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INTEGRATED MAINTENANCE INFORMATION SYSTEM (IMIS) FINAL PROGRAM REPORT VOLUME 1: EXECUTIVE SUMMARY

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The Executive Summary is the first volume in a three-volume final program report. It contains a summary of the objectives, methodology, results, conclusions, and recommendations of the Integrated Maintenance Information System (IMIS) program. The overall scope of the IMIS program was to (1) identify and define the requirements for IMIS; (2) develop specifications documenting the requirements; (3) design and develop a demonstration system capable of supporting the essential IMIS requirements; (4) evaluate the IMIS concept and requirements using the demonstration system; and (5) finalize the IMIS specifications by incorporating the results of the tests, demonstrations, and evaluations. The program was structured to satisfy the scope by applying information gained during each phase to the subsequent phases. The IMIS Field Test and Demonstration was separated into three parts: Debrief Test, End-to-End Demonstration, and Fault Isolation Test. The primary objectives of these activities were to (1) test the IMIS concept under realistic operational conditions, where possible, (2) evaluate the effectiveness of IMIS in supporting the maintenance mission of the unit, (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 defining requirements for a production implementation.

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PREFACE

The Executive Summary is the first volume in a three-volume Final Program Report. It contains a summary of the objectives, methodology, results, conclusions, and recommendations of the Integrated Maintenance Information System (IMIS) program. The overall scope of the IMIS program was to (1) identify and define the requirements for IMIS; (2) develop specifications documenting the requirements; (3) design and develop a demonstration system capable of supporting the essential IMIS requirements; (4) evaluate the IMIS concept and requirements using the demonstration system; and (5) finalize the IMIS specifications by incorporating the results of the tests, demonstrations, and evaluations. The program was structured to satisfy the scope by applying information gained during each phase to the subsequent phases.

The IMIS Field Test and Demonstration was separated into three parts: Debrief Test, End-to-End Demonstration, and Fault Isolation Test. The primary objectives of these activities were to (1) test the IMIS concept under realistic operational conditions, where possible, (2) evaluate the effectiveness of IMIS in supporting the maintenance mission of the unit, (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 defining requirements for a production implementation.

INTEGRATED MAINTENANCE INFORMATION SYSTEM (IMIS) EXECUTIVE SUMMARY

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 even 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 and 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.

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 and testing the prototype systems under realistic field conditions to ensure the systems satisfactorily met the needs of the users.

AL/HRG's R&D 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. Furthermore, effective user interface 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 indicated the need for a more comprehensive system, in which the maintenance information available to all Air Force maintenance personnel not just the technician, could be improved. The lessons learned from these efforts played a major role in developing the Operational Concept Document (OCD) which formed the basis of the IMIS program.

The overall scope of the IMIS program involved several different thrusts: to identify and define the requirements for 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 to allow maximum application of information gained during each phase to the subsequent phases.

This Executive Summary, the first-volume in a three-volume Final Program Report, contains a high-level summary of the objectives, methodology, results, conclusions, and recommendations of this program (contract #F33615-88-C-0024).

OBJECTIVES

The primary objective of IMIS is to improve the performance of aircraft 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, as identified in the OCD, are listed below.

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 an 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-aircraft 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 improve 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.

APPROACH

This 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 the products of those activities in the three phases. The following subsections 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; develop a system architecture which supported those requirements; and develop system functional requirements specifications. A critical task in support of the requirements analysis was interviewing maintenance personnel at several Air Force bases. The primary products of Phase I were the IMIS Architecture (IMISA), developed using a structured analysis methodology, and the System/Segment Specification (SSS), which documented the IMIS system requirements. This information was reviewed at the System Requirements Review, conducted at the end of Phase I.

Phase II: System Design and Development

After the desired IMIS capabilities of a full implementation were defined, program activities shifted to developing 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.

