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Aircraft Maintenance Intuitive Troubleshooting (AMIT)

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Warfighter Readiness Research Division
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Human Effectiveness Directorate
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FOR THE COMMANDER

//SIGNED//

DANIEL R. WALKER, Colonel, USAF
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14. ABSTRACT

The Aircraft Maintenance Intuitive Troubleshooting (AMIT) program was a 37-month, 6.3 funded research and development effort sponsored by the Air Force Research Laboratory's Human Effectiveness Directorate, Logistics Readiness Branch (AFRL/HEAL). Its purpose was to research and design an electronic maintenance aid for on-aircraft maintainers as they troubleshot difficult system malfunctions. The goals were to reduce troubleshooting time and increase troubleshooting accuracy, thereby increasing aircraft availability. Program execution occurred in three phases: 1) Explore the user environment, aircraft maintenance processes, expert technician troubleshooting strategies and resource utilization, and other past and current research work in pertinent areas in order to derive program requirements. 2) Design and develop the maintenance aid, evaluate and select applicable COTS tools, and validate the program requirements and associated design through end-user evaluations. 3) Plan and conduct a field demonstration test and analyze the results. Three hypotheses were proven during the 4-month field test at Luke AFB AZ: 1) Subjects using AMIT required less troubleshooting task time as compared to current processes, 2) Subjects using AMIT committed fewer errors compared to current processes, and 3) Novices using AMIT performed at or near the level of current experts not using AMIT.

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Forward: About This Document

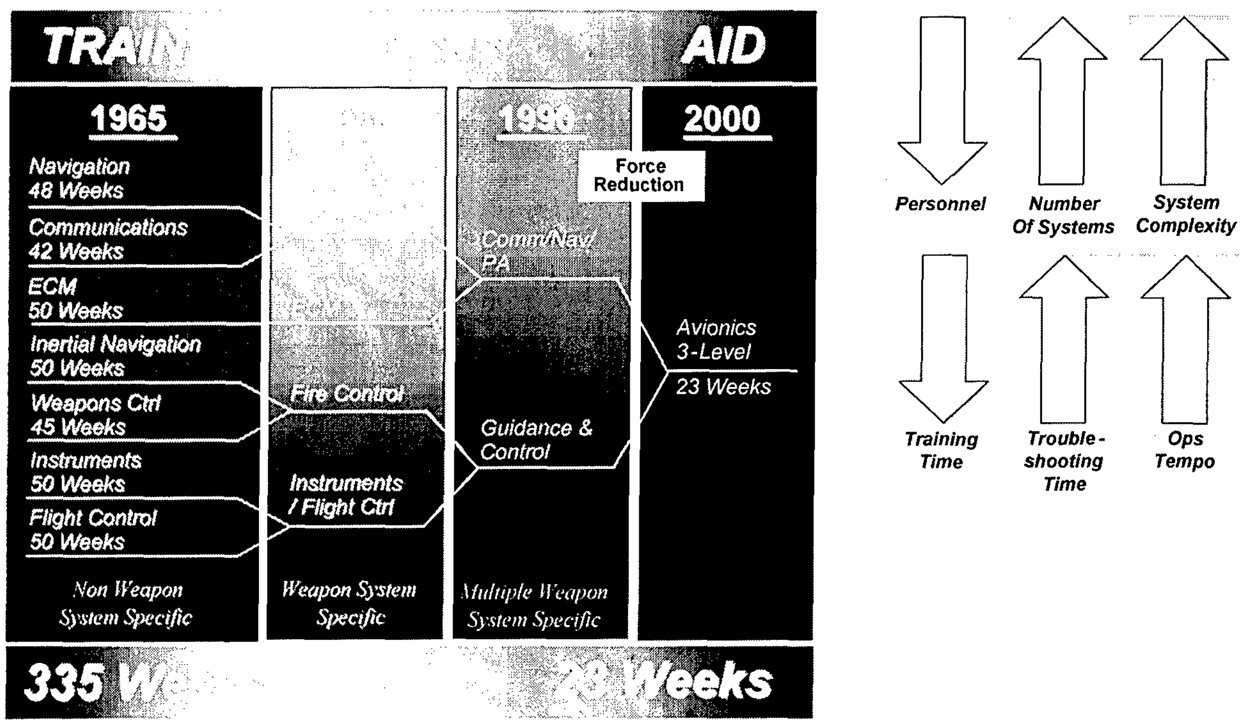
This document does not detail all activities and data associated with the Aircraft Maintenance Intuitive Troubleshooting (AMIT) program; rather, it provides the reader with an overview of AMIT program activities, with detailed focus on the AMIT Field Demonstration Test (FDT) and Results. Referring to the documents cited in the bibliography will provide the reader with detailed descriptions of other relevant program activities and results.

In this document, the AMIT team attempts to strike a balance in describing, in as concise and understandable a manner as possible, the execution and results of the AMIT program to three disparate groups of readers:

- the scientific community, whose primary interest is the applicability of the research and test methods used, the validity of the results, and the effort's contribution to the body of scientific knowledge
- the aircraft maintenance community, whose interests include the outcome of the test and the improvements the solution offers in the work place
- Air Force commanders and executives, who want assurance that fielding the AMIT solution is useful and cost-efficient

Preface

The impetus for the AMIT program was twofold. First, troubleshooting-intensive aircraft maintenance career fields have undergone over 40 years of consolidations, generalizations, and manpower cuts, while operational tempo and weapon system complexity have increased. (For example, the current "Avionics" Air Force Specialty Code (AFSC) was once seven separate career fields, as illustrated below.) Second, information technologies and applications have matured to the point they can be leveraged to significantly improve aircraft maintenance and troubleshooting processes.



- 1960's AFSCs (Avionics = 7 career fields) - highly specialized training, not weapon system specific
- 1970's - AFSC mergers begin to become less technically specialized
- 1980's - more mergers even less specialized, increasing weapon system specialization

- 1990's - more mergers begin weapon system specialization dilution (more than one aircraft)
- 2000's - final merger (Avionics now one career field)
- **Bottom line:** Technicians now receive less training, are less specialized, and thus require more on-the-job-training at their first assignment. These conditions are exacerbated by expert attrition and daily workload due to force reductions and high operational tempos.

The Aircraft Maintenance Intuitive Troubleshooting (AMIT) program was conceived at the U.S. Air Force Research Laboratory's Human Effectiveness Directorate as a revolutionary step in providing domain-specific knowledge and information to those in aircraft troubleshooting roles. AMIT's objective was to integrate modern approaches to human-computer interaction, knowledge-centric enterprise data management, interactive electronic technical manuals, and collaboration tools into a synergistic capability that can improve human performance. The resulting solution integrates and presents complete holistic knowledge and information at the point of task, allowing technicians to more effectively troubleshoot aircraft system problems. This capability was demonstrated in a field test that objectively measured performance, including task times, error rates, and user acceptance.

Acknowledgements

As with any major work, this document would not exist without the foresight, support, and plain hard work of several people.

First, to the Aircraft Maintenance Intuitive Troubleshooting (AMIT) Program Team at AFRL/HEAL - Chris Curtis (Program Manager), Chris Burneka, and Alex Nelson and to the men in uniform stationed there; Captains Tony Aultman, Derrick Barthol, David Lemery, Christian Randall, Brian Tidball, and Vaughan Whited, we thank each and every one of you on behalf of the NCI Team for your enthusiastic support. It was always readily and graciously given and was invaluable in seeing us through to a successful outcome.

Second, our deepest and warmest thanks to the many servicemen and women who participated in user groups, underwent interviews, provided materials, tested the AMIT solution, and supported the test environment, especially SMSgt. Ronald Miller at Luke AFB, AZ. We hope the time and effort you invested soon will benefit you, your fellow maintainers, and the maintainers who follow you.

Finally, our admiration and appreciation to all the others on the NCI Team who worked long and hard for this success: Scott Bachmann, Chris Colvin, Tony Gossard, Jackie Grody, Robin Joseph, Mark Miller, and Dave Roberts, and to our friends and teammates at the University of Dayton Research Institute (UDRI): Drew Bowers, Carlton Donahoo, Megan Gorman, Mary McWesler and Laura Militello.

1 Summary

1.1 Overview

Aircraft Maintenance Intuitive Troubleshooting (AMIT) was conceived at an AFRL/MAJCOM technical interchange meeting, with the realization that technician performance was an under explored and possibly significant contributor to aircraft availability and readiness. Heretofore, the Air Force (AF) has given much attention to maintenance levels, repair locations, spares, tools and test equipment, technician training, specialty codes, and even to job performance rating. Little attention, however, has been paid to factors affecting the technician's performance – the "how" and "why" technicians perform the way they do on the flightline. How do they successfully return highly complex aircraft to service in spite of the known limitations and challenges imposed by the maintenance process and related support and supply systems?

Given this line of thinking, the Logistics Readiness Branch of the Human Effectiveness Directorate of the Air Force Research Laboratory (AFRL/HEAL) initiated a 6.3 advanced research and development (R&D) program and awarded the AMIT contract to NCI Information Systems, Incorporated (NCI) in December 2003. NCI is an information technology services provider with relevant skills in the aircraft maintenance and maintenance management domains.

Discussions with subject matter experts (SMEs) in the program's formative days focused attention on the decision points in the maintenance process; specifically the decisions a technician makes while isolating a failed component. When a technician selects the correct fault isolation path or opts to remove and replace the appropriate line replaceable unit (LRU), time is effectively used, resource consumption minimized, and the aircraft is made available to perform its mission in minimum time.

The SMEs pointed out that fault isolation time or troubleshooting time is one of many contributors to an individual aircraft's total downtime. Other significant contributors to aircraft downtime include routine maintenance, periodic inspections, and repairs or replacements of routine problems like a worn or flat tire. Estimates validated by information from squadron preparedness briefings and ad hoc reports from the Integrated Maintenance Data System (IMDS), indicated 25-30% of all documented aircraft maintenance activities involve some form of troubleshooting. Therefore, a significant improvement in troubleshooting efficiency logically ought to have a material impact on downtime at an aggregated level such as a squadron. While any improvement ought to be evident at the organizational level, troubleshooting efficiency can only be achieved by improving the average troubleshooting proficiency of the organization's technicians.

After preliminary discussions, the AMIT Team decided to spend program resources researching ways to significantly improve Novice and Expert maintainers' troubleshooting proficiency, thereby increasing the organization's total aircraft availability. The Team did not attempt to determine how large the average proficiency improvement would need to be to become significant or even how much improvement was possible for the average maintainer. If the former approach were successful, the point would be proved with a developed and field-demonstrated solution. Following the later course would, at best, simply prove such an improvement were possible and yield yet another metric for the AF to collect.

For this effort, the AMIT Team defined troubleshooting as "a process that includes all activities related to determining the correct repair action." This included all activities from problem notification through repair verification; understanding the current discrepancy, technical data research, historical maintenance data research, determining aircraft condition, and communication. Two factors affecting troubleshooting efficiency were considered: **task time,** or the time taken to effectively isolate a faulty component, and **task accuracy,** a measure of the effectiveness of the decisions made during the troubleshooting process. Every experienced troubleshooter refers to some documents, establishes some mental reference points, and then takes a mental leap from observed symptoms to solution, trusting his or her intuition to guide the direction and distance of the leap. Hence, the word "intuitive" was included in the AMIT program title, to emphasize the cognitive dimension of troubleshooting.

By emphasizing the cognitive aspect of troubleshooting, the Team resolved to research and develop an effective method(s) of helping troubleshooters make well-informed decisions by providing complete, timely, and contextually relevant data, information, and knowledge at the point of task. Troubleshooters who more quickly form an accurate mental model will not only take less time to troubleshoot each failure, but, over time, their mental model would expand in size and increase in accuracy, resulting in each intuitive act becoming a well-placed step rather than a blind leap.

When matched with the necessary technical tasks and the program's 37-month duration, AFRL's desire for a three-phase approach almost naturally organized the effort into three 12-month phases along the following lines:

- *Defining Customer Needs and Processes*: A period of research and data gathering activities including extensive literature reviews, cognitive task analyses (CTA), user process interviews, product evaluations, user groups, and technical interchange meetings along with several iterations of analysis, summarizations, and data reductions. The result was a complete, current, and comprehensive understanding of aircraft system troubleshooting on a typical AF flightline. The resulting set of functional needs, or requirements, for the AMIT solution took into account related maintenance processes and issues, as well as technician attitudes, thought patterns, and protocols.

- *Design and Development*: Early in this phase, the AMIT solution's five primary features crystallized: task-specific electronic technical data presentation, focused history searches, electronic logbook (passive and active data collection), data/information/knowledge amalgamation, and collaboration mechanisms. (See CDRL A016, "System Design Description"). Design and development time was equally spent developing, integrating, and testing the components of the technical data presentation and the historical search capabilities, as well as identifying, down-selecting, installing, and configuring the commercial-off-the-shelf (COTS) hardware and software components necessary to support the troubleshooting environment. Also during this phase, the Field Demonstration Test (FDT) plan was developed, validated, and approved. Queries of actual maintenance data sources were developed and the data subsets were tested to assure fitness for use in the field demonstration test.
- *Field Demonstration Test*: The third phase of the program entailed conduct of the FDT wherein the AMIT capability was evaluated via a laboratory-style experiment conducted in a realistic (flightline troubleshooting) environment. The test was conducted, the results analyzed, conclusions were drawn, and recommendations were made. The test was constructed to directly compare the "*As-is*" or current AF flightline troubleshooting methodology with the "*To-be*" methodology that included the AMIT solution. The Team developed test cases designed to challenge personnel in two Air Force Specialty Codes (AFSC): Avionics (2A3X2) and Electrical and Environmental (E & E) (2A6X6). These specialties were selected because successful troubleshooting of Avionics and E & E

systems consistently relies on "intuitive leaps" of maintainers and because these systems were found to be both technically and operationally problematic. A mix of 72 F-16 aircraft maintenance personnel including system specific Novices, system specific Experts, and non-system specific Experts (i.e. Crew Chiefs) participated in the experiment.

1.2 Principal Results

Successful testing of the AMIT solution in a field maintenance environment demonstrated that the solution is a militarily-useful technology. The demonstrated savings of 45 to 55 minutes per repair would result in over 47,000 clock hours saved, per year, on the fleet of F-16 Block 40/42 aircraft. This hourly figure equates to roughly 5.4 aircraft available for service per year. While no direct metric exists to translate the hourly figure into an 8-Hour Fix Rate, such an improvement would undoubtedly be significant.

Of equal importance, senior maintainers across the AF who reviewed the AMIT requirements and verified their validity have repeatedly expressed their support for the AMIT program and affirmed the immediate need for the solution in the field. Periodic briefings and demonstrations to AF senior leadership at the wing, command, and headquarter levels met with equal approbation. To date, the program has received unilateral support from the Air Combat (ACC), Air Education and Training (AETC), and the AF Special Operations (AFSOC) Commands. Senior logistics leaders at Headquarters AF (HAF/A4M) have seen demonstrations of the solution and signed a Memorandum of Understanding (MOU) supporting the AMIT program and its objectives.

1.3 Recommended Course of Action

In light of the test results and command support, the AMIT Team recommends transitioning the AMIT concept and software to ACC for final development and initial implementation, with the ultimate goal of implementing the solution throughout the AF. The Team believes the solution can be fully developed and ready for initial deployment in 24 months or less, well within the 5 years stipulated in DoDI 5000.2, "Operation of the Defense Acquisition System."

2 Introduction

2.1 Aircraft Maintenance Intuitive Troubleshooting

Flightline aircraft maintainers have an excellent record of identifying and correcting causes of system and subsystem failures and keeping highly complex, aging aircraft flying. These technicians continue to troubleshoot an aircraft until the problem is isolated; sometimes aided and sometimes hindered by current maintenance and logistics processes and procedures or even the maintenance environment itself. It takes little analysis to determine that the success or failure of the troubleshooting process hinges on the technician.

The AF has placed great emphasis on enterprise process improvements and cost reduction programs. However, it has placed less emphasis on the processes and systems supporting the technician in making effective troubleshooting decisions at the task level. Thus, while the current troubleshooting environment is functional, it is often inefficient. The AMIT program's purpose was to identify the factors (especially human factors) that contribute to inefficiency in troubleshooting intensive portions of the maintenance process, and devise proven (i.e., field tested) means to improve efficiency. If those means are demonstrated to be statistically significant, their introduction into the AF maintenance environment should have a meaningful, positive impact on aircraft availability.

2.1.1 Terminology

For this effort, the AMIT Team defined **troubleshooting** as "a process that includes all activities related to determining the correct repair action." This included all activities from problem notification through repair verification; understanding the current discrepancy, technical data research, historical maintenance data research, determining aircraft condition, and communication.

Efficiency and inefficiency are inverse indicators of a technician's troubleshooting **proficiency**, where **proficiency** is a vectored quantity (i.e., a mathematical representation of a physical phenomenon where direction is as important as the value; "velocity" and "force" are two such physical phenomena). In other words, proficiency is a combination of the time it takes **(troubleshooting time)** to make *the right* decision **(troubleshooting accuracy)**.

The AMIT program did not measure AF technicians' troubleshooting proficiency quotients or even attempt to develop a method for doing so. Had that been done, however, an efficiency distribution with an upper bound of some practicable state of **proficiency** and a lower bound of an acceptable state of **sufficiency** would result as shown in Figure 1 (Gott, S. P. 1998).

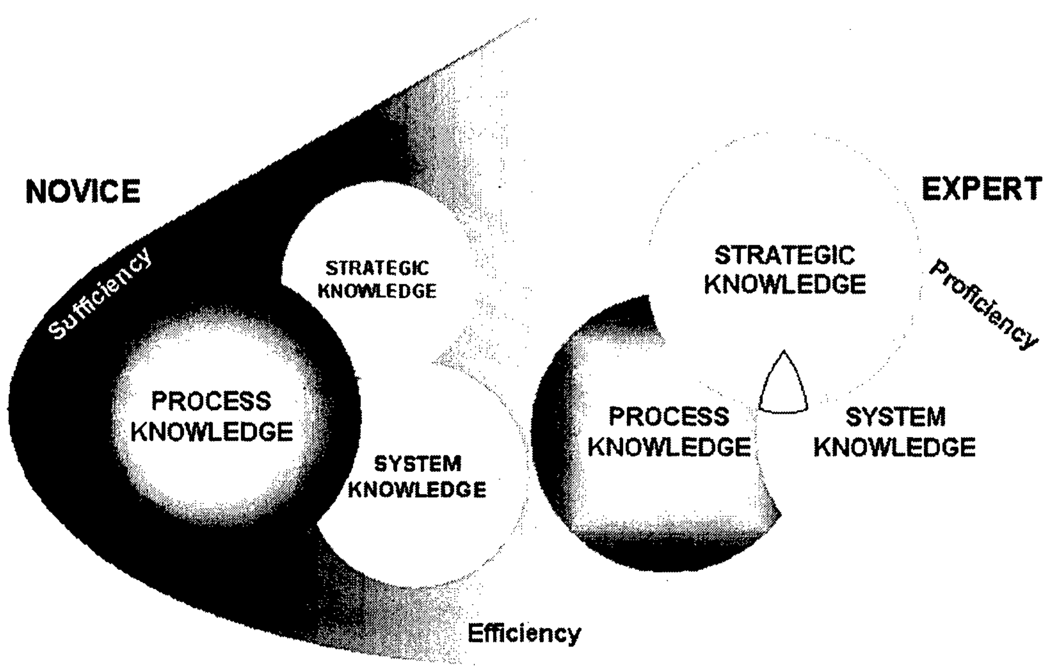


Figure 1 Relationship of Most Key Terms Used in the AMIT Program

A statistical analysis of this theoretical efficiency distribution would yield a dividing line. Those troubleshooters with proficiency quotients to the right of the line would be considered **Experts** (i.e., **proficient**) and those to the left would be considered **Novices** (i.e., **sufficient**) for the purposes of the AMIT program. (NOTE: In the AMIT program, an individual technician's proficiency quotient is neither a reflection of his or her fitness for the job nor a measure of their personal performance. The AMIT program simply used this theoretical construct of proficiency quotients to describe two classes of test subjects, "Novices" and "Experts".)

As illustrated in Figure 1, the troubleshooting process entails three domains of cognition: **process knowledge**, **strategic knowledge**, and **system knowledge.** A troubleshooter leaves technical school with relatively more **process** than **system** or **strategic knowledge**.

