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INTEGRATED MAINTENANCE INFORMATION SYSTEM: USER FIELD DEMONSTRATION AND TEST EXECUTIVE SUMMARY

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13. ABSTRACT *(Maximum 200 words)*

This Executive Summary summarizes the results of a field test and demonstration of the Integrated Maintenance Information System (IMIS). The IMIS project was an advanced development demonstration project which developed and field tested the technology to provide the maintenance technician with the capability to access all of the technical information (interactive electronic technical manuals, interactive diagnostics instructions, work orders, supply availability and ordering, historical data, training material, etc.) required to maintain aircraft via a single, integrated system, regardless of the source of that information. In the final phase of the project, an IMIS Demonstration System was developed and tested. In the field test, the performance of technicians on troubleshooting tasks when using the IMIS was compared with their performance on comparable tasks when using the paper technical orders. Test results indicated that technicians were able to perform the tasks significantly faster, used fewer parts, and made fewer serious errors when using the IMIS. In addition, the test indicated that, when using the IMIS, non-specialist (crew chief) technicians could perform the tasks as effectively as the specialists

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PREFACE

Since the late 1970s, the Logistics Research Division of the Armstrong Laboratory has conducted research to develop and evaluate the technology for an Integrated Maintenance Information System (IMIS). IMIS will provide maintenance technicians and managers with the capability to access all the technical information required to perform their jobs via a single, integrated system. The final phase of the IMIS program was to develop a demonstration system incorporating the technologies and illustrating the capabilities of IMIS. This report summarizes the results of a user field test and demonstration conducted to evaluate IMIS and demonstrate its capabilities to operational maintenance personnel. The user field test and demonstration was conducted at Luke Air Force Base, Arizona, during the summer of 1994.

IMIS is the product of the creativity, talents, and efforts of many people, including Armstrong Laboratory personnel and a number of contractors. The IMIS program was initiated and directed by Mr Robert C. Johnson, AL/HRGO. The program was accomplished by a dedicated staff of scientists and engineers, with the strong support of three Division Chiefs: Mr Bertram W. Cream, Col James C. Clark, and Col Donald C. Tetmeyer.

The IMIS project was conducted under Project 2950, Work Unit 2950-00-09. The program managers were Mr. Richard E. Weimer and Major Thomas M. Kruzick. The prime contractor for the development of the IMIS Demonstration System was GDE Systems, Inc., with its subcontractors Applied Science Associates, Inc., Softech, and Systems Control Technology. In addition, technical support was provided to the Laboratory by NCI Information Systems, the University of Dayton Research Institute, Computer Sciences Corporation, RJO Enterprises, and Robins-Gioia, Inc. Additional support was received from the Lockheed Corporation, under the sponsorship of the F-16 System Program Office.

The user demonstration and field test could not have been accomplished without the generous support of the host unit, the 310th Fighter Squadron. The efforts of Captains Tribble and Ramero, CMSgt Rios, and the technicians and supervisors under their command were a major factor in the success of the field test.

Integrated Maintenance Information System: User Field Demonstration and Test Executive Summary

SYNOPSIS

This report summarizes the results of the final phase of a program to develop and evaluate the concept of an Integrated Maintenance Information System (IMIS). IMIS will provide maintenance technicians and managers with the capability to access all the technical information required to perform their jobs via a single, integrated system. The project developed and field tested the technology to implement the concept. The technologies were then implemented in a demonstration system for evaluation. Technological developments include advances in the areas of Interactive Electronic Technical Manuals (IETMs); interactive, computer-generated diagnostics; human/computer interface; special-purpose portable computers; and integration of divergent data bases. An IMIS demonstration system, applying these technologies, was developed and evaluated.

The IMIS program was established to evaluate the IMIS concept and to develop and test the technology required for an operational IMIS. Major activities under the program included:

a. comprehensive analysis of maintenance information requirements to serve as the baseline for developing IMIS;

b. research to develop an advanced, interactive, diagnostic-aiding capability;

c. research to develop effective human/computer interface and technical information presentation techniques to make IMIS easy to use and an effective means of communicating technical information;

d. development of a methodology for authoring and coding, IETMs (technical orders [TOs]) in an efficient and cost-effective manner which provides flexibility and reduces redundancy;

e. development of demonstration portable maintenance aids (PMAs) using off-the-shelf components; and

f. development of an IMIS demonstration system which incorporates the major features and functions of IMIS for use in evaluating IMIS technology and validating requirements.

The IMIS Demonstration System was evaluated in a three-phase field test at Luke Air Force Base, Arizona, in the spring and summer of 1994. This report summarizes the findings of the third phase of the evaluation, a test to evaluate the ability of the system to support on-aircraft fault isolation and repair tasks. In the test, an experiment was conducted to evaluate the impact of IMIS on the performance of maintenance technicians. In the experiment, 12 avionics specialists and 12 non-specialists (airplane general [APG] technicians) performed 12 fault isolation problems on three F-16 subsystems: the fire control radar (FCR), heads-up display (HUD), and Initertial 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.

