Logistics Management Institute

Portable Maintenance Aids

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14. ABSTRACT
One of the fastest growing phenomena within the Department of Defense (DoD) today involves the use of portable maintenance aids (PMAs). The driving force behind this phenomenon is the rapidly increasing digitization of weapon systems and associated technical data. Within the DoD maintenance arena, PMAs are used for technical data display, fault isolation, repair mentoring, material management, maintenance documentation, health monitoring, prognostics, and operational data upload/download. The widespread use of PMAs has only recently gained momentum within DoD. Because most DoD PMA initiatives are still in their infancy, there is relatively little data available for quantification of benefits. While initial results indicate that PMAs can facilitate significant improvements in overall maintenance productivity, several cultural and technical obstacles must be overcome before PMAs will be truly effective DoD maintenance tools.

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Executive Summary

One of the fastest growing phenomena within the Department of Defense (DoD) involves the use of portable maintenance aids (PMAs). The driving force behind this phenomenon is the rapidly increasing digitization of weapon systems and associated technical data.

PMAs can be most succinctly defined as mobile computing devices that are used at the point of maintenance. Within the DoD maintenance community, these devices are often used for technical data display, diagnostic fault isolation, repair mentoring, materiel management, maintenance documentation, health monitoring, prognostics, and operational data upload/download.

In order to more fully understand current and emerging PMA concepts and programs in DoD, the Deputy Under Secretary of Defense (Logistics and Materiel Readiness), DUSD(L&MR), tasked LMI to identify and assess potential PMA benefits, issues, and challenges.

We examined how PMAs are employed within DoD and select commercial applications. We reviewed 33 PMA applications (i.e., 5 Air Force, 8 Army, 8 Navy, 5 Marine Corps, 1 Joint, 4 commercial airlines, and 2 commercial trucking companies). These applications ranged from relatively inexpensive commercial off-the-shelf (COTS) devices to highly ruggedized units that cost as much as $30,000 apiece because they were built to stringent military specifications.

Although mobile computing technology has been available for the last decade, the movement toward widespread use of PMAs only recently gained momentum throughout DoD. Consequently, because most DoD PMA initiatives are still in their infancy, very little data are available for quantification of benefits. Initial anecdotal evidence, however, indicates that PMAs can facilitate significant improvements in overall maintenance productivity, but several challenges must be addressed for PMAs to be truly effective tools for DoD maintenance.

DoD can obtain significant benefits from the use of PMAs to facilitate maintenance operations in the following ways:

◆ Giving maintainers on-the-job access to electronic technical information, maintenance documentation, and parts availability data.

◆ Providing a capability for maintainers to enter repair data from job sites in real time in order to provide instantaneous visibility to multiple users regarding maintenance actions and equipment status.

◆ Enabling on-the-job access to detailed technical data and remote engineering support via automated information technology (AIT) and telemaintenance.

◆ Allowing direct communications with weapon systems in order to facilitate troubleshooting, particularly for complex systems that do not have embedded diagnostic and prognostic functionality.

However, the following challenges must be addressed before PMAs can be effectively employed in DoD maintenance environments:

◆ Poor sunlight readability, short battery life, and environmental factors such as temperature extremes, moisture, and dust seriously degrade the performance of some commercial "off-the-shelf" PMAs in military environments.

◆ Insufficient integration with existing maintenance management systems and emerging maintenance automation initiatives is adversely affecting some DoD PMA initiatives (e.g., the F/A-18E/F program).

◆ Cultural resistance to use of electronic media is a major problem for some DoD organizations, particularly when there is lack of management focus or inadequate user training.

◆ Many DoD organizations are struggling to address common PMA issues, such as hardware, software, vendor selection, and funding, but there is minimal information sharing about PMA policies, plans, and projects.

In view of these benefits and challenges, we recommend the following actions to enhance the effectiveness of PMA acquisition and utilization throughout DoD:

◆ The Assistant Deputy Under Secretary of Defense (Logistics and Materiel Readiness) for Maintenance Policy, Programs and Resources (ADUSD[L&MR]MPP&R) should establish DoD-wide guidelines for assessing PMA benefits that are based on the following criteria:

  ➤ Maintenance functionality—What functions does the PMA perform, and how well does it support the performance of those functions?

➤ Military utility—How well does the PMA operate in military environments?

➤ Impact on operations and support costs—Is the PMA cost-effective?

◆ ADUSD(L&MR)MPP&R should sponsor periodic reviews of PMA acquisition and utilization processes in order to enhance information-sharing throughout the DoD maintenance community. These reviews should specifically address:

➤ Lessons learned regarding common PMA problems (e.g., economically satisfying ruggedization requirements and ensuring adequate security for wireless operations)

➤ Approaches for more effectively integrating PMAs with legacy management information systems and emerging maintenance automation initiatives (e.g., AIT and telemaintenance).

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Overview

BACKGROUND

Within the context of this study, portable maintenance aids (PMAs) are defined as mobile computing devices used at the point of maintenance. These devices vary in size and capacity from small handheld instruments to bulky units weighing up to 25 pounds. In general, PMA hardware options include two different types of devices. One encompasses "thin client" devices that contain very little resident memory; however, these devices can be updated on a near real-time basis when linked to servers for information retrieval and processing. The second type is composed of "thick client" devices, which are somewhat larger to accommodate onboard information storage and processing. There are distinct advantages and disadvantages for both types of PMAs, depending upon how they are employed. The most critical factor for ensuring successful PMA use is choosing the most appropriate device for use in a particular situation, and this report addresses a broad range of lessons learned in that regard. Figure 1-1 depicts the general range of mobile computing devices currently used as PMAs within DoD.

Figure 1-1. Sample PMA Hardware
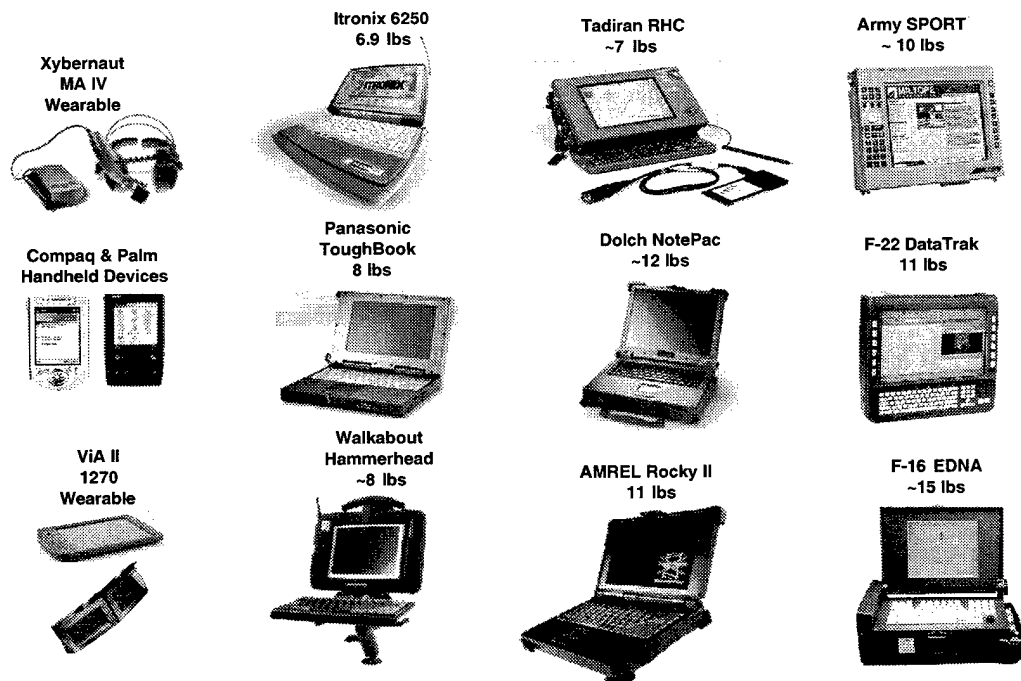
Recent advances in computing speed, hard drive storage, voice recognition capabilities, component miniaturization, and wireless communications are making PMAs more useful than ever before. Within the next few years, rapid technological improvements are expected to enable processing speeds up to 10,000 megahertz and more than 500 gigabytes of storage space. Onboard data storage requirements may lessen as technological advances provide worldwide real-time sharing of information via wireless networking.

Software and hardware manufacturers are already moving from stand-alone computing toward rapidly expanding mobile networks. Progress in artificial intelligence technology may soon allow computers to identify potential problems, determine appropriate corrective actions and provide technicians with detailed instructions regarding maintenance actions that should be taken.

STUDY OBJECTIVES AND METHODOLOGY

The overall objectives of the study were to:

◆ assess current and emerging PMA concepts, equipment and programs for DoD weapon systems;

◆ characterize potential PMA benefits; and

◆ identify implementation desirability, issues, and challenges.

This report is based on an extensive literature review and numerous interviews with PMA users in both DoD and the private sector, as well as suppliers of associated hardware and software. We conducted on-site visits to ascertain user perspectives and observe PMAs in use. These visits provided valuable insights regarding the effectiveness of various PMAs in maintenance environments. However, the intent of this research was to identify noteworthy challenges and opportunities regarding PMA acquisition and utilization rather than to evaluate specific PMA-related hardware and software applications.

MAINTENANCE FUNCTIONALITY

PMAs can be used to perform a broad range of functions. Maintainers frequently use them to access technical data and inspection checklists at the point of maintenance as well as to perform advanced diagnostics on complex systems. Additionally, wireless technology provides the capability to connect maintainers to central data repositories and subject matter experts at remote locations. This allows maintainers to obtain essential data when and where they need them.

The most common PMA functions include technical data display, fault isolation and repair mentoring, parts query and ordering, maintenance documentation and analysis, health monitoring and prognostics, and operational data upload and

download. In general, PMAs specifically designed for military applications have more capability than commercial off-the-shelf (COTS) devices.

Technical Data Display

PMAs are widely used in both DoD and the private sector to display electronic technical data. Throughout DoD, "hard-copy" technical documentation is gradually being converted into integrated electronic technical manuals (IETMs), which fall into the following general classes:

- ◆ Class I: bit map/raster files consisting of electronically indexed pages with some tools for pan, zoom, and hotspots used for reference purposes.

- ◆ Class II: American Standard Code for Information Interchange (ASCII) or Portable Document Format (PDF) text with graphics and browse function through electronic document scrolling, hotspots and cross-reference.

- ◆ Class III: linear ASCII with Standard Generalized Markup Language (SGML) tags, providing dialog-driven interaction, logical display of data with content, and "next" and "back" functions. Text and graphics can be displayed simultaneously.

- ◆ Class IV: hierarchically structured attributed databases possessing all class III functionality, coupled with a database management system.

- ◆ Class V: integrated databases with expert system support that mentors inexperienced maintainers through complex procedures while allowing more knowledgeable technicians to selectively access relevant technical data.

It should be noted, while all five classes are generically called IETMs, only classes IV and V are truly integrated. Technically, classes I through III should be referred to as electronic technical manuals (ETMs).

Fault Isolation and Repair Mentoring

Fault isolation is an advanced diagnostics function that significantly enhances a maintainer's ability to locate and correct problems. Repair mentoring systems are designed to assist inexperienced technicians in effectively diagnosing problems and performing repairs efficiently and safely. PMAs can help maintainers obtain "real-time" access to this information in while they are performing the work.

Parts Query and Ordering

PMAs can expedite the repair process by allowing maintainers to determine the availability of replacement parts and place orders directly from the work site.

Maintenance Documentation and Analysis

Maintenance management systems must contain current repair status information in order to permit efficient resource allocation and effective failure mode analysis. PMAs can accelerate the data-entry process by allowing maintainers to provide repair completion reports directly from the work site.

Health Monitoring and Prognostics

Health monitoring systems provide the capability to identify developing conditions and alert both operators and maintainers to conditions that may result in equipment failure. PMAs facilitate health monitoring by allowing maintainers to display and analyze prognostic data in "real time" at the work site.

Operational Data Upload and Download

Many advanced digital systems require the upload of operational data for specific missions. PMAs can be used to upload operational data as well as download valuable information on equipment condition and usage.

MILITARY UTILITY

The utility of PMAs in the military maintenance environment is largely determined by the ruggedness and user-friendliness of the PMA hardware, and by how effectively the PMA software interfaces with other systems.

Ruggedness

Maintainers often repair military equipment under adverse environmental conditions. Moisture, corrosion, vibration, electromagnetic interference, and extreme heat and cold are particularly problematic for military PMA applications. Figure 1-2 illustrates the diverse range of PMA ruggedization parameters.

Figure 1-2. PMA Ruggedization Parameters

GSA Schedule/Retail Distributors			Military Procurement	
lower ⟸ Unit Cost ⟹ higher				
Commercial Off-The-Shelf			Competitive	Sole-Source
Consumer-Oriented	Commercially Rugged	Industrially Rugged	"Mil Ruggedized"	Mil-Spec
Not ruggedized	Ruggedized enough for use in most commercial environments	Highly ruggedized for heavy industrial usage	Tailored to meet specific government specifications	Mil-Std-461C; Mil-Std-810E
Example: Compaq, Dell, etc.	Example: Walkabout Hammerhead Panasonic Toughbook	Example: PEI A760 Itronix 6250	Example: SPORT Tadiran RHC	Example: F-16 EDNA F-22 DataTrak
<$1,500	$1,500 - $3,000	$3,000 - $10,000	$10,000 - $20,000	>$20,000

User-Friendliness

SUNLIGHT READABILITY

A large amount of field-level military maintenance must be performed outside, but many portable computer displays are virtually unreadable in direct sunlight. However, photo sensor technology can be used to enhance sunlight readability, as evidenced by the easily readable computer screens used in commercial airliners.

VOICE RECOGNITION CAPABILITY

Researchers at the Carnegie Mellon Human-Computer Interaction Institute and the Air Force Research Laboratory anticipate that voice recognition capability will soon be practical for use in military maintenance environments in order to facilitate hands-free PMA operation. However, a complicating factor for many military PMA applications is the need to eliminate high-intensity background noise in order to focus on the desired source.

ERGONOMICS

Commercial providers of PMA hardware and software are making concerted efforts to optimize their products for maintenance use. Touch screens and wearable point and click devices are making the interface with PMAs more user-friendly. Size and weight are also primary concerns for maintainers who must carry these devices for extended periods. As computer processors are miniaturized, wearable computers are emerging as practical alternatives to laptop and handheld devices. Heat dissipation, however, is a major factor for these wearable devices because some generate intense heat when operated continuously.

BATTERY LIFE

Many PMAs have only 3–4 hours of useful battery life and cannot connect to weapons system power sources. In order to be useful, PMA batteries must, therefore, be recharged frequently when not in active use. Some units have hot-swappable batteries that extend the useful period of mobile computing and allow data savings before losing all power. Fortunately, devices specifically designed for military applications generally can connect to the weapons system power source.

