21.0 WIRELESS TECHNOLOGY: DELIVERING TECHNICAL INFORMATION TO LINE MAINTENANCE MECHANICS

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INTRODUCTION

As part of a joint effort between the Federal Aviation Administration and Continental Airlines, a study was conducted at George Bush Intercontinental Airport in Houston for the purpose of determining the feasibility of using Portable Data Terminals (PDT) to display aircraft maintenance documents. The PDT devices were connected to a network via spread spectrum (no FCC license required) Radio Frequency (RF) transmission.

The study was arranged to use the PDTs in much the same way as they would be used in a production environment. A script was created using actual aircraft maintenance documents such as the General Maintenance Manual (GMM), Illustrated Parts Catalog (IPC), Minimum Equipment List (MEL) and others.

The purpose of the study was two-fold, to evaluate the human factors using specific vendor equipment and to sample response times for additional vendors as a continuation of testing performed in the summer of 1996. A total of three vendors completed the requirements to participate in the study.

For the human factors evaluation, aircraft line maintenance mechanics performed simulated maintenance tasks while using the PDT devices. At the conclusion of the simulated maintenance the aircraft mechanics were surveyed to gather data necessary for the evaluation. This report concludes that based on the human factors issues that it would be feasible to use both RF and Portable Data Terminals in a production aircraft maintenance environment.

The objective of the Technical Test was to obtain a sampling of response times that can be expected when these devices are implemented in a line maintenance environment. Based on the results of the technical testing, it was determined that although some vendors response times were better than others, there were no clear cut winners that out performed the others conclusively. Furthermore with exceptions for certain dead zones, response times were for the most part acceptable for use in a production environment.

BACKGROUND

Aviation Maintenance Technicians (AMTs) typically access maintenance documents using microfilm or microfiche, and print copies of these documents for use during work tasks. Increasing demand for fast and accurate maintenance information prompted research into alternative methods of passing technical documents to AMTs. Continental Airlines, EDS, and Galaxy Scientific Corporation (under FAA Contract No. DTFA01-94-C-01013) worked in partnership to explore the feasibility of spread spectrum wireless technology in line maintenance. The study focused on the delivery of technical publications to line maintenance technicians using portable pen-based computers that displayed technical publications. Types of information tested during the study included Maintenance Manuals (MMs), Illustrated Parts Catalogs (IPCs), General Maintenance Manuals (GMMs), Minimum Equipment Lists (MELs) and Structural Repair Manuals (SRMs). The format of these documents was Adobe™ Portable Document Format (PDF).

The research team defined line maintenance tasks and compiled the relevant technical publications required for each task. The team developed a structured script that enabled mechanics to simulate five troubleshooting scenarios. The team also wrote a technical testing script that enabled the team to record response times for each vendor and network architecture.

Test Environment and Method

Tests were conducted during the night shift at Bush International Airport in Houston, TX. A total of three vendors participated in the testing which started July 29th and ended August 12th, 1997. Weather conditions were favorable during every test. Testing began with the outside setup of the hardware at Gate 40 around 9:00pm. A Boeing 737-500 arrived for overnight servicing around 10:00pm, when the simulation took place. The average length of time for a given test was approximately 5 hours.

The study consisted of two types of testing. The first type, called the *technical test*, evaluated response times and network load for each of the vendors. The technical test included a simultaneous use test, in which multiple computers downloaded technical documents at the same time. The second type, called the *human factors test*, involved a script of five troubleshooting tasks that were designed to require the testing mechanics to utilize all types of technical manuals. The mechanics simulated completion of five open logbook items while using the handheld computers to lookup necessary information in the technical manuals. After completing the script, mechanics rated the usability of the pen computer and digital manuals.

Participants

Participants in the study included the vendors who supplied the wireless LAN test equipment, the technical testers who measured performance aspects of the equipment, and the testing mechanics who gave subjective evaluations of the equipment.

Vendors

A total of three vendors participated in the wireless testing. A requirements list was provided to each vendor to standardize the testing environment, however this list was not strictly followed by any vendor. Requirements included pen computers with Windows 95 or Citrix Winframe™ Client, 2 wireless access points to an Ethernet-based LAN, extra batteries, carrying cases and straps, external keyboards if needed, and technical support during the testing.

All of the vendors provided portable pen computers capable of operating on a wireless spread spectrum LAN (frequency-hopping 2.4 GHz band). The server for the LAN was either provided by the vendor or by Continental Airlines, depending on vendor preference. The following paragraphs describe in detail each of the vendor's hardware and network architecture.