Analysis of the technicians performance on the 12 test problems suggests the following benefits from IMIS.

a. The rate for successful problem completion was improved by approximately 22 percent for specialists and 42 percent for APG technicians.

b. The frequency of serious errors (errors which could lead to failure to correct the problem) were reduced by 58 percent for specialists and 83 percent for APG technicians.

c. Overall problem times (troubleshoot, order parts, repair, and document) were reduced by approximately 17 percent for specialists and 29 percent for APG technicians. Analysis indicates that the reductions in times were due primarily to time saved by the automated parts-ordering and work order close-out features of IMIS.

d. Overall parts consumption for the 12 problems was reduced by 26 percent for specialists and 37 percent for APG technicians. In-depth analysis indicates that IMIS diagnostics are much more beneficial for the more complex problems (e.g., most of the part savings were from the INS system).

e. Part-ordering times were reduced by 94 percent for both specialists and APG technicians.

f. For all measures, the performance of the APG technicians when using IMIS was approximately equal to the performance of the specialists when using paper TOs.

A key finding is that the use of IMIS had the effect of "leveling the playing field" for the APG technicians. With IMIS, the APG technicians were able to perform the fault isolation problems as effectively as specialists using IMIS and more effectively than the specialists using paper TOs. This finding suggests that the use of IMIS will enable the crew chief to perform a much wider range of tasks, thus reducing reliance on specialists.

The responses to questionnaires administered to the technicians after completing the test problems indicate a high rate of acceptance of IMIS and a desire to see it implemented in the Air Force. IMIS features which were rated highly include the integration of technical data, automated parts-ordering by radio frequency (RF) link, automated close-out, and automated diagnostic advice.

BACKGROUND

The IMIS project was an advanced development demonstration project conducted by the Logistics Research Division of the Armstrong Laboratory. The project developed and field tested the technology to provide the maintenance technician with the capability to access all technical information (IETMS, interactive diagnostics instructions, work orders, supply availability and ordering, historical data, training material, etc.) required to maintain aircraft via a single, integrated system, regardless of the source of that information. This capability will help maintain the new technology found in advanced weapon systems and will support the current trend toward fewer maintenance specialties. In the future, portable computers will deliver the electronic data at the flightline work site, and a network of work stations will interact with existing maintenance computer systems in shops and work centers. IMIS is designed to be totally integrated with other maintenance information systems during peacetime at main operating bases, but the basic portable diagnostic and TO automation is fully deployable to remote dispersed locations during war (Johnson, 1994).

A full implementation of the IMIS concept will have the following features and capabilities.

- IETMs stored and presented on a PMA.
- Interactive diagnostic-aiding via a PMA, supported by an interface with the aircraft data bus to operate built-in-tests and down-load system performance data for use by an IMIS maintenance diagnostic algorithm.
- Interface with Core Automated Maintenance System (CAMS), Standard Base Supply System (SBSS), and other information systems and data bases which support maintenance operations.
- Training materials integrated with the IETM and automated diagnostics data base to support on-the-job and upgrade training.
- Maintenance data collection, via the CAMS interface.
- Radio communication capability between PMAs and IMIS local area network (LAN) provides digital data exchange with IMIS LAN.
- IMIS LAN connects IMIS workstations, RF modems, printers, data storage devices, and interfaces with external data bases.

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Fully implemented, IMIS would include the following basic hardware and software.

- PMAs, four to six pounds, fully ruggedized, multiple power sources, plug-in memory modules, screen readable under all conditions, self-contained batteries, interface to aircraft maintenance bus, usable with chemical and cold weather gloves, easy to operate without training, typing skills not required.

- Stationary Workstation Computers, to support maintenance management activities, maintain the IMIS data base, and interface with external data bases. Located in maintenance management and support offices.

- Mobil Workstation Computers with RF capability, mounted in maintenance supervisory vehicles for use in managing and controlling flightline maintenance activities.

- Technical data presentation software, presents IETM data and diagnostic procedures.

- Interactive diagnostics software, generates most efficient diagnostic strategy based upon technical data, system design information, component failure rates, and current system status (e.g., symptoms and test results).