ELECTRONIC INTERFACES

The interfaces between both equipment being repaired and maintenance data systems may impinge upon PMA effectiveness. Direct connections between PMAs and the equipment being repaired facilitate rapid analysis of system performance characteristics and allow faster transfer of critical information for ordering parts, reporting work performance, and receiving updated technical information. Most COTS products do not accommodate such interfaces, but recent innovations may enable virtually all PMAs to communicate directly with weapons systems.

Information security and bandwidth availability are major concerns for most military maintenance applications. Wireless operations require extra precautions to prevent interception and jamming of data transmissions. However, because most maintenance information is sensitive but unclassified, commercially available security features (e.g., data encryption and virtual private networks) may provide sufficient protection.

Although not necessary for many maintenance functions, wireless technology greatly enhances the use of other electronic information sharing initiatives, such as automated information technology (AIT) and telemaintenance. These ongoing DoD initiatives enable direct linkage between PMAs and remote locations to facilitate oversight of fault isolation and repair procedures.

REPORT STRUCTURE

Maintenance functionality (i.e., technical data display, fault isolation and repair mentoring, parts query and ordering, maintenance documentation and analysis, health monitoring and prognostics, and operational data upload and download) and military utility (i.e., ruggedness, user-friendliness and system integration) provide a consistent framework for assessing PMA applications in both DoD and the private sector. Chapters 2 through 4 examine PMA usage within each of the military services (i.e., Air Force, Army, Navy, and Marine Corps). Similarly, Chapter 5 provides insight into the way PMAs are employed within the commercial aviation and trucking industries. Finally, Chapter 6 summarizes our findings, discusses some noteworthy issues regarding PMA acquisition and utilization, and provides several specific conclusions and recommendations.

Chapter 2
Air Force Applications

BACKGROUND

During the mid-1990s, the Air Force began development of an Integrated Mainte-
nance Data System (IMDS) as a replacement for several maintenance information
systems, such as the Core Automated Maintenance System (CAMS), Reliability
and Maintainability Information System (REMIS), and Comprehensive Engine
Management System (CEMS). The functional requirements of IMDS were to:

◆ support production through the use of enhanced diagnostics, interactive
   electronic technical data, and parts ordering;

◆ support training activities; and

◆ measure performance of equipment through the collection of maintenance
   data, compute reliability/maintainability, and perform failure analysis and
   prediction.[1]

To be "mobile, deployable, and global,"[2] the IMDS concept provides for the use
of PMAs on the flight line. Conceptually, a single data entry on a PMA could
provide multiple Air Force users the necessary asset and resource visibility to
forecast, schedule, and track production events, mission capability, and weapons
system configuration.

Although the Air Force has abandoned the original IMDS concept (for reasons
beyond the scope of this study), Standard Systems Group (SSG) managers at
Gunter Annex, Maxwell Air Force Base (AFB), Alabama, are redesigning the
IMDS software as a future replacement for CAMS. In the interim, several Air
Force organizations are attempting to integrate PMAs into existing maintenance
data systems because the Air Force intends to digitize almost all technical data.

POLICY

Technical Data Digitization

The Air Force plan for technical data digitization is outlined in the Technical Or-
der Concept of Operations (TO CONOPS). As a result of personnel and budget

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[1] "Report of the Integrated Maintenance Data System (IMDS) Integrated Product Team," Col.
William J. Colmer, March 11, 1994, slide 7.

[2] Ibid, slide 5.

downsizing and the need to improve the management and distribution of technical manuals, the "distribution and use of digital data is the desired end-state."[3] The current technical orders (TOs) consist of paper manuals and compact discs (CDs) that require significant management attention to ensure data accuracy and timely delivery. Consequently, digitization of technical data is a very high priority within the Air Force.

Wireless Connectivity

Air Force Headquarters has issued interim guidance on wireless local area networks (LANs), pending publication of formal Air Force Communications Agency (AFCA) policy.[4] However, each command interprets this guidance differently, and mobile computing and wireless programs are evolving at significantly different rates. Also, because maintenance information systems such as CAMS and CEMS contain unclassified but potentially sensitive data, there is a lack of consensus regarding security requirements for maintenance data transmissions.

Portable Maintenance Aids

Given the current emphasis on data digitization and wireless connectivity, Air Force maintenance managers are seeking the most effective means to access technical information at the point of maintenance. However, there is currently no overall Air Force policy regarding PMA acquisition or utilization.

NOTEWORTHY INITIATIVES

Air Force Research Laboratory

To determine the feasibility of flight-line mobile computing, the Director of Maintenance on the Air Staff (HQAF/ILMM) tasked the Air Force Research Laboratory (AFRL) at Wright-Patterson AFB, Ohio, to evaluate emerging technologies and maintenance applications. AFRL's ongoing 15-month point-of-maintenance study is designed to "demonstrate timely, accurate, and effective data collection and logistics operations processing to meet the maintainer's needs at the point of origin."[5] Its objectives include: access to work orders, technical data, and parts information at the job site; identification of process changes in the field; utilization of barcode technology to improve component tracking; and demonstrated capability for forward deployment, voice activation and wireless operations. While the AFRL is evaluating mobile computing for widespread use and implementation, PMA initiatives are already underway within the Air Mobility Command (AMC) and at Nellis AFB, Nevada.

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[3] The Air Force TO CONOPS, August 2000.

[4] HQAF/SC Memorandum, Lt. Gen. John L. Woodward, August 26, 2000.

[5] Point-of-Maintenance Fact Sheet, Capt. Rudy W. Cardona, AFRL/HESR.

Air Mobility Command

The Air Mobility Command (AMC) has adopted a centralized approach to mobile computing, which revolves around the Global Combat Support System (GCSS) strategy for integrating and improving interoperability of currently independent combat support systems, applications, and data.[6] Using the GCSS as its foundation, AMC is pursuing mobile computing under the following general guidelines:

◆ Adapt as technology improves.

◆ Utilize a standard architecture and a common infrastructure.

◆ Include a mixture of hardware to meet specific mission requirements (i.e., hardwire, wireless, palm, notebook, or voice recognition devices).

◆ Implement incrementally and then improve upon it.

◆ Demonstrate return on investment through cost benefit analyses.

Because of cost considerations, AMC decided to digitize technical data as indexed PDF files rather than the more costly IETM format. The indexed PDF files are essentially Class II ETMs with digital hot-linked work cards. These AMC digitization efforts predate Air Force TO CONOPS requirements for SGML use.[7]

WIRELESS CONNECTIVITY

AMC considers wireless operations to be the most effective means of digital data access. Working with the Telos Corporation as its integrator, AMC is in the final stages of installing radio frequency (RF) capability on each of its bases. To achieve wireless maintenance operations, AMC uses CD-ROMs to load digitized TO data into central servers; an electronic signature composed of user name, password, and employee number; fixed locations around the aircraft for mobile computers; and a portable transceiver for forward deployments. As the program integrator, Telos provides all hardware and associated support for this program, with unit costs of approximately $3,000 to $4,500. AMC plans to implement web access this summer, and is currently working on voice activation methods. It is likely that future operations will almost exclusively utilize thin clients, with virtually all data stored on central servers.

INFORMATION SECURITY

Current approaches to wireless security involve Frequency Hopping Spread Spectrum (FHSS) and Direct Sequence Spread Spectrum (DSSS) encoding methods, both of which use the 2.4-gigahertz microwave band. FHSS "spreads the conversation across 75 one-megahertz (MHz) subchannels, continually skipping between

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[6] GCSS website <http://www.disa.mil/info/pao04ac.html>.

[7] AF TO CONOPS, p. 4.

them;" whereas DSSS "breaks the band into 14 overlapping 22-MHz channels and uses one at a time."[8]

The Institute of Electrical and Electronic Engineers (IEEE) has adopted DSSS as its standard and developed the 802.11b specification for wireless network communications. Utilizing the IEEE 802.11b specification provides enhanced security because the higher frequency wavelengths dissipate quickly and are harder to jam than the lower frequency wavelengths. Additionally, the IEEE 802.11b specification includes a Wired Equivalent Privacy (WEP) protocol, which involves additional security measures not available in wired networks. For this reason, "some people are of the opinion that a properly implemented, protected wireless LAN is more protected than a wired LAN."[9] However, University of California, Berkeley, researchers believe there are flaws in the WEP algorithm that "undermine the security claims of the system."[10]

Even though there is some disagreement about how effective current security systems are for wireless operations, a number of companies are attempting to enhance security mechanisms. Current efforts include work on longer encryption keys and sending data through virtual private networks (VPNs). The VPN tunneling protocol "involves encrypting data before sending it through the public network and decrypting it at the receiving end."[11] Additional security can be achieved by encrypting the addresses as well as the actual data.

AMC has plans to establish VPN capability at three of its bases within the next few months. Cisco Systems is developing routers that provide point-to-point VPN, and VPN concentrators for remote access. Cisco is also developing Type 1 encryption (designed for classified information) to enhance security during wireless operations.

SELECTED APPLICATIONS

Our review of major PMA applications in the Air Force focused primarily on the three legacy aircraft (C-5, E-8, and F-16) and two new aircraft (C-17 and F-22). For each of these aircraft, we examined the maintenance functionality and military utility of both COTS devices and PMAs developed specifically for military applications.

In terms of maintenance functionality, COTS hardware is primarily used for technical data display, parts query and ordering, and maintenance documentation and analysis. Many COTS devices offer a degree of military utility, involving some

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[8] Flickenger, Rob. "802.11b Tips, Tricks, and Facts," O'Reilly Network, March 2, 2001.

[9] Weatherspoon, Sultan. "Overview of IEEE 802.11b Security," Intel Technology Journal Q2, 2000, p. 2.

[10] Brewin, Bob. "Wireless LANs Have Serious Security Flaws, Berkeley Researchers Say," <www.computerworld.com/cwi/story/0,1199,NAV47_ST057394,00.html>, February 5, 2001.

[11] Definition from <www.WhatIs.com>.

ruggedization, sunlight readability, and battery life—but not to the extent of more expensive militarized PMAs. Electronic interfaces, such as peripheral component micro-channel interconnect architecture (PCMCIA) cards, enable COTS devices to operate wirelessly and afford access to central databases.

Militarized PMAs are primarily used for fault isolation and repair mentoring, health monitoring and prognostics, and operational data upload and download. In this category are the Enhanced Diagnostic Aid (EDNA) for the F-16, F-117, and B-2 aircraft and the DataTrak Model 20 for the F-22 aircraft. The EDNA functions extraordinarily well for diagnostics and operational flight plan (OFP) upload. Although capable of other PMA functions, such as TO display and parts ordering, it is not cost-effective to use the EDNA for these functions when less expensive devices are available. The F-22 DataTrak, on the other hand, has COTS hardware with specialized capabilities, and is intended for widespread use. Both devices offer generally good military utility in terms of ruggedness, sunlight readability, and moisture/humidity resistance. The EDNA and the DataTrak are capable of connecting and communicating to their respective weapon systems through a series of cables. Presently, this information is not transmitted wirelessly because of the classified nature of the operational flight data.

C-5 Galaxy

The C-5 aircraft, as part of the AMC maintenance mobile computing program, utilizes COTS equipment for the following functions:

◆ Technical data display

◆ Parts ordering

◆ Maintenance data collection and analysis.

In general, C-5 maintenance technicians accomplish isochronal (ISO) inspections through digital work cards, which list each area requiring inspection and functional check. Each inspection detects approximately 1,400 discrepancies, with each generating a maintenance data collection record. With the wireless operation, technicians input information on digitized work cards on a laptop computer at the aircraft, reducing the time spent traveling from the aircraft to the desktop computer in the office and eliminating much of the paperwork. The work cards are hot-linked to the G081 (CAMS for airlift) database, automatically updating maintenance records. AMC has phased in other functions to include links to the Illustrated Parts Breakdown and Quick Reference List, as well as e-mail access through the local intranet.

Dover AFB, Delaware, is AMC's prototype location for wireless ISO operations. In order to overcome cultural resistance, Dover management mandated laptop

usage in the inspection docks.[12] Laptops (primarily Panasonic Toughbooks and Zenith CruisePads) were placed in convenient locations on and around the aircraft, and managers stressed the benefits of data entry and access at the point of maintenance. Technicians have accepted the mobile system and have no desire to return to the previous paper methods.

The Dover flight-line operation is considerably different. The crew chiefs, who are primarily 3- and 5-level technicians, don't enter their own discrepancies into the G081. Instead, a designated technician enters the discrepancies, and, with no need for an electronic signature, technicians exchange employee numbers freely. Based upon a recent month-long test of the wireless usage, which detected more than 400 logons for the ISO docks and only 3 for the flight line, few flight-line personnel currently use the wireless operation. Flight-line technicians see no benefit to using the wireless system, and management has not yet mandated wireless usage in that area.

The learning curve for the paperless ISO process at Dover has evolved with each aircraft inspected. However, Dover has been working to correct all the problems, such as developing graphical user interface (GUI) screens instead of text-based screens. Subsequently, 16 aircraft have successfully employed the wireless ISO process. Dover is working with AMC to refine their operation and make the GUI screens easier to use. There are positive and negative aspects to the Dover mobile computing program:

◆ Positive aspects include:

➤ time savings—entering work at the point of maintenance reduces trips to the shop or desktop;

➤ personnel utilization—more people are performing direct maintenance versus support functions; and

➤ instant data access—electronic TOs provide a more accurate snapshot of the maintenance task.

◆ Negative aspects include:

➤ lack of computer proficiency—Dover managers have addressed this issue by teaching basic computer skills; and

➤ slow response time—RF response time is often slow because of the amount of metal in the hangars. Dover is in the process of upgrading the RF LAN infrastructure across the base, which should speed response time.

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[12] Interviews with Joseph Sabin, AMC/LGXI; David Jones, 436 LSS/LGLOC; MSgt Kenneth Stamm, 436 LG; SSgt Nikkol Bennett, 436 LG; and TSgt Edward Berner, 436 LG.

Areas of military utility, such as ruggedness, temperature tolerance, moisture re-sistance, and sunlight readability, are of less importance in the hangar environment than on the flight line because of the relative stability of the devices and the shelter the hangar provides. However, battery life is a primary concern, especially without hot-swappable batteries, which prevent the loss of information during a battery switch.

Electronic interfaces of the system include four Proxim antenna boxes located in each corner of the hangar and an RF card in each laptop. Though data security is a continual concern in the wireless environment, the lack of sophisticated security measures does not hinder the performance of maintenance functions because the maintenance information system is unclassified. Information sharing technology, such as telemaintenance capability, exists at Dover primarily in the form of Internet/intranet use.

F-16 Fighting Falcon

The maintenance functionality of the F-16 aircraft, utilizing the Enhanced Diagnostics Aid (EDNA), involves Operational Flight Program (OFP) upload and flight data download, as well as fault isolation/diagnostics. The EDNA (depicted in Figure 2-1) is a significant improvement over its predecessor, the Memory Loader/Verifier (MLV), which could only be used to upload/download software.

