex maintenance tasks that are performed by these personnel by processing, integrating, and displaying information from various sources. IMIS interfaces with external systems and supports their data and operational requirements, thereby providing a single system with which maintenance personnel can perform their day-to-day maintenance activities.

IMIS allows the user to extract many combinations of information without requiring complicated command sequences. By providing simple access to this information, IMIS facilitates the user's ability to perform troubleshooting and decision support. IMIS also has the ability to interface with the F-16 C/D Block 40/42 on-board diagnostics and to translate information received during fault verification for use in fault isolation.

The IMIS system is composed of an IMIS Computer Software Configuration Item (CSCI), an MIW component, a PMA component, and an AIP component. The IMIS CSCI encapsulates all the software functions associated with the user interface, maintenance, management, and diagnostics capabilities as described in the Software Requirements Specification (SRS). The purpose of the IMIS CSCI is to specify a single software design in terms of abstractions (system classes) and generic services that can be used as the baseline for modification to execute on all the MIW, PMA, and AIP components of IMIS. Thus, the need to specify a unique software design for each IMIS component is avoided.

This section documents the software design for the demonstration IMIS system. This includes a discussion of the object-oriented methodology used and the resulting software development environment selected, an overview of the software architecture, and a summary of the requirements and design in each of the major functional areas: user interface, diagnostics, TO presentation, message manager, external data management, and PMA-unique software. Additional detail regarding the software design can be found in the IMIS Software Design

Document (SDD), CDRL 26. Other supplemental information contained in the SDD includes State/Transition Diagrams, presentation storyboards, pseudo-code, class library structures, and attribute definitions.

Object-Oriented Design

The objected-oriented design paradigm is really a modeling point of view. The analysis and design phases of the traditional life cycle, while remaining distinctly separate activities in the object-oriented life cycle, work together closely to develop a model of the problem domain. The model is constructed by viewing the domain as a set of interacting entities. The software-based models of entities and the relationship between them are assembled to form the basic architecture of the application. The information developed in the analysis phase becomes an integral part of the design rather than simply providing input into the phase. This smooth transition is facilitated by the homogeneity of the "pieces" being used by each process.

The IMIS software requirements are expressed in terms of abstractions (system classes in the object-oriented methodology) and generic services that can be used as the basis for tailoring. The approach assists the software design process by partitioning the software into distinct system capabilities. The capabilities of IMIS are expressed in terms of the problem domain concepts. These concepts correspond to software classes whose behaviors provide the required capability. This approach to expressing the requirements is to facilitate an object-oriented design paradigm, as opposed to the traditional procedural paradigm.

Major benefits of an object-oriented development approach include reusability and extensibility. Given the nature of the IMIS program, it was believed that the object-oriented path would provide the greatest benefit during the development of the demonstration system and extending into full system development.

Software Development Environment

The IMIS software development environment was chosen to support object-oriented analysis, design, and programming. The essential requirements were based on the need for a repository approach to software development, where products of the software development process are integrated into a single repository. This provides facilities for evolutionary development and presumes an application architecture designed to facilitate change, which is necessary for IMIS.

The IMIS software development environment was chosen to support object-oriented analysis, design, and programming. The IMIS software development environment is an integrated environment centered on the ONTOS object-oriented database as the central repository. Associative Design Technology's Ptech was selected to act as the front end for the object-oriented database repository. This provided a high degree of integration for the design representations, in that the conceptual models go directly into the ONTOS database in terms of class libraries and process implementations.

The IMIS software development occurred before technology was sufficiently mature to support object-oriented analysis, design, and programming. The tools described in the following subsections were selected because of the potentially significant benefits which could be realized by using this repository approach.

Computer-Aided Software Engineering Tools

The primary Computer-Aided Software Engineering (CASE) tool used was Ptech. Ptech offers an integrated approach that describes processes and systems at all levels of detail, from requirements through design and implementation. It provides a flexible front-end method and tool that intimately links classes and processes. Ptech provided a formal foundation to allow the Air Force maintenance domain concepts to be mapped exactly onto the C++ typing system and, as a result, was used to develop correct, consistent, and executable specifications of many of the maintenance processes. This meant that the way the maintenance experts specified the problem determined precisely how the software engineers thought about the problem; concepts specified by the maintenance user were automatically preserved in code. The C++ code that was generated was ready for insertion into an ONTOS object-oriented database, providing a direct bridge between the concept in the Ptech knowledge base and classes (and, subsequently, instances of classes) in ONTOS.

Database Management Systems

Due to the object-oriented nature of the IMIS software development, an object-oriented database selection was necessary. The ONTOS database, written entirely in C++, was the only third-generation object database based on an architecture of "objects throughout" in which objects were implemented at every level of the database system, from the object model, storage managers, and memory managers to the data types and access methods. This architecture provided developers with an open interface and flexible access to all the capabilities of the database through class libraries and associated tools. ONTOS offered the functionality and a comprehensive tool set needed to develop network-based distributed database applications. In particular, the High Concurrency Object (HCO) technology allowed multiple users to access and update specific objects simultaneously. This provided a significant increase in concurrency on critical objects used in the multi-user application.

ONTOS did not appear to be suitable, however, as a vehicle for interfacing with a screen-oriented external system, such as CAMS. As a result, Sybase, a relational database management system, was selected to serve as an intermediate data repository between the two dissimilar systems. This selection also would allow for extensions to other external databases in the future with minimal impact.

Programming Languages

In selecting C++ and C as the programming languages for the IMIS software development environment, two constraints were considered. The first constraint was that a custom application communicating with ONTOS, the IMIS object-oriented database, can be written using C++ but not C. The second constraint is that the Sybase Application Programming Interface (API), used in the External Data Management (EDM) software, can be invoked by applications written in C but was not recommended for applications written in C++. Consequently, all IMIS software has been written in C++, with the exception of various EDM functions, written in C, which invoke the Sybase API.

User Interface Tools

The software tools used to implement the UI software are the ParcPlace User Interface Builder (UIB) and the Object Interface (OI) Toolkit. UIB is a graphical UI tool designed to work with the OI Toolkit to produce graphical presentations on underlying classes, and allow automatic update of class attributes displayed and modified in the presentations. Callback routines are attached to the component widgets used to design and display the class attributes. In addition, UIB allows the developer to encase the presentations in X-Window-based windows, which are manipulated like other windows in an X-based system. These windows can have menu systems designed by the developer with their associated callbacks. The UI paradigms presentations, described further in the subsection entitled, "Diagnostics," are implemented directly with facilities provided by UIB.

The OI Toolkit is an object-oriented toolkit built on the X-lib layer of the X-Window system. It provides a rich set of widget functionality based on a class hierarchy structure. The IMIS UI software utilizes the OI Toolkit to develop complex widgets which cannot be implemented with UIB.

Software Architecture Overview

IMIS is a multi-user application that operates on the MIW, PMA, and AIP. The architecture provides the user with functionality, data, and a UI that is consistent across these different platforms. The architecture consists of transactions and services that share a common class library. The services and transactions are the processes which access and manipulate the class library. The class library contains all reusable components of IMIS software.

A transaction is defined as an end-user task or unit of work. Each transaction is an interaction with the IMIS user. All transactions are implemented in a single process called the IMIS process. The IMIS process manages all user interaction and functional capability for the IMIS user. These capabilities include the ability to view and manipulate IMIS data, including user, personnel, A/C, work order, schedule, and part data.

A service is defined as providing a capability not directly visible to the user. Services typically involve an external or operating system interface. The EDM and CAMS Interface services provide an interface to external systems such as SBSS and CAMS. The Message Manager service provides communication between the ONTOS databases that reside on the PMAs and the ONTOS database that resides on the MIW network. The MML service moves instance information from the ONTOS database on the MIW network into an ONTOS database on the PMA.