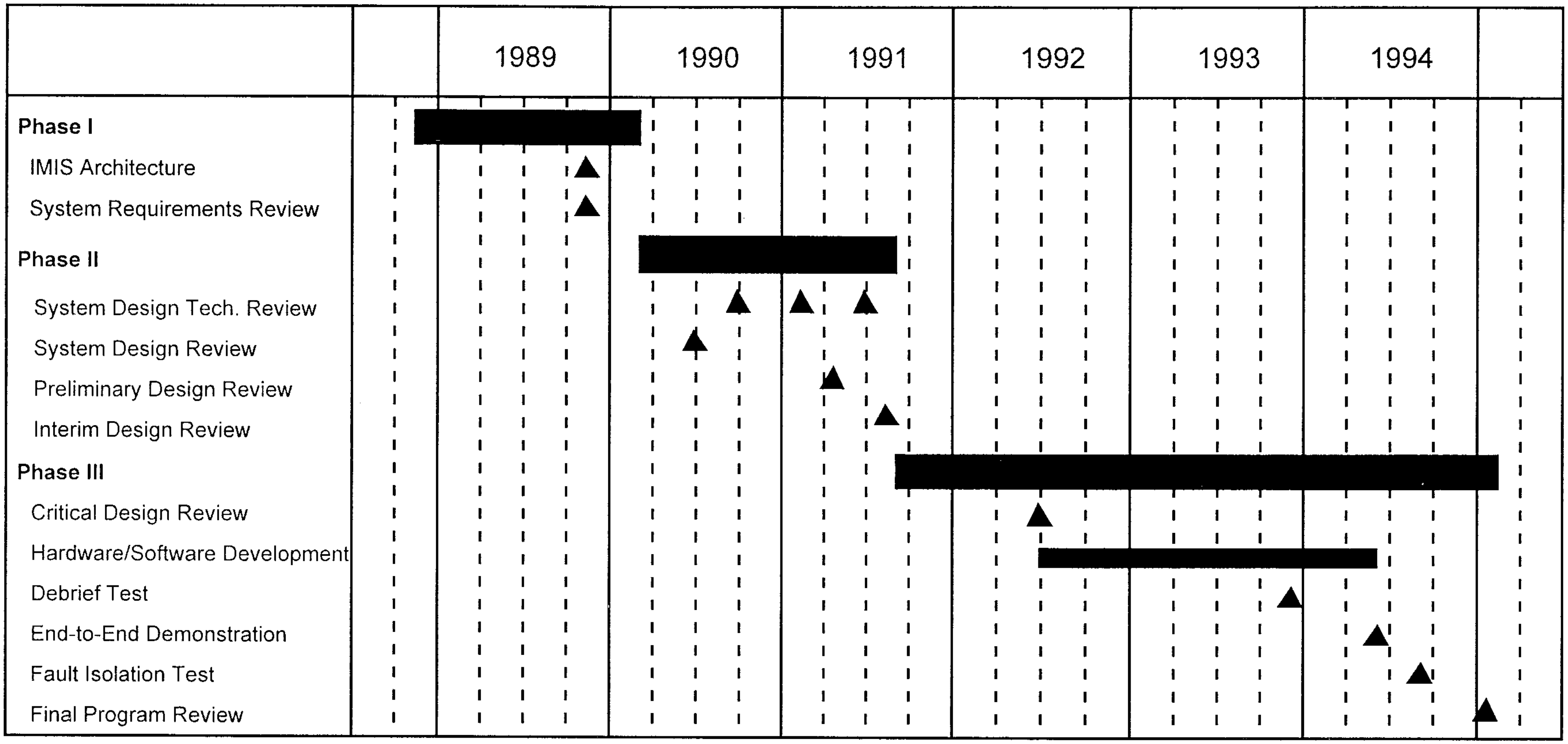

Figure 1.
IMIS Program Schedule

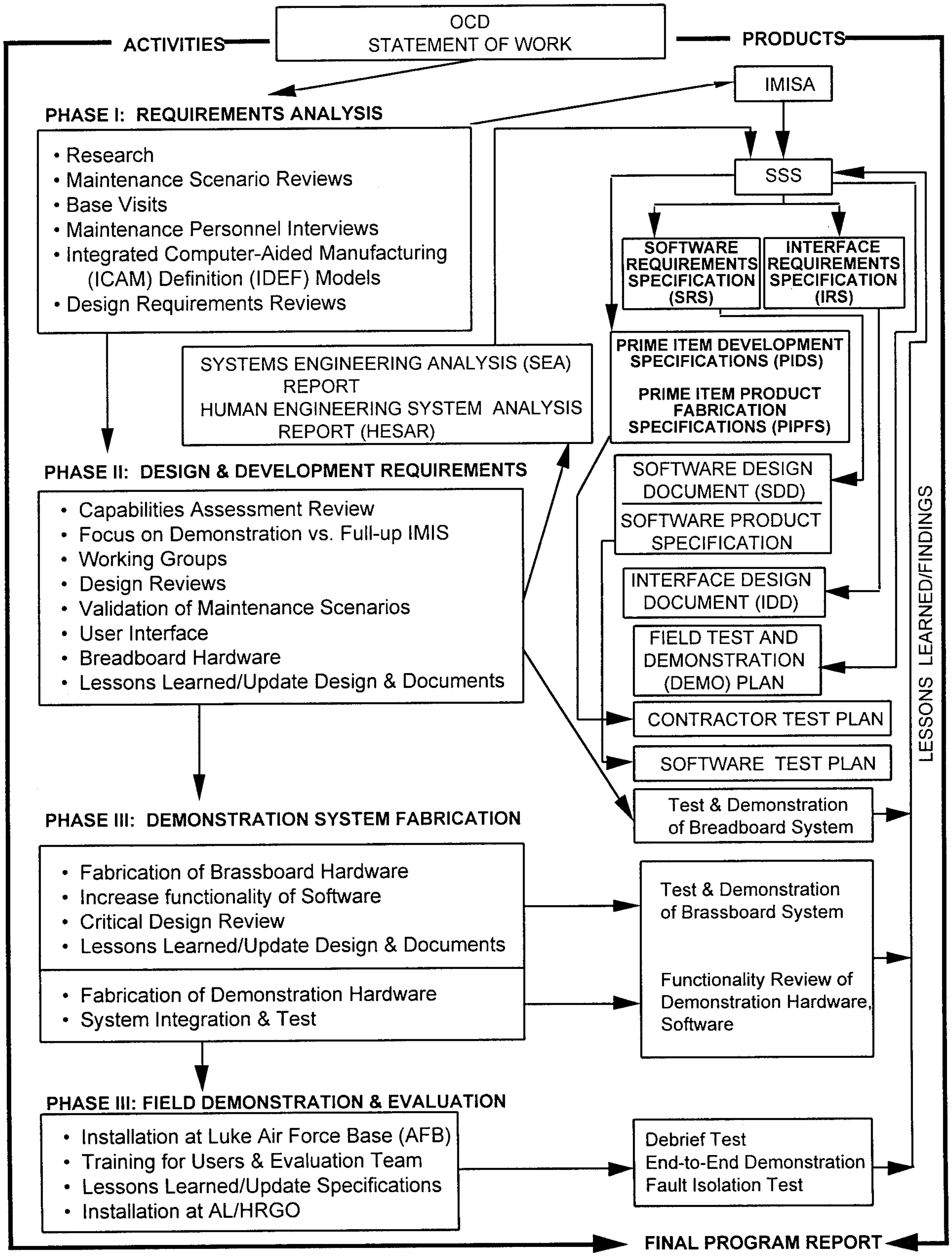

Figure 2. IMIS Phases I - III Key Activities and Products

Phase III: Demonstration System Fabrication and Field Evaluation

The main objective early in Phase III was to fabricate and test a brassboard system for demonstration at the Critical Design Review. Based on lessons learned from the breadboard and brassboard demonstrations, the final software and hardware designs for the demonstration system were approved (PIDS, PIPFS, IDD and SDD). The demonstration hardware and software were developed in accordance with these approved designs. Extensive system integration and testing was conducted in preparation for the field tests. 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 at Luke Air Force Base (AFB): the Debrief Test, the End-to-End Demonstration, and the Fault Isolation Test. Results of these tests and of this program were discussed at the Final Program Review and are documented in this Final Program Report.

Methodology and Results.