Process knowledge is general in nature. The troubleshooter knows the theory and operation of the major components and subsystems on an aircraft (e.g., jet engines, landing gear actuators, etc.), how to find and use the technical documentation, test equipment, and fault isolation procedures. The availability of accurate, current information is critical in this cognitive domain (Gott S. P.1989).

System knowledge is the knowledge of a specific type of system, or set of interrelated functional components on the aircraft, including design-specific interactions and interfaces with other systems. System knowledge in the Novice is minimal, but grows with on-the-job exposure to a myriad of details and situations. Experiential increases in process and system knowledge result in a more mature level of **strategic knowledge** (i.e., mental database) or reference model of facts and experiences that support better decision making. The relative size of the spheres in Figure 1 depicts the development of the troubleshooter's process, system, and strategic knowledge over time.

At this point, the troubleshooter's personality, training, innate abilities, and on-aircraft experience bring **process**, **system**, and **strategic knowledge** into balance and heighten the technician's ability to synthesize information, reducing **task time**. The technician's proficiency quotient is now to the right of the average and he or she can be acknowledged as an **expert**. Unfortunately, this **corporate knowledge** will soon be lost due to advancement, retirement, or separation, until another troubleshooter completes his or her pilgrimage to proficiency.

2.1.2 Theory

The AMIT program's strategic goal was to identify a set of changes to the current AF maintenance environment that would improve troubleshooters' overall proficiency, thereby increasing aircraft availability. The team's first challenge was to identify a set of metrics that establish a baseline, against which improvement could be measured. It was evident from the program's outset that the metrics collected during the field demonstration test (FDT) were vital to the program's credibility in the scientific community and critical to a business case for transitioning the solution into the field if the solution were successful. Those metrics and the practicability of their collection would be considerations in both the design of the solution as well as the design of the FDT.

Troubleshooting proficiency, a function of both task accuracy and task time, would be an ideal metric. Plotting the average troubleshooters' proficiency quotients over time would yield a trend line's direction and indicate whether or not changes in the AF's maintenance environment were beneficial or detrimental. In addition, its slope would indicate the rate of change. A positive and large slope would indicate that the changes were increasing proficiency; aircraft availability trend analyses should show a corresponding improvement. Since the AF does not presently derive such a metric, developing and validating a methodology for doing so was outside the spirit, scope, and resources of the AMIT program. The team had to identify other practicable metrics to quantitatively demonstrate any performance improvements afforded by the solution.

Since increased aircraft availability was the desired outcome, and the AF has long established data collection mechanisms and defined formulae for calculating aircraft operational availability (A_0), the AMIT team considered using those measurement systems and metrics as a barometer for the AMIT solution's success. However, a review of the existing AF A_0 metrics revealed that, for the purposes of this experiment, such an analysis would include such a large number of variables the program would have to extend much beyond the contract's period of performance, while also confounding the experimental findings.

A third approach considered was to measure the solution's impact on recurring or intermittent problems. If the solution caused significant improvements in task accuracy, then the number of problem reports closed with a *Can Not Duplicate* (CND) entry, and those determined to be *repeats* (same problem on the next flight) or *recurs* (same problem on the subsequent four or five flights, depending upon aircraft type) should decrease noticeably. Here again, deriving a viable test that involved flying the same aircraft four or five times under controlled conditions was not practical.

The AMIT team finally settled on a 3 x 3 x 2 mixed factorial experimental design that would yield empirical, objective results. The test was designed to include three (3) groups of test subjects: system specific Novices, system specific Experts, and a non-system specific Experts (referred to as "Novice," "Expert," and "Crew Chief," respectively, throughout the remainder of this document). These groups completed maintenance tasks of three (x 3) degrees of difficulty: Simple, Moderate, and Complex, to be accomplished With or Without (x 2) the AMIT solution.

Task Time and Task Accuracy measurements would be collected and the troubleshooting proficiencies of the test groups would be compared and contrasted. Any improvements in proficiency would become the basis for predicting the improvements of larger population groups. (See CDRL A008, "Demonstration Test Plan")

During test planning and preparation, SMEs pointed out two separate, but equally effective, approaches to troubleshooting: 1) hard failures of discrete components, which lend themselves to a procedurally oriented fault isolation tree approach, and 2) repeat and recur problems that indicate soft or intermittent failures, which favor a divide-and-conquer signal tracing approach. In order to gauge the applicability of the AMIT solution to both troubleshooting approaches, the test included two different subsystems, one favoring each troubleshooting approach.

2.1.2.1 Extent of Theory

A by–product of the AMIT program was the documented paradigm of the AF flight maintenance environment shown in Figure 2. The paradigm provided a working framework within which the Team could rate and prioritize all change opportunities for their potential impact.

The AMIT Solution Space

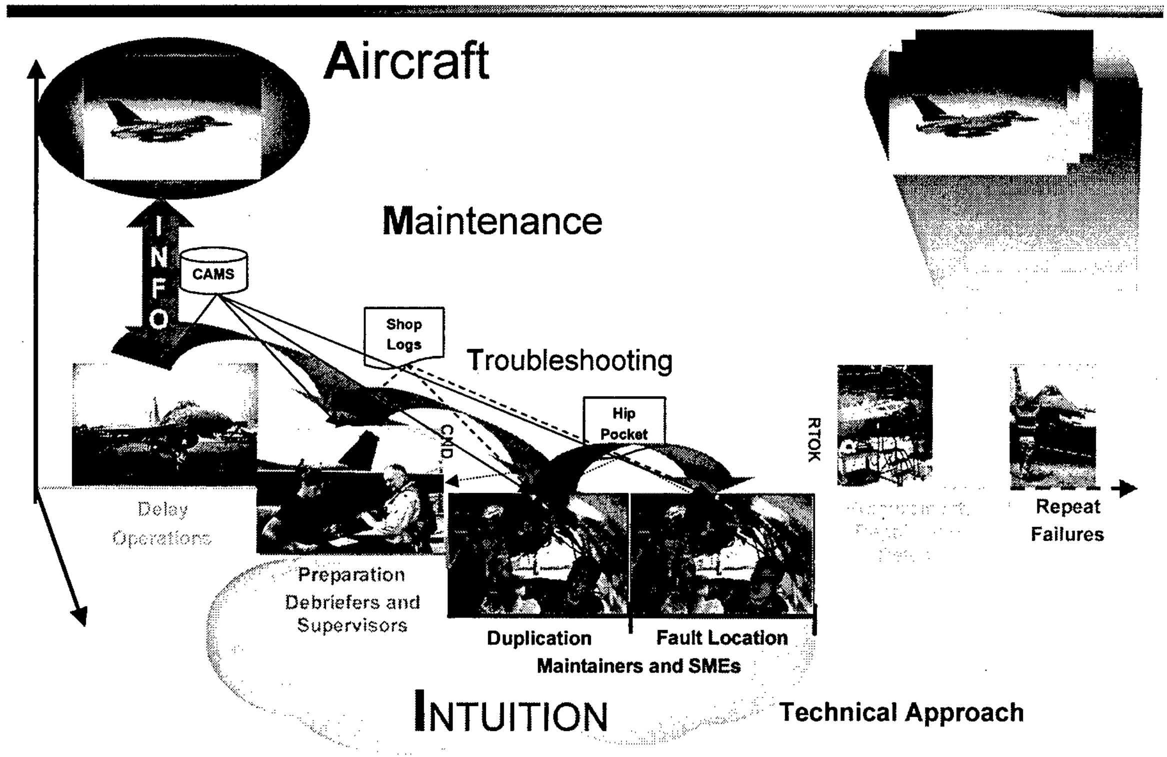


Figure 2 AMIT Covers the Entire AF Maintenance Environment

The three dimensions illustrate the three facets of on-aircraft maintenance believed to hold the greatest improvement potential. The x-axis represents the daily operational environment for a maintainer, predominately a time-based sequence of prescribed procedures and practices. If it can be assumed that all flightlines comply with Air Force Instruction (AFI) 21-101, "Aircraft and Equipment Maintenance Management," then, arguably, any improvement(s) made by the AMIT solution along this dimension are extensible across the entire AF.

The y-axis depicts the event-based nature of each maintenance scenario. Random failures occurring on an aircraft trigger and gauge the series of actions along the x-axis. Since random failures are the result of inherent characteristics in electrical, electronic, and mechanical devices and are not typically affected by human performance, the AMIT team left this area to those involved with the practical applications of probability theory.

The z-axis represents the cognitive dimension of maintenance. Troubleshooters synthesize data and information into knowledge, and make intuitive leaps from symptoms to solutions in this dimension. Cyclically, novices mature to experts as they gain wisdom and that wisdom or corporate knowledge erodes away as the experts move on with their lives and careers.

Thus, the AMIT program's problem/solution space encompassed the entire AF maintenance paradigm: doctrine, organization, training and education, materiel, leadership, personnel, and facilities; the physical work and information processing environments; the maintainer's psychological makeup, including the way they learn and think; their decision making skills and habits; and their character traits. All were considered to be within scope during the program's formative period.

2.1.2.2 Assumptions/Constraints

Because no initial constraints were imposed on either the problem or solution space, the AMIT Team had complete total freedom of thought about what the problems might be, what their underlying causes might be, and what solutions might affect positive changes. This mental freedom allowed the team to "think outside the box" regarding investigatory techniques, analytical approaches, and technologies.

The program's "freedom-of-thought" environment was nurtured by the initial operating assumptions stated at the AMIT program's outset:

- Any aspect of the current AF maintenance environment could be changed if the objective evidence provided confidence in the change's positive impact on human performance and the return on investment justified the resource expenditures.

This assumption gave the team the freedom to delve into any and every aspect of the current maintenance environment for its improvement potential.

- The AMIT program's efforts will result in the transition of one or more improved troubleshooting capabilities into the AF's System Development and Demonstration acquisition process and/or one or more changes to the current maintenance environment. This assumption not only bred an expectation of success, but it kept the team focused on deriving benefit to the troubleshooter. Moreover, this expectation established the need for efforts targeted toward successfully transitioning the AMIT solution from the program's outset. Other potential improvements in the maintenance process were identified, but if they did not directly benefit the troubleshooter, they were excluded from further consideration.
- No radical or disruptive changes will occur within the maintenance environment before the AMIT solution is fully developed and fielded. If such a change occurs, the cost analysis contained in this document would need to be reevaluated in light of the changed environment.

2.1.3 Purpose - Program Goals

In keeping with the restrictions upon 6.3 (Advanced Research) funds and the DoD 5000 series guidelines for technology development, the purpose was to identify an affordable increment of militarily-useful capability, to demonstrate that capability in a relevant environment, and describe how a system can be developed for production within a short timeframe (normally less than 5 years) (DoDI 5000.2, ¶ 3.6.7). In other words, the AMIT program had to design and develop a capability sufficient for a field demonstration, without fully developing the final fieldable solution.

2.1.4 Defining Customer Needs and Processes

Literature Reviews, Process Interviews, and Cognitive Task Analyses were chosen for the unique areas of insight they provided. The AMIT team believed that such a combination would paint a more accurate picture of the maintainers' thought processes, the maintenance environment, and the requirements for any solution intended to increase a maintainer's proficiency than any single technique. All three were conducted concurrently, because each targeted a different outcome: Literature Reviews to determine the state of knowledge and the state of technology as it pertained to the problem; Process Interviews towards discovering the current maintenance process; and Cognitive Task Analyses to determine how Novice and Expert maintainers mentally approached troubleshooting tasks.

2.1.4.1 Literature Review

A Literature Review (Lit Review) was performed to identify and scientifically qualify current and prototype technologies and research endeavors that might support the AMIT solution. Through this Lit Review, the AMIT team established user-based constraints, targeted key research findings for application, and identified additional research opportunities for future improvements to the maintenance environment.

Lit Reviews were conducted in two parts. Initially, the Team reviewed AFRL program reports in conjunction with Process Interview and Cognitive Task Analysis results to establish the Core Topic Areas listed in Table 1. An extended Lit Review then sought and analyzed Department of Defense (DoD) and academic works in the Defense Technical Information Center

(DTIC) and the Ohio Library and Information Network (OhioLINK) relevant to the Core Topic Areas.

Table 1 Core Topic Areas that Directed the AMIT Team Literature Search

Core Topic Areas	Reference Identifiers	# Documents Reviewed	# of Findings
Best Business Practices	BBP	3	5
Cognitive Task Analysis	CTA	13	28
Collaboration	COL	37	172
Decision Support	DSS	22	100
Integrated Human Interface	IHI	3	13
Maintenance	MTN	24	71
Models	MOD	4	18
Training	TRN	5	30
Transition	TRA	4	11
Other	OTH	4	63
Total Reviewed		119	511

Documents chosen for both reviews were analyzed and reduced to brief statements, or findings, with each expressing a single thought. The 830 statements, virtually verbatim extracts, were categorized and summarized into the 63 potential AMIT requirements shown in Figure 3.

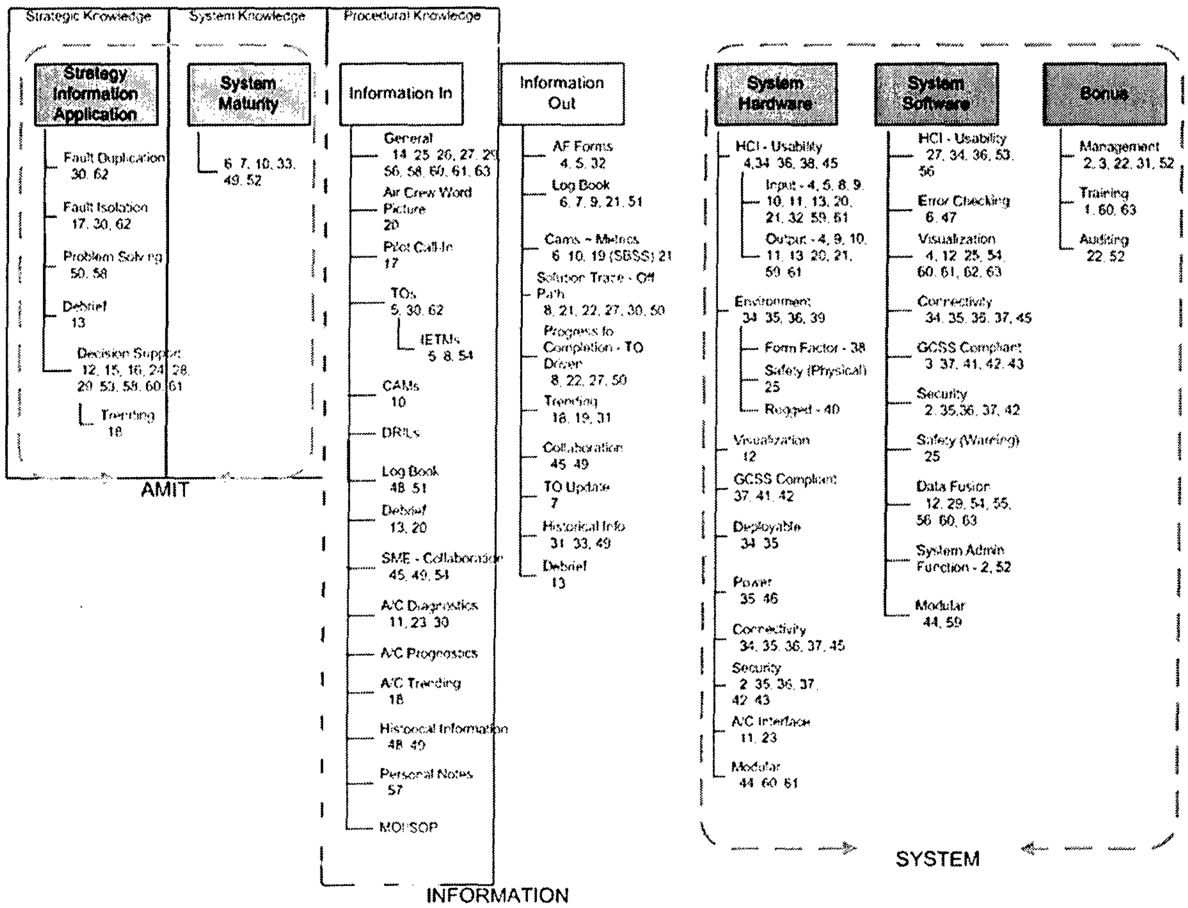


Figure 3 AMIT Solution Requirements Included Comprehensive Maintenance Processes

A full description of the methods used to build the complete AMIT requirements traceability matrix was provided in CDRL A017, "Systems Specification."

2.1.4.2 Process Interviews

In order to ensure that the AMIT solution would be "an increment of militarily useful capability," the Team conducted a series of process interviews to determine whether organizations and practices were indeed uniform across the AF. In all, 27 Process Interviews with subjects from ten different weapon systems, seven technical specialties, and two major commands demonstrated that the maintenance organization structures and processes were consistent across different AF wings, with very minor exceptions. The minor exceptions were due to the numbers of assigned maintainers and the type of aircraft, not to different maintenance philosophies, approaches, methodologies, or practices. The interviews uncovered some recurring themes that are indicative of problem areas for maintainers. Furthermore, it was determined that on-aircraft maintenance has not radically changed over the past 50 years and does not appear likely to change in the next 5 years. All process interview results were considered when the AMIT requirements were defined (See CDRL A017, "System Specification").

2.1.4.3 Cognitive Task Analysis

In order to understand the "intuitive" nature of troubleshooters, Cognitive Task Analysis (CTA) interviews were conducted to capture the thought processes that occur during aircraft system troubleshooting activities. The CTA focused on both Novice and Expert troubleshooter thought processes and information needs for cognitively difficult or complex maintenance tasks. Task Diagrams and Knowledge Audit techniques were used as the primary CTA instruments for this task. Task Diagrams yielded a procedural perspective on maintainer decision-making, while Knowledge Audits provided insight into Expert troubleshooting strategies and techniques. (See CDRL 017, "System Specification," for specifics on the AMIT CTA.)

Figure 4 depicts the similarities and differences between Novice and Expert AF on-aircraft maintainers' thought processes and awareness and usage trends of knowledge stores.

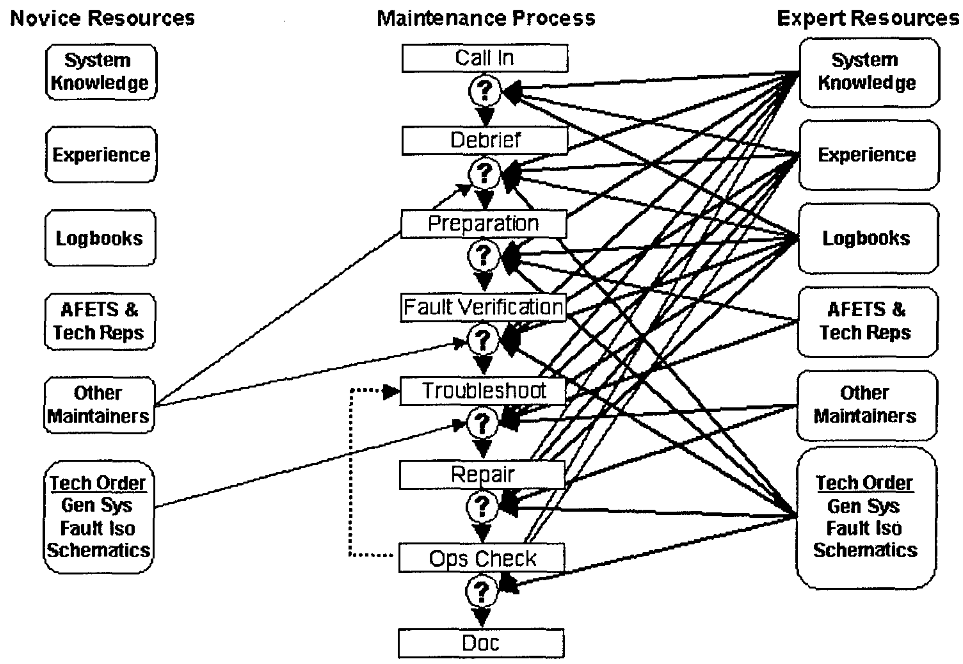


Figure 4 Expert Maintainers Think Differently Than Novices

An analysis was completed after each set of CTA interviews, and again when all sets were completed. High-level themes within and across interviews were identified using a Card Sort method. The findings were consistent with, and expanded upon, those from the Process Interviews. The CTA also identified three areas in the maintenance process that were most problematic, especially for Novice troubleshooters. These were debrief, problem duplication, and troubleshooting. As with the Process Interviews, the CTA contributed to the requirements for the AMIT solution (See CDRL A017, "System Specification").