The class library contains reusable software required to implement the transactions and services. The class library is subdivided into IMIS, EDM, System, Content Data Model (CDM), and Diagnostics class libraries. The IMIS class library provides the classes necessary to support all IMIS processes except diagnostics. The EDM class library supports the transfer of data between ONTOS and Sybase. The System class library is used to manage the user's environment and to manage the movement of data between the IMIS processes and within a single IMIS process. The System class library is also used to manage the transfer of data between the IMIS processes and the services. The CDM class library contains electronic TO data and related troubleshooting information to support automated diagnostics and interactive presentation of maintenance and repair instructions, illustrations, and parts information. The Diagnostics class library supports the diagnostic process.

The system is configured so that an IMIS process executes on each platform in the system. This provides a consistent interface to the user. However, resources are not allocated uniformly across all platforms. The method of accessing resources on the system differs depending on the type of platform, resulting in different configurations, as described in the following paragraphs.

MIW Architecture

The MIW Network architecture consists of IMIS processes and services sharing the central database. The resources that are unique to the MIW Network architecture are the central database and the external interface to other database systems.

The central database contains the current information for the IMIS system. The Message Manager service maintains consistency between peripheral databases and the central database. The Message Manager also provides communication between IMIS processes located on the PMAs and the services located on the MIW network.

The external interface to other database systems consists of an EDM process, the Sybase database, and a CAMS process. The EDM process converts objects in the ONTOS database into their relational equivalents and stores the data in Sybase when moving data from IMIS to an external system. When moving data from an external system to IMIS, the inverse set of operations is performed. The EDM process is responsible for maintaining consistency between the ONTOS database and the external databases. The CAMS process provides communication services by moving data from Sybase to an external database and vice versa.

PMA Architecture

The PMA architecture consists of an IMIS process and a local copy of the ONTOS database. The local database acts as a buffer for shared objects and messages. The shared objects and messages are integrated into the central database using the Message Manager. Static data such as the CDM are stored in the local database so that the IMIS process can provide efficient transactions for the user. The PMA contains the unique 1553 device driver software. The process provides this capability when in the PMA or AIP configurations.

AIP Architecture

The AIP architecture is identical to that of the PMA with one exception: the AIP is not capable of network communication over the RF link using the Message Manager. Synchronization and consistency between the local database and the central database are achieved by first downloading shared objects and messages to a PMA via the 1553 external bus connection available on the PMA and AIP configurations, and then integrating the shared objects and messages into the central database using the Message Manager via the RF link available on the PMA configuration.

MML Architecture

The MML architecture is an extension of the MIW Network architecture, which provides a gateway between the central database, which exists in the SunOS environment, and the local subset of the central database created for each PMA or AIP, which exists in the SCO UNIX environment. The sole function of the MML is to provide a platform for loading PMA/AIP local databases onto Memory Modules and to extract data from the Memory Modules in order to store it into the IMIS or external databases. The MML performs this service via the MIW Network architecture.

User Interface

The UI software was designed to be as reusable as possible, from both a development perspective and a user-friendly perspective. The initial set of UI paradigms was identified based on a knowledge of project requirements, high-level system design, and prototyping efforts. These paradigms were generic in nature and therefore reusable across a wide variety of applications. Specific screen states and state transition diagrams were developed with these generic paradigms in mind. This process maximized software reuse in terms of object-oriented software classes and reusable widgets.

The developmental building blocks for the UI software are: the menu bar for each IMIS user role, the main presentation associated with each menu item, and any callback routines associated with the presentation. Each main presentation can have associated additional presentations, and/or a variety of widgets associated with the callback routines for presentation. The UI widgets are implementations of the UI paradigms. The overall strategy was to develop the main presentations as fully functional units with all the associated callbacks and to add each completed presentation unit one by one to the menu system. One significant design constraint imposed on the UI was that it must work with the keyboard alone (mouseless navigation), a pointing device alone (mouse-based navigation), or both. This constraint was a key factor in the design of the UI paradigms. The following paragraphs describe the various UI paradigms, as well as the UI functionality.

User Interface Paradigms

The Menu Bar paradigm provides the primary mechanism for navigation through the IMIS UI. The IMIS software utilized a menu system constructed with the OI Toolkit. A single pulldown menu is attached to each menu item in the menu bar. The menu is tailored to the duty title of the user logged in.

Presentations are graphical displays of class attribute data created with the UIB tool. They are the most widely used of the UI paradigms. Most menu selections from the IMIS menu bar produce a presentation. Presentations consist of a set of display widgets arranged in the presentation window, each of which is assigned to a particular class attribute. At the base of each presentation is a row of function key buttons. These active function keys appear with labels appropriate to the context of the current presentation, such as "OK," "Edit," "List," or "Cancel." These function key buttons are active for mouse clicks and can also be used in conjunction with the hard function keys to provide a mouseless operating environment for the PMA and the MIW.

There are three types of dialog boxes in IMIS: the Message Dialog Box, the Respond Dialog Box, and the Scrolling List Dialog Box. All dialog boxes in the IMIS environment are modal in nature, that is, the user must perform some action in the dialog box before any interaction with the rest of the UI is permitted. Message dialog boxes are used to indicate an error condition to the user or to present information to the user which requires an acknowledgment. The user interacts with message dialog boxes by clicking on an "F1 OK" button to acknowledge the message presented in the box. Respond dialog boxes are used to indicate an error condition to the user or to present information to the user in a situation which requires a user decision. The user interacts with the respond dialog box by clicking on the appropriate button (e.g., "F1 OK" or "F7 Cancel"). Scrolling list dialog boxes present the user with a list of choices from which to select. If the list is larger than the current display, a scroll bar appears to allow the user to access the entire list.

The Entry Selector widget provides the user with a list of pre-defined choices that can be used to fill in a text entry area in the UI. The list may or may not scroll, depending on the size of the list. When the user has selected a choice from the list, the choice automatically appears in the text entry area. The Entry Selector is a modal widget.

The Row-Selectable widget presents a scrolling list of multi-column data in a dialog box format. The entire row of data is selectable by the user. This widget is useful to display object attribute values from one or more classes in the same row.

The Hierarchical Lister allows navigation through a list of nested lists, such as the WUC hierarchy. It is designed to work like file selection widgets found in other user interfaces. It appears as a scrolling list with a separate display area above the scrolling list. The initial set of entries in the list is the top set of categories in the hierarchy. As the user descends through the hierarchy of sublists by pressing "F2 Expand," the current selection level is displayed in the separate display area. The lists can be traversed in the reverse order by pressing "F3 Collapse." The Configuration Code widget is a special case of the Hierarchical Lister in which each selection from the last list can be appended to the Configuration Code being built in the separate display area.

The Cell-Selectable widget, also known as a spreadsheet, consists of a two-dimensional matrix of individually selectable cells which can be scrolled horizontally and vertically. It is used for applications such as display and modification of flying and maintenance schedules, where row data is logically related to an object such as an aircraft. After an individual cell has been selected, an operation on that cell can be performed by depressing a function key (e.g., edit cell contents, obtain supplemental information). After the cell operation has been performed, the cell is automatically deselected.

A soft keyboard paradigm permits manual editing of alphanumeric entry fields on the PMA. This keyboard has been implemented using the OI Toolkit and is accessible on both the MIW and PMA via one of the function keys.

User Interface Functionality

UI transactions developed for the IMIS application covered all aspects of the maintenance environment. Only a subset of these transactions was exercised during the field demonstrations at Luke AFB. These transactions included Debrief, Open Work Order, Task Assignment, Fighter Squadron A/C Status, Work Order History, Close Work Order, Display Flying Schedule, Display Maintenance Schedule, Order Parts (via the Quick Reference List [QRL] and/or the IPB), Prepare and Extract PMA Cartridge, and Send and Display Messages. Diagnostics functionality is discussed in the section entitled, "Diagnostics."