§ Vendor #1: July 29th, 1997

- Server: Dell Pentium 133Mhz with 64MB RAM, Windows NT 3.51 running sessions of Citrix Winframe.
- Clients: Wyse Winterm 2930, running Citrix Winframe client from the server. There is no hard drive in these units, only firmware ROM and 4MB RAM which contains the Winframe software and startup operating system. The display was dual-scan color LCD.
- Wireless Architecture: Two Proxim access points with standard gain antennae. Access points were mounted on adjacent jetways (approximately 150 ft from the server) and connected to the hub with twisted pair Ethernet cable.

§ Vendor #2: August 5th, 1997

- Server: Dell Pentium 133Mhz with 32 MB RAM, Windows NT 4.0.
- Clients: Fujitsu Stylistic 1000RF with 24MB RAM, Windows 95, transflective LCD displays. Used NetBEUI protocol with direct drive mapping to server.
- Wireless Architecture: Two Proxim access points, one with high gain omnidirectional antenna mounted above adjacent jetway, and one with medium gain directional figure-eight antenna mounted on the server platform in front of the aircraft. Connected to hub with twisted pair Ethernet cable.

§ Vendor #3: August 12th, 1997

- Server: Dell Pentium 120Mhz XPi with 32 MB RAM, Windows NT 3.51 running sessions of Citrix Winframe.
- Clients: Fujitsu-ICL TeamPad 7600 with 16MB RAM, each running Citrix Winframe™ client sessions. Active color LCD display.

ú Wireless Architecture: Two RDC access points mounted on adjacent jetways with standard gain antennae, connected to hub with twisted pair Ethernet cable.

Technical Testers

Participating technical testers were members of the research team that helped to facilitate the human factors scripting and then measured performance of the computers. The testing team was made up of representatives of Continental Technical Publications, EDS Network Architects, EDS Maintenance Automation Consultants, and the Galaxy Scientific Corporation.

Mechanics

The research team requested that three mechanics be present for each test, preferably the same mechanics each week to minimize variation of individual preference and initial training. However, only two mechanics were present for each test due to unforeseen sickness and scheduling difficulties. All participating mechanics had at least ten years experience as an AMT and understood the line maintenance tasks well. One mechanic was present for all three trials. One mechanic was present for the last two trials, and one mechanic was present for only the first trial. Mechanics had a wide variation of skill level with computers. The most proficient mechanic owned an Apple Macintosh computer and was familiar with the Adobe Acrobat Reader and the use of PDF files. The least proficient mechanic had not ever used a computer.

TECHNICAL TESTING

The Radio Frequency - Portable Data Terminal technical test was conducted to measure response times for hand-held portable computing devices at an airport aircraft maintenance environment. Multiple vendors participated in these tests with each operating under similar circumstances and with comparable equipment.

The testing was conducted over a period of three weeks. Five different vendors were originally scheduled to participate. The three previously mentioned vendors completed their participation, one however could not meet the time window for participation, the other had inadvertently routed their equipment to the wrong location.

Test Methodology

This test consisted of loading and navigating the same documents described in the Overview of Study section of this document. In each case the documents were loaded on the server and displayed on the portable data terminals.

A stopwatch was used to determine response times in loading and navigating through the various types of documents. The same tests were repeated in different sections of the aircraft. This was done to produce a test environment consistent with that which would be encountered in real life aircraft maintenance situations.

With the exception of the first test, the tests were performed simultaneously on two Portable Data Terminals loading the same data at the same time in the same section of the aircraft. The first test was performed on a single device while another device was being used to do similar tasks on other sections of the same aircraft, this situation would have likely produced better results in the response time testing.

Results

For vendor #1 and #2, certain areas of the aircraft were out of the range of coverage, causing the portable data terminal lose communications with the access point. The most troublesome area was the aft lavatory. However, vendor #3 had no difficulty with signal loss in any part of the aircraft.

In general, response times were adequate for use during line maintenance tasks. The average response time for a document load was only 1.9 seconds for the fastest vendor, #3. The most significant impact on response time appeared to be RAM and not the wireless link. This is an encouraging finding, suggesting that the only barrier to good response time is screen painting speed rather than lack of bandwidth. This means that feasibility of wireless connectivity is very positive. With augmented video RAM capability, response time should average in the sub-second range.