2.1.5 Design and Development

Whereas very few constraints were placed on the AMIT problem and solution spaces, giving almost total freedom of thought during the research and conceptualization phases, the resulting requirements placed several constraints on the AMIT solution's design and development. The design and development requirements posed a set of often competing institutional, engineering, and human factors challenges as shown in Figure 5. The AMIT solution needed to support multiple weapon systems, be usable on the flightline, integrate easily into existing AF maintenance support systems and emerging architectures such as Global Combat Support System – Air Force (GCSS-AF), and intuitively improve troubleshooting across a range of maintainer skill levels.

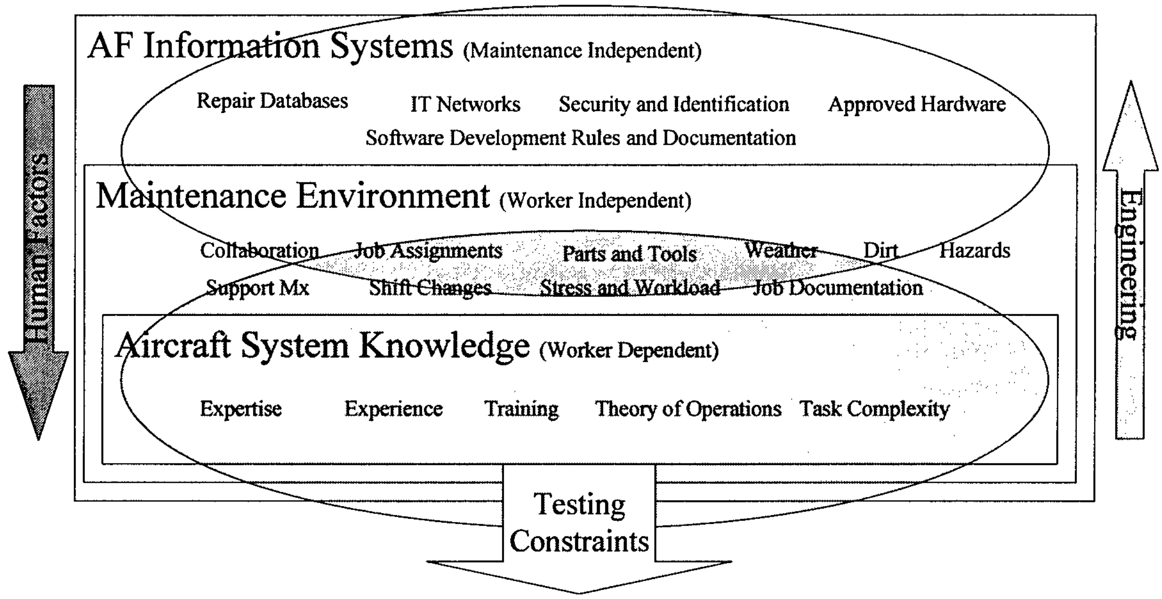


Figure 5 Competing Constraints of the AMIT Solution

The research revealed several promising techniques and technologies that will likely have a great impact on the maintenance of complex systems and troubleshooting one day, but few that were or would be mature enough to be incorporated into the AMIT solution and undergo field testing before the conclusion of the program.

Keeping focus on the troubleshooter, the Team reevaluated every requirement and challenge. Three overarching design constraints emerged during this requirements refinement: 1) improve troubleshooting, 2) integrate with established AF systems, and 3) transition easily into the flightline maintenance environment. The result was a system design description integrating existing AF maintenance data and applications, COTS software products, and a methodically designed, browser-based user interface to yield a job performance aid (JPA) within which basic functionalities of five core capabilities would be co-resident.

The five AMIT core capabilities are: (1) Visualization, (2) Cognitive Adaptation, (3) Process Adaptation, (4) Data Transformation, and (5) Collaboration (see Figure 6). Figure 6 also demonstrates the relationships of the capabilities to the types of knowledge shown in Figure 1. A full exposition of each of the capabilities, their derivation, and their relationships to one another was provided in CDRL A016, "Systems Design Description."

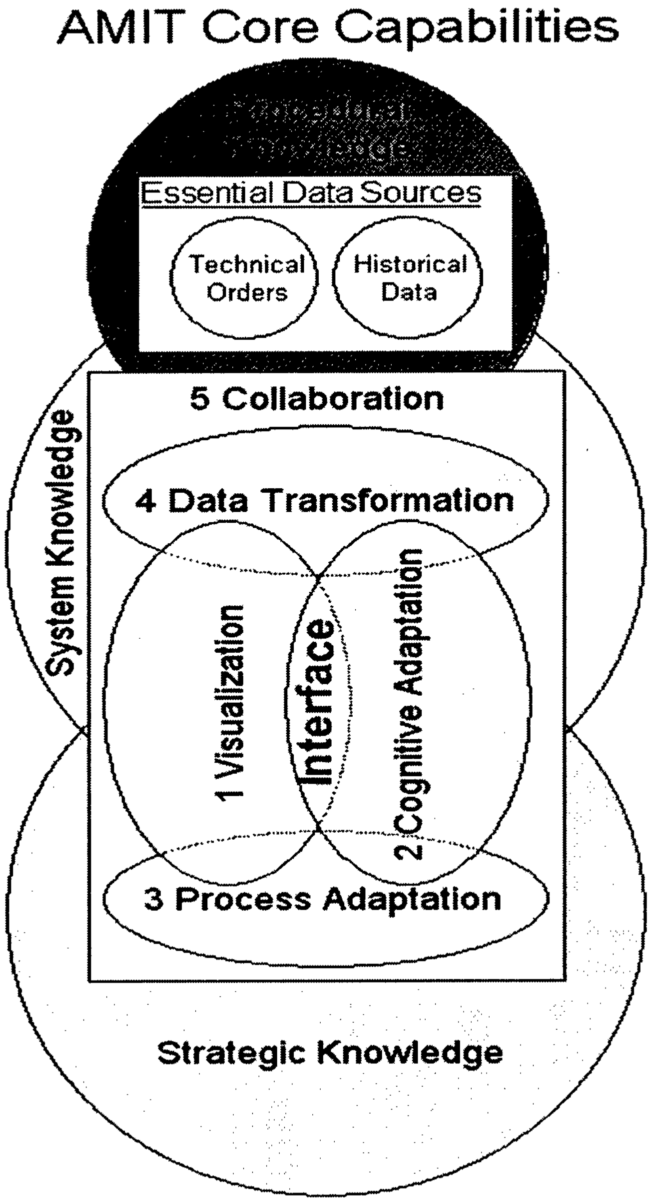


Figure 6 Co-resident Core Capabilities in the AMIT Solution

Thus, *the AMIT solution is neither a new technology, nor a collection of emerging, unproven technologies. Rather, it leverages existing data, maintenance applications, and information technologies in an innovative manner.* The use of technologically mature AF applications and COTS components enabled in a full scale system design will facilitate a final design and implementation phase of 24 months or less, as opposed to the 5 years allotted under the DoD's 5000-series acquisition framework.

The Screen Design matrix provided in CDRL A009, "Software Design Description," documents the transition from capabilities into the complete software architecture. CDRLs A010, "Software Requirements Specification" and A011, "Software User Manual," describes the browser-based user interface developed for the AMIT solution. The AMIT JPA is pictured in Figure 7 and consists of the device independent client solution installed on an e-tool qualified for flightline use. Ruggedized laptops were selected because they are already authorized for and in use on AF flightlines.

COTS laptops were used as servers to host the back office portion of the AMIT solution and to simulate standard AF maintenance support systems with which the fielded AMIT solution interfaced. Commercial Wide Area Network technologies were used to connect the two.

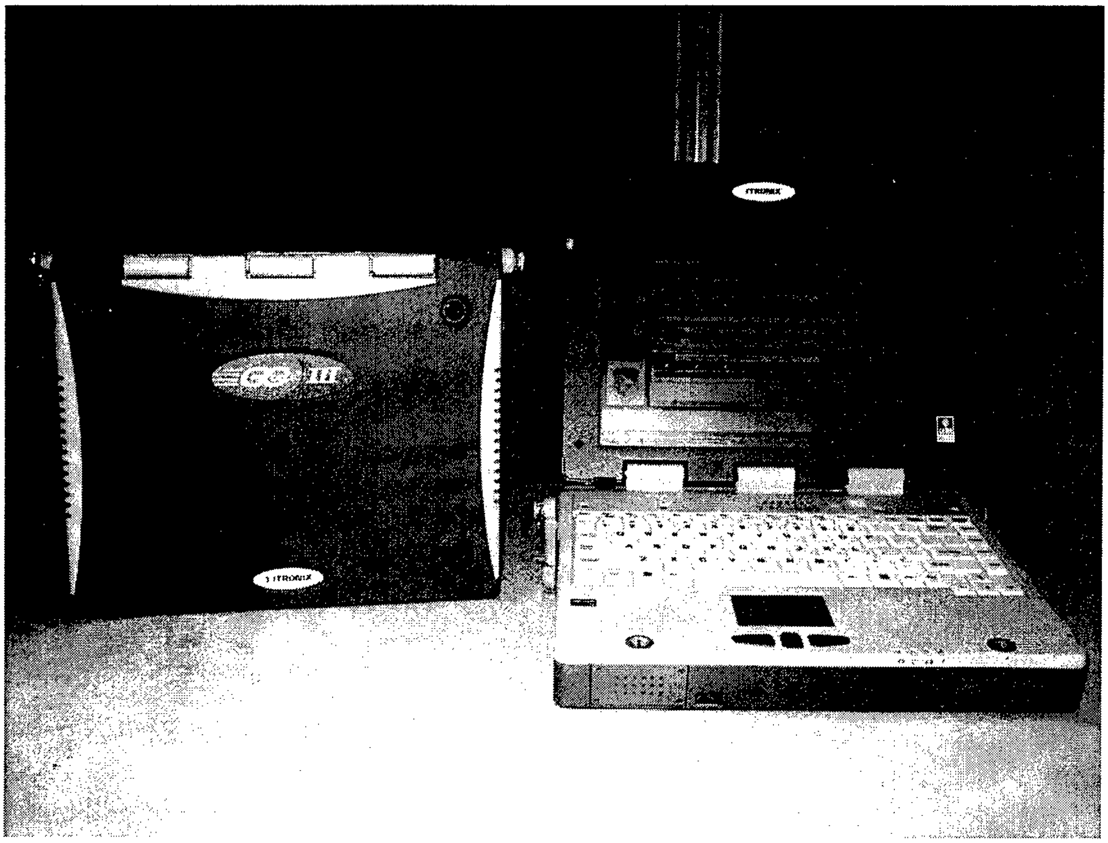


Figure 7 AMIT Job Performance Aid on Ruggedized Laptop

Expert maintainers were consulted throughout the research, design, and development of the AMIT solution, usually in a group forum. Aircraft Maintenance User Groups (AMUGs) were periodically held to ensure the team was addressing troubleshooter needs. The AMUGs verified the requirements, validated approaches and data, and participated in Design Consideration Tests (DCTs) when choices needed to be made between two seemingly equal technical approaches or solutions.

3 Test Methods, Assumptions, and Procedures

The goal of evaluating the AMIT JPA in the maintenance environment was to emulate, as closely as possible, the actual maintenance environment while quantifying improvements or degradations in task time, task accuracy, or both. Measured improvements would illustrate an "increment of militarily-useful capability" as "demonstrated in a relevant environment," (see CDRL A017, "System Specification") thereby satisfying the DoDI 5000.2 expectation of Technology Development efforts. The larger the improvement, the greater the cost-benefit associated with fielding the AMIT JPA.

3.1 Hypotheses

Three hypotheses were developed for the FDT. Formally stated, the AMIT hypotheses were:

- Hypothesis 1: Maintainers using the AMIT JPA will expend less total time troubleshooting and performing research than maintainers who don't use the AMIT JPA
- Hypothesis 2: Maintainers using the AMIT JPA will make fewer errors (diagnostic, unnecessary removals, and fewer repeat write-ups) than maintainers who don't use the AMIT JPA
- Hypothesis 3: Novice technicians using the AMIT JPA will successfully and efficiently troubleshoot difficult discrepancies at or near the same level Experts not using the AMIT JPA

3.1.1 Scope

AF leadership has consistently identified three areas of great concern to mission operations and support: 1) improved aircraft availability (e.g., readiness), 2) reduced cost, and 3) reduced deployment footprint. Figure 8 illustrates how the Team perceived reductions in task time, improvements in task accuracy, and increases in task proficiency logically impact these areas of concern. The FDT was scoped to quantify AMIT JPA impacts on aircraft availability and logistics labor costs. Deployment footprint was considered throughout the program, but thoroughly assessing and credibly quantifying footprint impacts proved to be outside the scope and beyond the duration of the program.

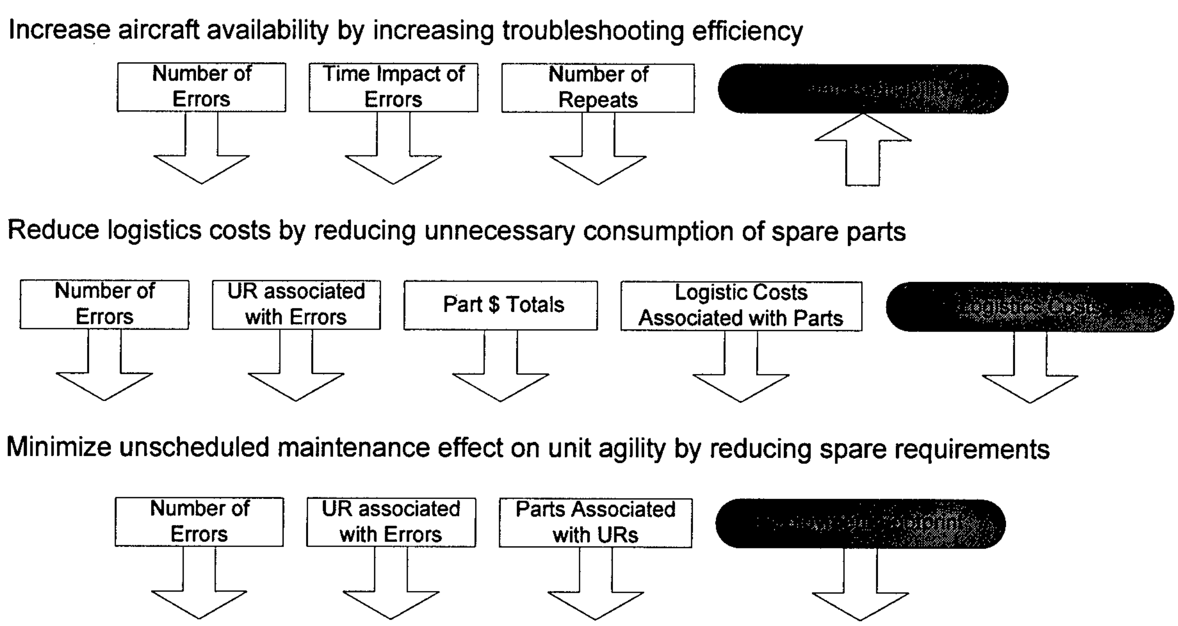


Figure 8 Positive Effects of AMIT on Critical AF Metrics

3.2 Testing Assumptions

CDRL A008, "Demonstration Test Plan," discusses the following assumptions pertaining to the FDT:

- The test environment will emulate a typical aircraft maintenance environment as much as possible
- Test data analysis, presentations, and reports will be concluded prior to contract completion
- Pilot Tests will be conducted prior to each test phase in order to:
    - Verify testing procedures
    - Confirm all system components are functioning as planned
    - Train evaluation team members on system and data collection procedures
- Tests will be conducted by AFRL/HEAL with support from the contractor team (NCI and UDRI)
- Data collection will be conducted by AFRL/HEAL with technical and administrative support provided by the contractor team
- FDT will occur at Luke AFB, AZ, over a 4-month period (June to September, 2006)

3.3 Methods

3.3.1 Experimental Design

The FDT experimental design was a 3 x 3 x 2 mixed factorial with repeated measures on one factor. The key metrics collected and analyzed were time and errors. Subjective feedback was collected, but not analyzed.

3.3.1.1 Test Variables

The experiment's independent variables were Technician Experience Type, Task Difficulty, and Tool Usage. The between-groups variable of Technician Experience Type consisted of three levels (Novice, Expert, Crew Chief). The within-groups variable of Task

Difficulty consisted of three levels (Simple, Moderate, and Complex). The between-groups variable of Tool Usage consisted of two conditions: without-AMIT JPA (*As-is)* and with-AMIT JPA (*To-be*).

The dependent variables were Task Time and Performance Errors. Task Time included total time elapsed, as well as the time needed to complete predetermined task segments. Performance Errors were categorized as described below and documented relative to a predetermined optimal path.

3.3.1.2 Apparatus

Equipment used in the FDT can be categorized as government furnished equipment (GFE), government furnished data, contractor furnished equipment (CFE), or contractor furnished software. It should be noted that all software was either COTS or developed in-house by the AMIT contractor team.

The GFE provided by the 56th Maintenance Group consisted of F-16C Block 40/42 aircraft with operational Avionics and E & E systems, all necessary Aircraft Ground Equipment (AGE), tools, test equipment, technical order (TO) repositories, and historical maintenance data typical of an aircraft maintenance unit.

The team evaluated the AMIT hardware and related test support hardware in the test environment and conducted pilot tests prior to FDT to ensure proper operation and sufficiency. AMIT JPA hardware included five laptops, two of which were Itronix Go-Book III (i.e., ruggedized laptops authorized for use as an e-tool on AF flightlines) and the remaining three were standard laptop computers: one functioned as the AMIT server, one as the SME "chat" workstation, and the third as the Integrated Maintenance Data System (IMDS) / E-logbook terminal. All but the IMDS / E-logbook terminal were wireless. The AMIT JPA provided the participants all needed information relating to the diagnostic scenario and simulated access to outside systems and sources.

The AMIT-developed and COTS software resident on the e-tools constituted the AMIT JPA, and incorporated the AMIT-identified features and capabilities required to achieve the program's objectives. The software was installed and evaluated via a pilot test in the test environment prior to the FDT. In addition to the AMIT-developed software, the test set-up included installations of TOMCAT and Jabber Chat Software for networking and on-line chatting in the *To-be* test cases.

3.3.1.3 Subjects

To ensure AMIT applicability across specialties, 24 participants were chosen from each of three Air Force Specialty Codes (AFSCs): Avionics (2A3X2), Electrical and Environmental (2A6X6), and Tactical Aircraft Maintenance, also known as "Crew Chief" (2A3X3). Avionics specialists were assigned a series of Avionics repair tasks, while the Electrical and Environmental (E & E) specialists were assigned a series of E & E repair tasks. Half the Crew Chiefs were assigned the Avionics tasks and half the E & E tasks. Thus, a total of 36 test subjects (24 specialists and 12 Crew Chiefs) participated in a given series of repair tasks. While no comparison between the Avionics and the E & E specialties was conducted, inclusion of both was essential to the experiment's integrity because of the different troubleshooting methodologies they invoke. Avionics specialists depend upon Built-In-Test/Self Test (BIT/ST) results to identify their troubleshooting strategy whereas E & E technicians largely depend upon human-observed and reported problems. While both approaches also have numerous commonalities, inclusion of members from both groups was necessary for a realistic representation of the AMIT end-user community. Additionally, the inclusion of both groups increased opportunities to extrapolate results across systems and airframes.

3.4 Procedure

3.4.1 Schedule

Participant schedules were based on an average discrepancy isolation/repair time of no more than 3 hours per discrepancy. The schedule (provided in CDRL A008, "Demonstration Test Plan") included four 3-week sessions with 72 total participants (24 participants from the each of the three specialty codes).