The Debrief transaction allows the user to perform a pilot debrief. The user enters sortie and system capability data, opens work orders, and prints out a sortie recap.

The Open Work Order transaction allows the user to open a work order against any A/C system or subsystem. IMIS pre-fills all possible data elements on the open work order form. The user has the option to enter the FRM to determine the fault code, which acts as an entry point into the diagnostics module. Whenever a work order is opened, IMIS checks to see how it affects the A/C status or if the entered Estimated Time in Commission (ETIC) exceeds the current A/C ETIC. Notifications of the new work order, as well as updates to A/C status, are sent to the appropriate personnel.

The Task Assignment transaction allows a technician to display a list of task assignments currently assigned to him/her. The work order associated with each task assignment may also be displayed. Maintenance management personnel use this transaction to display and update task assignment information.

The Fighter Squadron A/C Status transaction allows the user to display the status of all A/C assigned to a Fighter Squadron. The status displays and the ability to alter different data elements are tailored to the requirements of the different duty titles. Any changes to the data on this display are routed to the appropriate personnel for notification and approval.

The Display Work Order History transaction allows the user to display all the closed work orders generated over the previous 30 days for a given A/C or WUC.

The Close Work Order transaction allows a technician to fill out the necessary forms to document the work that was completed on a work order. The user enters the necessary data into IMIS, and the appropriate personnel are notified of the work order closure and resulting A/C status change, if necessary.

The Display Flying Schedule transaction allows the user to display the A/C flying schedule for the Fighter Squadron on a given day, including A/C that are available as spares. The Production Superintendent and Planning and Scheduling personnel are allowed to update the flying schedule. Any changes to the flying schedule are routed to the appropriate personnel for notification.

The Display Maintenance Schedule transaction allows the user to display the complete weekly A/C maintenance schedule for the Fighter Squadron. The Production Superintendent and Planning and Scheduling personnel are allowed to disregard update the maintenance schedule.

The Order Parts transaction can be accomplished through the QRL or the IPB. The QRL contains part information pertaining to the IMIS subsystems. The IPB is displayed by the TO Presentation (TO Present) and provides a graphic representation of the part. Once a part has been selected, from either the QRL or the IPB, the part order form is displayed with complete information about the part. The Production Superintendent is required to authorize all part orders by entering his password directly on the part order form or on a notification that is sent.

The Prepare PMA Cartridge transaction is used by the support section personnel to update the data contained on the PMA data cartridge prior to issuing the PMA to a technician. It presents a list of the subsystems (e.g., FCR) for which diagnostics will be performed. The database corresponding to the selected subsystem is then copied onto the cartridge via the MML. The Extract PMA Cartridge transaction is used by the support personnel when a technician returns a PMA to the support section after performing a maintenance task. It extracts all transaction data from the cartridge and sends it to the appropriate sections of the IMIS and the external databases.

The Send Message transaction allows a user to create messages to be sent to other IMIS users. A user can input the destination, subject, and body of the message, and then send the message to other users. The Display Message transaction allows a user to display any message that has been sent from other users. The messages are display only and cannot be updated.

Diagnostics

The IMIS Diagnostics Module (IMIS-DM) assists the maintenance technician by making maintenance action recommendations for diagnosing and repairing a faulty A/C in minimum time. In making its recommendations, IMIS-DM considers accrued test results and system knowledge, with decisions guided by a pre-defined model of A/C symptoms, faults, tests, and repairs, created in accordance with a customized version of the Air Force CDM, version 6.0x. This data is stored in and accessed through the IMIS object database. All access to CDM data objects by IMIS-DM is Read-Only; where IMIS-DM needs to modify the original data values obtained from CDM, that data is copied into local objects for manipulation.

The IMIS-DM architecture includes the IMIS Executive (including IMIS-DM), the task manager, and the TO Present system. Each of these components runs in its own C++ thread, operating within the IMIS process. Messaging is used to pass control and data from thread to thread. Communication between threads also takes place via shared database objects (in particular, the IMIS state table).

The IMIS Executive provides UI control to invoke a new or existing IMIS-DM session. It also provides access to related IMIS functions that may be needed during IMIS-DM operation, such as ordering parts or displaying messages. IMIS-DM analyzes reported and tested A/C symptoms and faults, and provides recommendations for an optimal troubleshooting and repair sequence. The TO Present module presents instructions for performing a selected task (test or repair) and provides display of diagnostic block diagrams. The Task Manager provides control over IMIS-DM and TO Present.

IMIS-DM is invoked by the IMIS Executive in response to the user's selection of the "Troubleshoot" option on the menu bar. The troubleshooting request identifies a target Work Center Event (WCE) which provides access to a work assignment and associated discrepancy. The discrepancy object provides a definition of the problem to be diagnosed and repaired, along with identification of the faulty A/C.

IMIS-DM initialization involves performing a number of queries on the IMIS object database to locate needed CDM and IMIS information about applicable faults, tests, symptoms, A/C data, and user information. Some up-front loading and context filtering of frequently accessed objects is warranted for efficiency. Given a target fault state (based on the fault code), IMIS-DM accesses the faults, tests, and repairs that are defined for that fault state. There is no direct link between a test and the faults it spans; consequently, this processing is completed during the database load process to improve the efficiency of the IMIS-DM software.

After initialization has been completed, the user is provided the opportunity to perform Aircraft Safe for Maintenance procedures and applicable verification tests. IMIS-DM then displays a block diagram of the subsystem being diagnosed, which can be used to see the hierarchy of subsystems that could be the cause of the fault. IMIS-DM provides a ranked list of actions (tests and repairs), from which the user can choose either the best (highest ranked) action or any other available test or repair. When a test or repair is selected, IMIS passes the necessary information to the TO Present system, which presents the TO to the user.

When a test passes, IMIS-DM eliminates any faults that are spanned by the test's pass outcome; when a test fails, each fail outcome that was observed yields a new fault state that implicates some faults. When a repair is completed, IMIS-DM initiates a system health check that spans all the faults which should be corrected by that repair. The user can continue to perform tests and repairs until all symptoms in the active troubleshooting group have been eliminated, signaling successful completion of that troubleshooting group.

After clearing all faults, the user can perform all the follow-on actions to restore the A/C to its original state. The user can then close the work order, which automatically contains a list of actions taken and the start and stop times of the diagnostics session.

Technical Order Presentation System

The TO Present system provides the means to interactively display TOs to the user. To provide this specialized functionality in as seamless a fashion as possible, TO Present appears as a subprocess within IMIS, with state information and certain functions in higher-level subprocesses accessible within TO Present. The thread mechanism is used to break TO Present into subparts which communicate with each other and with IMIS.

TO Present is implemented using three different threads. The manager thread controls all communication into and out of TO Present, as well as communication between the other two threads, presentation tasks and diagnostics tasks. Each of the three threads has its own queues, and all events are routed via the manager thread.

TO Present operates solely on CDM data contained in flat files for its processing. TO Present contains a parser which reads these flat files into an internal form of CDM which TO Present uses in its display. TO Present is invoked with the name of a flat file. A mechanism internal to TO Present exists to allow IMIS to pre-process a flat file before it is parsed by TO Present. This is used in IMIS-DM where flat files are built on the fly for use by TO Present. This mechanism also allows reuse of CDM objects in memory, which is useful in speeding up the parsing of the block diagram in IMIS-DM.

The other conduit for communication between IMIS and TO Present is the state table. Navigation through a TO is dependent upon the user's context and various assertions about the A/C system to which the maintenance procedure described by the TO applies. A user's context is defined as certain effectivity attributes selected by the user and kept in that user's profile. The assertions pertain to properties of the system being maintained, the user, and the maintenance process in the largest sense (e.g., history, equipment supplies, and personnel required). All these properties and their values are grouped into the state table. TO Present reads property values from the state table and makes assertions into the state table during the course of presenting a TO.