Volume 2, Program Methodology, (AL/HR-TR-1995-0041) documents the methodology used during the three program phases, including the requirements analysis, hardware design, software design, and field tests and demonstrations. A summary of the results observed during the field tests and demonstrations is also provided.

Requirements Analysis

The requirement analysis 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 IMIS had been developed, the process of selecting specific requirements to be implemented in the demonstration system was initiated.

The maintenance process analysis began with base visits, in which a large number of maintenance personnel performing a wide range of duties and functions within the maintenance environment were interviewed. Over 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 AB, FRG
Spangdahlem AB, FRG
Sembach AB, FRG
Leipheim AB, FRG
Ramstein AB, FRG
Moody AFB, GA
Shaw AFB, SC

In addition, interviews were conducted at Gunter AFB; the Standard Systems Center (SSC) at Gunter was responsible for the development and maintenance of the Core Automated Maintenance System (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 aircraft maintenance personnel were voluntary and anonymous, were conducted in accordance with paragraph 30 of Air Force Regulation (AFR) 12-35, and complied with the Privacy Act of 1974. To 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 aircraft status, allocate resources, troubleshoot aircraft, order parts, repair aircraft, and perform standard service.

The questionnaires used in these interviews were designed to extract data from the 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, what the results of the tasks are, what data is needed to perform the task, and how that data is accessed or provided.

The information collected during the data gathering interviews was then analyzed, and a model of the maintenance process was generated. The top-level model comprised maintenance that is performed at the organizational, intermediate, and depot levels. The primary emphasis was on the organizational level, which focuses on performing maintenance on the flight line. However, there were interfaces between the organizational and intermediate levels critical to the maintenance process that needed to be identified. Also included were base-level management functions performed by personnel on the staff of the Deputy Commander for Maintenance (DCM). As a result, this model included decompositions of the organizational-level, intermediate-level, and staff functions.

Extensive verification and validation of this model were then performed. This included 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.

The methodology used to model the existing maintenance environment was 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. Models of the "AS-IS" and the "TO-BE" environments were developed for the Control

Architecture (CA), which defines the maintenance functions; the Information Architecture (IA), which defines the information relationships; and the Computer Systems Architecture (CSA), which defines the information handling requirements of the maintenance process.

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").

The IMISA was then used as a primary source in developing the SSS, CDRL 14, which establishes the system definition, performance, design, development, and test requirements for a full implementation of IMIS. Additional sources include 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 this contract 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.

To develop a demonstration system meeting all these requirements would have exceeded the schedule and financial constraints for the program. Consequently, an approach for identifying specific functions and requirements to be implemented and demonstrated was developed. During a series of reviews, these requirements were prioritized and categorized for consideration during the demonstrations. This final list of requirements was used as the basis for the hardware and software design.

The Maintenance Information Workstation (MIW) segment provides an interface to the external data systems and to the Portable Maintenance Aid (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 radio frequency [RF] link). The MIW also serves as a user station for personnel who do not perform their main tasks on the flight line (e.g., maintenance debriefers and Maintenance Operations Center [MOC] personnel).

Hardware Design

Based on the requirements analysis, the IMIS configuration was found to consist of three system segments: the MIW, the PMA, and the Aircraft Interface Panel (AIP). Figure 3 depicts the configuration of the IMIS demonstration system, as installed at Luke AFB. An additional MIW was added to the network to support integration and demonstration activities.

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 aircraft 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.