Figure 2-1. F-16 Enhanced Diagnostic Aid

Maintenance technicians and managers at the 113 Wing, D.C. Air National Guard, Andrews AFB, Maryland, compared the capabilities of the EDNA device to the MLV capabilities.[13] Table 2-1 shows these comparisons.

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[13] Interview with MSgt Louis Keeler and TSgt David Malone, 113 LG, DCANG.

Table 2-1. Comparison of EDNA and MLV Capabilities

Capabilities	Unit	
	EDNA	MLV
Software load time–threat warning system (in minutes)	10	60
Mobility requirements (in boxes)	2	15
Procedural processes–crash survivable flight data recorder (in steps)	13	49

Major EDNA benefits include the following:

◆ Data/fault integrity. Before the EDNA, technicians had to remove the line-replaceable unit (LRU) and run it on the automated test set. Removing the LRU would end the connection and eliminate the data.

◆ Ease of data upload. Technicians can download any software from the electronic bulletin board directly to the EDNA via modem.

◆ Excellent diagnostic capability. The EDNA greatly facilitates fault isolation, especially for flight control system discrepancies that can be difficult to duplicate.

◆ Improved operability. With a Pentium II processor and improved sunlight readability and weatherproofing, the current EDNA is faster and more durable than its predecessors.

Significant EDNA challenges include the following:

◆ Training. Early on, EDNA training consisted only of reading job guides and TOs with help from technical representatives. Today, technical schools provide formal EDNA training that is supplemented by on-the-job training (OJT).

◆ Cultural issues. Approximately one-quarter of the technicians were initially uncomfortable with computers and were reluctant to use the EDNA; however, OJT has helped to overcome their reluctance.

◆ Connector cables. The EDNA currently has a variety of different connector cables that significantly increase acquisition costs (i.e., base price is $30,000, but total cost may exceed $70,000 with peripheral cables and equipment). Modifications are in progress to replace many of these cables with one standard cable for avionics systems on the military standard (MIL-STD)1553 data bus.

Although F-16 TOs lack complete digitization, the System Program Office (SPO) managers expect imminent release of its pilot program, with field distribution in

2004.[14] Currently, there is a 3-year program to equip the F-16 fleet with laptop computers. The F-16 SPO will fund the first-time purchase, with each Wing providing replacement units as they are needed. Air Combat Command is also considering a suite of devices, (e.g., notebooks, tablets, and palm-tops), as appropriate for specific tasks.[15] For the foreseeable future, however, the EDNA will continue to be used for complex diagnostics, OFP upload, and flight data download.

All F-16 units use the EDNA; however, this report focuses on the mobile program at Nellis AFB and its advanced wireless operations. There are two types of PMAs evident at Nellis: the EDNA and the COTS Walkabout Hammerhead illustrated in Figure 2-2.

As mentioned earlier, EDNA functionality includes OFP software upload and verification, flight data download and display, and enhanced fault diagnostic capability. At present, the EDNA is the only PMA capable of connecting with the F-16, F-117, and B-2 via a MIL-STD 1553 data bus (the F-16 and B-2 also connect via a unique protocol interface). The Hammerhead mounts onto the expediter trucks and serves as an input device for the CAMS and for the locally fabricated Aircraft Maintenance Automated Tracking System (AMATS), which provides a comprehensive view of aircraft flight, maintenance, and supply information.

Figure 2-2. Walkabout Hammerhead Truck-Mounted Laptop

The Nellis AFB wireless operation evolved out of a test program to accelerate the time required to load OFP data onto the EDNAs for transfer to F-16 aircraft. Working with Cisco Systems, Nellis Aircraft Generation Squadron (AGS) managers installed RF capability on the flight line and associated maintenance hangars for a total cost of less than $75,000.[16]

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[14] Interview with Gregory C. Campbell, F-16 SPO, Wright Patterson AFB, OH.

[15] Interview with MSgt Steven G. Carlson, 57 AGS LAN Manager, Nellis AFB, NV.

[16] From 57 AGS web page, TSgt Brian P. Chartier and MSgt Steven G. Carlson, 57 AGS/AGX, Nellis AFB, NV. Updated and reviewed July 18, 2000.

Previously, using floppy disks to load the EDNA hard drives required approximately 12 hours for each EDNA (totaling 180 hours each month for 15 EDNAs). Using wireless technology, the EDNAs can be updated via either a PCMCIA card or external antenna, from software that is loaded on a server. All 15 EDNAs can access the server as needed, and potential savings exceed 175 hours per month. These savings are not currently achievable, however, due to security restrictions on wireless transmission of classified information.

To facilitate the use of digitized F-16 technical data, the Nellis AGS has expanded coverage to include 99 percent of the flight line and associated maintenance hangars. Once the digitized data are available, the server can be updated and data automatically shared with users. AGS operates all of its desktop computers in the wireless mode, but Nellis mobile computing managers prefer to use thick client PMA devices (e.g., Hammerhead) as protection against server outages.

With the Hammerhead PMA, maintainers have the ability to input data directly from the point of maintenance into CAMS and AMATS. The EDNA actually could provide this capability; however, ACC has restricted its functionality to data upload and download, diagnostics, and limited TO access related specifically to diagnostics. Also, CAMS inputs at the point of maintenance are limited by lack of hardware and digitized TOs. Until there are enough mobile devices and digital TOs, technicians will continue to input data on desktop office computers. At this time, CAMS and AMATS lack integration, requiring dual entries. Similarly, CAMS is not able to compile data for presentation on a single screen. Most technicians and managers agreed that, because of the tremendous benefit of total asset visibility, AMATS justified the dual entry process.[17]

PMA-related benefits of the Nellis wireless operation include the following:

◆ Data access. Technicians have immediate access to maintenance and supply information during "redball" conditions (i.e., correcting problems detected during aircraft launch operations).

◆ Data input. Technicians have immediate access from the point of maintenance to AMATS for the most up-to-date aircraft schedule and status.

The following are major challenges faced by the Nellis wireless program:

◆ Hardware shortages. Limited hardware prevents most technicians from using the mobile system at the point of maintenance.

◆ Accreditation. The wireless operation at Nellis is a unit-level design and implementation and has yet to gain accreditation from the Air Force Standard Systems Group (SSG) at Gunter Annex, Maxwell AFB, Alabama. Nellis continues wireless operations under interim approval authority.

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[17] Interview with Nellis maintenance managers.

At Nellis, military utility issues are a major consideration in the harsh desert environment. Because of the Nellis environment, which represents "the most demanding climate and operating environment across the Combatant Air Forces,"[18] the F-16 SPO selected Nellis as its test site to evaluate PMAs for heat durability and sunlight readability under flight-line conditions. In "one of the worst case scenarios for hardware,"[19] evaluators tested various models of the Panasonic Toughbook, the Itronix, and the Amrel Rocky II laptops, concentrating exclusively on high temperatures and sunlight readability. As part of an ongoing effort to standardize PMAs in the F-16 community, utility testing under harsh conditions will continue this summer at Nellis.

In terms of electronic interfaces, mobile computing managers at Nellis have eliminated many of the challenges posed by wireless operations. However, data security remains an impediment to uploading classified F-16 OFPs via wireless transmissions. Cisco Systems, the company providing the wireless infrastructure, is in discussions with the National Security Agency to develop Type I encryption to ensure maximum security during wireless operations.

E-8 JSTARS

The maintenance functionality of the E-8 Joint Surveillance Target Attack Radar System (JSTARS) maintenance mobile computing program, located at the 93rd Air Control Wing, Robins AFB, Georgia, involves technical data display, fault isolation and repair mentoring, and maintenance documentation and analysis. The "backbone" of the JSTARS maintenance program is the Joint Integrated Maintenance Information System (JIMIS), which provides digital TOs in the form of Class III and IV IETMs.

Though first introduced to the 93rd Wing in July 1998, maintenance technicians didn't start using JIMIS until July 2000, when management mandated its use.[20] Although implementation was to be incremental, the JIMIS program evolved directly from preliminary TOs to IETMs, with use of paper manuals severely restricted or discouraged. Conversations with technicians using the JIMIS program reveal mixed feelings about the system. While they generally accepted the system, technicians believe some significant problems need to be corrected.

JSTARS technicians use both the Panasonic Toughbook and Itronix ruggedized laptop. The military utility of these generally revolves around battery life and explosive atmosphere operation. The Wing has a total of 178 PMAs, the majority of which are Panasonic Toughbooks. Although more cumbersome and heavier than the Itronix laptop, many technicians consider the Toughbook to be more useful

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[18] "COTS Environmental Assessment Test Report," F-16 System Program Office PMA Phase One Evaluation, August 2000.

[19] Ibid, p. A-2.

[20] Interviews with TSgt Matthew Jones, TSgt Edward Didalesky, Hal Stewart, etc. 93rd Air Control Wing, Robins AFB, GA.

because it has a larger screen and longer battery life. However, the Itronix is intrinsically safe, which makes it a better choice for fuel cell work.

Some problems the technicians have encountered with both the Toughbook and Itronix and their associated software include hard-to-use touch pads, the inability to open multiple pages without jamming the devices, running multiple programs slows response, and battery failure that results in loss of information.

The JIMIS Class IV IETMs facilitate task work, provide technical data and enable maintainers to enlarge drawing details. There are several impediments, however, that currently limit JIMIS potential as a truly effective maintenance tool.

First, multiple schematics have the same titles, forcing technicians to flip through numerous pages to find the appropriate one. Secondly, JIMIS lacks a "checkmark" function for inspection checklists. This can be very troublesome during shift changes or battery outages because shift change procedures require manual entries in a logbook and battery outages may cause loss of all checklist data.

In addition, the following problems inhibit JIMIS effectiveness:

◆ Difficulties in research and in-depth work, such as search problems with indexing and multiple names for the same job or component.

◆ Program inaccuracies in the troubleshooting mode.

◆ No user-friendly printing capability. Most technicians agree that a printing capability is needed for schematics and wiring diagrams, but the number of IETM pages needed for removal of certain access doors is 90, in comparison to 10 pages for paper TOs.

◆ Ineffective failsafe. Technicians can bypass information by repeatedly hitting "Enter," and warnings are tediously repeated on every digital page as compared to their one-time appearance in a paper manual.

Technicians stressed the need for flexibility when using backup paper manuals as they transition to digital data. This is particularly true when conducting engine runs. They believe it's essential to have a paper checklist available in the cockpit, rather than the current procedures that use three PMAs (one for the task, one for external procedures, and one for internal procedures). This current electronic procedure takes up a lot of space in an already crowded cockpit and, with no backup checklist, is potentially unsafe in the event of device or battery failure.

There appears to be some cultural dichotomies regarding the use of electronic methods. The younger technicians are less critical of the system as a whole, emphasizing only the significant areas that they believe would improve the JIMIS process. Older technicians seem more resistant to the entire system, however, possibly because they are more comfortable using traditional repair procedures.

C-17 Globemaster

The C-17 is the newest transport aircraft in the Air Force inventory, and all of its technical manuals are digital. Although originally digitized in raster scan format on CDs, recent improvements that utilize SGML and indexed PDF on digital video disc (DVD) media are upgrading the technical manual system. One DVD replaces more than 20 compact discs, making digital TO access far more convenient. C-17 PMA functionality includes technical data display, fault isolation manuals and drawings, parts ordering, and maintenance documentation and analysis utilizing the G081 data management system.

The C-17 program at Charleston AFB, South Carolina, is AMC's prototype for wireless flight-line operations. Mobile computing devices currently in use at Charleston AFB include the Zenith CruisePad and C-17 Aircrew Data Transfer Device (ADTD), a dockable Dolch computer located at the loadmaster station in the rear of the aircraft. The ADTD was originally called a PMA even though it is not generally portable or geared toward maintenance, but it is primarily used to upload mission data into the aircraft systems and download Aircraft Diagnostics Integrated Test System (ADITS) Periodic BIT fault data tables after flight.[21] Technicians download the ADITS data onto a floppy disk using a 1553B connection, transferring data into the G081, where the definition tables identify faults and print work orders for repairs. Maintenance technicians can use the ADTD as a backup system for technical data access; however, with more than 20 different CDs, the process has been cumbersome.

Even though most of the required infrastructure is in place, Charleston has experienced difficulty implementing mobile computing. After the initial installation, there were a number of areas where the RF signal was not accessible on the flight line. Also, the original installation did not include the C-141 portion of the flight line, frustrating technicians who could work wirelessly on the C-17 but not on the C-141. Working with Telos, AMC installed repeaters on the flight line, eliminating most of the dead spots. They also developed a mobile repeater for placement at the aircraft nose in order to work wirelessly within the aircraft.[22]

F-22 Raptor

The F-22 Raptor is a completely digital weapon system with integrated maintenance support systems and devices. The DataTrak™ PMA has a Honeywell frame and an IBM ThinkPad's internal hardware.[23] It provides a direct communications link between the aircraft—including installed components—and logistics support systems. Currently the DataTrak is used exclusively for engineering support to verify and validate IETM procedures and flight-line work packages as illustrated in Figure 2-3. Eventually, the functions of the PMA will include technical data

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[21] Interview with Daniel Hamblin, C-17 SPO, Wright Patterson AFB, OH.

[22] Interview with Marion Tumbleston, Charleston AFB, SC.

[23] Interview with Ray Horn, Lockheed Martin Aerospace.

display in the form of Class V IETMs, fault isolation and repair mentoring, parts query and ordering, maintenance documentation and analysis, health monitoring and prognostics, and OFP upload and flight data download. The first operational F-22 squadron will be located at Nellis AFB, with aircraft deliveries beginning October 2001,[24] and PMAs should be available for routine use by August 2002. Current plans call for 104 PMAs and 9 servers per Wing.

Figure 2-3. F-22 Maintainers Viewing Honeywell DataTrak 20

Military utility issues such as ruggedness and user-friendliness continue to be concerns, even in this newest of aircraft designs. Environmentally rugged, the DataTrak combines a fairly long battery life (i.e., 7 hours with 2 hot-swappable battery packs) with a sunlight readable screen. It also has the ability to connect to the aircraft for power. Five PMA data bus connection points on the aircraft make connectivity accessible, including one under each wing plus one in the nose wheel well, tail, and cockpit. However, heat issues appear to require improvement, as the screen will blacken at 67° F after 20 minutes in the sun. Technicians also find the built-in keyboard difficult to use, preferring to connect an external full-size keyboard.

Costing over $30,000 per unit, the DataTrak offers a great deal of flexibility. Air vehicle interface enables the technician to exercise and control BIT access, download and display diagnostic data, start the Auxiliary Power Unit, open weapons bay doors, and test and manipulate flight control surfaces. Additionally, the PMA captures engine test data and displays engine status to facilitate health monitoring.

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[24] Ibid.