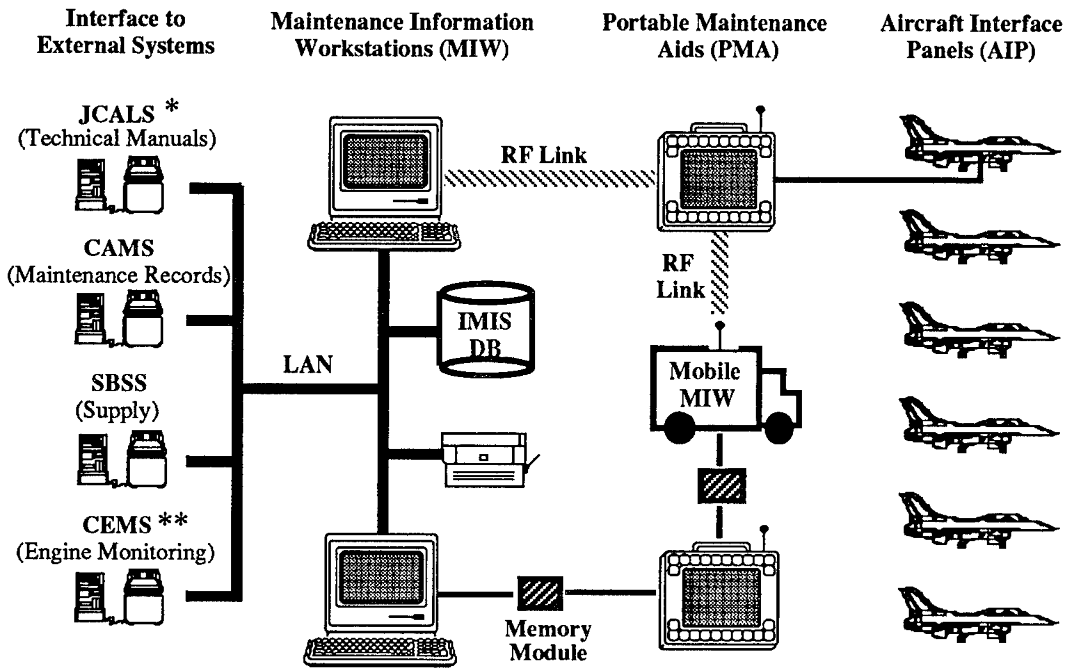
- IMIS data base, maintains data required to support IMIS and maintains a backup copy of the relevant CAMS information to prevent interruption of operations if CAMS is down.

- External Data Base Interface software, controls interface with CAMS, SBSS, and other external data bases.

The architecture of a full-scale implementation of IMIS is presented in Figure 1.

IMIS DEMONSTRATION SYSTEM

The demonstration system incorporated the major IMIS functions, including enhanced debriefing, presentation of TO data, automated diagnostic-aiding with aircraft data bus interface, RF communications, CAMS/SBSS interface, PMA, and advanced human/computer interface techniques. The IMIS Demonstration System was installed in the facilities of the 310th Fighter Squadron, Luke AFB. The IMIS installation at Luke AFB consisted of a network of four workstations (located in the debriefing room, Combat Oriented Support Organization [COSO], and the IMIS field office), seven PMAs, and two laptop computers used as portable



* Joint Continuous Acquisition and Lifecycle Support

**Centralized Engine Monitoring System

Figure 1
IMIS Architecture

workstations in the production superintendent and expediter vehicles. The IMIS workstations were linked by a fiber optic cable to form the IMIS LAN. The LAN was connected to CAMS. See Ward, Weimer, and Kruzick (1995) for a detailed description of the IMIS Demonstration System.

The IMIS Demonstration System was evaluated in a three-phase field test. These phases are described in the following paragraphs.

Phase I. In Phase I, the IMIS debriefing function was evaluated. The results of this evaluation indicate that IMIS provides an effective debriefing capability. Use of the system resulted in faster debriefs for Code 1 aircraft. In addition, IMIS has the capability to provide technicians with more extensive information on reported system failures than is provided by current debriefing procedures.[1] Debriefers who used the system found it effective and easy to use.

[1] This benefit was not fully evaluated because the test was conducted under operational

Phase II. The Phase II evaluation was an "End-to-End" Demonstration. The demonstration was designed to evaluate the capability of IMIS to support flightline management functions, especially those performed by the production superintendent and expediters. To avoid interfering with ongoing maintenance operations, the evaluation was conducted in a classroom environment. Expediters and production superintendents used IMIS to perform typical scenarios incorporating the tasks they normally perform in their day-to-day activities. These activities included performing actions such as assigning a work order to a technician, creating and closing work orders, approving part orders, retrieving aircraft status information, changing aircraft status, and sending messages. The participants were asked to evaluate the system as an aid for performing their jobs; the evaluations were very positive. See Ward, Weimer, and Kruzick (1995) for additional information on the End-to-End Demonstration.

Phase III. The Phase III evaluation (Field Test) was designed to evaluate the capability of IMIS to support on-aircraft maintenance, especially diagnostics. The results of this test are described in the remainder of this report.

FIELD TEST

IMIS is expected to have several advantages over the current paper TOs for supporting the flightline maintenance processes. These advantages include reduced time to accomplish troubleshooting tasks, reduced spare parts consumption, reduced time to complete documentation, and more accurate maintenance data collection. In addition, preliminary studies have indicated that the use of IMIS may enable technicians without extensive training on specific systems to effectively maintain and troubleshoot those systems. For example, with the use of IMIS, it has been suggested that an APG crew chief should be able to troubleshoot as rapidly and accurately as avionics specialists are able to troubleshoot when using paper TOs. If this proves to be valid, the use of IMIS would have major implications for the maintenance force structure because it could somewhat reduce reliance on highly trained specialist and would make greater use of generalists without this extensive and expensive training. The IMIS Constrained Test was conducted to test the above assertions and to provide additional data for use in evaluating the overall effectiveness of IMIS.