As depicted in Table 2, participants were scheduled for a Training session (T), and three subsequent discrepancy isolation/repair sessions (S), (S1, S2, and S3). Three difficulty levels are depicted as well: Simple, Moderate, and Complex (-S, -M, -C). Examples shown in the "Week Days" columns indicate a typical activity schedule for a given day. For example, the notation *T/S1-S* indicates the subject received training (as denoted by *T*). *S1-S* denotes his/her first session was the Simple difficulty level. *As-is* and *To-be* situations were scheduled and controlled by the test team, and are not depicted in the table. Each participant took part in no more than two sessions per day, lasting no longer than 7 hours per day. Maximum total time per participant was 2 duty days.

Table 2 Typical Session Schedule for Two AMIT Test Subjects

Avionics Session 1				**Week Days**				
	Participant Number	**Tool**	**Technician Type**	**M**	**T**	**W**	**T**	**F**
Week 1	1	Without AMIT	Expert	T/S1-S **0800 -- 1200**	S2-M/S3-C **0700 -- 1300**			
Week 1	2	With AMIT	Novice	T/S1-M **1100 -- 1500**	S2-C/S3-S **1300 -- 1800**			

Presentation order of the three levels of Task Difficulty (Simple, Moderate, and Complex) was counterbalanced across all conditions and identical for the Avionics and the E & E repetitions. The six possible orders were distributed evenly across the three Experience Levels (Novice, Expert, and Crew Chief) and the two AMIT JPA usage conditions (*As-is* and *To-be*). Additionally, participants were grouped by three so that within a group, each Experience Level was present, and order of Task Difficulty was represented orthogonally, via Latin Square methodology. The purpose for the counterbalanced design was to offset any potential effects due to order, practice, or fatigue.

3.4.2 Experimental Tasks

Six test situations were developed, one for each task difficulty level (Simple, Moderate, and Complex) and for each system (Avionics and E & E). While the actual discrepancy remained identical across AMIT JPA usage, specific versions of each test situation was developed for AMIT JPA usage conditions. For example, format requirements for logbook and TOs differed between the with-AMIT JPA (*To-be*) and without-AMIT JPA (A*s-is*) conditions. Although the format was different, every effort was made to ensure that the information content and data for both conditions remained parallel.

Three levels of Task Difficulty were addressed, as follows: *Simple* tasks involved a maintenance discrepancy in which the current Fault Isolation (FI) tree indicates an acceptable solution via the first or second option listed. *Moderate* tasks involved a maintenance discrepancy in which the solution was listed last on the FI tree. For example, such a situation might have involved a complex or lengthy fault isolation procedure with wiring as the last option or a discrepancy that occurred intermittently. *Complex* discrepancies involved one of three situations: 1) a CND occurrence where no FI tree option was appropriate, 2) a "problem persists" situation, where the Technical Data identified a corrective action if the discrepancy was persistent (Repeat/Recur) and all previous attempts at solving were unsuccessful; and, 3) an "unanticipated" solution in which the FI tree identified via the fault code did contain the solution.

Each test situation is listed below and is labeled based on the system affected. The list includes the fault code mapping to the fault isolation information, a sample write-up that would be found in the aircraft forms, method and location of problem insertion, and the targeted solution. The six situations used are:

- Avionics Situation 1 -- Radar Altimeter
    - Fault Code 9462XD (Simple)
    - Aircrew Write-up: Radar Altimeter (RALT) inoperative
    - Insertion Method: Pull Circuit Breaker 3943CB71
    - Location of Problem Insertion: Door 2204
    - Targeted Solution: signal data converter (SDC)
- Avionics Situation 2 -- Fire Control Radar
    - Fault Code 9461XD (Moderate)

- Aircrew Write-up: Fire Control Radar shut down in flight. Would not reset.
- Insertion Method: 9461K2 Clip pin X
- Location of Problem Insertion: Panel 2206
- Targeted Solution: 9461K2 relay

- Avionics Situation 3 -- Fire Control Radar
  - Fault Code 9461AJ (Complex)
  - Aircrew Write-up: Had MFL 093 and 112 in flight. Would not reset.
  - Insertion Method: N/A -- Problem can not be duplicated on ground
  - Location of Problem Insertion: N/A
  - Targeted Solution: Absolute pressure regulator
- E & E Situation 1 -- External Power
  - Fault Code 2440MH (Simple)
  - Aircrew Write-up: During quick turn, aircraft would not accept external power
  - Insertion Method: Relay 2441K1 Clip pin A1
  - Location of Problem Insertion: Panel 3312 and 3308
  - Targeted Solution: 2441K1 relay
- E & E Situation 2 -- Air Conditioning
  - Fault Code 2160BH (Moderate)
  - Aircrew Write-up: Air Conditioning goes full cold in both Auto and Manual
  - Insertion Method: 2161K2 Clip pin A3

    - Location of Problem Insertion: Panel 2101
    - Targeted Solution: Cabin temperature control valve

- E & E Situation 3 -- Air Conditioning
    - Fault Code 2160XF (Complex)
    - Aircrew Write-up: Repeat, defog stayed on all the time
    - Insertion Method: 2161K1 Clip pin A2
    - Location of Problem Insertion: Panel 2101
    - Targeted Solution: 2161K1 relay

3.4.3 Data Collection Instruments

This section describes the equipment and techniques used by the FDT team to collect performance data and subjective feedback.

3.4.3.1 Measuring Task Time

Using a stopwatch total Task Times were collected, including individual times associated with specific processes and/or sub-processes. Task Time was measured in terms of overall time elapsed from beginning (fault ID) to end (correct fix identified via ops check), in addition to predetermined task segments. Examples of task segments included time spent collaborating with an SME, searching through the TOs, troubleshooting, and conducting searches of historical documentation. Certain task segments were assigned standard times; for example, estimated travel time between aircraft and hangar, and time to remove and install components.

This granular collection and analysis of time data allowed quantification of AMIT JPA impacts at the process and sub-process levels. Comparisons between *To-be* and *As-is* conditions reflect Task Time performance improvements afforded by the AMIT JPA. As described in the Results section, this comparison was conducted across the entire task, as well as between subtasks. Also, by grouping like steps together, such as collaboration or historical research, analysis identified the effects of individual capabilities across the complete maintenance process. This approach also allowed the optional exclusion of time contributions outside the scope of the FDT, such as repair time or part acquisition time, which for purposes of the test, were given typical constant values.

Figure 9 depicts the granular time collection strategy, spanning the overall maintenance process. It identifies the individual processes impacted by the AMIT JPA and denotes whether each process was measured during the FDT or assigned a standard time. If the Repair Verification failed after the first pass through the process, the four processes spanned by the "1 to n cycles" bar were looped. That is, the maintainer was permitted to start over at "Time to Isolate." The number of "loops" as well as the times for each process within each loop were collected and analyzed to identify AMIT JPA impacts.

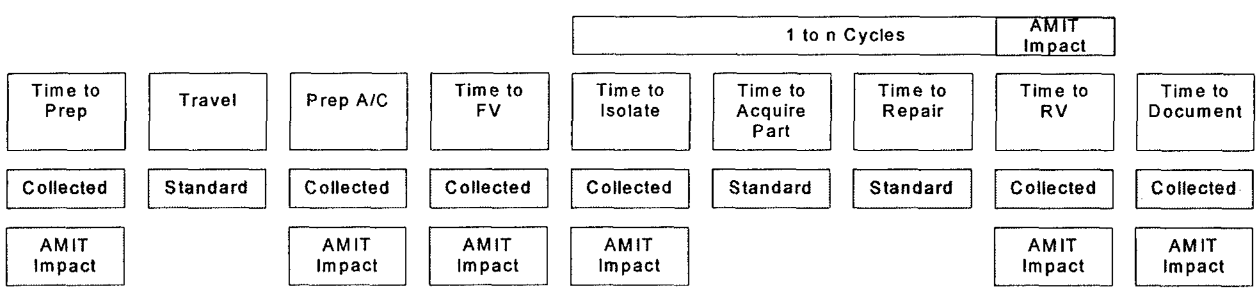


Figure 9 FDT Task Segments and Measurement Approach

Collaboration and historical maintenance data research are important strategies for understanding difficult maintenance problems. To accomplish collaboration or historical research in the *As-is* environment, the maintainer must physically travel to an "access point" for collaboration or historical data research (e.g., phone, e-mail, in person for collaboration, logbook, or IMDS terminal). This would have required him/her to secure the aircraft prior to travel and prepare the aircraft upon return; therefore, these times were included as part of the total time for the function. Multiple occurrences of such actions were allowed and included as part of the analysis. Figure 10 illustrates the means by which the granular data collection strategy allowed comparison of collaboration or historical research between the *To-be* and *As-is* conditions.

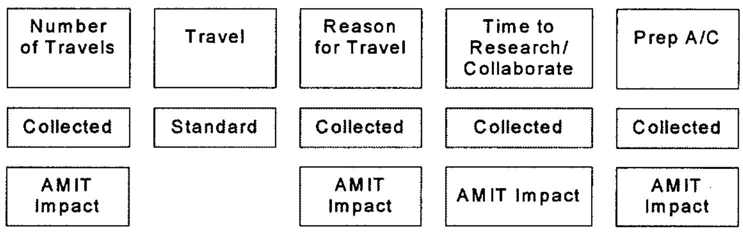


Figure 10 Collaboration and Historical Research as Part of Overall Repair Time

3.4.3.2 Measuring Task Accuracy

Using an optimum solution set developed and validated for each discrepancy, maintainer actions were logged and evaluated for accuracy. Two categories of decision errors were created for the FDT based upon the underlying cause for the incorrect decision. *System Presentation* errors were those caused by either the AMIT JPA or existing technical data presenting incorrect or incomplete information to the test subject. *User Interpretation* errors were those where the test subject misunderstood, misapplied, or simply did not absorb the information presented by the AMIT JPA or existing technical data.

Maintainers participating in the FDT, however, exceeded expectations with regard to the original definition of Task Accuracy. The concept of an "error" was initially defined as "a repair decision not consistent with the optimum repair solution," with a cause rooted at the user and/or system level. These instances, however, were rarely observed. Therefore, task accuracy was redefined to include either *Critical Errors* or *Non-critical Deviations* from the optimum solution.

Critical Errors were those leading directly to an incorrect repair (e.g., using the wrong TO or performing the wrong repair). Non-critical Deviations were instances in which the technician omitted an ops check or a sub task listed in the tech data (e.g., conducting Inertial Navigation System alignment in the Fire Control Radar tasks), but nonetheless successfully completed the repair.

4 Test Results

4.1 Presentation of Results

The FDT comprised two separate, parallel tests: One addressed Avionics-related systems and the second addressed E & E systems. Direct statistical comparisons between the two were never planned, but the results for both are provided concurrently, so the reader may make notional comparisons in the patterns of results contained within each specialty.

4.1.1 Quantitative Results

Statistical Analyses were accomplished via an Analysis of Variance (ANOVA), or F-Test statistic. When described in the body text of this report, data presentation uses the following format: $F(dfv,dfe) = f$, $(p = p)$ where dfv is the degree of freedom associated with the variable, dfe is the degree of freedom in the error term, f is the numeric value of the f ratio, and p is the measured alpha value, indicating the probability that statistical significance was due to chance or sampling error. Post hoc t-test statistical analyses were performed, where appropriate. Results were categorized by system (Avionics and E & E) and measure (Time and Errors). Tables of descriptive statistics and ANOVA summary tables are provided within each section.

4.1.1.1 Task Time

The mean total task time for each Avionics test scenario is provided in Table 3 and Table 4 provides the results of the ANOVA for the Avionics condition task time analysis.

Table 3 Descriptive Statistics for Avionics Task Completion Times

Task Completion Time (Minutes) - Avionics				
	Difficulty			Grand Average
Experience	**Simple**	**Moderate**	**Complex**	**(Usage by Experience)**
As Is	**95.95**	**119.77**	**218.19**	**144.64**
Crew Chief	96.01	124.13	235.96	152.04
Novice	105.66	110.88	247.05	154.53
Expert	86.18	124.31	171.56	127.35
To Be	**55.00**	**72.61**	**181.98**	**103.20**
Crew Chief	57.14	89.29	208.39	118.27
Novice	59.58	74.93	187.25	107.25
Expert	48.30	53.63	150.31	84.08
Grand Average (Difficulty):	**75.48**	**96.19**	**200.09**	

Table 4 Avionics Task Completion Time ANOVA Summary Table

Variable	Sum of Squares	Df	Mean Square	F	p
Tool Usage (T)	**46361.138**	**1**	**46361.138**	**17.765**	**.001**
Experience (E)	**18224.528**	**2**	**9112.264**	**3.492**	**.043**
T x E	866.912	2	433.456	.166	> .05
Error	*78291.951*	*30*	*2609.732*		
Difficulty (D)	**321004.747**	**2**	**160502.373**	**99.816**	**< .001**
D x T	543.082	2	271.541	.169	> .05
D x E	13043.697	4	3260.924	2.028	> .05
D x T x E	4309.008	4	1077.252	.670	> .05
Error	*96479.053*	*60*	*1607.984*		

As hypothesized, the main effect of Tool Usage was significant for the Avionics task scenarios ($F(1,30) = 17.77$, $p = .001$). Participants using the AMIT JPA successfully completed the repair process roughly 41 minutes faster than those who used available maintenance resources.

The main effect of Task Difficulty was significant for the Avionics task scenarios ($F(2,60) = 99.82$, $p < .001$). Post hoc pairwise comparisons indicated that the Difficult condition yielded greater times to complete than the Moderate condition ($t(35) = 9.40$, $p < .001$), and the Moderate condition yielded greater times to complete than the Simple condition ($t(35) = 2.55$, $p < .01$).

No significant interactions were observed for Task Time in the Avionics task condition. The mean total Task Time for each E & E test scenario is provided in Table 5.

Table 6 provides the results of the ANOVA for the E & E condition Task Time analysis.

Table 5 Descriptive Statistics for E & E Task Completion Times

Task Completion Time (Minutes) – E & E				
	Difficulty			Grand Average (Usage by Experience)
Experience	Simple	Moderate	Complex	
As Is	**90.45**	**319.18**	**148.30**	**185.05**
Crew Chief	97.42	324.44	135.48	185.78
Novice	85.51	316.49	119.94	173.98
Expert	88.41	316.61	189.49*	198.17
To Be	**51.16**	**284.89**	**72.55**	**136.26**
Crew Chief	52.70	291.33	93.29	145.77
Novice	52.73	279.36	65.68	132.59
Expert	48.05	283.97	58.70	130.24
Grand Average (Difficulty):	**70.80**	**302.03**	**110.43**	

*Reflects higher than expected value due to one outlier. See section 4.2.2.1.

Table 6 E & E Task Completion Time ANOVA Summary Table

Variable	Sum of Squares	Df	Mean Square	F	p
Tool (T)	**66896.356**	**1**	**66896.356**	**41.257**	**< .001**
Experience (E)	**333.339**	**2**	**1666.669**	**1.028**	**> .05**
T x E	4459.003	2	2229.502	1.375	> .05
Error	*48644.170*	*30*	*1621.472*		
Difficulty (D)	**1100987.085**	**2**	**550498.542**	**384.087**	**< .001**
D x T	9220.059	2	4610.030	3.216	.047
D x E	3801.651	4	950.413	.663	> .05
D x T x E	9645.289	4	2411.322	1.682	> .05
Error	*85995.851*	*60*	*1433.264*		

As hypothesized, the main effect of Tool Usage was significant for the E & E task scenarios ($F(1,30) = 41.26$, $p < .001$). Similar to the Avionics test, participants using the AMIT JPA successfully completed the repair process roughly 50 minutes faster than those who used available maintenance resources.

The main effect of Task Difficulty was significant for the E & E task scenarios ($F(2,60) = 384.09$, $p < .001$). Post hoc pairwise comparisons indicated that the Moderate condition yielded greater task times than the Difficult condition ($t(35) = 18.66$, $p<.001$), and the Difficult condition yielded greater task times than the Simple condition ($t(35) = 3.28$, $p<.01$). No other main effects were found to be statistically significant.

The interaction of Tool Usage x Task Difficulty was marginally significant ($F(2,60) = 3.22$, $p = .047$). Figure 11 illustrates the relationship between Tool Usage and Task Complexity. The difference between *As-is* and *To-be* completion times is greatest in the Complex task condition; however, post hoc analysis revealed the strongest effect of Tool Usage for the Simple ($t(34) = 6.34$, $p <.001$) and Moderate tasks ($t(34) = 6.19$, $p <.001$); and a slightly weaker but still significant effect of Tool Usage for the Complex task (t(34) = 3.41, p <.01). This was likely due to increased variability in *As-is* and *To-be* Task Times in the Complex task condition, as depicted by the vertical error bars.

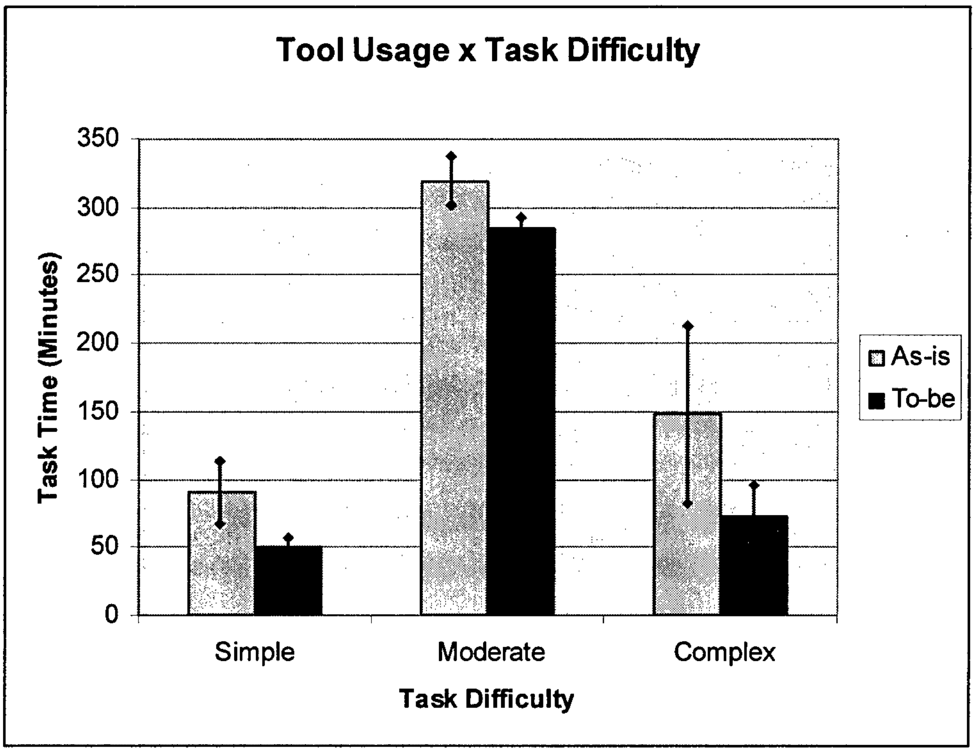


Figure 11 Tool Use x Task Difficulty Interaction on Task Time

4.1.1.2 Task Accuracy

Using the error definition methodology described in section 3, no "System Incomplete" or "System Incorrect" error categories occurred during the FDT. All observed errors fell under the predefined categories of "User Incomplete" and "User Incorrect." In lieu of error data oriented toward pinpointing the root cause as the system and/or the user, errors were reclassified more simply as *Critical Errors* or *Non-critical Deviations,* as noted in 3.4.3.2 above.

Six Critical Errors occurred during the Avionics task; all occurred in the *As-is* condition with five erroneous navigations through the paper TO. The remaining Critical Error occurred when a maintainer intentionally, but incorrectly, chose a repair not prescribed by the appropriate

FI TO. Because the total number of Critical Errors were minimal across all participants and conditions, statistical analysis was not conducted on Critical Error data.

For Non-critical Deviations, technicians using the AMIT JPA deviated less often from the optimum resolution (i.e., made fewer Non-critical errors) as shown in Table 7. Nearly all Non-critical Deviations involved the technician omitting a procedure in the maintenance process, such as fault verification or a specific operations check. An unusual condition occurred when Expert technicians using the AMIT JPA made more Non-critical Deviations when completing the difficult repair task than Expert technicians conducting the same repair in the *As-is* condition.