SUMMARY

The Air Force has been working with PMA concepts since the mid-1990s (even earlier for the AFRL). Today, technical data digitization is a very high priority, yet there is currently no overall policy regarding PMA acquisition or utilization. Despite promising maintenance mobile computing prototypes, such as the wireless operations at Dover and Nellis AFBs, most Air Force PMA efforts remain in their infancy. It is noteworthy, however, that the EDNA device has been in use on F-16, F-117 and B-2 aircraft for more than 5 years. This device appears to be virtually indispensable for complex diagnostics, OFP upload, and flight data download. The F-22 DataTrak also appears to have the potential for performing other PMA functions, but that potential has not yet been fully demonstrated.

Chapter 3
Army Applications

BACKGROUND

Army PMAs began as diagnostic devices used to troubleshoot equipment at the unit level. These devices ranged from cumbersome "suitcase" testers to handheld multimeters with probes. Today, Army PMAs primarily display electronic technical data and facilitate fault isolation. Coincidentally, the ongoing transformation of fighting equipment from analog to digital systems has dramatically increased PMA requirements in recent years.

POLICY

In consonance with DoD policy for acquiring large-scale automated test equipment, the Army strongly discourages the development of special-purpose test, measurement, and diagnostic equipment, including PMAs. In order to consolidate acquisition management of such devices, the Army established a program manager for test, measurement, and diagnostic equipment (PM TMDE) more than 20 years ago. The PM TMDE compiles PMA requirements from individual Army weapon system programs, melds those requirements into general-purpose PMA specifications, and acquires PMA devices through competitive solicitation. The PM TMDE is funded directly under its own program element and does not levy cost sharing on the weapon systems it supports. Because one of the Army's objectives is to reduce proliferation of test equipment, PM TMDE is the designated approval authority for development of special-purpose TMDE and PMAs throughout the Army.

Scope

The Army's current stated requirements for PMA employment involve more than 10,000 portable maintenance aids, and the next-generation Army PMA will more than double that figure. The breadth of Army PMA usage spans multiple commodity groups. This includes ground and air fighting vehicles of all types (i.e., helicopters, artillery, tanks, and infantry and cavalry vehicles), missiles, combat support and combat service support equipment, tactical wheeled vehicles, engineer equipment, communication-electronic equipment, mobile power generators and even watercraft. Several major weapon systems and more than one hundred smaller systems currently use PMAs.

The Contact Test Set (CTS) depicted in Figure 3-1 was the first generation of Army PMAs. CTS fielding began in 1991 and about 2,900 units are still in use.

Figure 3-1. Contact Test Set
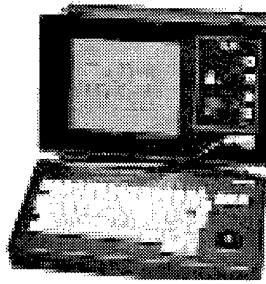
The Soldier's Portable On-system Repair Tool (SPORT) depicted in Figure 3-2 is the current generation of Army standard PMAs. The Army fielded SPORT in 1997, and approximately 3,100 units are currently in use.
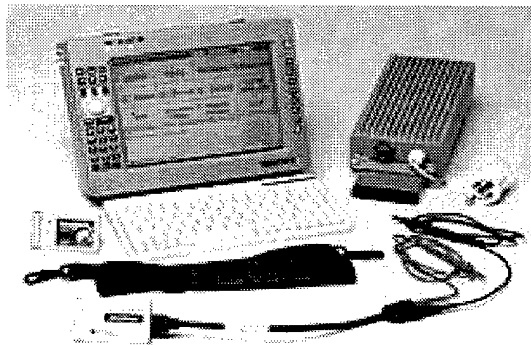
Figure 3-2. Soldier's Portable On-System Repair Tool

Figure 3-3 illustrates the Maintenance Support Device (MSD)—the next-generation Army standard PMA. Procurement of 11,000 MSD units will begin in 2002.

Figure 3-3. Maintenance Support Device

Table 3-1 displays procurement quantities and functional characteristics for all three generations of Army PMAs.

Table 3-1. Army PMA Programs

Program	Quantity	Functions
CTS (25 pounds)	2,900 still in use	LAN connectivity; diagnostics; software upload/download
SPORT (10 pounds)	7,349 procured	IETM display; diagnostics; software upload/download
MSD (15 pounds)	11,000 projected	IETM display; diagnostics; software upload/download

Note: IETM = integrated electronic technical manual; LAN = local area network.

Maintenance Functionality

In general, standard Army PMAs enable maintainers to display technical data, perform diagnostic fault isolation, and upload and download operational data.

TECHNICAL DATA DISPLAY

Current Army IETMs "support both digital data buses and analog sensor-equipped vehicles,"[1] but there is wide variability in the quantity and quality of electronic data. The Army Diagnostic Improvement Program (ADIP) envisions transition to a paperless maintenance environment in order to reduce operations and support costs and minimize the logistics footprint during deployed and garrison operations.[2]

FAULT ISOLATION AND DIAGNOSTICS

"Diagnostic data collection is critical to the further development and enhancement of the predictive and anticipatory maintenance capability."[3] PMAs accomplish this predictive health assessment by connecting to on-board sensors that are read and stored in an historical database. Trends are monitored to facilitate failure prediction.

OPERATIONAL DATA UPLOAD AND DOWNLOAD

This function principally involves the upload of operational data to computer-controlled components on the weapon system. In the case of the Abrams tank and the Bradley Fighting Vehicle System (BFVS), this process involves uploading software to eight to ten major components. The upload process is required with every new software release, which can be monthly. To upload the PMA is connected to a component via the vehicle's data bus. Download usually involves

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[1] *Third Brigade Test Bed Implementation Plan* (Draft), Army Diagnostic Improvement Program (ADIP) 2000 Test Bed Initiatives, December 1999, p. 4-9.

[2] Ibid, pp. 1-2 and 3-8.

[3] Ibid, p. 4-8.

access to built-in test data. As with software upload, the PMA connects to either the data bus or the specific component.

Military Utility

RUGGEDIZATION

Ruggedization has been a driving force behind the Army's PMA program. Procurement specifications include temperature, drop/shock/vibration, rain/humidity, chemical/biological, and sand/dust requirements.

USER-FRIENDLINESS

The designs of the CTS and SPORT have ranged from 10–25 pounds, making these devices cumbersome in a mobile field environment. The SPORT does have a more sunlight-readable screen that its predecessor; but the mouse on the left side of the screen presents problems to many right-handed technicians.

ELECTRONIC INTERFACES

The SPORT device has PCMCIA slots and a modem for network connectivity. Also, the ADIP requires a PMA interface with contact memory buttons in order to facilitate vehicle identification and serial number tracking.[4]

SELECTED APPLICATIONS

Ground Fighting Vehicles

In their most modern versions, the Abrams Tank and the BFVS are examples of the high-tech nature of ground warfare. We collected data regarding the use of PMAs for these two systems from Fort Hood, Texas.

Both the Abrams and Bradley programs plan to eliminate as much external test equipment as possible by relying on embedded BIT in their respective digital models, but legacy vehicle programs will continue to rely on PMAs for diagnostic support.

ABRAMS TANK

Abrams maintainers use the SPORT device almost exclusively for software upload. This involves loading software into eight to ten major system components, which is required whenever software is updated or after a catastrophic failure (i.e., reload). For software uploads, the PMAs can either connect directly to the component or via the vehicle data bus.

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[4] Ibid, p. 5-3.

On the other hand, the Abrams program manager and General Dynamics are testing a Remote Maintenance Assistant (RMA) system, which consists of a ViA II Wearable Computer, IETMs, and doctrinal and training databases. The RMA enables maintenance and training personnel at remote or multiple sites to

- access technical, logistics and training information about supported systems;

- more accurately and rapidly perform maintenance operations on complex systems;

- collaborate and share computer applications, data and information between distant locations;

- support a "paperless" work environment in both field and garrison; and

- provide a directly linked, portable user interface to automated logistics, training, electronic diagnostic systems, and system BIT capability.[5]

BRADLEY FIGHTING VEHICLE SYSTEM

The BFVS will use SPORT in three ways:

- Technical data display, as an ETM reader.

- Fault isolation, as a part of the Bradley Diagnostic System (BRADS), the BFVS version of SPORT coupled to a Vehicle Automotive Diagnostic System (VADS) for diagnostic purposes. Using SPORT for diagnostics as a part of BRADS is still in the planning stage because VADS is still under development. The eventual goal for the A3 vehicle diagnostics is to eliminate the PMA altogether and rely totally on embedded BIT functionality.

- Operational data upload and download, as a software downloader (e.g., downloading mission software into Bradley components that use software). Each mechanized infantry company has 14 Bradley vehicles, but it is issued only one SPORT. Consequently, SPORTs are not normally available for any Bradley tasks other than software upload and download.

For legacy vehicles, the architecture is designed for external test equipment. The availability of test points at existing test connectors facilitates diagnostic access and improvement without major vehicle redesign. Bradley maintainers had serious concerns about the fragility of the PCMCIA card connector cable shown in Figure 3-4.

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[5]General Dynamics Information Systems, RMA Product Page, < http://www.gd-cs.com/>.

Figure 3-4. SPORT PCMCIA Connector
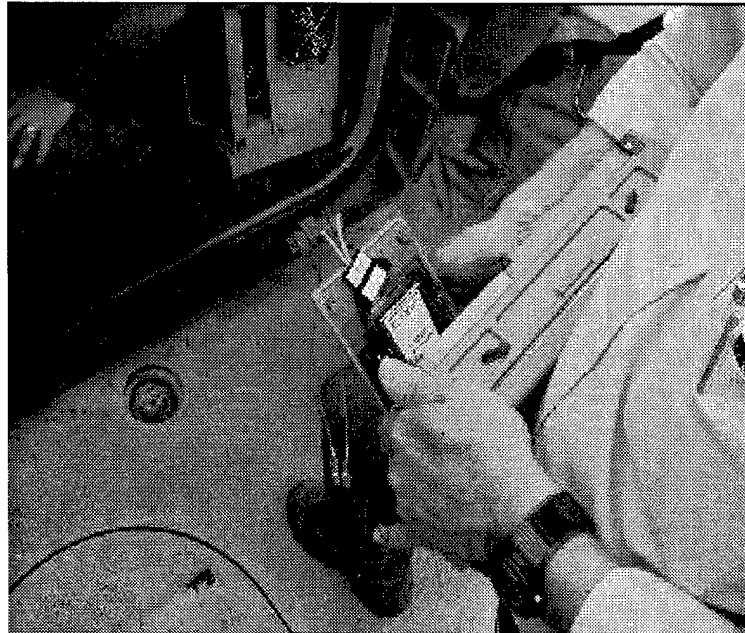
Tactical Wheeled Vehicles

The Army's tactical wheeled vehicle fleets make extensive use of PMAs. We discuss three of the major families of vehicles and their respective PMA uses below. Each of the vehicle fleets comprise earlier models, which are principally mechanical with little embedded electronics, and newer models, which contain significant electronics that are consistent with the Society of Automotive Engineers' (SAE) emphasis on electronically managed engines and other drive components.

FAMILY OF MEDIUM TACTICAL VEHICLES

The Family of Medium Tactical Vehicles (FMTV) fleet size exceeds 20,000 vehicles, split about evenly between legacy vehicles and the more modern vehicles, which are currently being fielded. SPORT is the designated PMA used for diagnostics of the FMTV fleet.

According to the FMTV maintainers we interviewed, SPORT has several advantages and disadvantages:

◆ Advantages include

➤ IETM concept is great—it allows experienced users quick movement within technical manuals;

➤ internal diagnostics save time; and

➤ rugged handling is good.

◆ Disadvantages include

➤ SPORT bulkiness makes use inconvenient;

➤ probes are easily damaged;

➤ SPORT parts have not been provisioned;

➤ battery operating time is only 30–45 minutes per charge;

➤ location of the mouse on the left side of the screen make it difficult to use for right-handed people;

➤ screen is hard to read in the sunlight; and

➤ cables pull off easily.

M900 FAMILY OF LINE-HAUL TRUCKS

The M900 family of line-haul trucks represents both old and new systems. The older M915 trucks are completely mechanical, but the M916 and the newly built M917 have an electronically managed system of modern drive train components coordinated across a vehicle data-bus network. Therefore, the PMA missions profile for tactical trucks runs the gamut: from limited analog sensor interaction to full-blown complex diagnostic IETM, health monitoring, and management applications that interact with the truck via state-of-the-art hardware and software protocols.

The initial acquisition of M916 trucks from Freightliner included a handheld data-bus "reader" that deciphers and displays fault codes on the data bus. It is simple to connect and use, easier to handle, and less cumbersome than the larger and more sophisticated SPORT. Soldiers who maintain these vehicles find the handheld data-bus reader useful and would like to see it coexist with the army standard PMA.

HIGH MOBILITY MULTI-PURPOSE WHEELED VEHICLE

The High Mobility Multi-Purpose Wheeled Vehicle (HMMWV) fleet is the largest army vehicle fleet, comprising more than 100,000 vehicles across all Army components. The legacy vehicles—the vast majority of the fleet—have analog systems with only a few test points for electronic diagnosis. The technical manual is undergoing digitization and will use SPORT as the ETM reader. However, the HMMWV currently uses the CTS. User comments reflect limited use of the CTS, with the principal criticism being it is too difficult and time consuming to use.

Helicopters

The AH-64D Apache Longbow Helicopter represents a technology-intensive weapon system that the Army will rely on for many years to come. The SPORT has two principal missions in the AH-64D battalion: IETM display and downloading of BIT data from the aircraft data bus, which is used in troubleshooting the aircraft. Because the IETM is a Class V, this mission also includes system diagnostics integral to the IETM process.

For helicopters such as the AH-64D Apache Longbow, BIT download is accomplished by connecting to the aircraft data bus. The BIT data then passes through additional software that analyzes them and extracts diagnostic information.

The AH-64D maintenance personnel interviewed for this study were generally critical of the SPORT and its peripheral equipment. Specific comments include

- ◆ poor ruggedization and weather-proofing,

- ◆ slow speeds,

- ◆ difficult to use for data download from the aircraft,

- ◆ limited battery life,

- ◆ poor design for PCMCIA card use,

- ◆ no built-in keyboard or floppy, and

- ◆ too much extra equipment (i.e., power supply, external floppy disk drive, extra batteries, spliced cables, etc.)

SUMMARY

Use of SPORT as a diagnostic tool varies from unit to unit. It appears that the frequency of use is commensurate with the amount of training applied and the experience already gained by an individual maintainer. Experienced mechanics tend to rely on the SPORT, whereas less experienced mechanics tend to avoid it. We can attribute this basic difference to the reluctance of less experienced mechanics to accept a SPORT diagnosis without understanding how it was derived. The perception is the SPORT diagnostics do not provide enough information, even though they may accurately diagnose the problem and recommend the correct repair.

In contrast, more experienced mechanics support the SPORT diagnostic tool and report using it more often. Their comments indicate they already understand the fundamental theory involved and are more interested in quickly moving through the repair. Still, equipment setup and diagnostics appear to be more time

consuming than initiating troubleshooting by simpler methods (e.g., multimeter and jumper-wires). Consequently, use of the SPORT is largely dependent on the perception of an experienced mechanic that specific symptoms are indicative of a "more serious, lengthy problem."