HUMAN FACTORS EVALUATION

Human factors refers to a set of engineering principles that takes into account the perceptual, physical, and mental constraints of humans as they complete work tasks. A central goal of human factors is to create and evaluate work tools and environments to achieve an optimum "human" fit. With the introduction of new technology, an assessment of the human impact should be undertaken to understand the benefits and costs associated with the technology. Prototype analysis and pilot group user feedback are valuable sources of information about how changes in work design affect productivity and job satisfaction.

The current study attempts to evaluate the usability of a proposed method of delivering technical manuals to AMTs. The human factors evaluation targets a number of subjective aspects of the system, including screen legibility, computer responsiveness, timesaving potential, usefulness for the job, and other characteristics.

Methodology

The objective of the human factors test was to ask mechanics to use the proposed system for an extended period of time and make an assessment about it's usefulness and usability. In order to make certain that each mechanic tested all aspects of the system in a standard way, a structured script was developed. Members of Continental's Maintenance Operations and Technical Publications met to create a set of five troubleshooting tasks that would require technical manual lookups. A stipulation of the scenarios was that the mechanics would need to visit major zones of the aircraft to complete the lookups. Additionally, the mechanics would have to solve simple troubleshooting tasks and record their answers on the scripts so that the researchers could be sure that the mechanics were completing the entire script.

The scriptwriting was assisted by an outside consultant from Galaxy Scientific Corporation to ensure that clear and concise language was used. Hints were also added to the right hand side of the script so that mechanics could refer to them if needed. The script underwent minor revisions after the first trial due to typographical errors. These changes resulted in the deletion of one subtask lookup, and the correction of a reference pointer to reflect the proper digital document. The changes were assumed have no influence on the subjective ratings of the system. The time it took to complete the scenarios remained roughly equal. The final script is located in Appendix A.

A brief training program oriented the mechanics to all of the features of the software used to view the technical documents. PDF files were viewed using the Adobe Acrobat Reader™ 3.0. The training session was scripted for standardization purposes, and may be found in Appendix B. At the conclusion of the training, a walkthrough of the first seven steps of a troubleshooting task was used to gain proficiency with the program. A reference card that details the major functions of the Acrobat Reader was provided to the mechanics during the testing. This card may also be found in Appendix B.

The human factors evaluation consisted of two parts, the troubleshooting scenarios and the survey questions. Mechanics were given a script that described four open logbook items, and one routine servicing item. The five tasks involved a VHF communications transceiver, a lavatory pump motor assembly, foreign object damage (FOD) in the #1 engine, a leading edge bird strike on the right horizontal stabilizer, and an oxygen cylinder replacement. These five tasks enabled the mechanics to visit all major zones of the aircraft to test the wireless coverage for each area. The mechanics simulated each task according to the script, but did not actually replace or repair any components of the aircraft.

The troubleshooting scenarios were followed by the completion of a two-page survey measuring the following aspects of the pen computers:

§ Potential Timesaving: a three-item scale measuring the potential for saving time using digital documents on a mobile computer compared to the current method of accessing technical documents.

§ Usefulness to the Job: a four-item scale measuring the degree to which mobile computerized technical manuals would be useful to a line maintenance technician.

§ Pen Computers vs. Microfilm: a five-item scale measuring the degree to which the pen computers are preferred to the microfilm readers.

§ Legibility: a six-item scale measuring the legibility of both words and graphics, combined with items about the size of the screen and glare from the screen.

§ Navigation: a four-item scale measuring the ease with which mechanics were able to access, view, and manipulate technical documents on the pen computers.

§ Input: a two-item scale measuring the ease of using the pen as a pointing device.

§ Responsiveness: a four-item scale measuring the speed of loading and displaying the technical documents.

§ Handling: a three-item scale measuring the ease of carrying and handling the pen computer on the job.

§ Durability: a three-item scale measuring the subjective durability of the pen computer.

Survey Scales

The survey may be found in Appendix C. Scales were content validated for consistency and relation to target domain by the research team. All items were answered using a 1-5 Likert scale indicating agreement with statements about the computers. Scales were constructed by averaging items within each of the nine domains. Scales ranged from 1 to 5, with 5 being a positive evaluation. Some items were reverse coded as a check against rater repetition (e.g. when raters simply answer each question with the same value). Inspection of the data revealed no such repetitive trends. Due to the small sample size, accurate reliability estimates of the scales cannot be provided.