Contrary to hypothesis, the main effect of Tool Usage was non-significant for the Avionics task scenarios ($F(1,30) = 1.46$, $p > .05$) as shown in Table 8. Participants using the AMIT JPA did not commit significantly fewer Non-critical Deviations than those who used currently available maintenance resources.

The main effect of Task Difficulty was significant for the Avionics task scenarios ($F(2,60) = 88.83$, $p < .001$). Post hoc pairwise comparisons indicated that the Complex condition yielded more non-critical deviations than the Moderate and Simple conditions ($t(34) = 12.54$, $p<.001$), and the Moderate condition yielded more Non-critical Deviations than the Simple condition ($t(34) = 12.91$, $p<.001$).

No significant interactions were observed for errors in the Avionics task condition.

Table 7 Descriptive Statistics for Avionics Non-critical Deviations

Non-critical Deviations – Avionics				
Experience	**Difficulty**			**Grand Average (Usage by Experience)**
	Simple	**Moderate**	**Complex**	
As Is	**0.44**	**2.56**	**3.67**	**2.22**
Crew Chief	0.83	2.33	3.83	2.33
Novice	0.00	2.50	4.50	2.33
Expert	0.50	2.83	2.67	2.00
To Be	**0.28**	**2.00**	**3.56**	**1.94**
Crew Chief	0.17	2.33	3.83	2.11
Novice	0.50	1.50	3.17	1.72
Expert	0.17	2.17	3.67	2.00
Grand Average (Difficulty):	**0.36**	**2.28**	**3.61**	

Table 8 Avionics Non-critical Deviations ANOVA Summary Table

Variable	Sum of Squares	Df	Mean Square	F	p
Tool (T)	**3.000**	**1**	**3.000**	**1.462**	**> .05**
Experience (E)	**1.556**	**2**	**.778**	**.379**	**> .05**
T x E	2.889	2	1.444	.704	> .05
Error	*61.556*	*30*	*2.052*		
Difficulty (D)	**202.667**	**2**	**101.333**	**88.831**	**< .001**
D x T	.889	2	.444	.390	> .05
D x E	5.111	4	1.278	1.120	> .05
D x T x E	7.556	4	1.889	1.656	> .05
Error	*68.444*	*60*	*1.141*		

Eighteen Critical Errors were observed in the E & E task scenarios. All Critical Errors occurred in the *As-is* condition. Five errors were incorrect navigation through the paper based TO. Four were the result of entering completed session information into the e-logbook against the wrong aircraft. The remaining nine errors occurred when a technician intentionally, but incorrectly chose a repair not prescribed by the appropriate FI TO. As with the Avionics task, the total number of Critical Errors were minimal across all participants and conditions; therefore, statistical analysis was not conducted on Critical Error data.

Average Non-critical Deviations for the E & E tasks are depicted in Table 9. As hypothesized, the main effect of Tool Usage was significant for the E & E task scenarios ($F(1,30) = 7.80$, $p < .01$) as shown in Table 10. Participants using the AMIT JPA committed fewer Non-critical Deviations than those who used available maintenance resources.

No significant interactions were observed for the measure of Non-critical Deviations.

Table 9 Descriptive Statistics for E & E Non critical Deviations

Non-critical Deviations – E & E				
Difficulty / **Usage by Experience**	**Simple**	**Moderate**	**Complex**	**Grand Average (Usage by Experience)**
As Is	**0.61**	**0.89**	**0.39**	**0.63**
Crew Chief	0.67	0.67	0.17	0.50
Novice	0.33	0.67	0.00	0.33
Expert	0.83	1.33	1.00	1.06
To Be	**0.11**	**0.28**	**0.22**	**0.20**
Crew Chief	0.00	0.33	0.17	0.17
Novice	0.17	0.33	0.17	0.22
Expert	0.17	0.17	0.33	0.22
Grand Average (Difficulty):	**0.36**	**0.58**	**0.31**	

Table 10 E & E Non-Critical Deviations ANOVA Summary Table

Variable	Sum of Squares	Df	Mean Square	F	p
Tool (T)	**4.898**	**1**	**4.898 7**	**7.802**	**.009**
Experience (E)	**2.722**	**2**	**1.361**	**2.168**	**> .05**
T x E	2.463	2	1.231	1.962	> .05
Error	*18.833*	*30*	*.628*		
Difficulty (D)	**1.556**	**2**	**.778**	**2.979**	**> .05**
D x T	.963	2	.481	1.844	> .05
D x E	.556	4	.139	.532	> .05
D x T x E	.593	4	.148	.567	> .05
Error	*15.667*	*60*	*.261*		

4.1.1.3 Task Proficiency – Novice vs. Expert Performance

Hypothesis 3 stated, for complex tasks, performance of Novice maintainers using the AMIT JPA would approach that of Experts using current methods. Test results confirm that, when completing the Complex task, *To-be* Novice performance approached or exceeded *As-is* Expert performance. Four one-tailed, independent sample t-tests were conducted for the combinations of specialty (Avionics, E & E) and performance measure (Task Time, Non-critical Deviations), in the Complex task condition. Performance measures of the *To-be* Novice were not significantly different from the *As-is* Expert for Avionics completion time ($t(10)=.74$ $p > .05$), Avionics Non-critical Deviations ($t(10)=.38$, $p > .05$), and E & E Non-critical Deviations ($t(10)=1.27$, $p > .05$). For E & E task completion times, Novice performance using the AMIT JPA was significantly *shorter* than Expert times in the *As-is* (i.e. without the AMIT JPA) condition, for the Complex task ($t(10)=2.07$, $p < .05$).

4.1.2 Qualitative/Subjective Results

Participants were given a Likert scale questionnaire regarding their use of information sources to help prepare for or accomplish a repair prior to starting their first test scenario. The information sources included: Logbook, IMDS, TOs, communication with other maintainers, technical representatives, and management-level maintenance personnel. On a scale of 0 ("never") to 5 ("often"), participants were asked to rate the frequency of interaction with each of the above information resources.

After completing all maintenance tasks, participants were given two short (one page) questionnaires. The first asked them to compare the difficulty of the following task elements versus everyday maintenance tasks: *Research, Collaboration, TO Access, Logbook Use, Media, and Transport of Media to/at the Aircraft.* The second asked them to rate the "value added" by the AMIT JPA in each of the same task elements.

4.1.2.1 Resource Use

Results for the Avionics group indicates both Novice and Expert maintainers tended to consult with other maintainers to help with a difficult repair. Novices were less likely to contact a technical representative, while neither group indicated they contacted management-level maintenance personnel for assistance. Consultations were usually conducted face-to-face rather than by telephone or electronic means. All technicians indicated a likeliness to prepare for a job using IMDS, historical logbook information, and in-depth, preparatory study of technical orders. The findings are consistent with those of the CTAs discussed in section 2.1.4.3.

Results for the E & E group indicates that both Novices and Experts tend to consult with other maintainers to help with a difficult repair, but are less likely to contact technical representatives or management-level maintenance personnel for assistance. Such contact is generally face-to-face, rather than by telephone or electronic means. Experts indicated a greater likeliness to prepare for a job with thorough research of IMDS and historical logbook information and in-depth review of TOs.

4.1.2.2 Comparison of Difficulty

After completing all simulated maintenance tasks, participants were asked to rate the difficulty of *Research, Collaboration, TO Access, Logbook Use, Media, and Transport of Media to/at the Aircraft* as compared to everyday maintenance tasks. The scale ranged from -3 (more difficult) to +3 (less difficult), with "0" indicating no difference in difficulty.

Those using the AMIT JPA felt the simulated maintenance task was less difficult than those using the current maintenance resource set. While all AMIT JPA users ranked the tasks as easier than everyday tasks, Novices gave the *To-be* condition stronger "easy" rankings than Experts, across all categories. Crew Chiefs' responses were mixed with regard to category; for *Research, Collaboration, Logbook,* and *Media Transport*, their responses were similar to those of the Novices. However, for *Accessibility* and *General Use of Media*, the responses were similar to those of the system Experts. Average ratings for participants in the *As-is* condition fell near 1.0 for all categories, indicating "slightly less difficult." In the *To-be* condition, average Novice ratings of difficult ranged from 1.8 to 2.6, while Expert ratings of difficulty comparison ranged between 1.0 and 2.0. In the *As-is* condition, all experience levels indicated that participating in the study was no less or more difficult than everyday work, while in the *To-be* condition, less experienced technicians gave AMIT more extreme "easy" ratings than did experienced technicians.

The E & E pattern of responses differed from the Avionics tasks. For example, technicians who performed the E & E tasks, regardless of whether they used the AMIT JPA, rated difficulty of the simulated tasks as easier than actual. A potential explanation of this result may be that many of the common E & E sub-tasks (i.e., lengthy operation checks and repairs) were not required for the FDT. One of the selection criteria for the test scenarios was length of subtasks, because they often increased the total test time, but did not provide any data pertinent to the AMIT JPA. This was an experimental design decision based on time constraints and the goal of the project.

4.1.2.3 Value Added

After completing all simulated maintenance tasks, participants were asked to rate the "value added" of the AMIT JPA for the following tasks: *Research, Collaboration, TO Access, Logbook Use, Media, and Transport of Media to/at the Aircraft.* The scale ranged from +3 (High value added) to -3 (High value subtracted) with "0" indicating no difference. All but two of the 36 Avionic responses fell between +2 and +3, the only significant differences in responses between groups involved *As-is* Novice and Expert specialists rating for *Collaboration.* While both groups gave positive value added ratings for this capability, their average rating was lower than the Crew Chiefs'. All ratings for value added except *Collaboration* fell at +2.6 to +2.8 out of a possible +3.0.

E & E data revealed a similar pattern. *Collaboration* was the low point, but still greater than 2 in all groups except *To-be* Novice (1.8).

4.1.2.4 Testimonials/Interviews

Participants were asked to comment on a variety of AMIT JPA capabilities and features. Participant feedback was resoundingly positive. Maintainers liked the automatic collection of logbook data and the focused history searches. They specifically indicated that the Line Replaceable Unit (LRU) history feature would be of great help. Another favorite was the focused TO search feature, which went beyond electronic format by providing the ability to automatically navigate to the appropriate location in the TO library based on current fault code.

Feedback on the FI history tool was mixed; several cultural issues may exist regarding feedback on this feature. Further elaboration is provided in the Results Discussion section (4.2).

Response to the collaboration capability was also mixed--although not all of the participants were convinced it would always work, especially when attempting to contact the aircrew, none particularly disliked it.

When asked if using AMIT would help make the Novice a better troubleshooter more quickly, the majority of participants responded "yes." Likely reasons for this response included instant access to the correct TO information, having access to path-to-resolution information, and the ability to look up LRU and FI histories. Opinions were mixed on what would occur if you removed the AMIT JPA after they had used it for some time, although most participants agreed that the AMIT JPA would leave a positive residual effect.

4.1.2.4.1 General Impressions

Participants were impressed with the ease with which they learned to use the AMIT JPA. Certain features, such as smooth transitions between screens and links, the layout of tabs to parallel the maintenance and troubleshooting process, were singled out as design features that made the AMIT JPA usable and user friendly.

4.1.2.4.2 Access to TOs

Participants generally agreed that having access to the TOs electronically would save tremendous time as opposed to walking to and from the support section to obtain TOs. Furthermore, technicians were impressed by the ease of navigation afforded by the electronic TO system utilized by the AMIT JPA.

4.1.2.4.3 Collaboration

Participants liked the collaboration capability, but expressed curiosity with regard to identifying available collaborators. Participants also questioned who, specifically, would give them the authority to talk to the aircrew or other personnel (i.e., Pro-super, expediter, supply, AGE, etc.). As with TO usage, participants indicated the AMIT JPA would save time by eliminating the need to secure the worksite and travel to meet with collaborators.

4.1.2.4.4 Research

Participants voiced praise for the ability to easily and quickly extract historical data from IMDS. They said they would be more willing to do more complete historical searches if they had the AMIT JPA.

4.1.2.4.5 Would AMIT Help the Novice?

Each participant was asked if he or she felt that the tool would help Novices become better troubleshooters more quickly. The consensus was "Yes!" because of resource availability (TOs, IMDS, collaboration) at the aircraft and the time savings associated with avoiding travel to TOs, IMDS terminals, and collaborators. Technicians also said that the AMIT JPA would help show Novices a better or more efficient way to accomplish tasks; specifically, referencing the FI history capability. Another positive involved the general layout of the graphical user interface (GUI). The tabs along the top of the interface provided a useful guide for Novices in terms of following the correct and logical path to repair. That, in general, would help keep Novices focused when troubleshooting. Some Experts felt the AMIT JPA would help Novices be more independent when troubleshooting, thereby freeing Experts to perform other tasks and less time helping Novices search TOs, IMDS, and other materials.

4.2 Discussion

4.2.1 "Errors" vs. Non-Critical Deviations – Implications

4.2.1.1 Definitions: Error vs. Non-Critical Deviation

Table 11 depicts the originally intended error classification methodology, with nine possible outcomes. A tenth outcome was added before testing, under the general classification of "usability." Usability errors were those not specific to the presentation or application of information, but rather were attributable to GUI design contributions to user mistakes.

Table 11 Errors per the Interaction between System and User Actions

		System		
		Correct	Incorrect	Incomplete
User	Correct	Best case, the system presents correct information and users perform correct actions. NOTE: Not an error.	System presents erroneous information; users likely choose one of two correct options: a) Follow incorrect information as presented or b) Realize information is not correct and follow correct alternative actions	System does not present all appropriate task information; users likely choose one of two correct options: a) Perform correct actions based only on system presented information, b) Realize that presented information was incomplete and follow correct alternative action
	Incorrect	System presents correct information and users absorb all presented information, however they interpret it incorrectly. Likely Result: Incorrect maintenance action	System presents erroneous information; users incorrectly interpret information. Likely Result: Incorrect maintenance action	System does not present all appropriate task information; users do not correctly interpret presented information. Likely Result: Incorrect maintenance action
	Incomplete	System presents correct information and users fail to absorb all presented information. Likely Result: Incorrect maintenance action	System presents erroneous information; users do not absorb all presented information. Likely Result: Incorrect maintenance action	System does not present all appropriate task information; users do not absorb all presented information. Likely Result: Incorrect maintenance action

As mentioned earlier, no "System Incomplete" or "System Incorrect" errors occurred during the FDT. All observed errors fell under the predefined categories of "User Incomplete" and "User Incorrect," and are highlighted in Table 11. Removing the *system* aspect of the formula greatly reduced potential outcomes, resulting in a basic categorization of user-oriented actions. This resulted in the reclassification of errors into two categories: *Critical Errors* (those which lead directly to an incorrect repair) and *Non-critical Deviations*. This distinction is important, as it demonstrates AMIT's flexibility in allowing deviations from a structured repair path (Non-critical Deviations) while preventing errors great enough to critically disrupt the repair process. Each error category and its implications are discussed below.

4.2.1.2 All Critical Errors in As-Is Condition

Six critical errors were documented in the Avionics task sessions, and eighteen in the E & E sessions. Distribution among experience levels indicated all Avionics errors were made by Experts, while for the E & E tasks, 9 were made by Experts, 5 by Novices, and 4 by Crew Chiefs. Regardless of experience level, all Critical Errors occurred in the *As-is* condition; these participants were using paper TOs. The majority of Critical Errors were related to incorrectly navigating the TO and conducting the incorrect ops check, returning to the wrong FI, or using an inappropriate section of the TO for task accomplishment (i.e., using the FI as a checklist for the ops check). The remaining Critical Errors involved the technician relying on "gut feel" to ultimately choose an incorrect repair. No Critical Errors occurred in the *To-be* condition.

4.2.1.3 Non-Critical Deviations

Non-critical Deviations were defined as "a deviation from the prescribed repair path, but not to the degree the repair was compromised." For definition purposes, *prescribed* meant the repair path as dictated by the TO, including any and all preparatory and close-out steps. Were a technician to omit an operational check or a subtask listed in the technical data, even if this step was not necessary to complete the repair (e.g., conducting INS alignment in the complex FCR repair task), it was considered a Non-critical Deviation.

While the TO was used as the basis for defining Non-critical Deviations, the path prescribed by the TO may not have equated to the optimal, or most efficient path. For example, one of the FCR discrepancies involved a failure of the absolute pressure regulator at altitudes above 13,000 feet. This situation resulted in the aircraft returning with a fault code, which was interpreted by many technicians as legitimate. The technicians may have considered fault verification unnecessary because the discrepancy occurred in the flight environment. But because AF regulations dictate that the TO be followed without exception, the choice to skip fault verification, regardless of the reason, was logged as a Non-critical Deviation. This did not mean the aircraft was incorrectly repaired. Rather, it illustrated the AMIT concept's flexibility in allowing technicians the option to interpret and follow the TO according to level of expertise.

4.2.1.4 Information Presentation, Timing, and Errors

As previously mentioned, the collection and analysis of errors did not follow the original methodology outlined in the test plan. Several factors contributed to this, but most significantly the AMIT JPA did not contribute to error occurrences. Once testing began, it became apparent that the AMIT JPA was performing as intended, and the errors that were observed involved the user misapplying or altogether omitting the use of key information that would lead to the most efficient repair path. These occurrences were flagged as Non-critical Deviations and tracked across all experimental conditions. Interestingly, the AMIT JPA did not proportionally reduce the amount of Non-critical Deviations associated with the lack of critical information. Rather, it revealed, even with all critical information, technicians were equally likely to commit Non-critical Deviations.

In the *As-is* condition, technicians conducted historical research on their own, without prompting or encouragement. Thus, if he or she made the choice not to conduct such an historical research, the likelihood of repeating earlier, unsuccessful troubleshooting efforts was high. However, in the *To-be* condition, technicians were always presented with historical information as part of the GUI Preparation tab. In either case, if information was present, two potential types of Non-critical Deviations were then possible: 1) the information could be misapplied, or 2) the information could be ignored. Misapplication of the information indicated the technician retained the information, but incorrectly used it. Disuse of critical information is likely rooted in one of two causes: 1) either the technician forgot the information, or 2) the information was retained but conflicted with the TO and was thus discarded. The latter case is an AF doctrinal issue. In the AF, TOs are just that, *Orders*, mandating compliance under the Uniform Code of Military Justice.

In general, the FDT results indicate that automatic access to information does equate to effective application of that information. Timing is the key. In preparation for full development and field deployment, AMIT designers will need to determine a method to display relevant information when it is most needed. The most pertinent example observed during the FDT was the display of historical data at the appropriate steps in the FI. A potential way of accomplishing this would be integrating such historical information as an official part of the technical data. By fusing the historical information with technical data in this way, technicians could see when a given step was accomplished on a previous repair, so that he/she would not duplicate work already accomplished.

4.2.2 Hypotheses; In-depth Discussion

4.2.2.1 Hypothesis 1: AMIT Will Reduce Time

The improvement in Task Time resulting from use of the AMIT JPA can be traced to several features not found in the current *As-is* condition. These features included focused historical searches, directed TO navigation, hyperlinks within the TO framework, and collection of repair information. The role of historical research, especially on repeat discrepancies, is central in establishing preexisting patterns and tendencies for given system or subsystem. Such historical patterns help guide technicians to the best repair when selecting options from the FI. The AMIT JPA provided easy access and presentation of this information, and allowed technicians to quickly make decisions on the appropriate cause of the discrepancy and helped in selecting the subsequent repair.

Once the appropriate repair was selected, the technician accessed the TO library for instructions on completing the repair. The AMIT JPA assisted with this process, using the fault code to identify the necessary TOs for the technician and displaying them in the AMIT GUI. Once in the TO, AMIT again aided the technician in navigating to the appropriate TO chapter and paragraph. The value of this capability was demonstrated by the absence of Critical Errors attributed to TO navigation when using the AMIT JPA, versus the significant number of TO navigation errors made in the *As-is* condition.

Finally, the AMIT JPA collected information as the technician carried out fault verification, selected and executed a repair, and conducted operational checkouts. This automatic, unobtrusive data collection capability allowed the AMIT JPA to generate a logbook record of the repair. The record was stored in a standard format immediately available to other AMIT users. Specific comparisons of the AMIT JPA-generated logbook information and the manual logbook entries created by technician in the *As-is* condition are discussed in section 4.2.5.