Embedded diagnostics capability is an important part of the Army's vision for support and sustainment currently pursued by individual weapon system programs (e.g., Abrams Tank and Bradley FVS) as well as the Army Diagnostic Improvement Program. The ADIP vision for condition-based predictive maintenance is to attain the optimum mix of embedded diagnostic and communication technologies. This is coupled with the computing power that allows weapon systems and vehicles to assess their health and operational status, transmit the results to commanders and logisticians, and allow mechanics and supervisors at various maintenance levels to efficiently and effectively anticipate and plan maintenance support tasks.[6] Consequently, use of PMAs may diminish as more diagnostic and prognostic capability is embedded into weapon systems.

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[6] ADIP Operational Concept, Draft, 29 December 2000.

Chapter 4
Navy/Marine Corps and Joint-Service Applications

NAVY APPLICATIONS

Policy

There is currently no definitive Navy policy regarding PMA acquisition or usage. Several years ago, the Naval Air Systems Command (NAVAIR) attempted to develop a command-wide policy regarding acquisition of portable electronic display devices (PEDDs). In 1998, a draft policy document was developed among key NAVAIR stakeholders, but this document was never published because of funding issues. It should be noted, however, that very few of the Navy personnel interviewed during this study considered the lack of an overall PEDD policy to be a significant problem. In fact, some maintainers felt an overall policy might be counter-productive, as PEDD capabilities must be well suited to their own unique working environment. For example, PEDDs used aboard ship generally need to be better protected against moisture and electromagnetic interference than those used exclusively in land-based operations. Numerous PEDD initiatives are currently underway in the Navy, but these are proceeding independently of one another, and sharing of information is very limited.

Selected Shipboard Applications

The Naval Sea Systems Command is testing several COTS laptop, tablet, and wearable computers to determine the most effective employment of shipboard PMAs. These PMAs primarily standardize data collection on the condition of shipboard systems. They reduce shipboard maintenance workload by providing paperless data collection, ready access to IETMs, logistics data, and training videos. Ultimately, PMAs will offer a troubleshooting capability and generate electronic work documents at the point of maintenance. PMAs will also allow maintainers to record key operating parameters while observing the machinery; making the collection of relevant data timelier. Consequently, use of PMAs will eliminate a large portion of paper documentation and allow tailoring of maintenance tasks to account for differences in equipment configuration. Using a wireless link, maintainers will also be able to share data with shipboard and shore-based maintenance management systems, as depicted in Figure 4-1. This should save time and minimize the use of outdated technical information. Several COTS devices have been procured and initial evaluations have been conducted onboard the USS *McFaul* (DDG 74) and USS *The Sullivans* (DDG 68), but user feedback to date has been extremely limited.

Figure 4-1. Shipboard PMA Connectivity
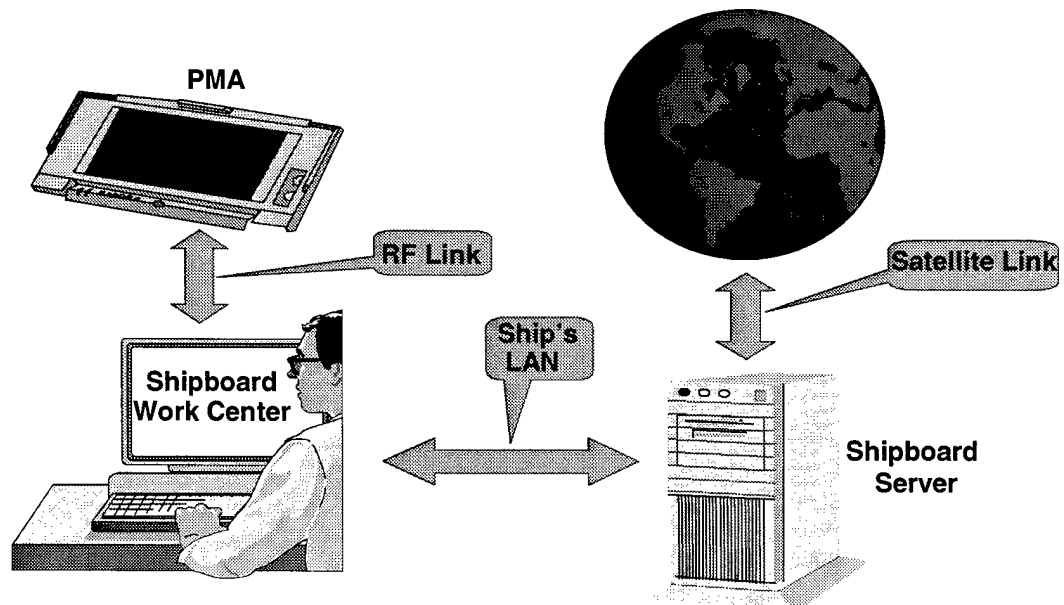
Source: USS Stennis PMA Demonstration Briefing, NAVSEA (04M).

The Tomahawk Remote Technical Assistance System (RTAS) is a wearable computer that involves the shipboard preparation, installation, checkout, and maintenance of Advanced Tomahawk Weapons Control System (ATWCS) components and equipment. ATWCS shipboard installations and upgrades are currently performed in a commercial shipyard or Navy industrial facility and require the presence of engineering personnel to provide expert on-site oversight.

Use of wearable computers and portable sensors by Tomahawk maintenance personnel will allow engineers to provide oversight with minimal on-site presence. RTAS will facilitate detailed and timely surveys of site preparations, inspections of received material and equipment, tracking of installation processes and procedures, and oversight of system tests and operational verifications.

As depicted in Figure 4-2, the remote component of RTAS utilizes compact belt or vest-mounted computer systems with head-mounted or wrist-mounted displays and a video camera. This setup links on-site technicians and off-site engineers via local area networks (LANs) or modems in order to provide real-time collaboration without actual face-to-face interaction.

Figure 4-2. Remote Technical Assistance System
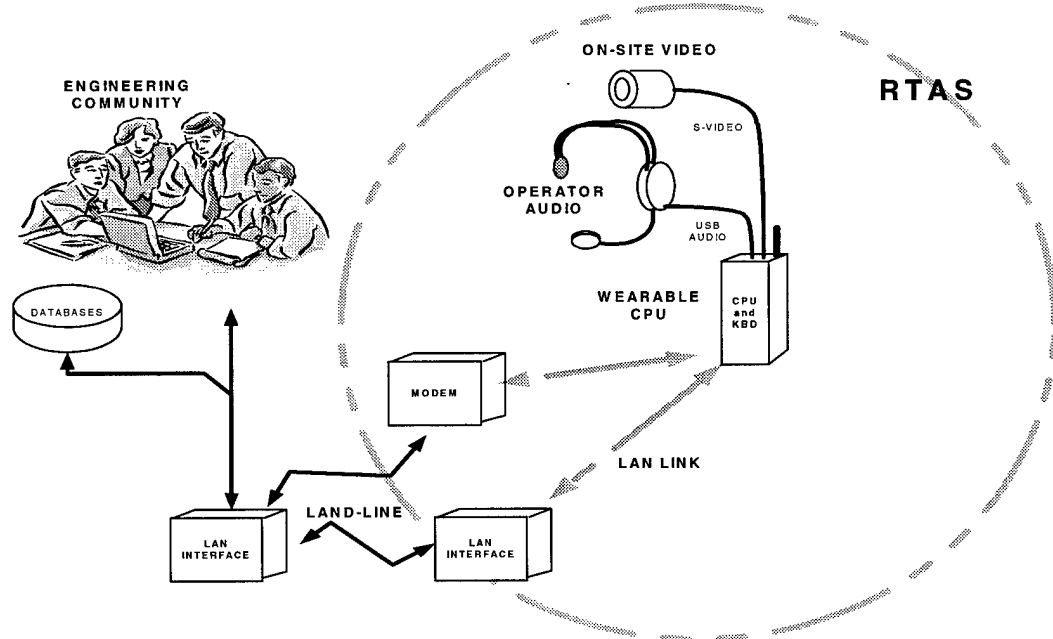
Source: Remote Technical Assistance System (RTAS) Wearable Computer Pilot Project Implementation Plan, Naval Undersea Warfare Center, February 2001.

Successful demonstration of the ability of RTAS to facilitate effective remote expert participation in ATWCS installations, modifications, or repair enables potential expansion and use in several different fields:

◆ Engineering-intensive on-site applications

◆ Ship/shore torpedo handling evolutions, issues, and maintenance actions

◆ Mine Warfare operations and maintenance

◆ Drydock hull inspection

◆ Gas-free engineering.

Selected Aviation Applications

EA-6B PROWLER AND SH-60B SEAHAWK

Last year, NAVAIR provided the Fujitsu Stylistic tablets and Panasonic Toughbook laptops depicted in Figure 4-3 to EA-6B and SH-60 maintenance personnel to display electronic technical data during a recent deployment of the USS *Abraham Lincoln* (CVN-72) Battle Group.

Figure 4-3. Fujitsu Tablet and Panasonic Laptop
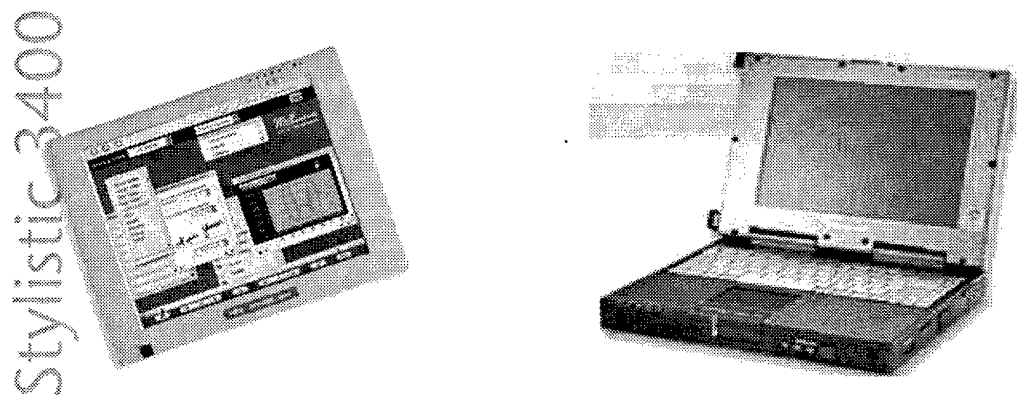
Note: Fujitsu Stylistic 3400 and Panasonic Toughbook illustrations used with manufacturer's permission.

After completion of the *Lincoln* Battle Group deployment, several of the EA-6B and SH-60 maintainers suggested the Panasonic Toughbook laptops were better suited for shipboard maintenance support than the Fujitsu Stylistic tablets. These maintainers were especially concerned about the poor readability of the tablet screens in direct sunlight and the short (1–2 hour) operating cycle of the batteries for both tablets and laptops. The following comments are representative of those concerns:

"[Tablet] touch screens stopped working."

"PEDD batteries die quickly."

"Words are too small on PEDD screens."

"PEDD schematic displays are hard to read."

E-6B TACAMO

The E-6B was among the first naval aircraft programs to use ETMs and PEDDs. The PEDDs for E-6B maintainers were procured under a NAVAIR Affordable Readiness initiative that projected accrual of more than $440,000 in annual savings per year for an initial investment of about $860,000. These projected savings would primarily result from the use of ETMs, which would eliminate the need to print and distribute periodic updates of technical manuals. The PEDDs would also be key to achieving those savings because ETMs have only limited value if they cannot be used at the work site. Initial indications are that the ruggedized COTS laptops used for ETM display have good functionality but relatively poor reliability under operational conditions.

F/A-18E/F SUPER HORNET

PEDDs are also elements of the Navy's highly integrated F/A-18E/F Automated Maintenance Environment (AME), but PEDD usage is currently restricted to IETM storage and display on Panasonic Toughbooks.

After an aircraft returns from a flight, discrepancies (or faults) are reported by the pilot or determined by downloading the contents of a data storage unit that records data from key systems during flight. Once recorded, fault information reports are generated and maintenance tasks are downloaded to PEDDs. Once the work is completed, the PEDDs are returned to maintenance control where work documentation is automatically uploaded into the AME Tracking Reports System and manually input into the Naval Aviation Logistics Command Management Information System (NALCOMIS).

Boeing currently maintains the IETMS for the F/A-18E/F, which are formally updated every quarter. Boeing loads the updates on each PEDD as well as the LAN at the Naval Air Station (NAS) Lemoore. Recommended changes are tracked online through the engineering approval process until they are formally incorporated into IETMs as the next quarterly cycle is completed. Meanwhile, approved changes are temporarily loaded onto PEDDs as IETM bookmarks.

While the IETMs and PEDDs save space and weight by allowing technical documentation to be stored on CDs, legacy avionics systems still require paper documentation. Consequently, maintainers may need to use both the PEDDs/IETMs *and* paper documentation when working on some F/A-18E/F systems. Also, F/A-18 maintainers expressed concern that Panasonic Toughbooks only run about 2 hours on batteries. The F/A-18 flight-line experience indicates that PEDD readability is a serious problem, even when the screen is partially shaded, as shown in Figure 4-4.

Figure 4-4. Using a Panasonic Toughbook in an F/A-18 Cockpit

Note: Photograph taken by LMI analyst Jerry Bapst at NAS Lemoore, California, February 2001.

F/A-18 maintenance personnel have also tested a wearable PMA developed by Inmedius in collaboration with the Carnegie Mellon University (CMU) Human-Computer Interaction Institute. The prototype for this PMA (depicted in Figure 4-5) included a wearable IBM computer that was integrated into a flight deck flotation jacket and an eyepiece that was integrated into a flight deck cranial helmet. Maintainer interface with the computer was via a chest-mounted dial-and-pointer device. Feedback from the maintainers who tested this device was generally very positive, although testers expressed some concern about whether the eyepiece would obstruct peripheral vision when used on the flight deck.

Figure 4-5. CMU-Inmedius Wearable PMA

Note: Photograph provided by CMU Human-Computer Interaction Institute.

P-3 ORION

The Georgia Tech Research Institute (GTRI) Logistics and Maintenance Applied Research Center is currently prototyping a Maintenance Electronic Performance Support System (MEPSS) for the P-3 aircraft.[1] Conceptually similar to the F/A-18 AME, the P-3 MEPSS will integrate information databases with troubleshooting and diagnostic tools in a common framework that can be displayed on a PMA. GTRI currently plans to utilize COTS hardware, along with a hybrid of existing and newly developed software. Planned MEPSS features include the following:

◆ Hyperlinks to databases and information systems

◆ Graphical user interfaces (GUI) for ease in accessing information

◆ Voice-activation software to facilitate hands-free maintenance

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[1] Gisele Welch, Jennifer G. Sheridan, Valerie Lafond-Favieres, Keesah Hall, Ron Wagner. "Electronic PerformanceSupport Systems for Maintenance Tasks." Logistics and Maintenance Applied Research Center, Georgia Tech Research Institute.