The audit trail allows access to information about which CDM nodes were visited during a TO Present traversal. IMIS uses this information during an IMIS-DM session to determine which tasks the user has accessed.

Message Manager

For personnel using IMIS to make accurate and informed decisions regarding their assigned maintenance tasks, it is critical to have reliable and consistent process-to-process communication. The Message Manager is responsible for maintaining consistency between the MIW shared database and the PMA local databases. The Message Manager also sends updates to the MML copy of the shared database, which is used for downloading memory modules. The Message Manager operates over the RF link and over the network.

IMIS data is either read-write data, Read-Only data, or data local to the process. Certain instances of the IMIS class library, EDM class library, System class library, and Diagnostics class library are read-write data. The Message Manager must keep the read-write data consistent across all databases and platforms. Every change to read-write data is recorded in the database and reported to the message manager, which then sends the transaction to all appropriate databases for update.

The Message Manager is also responsible for the decomposition of an object into a byte stream and the recomposition of the byte stream into an object for communication. The byte stream is sent from one database to another over the RF link or over the network. The following paragraphs describe the Message Manager operations on the PMA and on the MIW.

PMA Message Manager

On the PMA, a buffer exists between IMIS and the Message Manager to hold the outgoing requests and the incoming responses. Requests remain in the buffer until the corresponding responses are received. If the RF communication is off or out of range, the requests will remain in the buffer until RF communication is possible or the memory module is uploaded in the MML. The PMA Message Manager uses the RF link to communicate with the MIW. Requests from IMIS are sent out as messages over the RF link. The PMA Message Manager will remain active, trying to receive a response to the request, for a configurable time limit.

The PMA Message Manager places responses in the buffer for IMIS to receive. It also informs the user of the use of the RF link and any of the following errors: inability to transmit to the MIW, no response received from the MIW, and abort received from the MIW in response to a request for change from the PMA.

There are three categories of remote requests which are handled by the PMA Message Manager: change request, data request, and update request. A change request allows changes to the PMA local database to be repeated on the MIW shared database by the receiving MIW Message Manager. The MIW Message Manager responds with a confirmation if the change was completed or an abort if the change could not be performed on the shared database. An abort condition can occur if a user on another PMA or MIW has changed the database first.

A data request seeks data from the shared database. The MIW Message Manager responds with the requested data if it can be obtained from the MIW shared database or with a response that the requested data was not found. The requested data will then be stored in the local database.

An update request asks the MIW Message Manager to transfer the queued updates for the local database to the PMA. The MIW Message Manager will transmit all the updates which have been queued for the PMA's particular local database. The updates will then be performed on the local database.

MIW Message Manager

The MIW Message Manager handles the requests of each PMA and manages the updates which must be queued for each PMA local database until they are requested. The Message Manager also queues the updates for the MML copy of the shared database. Modifications to the shared database by MIW IMIS, EDM, and the Data Module Loader process also need to be written to the PMA local databases through Message Manager updates. The modifications are written to a buffer and read by the MIW Message Manager, which determines which PMAs need to receive the update based on the list of "checked out" PMAs.

When the IMIS process on the MIW (or the EDM process) makes a change to the shared database, an update is also written which can be used to re-create the same changes on the local database on each PMA and the MML. The update is read in by the MIW Message Manager, which determines which PMAs the change needs to be sent to. The updates are stored until they are requested by the PMA over the RF link or the PMA is checked in. Similarly, when the IMIS process on the MIW creates a message to be sent to another user, the MIW Message Manager reads in the message and follows the same process.

The MIW Message Manager must also handle the three types of remote user requests described in the preceding section: change request, data request, and update request. In the case of the change request, the MIW Message Manager will perform the change on the shared database (sending an abort response to the PMA if the update was unsuccessful), determine which PMAs need to receive the update, and write out the update to buffers for each of those PMAs. The updates are stored until they are requested by the PMA over the RF link or the PMA is checked in. The MIW Message Manager handles the PMA update requests by getting the queue of updates for that PMA and transmitting the updates across the RF link. The MIW Message Manager responds to the PMA data requests with the requested data, if available, or with an error response if the request could not be fulfilled.

External Data Management

The EDM interface runs on the MIW and serves as the interface between the IMIS object database and CAMS, the legacy system. The main function of the EDM interface is to maintain consistency between IMIS and CAMS. User-induced changes to IMIS data which is also resident in CAMS must be made to CAMS, and data from CAMS or SBSS must be retrieved periodically for display to the IMIS user. The IMIS object database is initialized with data needed from CAMS; thereafter, consistency is maintained with batch scheduled updates.

EDM uses the Sybase Structured Query Language (SQL) server as an intermediate data repository to provide a vehicle for communication between the object-oriented IMIS application and the screen-oriented CAMS application. This architecture allows for extensions to other external databases in the future with minimal impact on existing IMIS software.

When IMIS objects which have attributes tracked in CAMS are created or updated, a process to transfer this data to Sybase is initiated. From the IMIS perspective, the flow of data between IMIS and CAMS is accomplished by procedures which add rows to Sybase tables (to send data to CAMS) or which copy rows from Sybase tables (to get data from CAMS).

There are four types of Sybase tables: shared data tables corresponding to IMIS classes, a control table to support the communication protocol between the IMIS and CAMS interface processes, tables used for administrative purposes, and CAMS data tables.

Each Sybase shared data table corresponds to an IMIS class, each row relates to an instance of an IMIS object and each column relates to an attribute of an IMIS object. Each table name is identical to the name of its class counterpart. The data contained in these shared tables is transitory, remaining only until it has been processed.

When IMIS requires CAMS data or must send data to CAMS, an entry to the ONTOS EDM Service queue is added. The entry on this first-in, first-out ordered queue is read and sent to the EDM control table, specifying the information necessary for the CAMS server process to service the request. The CAMS process satisfies these request by either retrieving one or more data tables to send to CAMS, or adding data to one or more data tables to send to IMIS.

The Sybase CAMS data tables permanently store data sent to or received from CAMS and SBSS (unlike the shared tables, which are transitory). These tables are automatically updated periodically so that IMIS does not normally need to wait for an actual query to CAMS data to be completed.

Once a request for data has been placed in the control table, the Extract Queue Manager, a stand-alone process that is invoked at regular intervals, extracts data from Sybase, builds a fixed-format, variable-length record corresponding to the request type, and inserts that record into the transaction queue. The Transaction Control module reads the transaction queue, determines the screen number related to the current queue record, and retrieves the screen template and field format of the CAMS screen. The Communications Interface, which consists of a screen handler and a communications handler, then communicates with the Uniscope terminal port and CAMS. The screen handler allows the emulation of a Uniscope terminal on a Sun workstation. To send data to CAMS, the input screen buffer is first updated to reflect the correct field positions for a specific CAMS screen, then the communications handler sends the screen to CAMS. If the transaction sent to CAMS is a query, the output buffer that was processed will return data to be passed back to IMIS. The Update Queue Manager will then extract this data and insert it into the appropriate Sybase tables.

The CAMS interface transaction types which have been fully tested include: Send Flightline Open Work Order, Send Debrief Open Work Order, Get Open Work Orders from CAMS, Send Closed WCE to CAMS, Get Closed Work Orders from CAMS, Send Sortie Debrief, Get Fighter Squadron Sorties from CAMS, Get Certification Roster from CAMS, Get Part Inventory, and Send Part Order to SBSS. In addition, other transactions which were implemented but not fully tested during the IMIS demonstrations include: Send Opened WCE to CAMS, Send Updated WCE to CAMS, Send Cancel Back Order to SBSS, Get Back Ordered Parts Status from SBSS, Send Back Order Part Request to SBSS, and Get Scheduled Work Order from CAMS (Maintenance Schedule).