Of note is an outlier in the *As-is* E & E time data for the complex task, as identified by the asterisk in Table 5. This individual, an Expert, followed the maintenance process as he would have during an actual repair. However, this individual's unorthodox (but legitimate) repair strategy resulted in an outlying Task T ime for the Complex task. Removal of this individual from the data set after the fact would have created an "unequal n" situation, but would not have significantly changed the results of the statistical analysis. Therefore, the team decided to retain this participant's data, as the performance was considered representative of a legitimate repair decision process.

4.2.2.2 Hypothesis 2: AMIT Will Reduce Errors

Given that all 24 Critical Errors occurred in the *As-is* condition, Hypothesis 2 was met. The AMIT JPA did not contribute to a single error that resulted in an incorrect repair.

For Non-critical Deviations, one might expect a similar pattern of results. However, the AMIT JPA reduced Non-critical Deviations only for the E & E tasks, not the Avionics tasks. This is likely attributable to the difference troubleshooting strategies across the two specialties. Avionics technicians rely on Built In Test (BIT) results, while E & E technicians tend to use human-reported fault data, which can then be verified via test equipment. In the FDT, most Non-critical Deviations involved skipping fault verification. For the E & E tasks, the chance to verify the fault came via a TO procedure, to which the AMIT JPA automatically navigated the technician. For Avionics tasks, however, a BIT result had already "verified" the fault. With this information, technicians may have felt more comfortable skipping fault verification, regardless of whether they were using the AMIT JPA.

Two additional factors may have contributed: technician experience level and Task Difficulty. Examination of the (non-significant) interaction of *Experience x Task Difficulty* for the E & E tasks showed a tendency of Experts to commit more Non-critical Deviations in the complex task, as compared to the Simple and Moderate tasks. Conversely, Novices and Crew Chiefs tended to commit fewer Non-critical Deviations in the Complex task, as compared to the other tasks. While not statistically significant, this pattern is indicative of behavior described by the AMUG and other SMEs -- a tendency for less experienced technicians to follow the TO "to the letter" in difficult situations. On the other hand, more experienced technicians may have decided to skip non-critical steps in the maintenance process for the Complex task, focusing instead on information relevant to correct diagnosis and repair. In either case, AMIT supports the technician's troubleshooting decisions.

4.2.2.3 Hypothesis 3: Using AMIT, Novices Can Perform Like Experts

One of the stated goals of the AMIT program was to not only identify and accommodate the needs of both Novice and Expert technicians, but also move Novice technician performance when using AMIT JPA to a level similar to that of an Expert not using the AMIT JPA. FDT performance metrics demonstrated this by the similarity of Task Time and Task Error rates. In some cases, Novices using AMIT actually outperformed Experts using existing processes. The key design factor that produced this result was accommodating the needs and tendencies of the Novice (e.g., procedural focus and heavy reliance on TOs), while also making available the information resources beyond the TO that the Experts use (e.g., aircraft and maintenance histories, communication with aircrew). The result was a fairly balanced GUI in terms of layout and content, accommodating both the Novice and Expert technician t hought processes and information needs.

4.2.3 Comparing Moderate and Complex E & E Task Times

An interesting quantitative result was significantly higher task completion time associated with the Moderate E & E task as compared to the Simple and Complex tasks. It would seem logical that task completion times would increase as a function of Task Difficulty as they did with the Avionics tasks. However, this was not the case in the E & E tasks, for two specific reasons: 1) the cognitive requirements of the task, and 2) the physical requirements of the task.

First, the overall concept of Task Difficulty was defined as a function of the level of cognitive complexity associated with correctly troubleshooting, diagnosing, and implementing a repair. In the E & E task suite, the Complex task required the technician to identify a solution that existed beyond the predefined repairs as provided by the TO. To correctly repair the aircraft, the technician needed to deduce from the results of a wiring check that a relay was faulty; this relay was not identified as a candidate cause in the FI.

A second factor which contributed directly to task completion time was the time required to physically conduct the repair. The standard repair time for replacing the above mentioned relay in the Complex task was 3 minutes. The standard repair time for the Moderate task was 4 hours. If these times are subtracted from the total Task Times, the completion times associated with the Complex task become greater than the Simple and Moderate tasks as would be expected.

4.2.4 Collaboration: User Requirements and Available Technology

When technicians did not successfully apply historical information when working on a repeat write-up, the AMIT JPA provided a collaborative capability when it was needed most. However, the format and level of information necessary during a collaborative session remains open for debate.

As the collaborative requirements for the AMIT JPA were developed, members of the design team assumed that technicians would want to use the latest technology in developing a collaborative capability. Streaming video, shared workspace and high-fidelity image transmission and audio were seen as not only technologically possible, but necessary. Contrary to this assumption, review sessions with the AMUG revealed that technicians were more inclined to seek out another technician if the collaborative session required more than instant messaging. Indeed, a review of the number of collaborative sessions during the FDT indicates that technicians collaborated nearly twice as often in the *As-is* condition than when using the AMIT JPA. This basic pattern held for both the Avionics and E & E tasks, with the majority of collaborative sessions occurring in the Complex task. Tables 12 and 13 illustrate this finding, which begs the question, *"Why, with an easily accessible collaborative capability, did AMIT users collaborate less than non-AMIT users?"*

The Team believes the AMIT JPA provided enough relevant and timely information to minimize the need to collaborate. By design, the AMIT JPA provided answers to certain anticipated questions that might warrant collaboration; for example, the next repair step as per the FI. The AMIT JPA negated the need to ask many questions by playing the role of "surrogate SME." That is, in all situations save the Complex FCR repair task, the AMIT JPA provided information immediately to a technician who may otherwise have dedicated time and resources to find and query a SME. Thus, AMIT not only saved time, but also kept available an important information resource (the SME) for potentially more difficult situations that would benefit from his or her expertise.

Table 12 Collaboration Totals for all Task Difficulty Levels, Avionics

	As-is			*To-be*		
	Simple	Moderate	Complex	Simple	Moderate	Complex
Novice	6	3	13	1	1	12
Expert	4	5	9	3	0	5
Crew Chief	5	3	9	0	0	12

Table 13 Collaboration Totals for all Task Difficulty Levels, E & E

	As-is			*To-be*		
	Simple	Moderate	Complex	Simple	Moderate	Complex
Novice	1	4	4	0	0	4
Expert	1	1	6	0	0	2
Crew Chief	3	1	12	0	2	7

Notable parallels were observed in the patterns of collaborative behavior between the Avionics and E & E tasks. Experts generally did not collaborate with other Experts in the *As-is* or *To-be* conditions. In terms of the effect of Task Difficulty on the amount of collaboration, the majority of all collaboration was accomplished on Complex problems. However, noticeable differences in collaboration frequency were observed during the Simple and Moderate tasks. Finally, in the Avionics task, which involved an in-flight discrepancy that could not be duplicated on the ground, Experts collaborated with pilots more often than in other cases.

An additional issue involves the technician's actual level of collaborative need. AMUGs repeatedly stated once the need to collaborate went beyond the level of an instant message (IM), a technician would probably seek out a collaborator in person. Design Consideration Testing helped confirm the practicality of IM; as such, it was chosen as the AMIT JPA collaborative capability. However, the level of information exchange described by the AMUG (i.e., the "in-person" meeting with the collaborator) *is achievable* with existing technology. Specifically, collaborative technologies such as "shared workspace" can give technicians and remotely located collaborators literal "same page" synchronicity during a collaborative session. These capabilities were discussed during the AMUG sessions, but were not demonstrated or evaluated. While all AMUG members were familiar with IM, the concept of a shared workspace capability may not have been fully understood, and therefore overlooked.

4.2.5 AMIT JPA Effect on Logbook Entries

The role of the maintenance logbook has many functions, including a general historical record, a place to add information that IMDS does not ordinarily collect, and a means for communicating unusual or non-standard conditions and repairs associated with a particular aircraft. While such information is considered invaluable within a squadron, it is rarely shared with other organizations. Furthermore, no AF standard exists in terms of configuring a logbook, or even what information or the appropriate level of detail should be included in a given entry.

The test team did not develop metrics to directly compare information collected by the AMIT JPA with the simulated e-logbook. However, technicians indicated the AMIT JPA logbook feature would add value to the overall collection of maintenance information. AMIT SMEs recommended that *any* logbook entry should include the aircraft tail number, description of the discrepancy, and the corrective action. Examination of logbook entries made by technicians in the *As-is* condition illustrates how the AMIT logbook capability would help to increase input accuracy, standardize format for re-use, and help maintainers avoid critical omissions during log entries.

A total of 130 log entries were created by 36 different technicians in the *As-is* condition, using a representative e-logbook format as provided by the 63rd Aircraft Maintenance Unit, 756th Aircraft Maintenance Squadron at Luke AFB. A review of logbook entries made in the *As-is* condition revealed a series of input errors. Seven technicians entered incorrect tail numbers when entering data into the log. Further, 28 entries were made without noting the discrepancy. The AMIT JPA logbook function addresses such issues by automatically collecting key information and decisions made during the maintenance process, thus relieving the technician of data collection burdens at the end of his or her shift.

4.2.6 AMIT Facilitates Efficient Use of Time

The AMIT JPA facilitated a more efficient use of time. This was illustrated by the capability to conduct historical searches before going to the aircraft and continued as the AMIT JPA facilitated step-by-step procedural guidance through the tech data, including steps that might be skipped when using paper TOs (e.g., fault verification). Conversely, technicians in the *As-is* condition spent more time searching the TO library, rather than historical maintenance data. These technicians were necessarily searching through paper-based technical data to find the appropriate procedures for the given discrepancy.

Deeper evaluation of Task Time data highlighted technicians using the AMIT JPA spent a greater amount of time conducting research and fault verification tasks, yet total Task Times for those using the AMIT JPA were lower than those not using the JPA. While statistical analyses were not performed on this data, this pattern of results illustrates a key benefit of the AMIT JPA.

A counterintuitive finding was technicians using the AMIT JPA spent less time collaborating than those in the *As-is* condition. Two potential reasons exist for this observation. First, as noted earlier, technicians found the information they needed in the *To-be* condition without consulting with additional personnel. Second (and not as positive) technicians may have found the AMIT collaboration capability cumbersome, as their only option was to type an instant message. Collaboration results notwithstanding, the reallocation of time in the *To-be* condition illustrates a more efficient focus on the maintenance process in terms of both resource allocation and task completion.

4.2.7 Interpretation of the Subjective Results

While collection of subjective feedback was not intended to undergo statistical analysis, a number of inferences can be drawn from the subjective data. Nearly every participant, whether they used the AMIT JPA or saw the demonstration afterwards, asked, "When will the AMIT JPA be implemented?" The Team perceived this as a firm validation of the AMIT concept and an endorsement that the JPA is needed and wanted by those for whom it was designed. The AMIT JPA's design for seamless integration with legacy AF systems prepares the way for quick, efficient integration into existing and emerging AF logistics infrastructure. A second, well-received global benefit was the notion that the AMIT JPA could not only use existing historical data, but also build a more detailed historical database for re-use. In general, technicians were impressed that the AMIT JPA was designed to work with existing AF systems, as opposed to another stand alone system requiring protracted installation, training, and debugging time.

Subjective feedback on specific design characteristics and capabilities were also generally positive. Technicians liked the overall design of the user interface, and remarked that its layout would benefit both Novice and Expert technicians. Directed TO searches; that is, the ability of AMIT to navigate automatically to the section of the TO library appropriate for the given fault code, was often favorably noted. This capability was specifically mentioned by Expert technicians as a feature that would help Novices learn more quickly, making the connection between specific faults and specific areas of the TO library. Focused historical search capability and the automatic collection of logbook data also garnered praise for most technicians. Both of these capabilities were seen as time savers, especially the logbook capability, which is sometimes seen as a "necessary evil" along with IMDS data entry. In fact, several technicians spoke of being directed to stop work on the aircraft specifically to complete the required IMDS documentation per AF protocol, hindering overall repair efforts.

The only AMIT capability that received a lukewarm response was the collaborative capability. Overall, technicians were skeptical that an aircrew would be available for direct question and answer sessions, as was simulated in the FDT scenarios. In fact, technicians felt the primary benefit of such a capability was the ability to contact other maintenance personnel from the point of maintenance, and said it would most likely be used to request the presence of the Production Superintendent or another technician. Such feedback recalls the question of just how robust the design of a collaboration capability should be, as discussed above. In general, technicians felt that a collaborative capability should at least reflect current practices by including audio, which the AMIT JPA did not. Other potential capabilities include a shared workspace and the ability to email a remotely located SME, who may not be at the ready for real time information exchange. In general, technicians felt that collaboration, at least in the form of instant messaging, would provide only minimal assistance.

4.3 Cost Analysis (CA)

4.3.1 Overview

The AMIT cost analysis (CA) purposes to quantify time (personnel and aircraft availability) and dollar savings potential based on AMIT FDT results. To accomplish this, the AMIT CA acknowledges three data sources: 1) FDT results, 2) Air Force Data Services (AFDS), a repository for historical maintenance data, and 3) the President's 2006 defense budget. In concert, these three sources provide *projected time savings* data, a baseline account of *actual maintenance task times* on numerous AF aircraft, and *technician (labor) costs.* These sources facilitate calculations of cost associated with the F-16C Block 40/42, but also afford the opportunity to extrapolate to other AF weapons systems. Because inferential assumptions must be made regarding the applicability of both the FDT data and AFDS, maintenance data to other weapons systems and certain of trade-offs exist. Figure 12 depicts the nature of these trade-offs.

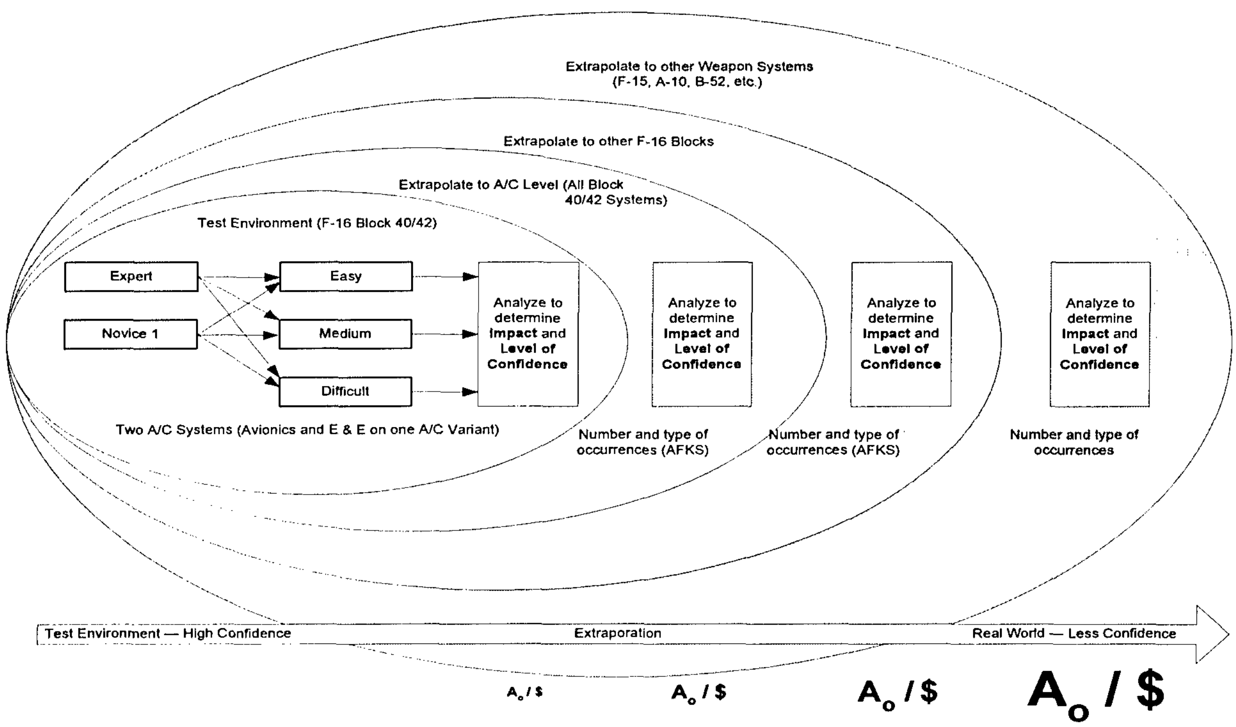


Figure 12 Extrapolation Risk

The following sections detail the methodology for calculating costs associated with the F-16C Block 40/42 weapon system and projecting savings due to AMIT implementation. **A detailed description of the AMIT CA, including extrapolation to additional F-16 blocks and other aircraft, is in Appendix A.**

4.3.2 F-16C Block 40/42 CA Results

The AMIT FDT collected performance data with the intent of illustrating AMIT impacts on the aircraft maintenance community. The FDT data used in this CA only includes the average task time collected for the system specific expert and novice user groups. The average task time collected for the Crew Chief user group was excluded here because Crew Chiefs would not normally perform troubleshooting tasks for Avionics and E & E systems. Using FDT results, actual AFDS maintenance data, and cost data from the President's 2006 budget, the AMIT CA indicates:

Time savings of **45 minutes per task for the Avionics** tasks

Time savings **55 minutes per task for the E & E tasks**

The second variable in calculating an AMIT cost-benefit was representative historical repair data. Five months of F-16 maintenance data was drawn from the AFDS database, examined, and approved by SMEs in terms of overall level of representation.

Not every maintenance action involves troubleshooting; those that do will realize the greatest benefit from AMIT. Thus, a key calculation in the AMIT CA was the proportion of maintenance actions from the AFDS data that required troubleshooting. Detailed analysis by AMIT SMEs indicated that *at least* 50% of the total actions involve troubleshooting. Prorated over 12 months, these figures indicate approximately:

16,742 Avionics tasks per year involve troubleshooting

37,747 E & E tasks per year involve troubleshooting

Application of the FDT time savings figures yields:

annual time savings of 12,557 clock-hours for Avionics repairs

annual time savings of 34,601 clock-hours for E & E repairs

combined **increase in aircraft availability of 47,158 clock-hours**

In order to project the impact of this savings at the fleet level, 47,158 availability hours were divided by 8,760 hours per year (365 x 24), resulting in:

an equivalent **increase of 5.4 F-16C Block 40/42 aircraft per year**

In order to convert these figures to man-hour savings, the clock-hour savings noted above were multiplied by the average crew size of two, resulting in:

savings of 94,316 man-hours per year.

Man-hour cost was calculated by multiplying the man-hour savings by the average hourly (burdened) cost of maintenance technicians as stated in the 2006 President's defense budget (AFI 65-503, Table A20-1). This average hourly wage for E-4, E-5, and E-6 technicians is $30.03. Therefore; an **annual labor dollar savings of $2,828,561** can be realized for the F-16C Block 40/42 fleet for Avionics and E & E tasks alone.

Note this dollar figure represents labor hours only and does not include other cost considerations, such as unnecessary use of parts. Additionally, these figures do not highlight the intangible benefits realized in personnel availability, Novice performance enhancements, scheduling impacts, and training impacts.

4.4 Summary

4.4.1 Why Did AMIT Work?

As a research project conceived with the goal of proving a concept, AMIT succeeded. Beyond this goal, however, the team designed and tested a prototype solution for the maintenance community that has been embraced by technicians, managers, and senior leaders alike. While the AMIT concept of bringing together disparate information sources to the technician is not necessarily cutting-edge, the overwhelming positive response from the maintenance community was the result of a methodical process. That is, inclusion of the user community from the project's outset and a visionary perspective toward integration with existing and anticipated AF infrastructure. In the end, the AMIT concept's potential for success and implementation lies in the background and evaluation work accomplished throughout the 3 years of the program.

The first year of the AMIT project was dedicated to understanding, evaluating, and prioritizing user requirements. With an understanding that Novice and Expert technicians do things differently, the team was aware from the outset that they would be designing for at least two groups of users. Thus, year one was dedicated to detailed analysis of maintenance processes from Novice and Expert perspectives, and subsequently generating a series of requirements that would benefit both groups of users. This was accomplished with a series of Process Interviews, Cognitive Task Analyses, and a Literature Review. The combined results of these three efforts formed the basis for the early GUI design.

Over the next year of the project, GUI development continued. During this period, the user interface was shown to the potential end-user community via a series of AMUG sessions. The goal of these sessions was to get "reality checks" from the end-user community regarding the overall design of the GUI to the prioritization of certain capabilities, as well as terminology usage. The results of the AMUG sessions helped to solidify much of the final design of the AMIT JPA, both in terms of appearance and capability.