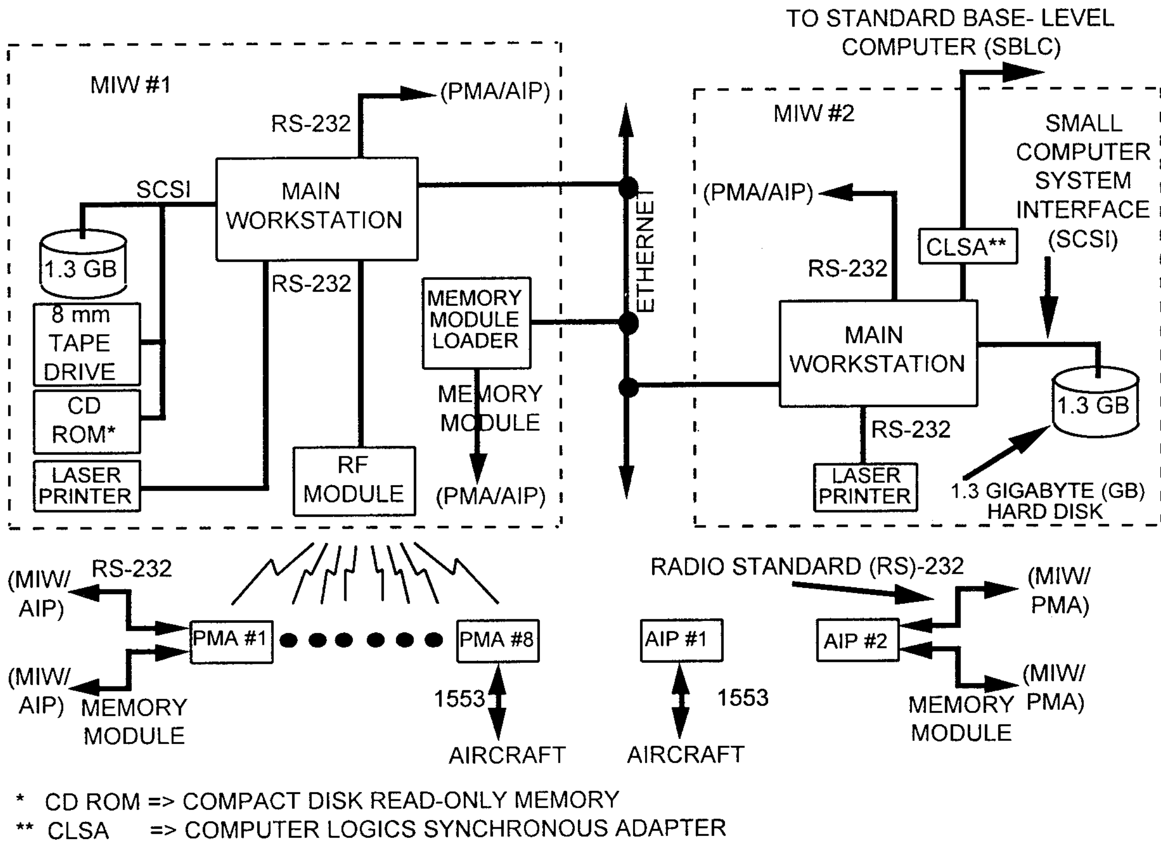

Figure 3
IMIS Configuration

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

The requirements analysis which examined the functional capabilities for each segment also took into consideration the way in which the IMIS segments must interface with one another. Each segment provides multiple methods for interfacing with the others to ensure that critical data can be distributed throughout the system. Figure 4 provides an overview of the interfaces between the three IMIS hardware segments (e.g., Radio Standard [RS]-232), as well as the external interfaces with the F-16 aircraft (via the 1553 bus) and the legacy databases (via the Standard Base-Level Computer [SBLC]).

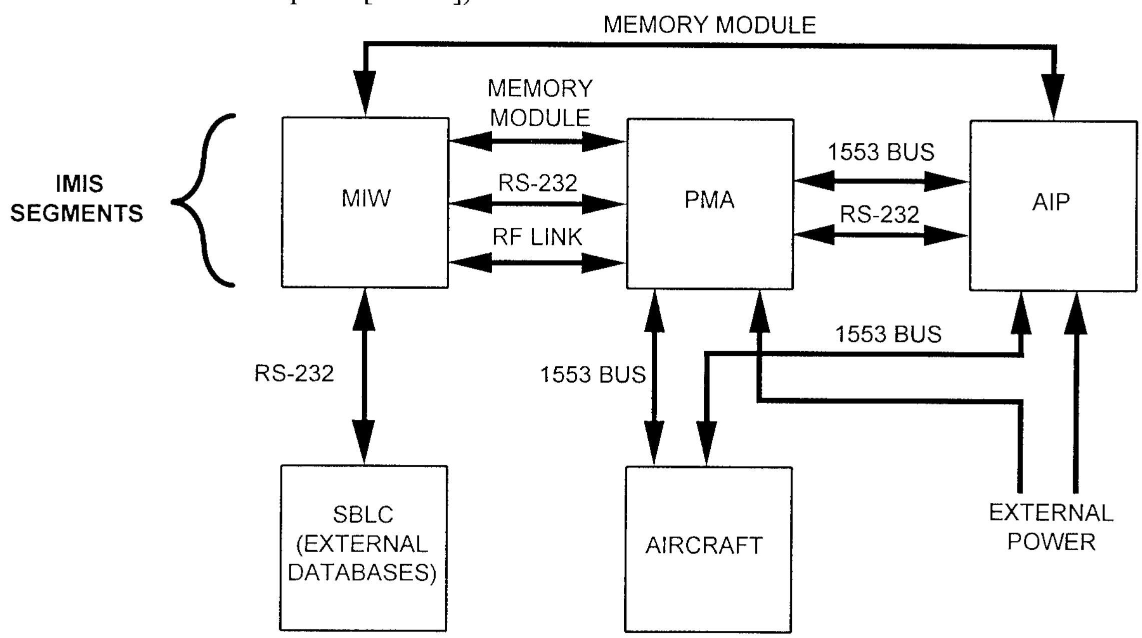

Figure 4
IMIS Segment Interfaces

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. The hardware for the demonstration system was selected by first performing a trade study to identify the commercial equipment that could support the functional requirements and contractual requirements within 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.

The workstation selected for the MIW as a result of this trade study 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 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 local area network (LAN) is 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 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 Adapter (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 flight line. 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 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 16 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 provided significant improvements to the PMA's performance.

The display is a 640 x 480 VGA, transflective liquid crystal 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.

The PMA uses a non-volatile memory module, which is programmed by an 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 the technology matured, this mass storage capacity grew to 340 MB, fitting within the same form factor.

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 with each channel individually addressed. 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 user interface to the PMA. These switches provide tactile feedback and are resistant to jet fuel and most other solvents.

The battery module is a rechargeable Nickel-Cadmium (NiCad) battery pack. This unit provides a nominal 7.2 volts 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 aircraft information to the PMA. The MIL-STD-1553 aircraft internal time division command/response multiplex data 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 aircraft. The goal of the demonstration AIP design was to represent, as closely as possible, an actual AIP that would be embedded in an aircraft.

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, it was decided that the AIP would use the internal components of the PMA to the extent possible. In fact, with the exception of the RF modem (required on the PMA but not on the AIP), the internal electronics of the two devices are identical.

Since the AIP was a functional mockup of a device which would eventually be installed on an aircraft, 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 easy removal and replacement.

Software Design

The IMIS software has been designed to support the complex maintenance tasks that are performed by the O-Level maintenance 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, maintenance analysis, 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 Computer Software Configuration Item (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.

An object-oriented development approach was used for IMIS to take maximum advantage of the benefits, including 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 the full system development.

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.

Two constraints were considered in selecting C++ and C as the programming languages for the IMIS software development environment. 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 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 external data management functions, written in C, which invoke the Sybase API.

IMIS is a multi-user application that operates on the MIW, PMA, and AIP. The IMISA provides the user with functionality, data, and a user interface that are consistent across these different platforms. The IMISA 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. The system is configured so that an IMIS process executes on each platform in the system. This provides a consistent interface to the user.

The IMIS User Interface (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 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.

User interface 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, FS Aircraft Status, Work Order History, Close Work Order, Display Flying Schedule, Display Maintenance Schedule, Order Parts (via both the Quick Reference List and the Illustrated Parts Breakdown), Prepare and Extract PMA Cartridge, and Send and Display Messages.

The IMIS Diagnostics Module (IMIS-DM) assists the maintenance technician by making maintenance action recommendations for diagnosing and repairing a faulty aircraft in minimum time. In making its recommendations, IMIS-DM considers accrued test results and system knowledge, with decisions guided by a predefined model of aircraft symptoms, faults, test, and repairs, created in accordance with a customized version of the Air Force Content Data Model (CDM), version 6.0x. This data is stored in and accessed through the IMIS object database.