◆ Wireless links between PMAs and central servers

◆ On-line electronic signature and quality assurance review

◆ Tracking of technician performance in executing maintenance tasks

◆ Communications interfaces that allow technicians to provide comments on technical data, troubleshooting procedures and system performance.

MARINE CORPS APPLICATIONS

Policy

In general, PMA policy in the Marine Corps falls under the United States Marine Corps (USMC) Digitization Program because PMAs primarily provide access to IETMs at the point of maintenance. The first phase of the USMC Digitization Program involved a review of all Marine Corps technical publications to determine which documents should be converted to Indexed Portable Document Format (IPDF) files. The remaining technical publications were then reviewed to determine which should be converted to SGML-based IETMs using the Interactive Authoring and Display System software developed by the Army. The Marine Corps Systems Command is responsible for converting paper technical publications to digital formats, but individual program managers are responsible for acquisition and fielding of PMA hardware.

Selected Ground Vehicle Applications

LEGACY SYSTEMS

To date, PMAs have primarily displayed electronic technical data about the Tactical Remote Sensor System, Avenger Air Defense Weapons System, Portable Communications Intelligence System, and 5-ton trucks. PMA hardware for these applications includes the Panasonic Toughbook and the Tadiran Ruggedized Handheld Computer (RHC) depicted in Figure 4-6, which the Marine Corps procured for combat units in the field.

Figure 4-6. Tadiran Ruggedized Handheld Computer AAAV

Note: Tadiran RHC illustration used with manufacturer's permission.

The Advanced Amphibious Assault Vehicle (AAAV) program manager is currently testing several different portable maintenance devices (PMDs) to ascertain which is best suited for operational use by AAAV maintenance technicians. These devices include a computer installed in the AAAV, a Tadiran RHC, a Xybernaut wearable computer, and a Panasonic Toughbook. During initial suitability tests, it was determined that, in most cases, maintainers cannot use the installed computer because they need access to technical data where they are working, which could be either inside or outside the vehicle. The Xybernaut wearable computer depicted in Figure 4-7 provides significantly more capability than the hard-mounted vehicle screen, but the Tadiran RHC is considered by some Marine technicians to have the best overall capability for AAAV maintenance because it is relatively compact and highly ruggedized, and its screen is easy to read—even in direct sunlight.

Figure 4-7. AAAV Technician Using Xybernaut Wearable PC
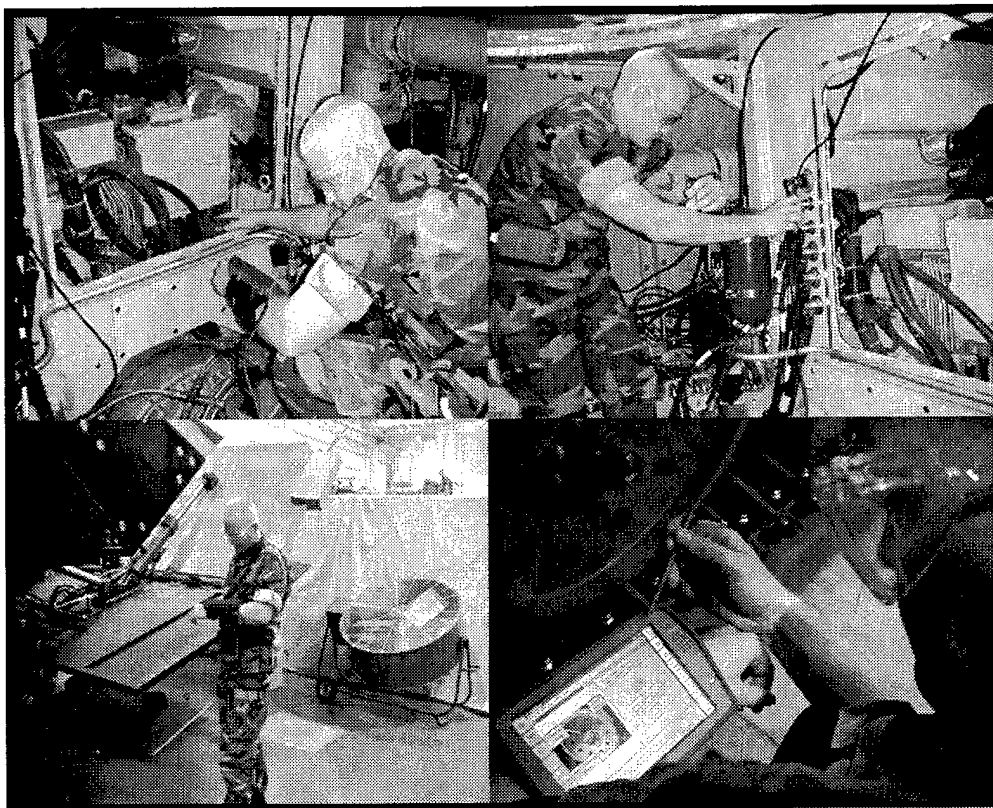
Source: AAAV Briefing, Interoperability Workshop, October 31, 2000.

Selected Aviation Applications

AH-1W Super Cobra

The AH-1W helicopter community is testing a Maintenance Mentoring System (MMS) that includes a portable interactive digital information processor for support of maintenance troubleshooting and diagnostic queries. MMS uses a strategy-based diagnostics methodology originally developed by General Motors (GM) for training mechanics, which used repair work on Cadillac Northstar automobile engines for validation. The MMS hardware consists of a ruggedized tablet-style computer developed by Intelliworxx, Inc., that a maintenance technician can either wear or carry. The primary interface is via voice recognition software, with a touch-sensitive screen as a backup. Based on the symptoms of a particular problem, the MMS will guide a maintenance technician through a series of troubleshooting steps to identify the most probable cause. A web browser gives the technician access to supplementary information (i.e., schematics, animation, and movie clips) via hyperlinks.

The MMS adapted GM's mentoring system to H-1 air-launched missile system maintenance. This process primarily involved the creation of interactive,

task-based, electronic data from standard, paper technical manuals and the adaptation of the MMS hardware for use in a DoD maintenance environment. In addition, the Fleet Replacement Enlisted Skills Training (FREST) at Camp Pendleton beta tested the MMS prototype, and Marine AH-1W technicians in Okinawa performed informal operational testing.[2]

An on-site demonstration by FREST instructors highlighted MMS benefits but also revealed several serious shortcomings in the current MMS configuration. Overall, the FREST instructors appeared to strongly prefer the MMS to paper technical manuals because the MMS greatly reduces the time and effort needed to locate and assemble the technical data, schematics, and drawings required to diagnose and troubleshoot weapons system problems. However, the FREST demonstration indicated that the MMS speech recognition functionality was not yet sufficiently robust for routine operational use, particularly in high-noise environments. Also, carrying the MMS tablet in a pouch suspended from a strap around the neck was awkward and the cord connecting the headset to the tablet appeared to be a potential safety hazard. Finally, the pointer used to interface with the tablet's touch screen could be a source of foreign object damage (FOD) on the flight line and the tablet's screen was too dim to be effective in direct sunlight.[3]

V-22 OSPREY

V-22 PMAs are primarily used to display IETMs that are designed to "interactively provide procedural guidance, navigational directions, and supplemental information; and also [provide] assistance in carrying out logistic-support functions supplemental to maintenance."[4]

The overall objective of V-22 IETMs is to increase mission capability and improve maintenance productivity through effective presentation of technical data. V-22 IETMs are also designed to

◆ integrate multiple information sources into a single easy-to-use information system;

◆ tailor information to meet the specific needs of the task and the technician's level of expertise;

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[2] Maintenance Mentoring System Phase I Deployment, NCMS, October 2000.

[3] Maintenance Mentoring System Assessment, LMI, October 1999.

[4] V-22 IETM Fielding Implementation Plan, Bell Helicopter Textron and Boeing Defense and Space Group, August 1999.

◆ assist maintenance training by providing an effective on-the-job training aid for new systems and proficiency training for existing systems; and

◆ reduce manual data entry required for paperwork and associated tasks through electronic interfaces with other systems.[5]

Using PMAs to access IETM data should enable all V-22 maintenance personnel to perform tasks more efficiently and help inexperienced personnel to trouble-shoot functions that normally require more extensive training. Two PMA devices (depicted in Figure 4-8) are currently being tested by V-22 maintenance personnel:

◆ A Getac laptop computer, with a removable internal hard drive that can be configured with removable CD-ROM or floppy disk drives, is commercially ruggedized and relatively inexpensive; however, it is not protected against electro-magnetic interference (EMI). Hence, it can only be used in locations where EMI is not a major factor.[6]

◆ The Honeywell tablet, with a removable internal hard drive that can be configured with removable CD-ROM or floppy disk drives, is similar to the Air Force F-22 PMA and is EMI protected and more heavily rugge-dized than the Getac laptop; however, it is significantly more expensive.[7]

Figure 4-8. Getac Laptop and Honeywell Tablet
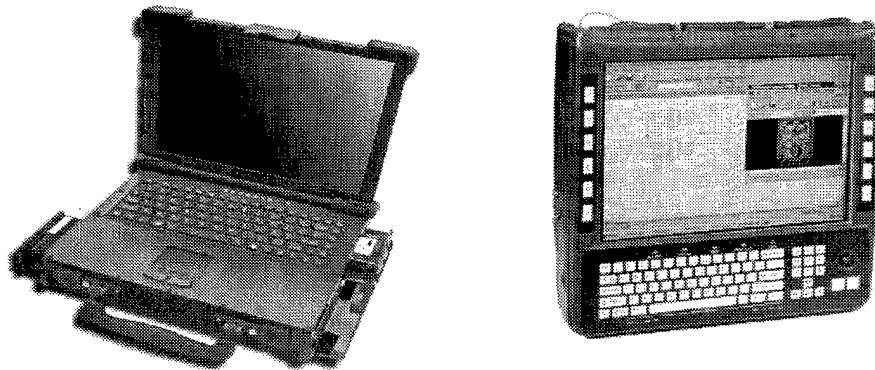
Note: Illustrations reproduced with the manufacturers' permission.

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[5] Ibid.

[6] Getac Ruggedized Notebook, <http://www.getacusa.com/>.

[7] DataTrak Data & Diagnostics, <http://www.honeywell.com/>.

JOINT STRIKE FIGHTER

PMA missions and functions for the Joint Strike Fighter (JSF) fall under the JSF Prognostic Health Management (PHM) development program, which is driving many innovations in prognostic technology, from software architecture to open systems integration.

Even though robust diagnostic and prognostic technology will be embedded in the JSF weapon system platform, PMAs will be a key component of the autonomic logistics and maintenance processes involved in JSF Joint Distributed Information System (JDIS). The JDIS concept involves a paradigm shift from sensor-based diagnostics to intelligent system-based prognostics. This system is predicated upon wireless connectivity in all aspects of design, including the aircraft platform, the PMA and the ground-based logistic systems.

The JSF PMA hardware has yet to be selected, but some observations about form and function can be made. In an IETM display role, the JSF PMA will not need to host the entire aircraft technical data package, but onboard information can be tailored to the troubleshooting or repair requirement. Maintenance data will be hosted on a central server and uploaded onto the PMA as needed. The PMA will also have the capability to access and display all required unique, and legacy technical data (both from and through JDIS) in support of the JSF system. A maintenance interface panel may also be used for inspection checklists, load checklists, and tailored trouble shooting and repair data.[8]

SUMMARY

The Navy and Marine Corps have a number of PMA initiatives, but most of these have only recently begun and are proceeding independently. To date, most PMA-related initiatives in the Navy and Marine Corps have focused on systems being transitioned from paper technical manuals to digitized technical data. In this context, Navy and Marine Corps maintenance personnel are experimenting with a variety of COTS laptop, tablet, and handheld PMAs in order to ascertain the best way to view electronic technical data in a variety of environments—equipment designed for sea, ground, and air missions. These environments differ greatly (i.e., temperature extremes, EMI, moisture/salt water, sand/dust, and potential flight deck usage) and should be significant factors in determining PMA utility. Use of PMAs for other applications, such as diagnostic support and maintenance mentoring, is currently limited to new weapon systems, such as the F/A-18E/F and the AAAV.

[8] Interview with CDR Girard (JSF PMO), May 2001.

Chapter 5
Selected Private-Sector Applications

COMMERCIAL AVIATION

Lower distribution costs and ease of electronic authoring are prompting most commercial airlines to digitize their technical publications. Some airlines are also embracing the use of PMAs. Increasingly, aircraft manufacturers are embedding diagnostic tools within new production aircraft.[1] In the design of the Boeing 777, engineers embedded diagnostic capabilities in order to expedite aircraft turns. To expedite access to diagnostic data, a portable maintenance access terminal (PMAT) is bolted into the avionics bay, with additional PMAT connectors located in the tail and nose wheel well. The PMATs (shown in Figure 5-1) help mechanics perform a broad range of troubleshooting procedures.

Figure 5-1. Portable Maintenance Access Terminal
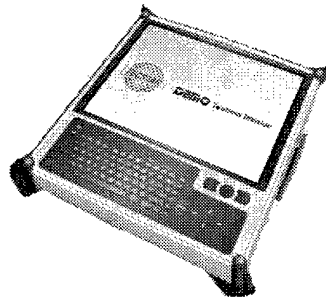
United Airlines

Newer aircraft (e.g., Boeing 777 and Airbus 320) at United Airlines (UAL) have embedded diagnostic capabilities, but older aircraft (e.g., Boeing 747) generally do not. Although United has a fully computerized maintenance operation (i.e., all manuals, log book entries, and associated documents are digitized), their use of portable devices is limited. UAL technicians have the option of carrying a laptop with CD technical manuals to the aircraft for repair work. However, most find this tedious because of the bulk of the laptop, the cramped cockpit workspace, and the number of CDs required.

After discerning an in-flight equipment malfunction, UAL pilots record applicable discrepancy codes into the Aircraft Communication Addressing and Reporting System (ACARS). These codes are transmitted to Aeronautical Radio, Inc.

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[1] Telephone interview with Jack Hessburg, retired Chief Mechanic for Boeing Aircraft Company, January 2001.

(ARINC), which operates the ACARS network. ARINC then forwards the data to the UAL Maintenance Control Center where the data are routed to an appropriate technician who gathers the necessary technical orders and tools in preparation for aircraft arrival.

Like most airlines, UAL wants to turn aircraft at the gate as quickly as possible in order to prevent scheduling delays and possible loss of revenue. Before digitization, the time required to turn an aircraft was approximately 1.5 hours. In the digital environment, that time has been reduced to approximately 35–40 minutes, including cargo loading and maintenance.