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conditions and the current paper-based system has no mechanism available to provide this information to the technician. In a full implementation of IMIS, this information would be automatically entered into the IMIS data base, loaded onto the technician's PMA, and used by the diagnostic routine to isolate the fault.

Objectives

The objectives of the Field Test were to demonstrate that use of 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. Additional objectives were 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 IMIS.

To accomplish the above objectives, it was necessary to 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.

Experimental Procedures

An experiment was conducted in which avionics specialists and APG technicians each performed 12 troubleshooting tasks: six using IMIS and six using paper TOs. The order of task presentation was counterbalanced so that half the technicians performed their IMIS tasks first and half performed their paper-based TO tasks first. Twelve troubleshooting tasks for three F-16 subsystems were used as test problems for the study. The test-bed systems were the F-16 FCR, HUD, and INS. The tasks were selected in pairs so that paired tasks were approximately equal in difficulty and required the same skills. The tasks were based on faults which can occur in the test-bed systems and are considered representative of the troubleshooting tasks normally encountered in maintaining these test-bed systems. Breakout boxes were used to insert the faults into the systems.

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.[2] To successfully complete a problem, the technician was required to verify that the reported malfunction existed in the aircraft, identify the faulty component, identify the

[2] 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 TO. Frequently, the helps were little more than a hint (e.g., remember what you were taught in training).

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 in order 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, the technicians completed an open-ended questionnaire which asked them what they liked about IMIS, what they did not like, and how IMIS could be improved.

Field Test Results

Analysis of variance was used to evaluate the technicians' performance on the fault isolation tasks. The findings are presented below.

Successful Task Completion

The technicians' performance was evaluated to determine if they had satisfactorily completed all requirements (as defined above). The percentage of problems successfully completed under each test condition (using IMIS or paper TOs) was computed. These percentages are presented in Table 1.

Table 1. Percent of Problems Successfully Completed by Avionics Specialists and APG Technicians

	TO	IMIS	Significant
Avionics Specialist	81.9	100.0	Yes **
APG Technician	69.4	98.6	Yes ***
Total	75.7	99.3	Yes***

** $p < .01$
*** $p < .001$

The specialist and APG technicians successfully completed nearly all the problems when using IMIS. Only one problem was failed when using IMIS compared to 26 (of 144) problems failed when using paper TOs as the source of technical data. Of particular interest is the fact that when using IMIS the APG technicians were nearly as successful in completing the fault isolation problems as were the avionics specialists. This is an important finding because it indicates that, with IMIS, crew chiefs could perform a much wider variety of tasks, reducing the dependence on highly trained specialists.

The observed differences in performance with IMIS and paper TOs are statistically significant for both specialists and APG technicians. Also, the difference in the observed success rate for technicians using IMIS versus avionics specialists using paper TOs is statistically significant.

The success rate for both specialists and APG technicians was much lower when the TO was the source of technical data. Close examination of the data reveals that most of the failures with the TO were due to a failure to complete all the required system health checks. The difference in performance can be explained by the fact that one or more built-in-tests or operational checks are required to verify that the system has been returned to operational status. System health tests and checkout requirements are presented in the follow-on maintenance requirements section of the TO. The manner in which the follow-on maintenance requirements are presented in the TOs for some systems makes it easy to overlook required checks. As a result, several technicians failed to complete all the required checks and failed the problem. With IMIS, it is impossible to overlook the required checks. When a technician completes a task, IMIS automatically presents the instructions for the follow-on task. The technician must follow the instructions or consciously choose not to do the task.

Parts Used

The mean number of parts used by each technician to complete the six problems under each condition is shown in Table 2. The specialists required an average of 8.67 parts to complete the six problems using the TO, compared to 6.42 parts when using IMIS.[3] The APG technicians

[3]Three of each set of six problems required replacement of a part to correct the fault. The remaining faults were caused by wiring and required no parts. Thus, rectification of the problems required three parts per subject, per condition. Any parts used in excess of three were "good" parts either replaced by the diagnostic strategy or because of an error by the technician. The diagnostic strategy employed in the TOs required replacement of five good parts for the six problems. The diagnostic strategy generated by IMIS required the replacement of two good parts for the six problems. The F-16 TOs often direct the replacement of a component to determine if it is good or bad. This normally occurs when there is no test available to determine if it is good or bad, or because the troubleshooting procedure does not take advantage of an available test.

required 8.30 parts for the problems when using the TO, compared to 5.30 parts when using IMIS. Again, it should be noted that, on this measure, the APG technicians were as proficient as the avionics specialists.

Table 2. Mean Number of Parts Used by Each Technician for Six Problems Under Each Condition

	TO	IMIS	Significant
Avionics Specialists	8.67	6.42	Yes***
APG Technicians	8.30	5.30	Yes***
Total	8.48	5.84	Yes***

*** $p < .0001$

Detailed analysis of parts usage revealed that the great majority of the part savings for IMIS were from one subsystem: the INS. This appears to be due to the differences in the complexity of the troubleshooting tasks for the system. INS troubleshooting procedures are much more complex than procedures for the FCR and HUD. Additional analyses are being performed to evaluate the observed differences.