The Technical Order Presentation (TO Present) system (developed by the Lockheed Fort Worth Compnay [LFWC]) 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.

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.

The External Data Management (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.

The IMIS software was designed so that the type of hardware platform 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 aircraft 1553 bus, allowing the user to initiate built-in test (BIT) on the three aircraft subsystems selected for the demonstration (Fire Control Radar [FCR], Head-Up Display [HUD], and Inertial Navigation Set [INS]) and view the results.

Field Tests and Demonstrations

Following the system integration and test of the hardware and software described in the previous sections, the IMIS demonstration system was installed at Luke AFB, AZ, to begin the field evaluation phase. 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 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 test of the IMIS demonstration system conducted at Luke AFB, AZ. It was a six-week evaluation period during November and December 1993.

The primary objective of the Debrief Test was to evaluate the IMIS debrief capability under realistic conditions. The Debrief Test was accomplished by observing and timing a relatively large number of real (not simulated) debrief sessions. One half of the debriefs used IMIS and the other half using the current method. The debriefs were performed by maintenance personnel using actual sorties and pilots. The data collected was compared to debriefs performed using IMIS with those performed using the current method. The data collected during each pilot debrief session included start and stop times, problems encountered, and observations. Data collected about each discrepancy included the Job Control Number (JCN), Work Unit Code (WUC),and if the pilot reported additional data about the discrepancy.

After completion of the debrief session, a maintenance data collector tracked all reported discrepancies through the maintenance system to determine what maintenance actions, if any, were taken to correct each discrepancy and which discrepancies 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 demonstration of the primary functions of IMIS. This demonstration was conducted at Luke AFB, AZ, from June 1-through June 30, 1994.

The End-to-End Demonstration was to illustrate to the users the overall IMIS concept by using the system to support a series of typical scenarios of maintenance activities, under structured conditions, in an operational environment. The End-to-End Demonstration demonstrated system functional capabilities in all primary IMIS functional areas: debrief, diagnostics, electronic TOs, work order generation and close-out, and flightline management support.

The primary objectives of the End-to-End Demonstration were to (1) evaluate the overall IMIS concept by exercising IMIS capabilities in all functional areas, (2) obtain user feedback in each primary functional area, (3) observe the system in operation under conditions approaching those in the real world of aircraft maintenance, (4) and identify candidate changes/improvements needed for a fully implemented IMIS

Scenarios intended to demonstrate 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 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. After being trained, each subject then 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 each subject was through with the scenario, 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), were completed. The first questionnaire was a lengthy set of subjective questions about IMIS in general, presented by the computer, with answers on a sliding scale which 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, debrief, 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 caused the most workload stress.

Fault Isolation Test. The Fault Isolation Test was the final field test of the IMIS demonstration system conducted at Luke AFB, AZ, in August and September 1994. The purpose of the Fault Isolation Test was to determine whether performance improvements could be achieved in several inefficient areas identified in the current maintenance process. For example, by (1) providing a technician a single PMA cartridge which contains all the current TO data needed to perform a task, the task preparation and completion time could be reduced; (2) providing the capability to initiate and approve a part order from the flightline, the maintenance process could become more efficient; or (3) collecting maintenance data during a diagnostics session and allowing the work order to be closed from the flightline, the technician's time required to complete paperwork and interact with CAMS can be substantially reduced.

The primary objectives of the Fault Isolation Test were to evaluate aspects of each of the tests to determine the effectiveness of IMIS in supporting the diagnostic and repair processes, and to determine improvements to make in future systems. These objectives were accomplished (1) by quantitatively comparing each participant's performance using IMIS versus using the current paper TOs and (2) by comparing user acceptance of IMIS versus the paper TOs.

The Fault Isolation Test was designed using three subsystems that are supported by data authored for IMIS: FCR, HUD, and INS. Simulated faults were inserted into the aircraft subsystems, and technicians were required to diagnose and simulate correcting the discrepancies. Twenty-four technician participants performed twelve fault isolation tasks (four on each of the three subsystems). Two of the tasks for each subsystem were performed using the paper TOs as job performance aids, and the remaining two tasks used the IMIS PMA. No participant performed the same task more than once. Twelve subjects were qualified in avionics maintenance specialties; the remaining twelve were qualified crew chiefs.

Quantitative measures were gathered by data collectors observing each technician's performance of each maintenance task. Data was collected according to a structured protocol for each maintenance task. Time values were corrected for instances beyond the control of the evaluation team, such as transportation delays, support equipment malfunctions, and so forth.

Qualitative and descriptive measures were collected primarily through structured question sets on data collection forms. Qualitative measures included experience level of subjects, specific problems encountered in using technical information (either TOs or the PMA) to perform maintenance tasks, information from short debriefings of each technician after performing each maintenance task, and information from a technical information evaluation questionnaire and structured interview administered after maintenance tasks had been performed.

Data was collected in the 310th Fighter Squadron (FS) over a span of 30 workdays. Each subject was assigned to participate in the test for five workdays. On the first of the five days, subjects were trained in the use of paper TOs, in the use of IMIS, and in the conduct of the test. On the remaining four days, each subject performed an average of three tasks per day. Four subjects performed troubleshooting tasks on an actual F-16 aircraft each day: two on the day shift and two on the swing shift. Two teams of data collectors gathered performance data, one team assigned to each shift.

Results

The results of the Debrief Test, the End-to-End Demonstration, and the Fault Isolation Test are summarized in the following subsections.

Debrief Test. The Debrief Test was conducted at Luke AFB from November 3 through December 9, 1993. Data was collected by observing and timing actual debrief sessions, some using IMIS and the rest using the current method. Four maintenance debriefers participated to varying degrees over the six-week period; only two debriefers were involved in the majority of the debrief sessions. Information collected during the sessions included start and stop times, problems encountered, discrepancy data (for use in subsequent tracking of work orders), and observations or remarks.

The data for the Debrief Test was collected by observing live debrief sessions, therefore, the Debrief Test could not be designed to provide a statistically valid test of various hypotheses. Instead, a quantitative comparison of the data was performed to determine trends in the debrief data collected using IMIS and the current method. The data collected and the results are summarized in the following subsections.