While the current environment is digital, it is not yet entirely paperless. Federal Aviation Administration (FAA) regulations require technicians have technical documentation available at the point of maintenance. Most UAL technicians fulfill this requirement by printing a paper copy of the information they receive to complete a specific maintenance action. The printed information is good only for one day, which reduces the risk of using outdated information. Even though notebook computers with technical manual CDs meet FAA requirements, many technicians prefer printed data because the notebook computers currently available are too bulky and fragile for effective use in an aircraft maintenance environment.

UAL maintenance documentation is completely digital; however, the flight line does not yet have wireless connectivity. Consequently, UAL has installed maintenance kiosks to facilitate a technician's access to maintenance and parts data. Once the new midfield terminal at Dulles Airport is completed in 2006, UAL plans to install RF capability on the flight line and equip technicians with handheld devices. Until that time, technicians will continue to use the flight-line maintenance kiosks.

Continental Airlines

Continental Airlines has completely digitized its technical publications using web-based TOs, with access primarily through hardwired terminals in the gatehouses. At this time, only members of their rapid deployment team carry mobile devices. Using Dell laptops, these team members have immediate access to technical information via phone line to the server or by retrieving data already loaded on the hard drive. Continental is investigating the use of mobile devices for widespread use in maintenance, and is looking at a number of devices, from palm to laptop size. One concern they have is the commonality between the devices the pilots will use for their flight data and checklists and those the maintainers will use. Another consideration is the trend toward wireless operations at many airports (e.g., Continental's headquarters, Houston Intercontinental Airport, is within 12–24 months of installing RF capability[2]).

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[2] Telephone interview with Dave Southern of Continental Airlines, April 2001.

Northwest Airlines

Environmental concerns, particularly rain and temperature extremes, and durability were significant considerations for Northwest Airlines when it decided to implement a wearable computer system in their non-routine maintenance inspection process. Tight spaces and rough equipment handling being the norm, they selected the ViA II shown in Figure 5-2. In lieu of desktop devices that are hardwired into the hangar, Northwest inspectors can use the ViA II wearable system for data input when creating job cards for non-routine maintenance discrepancies discovered during scheduled aircraft inspections. Inspectors then transmit the job card via RF to the job control section, where it is printed and picked up by a mechanic. At the onset of the program more than a year ago, most inspectors were willing to try the wearable system. Unfortunately, many of the early units malfunctioned; and only 5–15 percent of the inspectors continued using them.

Figure 5-2. ViA Wearable Computer System

Note: ViA II illustration used with manufacturer's permission.

Northwest maintainers encountered some initial problems with the ViA II wearable units, but these problems have been resolved and Northwest management may expand the use of mobile computing to other areas, such as parts ordering.

To enhance maintenance technician effectiveness on its new Canadian Regional Jets, Northwest also uses innovative diagnostic software developed by CaseBank Technologies. This software, called Spotlight™, helps maintainers identify the cause of elusive, hard-to-diagnose problems that waste time and disrupt schedules. To rapidly resolve those problems, maintainers describe the symptoms they are experiencing, and SpotLight™ checks its database and displays the details of all similar problems previously experienced, including causes. SpotLight™ can

also link to external data systems to retrieve appropriate maintenance repair procedures, instructions, service bulletins, training and other useful information."[3]

Federal Express

Mobile computing plans at FedEx include the integration of several different mobile devices, gearing the device to the particular job requirement. Currently on hand, but not fully implemented, are the Xybernaut Mobile Assistant® (MA) IV (depicted in Figure 5-3) and the Walkabout Hammerhead devices. Functions for both devices include technical manual display, diagnostics, parts ordering, and maintenance data collection and analysis.

Figure 5-3. Xybernaut Mobile Assistant IV
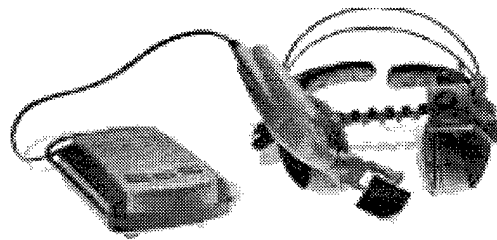
Note: Xybernaut illustration used with manufacturer's permission.

FedEx plans to use their approximately 30 Hammerhead devices for lead mechanics, who operate primarily out of vehicles. The more mobile the job, the more likely the selection will be the wearable system. With about 10 MA IVs operating at the Memphis International Airport, FedEx owns 190 units and plans to deploy the next 10 in Indianapolis, while the company develops a series of "best practices" for wearable use.[4]

COMMERCIAL TRUCKING

The commercial trucking industry is using technology in several ways in order to achieve performance, improve economy, and maximize the return on investment. The rate of technology adoption has been increasingly swift in the past 10 years and the effect on truck maintenance has been dramatic.

Diagnostic practices have gone through three technology generations in the past decade. The 1990s began with a preponderance of mechanical legacy engines and equipment using off-board analog testing equipment, such as multimeters and large engine analyzers.

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[3] <http://www.casebank.com/5spotlight.htm>.

[4] Telephone interview with Russ Young, Federal Express Maintenance Projects Manager, April 2001.

The mid-1990s saw the widespread introduction of electronically managed engines, transmissions, and anti-lock braking systems, with sensors coupled to an embedded data bus and engine control module (ECM). Test equipment included handheld data readers to display fault codes generated by the ECM. The latest generation of electronics has embedded diagnostics capability onboard the vehicle with wireless data links for transmitting information.

There are two separate standards for diagnostics systems in the trucking industry, one for hardware and another for software. These diagnostic standards, developed by the Society of Automotive Engineers (SAE) and the American Trucking Association (ATA), define the structure of the embedded data bus as well as the diagnostic message content. In general, the SAE/ATA standards include

◆ embedded diagnostics,

◆ IETMs, and

◆ predictive maintenance.

Satellite communication is also widespread in the construction, agriculture, and trucking industries. Operational data, diagnostic data, and position/location data are transmitted via satellite to ground stations that provide these data to fleet management centers. Leading vehicle and engine manufacturers are leveraging advanced diagnostics and satellite communication capabilities to gain a competitive edge in the marketplace. Key innovations are discussed in the following sections.

Freightliner

Freightliner's onboard Truck Productivity Computer (TPC) is capable of performing 300 million instructions per second—with an equivalent in power to many desktop computers.[5] This computer has two Universal Serial Bus (USB) connections for such devices as magnetic card readers, bar-code scanners, printers, flatbed scanners, cellular telephones, digital cameras, and game controllers.

The driver can plug a keyboard into the USB and a full-size monitor for enhanced display and alphanumeric data entry. The unit also has an infrared serial port for drivers who want to download information from handheld or laptop computers. In addition, the TPC provides wireless communications to transmit messages and data via satellite, specialized mobile radio or cellular networks. It also displays incoming messages, which the driver can acknowledge by manipulating the unit's controls.

Besides functioning as the platform for various mobile computing and communications applications, the TPC also serves as the gateway to information about the vehicle. It connects to the truck data link and, therefore, can provide key information on vehicle status, fuel usage, engine operation and diagnostics. Among other

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[5] <http://www.freightlinertrucks.com/about_us/press_room/press_release.asp?id=174>.

functions, the device will let the driver check miles driven for an entire trip or current leg, monitor fuel economy, and record current oil pressure, water pressure, and other vital signs.

John Deere

The DeereTrax™ equipment tracking system depicted in Figure 5-4 provides remote tracking of engine performance for John Deere equipment. This system facilitates preventive maintenance, improves productivity, and increases utilization of fleet assets.

Figure 5-4. DeereTrax Equipment Tracking System
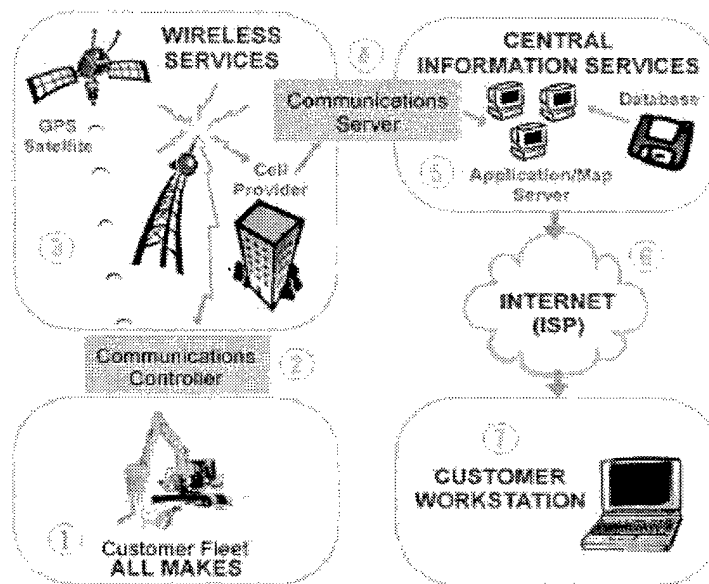
Source: <http://www.johndeere.com/deerecom/_Special+Technologies/DeereTrax/About+DeereTrax/default.htm>.

Prolink Data Reader

The Prolink Data Reader depicted in Figure 5-5 represents the trucking industry's standard for simple, handheld engine test devices. These devices weigh less than a pound and display up to four lines of engine fault codes, which are tailored by data cartridges for particular engines and transmissions.

Figure 5-5. Prolink Data Reader
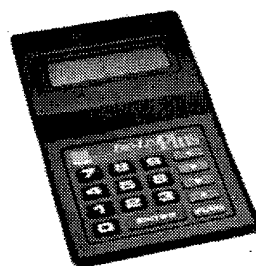
SUMMARY

Use of PMAs in the private sector is governed primarily by perceived return on investment. In commercial aviation, the continued digitization of technical data and the impending installation of wireless capability at several major hubs (e.g., Washington Dulles and Houston Intercontinental), have prompted many airlines to experiment with PMAs. However, even though the airlines have a number of mobile computing initiatives, widespread acceptance and use has yet to materialize. In contrast, the commercial trucking industry currently uses PMAs to perform a broad range of functions, from administrative support to diagnostic data display. In fact, PMAs have become an integral part of the en-route communications link between dispatching offices and individual trucks.

Chapter 6
Research Summary

MAJOR FINDINGS

Although mobile computing technology has been available for the last decade, the movement toward PMAs has only recently gained momentum throughout DoD. Consequently, there is no apparent consensus on how to implement this rapidly expanding technology, and few definitive statistics to validate savings in time or other resource requirements. However, anecdotal evidence gathered during interviews for this study indicate that PMA usage can facilitate significant improvement in overall maintenance productivity if: PMAs are effectively integrated with other systems; appropriate hardware and software are utilized; and there is clear support from management for PMA implementation.

Maintenance Functionality

TECHNICAL DATA DISPLAY

Display of technical data is the most prevalent PMA function, but many PMA screens are too small for effective display of drawings and schematics. The more advanced Class IV–V IETMs mitigate this problem, allowing users to adjust the size of drawings either to examine details or view the overall system. While most maintainers appreciate the IETM functionality that leads them through troubleshooting procedures, some stated it is awkward to scroll through the pages to look for specific references or confirm the proper maintenance sequence. More experienced maintainers stated they miss the ability to "randomly flip through paper manuals" to search for information or determine the relationship between different components. They also stated that IETMs are not conducive to a search for possible solutions to atypical faults.

FAULT ISOLATION AND REPAIR MENTORING

Given the increasing complexity of modern digital weapon systems, diagnostic fault isolation has become an extremely important PMA function. Consequently, multiple-purpose PMAs—such as the EDNA and SPORT—possess robust diagnostic capabilities. Even though most new weapon systems rely on embedded diagnostics for fault isolation rather than external test equipment, PMAs will continue to play an important role in displaying the diagnostic information provided by embedded sensors so that it can be used effectively at the point of maintenance.

PARTS QUERY AND ORDERING

Many maintenance support systems used in the private sector not only enable maintainers to determine what parts need to be replaced, but allow them to order necessary replacement parts in order to minimize processing delays. Such capabilities exist only on a limited basis in DoD. In fact, due to concerns about cost and inventory control, maintainers in most DoD organizations must obtain approval from supervisors or materiel managers to order replacement parts.

MAINTENANCE DOCUMENTATION AND ANALYSIS

Mobile computing devices should enable maintainers to input data into maintenance information systems at the job site. The goal is to enter data at the point of maintenance in order to provide instantaneous visibility to multiple users. However, lack of integration with new maintenance management systems (e.g., F/A-18 AME and the Nellis AFB AMATS) often necessitates redundant data entries.

HEALTH MONITORING AND PROGNOSTICS

While many PMAs specifically designed for military applications can be used for health monitoring and prognostics, most COTS devices cannot. Recent advances in data bus and cabling technology may soon make it feasible for generic COTS devices to communicate directly with DoD weapon systems, but it is currently unclear how robust such capabilities will be.

OPERATIONAL DATA UPLOAD AND DOWNLOAD

Two types of devices are currently used within DoD for operational data upload and download: multi-purpose PMAs developed in accordance with military specifications; and dedicated modules designed specifically for data upload and download. The Army and Air Force generally prefer multiple-purpose PMAs, while the Navy prefers to use dedicated modules for data upload and download so COTS devices can be used for other PMA functions.

Military Utility

RUGGEDNESS

Military ruggedization requirements can significantly increase PMA procurement costs, with militarized units costing several times more than COTS units with similar functionality. Consequently, several DoD maintenance organizations are revising ruggedization requirements in order to facilitate procurement of more cost-effective COTS hardware. As one military user described it, "I can buy two or three commercially available laptops for the price of one militarized unit; and if a COTS unit fails or breaks, I can buy a new one with upgrades and still not exceed the price of one militarized unit." It should be noted, however, that such

logic might be shortsighted unless the selected COTS units are durable enough to operate reliably in military environments.

Moisture and Dust Protection

Exposure to moisture (including humidity) and dust are key sources of PMA deterioration. Some ruggedized PMAs can withstand up to 1.4 inches of rain per hour but may cost as much as $30,000 per unit—especially if they are specifically designed for use in military environments. Also, while highly ruggedized units can withstand up to 40-miles per hour wind-driven dust and sand, most COTS units are more vulnerable because of unsealed external vents and ports.

Temperature Tolerance

Some ruggedized PMAs can operate effectively under wide temperature ranges (e.g.,–40 to +50° C), but most COTS units fail when subjected to significant temperature variations.

Vibration

Highly ruggedized PMAs can withstand very strong vibrations (i.e., up to 1.14 G_{rms} at frequencies of 10–500 Hertz) but user feedback suggests many COTS units begin to break down at relatively low vibration levels.

EMI Protection

Electromagnetic interference is often a major concern for wireless connectivity in operational military environments. However, several Air Force bases currently have wireless capability on their flight lines; and the USS Kitty Hawk recently demonstrated wireless operations on its hangar deck. Proper antenna placement and precise positioning and shielding appear to be critical for successful wireless operation in an EMI-intensive environment.

USER-FRIENDLINESS

Sunlight Readability

Many PMA screens become virtually unreadable in direct sunlight because of magnification of light through the display screen media, making most COTS PMA use in open areas extremely difficult under bright sunlight. The technology required to alleviate this problem is readily available but has not been widely used in COTS devices because it is fairly expensive.