Task Performance Times

The mean times for technicians to perform their assigned tasks using either IMIS or paper TOs were computed. The means are presented in Table 3.

Table 3. Mean Problem Performance Times (in Minutes) for Each Problem

	TO	IMIS	Significant
Avionics Specialists	149.29	123.64	Yes**
APG Technicians	175.82	124.04	Yes***
Total	161.46	123.83	Yes***

** $p < .01$
*** $p < .001$

Both the avionics specialists and APG technicians required significantly longer to complete the fault isolation problems when using the TO. Use of IMIS reduced the problem performance times of the specialists by approximately 17 percent and the times of the APG technicians by approximately 29 percent. The performance times of the specialists and APG technicians were essentially the same, indicating that the APG technicians using IMIS were able to perform the job as efficiently as the avionics specialists (and more efficiently than the avionics specialists using their current methods).

A more detailed analysis of the performance times was conducted to identify which elements of IMIS contribute the most to the observed reductions in performance times. The analysis indicated that nearly all the observed differences were due three factors:

a. the reduction in the number of good parts replaced,

b. the reduction in the time required to order parts when IMIS is used, and

c. the reduction in the time required to complete work order close-out documentation.

Part-Ordering Time

By reducing the number of good parts unnecessarily replaced, IMIS reduces the time required to isolate and repair a system fault. Time savings were realized by eliminating unnecessary tasks, such as removing a good part, replacing it with a new part, and performing system health checks to determine that the new part did not fix the problem.

A large percentage of the observed total time difference between the IMIS and paper TO conditions was due to the difference in the way parts are ordered under the two systems. When using the paper TO, the technician must go to COSO, look up the part number, obtain authorization to order the part, and submit the part order to the COSO clerk who must input the order into the SBSS. Thus, ordering parts is a time-consuming process (a conservative estimate of 15 minutes per part ordered was used for this study). In contrast, when using IMIS, technicians are asked if they want to order the part. If they answer "yes," IMIS automatically submits the order by RF link to the Production Superintendent for approval. IMIS then submits the approved order to the SBSS. While IMIS is processing the part order, the technician is free to remove the defective part or perform other maintenance activities. Thus, at least 15 minutes are saved per part order.

The difference in mean part-ordering times using IMIS versus the current parts-ordering procedure are illustrated in Table 4. As may be observed from the table, the time savings resulting from the use of IMIS are dramatic. The observed differences are statistically significant, well beyond the 0.001 level of confidence.

Table 4. Mean Time (in Minutes) to Complete Each Part Order

	TO	IMIS	Significant
Avionics Specialists	19.42	1.16	Yes***
APG Technicians	25.28	1.47	Yes***
Total	22.35	1.32	Yes***

*** $p < .001$

Close-Out Time

The third primary source of time savings is from the use of IMIS's work order close-out and RF functions to enter close-out information into CAMS. With a full implementation of the IMIS concept, IMIS will automatically record all information required to complete the work order close-out process. When the job is completed, the technician will instruct the system to assemble the work order close-out information; the information will be presented to the technician for verification and correction, if needed. After verification by the technician, the information will be sent by RF to CAMS to complete the work order close-out process. Under the current procedures, the technician must make notes on actions taken, parts used, part numbers, and so forth during the fault isolation and repair process. The technician must then go to the maintenance office, find a CAMS terminal, and enter the information from the notes taken (or from memory).

The IMIS demonstration system did not fully implement the IMIS concept for work order close-out. The system did not automatically record all the required information. The system presented a form (similar to Air Force Technical Order [AFTO] Form 349) with some blocks filled in and others to be completed. The technician filled in the blanks by selecting from lists of options. When the form was completed, the information was transmitted by RF to the IMIS workstation for forwarding to CAMS. As indicated earlier, it was not possible to enter the closeout information into CAMS for the TO-based condition. To provide an estimate of the times to close out a work order with the current procedures, the technician completed a paper form with the required information. The time required to complete the form, plus a standard time (10 minutes) was used as an estimate of the time it would have taken to close the work order using the current procedures. The mean observed times are presented in Table 5. The differences in observed close-out times for both the specialists and APG technicians were statistically significant at the 0.001 level of confidence. In addition, the times for the APG technicians using IMIS were significantly shorter than the times for the specialists using the current CAMS-based procedures ($p < .001$). In a full implementation of IMIS, the required information would automatically be collected and used to complete the data-reporting requirement. The technician would not have to add information, only verify that the information is correct. Thus, the time for the IMIS condition would be near zero.

Table 5. Mean Times (in Minutes) to Close Out Each Problem

	TO	IMIS	Significant
Avionics Specialists	14.67	8.17	Yes***
APG Technicians	17.31	8.82	Yes***
Total	15.98	8.49	Yes***

*** $p < .001$

Errors

It was anticipated that the use of IMIS would reduce the number of errors made by the technicians. As shown in Table 6, this expectation was realized. The use of IMIS resulted in a dramatic reduction in serious maintenance errors (errors which could cause the fault not to be identified or cause the unnecessary replacement of a good part). The use of IMIS resulted in a 56-percent reduction in major errors made by the specialists and an 82-percent reduction in major errors by the APG technicians. These observed differences were statistically significant at the 0.001 level of confidence. In addition, the APG technicians using IMIS made significantly fewer major errors than did the specialist technicians using the paper TOs ($p < .001$).