A series of Design Consideration Tests (DCTs) were conducted to address a short list of design features that had not been finalized via end-user feedback. The DCTs were "mini field studies," and as with the AMUG sessions, using aircraft maintenance technicians as participants. Results of the DCTs answered the final array of design questions, including prompting (icon vs. dialogue box vs. screen overlay), collaboration (voice vs. IM vs. IM with shared graphical workspace), data entry technique (voice vs. keyboard), data retrieval format (audio vs. text), and enhanced electronic logbook format (inclusion of "breadcrumb trails" and integrated historical information).

The final AMIT JPA, validated by the results of the FDT in year three, represents a design that from the beginning has incorporated the end-user community as an evaluative mechanism. The resultant tool brings information resources together, focuses relevant information to the user in a format that he/she can understand, while reducing the physical and cognitive overhead associated with gathering and sorting through the TO library. The automatic collection of key information throughout the maintenance process relieves the technician of the need to mentally review and document the repair at the end of the shift. Finally, the information is presented in a configuration that is understandable by all members of the AF maintenance community.

4.4.2 Why Will AMIT Work?

From an implementation perspective, the AMIT JPA's strength lies in its design to work with existing AF systems, while creating a new, robust data set that is immediately available for reuse during later troubleshooting activities. Throughout the project's duration, briefings to upper level management personnel resulted in praise and positive comments. As word of the AMIT project spread throughout the AF, unsolicited positive feedback from other groups was received as well. Added to the resounding endorsement from the technician community itself, all levels of the AF maintenance community clearly express a desire to see AMIT transition into a fielded system.

5 Conclusion

The AMIT concept, instantiated by the AMIT JPA, proved beneficial to troubleshooters in the operational environment at Luke AFB, Arizona. The Field Demonstration Test (FDT) results clearly point toward an easily implemented, cost effective capability with high potential to meet the goals of AF leadership, including improved aircraft availability (e.g., readiness), reduced cost, and reduced deployment footprint. As highlighted in the FDT, technician performance can be dramatically improved, thereby positively affecting Task Time, Task Accuracy, and technician proficiency. The demonstrated savings of 45 to 55 minutes per repair translates to over 47,000 clock hours saved, per year, on the fleet of F-16 Block 40/42 aircraft, equating to an approximate **increase of 5.4 available aircraft**. Additionally, **man-hour dollar savings of $2,828,561** per year are plausible for the F-16C Block 40/42 fleet alone. The CA in **Appendix A** shows implementation across additional aircraft fleets will produce similar savings potential.

As shown in the cost analysis (paragraph 4.3 and Appendix A), improvements in these metrics can only positively impact aircraft Non-Mission Capable rates, 8-hour fix rates, personnel availability, reduced supply demand, and deployment footprint.

Another noteworthy program conclusion is technician acceptance of the AMIT JPA, and desire for near-term implementation. Nearly all test subjects indicated an immediate need for such a performance aid and asked when they might see AMIT JPAs on their flightline. Almost every participating Expert technician agreed that AMIT would certainly improve on-the-job training, skill progression, and overall competence across any aircraft maintenance career field.

6 Recommendations

6.1 Transition

Based on the results of the FDT and the potential savings illuminated by the CA, the AMIT Team recommends immediate transition of the AMIT concept and JPA to an operational command, preferably Air Combat Command (ACC), for pilot implementation. This transition is necessary to move the AMIT concept from an advanced research and development initiative to a real-world pilot application. The proposed pilot is not intended to be a production-ready system. Rather it will build upon the tested and proven AMIT JPA by establishing technological integration points and relevant interfaces within the GCSS-AF Integration Framework, the Air Force Data Services (AFDS), the Air Force Portal, and the technical order services module in GCSS-AF. These activities will pave the way for optional MAJCOM and/or Air Force-wide implementation.

AMIT transition must occur immediately upon program completion to facilitate development of the pilot application in calendar year 2007. A successful AMIT pilot in 2007 would bridge the advanced research effort, which ends in January 2007, with the Program Objective Memorandum (POM) established by the ACC for its Combat Air Forces (CAF) needs in 2008. **Appendix B** contains detailed AMIT transition activities and recommendations.

6.2 Future Research

6.2.1 Explore Fused Historical and FI Views

The *collection*, *use,* and *application* of historical data are key AMIT features. The capability of the AMIT JPA to provide relevant historical repair information, especially in the case of repeats and recurs, reduces duplication of effort and saves time, ultimately reducing maintenance costs. Simply providing this information at the beginning of the maintenance process (e.g., within the Discrepancy tab) as done during the FDT, however, does not facilitate a full understanding of exactly how and/or when to apply the information. Historical data generally is most applicable during troubleshooting when the maintainer is likely to repeat tasks that were previously accomplished, wasting time and adding no value.

The recommended solution is to display relevant historical data as an inherent component of the FI procedure. Future research should address *when, where, and how* historical information should be fused with fault isolation procedures. Results of such a research effort will directly contribute to reaching AF aircraft availability goals by enhancing troubleshooter effectiveness. Primary considerations during the research should include the amount of information needed for an effective fusion strategy, whether it is possible to include too much information, and whether fusing historical and FI information facilitates a change in general repair strategy at all. Answers to these questions will help drive the next version of AMIT's historical and electronic TO capability, as well as address cultural issues involving maintenance TO format and usage.

6.2.2 Increase Collaborative Capabilities in Future Versions

During the design and development process, the team collected and evaluated basic collaborative requirements. Feedback from the AMUG indicated a fairly basic, "conversational" level of need, beyond which the technician would seek out an SME in person. While the AMUG discussed additional collaborative capabilities such as shared workspace, streaming video, and real time audio, no demonstrations were seen first-hand. Application of these capabilities may not have been fully understood, and their inclusion was not highly recommended for the FDT. All AMUG members indicated a familiarity with IM; however it was subsequently developed as the AMIT JPA collaborative capability.

While the AMUG did not indicate a need for anything beyond IM, observations from the FDT revealed that the majority of collaborative sessions (in both the *As-is* and *To-be* conditions) involved some reference to the TOs. For example, most repeat/recur scenarios involved collaboration with the SME to review options on the FI. During such sessions, a shared workspace capability would allow the technician and SME to literally be "on the same page" and potentially save time. Other situations may be even more complex, requiring an exchange of information that is most easily evaluated via a visual or aural inspection. Aircraft battle damage, for example, might involve both. A more robust collaborative capability would allow the technician to utilize these additional modes of communication, rather than generating a text description for the SME. Future versions of the AMIT JPA should include such additional collaborative features, at least in an evaluative form, to demonstrate further savings in time and efficiency.

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9 List of Symbols, Abbreviations, and Acronyms

List of Acronyms

Acronym	Meaning
A/C	Aircraft
ACC	Air Combat Command
AETC	Air Education Training Command
AF	Air Force
AFDS	Air Force Data Services
AFRL/HEAL	Air Force Research Laboratory, Logistics Readiness Branch, Human Effectiveness Directorate
AFSC	Air Force Specialty Code
AFSO 21	Air Force Smart Operations for the 21st Century
AFSOC	Air Force Special Operations Command
AGE	Aircraft Ground Equipment
AMC	Air Mobility Command
AMIT	Aircraft Maintenance Intuitive Troubleshooting
AMUG	Aircraft Maintenance Users Group
ANOVA	Analysis of Variance
A_o	Operational Availability
AT	Action Taken
BIT/ST	Built-in Test/Self Test
CA	Cost Analysis
CAF	Combat Air Force
CBA	Cost Benefit Analysis
CDRL	Contract Data Requirement List
CENTCOM	Central Command
CITS	Combat Information Transportation System
CND	Can Not Duplicate
COCOM	Combatant Command
COTS	Commercial-off-the-shelf
CTA	Cognitive Task Analysis
DCT	Design Consideration Test
df	Degree of Freedom
dfe	Degree of Freedom, Error
dfv	Degree of Freedom, Variable
DoDI	Department of Defense Instruction
DTIC	Defense Technical Information Center
E & E	Electrical and Environmental
ECSS	Expeditionary Combat Support System

Acronym	Meaning
eLOG21	Expeditionary Logistics for the 21st Century
EUCOM	European Command
FCR	Fire Control Radar
FCS	Flight Control System
FDT	Field Demonstration Test
FI	Fault Isolation
FY	Fiscal Year
GCSS-AF	Global Combat Support System – Air Force
GFE	Government Furnished Equipment
GWOT	Global War on Terrorism
HAF	Headquarters Air Force
IM	Instant Messaging
IMDS	Integrated Maintenance Data System
IT	Information Technology
JFCOM	Joint Forces Command
JPA	Job Performance Aid
Lit	Literature
LOA	Logistics Officer Association
M	Million
MAF	Mobility Air Forces
MAJCOM	Major Command
NATO	North Atlantic Treaty Organization
NCI	NCI Information Systems, Inc.
OhioLINK	Ohio Library and Information Network
Ops	Operations
PACOM	Pacific Command
PERSTEMPO	Personnel Tempo
POM	Program Objective Memorandum
R&D	Research and Development
RALT	Radar Altimeter
RE 21	Repair Enterprise for 21st Century
SME	Subject Matter Expert
TF 720	Task Force 720
TO	Technical Order
TRANSCOM	United States Transportation Command
TTP	Technology Transition Plan
UCMJ	Uniform Code of Military Justice
UDRI	University of Dayton Research Institute
WS	Weapon System

Acronym	Meaning
WUC	Work Unit Code

Appendix A: Cost Analysis (CA)

A.1. Overview

In general, a Cost Benefit Analysis (CBA) compares monetary calculations of initial and ongoing expenses against expected return. Constructing plausible measures of the costs and benefits of specific actions, however, is often very difficult (Frank, R.H. 2000). In practice, an estimation of costs and benefits is accomplished via survey methods or by drawing inferences from general behavior. The AMIT cost analysis (CA) sought to quantify time (personnel and aircraft availability) and dollar savings potential based on AMIT field demonstration test (FDT) results. To accomplish this, the AMIT CA acknowledged three data sources: 1) FDT results, 2) Air Force Data Services (AFDS), a repository for historical maintenance data, and 3) the President's 2006 defense budget. In concert, these three sources provided *projected time savings* data, a baseline account of *actual maintenance task times* on numerous AF aircraft, and *technician (labor) costs*. These sources facilitated calculations of cost associated with the F-16 Block 40/42, but also afforded the opportunity to extrapolate to other Air Force (AF) weapon systems. Because inferential assumptions must be made regarding the applicability of both the FDT data and AFDS maintenance data to other weapons systems, certain of trade-offs exist. Figure A-1 depicts the nature of these trade-offs. When extrapolating beyond the FDT aircraft, confidence in the CA decreases.

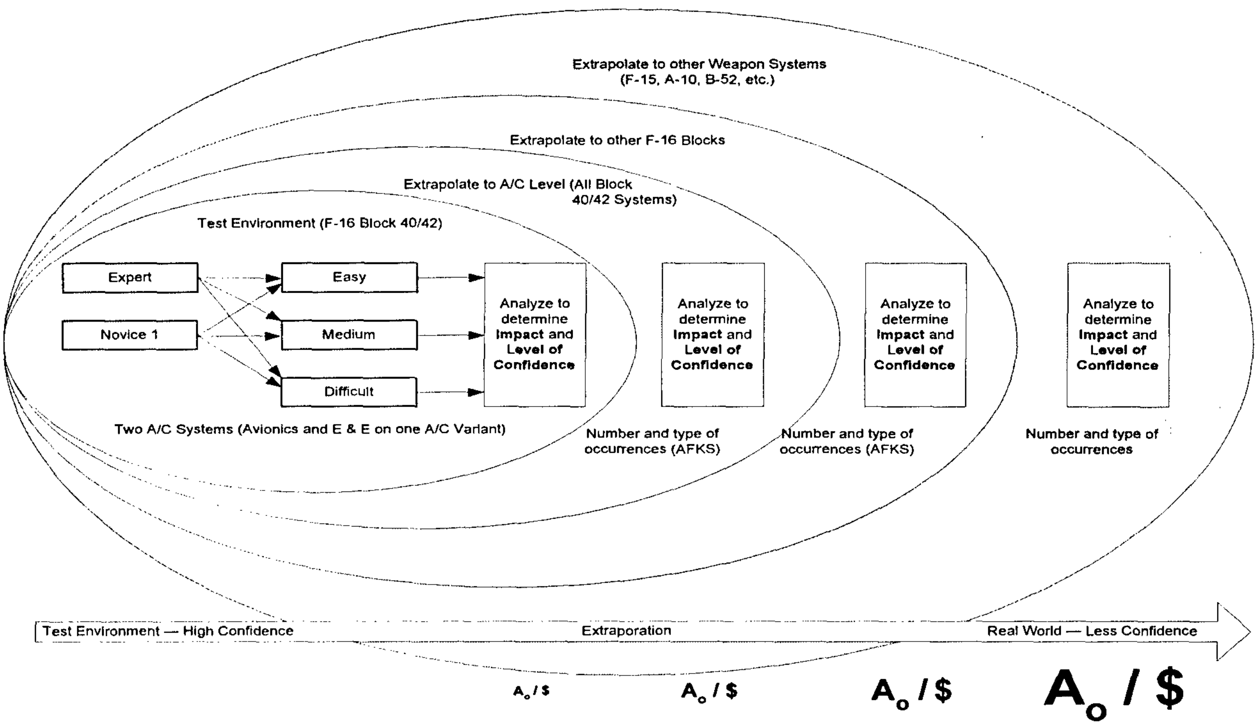

Figure A-1 Extrapolation Risk Increases when Results are applied Beyond the Test Environment

The extensibility of the AMIT CA depends on a specific set of assumptions. Each assumption builds on the previous, and as A-1 illustrates, a reduction of confidence as extrapolation moves from the test environment airframe (F-16C Block 40/42) to the overall AF aircraft fleet. The assumptions, listed for the applicable specialties of Avionics and E & E, are as follows:

1a. Avionics savings observed during the AMIT FDT can be applied across the entire Avionics suite for F-16C Block 40/42.

1b. E & E savings observed during the AMIT FDT can be applied across the entire E & E suite for F-16C Block 40/42.

2. These savings are representative of savings that can be applied to all functional systems on the F-16C Block 40/42.

3. Savings are representative of those for all systems and blocks of F-16 aircraft.

4. Savings are representative of those for all systems on other weapon systems (C-130, A-10, F-15, etc.)

A.2. Methodology and Calculations

A basic requirement of any CA is the notion of data integrity. The AMIT CA data was drawn from AFDS. The initial data set was pulled based on Action Taken (AT) codes to identify documented maintenance actions most likely to require troubleshooting. The initial set contained 5 months of F-16 Block 40/42 maintenance data and covered all systems. This set contained 43,142 records of interest. These records were reviewed by AMIT SME team to ensure relevance. For example, an unusually high or low number of maintenance actions would raise concerns as to whether the data represented "typical" maintenance activity for the time period in question.

This initial set excluded all actions associated with daily inspections, cannibalization, scheduled maintenance, loading, arming, de-arming, and all off-equipment maintenance. Therefore, the following on-equipment AT codes were used:

- R – Remove and Replace
- P – Removed with an assumed follow-on action of Q – Installed
- G – Repair and/or replacement of minor parts
- L – Adjust to include adjustments necessary for proper functioning of equipment
- Y – Troubleshoot

The SME team then calculated a one-year total of 103,541 relevant maintenance actions in the initial data set for the F-16 Block 40/42 aircraft, based on the 5-month data set (43,172 / 5 x 12).

The Team associated the work unit code (WUC) with aircraft system/sub-systems to identify the subset of data relevant to the Avionics and E & E suites, allowing FDT result application across both specialty suites (see Assumptions 1a and 1b above). These associations were accomplished by identifying the Avionics tasks requiring troubleshooting (when the technician used aircraft controls and displays to determine operational condition). In such tasks, technicians must interpret system operating characteristics to isolate malfunctions. The systems and subsystems identified as relevant included: attack control, radar, infrared, laser, instruments, displays, flight control, communication, navigation, satellite communications, identification (defensive and offensive), and defensive or offensive electronic warfare systems.

Similarly, E & E on-equipment systems include direct and alternating current, gas turbine compressors and auxiliary power units, landing gear, anti-skid, and nose wheel steering, electronic engine control, ignition, and starting. Other E & E systems include lighting, master caution and warning, take-off warning, flight controls, cargo door and cargo delivery equipment, non-electro static application windows, anti-icing, fire and overheat warning, fire suppression, fuel control, liquid cooling, air conditioning, bleed air, cabin pressurization, and auxiliary pressurization, oxygen, and aircraft utility systems.

Table A-1 shows an example of the system selection strategy for the F-16 Block 40/42 aircraft. The first four columns (Block; WUC; Occurrences; Description) contain actual AFDS data. The last two columns (E & E; Avionics) indicate the number of applicable instances by system.

Table A-1 Example of Filtering by WUC and Aircraft System/Subsystem

Block	WUC	Occurrences	Description	E & E	Avionics
40	46E	339	FUEL INDICATING-CON		339
42	46E	118	FUEL INDICATING-CON		118
40	46F	803	FUEL TANKS EXTERNAL		
42	46F	401	FUEL TANKS EXTERNAL		
40	47A	922	LIQ OXY SYS SUP&DST	922	
42	47A	1094	LIQ OXY SYS SUP&DST	1094	
40	49A	107	FIRE DETECTION SYS	107	
42	49A	48	FIRE DETECTION SYS	48	
40	49B	10	OVERHEAT DETCTN SYS	10	
42	49B	5	OVERHEAT DETCTN SYS	5	
40	51A	86	PRIMARY FLIGHT INST		86
42	51A	71	PRIMARY FLIGHT INST		71
40	51B	26	ARTIFICAL REF INSTR		26
42	51B	24	ARTIFICAL REF INSTR		24
40	51C	20	SECONDARY INSTRUMENTS		20
42	51C	22	SECONDARY INSTRUMENTS		22
40	51D	4	STANDBY INSTRUMENTS		4

Using these figures, the team calculated a one-year total of 103,541 relevant maintenance actions. The next step was to calculate a representative 12-month figure for the total number of Avionics and E & E maintenance tasks that involve troubleshooting. The resulting calculations were 16,742 for Avionics and 37,747 for E & E. Approximately 50% of the initial data were determined to involve Avionics and E & E troubleshooting according to these selection criteria.

Following these calculations, the Task Time delta observed between the *To-be* and *As-is* test conditions for the system specific expert and novice user groups was multiplied by the relevant number of repairs involving troubleshooting, for both Avionics and E & E systems. The result was a calculated savings of 45 minutes per Avionics task and 55 minutes per E & E task (see Table A-2 below). Multiplying the quantity of relevant repairs by the average time savings revealed a fleet-wide savings of 12,557 Avionics troubleshooting hours, and 34,601 E & E troubleshooting hours. Table A-2 illustrates the calculations of an anticipated total savings of 47,158 hours for a 12-month period. Dividing 47,158 hours by the clock hours available in a year (365*24 = 8760) reveals AMIT potential to add the equivalent of 5.4 aircraft to the available fleet (47,158 / 8760 = 5.4).

Table A-2 F-16 Block 40/42 Aircraft Anticipated Savings

12 months of Write-ups			A/C Savings						
Total	E & E	FC	E & E Time Savings			Avionics Time Savings			Combined Totals (Hrs)
			Session (Min)	Total (Min)	Total (Hrs)	Session (Min)	Total (Min)	Total (Hrs)	
103541	37747	16742	55	2076096	34601	45	753408	12557	47158

The calculated time savings used to calculate man-hour cost savings. Assuming an average crew size of two (some tasks take more than two; some only accommodate one), the increase in aircraft availability hours (47,158) is multiplied by two to provide the anticipated total man hour savings across all relevant maintenance actions (94,316). This time can then be converted to a dollar figure by multiplying the average labor-hour cost. Table A-3 (extracted from AFI 65-503, Table A20-1) displays the cost per hour of the three most likely troubleshooting grades. The average of the three is $29.99.