PMA-Unique Software

The IMIS software was designed so that the hardware platform on which a user was executing the application would have minimal impact on the available functionality. Some software, however, had to be developed specifically for the PMA, due to the unique capabilities required for that platform. In particular, it was critical to develop the ability for the PMA to interface with the A/C 1553 bus, allowing the user to initiate Built-In-Test (BIT) on the three demonstration subsystems and view the results.

Since SCO Unix does not incorporate a real-time pre-emptible kernel, user access to hardware devices (e.g., the 1553 module on the PMA) is restricted. To provide access to these hardware devices, it is necessary to create a device driver which is linked with and becomes part of the operating system executable kernel. The 1553 device driver consists of routines that initialize the device for use, prepare the device for shutdown, open the device for use, close the device (thereby prohibiting further access), perform device-specific control commands, and perform interrupt servicing whenever the device generates an interrupt.

SYSTEM INTEGRATION

To ensure that the IMIS demonstration system was capable of supporting the field test and demonstration activities, all aspects of the system, including hardware and software, were tested. The following subsections describe the testing conducted for the hardware, software, and system prior to installation at Luke AFB for the various field tests and demonstrations.

Hardware Testing

Prior to the Hardware CDR, hardware testing was conducted in accordance with the procedures defined in the Contractor Test Plan, CDRL 25. Limited environmental tests were performed on the 80386 PMA only; the MIW used COTS components, and the AIP design was similar to the PMA, allowing comparisons to the PMA testing results to be made. The testing performed is discussed in the following subsections.

PMA Weight and Dimension Test

This test was conducted to determine if the weight and size of the PMA met the specifications. The PMA was weighed on a calibrated scale with the strap removed and without the 1553B interface circuitry installed. The PMA was then measured with a caliper to determine its length, width, and height. The weight of the PMA, excluding the strap, handle, and 1553B interface circuitry, was 3.21 kilograms (7.06 pounds). The weight of the 1553B module is approximately 0.04 kilograms (0.1 pounds), for a total of 3.25 kilograms (7.16 pounds). The PMA dimensions, exclusive of the handle, RF antenna, disk drive cover, and 1553 port protective caps, were measured to be 31.1 x 25.4 x 5.7 centimeters (12.25 x 10.00 x 2.25 inches).

PMA Environmental Tests

A series of environmental tests were performed in accordance with MIL-STD-810, tailored as appropriate, to determine the PMA's ability to withstand various environmental conditions. These included temperature/humidity, altitude, vibration, shock, water resistance, and explosive atmosphere.

The temperature/humidity test was conducted to determine if the PMA would operate properly after being stored at its minimum (-20°C) and maximum (40°C) storage temperatures and also throughout its operating temperature range of 5°C to 40°C under conditions of varying relative humidity (from 25% to 80%). The PMA operated satisfactorily during exposure to the operational temperature/humidity limits and following exposure to the storage limits. At each test point, the PMA operational test routine was successfully completed.

The altitude test was conducted to determine if the PMA would operate properly after being exposed to its non-operating altitude limit of 4572 meters (15,000 feet) and at its operating altitude limit of 3048 meters (10,000 feet). The PMA operated satisfactorily following exposure to its non-operating altitude limit of 4572 meters and operated satisfactorily at an altitude of 3048 meters.

The vibration test was conducted to determine if the PMA would be damaged by vibration in any of its three axes between 5 Hertz (Hz) and 55 Hz. In the vertical and transverse axes, both the handle and RF antenna resonated from 46 Hz to 55 Hz. The peak-to-peak amplitude of vibration was 0.25 to 0.375 inches (0.635 to 0.95 centimeters). A resonance dwell was performed at 46 Hz in the transverse axis, and no increase in amplitude was noted during the 10-minute dwell. In the vertical axis, a slight resonance was found in the inverter at 52 Hz. An accelerometer was attached to the point of greatest displacement, and a resonance dwell was conducted at 52 Hz. The accelerometer measured a g-force of 2.2 g when the table g-force measured 1.9 g. This was not considered a significant increase and therefore not noted as a resonance. There was no degradation of either equipment or performance during these dwell tests. No resonances were observed for the longitudinal axis.

The shock test was conducted to measure the ability of the PMA to withstand shocks liable to occur during use or servicing. Using one edge as a pivot, the opposite edge was raised four inches above the horizontal bench top and dropped. The PMA met all bench-handling requirements. There was no physical damage noted concerning the case and the operating performance was consistent with normal operations.

The water-resistance test was conducted to determine the ability of the PMA to function properly after being subjected to a drip-proof test. The requirements for water flow were 16.3 liters per hour for each square foot (0.09 square meters) of area covered by the spray 0.9 meters below the nozzle. The initial water resistance test of the PMA failed because some moisture was found inside the case upon opening. The cause of this problem was loose connections at the connector panel. After tightening the hold-down hardware, the test was repeated. The PMA operational test was successfully completed, and no moisture was found inside the case upon opening.

The explosive atmosphere test was conducted at Wyle Laboratories test facility to evaluate the ability of the PMA to operate in a fuel-vapor-laden environment without igniting that environment. The PMA operated satisfactorily when subjected to an explosive atmosphere. No detonations occurred upon the activation of any button or switch.

PMA Interface Tests

A series of three tests was conducted to determine whether the PMA interfaces operated correctly. These included the Memory Module, the RF Module, and the battery.

The Memory Module test was conducted to demonstrate the ability to transfer and store data via the Memory Module. These abilities were verified by the test.

The RF Module test was conducted at Edwards AFB to demonstrate the capability to communicate between a hand held PMA and a fixed-site MIW by transmitting and receiving data via an RF link. The ability to transfer data via the RF link was verified. During this test, the ability to transmit and receive data at each required distance when in direct line-of-sight of the receiving antenna was demonstrated. The maximum range verified under line-of-sight conditions was 3500 feet (1067 meters). The maximum range verified with the line-of-sight interrupted by various obstructions was 2000 feet (610 meters).

The battery test was conducted to verify the PMA's ability operate from either a rechargeable battery or an external power source. The PMA operational test was successfully completed when operating with either the external power source or the battery pack. There was no degradation of performance noticed when using either of the power sources.

PMA Electromagnetic Radiation Test

This test was conducted to determine the level of radiation emanating from the PMA and also to determine how susceptible the PMA is to a radiated field. The PMA passed all testing requirements as determined by MIL-STD-461C, Part 2: Requirements for Equipment and Subsystems Installed Aboard Aircraft, Including Associated Ground Support Equipment (Class A1). The test methods performed were RE02 for radiated emissions and RS03 for radiated susceptibility. All measurements taken were well within defined limits, except when performing the susceptibility test at the transmitting and receiving frequencies of 900 to 910 MHz. At these fundamental frequencies, the PMA RF module would not function, even when subjected to energy levels of only 0.5 volts per meter. This was expected, due to the sensitivity of the RF Module in the PMA. The fundamental transmitting and receiving frequencies of the PMA should be exempt from meeting the RS03 requirement.

Software Testing

The software testing performed to support system integration has been broken down into the five main functional areas of the software: UI, Diagnostics, EDM, PMA Software, and Message Manager. Due to the dynamic nature of the software development process, the testing as described in the following subsections was repeated whenever conditions existed that could affect the performance of the software that had worked correctly at one time. This could be the result of a database change, in the case of the diagnostics testing, or as a result of a change to CAMS, in the case of the EDM testing.

User Interface Testing

The UI testing focused on the correct behavior of the software from the user perspective. Checklists were developed to document the expected software functionality and to record any deviations observed. These checklists covered each of the functions accessible from the IMIS main menu bar and were conducted in order to simulate realistic conditions when possible. Testing was conducted on both the MIW and PMA platforms and was repeated each time a new software release was created. Elapsed time measurements were also gathered when utilizing these checklists, to allow identification of functions where software enhancements were necessary.