Table 6. Mean Number of Major Errors per Problem

	TO	IMIS	Significant
Avionics Specialists	.69	.29	No
APG Technicians	1.06	.18	Yes***
Total	.87	.23	Yes***

***$p < .001$

IMIS Characteristics Questionnaire Results

Examination of the responses to the IMIS Characteristics Questionnaire reveals that the various features of IMIS were generally rated very positively. The most highly rated features include using IMIS to order parts and close work orders, the ease of completing forms, the ease of using the IMIS fault isolation procedures, and the ease of navigating through the TO. Items which received negative ratings included the response time of the IMIS PMA, the weight of the PMA, and the PMA keyboard.

Exit Questionnaire Comments

The written comments provided by the technicians at the end of the test indicate that the technicians have a very positive view of IMIS. The exit questionnaire statements clearly demonstrate that the technicians like the concept of IMIS and believe it has great potential. This observation is based upon statements such as:

> Great project - quite a bit better than having to use TOs. I hope I see it in use somewhere, sometime before I get out of the service or even in the civilian world.

> IMIS definitely needs to be an integral part of the AF. The AF will benefit greatly from the implementation of IMIS.

> Very good unit. If it were not for the waiting on the computer, it would be great.

A complete listing of the exit questionnaire comments is presented in Appendix A.

DISCUSSION AND CONCLUSIONS

The IMIS field test successfully demonstrated the feasibility of the IMIS concept and the potential benefits of developing the system for operational Air Force use. The Debriefing and End-to-End tests demonstrated the ability of IMIS to enhance the debriefing process and to improve the efficiency of maintenance management functions (Ward et al, 1995). The IMIS Field Test provides strong evidence of IMIS's capability to enhance the performance of maintenance technicians performing on-aircraft maintenance. It also provides the basis for determining the potential cost savings which will accrue from the implementation of IMIS in the Air Force. The primary findings of the Field Test and their implications are discussed briefly below.

IMIS Concept Validation

The Field Test clearly demonstrated that the use of IMIS for on-aircraft maintenance will improve technician performance. When using IMIS, technicians were able to complete fault isolation and repair problems with greater accuracy, in a shorter time, and with fewer errors. In addition, fewer parts were used in the process. The improved performance will significantly reduce the time required to return an aircraft to operationally capable status, provide for more effective utilization of available personnel, and reduce expenditures for procuring, repairing, and stocking aircraft replacement components.

The Field Test and End-to-End demonstration clearly showed the advantages of the IMIS RF link capability. These advantages were most clearly demonstrated in the Field Test, where it was found that using the RF for ordering parts and transmitting work order close-out information was the major contributor to faster job completion. The End-to-End Demonstration showed the advantages of the IMIS RF capability in supporting flightline maintenance managers in a variety of ways, including providing up-to-the-minute aircraft and maintenance status information and offering the capability to make personnel assignments, open and close work orders, and communicate with other maintenance managers.

The Field Test demonstrated that IMIS is easy to use and is preferred by technicians. The technicians had very little trouble using IMIS. After receiving a short training session, both the specialist and APG technicians were able to perform the test tasks with minimal difficulty. In contrast, the APG technicians (and some specialists) experienced significant difficulties in using the paper TOs.

The IMIS user interface provides an effective means of retrieving the information that technicians require to perform on-aircraft maintenance. The test identified a number of modifications to the user interface which would make it more effective. These include presenting more than one step at a time so the technician can look ahead and see the next step, providing a browsing capability, and providing better locator information. The IMIS user interface provides a good starting point for the development of the user interface for an operational IMIS. Designers of an operational IMIS would benefit greatly from a careful study of the Demonstration System interface.

IMIS and the Non-Specialist Technician

One objective of the study was to demonstrate that, when using IMIS, APG technicians could troubleshoot complex systems as effectively as avionics specialists could troubleshoot the problems when using TOs. This objective was exceeded. The APG technicians were significantly more successful in performing the problems with IMIS than were the avionics specialists using the TO.

The above finding has significant implications for how the Air Force trains and assigns maintenance personnel. It suggests that, with IMIS, the crew chief can be assigned a much broader range of tasks than is possible with the current paper-based TO system. However, the finding applies only when the crew chief is using an IMIS-like system with high-quality technical data which directly leads to the isolation of most faults. The crew chief will not have the background necessary to handle those occasional problems not covered by the IMIS technical data; the highly trained specialist will still be required to resolve these problems. Furthermore, for the crew chief to be assigned to the broader range of tasks, he or she will require additional training. This training would include an orientation to the systems to be maintained (including component location, operation, and basic maintenance procedures) and training on any required test equipment (e.g., use of multimeter). The additional training should require the addition of only a few days to the current APG training.