Results

Descriptive scale characteristics are presented in Figure 21-1 below, in Box and Whisker plot format. As can be seen below, mean ratings across vendors for every scale are above the midpoint (3.0) of the scales, suggesting a possible halo effect or leniency bias. However interviews with mechanics after completion of the surveys confirmed this generally positive attitude toward the wireless units. Figure 21.1 illustrates overall averages across vendors on each scale. The next section presents more detailed graphs that breaks each scale into it's own Box and Whisker plot for a comparative assessment of vendor equipment.

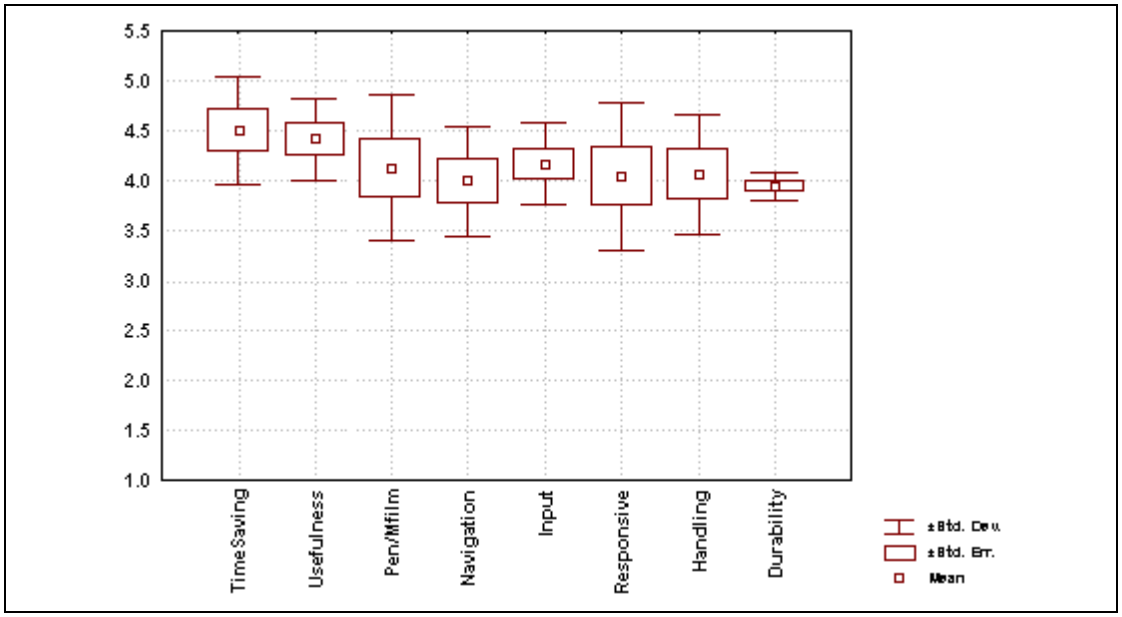

Figure 21.1: Descriptive Statistics for Survey Scales

DISCUSSION

Following is a discussion of the specific features and performance of the vendor products. The discussion is based on observations, survey results, and comments from the research team and the mechanics during the tests.

Vendor #1

The WyseTerm 2930 is a thinly designed pen computer with an integrated wireless antenna. The thin profile and lack of a hard drive contribute to its fairly light weight at 3.4 lbs. The unit is surrounded on its edges by a rubber bumper to reduce the shock of impact, although the bumper does not cover all edges. The grip of the unit is comfortable due to a thin and wide lip surrounding the unit.

A benefit of this unit is that it does not maintain any data on the client side; all transactions except for the graphical display commands occur on the server. This means that if a unit is damaged during data entry or data lookup, the session can be completely recovered on any other working unit. Additionally, the WyseTerm is a fairly simple implementation of an LCD touch screen display and integrated firmware, meaning that the unit is relatively inexpensive and requires less configuration maintenance than more complex designs. The pointing device is not active, so that any pen or tool (including a finger) can be used as the pointer. The display controls are located as icons on the right side of the unit and are fairly intuitive to use. The display was disappointing in bright fluorescent lighting, where there was a noticeable screen glare. It is assumed that daylight conditions would further decrease screen legibility due to glare. The vendor advised that there are monochrome screen options that are less vulnerable to glare. Battery life for the unit was superior to all other units tested. After 3.5 hours of testing, approximately 75% of battery life was left.

No carrying case or shoulder strap was provided for assessment. According to the representatives cases and straps are available as options.