Table A-3 Pay Rates for Typical Maintenance Technician Ranks

Rank	Annual	Month	Week	Day	Hour
E-6	$71,906	$5,992.16	$1,382.81	$276.56	$34.57
E-5	$63,026	$5,252.13	$1,212.03	$242.41	$30.30
E-4	$52,200	$4,349.97	$1,003.84	$200.77	$25.10

Using the above methodology, the calculated one-year dollar savings for F-16 Block 40/42 fleet would be $2,828,561. See Table A-4 for calculations.

Table A-4 Anticipated Manpower Savings for Block 40/42

Combined	Manpower Savings			
Totals (Hrs)	Crew size	Total (Fleet)	$ per hour	Cost
47158	2	94316	$29.99	$2,828,561

A.3. Extrapolation beyond Block 40/42

As Table A-1 illustrates, extrapolation beyond the test bed aircraft (F-16C Block 40/42) is possible, but carries an inherent degree of reduced confidence. Certainly, the total dollar savings will increase as additional weapons systems are factored into the analysis. These increases, however, are mitigated by the fact that similar troubleshooting techniques or "rules-of-thumb," while applicable to the F-16C Block 40/42 and other F-16 blocks, may not apply as directly to other airframes.

Extrapolation to the entire F-16 fleet, consisting of 1,314 aircraft, generates a 135,199 hours of aircraft availability (Mission Capability) across Avionics and E & E tasks see Table A-5). This equates to 15 additional aircraft in the fleet. To compute the total man hour savings multiply by two based on average maintainer crew size would produce an anticipated savings of 270,398 man hours at a cost savings of $8,109,224 annually (see Table A-6). See Table A-5 and A-6 for computations.

Table A-5 F-16 Fleet Calculations - Aircraft Hours

A/C		12 months of Write-ups			A/C Savings					
Type	#	Total	E & E	FC	E & E Time Savings (Min)			FC Time Savings (Min)		
					Session (Min)	Total (Min)	Total (Hrs)	Session (Min)	Total (Min)	Total (Hrs)
15	62	8638	3312	859	55	182160	3036	45	38664	644
25	202	46428	17210	5208	55	946572	15776	45	234360	3906
30/32	396	74719	23321	11484	55	1282644	21377	45	516780	8613
40/42	402	103541	37747	16742	55	2076096	34602	45	753408	12557
50/52	252	77266	25982	14494	55	1429032	23817	45	652212	10870
F-16 Total	1314	310591	107573	48787		5916504	98608		2195424	36590

Table A-6 F-16 Fleet Calculations - Manpower

F-16				Manpower Savings			
Block	# of A/C	Combined Totals (Hrs)	Equivalent Additional A/C	Crew size	Total (Fleet)	$ per hour	Cost
15	62	3680	0.42	2	7361	$29.99	$220,750
25	202	19682	2.25	2	39364	$29.99	$1,180,538
30/32	396	29990	3.42	2	59981	$29.99	$1,798,824
40/42	402	47158	5.38	2	94317	$29.99	$2,828,561
50/52	252	34687	3.96	2	69375	$29.99	$2,080,550
F-16 Totals	1314	135199	15.43	2	270398	$29.99	$8,109,224

The same search and selection criteria can be used to calculate potential savings for other Weapon Systems (WS) such as the A-10, F-15, and C-130. While the confidence level in such extrapolations is less than with that for the F-16s, an equally noteworthy degree of savings can be projected. Tables A-7 and A-8 detail the extrapolation of savings to the airframes mentioned above, using actual historical data in terms of maintenance actions taken.

Table A-7 A-10, F-15, and C-130 Fleet Calculations

A/C		12 months of Write-ups			A/C Savings					
Type	#	Total	E & E	FC	E & E Time Savings (Min)			FC Time Savings (Min)		
					Session (Min)	Total (Min)	Total (Hrs)	Session (Min)	Total (Min)	Total (Hrs)
A-10A	246	50933	22442	9031	55	1234332	20572	45	406404	6773
F15A/B	104	26112	11263	2726	55	619476	10325	45	122688	2045
F15C/D	392	73440	36499	9110	55	2007456	33458	45	409968	6833
F15E	224	51247	23071	7445	55	1268916	21149	45	335016	5584
F-15 Totals	720	150799	70833	19281		3895848	64932		867672	14462
AC130H	8	8263	3046	1006	55	167508	2792	45	45252	754
AC130U	15	8081	3094	871	55	170148	2836	45	39204	653
C130E	167	110448	56206	11678	55	3091308	51522	45	525528	8759
C130H	278	175140	76212	30638	55	4191660	69861	45	1378728	22979
C-130J	34	12487	4762	3046	55	261888	4365	45	137052	2284
EC130H	10	4915	1936.8	1366	55	106524	1775	45	61452	1024
HC130N	9	4754	2057	607	55	113124	1885	45	27324	455
HC130P	22	12746	5777	2143	55	317724	5295	45	96444	1607
LC130H	10	5467	2155	710	55	118536	1976	45	31968	533
MC130E	14	20808	7493	3936	55	412104	6868	45	177120	2952
MC130H	20	17923	6809	3317	55	374484	6241	45	149256	2488
MC130P	27	26866	11467	3646	55	630696	10512	45	164052	2734

Table A-8 A-10, F-15, and C-130 Fleet Calculations

				Manpower Savings			
Type	# of A/C	Combined Totals (Hrs)	Equivalent Additional A/C	Crew size	Total (Fleet)	$ per hour	Cost
A-10A	246	27346	3.12	2	54691	$29.99	$1,640,189
F15A/B	104	12369	1.41	2	24739	$29.99	$741,917
F15C/D	392	40290	4.6	2	80581	$29.99	$2,416,618
F15E	224	26732	3.05	2	53464	$29.99	$1,603,397
F-15 Totals	720	79391	9.06	2	158784	$29.99	$4,761,932
AC130H	8	3546	0.4	2	7092	$29.99	$212,689
AC130U	15	3489	0.4	2	6978	$29.99	$209,282
C130E	167	60281	6.88	2	120561	$29.99	$3,615,630
C130H	278	92840	10.6	2	185680	$29.99	$5,568,531
C-130J	34	6649	0.76	2	13298	$29.99	$398,807
EC130E	3						
EC130H	10	2800	0.32	2	5599	$29.99	$167,920
HC130N	9	2341	0.27	2	4682	$29.99	$140,401
HC130P	22	6903	0.79	2	13806	$29.99	$414,030
LC130H	10	2508	0.29	2	5017	$29.99	$150,454
MC130E	14	9820	1.12	2	19641	$29.99	$589,028
MC130H	20	8729	1	2	17458	$29.99	$523,565
MC130P	27	13246	1.51	2	26492	$29.99	$794,483

Note the anticipated savings for the F-15 fleet, which equates to nearly 80,000 hours of aircraft availability. This, in turn, represents an additional nine F-15 aircraft in the fleet. The C-130 savings were not summed due to the diverse missions associated with each model. However, examination of those C-130 aircraft with similar missions (specifically the -E, -H, and –J), the combined aircraft availability savings of 159,770 hours equates to an additional 18 aircraft. Combined man hour savings and cost for these three models are 319,540 man hours and $9,582,968.

Appendix B: Transition Activities and Recommendations

B.1. Program Introduction

Aircraft Maintenance Intuitive Troubleshooting (AMIT) was conceived at an AFRL/MAJCOM technical interchange meeting, with the realization that technician performance was an under explored and possibly significant contributor to aircraft availability and readiness. Heretofore, the Air Force (AF) has given much attention to maintenance levels, repair locations, spares, tools and test equipment, technician training, specialty codes, and even to job performance rating. Little attention, however, has been paid to factors affecting the technician's performance – the "how" and "why" technicians perform the way they do on the flightline. How do technicians successfully return highly complex aircraft to service in spite of the known limitations and challenges imposed by the maintenance process and related support and supply systems?

Given this line of thinking, the Logistics Readiness Branch of the Human Effectiveness Directorate of the Air Force Research Laboratory (AFRL/HEAL) initiated a 6.3 advanced research and development (R&D) program and awarded the AMIT contract to NCI Information Systems, Incorporated (NCI) in December 2003. NCI is an information technology services provider with relevant skills in the aircraft maintenance and maintenance management domains.

B.2. Transition Overview

AFRL/HEAL placed highest priority and value on transition at the project outset, which continued throughout the program. The strategic objectives of AMIT transition were simple:

- Coordinate with the senior AF leadership to ensure that AMIT fits into the big picture of logistics transformation initiatives.

- Find the right transition agent to take over the implementation role post-research, development, and testing
- Coordinate a deliberate Technology Transition Plan (TTP) with the transition agent and the operational users that would be included in the implementation effort
- Coordinate with operational users to plan ahead for future POM wedges and funding for an AMIT pilot implementation

These objectives were all critical and are necessarily prioritized.

The AMIT Team conducted the research and developed the capability within the guidelines and in the spirit of critical AF programs such as the Expeditionary Logistics for the 21st Century (eLOG21), the Expeditionary Combat Support System (ECSS), and the Global Combat Support System – Air Force (GCSS-AF).

B.3. Approach

The AMIT transition approach hinged on a philosophy of discovering and frequently engaging potential transition agents, operational sponsors, and funding sources. For the purposes of transition, there was no single preferred customer. The primary rationale for this approach was AMIT, as a concept, was generically applicable to all flightline maintenance troubleshooting activities, regardless of Department of Defense, Air Force, MAJCOM, Base, Group, or Squadron mission. The underlying transition theme was to support Combatant Commanders fighting the global war on terrorism (GWOT) and conducting other combat operations.

In approaching transition throughout the research, development, and testing phases of the program, the AMIT Team put considerable thought and effort into finding where the AF is heading with its Information Technology (IT) transformation vision. We learned how senior policy makers at Air Staff plan to address enterprise level initiatives – programs like eLog21, ECSS, GCSS-AF, and Air Force Smart Operations for the 21st Century (AFSO 21). Awareness of challenging initiatives impacting the logistics domain in both the near and long term were also important – force sizing and enterprise transformation actions like Task Force 720 (TF 720) and Repair Enterprise 21 (RE 21) – when addressing the future operational flightline environment that included the AMIT concept.

B.4. Transition "Roadshow" Team

In order to maximize transition dollars, the AMIT PM formed the AMIT "Roadshow Team" very early in the program. The basic charter of the Team was to take the AMIT message to logistics leaders at all levels of the Air Force, joint service commands, and mid-tier maintenance managers at MAJCOM, Group, and Squadron levels.

The Team was comprised of core AMIT personnel, including the AFRL/HEAL Program Manager (PM), Mr. Chris Curtis, two seasoned HEAL aircraft maintenance officers, Captains Vaughan Whited and Derrick Barthol, and the NCI PM/transition lead, Mr. Charles Botello. The Roadshow Team succeeded in presenting AMIT to the logistics warfighter on many fronts – in the offices of the senior logistics policy staffs at the Pentagon, the technical training schoolhouses, the MAJCOM headquarters, operational aircraft maintenance units, and in the aircraft depot maintenance hangars and back shops. Figure B-1 summarizes milestone contacts with potential transition agents, operational sponsors, and potential funding agents. The fishbone chart chronicles actual transition activities and accomplishments during the course of the AMIT program – May 2004 through contract end in January 2007.

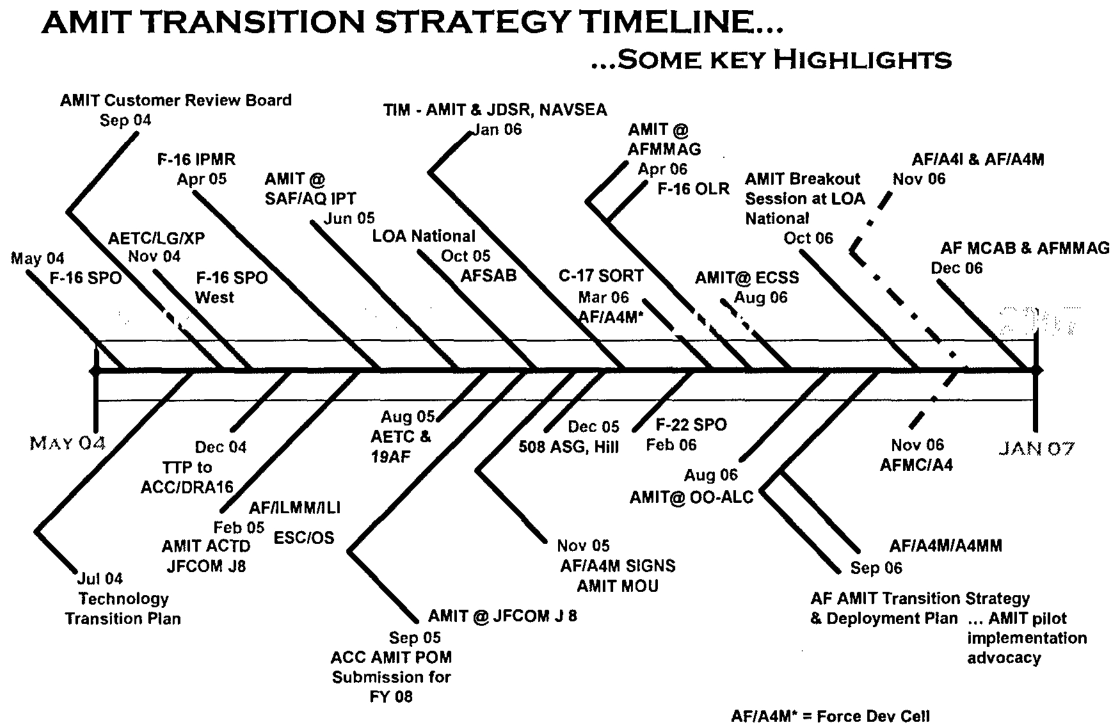

Figure B-1. AMIT Transition Activity Timeline

The transition team met weekly for the duration of the program. In the first 6 months of the program, the team had identified many of the critical players in the AF infrastructure, and placed a priority on selecting viable transition paths and strategies. By May of 2004, the AMIT transition strategy was initially developed, and the team planned to establish ongoing dialog with key organizations representing the operational warfighter and our primary AMIT target – the aircraft maintenance flightline technician.

The AMIT transition strategy was outlined in an informal TTP. The TTP helped our transition team lay out the focus of the AMIT message, identify and list the intended target organizations and key personnel, capture the strategic roadmap on how to coordinate planned visits, and measure our level of progress in our Roadshow team efforts. With the TTP as the guiding document, the team continually adjusted and re-baselined execution of planned transition activities. On a weekly basis, the team reviewed strategic objectives and executed activities to meet those goals in 30, 60 and 90-day intervals. After key visits, results were documented in trip reports. The critical data captured from these trips included an analysis of whether objectives and takeaways were achieved, notes of key discussions and resultant action items that aided in transforming the transition strategy and in updating the TTP, accordingly.

One of the most intriguing transition obstacles the AMIT Roadshow team consistently had to overcome was the operational users' lack of understanding regarding what AFRL/HEAL was trying to do with performance enhancement initiatives like AMIT. Regularly visiting the major commands, operational bases, joint service commands, Headquarters Air Force, and selected logistics-related conferences proved to be beneficial.

One of the primary drivers in the AMIT transition strategy was a comprehensive, working knowledge of where AMIT could fit into an operational environment and how AMIT could be sustained within the information technology upgrades envisioned within the next 5-10 years. As we envisioned in the transition strategy in years one and two of the program, an AMIT pilot application or limited-scale implementation became the focus of transition discussions, as AMIT was developed to integrate into the GCSS-AF Integration Framework. In the implementation concept, the AMIT service would be accessible through the AF Portal, where the operational user could gain access through the single log-in point of entry. In this IT-secure environment, the technician would have at his or her disposal interfaces to aircrew debriefing documentation, the relevant aircraft technical orders, the historical data for aircraft systems/subsystems/components, shop level logbook data, and the means to collaborate with others.

B.5. Results, Discussion, and Recommendations

The ACC logistics staff has fully embraced and formally adopted the AMIT concept in submitting a Programmed Objective Memorandum (POM) line item wedge for AMIT in addressing its Fiscal Year 2008 combat logistics support needs. In the August-September 2006 timeframe, when racked and stacked at ACC amongst other logistics operational CAF needs for the F-16 Block 40/50, AMIT ranked 13th of approximately 24 inputs on the list.

Since Brig Gen David Gillette (then AF/A4M, and now ACC/A4) signed the AMIT Memorandum of Understanding in late 2005, there has been significant personnel turnover at both AF/A4M and AF/A4MM, the chief policy makers for all Air Force maintenance and the maintenance information systems portfolio managers within the eLOG21 Portfolio Management Program of AF/A4I.

In December 2005, Brig Gen Gillette gave our AMIT Roadshow team direction to pursue an implementation of AMIT within the principles of the ECSS, rather than the pursuit of an ACC-sponsored Advanced Concept Technology Demonstration (ACTD). His preference was to focus near-term AMIT transition efforts on a pilot implementation vice using critical resources for yet another demonstrator.

Therefore, the AMIT team has embarked on integrating AMIT as a pilot into pre-existing programs in lieu of doing additional AMIT user assessments. The programs Brig Gen Gillette suggested included GCSS-AF, ECSS, and Point of Maintenance (POMx). Collaboration work is being performed with each of these efforts. However GCSS-AF is only the technical framework that will provide access to the AMIT application. ECSS just concluded its source selection process for the System Integrator and is at least 3-5 years from hosting the AMIT capability. POMx is anticipated to be absorbed into the higher level requirement of IMDS.

The primary objectives of an AMIT deployment plan are to help the Air Staff, as the champion of the AMIT concept, and the operational major command to form a basic, deliberate, and incremental approach to instituting AMIT into base level operations. This deployment plan will require full coordination with, and direct support from, the owning major command.

Consideration of the AMIT pilot implementation options is a function of full and thorough coordination with the major command that is stepping up to take ownership of the transition agent role, such as the ACC as the primary CAF lead. The common denominator with these options is that the technical data can be provided by the respective technical order distribution accounts (TODAs) in the aircraft sustainment groups, as well as the Original Equipment Manufactures (OEMs). The historical data can be accessed through the Air Force Portal from AFDS and the respective weapons system's data in IMDS. Logbook data can be gathered from the base level organization sponsoring the pilot application. Based on our transition activities over the past 18 months, the AMIT team recommends the options described in the paragraphs below.

- CAF F-16 Fixed Wing Aircraft

The F-16 aircraft is the top operational contender for an AMIT pilot implementation. It has been our platform of choice since the development program inception in late 2003. We have conducted our field test using F-16 Block 42 aircraft assigned to the 56th Maintenance Group at Luke AFB. Both ACC and AETC, with its 19th AF logistics and operations contingent, have fully supported the FDT at Luke AFB. The 508th Aircraft Sustainment Group at Hill AFB, Utah has been tremendously supportive and provided the F-16 technical data in Standard Generalized Markup Language for our AMIT team to use.

Depending on availability of aircraft and other critical resources, as well as non-interference operational considerations, an AMIT pilot application could be implemented at one of the following bases: Luke AFB, Hill AFB, or Shaw AFB. In addition, implementation at Burlington ANG, Vermont could be accomplished within the operating guidelines of the ANG/ACC CAF Total Force Program.

- AFSOC MQ-1 Predator Unmanned Air Vehicle

The MQ-1 Predator is another viable platform, soon to be within the operational inventory of AFSOC mission commitments. The senior leadership in the AFSOC logistics (A4M) community is highly supportive of the AMIT concept and wants to consider an AFSOC pilot implementation. The AMIT team understands that the technical data for the MQ-1 can be provided in Interactive Electronic Technical Manual (IETM) format.

- CAF H-60 Rotary Wing Aircraft

The H-60 helicopter is also a viable candidate platform for an AMIT pilot application. H-60 helicopter maintenance troubleshooting, data interfaces and other maintenance processes essentially mirror the fixed wing assets.

B.6. Transition Summary

The AMIT transition team followed the right path in its transition strategy, and started that path early. Operational users at all levels were convinced that AMIT was the right technology with high potential to be a force multiplier for one of our most critical resources – the flightline maintenance technician. General officers, Senior Executive Service civilians, and Expert/Novice technicians alike embraced the AMIT concept. The universal thread of their comments focused on the need to have an AMIT capability operational as soon as possible.

The strategy used by the AMIT team proved to be beneficial in successfully transitioning the AMIT concept to key organizations that bear direct responsibilities in transforming and sustaining the resources for the operational logistics forces involved in the GWOT efforts and other war fighting activities worldwide.