Lessons Learned

Many lessons were learned in conducting the IMIS program. Some of the more important lessons are described below. Additional lessons learned and discussions are provided in the basic complete test report (Thomas, 1995).

a. The user interface is critical. The IMIS user interface proved to be quite effective and was a major factor in the positive response of the technicians to the system.

b. The quality of the technical data used by IMIS is critical. The data used for the Field Test was converted directly from the existing paper TOs. As a result, many of the problems in the TOs were carried over to the IMIS data base (e.g., inadequate illustrations, insufficient diagnostic tests, etc.). Consequently, the full potential of IMIS to improve performance was not demonstrated in this test. The addition of a few more tests, a few more illustrations, and clarification of some confusing text could have reduced the number of parts consumed and errors made.

c. Adequate test points are essential for effective diagnostics. To achieve the full potential of the IMIS diagnostics, the aircraft system must be designed with sufficient test points to allow the isolation of a fault to a single component. Adequate test points were not available for the test-bed systems, limiting the effectiveness of the IMIS diagnostics. Had adequate test points been available and included in the technical data, the number of parts used under the IMIS condition would have been significantly reduced.

d. IMIS diagnostics may be more appropriate for some systems than others. The IMIS diagnostics appear to be most beneficial for complex systems with lengthy, complex troubleshooting procedures.

Concluding Comments

The IMIS Field Test clearly demonstrates that the IMIS has a great potential for improving the effectiveness and efficiency of Air Force maintenance operations. The next step is to build an IMIS for operational use. This project has provided a firm basis for the development of the operational IMIS. The Air Force has directed that the IMIS capabilities be implemented in a new information system currently under development. This system, the Integrated Maintenance Data System (IMDS), will be a full implementation of the IMIS concept. The IMIS Demonstration System has been transitioned to the IMDS Program Office for further testing and evaluation.

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ACRONYMS

AFB	Air Force Base
AFTO	Air Force Technical Order
AIP	Aircraft Interface Panel
APG	Airplane General
CAMS	Core Automated Maintenance System
CEMS	Centralized Maintenance Management System
COSO	Combat Oriented Support Organization
FCR	Fire Control Radar
HUD	Heads-Up Display
IETM	Integrated Electronic Technical Manuals
IMDS	Integrated Maintenance Data System
IMIS	Integrated Maintenance Information System
INS	Inertial Navigation System
JCALS	Joint Continuous Acquisition Lifecycle Support
LAN	Local Area Network
MIW	Maintenance Information Workstation
PMA	Portable Maintenance Aid
RF	Radio Frequency
SBSS	Standard Base Supply System
TO	Technical Order

APPENDIX A

EXIT QUESTIONNAIRE COMMENTS

Question: What did you like about IMIS as an aid to doing your job?

Comments:

The speed with which you and IMIS can do a job, the graphics were good for aiding with wire troubleshooting.

The whole concept is pretty good. Go to aircraft, diagnose, order part, not have to carry paper.

The speed in diagnosing and accomplishing a task.

When the PMA was connected to the 1553 Bus, it was very quick and accurate.

Parts ordering, debriefing and job close-out were much simpler than using CAMS.

Information easily accessible, accurate, easy to understand.

It cut down on the mental frustration of my job and the amount of tech data that I would normally have had to go through to do my job. Also, the part ordering feature cut down part ordering time considerably.

It cut the time down to nothing.

You had one unit instead of many TOs. It gives you only necessary information, less confusion.

It makes sure everything is done in order.

The integration of all TOs and the ease of ordering parts.

The troubleshooting fault tree and the job guides. They replicated the paper ones very well.

It was very straightforward. It took everything associated with the system into consideration, and gave the choice to the technician as to the action he feels to be best. It made ordering parts very simple, actually it does it for you. It saves time on paper work. I feel with IMIS that anybody, regardless of experience, can work on the aircraft.

The ease of closing work orders and the ordering of parts. The troubleshooting was also helpful.

Simplified troubleshooting.

Easier than carrying a library of TOs.

Saved effort in fumbling through books when shooting wires.

Convenient way to order parts.

Integration with aircraft systems (BIT checks), faster than the aircraft (GAC).

Made troubleshooting easier.

It made troubleshooting much easier and eliminated tedious job of checking out tech data and equipment from support. I also feel that IMIS will decrease the down time of the aircraft.

IMIS was very helpful in all aspects of completing a job from starting the work order, to verifying a fault, and to rectifying the fault. The most impressive aspect of IMIS is parts order!

If the system is used on the flightline, it could speed up different jobs and take away a lot of other frustration with dealing with the different TOs.

The auto BIT feature was extremely helpful, and the recommended best action was a good feature as well.

It made unknown tasks easy to understand; parts ordering and job closings were fast.

I found it very helpful. With me being fairly new to my job, I hadn't used hardly any of the TO material, as far as FI are concerned. From just learning to use both, after some basic TO (paper) training I found IMIS much more easier.

It takes up the repetitious workload.

Parts ordering, CAMS interface, not having to carry a lot of books.

Makes troubleshooting very easy.

It works very well as aid.

Question: What did you dislike about IMIS.

Comments:

There is nothing I can think of that would make me dislike this system.