IMIS Debrief Results. Forty-five debrief sessions using IMIS were observed; discrepancies were reported in only thirteen of these. Because of this small number, conclusions regarding the quantities of work orders opened and the effectiveness of the discrepancy information captured could not be supported. Minor problems were identified during the IMIS debrief sessions. These included discrepancies in the authored Fault Reporting Manual (FRM) data, recommended software enhancements (especially involving facilitating error correction), and environmental difficulties resulting when inundated with pilots to be debriefed. None of these problems significantly affected the outcome of the debrief sessions.

Paper Debrief Results One hundred and eleven debrief sessions using the current system were observed. Data from two of these sessions was incomplete or inconsistent and was discarded, leaving a total of 109 data points. The problems encountered during some of these debriefs centered primarily on CAMS. In one case, CAMS rejected a debrief because the maintenance debriefer had not been notified of a tail number swap. Several other sessions reported CAMS as performing slowly, taking an extremely long time between screens, and not accepting input. These problems added to the overall debrief times, since debriefer interaction was required.

Comparison of Debrief Results. When comparing the data collected during the Debrief Test, some clear trends were evident. A summary of the comparison data can be found in Table 1, which lists average times and sample sizes for each categorization of the data. Again, it is important to note that the data was not collected in accordance with a statistically valid experimental design, so that a comparison with any level of statistical significance is not possible.

Table 1. Comparison of Results

	IMIS	Current Method
Debrief Time (All)	5:56 (45 debriefs)	13:26 (109)
Pilot Time (All)	3:57 (45)	4:36 (109)
Debrief Time (Code 1 Only)	3:15 (32)	9:36 (56)
Pilot Time (Code 1 Only)	2:58 (32)	3:26 (56)
Debrief Time (Code 2, 3)	12:32 (13)	17:29 (53)
Pilot Time (Code 2, 3)	6:23 (13)	5:50 (53)
Debrief Time (1 Work Order)	9:27 (11)	14:05 (37)
Pilot Time (1 Work Order)	5:05 (11)	5:19 (37)
Debrief Time (>1 Work Order)	29:30 (2)	25:23 (16)
Pilot Time (>1 Work Order)	13:30 (2)	7:00 (16)

Overall, the debrief time using IMIS was less than half that using the current method (5:56 vs. 13:26). The pilot time considering all data was also less, although the difference was not nearly as dramatic (3:57 vs. 4:36).

For only Code 1 debriefs (i.e., no discrepancies reported), the total debrief time is reduced by a factor of two-thirds when using IMIS (3:15 vs. 9:36). In these cases, the completion of the

IMIS debrief required only an additional 17 seconds after the pilot was done (2:58 vs. 3:15), as compared to the current method, where an additional six minutes was required (3:26 vs. 9:36).

In debriefs where discrepancies were reported and work orders were opened, the pilot time was not less when using IMIS compared to the current method (6:23 vs. 5:50). The 33 second delay was because the pilot was present as each work order was opened and as the appropriate entry from the FRM data was selected. The overall debrief time for these debriefs was still less (12:32 vs. 17:29).

The data when considering debriefs where a single work order was opened is similar. Because of the small number of debriefs where multiple work orders were opened using IMIS (only two), no comparisons can be made.

User Feedback. The user feedback provided after the completion of the Debrief Test was very valuable. When asked what they liked most about the IMIS debriefing function, the maintenance debriefers stated that conducting a debrief session for a Code 1 (no discrepancies) aircraft was extremely fast, aided especially by the pre-filling of data elements from the flying schedule and by the availability of pull down menus to select data and minimize data entry errors. They noted that the enhanced question sets used when opening a work order were helpful to technicians when they were not qualified for or familiar with a particular discrepant aircraft system. They felt that anyone could debrief a system with the enhanced question sets to assist in the debrief process. However, the enhanced question sets were also viewed somewhat as a negative factor, since this required additional time when debriefing a Code 2 or Code 3 aircraft.

The maintenance debriefers also made several recommendations regarding functionality enhancements which would make the system even better, including the ability to interactively update the enhanced question sets. The debriefers also noted that they must frequently update the debrief results in CAMS when new or revised information becomes available; providing the capability to edit debrief data in IMIS after it has been accepted would make the debrief process more efficient. Flying schedule and tail number swaps occurred frequently during the Debrief Test, and IMIS demonstrated limited ability to respond to these last-minute changes. The debriefers felt it would be desirable to provide the capability to debrief a tail number which is not on the list of undebriefed sorties rather than to wait for the change to be entered into CAMS and propagated to IMIS manually.

End-to-End Demonstration. The IMIS End-to-End Demonstration was a field demonstration of the primary functions of IMIS. This demonstration was conducted on F-16 Block 40/42 aircraft assigned to the 310th FS at Luke AFB, AZ from 1 June through 30 June 1994. It was intended to illustrate to users the overall IMIS concept by using the system to support a series of typical maintenance scenarios 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/close-out, and flightline management support.

The basic objectives of the End-to-End Demonstration were achieved with the validation of the IMIS concept. The demonstration showed that IMIS does effectively provide information that the technicians require, that it provides information in a way that is acceptable to them, and that it is something they want. The participants also provided valuable feedback, including suggestions for improving the system, as well as suggestions for improving the content and organization of data presented by the system.

A total of 32 participants, including expediters, production superintendents, maintenance debriefers, and technicians, completed the exercise. All the participants either were currently performing in the job they represented or had recent experience in that position. Three types of data were collected from the participants: an exit questionnaire, an automated questionnaire that collected opinions on IMIS functional characteristics, and the NASA TLX.

Exit Questionnaire Results. The exit questionnaire contains three direct questions and a place for the respondent to add written comments. The participants readily recognized that the current demonstration system is intended only for use in evaluating the concept of an IMIS as a tool for establishing requirements for a system to be developed for operational use. Consequently, they were able to evaluate the system on its potential. Overall responses to the questionnaire indicate a positive reaction to the IMIS concept. Many of the responses were very laudatory. The only exceptions were comments directed toward weaknesses in the demonstration system.