Diagnostics Testing

Because of the dependencies of the diagnostics software and the authored TO data, the diagnostics testing included significant amounts of data testing. The problems found first had to be analyzed to determine whether they were caused by software or by data. To support this complicated process, two types of diagnostics testing were performed: path testing and numeric testing. The path testing served as a check of all the data used during the Fault Isolation Test to ensure that the correct recommendations for best action were made by the diagnostics algorithms, that the data was displayed in the proper sequence, and that the necessary ancillary information (such as required conditions, follow-on tasks, and block diagram) was updated to correctly reflect any new actions taken. The numeric testing examined the weights and probabilities authored in the TO data to ensure they were correctly processed through the diagnostics algorithms. Again, the focus was on the data that was exercised during the Fault Isolation Test. As new data deliveries were received, this testing was repeated.

External Data Management Testing

The EDM testing verified the interactions between the ONTOS database, the Sybase database, and CAMS. This integration testing was complicated for two reasons: the software was developed by two different organizations (GDE Systems and SCT), and, as frequent changes were made to the CAMS system, the EDM software had to be changed. The CAMS transactions were analyzed for applicability to each field test and prioritized accordingly. The entire process for each transaction was tested, beginning with the action at the UI level, storing the data in the Sybase database, transmitting the data to CAMS, and verifying that the data was correctly stored in CAMS. Responses received from CAMS and SBSS were also verified. This testing was repeated for each new CAMS release that was installed.

PMA Software Testing

The PMA software testing verified the capability of all PMA-unique software modules, as described in the subsection entitled, "PMA-unique software." The primary PMA software testing was in the area of the 1553 interface. Testing to ensure that the software would initiate BIT on the applicable 1553 MUX buses and retrieve the results had to be conducted on the A/C. The testing was conducted at both Edwards AFB and at Luke AFB.

Message Manager Testing

The Message Manager testing verified the capability to disseminate information between system users and to ensure that all databases remained consistent. This testing began on the MIW to test the basic message-handling functions. As the RF drivers for both the PMA and the MIW became available, this testing migrated to a multi-platform environment. MIW-to-PMA and PMA-to-MIW communications using the RF link were thoroughly tested to ensure that data and messages were correctly and reliably transmitted throughout the system. The final phase in the Message Manager testing was the testing of multiple PMAs and MIWs to support the various field tests and demonstrations.

System Testing

Prior to the CDR, system testing was informally controlled. Systems Engineering, Human Factors, and the Maintenance Subject Matter Expert were involved in the testing to ensure early compliance with requirements and to ensure UI issues were addressed and incorporated during the implementation stages. This policy was designed to ensure the accuracy of the IMIS representation of the maintenance environment, as well as to ensure the system's user friendliness. This not only provided the ability to recommend system changes early but also increased the likelihood of user acceptance.

After CDR, system testing was organized around the software builds and was more formally controlled. All discrepancies were documented on Discrepancy Reports (DRs) and reviewed by the Discrepancy Review Board, which was composed of representatives from

Systems and Software Engineering, Human Factors, and Maintenance. The Chief Engineer chaired the board. The board reviewed all discrepancies and assigned each DR a priority within a particular build. Assignments were made to the corresponding focus area for resolution. Once the DRs were fixed, they were verified by Systems Engineering and submitted to the Chief Engineer for closure. Matrices were generated on a weekly basis to keep track of all DRs and to monitor status.

System testing focused initially on the engineering environment. As the field tests and demonstrations approached, the need to conduct realistic testing in the demonstration environment was recognized. As a result, significant testing was performed at Luke AFB prior to each test or demonstration to ensure the correct functioning of the system. Detailed procedures, based on the requirements for the test, were developed and exercised to verify that all components of the system interacted correctly. After sufficient testing of the hardware, software, and data had taken place and the necessary dry runs of the demonstration activities had been successfully completed, the field test was begun.

FIELD TEST AND DEMONSTRATION OVERVIEW

The IMIS Field Test and Demonstration was separated into three segments: Debrief Test, End-to-End Demonstration, and Fault Isolation Test. The primary objectives of these activities were: to test the IMIS concept under realistic operational conditions where possible, to evaluate the effectiveness of IMIS in supporting the maintenance mission of the unit, to demonstrate the technical and cost advantages of IMIS over the current system, and to identify strengths and weaknesses of the demonstration system which could be used in defining requirements for a production implementation. The following sections describe the objectives and methodology of each of these tests.

Debrief Test

The Debrief Test was the first of the three field tests and evaluations of the IMIS demonstration system conducted at Luke AFB, AZ. Real debriefs were observed during a six-week period in November and December 1993 to compare the current method of debriefing to that using IMIS.

Objectives

The primary objective of the Debrief Test was to evaluate the IMIS debrief capability under realistic conditions by observing actual maintenance debriefs of pilots and by collecting data to compare the results of debriefs performed using IMIS with those performed using the current method. Specifically, the following hypotheses were tested using the data collected during the Debrief Test.

a. Significantly more discrepancies are identified when the debrief is conducted using IMIS than when the debrief is performed using the current system.

b. Significantly less time is required when the debrief is performed using IMIS than when it is performed using the current system.

c. Debriefs performed using IMIS describe discrepancies in greater detail than debriefs performed using the current method (e.g., using IMIS, Maintenance Fault Lists (MFLs) and the resulting fault codes are more specific and further narrow the scope of the diagnostics required).

d. Maintenance debriefers will prefer the IMIS debrief method to the current debrief method.

Methodology

The Debrief Test was accomplished by observing and timing a relatively large number of actual debrief sessions, half using IMIS and half using the current method. The maintenance debrief process is performed by a technician at a CAMS terminal, with one or more F-16 pilots seated across a low counter from the technician. The pilots hand their data transfer cartridge (DTC) to the maintenance debriefer and provide their flight data, subsystem usage, capability codes, and discrepancy information as well, partly spontaneously and partly in response to the debriefers questions. During this process, the debriefer places each DTC in the DTC reader, downloads the MFL file, and returns the DTC to the pilot. The debriefer may interact with one or more of the pilots, may input information directly into CAMS, or may write it down for later entry. The debriefer will endeavor to delay each pilot's departure from the debriefing area as little as possible. Once the pilots have left the debriefing station, the debriefer enters into the CAMS terminal any flight and discrepancy data written by hand, opening work orders, as appropriate.

The IMIS debrief sessions were performed using an IMIS MIW located in the maintenance debriefing section. After reading and returning the DTC to the pilot, the maintenance debriefer asked the pilot questions about the flight and any A/C discrepancies. The IMIS debrief included an automated implementation of the F-16 FRM, a list of other standard narratives of discrepancies in each subsystem and a set of weapon system peculiar questions (enhanced question set). Use of the FRM and enhanced question set enabled IMIS to translate the reported discrepancy directly into a fault code. The fault code will lead the technician to the correct path in diagnosing the problem. After opening all work orders, the maintenance debriefer reviewed and printed the Sortie Recap. IMIS then queued the sortie and work order data for transmittal to CAMS, which was done in the background without inconvenience to or involvement of the IMIS debriefer, regardless of whether CAMS was operational at that moment.

The Debrief Test was conducted by observing and recording data (including start and stop times, problems encountered, and any other observations or remarks) during each pilot debrief session. Information collected about each discrepancy included the WUC, whether the pilot provided any amplifying data about the discrepancy, and the Job Control Number of the work order opened to correct the discrepancy.

After completion of the debrief session, a data collector tracked all reported discrepancies through the maintenance system to determine what maintenance actions, if any, were taken to correct each one and which turned out to be CNDs or RTOKs. At the end of the Debrief Test, the maintenance debriefers were asked to complete two questionnaires soliciting their evaluation of the system and recommendations for changes or improvements.