Voice Recognition

According to researchers at the Carnegie Mellon Human-Computer Interaction Institute and Air Force Research Laboratory, the voice recognition capability is rapidly improving. This functionality is more evident in such commercial

products as voice recognition software for personal computers and voice-controlled systems in automobiles. A major factor that limits the use of voice recognition software in military PMA applications is the need to eliminate background noise to focus on the desired source. If noise cancellation issues can be effectively resolved, voice recognition systems could provide hands-free support for maintenance troubleshooting, parts ordering, and labor reporting.

Battery Life

Most COTS PMAs have only 4 to 6 hours of useful battery life and cannot be connected to weapons system power. However, some COTS devices have hot-swappable batteries that enable the extension of the useful period of computing and avoid lost data when the battery dies.

Ergonomics

PMA size, shape, and weight can influence how readily maintainers accept mobile computing technology. Ergonomic issues are particularly important for PMAs used to access ETMs, checklists, or parts availability because of the amount of time maintainers need to spend holding and operating the device. Consequently, some Army maintainers prefer to use light COTS devices rather than the 10-pound SPORT when they are accessing IETMs. On the other hand, only a few Air Force maintainers expressed concern about the size and weight of the 15-pound EDNA. F-16 maintainers simply place the EDNA on a cart and wheel it to the aircraft when performing advanced diagnostic functions.

PMA touch screens are generally easier to use than keyboards if they are well designed and durable. However, using touch screens can be problematic in cold weather or when maintainers are wearing chemical gear. In addition, many oils and lubricants used in maintenance can damage a touch screen, and an un-tethered stylus can become a FOD hazard. Consequently, keyboards and mouse devices are still preferred as data entry tools by many maintainers, even though (like touch screens) they are difficult to use when wearing gloves. This is equally true for internal keyboards on smaller devices. For example, while the F-22 DataTrak has a built-in miniature keyboard, technicians frequently connect an external full-size keyboard. Using mouse devices can also be challenging depending upon their placement and durability. A wearable point-and-click dial device developed by Carnegie Mellon researchers may prove to be a valuable alternative.

ELECTRONIC INTERFACES

Some PMAs can connect directly to the weapons systems they support. Direct connectivity facilitates diagnostic and prognostic analysis of system performance characteristics, but is generally limited to PMA devices developed specifically for military applications (e.g., SPORT and EDNA).

In addition, wireless technology offers opportunities for connecting virtually all PMA devices with central servers in order to facilitate rapid transfer of information when obtaining technical data updates, ordering replacement parts and documenting maintenance tasks. Emerging technologies, such as Blue Tooth, and onboard sensors should facilitate wireless operations, but maintaining reliable wireless connectivity is challenging in many military environments.

Data Security

Data transmission via non-secure channels is a primary concern for wireless operations. While most routine maintenance data are unclassified, uploading and downloading operational data often requires secure transmission capabilities.

Information Systems Integration

Several new technology initiatives (e.g., AIT and telemaintenance) might significantly enhance maintainer performance at the job site. However, these new technologies have not been effectively integrated with existing maintenance management systems.

AIT efforts currently use single-purpose bar-code readers, but most PMA devices with infrared ports can also be used to read bar codes. In addition, some PMAs have telemaintenance capability that can transmit images to remote locations for expert repair advice. However, there are significant issues regarding frequency, bandwidth, and security firewalls that still must be resolved. In the interim, DoD maintainers often obtain permission from communications managers before sending images electronically.

Other Significant Factors

ACQUISITION AND SUPPORT COSTS

In most cases, COTS devices can be inexpensively acquired and supported, thanks to marketplace competition. When PMAs must be designed to meet environmental and ruggedization specifications, the result is often low-volume, high-cost production. For example, Army PMA acquisition volumes have historically averaged about 2,000 units per year, which is far less than a single day's manufacturing volume for COTS devices. Consequently, these devices cost significantly more than COTS products with similar computing capabilities.

TECHNOLOGY REFRESHMENT

Electronic devices can quickly become obsolete if developers do not support the insertion of new technology. In order to minimize cost, however, many organizations in DoD continue to use older equipment that is still functional even though the commercial marketplace considers it obsolete.

Army PMA contracts provide for periodic technology insertion. The frequency has been two major upgrades per 5-year contract, with one or two smaller configuration changes between major upgrades. The acquisition process requires extensive reviews and approvals, often amounting to many months, which affects the timeliness of engineering change proposals (ECPs). The resulting upgrades are frequently well behind the pace of commercial technology. Even when developed and approved, ECP upgrades must still be contracted, manufactured, and delivered. Because the PMAs that need an upgrade are usually in the field, the replacement strategy is often based on attrition. Consequently, while better PMAs may already be available, they will not be given to users who have existing PMAs with serviceable life remaining.

CONFIGURATION MANAGEMENT

To remain effective in the midst of changing technology, PMAs need periodic hardware and software upgrades. Ensuring all units receive each upgrade in an orderly manner required close attention and diligence. It should be noted that upgrade decisions must consider the overall cost and return on investment for upgrades versus purchasing new systems.

CULTURAL RESISTANCE

Some studies and interviews indicate older maintainers are reluctant to use electronic media, while younger maintainers are more receptive because of their familiarity with personal computers. The level and intensity of training seem to be key factors in this regard, along with the complexity of the computer systems. Also, the level of management support appears to be an important factor. Historically, when management aggressively supports mobile computing, user resistance is overcome more quickly.

INFORMATION SHARING

An issue that surfaced repeatedly during this study is the lack of information sharing about PMA-related policies, initiatives, and technology within the individual Services as well as across DoD. In fact, we encountered one situation in which a military unit was employing wireless technology while another unit on the same base was not even aware that wireless capability was available.

NOTEWORTHY ISSUES

Centralized versus Decentralized Acquisition and Management

PMA programs are centrally managed in the Army and the Air Force Air Mobility Command, but decentralized in other DoD organizations. There are definite advantages and disadvantages to both approaches. It can be valuable to have a single manager who acquires standardized equipment and arranges for life-cycle

support, but the Army has experienced significant problems trying to adapt a standardized "one-size-fits-all" PMA for use in a wide range of applications with different functionality requirements.

Multiple-Purpose versus Single-Purpose Devices

Two types of PMA devices are currently being used within DoD. The Air Force and Army appear to prefer multiple-purpose PMAs (e.g., EDNA and SPORT) capable of performing several different functions, such as technical data display, diagnostics, and operational data upload and download. In contrast, the Navy and Marine Corps generally prefer to use PMAs almost exclusively for technical data display, along with separate test equipment for diagnostics and dedicated memory modules for operational data upload and download. There are significant cost and effectiveness trade-offs between these two approaches. Because multiple-purpose PMAs—such as EDNA and SPORT—are normally built to military specifications, they are generally more robust and durable than COTS devices, but are also considerably more expensive to acquire, maintain, and upgrade.

CONCLUSIONS

PMA Benefits

INFORMATION ACCESS

Display of technical data is the most prevalent use of PMAs at the point of maintenance. Because the military services are rapidly digitizing technical manuals in order to improve accuracy and timeliness and reduce distribution costs, PMAs have become important tools for displaying electronic technical data at the job site. Some PMAs also give maintainers access to relevant maintenance documentation and parts availability, which greatly reduces time spent traveling between weapon system and shop to review repair records and research parts availability.

Real-Time Data Entry

PMAs offer the capability for maintainers to enter data from job sites in real time, providing instantaneous visibility to multiple users regarding maintenance actions and equipment status.

ADVANCED MAINTENANCE TECHNOLOGIES

PMAs facilitate on-the-job access to advanced maintenance technologies, such as AIT for component tracking and telemaintenance for immediate wireless access to technical data updates and engineering support.

DIRECT COMMUNICATIONS WITH WEAPON SYSTEMS

Direct communications with weapon systems may be the most valuable PMA function in an increasingly digital environment. This capability greatly facilitates troubleshooting, particularly for highly complex systems that do not have embedded diagnostic and prognostic functionality.

Current PMA Challenges

PERFORMANCE DEGRADED BY TECHNICAL DEFICIENCIES

Poor sunlight readability, short battery life, and environmental factors (i.e., temperature extremes, moisture, sand, and dust) seriously degrade the performance of many COTS PMAs in military environments.

INSUFFICIENT INTEGRATION

Existing service-wide maintenance management systems have yet to effectively integrate all relevant logistics elements. Although there are several promising maintenance automation initiatives throughout DoD, lack of system integration often necessitates duplicate data entries. For example, F/A-18E/F maintenance data must be entered separately into AME and NALCOMIS at this time.

Because PMA effectiveness is largely dependent upon the framework in which they are used, several DoD PMA initiatives have been adversely impacted by insufficient integration with existing maintenance management systems or emerging maintenance automation initiatives. However, careful integration can improve PMA effectiveness, even when legacy system interfaces limit available options. For example, the Air Mobility Command effectively uses PMAs in several different environments because AMC designed its PMA implementation process to ensure PMAs could be productively employed in conjunction with existing maintenance management systems.

CULTURAL RESISTANCE

Cultural resistance is more pronounced when there is lack of management focus or inadequate training. Without clear management support and proper training, cultural resistance can cripple an otherwise viable PMA program.

MINIMAL INFORMATION SHARING

There is very little information sharing within DoD regarding PMA policies, plans, and projects. In one case, even maintainers on the same base were unaware of what was happening on the other side of the flight line. Without information sharing, many organizations are struggling to address common issues—such as hardware, software, vendor selection and funding—and are duplicating efforts.

RECOMMENDATIONS

DoD Guidelines for Assessing PMA Benefits

ADUSD(L&MR)MPP&R should establish the following DoD-wide criteria for assessing the benefits of PMA applications:

- ◆ Maintenance functionality (i.e., What functions does the PMA perform and how well does it support the performance of those functions?)

  - ➤ Technical data display

  - ➤ Fault isolation and repair mentoring

  - ➤ Parts query and ordering

  - ➤ Maintenance documentation and analysis

  - ➤ Health monitoring and prognostics

  - ➤ Operational data upload and download

- ◆ Military utility (i.e., How well does PMA operate in DoD environments?)

  - ➤ Ruggedness

  - ➤ User-friendliness

  - ➤ Electronic interfaces

- ◆ Impact on operations and support costs (i.e., Is the PMA cost-effective?)

  - ➤ Procurement and repair/replacement costs

  - ➤ Return on investment

DoD PMA Acquisition and Utilization Reviews

ADUSD(L&MR)MPP&R should sponsor periodic reviews of PMA acquisition and utilization processes in order to enhance information-sharing throughout the DoD maintenance community. These reviews should specifically address:

- ◆ Lessons learned regarding common PMA problems (e.g., economically satisfying hardware ruggedization and information security requirements)

- ◆ Approaches to more effectively integrate PMAs with legacy management information systems and emerging maintenance automation initiatives (e.g., AIT and telemaintenance).

Appendix
Abbreviations

AAAV	Advanced Amphibious Assault Vehicle
ACARS	Aircraft Communication Addressing and Reporting System
ACC	Air Combat Command
ADIP	Army Diagnostic Improvement Program
ADITS	Aircraft Diagnostics Integrated Test System
ADTD	Aircrew Data Transfer Device
ADUSD(L&MR)MPP&R	Assistant Deputy Under Secretary of Defense (Logistics and Materiel Readiness) Maintenance Policy, Programs, and Resources
AFB	Air Force base
AFCA	Air Force Communications Agency
AFRL	Air Force Research Laboratory
AGS	Aircraft Generation Squadron
AIT	automated information technology
AMATS	Aircraft Maintenance Automated Tracking System
AMC	Air Mobility Command
AME	Automated Maintenance Environment
ARINC	Aeronautical Radio, Inc.
ASCII	American Standard Code for Information Interchange
ATA	American Trucking Association
ATWCS	Advanced Tomahawk Weapons Control System
BFVS	Bradley Fighting Vehicle System
BIT	built-in test

BRADS	Bradley Diagnostic System
CAMS	Core Automated Maintenance System
CD-ROM	compact disc-read only memory
CEMS	Comprehensive Engine Management System
CMU	Carnegie-Mellon University
CONOPS	concept of operations
COTS	commercial off-the-shelf
CTS	Contact Test Set
DSSS	direct sequence spread spectrum
DUSD(L&MR)	Deputy Under Secretary of Defense (Logistics & Materiel Readiness)
DVD	digital video disc
ECM	engine control module
ECP	engineering change proposal
EDNA	Enhanced Diagnostic Aid
EMI	electro-magnetic interference
ETM	electronic technical manual
FAA	Federal Aviation Administration
FHSS	frequency hopping spread spectrum
FMTV	Family of Medium Tactical Vehicles
FOD	foreign object damage
FREST	Fleet Replacement Enlisted Skills Training
GCSS	Global Combat Support System
GM	General Motors
GTRI	Georgia Tech Research Institute

GUI	graphical user interface
HMMWV	High Mobility Multi-Purpose Wheeled Vehicle
IEEE	Institute of Electrical and Electronic Engineers
IETM	integrated electronic technical manual
IMDS	Integrated Maintenance Data System
IPDF	Indexed Portable Document Format
ISO	isochronal
JDIS	Joint Distributed Information System
JIMIS	Joint Integrated Maintenance Information System
JSF	Joint Strike Fighter
JSTARS	Joint Surveillance Target Attack Radar System
LAN	local area network
LRU	line-replaceable unit
MA	Mobile Assistant
MEPSS	Maintenance Electronic Performance Support System
MHz	megahertz
MIL-STD	military standard
MLV	Memory Loader/Verifier
MMS	Maintenance Mentoring System
MPH	miles per hour
MSD	Maintenance Support Device
NALCOMIS	Naval Aviation Logistics Command Management Information System
NAS	naval air station
NAVAIR	Naval Air Systems Command

OFP	operational flight program
OJT	on-the-job training
PCMCIA	peripheral component micro-channel interconnect architecture
PDF	Portable Document Format
PEDD	portable electronic display device
PHM	Prognostic Health Management
PM	program manager
PM TMDE	Program Manager–Test, Measurement, and Diagnostic Equipment
PMA	portable maintenance aid
PMAT	portable maintenance access terminal
PMD	portable maintenance device
REMIS	Reliability and Maintainability Information System
RF	radio frequency
RHC	Ruggedized Handheld Computer
RMA	Remote Maintenance Assistant
RTAS	Remote Technical Assistance System
SAE	Society of Automotive Engineers
SGML	Standard Generalized Markup Language
SPO	system program office
SPORT	Soldier's Portable On-system Repair Tool
SSG	Standard Systems Group
TMDE	Test, Measurement, and Diagnostic Equipment
TO	Technical Order
TPC	Truck Productivity Computer
UAL	United Airlines

USB	universal serial bus
USMC	United States Marine Corps
VADS	Vehicle Automotive Diagnostic System
VPN	virtual private network
WEP	wired equivalent privacy