When asked what they liked about IMIS as an aid to help them do their jobs, the participants responded that they were impressed with the amount of information available through IMIS, and that, with a few key strokes, they could quickly access information which they would normally have to track down manually. They noted that not only are schedules and similar information kept current but key people are notified of changes. They were especially pleased that they did not have to work directly with CAMS to extract or input data, since IMIS interfaces with CAMS and enters the data automatically. The availability of all required TOs on the PMA and the ability to access parts information were also seen as benefits to the users.

When asked what they did not like about IMIS, participants most often cited speed. However, respondents differed in their perception of the impact of speed, noting that the response times were still considerably less than the times required to perform those same functions today. A lack of consistency in the use of certain function keys caused some confusion. Furthermore, many participants encountered difficulty using the PMA keypad, which required a firm press; it was easy to think a function had been activated when, in fact, it had not. The PMA was also prone to software failures during the End-to-End Demonstration. These problems were documented and most were corrected before the Fault Isolation Test began.

Characteristics Questionnaire Results. The characteristics questionnaire consisted of 97 questions designed to measure participants' evaluations of various characteristics of the IMIS demonstration system. The questionnaire required the participant to indicate the degree of agreement with a statement about an IMIS characteristic. The response was made on a seven-point scale. The complete questionnaire covered all key features and characteristics of the IMIS.

The rating scale used ranged from 1 (very positive) to 7 (very negative). The participants only responded to questions on features which they had experienced during the demonstration. Consequently, from a total of 97 questions, 41 were relevant during the End-to-End Demonstration. Some of these 41 questions were determined to have been incorrectly structured and were subsequently eliminated, reducing the total number of questions to 35.

Questionnaire results indicate that responses are generally consistent with respondents' answers to the exit questionnaire. Overall, responses were positive. The total overall rating for all responses was 3.01. Nineteen of the questions were classified as either very positive or positive. Three items were classified as negative (none were classified as very negative). Ratings for the remaining thirteen questions were classified as neutral. A review of all responses showed that the items receiving positive ratings include those concerning the manner in which information was presented on the PMA, procedures for accessing information, and techniques for interacting with the system. Most of the negative ratings related to the specific characteristics of the demonstration PMA, specifically the responsiveness of the keypad and the reliability of the RF link.

NASA Task Load Index Results. The NASA TLX is a multidimensional workload assessment tool designed to provide a measure of the workload imposed by a given job/work situation. The index is composed of weighted subscores of ratings on six factors which are believed to contribute to workload. The factors are: mental demands, physical demands, temporal demands, own performance, effort, and frustration. The NASA TLX produces a workload measure for each factor plus a cumulative index of workload. Each index can range from 0 to 100 and represents a measure of the workload imposed by the job/work situation.

By completing the NASA TLX twice (once using the current paper-based methods as the frame of reference and once using IMIS), it was possible to measure the relative workload imposed by the two work situations. Complete NASA TLX ratings were made by 16 subjects. Analysis of the ratings yielded a mean TLX workload index of 62.75 for the paper-based condition and 44.44 for the IMIS condition. The difference between means is statistically significant at the .0001 confidence level.

The results suggest that for this End-to-End Demonstration, IMIS significantly reduced the workload experienced by expediters and production superintendents, reinforcing the results from previous field tests. However, caution should be used in interpreting the NASA TLX results because they are based upon a relatively small sample and the paper-based ratings are based on retrospection rather than immediate experience.

Other Activities/Results. The PMA RF capability was tested by transmitting and receiving messages from the PMA to the IMIS base antenna located on the 310th FS hangar (Building 913). Transmissions were made at distances of up to 2500 feet (762 meters), sufficient to cover the 310th FS aircraft parking area. No problems were encountered in transmitting messages at these distances. In addition, the RF capability was tested with up to four PMAs sending and receiving. No problems were encountered. However, it became apparent that the more PMAs in operation, the slower the transfer of messages between the PMAs and the base station. Also, using the RF slows down non-RF related processes on the PMAs because the PMA has to interrupt ongoing processes to receive messages and updates.

The PMAs were installed in the expediter vehicle and tested without problems. It was also installed in the production superintendent's vehicle but not used for transmissions. Some minor modifications for the mounting racks were identified.

The PMA was not formally tested for heat tolerance during the End-to-End Demonstration; however, it was used under high-temperature conditions. It was used in an expediter truck without air conditioning in ambient temperatures up to 117°F (47°C). In addition, it was used in a hangar environment for several hours per session in temperatures up to 110°F (43°C). No problems were encountered with the PMAs due to heat.

Fault Isolation Test. The results from the Fault Isolation Test are documented in a separate Armstrong Laboratory reports (AL/HR-TP-1995-0033 and AL/HR-TP-1995-0034).

CONCLUSIONS AND RECOMMENDATIONS

The IMIS field tests and demonstrations proved to be a valuable source of information regarding the IMIS concept and implementation. In addition, the knowledge gained and experiences provided valuable information in many different areas. The conclusions and recommendation of the field tests are described in the following paragraphs.

Conclusions

The Debrief Test showed the IMIS debrief process to be much more efficient compared to the current method. The efficiency was due to the smaller number of CAMS debriefing screens accessed and due to the IMIS/CAMS interface. This was especially true for the Code 1 debrief sessions when no work orders were opened. In addition, the amount of time the pilot was involved did not increase, even though the maintenance debriefer entered the information into IMIS with the pilot present (in contrast to the current system, where the debriefer often waits until later to enter the information into CAMS).

The debriefers also preferred the IMIS user interface, with features like pre-filled data fields and pull-down menus. The debrief enhanced question sets also provided the capability for any maintenance debriefer, regardless of experience level or AFSC, to ask technical questions about the discrepant system and enter the descriptive discrepancy information based on the pilot's observations.

The End-to-End Demonstration showed IMIS is capable of providing maintenance personnel with both the management and technical information they require. Both the quantity and the currency of information exceed the data currently available to them. IMIS automatically interfaced with CAMS, relieving the user of manually entering data into CAMS. This was seen as a great advantage, in that this automatic interface could save time and provide more accurate information for all maintenance personnel and the maintenance information management system.