End-to-End Demonstration

The End-to-End Demonstration was a field demonstration of the primary functions of IMIS. The overall scenario used for the End-to-End Demonstration is depicted in Figure 11. This demonstration was conducted at Luke AFB, AZ, from 1 June through 30 June 1994. The purpose was to illustrate to users the overall IMIS concept by using the system to support a series of typical scenarios of maintenance activities in an operational environment, under structured conditions. It demonstrated system functional capabilities in all primary IMIS functional areas: debrief, diagnostics, electronic TOs, work order generation and close-out, and flightline management support.

Objectives

The principal objectives of the End-to-End Demonstration were as follows.

a. To test the overall IMIS concept by exercising IMIS capabilities in all primary (e.g., debrief, diagnostics, etc.) functional areas by demonstrating a limited set of functions within each area.

b. To obtain user feedback in each primary functional area. This feedback could provide information for use in identifying candidate changes/improvements for a fully implemented IMIS.

c. To provide an opportunity for the IMIS team members to observe the system in operation under conditions approaching those in the real world of A/C maintenance, to aid them in identifying changes/improvements needed in a fully implemented IMIS.

Methodology

Scenarios demonstrating the maintenance functionality were developed for the production superintendent, airplane general (APG) expediter, specialist expediter, debriefer, and maintenance technician. These scenarios required each participant to perform a series of tasks using IMIS. The actions were designed to cause the participant to exercise those functions available in IMIS to do their assigned tasks. For example, the specialist expediter received a work order through IMIS and was required to assign a technician to the job. Similarly, the production superintendent received a request for authorization to order a part, and was required

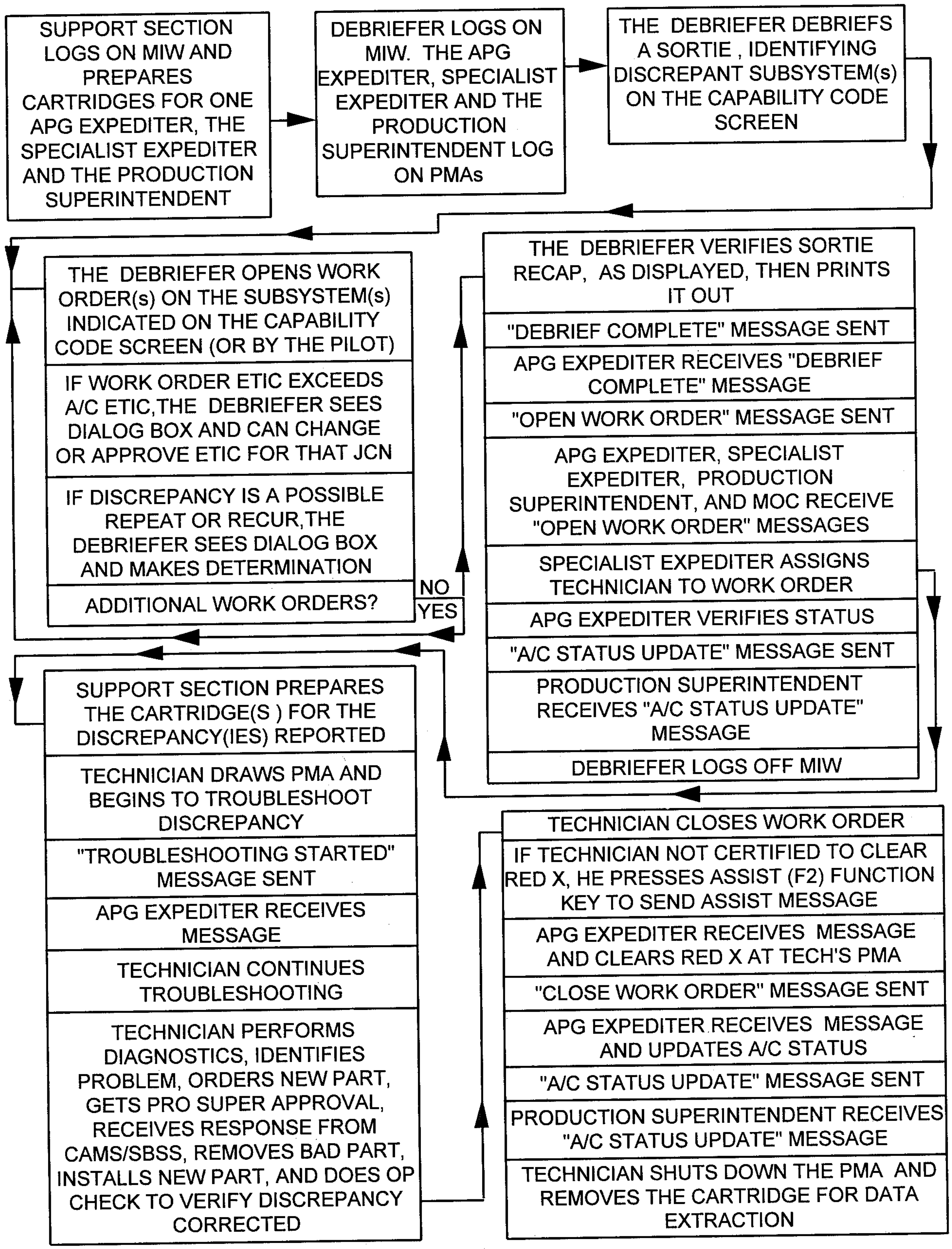


Figure 11. End-to-End Demonstration Functional Flow

to respond to that request. The scenarios were designed to overlap so that an action by one participant might require another participant to take action. For example, the maintenance debriefer created the work order to which the specialist expediter responded.

Four personnel, when available, were tested in each session: an APG expediter, a specialist expediter, a production superintendent, and a maintenance debriefer. They were first given an introduction to IMIS and their role in the demonstration was explained; the group was then split up. Next, each subject was assigned a trainer who taught him or her the basics of using IMIS and how IMIS supports his or her particular job.

After being trained, each subject followed the scenario designed to exercise the IMIS functions relevant to his or her job. The exercises required the subjects to deal with the messages previously loaded on the PMA cartridge. They were also told to expect new messages via RF while they were going through the scenario. After the scenario was completed, the subjects were allowed to experiment on their own and to try other features of IMIS, with the assistance of the trainer.

When the subjects finished the scenario, they then completed two questionnaires (to elicit their reaction to various IMIS features and characteristics) and a workload assessment instrument (the National Aeronautics and Space Administration (NASA) Task Load Index (TLX)). The first questionnaire was a lengthy set of subjective questions about IMIS in general, which were presented by the computer; answers, on a sliding scale, were easily marked with a mouse or pointing device by the participant. The NASA TLX is a method of collecting information on individual maintenance segments (such as troubleshooting, debriefing, scheduling, and so forth) of the IMIS demonstration. After each segment, the user was presented with a set of questions to determine the amount of workload he or she experienced with that segment. The results were automatically tabulated at the end of each set to determine which segments cause the most workload stress.

Finally, the suitability of the PMA for supporting maintenance management activities on the flightline was evaluated by installing the PMA in an expediter vehicle and in the golf cart used by the production superintendent. A limited evaluation of the suitability of the PMA in the expediter truck was conducted by observing the ease and convenience of its use. The effectiveness of the PMA RF communications was evaluated by installing it in a vehicle and transmitting work order opening and closing actions from various distances. In addition, it was tested by installing it in an expediter vehicle and transmitting messages from the flightline as the expediter was performing his duties.