Transition times between screens.

Some text is misleading. For example, hook up of the PMA to A/C could be clearer. INS task seemed to require more thought.

I personally read over the job guide before I do a job. With IMIS, you can't really do that.

Periodic delays between screens.

It still had lock-ups and that you did not have the option to go back if you happened to hit the wrong button during operational checks.

Typical prototype bugs.

The user interface. The hourglass should consistently go to a place on the screen where it is visible. As, the PMA is transitioning, it is quite confusing. There is no cue that the machine is busy. It actually prints "Press F1 for OK," when you can't. Also, having three methods to select an option is not a good idea. Use F1, F8, and Select consistently, not F1 for this F8 for that and Select for something else. Use either the thumb knob or arrow keys.

The fact that steps were given only one step at a time in the job guide portion. It can slow down a job.

It was a little heavy. A keyboard would have been convenient. When troubleshooting wires, it could be more specific about the whereabouts of some of the components, i.e., "station 88 disconnect...." A little slow at times.

The speed of the software. No link between part number and serial number removed (with work order close-out).

IMIS is slow.

Slow to process information at times.

Keys sometimes hard to press; desired result doesn't occur.

At times was a little slow.

In the short time I used the IMIS, I can't really say that I disliked anything about the system.

The pros definitely outweigh the cons. However, IMIS seems to sometimes get into slow modes, i.e., changing from screen to screen, giving completed task information.

I did not like the reliability factor. If you are in the middle of a job and it goes down, it tends to be frustrating.

The time it took to process during RF operations, the amount of breakdowns, and a few minor misleading or irritating display errors.

The screen is difficult to see unless you are looking at just the right angle. Sometimes when it is thinking, it doesn't let you know what it is doing and you are apt to get frustrated with it when you try to do something and it won't respond.

About the only thing I didn't like about IMIS is the thumb control for the cursor.

Nothing.

Speed, poor pictures, one step at a time. A page down or up to proceed would be nice.

It's too hard to get back to a step you miss. It takes too long to change screens at certain times.

How slow it is in processing information! Having to skip from F1 to the select key.

Question: What Changes would you make to improve the system?

Comments:

Less redundancy, e.g., safe for maintenance question being asked over and over. Make safe for maintenance an option to get to if you want to.

Allow the maintainer the option to look over the job before doing a job, so there are no surprises.

Speed of processing improvements.

Try and add some more prompts to the screens on choices. Breakdown pictures of Lures could be a little more clear. Color screens would be great.

More detailed pictures, faster response time.

Fix user interface (see previous user interface comments).

Speed up the reaction time. It was slow at times.

Speed up the PMAs.

Continuity in using the system, i.e., no shifting between F1 and SELECT keys.

Give better instructions for some of the more obscure items, for example, disconnects and transformer assemblies.

If you remove a part it should update the work order. The speed and everything else was fine.

Process faster.

Add schematic/wiring diagram type diagrams. This is a must. From time to time we see a problem that "can't happen" according to the FI. In other words, there is nothing listed for "Pilot Detectable" or "Maintenance Detectable" faults. Thus there is no fault tree to follow. Since the avionics systems of the F-16 are so integrated, a component not in the "suspected bad" system can cause a malfunction. The only way, in most cases, to troubleshoot these kind of discrepancies is to break out the schematics and "chase" the signal flow.

Response time.

Other than a few minor computer glitches, the system worked well, It would be nice if the PMA could operate longer on a charged battery.

Make the system convert from page to page faster and fix the RF problems.

Improve reliability and response time.

Increase the amount of back light, drop a glare shield on it (maybe with solar panels), put a zoom feature on the pictures.

Try to speed it up on some things, make the keyboard a little more user friendly, unless you are really careful, the screws can become a FOD hazard in the cockpit.

I think that maybe a separate detachable mouse or maybe a track ball would be a good improvement.

Quicker response times to the commands.

Speed.

Use a process or unit to speed it up.

Make the system memory faster. Sometimes it takes awhile between choices.

Speed up some of the reaction times. It was slow at some times.

Question: Other comments?

Comments:

Good/excellent idea.

IMIS would be an outstanding system to supplement existing tech data. However, its ability to present the "big picture" of a problem appears to be limited and it does not explain why something is happening.

Thank you for the training on the jet. The hands-on troubleshooting was very helpful. People "in charge" were friendly and informative as to what was going on with the program.

It is difficult to form a real opinion of the system at this time, as a fair judgment can't really be made until the system is truly "in the field." But, I like what I see so far, and have every bit of confidence that your team will perfect this system and put it into use. It has been a pleasure to work with you.

Overall a good system.

IMIS definitely needs to be an integral part of the AF. The AF will benefit greatly from the implementation of IMIS.

I think this program is a good one and has been very educational for me.

Great project - quite a bit better than having to use TOs. I hope I see it in use somewhere, sometime before I get out of the service or even in the civilian world.

I really hope this system takes effect soon.

Very good unit. If it were not for the waiting on the computer, it would be great.

I like the idea and the concept! I hope to see it in the future on all A/C systems.

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