The ability of IMIS to automatically create and record accurate maintenance data in a single system (open and close work orders, record maintenance actions, and send the MDC data to the necessary legacy databases) are very desirable features. Eliminating the unique database interfaces (single data entry that will feed the data to multiple databases), having all the needed technical data and simplified wiring diagrams on the PMA, and being able to order parts from the job site will help make the maintenance personnel be more efficient. However, system response times and reliability need to be improved in order to enhance the user's overall efficiency.

A seamless interface between the various software processes must be developed. The transition from IMIS to the TO Present software was apparent to the user and was magnified by the differences in the user interface. The user interface must be made consistent throughout the system.

Recommendations

Overall, the IMIS system performed well and was well-received during its field test at Luke AFB. A large number of lessons learned and recommendations regarding hardware, software, system, functionality, human factors, data, and programmatics are included in Volume 3 of this Final Program Report and have been incorporated in the SSS. The key hardware and software recommendations are summarized in the following paragraphs.

The bubble-dome-type keys used on the PMA keypad made it difficult to tell whether the key had responded to a key press, resulting in the user pressing the key numerous times. The tactile feedback provided by the keypad did not guarantee that electrical contact had been made. Lowering the resistance in the keypad, thereby reducing the force required to press the PMA key, could also enhance key activation.

The PMA batteries worked well, but the battery replacement was inefficient. There was often inadequate time between the receipt of a low-power message and the occurrence of power failure; this may require a different type of battery, since this is typical of the NiCad batteries used. The captive screws which held the cover in place were very small, and the cover was not hinged or otherwise fastened to the body of the PMA, making battery replacement awkward. Some non-volatile memory, which would allow the PMA battery to be changed without having to shut it down all the way, would also be desirable.

Direct sunlight affected the readability of the PMA display, which would become darker and eventually unreadable. The adjustment of contrast via software accessible through the main menu bar is not adequate if screen visibility has already deteriorated to the point where the screen is unreadable. The contrast adjustment should be on the PMA box itself. In addition, glare and off-angle visibility need to be improved. Displays considered for future PMAs should undergo thorough evaluations and tradeoffs considering these factors, as well as cost and power.

Wireless communication is required for an effective maintenance operational environment. Without the wireless communication, flightline managers would not have the most current information available to perform their tasks. The entire aircraft maintenance area must be supported by wireless communication. RF coverage was adequate for the flightline area but was inconsistent in the hangars, where it was also required. Providing large area coverage may require the use of repeaters.

The system was saturated by the RF messages sent to a relatively small number of PMAs. To support messaging in an unconstrained environment when dealing with the number of PMAs required to support an entire FS, a mechanism for filtering messages may be required. Improving the efficiency of parsing the messages into the database would also help alleviate this problem.

The screen-based CAMS interface was inefficient and susceptible to frequent interruptions due to minor software changes. A standard legacy database interface, which could require changes to both CAMS and IMIS, should be developed. A better method would utilize Structured Query Language (SQL). In addition, detailed information regarding updates to CAMS was not disseminated to the organizations which needed access to that information. Time and effort were wasted because this information was either unavailable or incomplete. The existence of a CAMS data dictionary, in which attributes and their values were defined, would have been of immense help.

The tools selected for the software development environment were insufficiently mature to support the functional and performance requirements. Throughout software development, various bugs and limitations were encountered, with very few quick fixes. A more extensive analysis of the available tools and platforms should be conducted before beginning implementation.

Utilities to perform certain database changes (such as updating the list of aircraft or personnel) would have provided a much faster mechanism for updating databases. With the current software, many of these changes could only be done by building a new database, a process which takes a significant number of hours between creation and testing.

Aural and more attention-getting visual alerts regarding incoming messages should be available on both the PMA and the MIW, especially for time-critical messages for certain users like expediters or the production superintendent. The display of the message icon did not provide adequate notice to the user that a message had been received.

ACRONYMS

ACC	Air Combat Command
AFB	Air Force Base
AFR	Air Force Regulation
AFSC	Air Force Specialty Code
AIMS	ATF Integrated Maintenance System
AIP	Aircraft Interface Panel
AL/HRG	Armstrong Laboratory Logistics Research Division
APG	Airplane General
API	Application Programming Interface
ATF	Advanced Tactical Fighter
BIT	Built-In Test
CA	Control Architecture
CAMS	Core Automated Maintenance System
CD ROM	Compact Disk Read-Only Memory
CDM	Content Data Model
CDRL	Contract Data Requirements List
CLSA	Computer Logics Synchronous Adaptor
CND	Can Not Duplicate
CPU	Central Processing Unit
CSA	Computer Systems Architecture
CSCI	Computer Software Configuration Item
DC	Direct Current
DCM	Deputy Commander for Maintenance
DEMO	Demonstration
EDM	External Data Management
FCR	Fire Control Radar
FRM	Fault Reporting Manual
FS	Fighter Squadron
GB	Gigabyte
HESAR	Human Engineering System Analysis Report
HUD	Head-Up Display
I-Level	Intermediate Level
IA	Information Architecture
ICAM	Integrated Computer-Aided Manufacturing
IDD	Interface Design Document
IDEF	ICAM Definition
IMIS	Integrated Maintenance Information System
IMIS-DM	IMIS Diagnostics Module
IMISA	IMIS Architecture
INS	Inertial Navigation Set
IRS	Interface Requirements Specification
LAN	Local Area Network
LFWC	Lockheed Fort Worth Corporation

LRU	Line Replaceable Unit
MASA	Modular Avionics Systems Architecture
MB	Megabyte
MHz	Megahertz
MIW	Maintenance Information Workstation
MML	Memory Module Loader
MOC	Maintenance Operations Center
NASA	National Aeronautics and Space Administration
NiCad	Nickel-Cadmium
O-Level	Organizational Level
OCD	Operational Concept Document
PIDS	Prime Item Development Specification
PIPFS	Prime Item Product Fabrication Specification
PMA	Portable Maintenance Aid
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
SDD	Software Design Document
SEA	Systems Engineering Analysis
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
USAFE	United States Air Forces - Europe
VGA	Video Graphics Array

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