Fault Isolation Test

The Fault Isolation Test was conducted at Luke AFB, AZ during July and August 1994 using maintenance people from the 310 FS. The Fault Isolation Test evaluated the ability of the demonstration system to support on-aircraft fault isolation and repair tasks. The Fault Isolation Test is fully documented in separate Armstrong Laboratory reports (AL/HR-TR-1995-0033 and AL/HR-TR-1995-0034).

Objectives

The objectives of the Field Test were as follows:

a. To demonstrate that use of the IMIS can significantly improve troubleshooting performance of technicians by reducing the time required to return an aircraft to service, spare parts consumption, the number of serious errors made by maintenance technicians, the time to order parts, and the time to complete work order close-out and documentation procedures.

b. To demonstrate that APG technicians using IMIS are able to perform troubleshooting tasks on F-16 avionics subsystems at least as effectively as specialists using paper TOs and to collect data for use in evaluating the cost benefits of the IMIS.

c. Compare the performance of specialists and non-specialist technicians (APG technicians) using IMIS with their performance using paper TOs. To ensure an accurate comparison, it was essential that the technicians' performance be measured under comparable conditions. Thus, it was necessary to measure the performance of technicians engaged in very similar tasks under very similar conditions--preferably doing the same tasks under identical conditions. To ensure the required similarity of tasks and data collection conditions, an experimental approach was adopted.

Methodology

An experiment was conducted in which avionics specialists and APG technicians each performed 12 troubleshooting tasks: six using IMIS and six using paper TOs. Twelve avionics specialists and 12 non-specialists (airplane general [APG] technicians) performed 12 fault isolation problems on three F-16 subsystems: fire control radar (FCR), head-up display (HUD), and inertial navigation system (INS). Half the problems were performed using the current paper-based technical orders TOs and part-ordering and documentation procedures. The APG technicians were included in the study to determine if the use of IMIS would enable non-specialist technicians, with little or no training on a specific aircraft subsystem, to isolate and repair faults in that system at least as effectively as specialists, with specific experience and training on the system, using paper TOs.

The technicians were closely observed as they completed each task. A data collector timed the technicians performance and recorded data on problem completion/failure, errors made, and helps given.[1] To successfully complete a problem, the technician was required to verify that the

[1] Helps were given in selected situations, when requested by the technician. Helps for specialists primarily were limited to questions on the use of IMIS. A more liberal policy was followed with the APG technicians because they were unfamiliar with the test-bed systems. APG technicians often required help in locating components and using the TOs. Frequently, the helps were little more than a hint (e.g., remember what you were taught in training).

reported malfunction existed in the aircraft, identify the faulty component, identify the required repair, order any required part, identify the checks required to verify that the repair returned the system to a fully operational condition, and complete work order close-out documentation.

Actual repairs were not made, to reduce the risk of damaging the aircraft. Standard times were used to account for the times required to remove and replace parts and for the final system health. Also, standard times were used to account for the time to submit part orders and enter close-out data into CAMS under the paper TO condition. The use of standard times was necessary because there was no way to complete these tasks under the paper TO condition without interfering with squadron operations.

After completing the assigned problems using IMIS, the technicians completed an automated questionnaire designed to evaluate various features or qualities of IMIS (e.g., readability of the display). After they had completed all their tests, they completed an open-ended questionnaire which asked them what they liked about IMIS, what they did not like, and how IMIS could be improved.

ACRONYMS

A/C	Aircraft
ACC	Air Combat Command
AFB	Air Force Base
AFR	Air Force Regulation
AFSC	Air Force Specialty Code
AIMS	Advanced Tactical Fighter Integrated Maintenance System
AIP	Aircraft Interface Panel
AL/HRG	Armstrong Laboratory Logistics Research Division
APG	Airplane General
API	Application Programming Interface
ASA	Applied Science Associates, Inc.
ATF	Advanced Tactical Fighter
BCS	Baseline Comparison System
BIT	Built-In-Test
CA	Control Architecture
CALS	Computer-Aided Acquisition and Logistics System
CAMS	Core Automated Maintenance System
CASE	Computer-Aided Software Engineering
CCA	Circuit Card Assembly
CD ROM	Compact Disk Read-Only Memory
CDM	Content Data Model
CDR	Critical Design Review
CDRL	Contract Data Requirements List
CLSA	Computer Logics Synchronous Adaptor
CND	Can Not Duplicate
COTS	Commercial Off-The-Shelf
CPU	Central Processing Unit
CRT	Cathode Ray Tube
CSA	Computer Systems Architecture
CSCI	Computer Software Configuration Item
DC	Direct Current
DCM	Deputy Commander for Maintenance
DEMO	Demonstration
DEPR RET	Depress Reticle
DM	Diagnostics Module
DR	Discrepancy Report
DTC	Data Transfer Cartridge
DVAL	Data Link Vulnerability Assessment
EDM	External Data Management
EL	Electroluminescent
EMC	Electromagnetic Compatibility
ETIC	Estimated Time In Commission

EU	Electronic Unit
FCC	Fire Control Computer
FCR	Fire Control Radar
FI	Fault Isolation
FRG	Federal Republic of Germany
FRM	Fault Reporting Manual
GAC	General Avionics Computer
GB	Gigabyte
HCO	High Concurrency Object
HEMP	High-Altitude Electromagnetic Pulse
HESAR	Human Engineering System Analysis Report
HSI	Horizontal Situation Indicator
HUD	Head-Up Display
Hz	Hertz
I-Level	Intermediate Level
I/F	Interface
IA	Information Architecture
ICAM	Integrated Computer-Aided Manufacturing
ID	Identification
IDD	Interface Design Document
IDE	Intelligent Drive Electronics
IDEF	ICAM Definition System
IMIS	Integrated Maintenance Information System
IMIS-DM	IMIS Diagnostic Module
IMISA	IMIS Architecture
INS	Inertial Navigation Set
IPB	Illustrated Parts Breakdown
IRS	Interface Requirements Specification
JCN	Job Control Number
LAN	Local Area Network
LCD	Liquid Crystal Display
LED	Light Emitting Diode
LFWC	Lockheed Fort Worth Company
LRU	Line Replaceable Unit
LSA	Logistics Support Analysis
MASA	Modular Avionics Systems Architecture
MB	Megabyte
MDB	Maintenance Data Base
MDC	Maintenance Data Collection
MESL	Minimum Essential Subsystem List
MFL	Maintenance Fault List
MHz	Megahertz
MIDAS	Maintenance Integrated Data Access System
MIL-STD	Military Standard
MIW	Maintenance Information Workstation

MML	Memory Module Loader
MOC	Maintenance Operations Center
MRP	Maintenance Review Panel
MTBF	Mean Time Between Failures
NASA	National Aeronautics and Space Administration
NCI	NCI Information Systems, Inc.
NCVA	Network Communications Vulnerability Assessment
NiCad	Nickel-Cadmium
O-Level	Organizational Level
OCD	Operational Concept Document
OI	Object Interface
PIDS	Prime Item Development Specification
PIPFS	Prime Item Product Fabrication Specification
PMA	Portable Maintenance Aid
QRL	Quick Reference List
R&D	Research and Development
RAM	Random Access Memory
RF	Radio Frequency
RS	Radio Standard
RTOK	Retest OK
SBLC	Standard Base Level Computer
SBSS	Standard Base Supply System
SCO	Santa Cruz Operation
SCSI	Small Computer System Interface
SCT	Systems Control Technology, Inc.
SDD	Software Design Document
SEA	Systems Engineering Analysis
SPO	System Program Office
SQL	Structured Query Language
SRS	Software Requirements Specification
SSC	Standard Systems Center
SSS	System/Segment Specification
TAC	Tactical Air Command
TLX	Task Load Index
TO	Technical Order
TO Present	TO Presentation
UI	User Interface
UIB	User Interface Builder
USAFE	United States Air Forces - Europe
VGA	Video Graphics Array
WCE	Work Center Event
WUC	Work Unit Code

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