Response times for these units were adequate but the slowest of all units tested. There was an occasional problem with continued scrolling of documents after the pointer was removed from the screen. Wireless coverage was problematic in the aft lavatories and in the aft cargo area. Slower response times were also encountered at the tail of the aircraft.

Vendor #2

The Fujitsu Stylistic 1000RF was the heaviest of the units evaluated at just under five pounds, but also contained the most components. Carrying cases and straps were provided for the Stylistic units, along with screen covers which protected the units and decreased glare. The handles on the carrying case were comfortable, and the unit was believed to be durable within its casing. This was the only unit containing a hard drive. The pointing device was active electromagnetic field and required a small battery. The mechanics believed that the pen would be easy to lose if it were not tethered to the machine. There was a tethering loop on the pen.

The unit had a transflective LCD black and white display with the largest screen size. The display was the most bright and legible of all units tested. It was the favorite display of the mechanics. Battery life was not as great after 3.5 hours of testing as the WyseTerm and was about the same as the TeamPad 7600, at about 42%.

The response time for this unit was much faster than the WyseTerm 2930, and almost as fast as the TeamPad 7600.

There were temporary coverage problems in the aft lavatories, but overall coverage was better than the WyseTerm 2930. It should be noted that Fujitsu-Personal Systems used higher gain antennae, which probably increased the coverage.

Vendor #3

The Fujitsu-ICL TeamPad 7600 was the lightest unit evaluated, at 2.7 pounds. A rubber bumper surrounded it on the edges, and all openings to the unit were sealed with rubber plugs. There were no external switches or controls except for the on/off buttons. The most prominent feature was the passive color touch screen display that covered most of the area of the computer. As with the WyseTerm 2930, any pointing tool could be used with the touch screen. The brightness of the screen was adequate, although it seemed that the screen was smaller than the Stylistic 1000RF and therefore words from technical documents were slightly less readable.

A wide stretchable hand-strap went across the back of the machine so that one could slide an open palm into the back of the unit rather than hold the computer on the sides. No carrying case or shoulder straps were provided. Representatives claimed that the cases and straps would be available soon. Other options demonstrated were an attachable numeric keypad, a docking station, and a barcode reader.

As with the WyseTerm 2930, there was no hard drive in the machine. All of the disk storage was located on a 20MB FlashRAM card, which contained the operating system and the WinFrame Client software for connection to the server. Thus there are similar benefits of data recovery discussed previously. However, the machine is not designed to be a graphics terminal machine, but follows the Intel™ specifications for a 80486 processor and circuit board. This contributes to more complex internal design and more expensive components.

Responsiveness for this unit was the best of all units tested, although probably not significantly better than the Stylistic 1000RF. Loading documents was very fast and scrolling through documents was also good. Though a standard gain RDC antenna was used for the testing, coverage was easily the best of any vendor. Connection to the server was reliable even within the aft lavatories, unlike the other trials.

CONCLUSIONS

The research team explored three major issues concerning the use of wireless technology to deliver accurate technical information to line maintenance technicians. First, we examined the feasibility of a wireless LAN in the line maintenance environment using technical measures. Second, we surveyed mechanics who used the system in order to evaluate its usability. Third, we interviewed mechanics to discover in what cases a similar system would be useful in relation to their work tasks. The question of feasibility is fairly easy to answer in the affirmative. Network speed for wireless LANs is fast enough to handle fairly large technical graphics, especially when using a graphics terminal architecture. Coverage was adequate even for the worst performing system tested, and could be considered excellent with the best system. Even when dead zones were encountered due to interference or distance, mechanics would simply walk toward an access point until the connection was restored. It is obvious when one encounters these dead zones; the machine is not able to respond to screen commands or load documents. However, in our tests the worst dead zone was inside of the aft lavatory. Mechanics handled this quickly by walking back into the main aisle without prompting. The radio technicians believed this was due to the large amount of steel contained in the lavatory. The question of usability is more complex because so many factors enter into a rating of usability. Responsiveness, software interface, bulkiness, and screen size all interact to produce this overall concept of usability. However, certain aspects of the system can be improved to greatly increase user acceptance. These ideas originated from comments made by mechanics during the testing and are presented below.

§ Responsiveness of the units is a top priority for user acceptance. Mechanics will not be satisfied with a system that requires noticeable "wait time" during screen updates and scrolling procedures. Even if the total amount of time to retrieve a technical document is far less than finding and using a microfilm machine, the user's perception of time is what matters.

§ Accessories, such as carrying cases and straps that are designed to fit well, are important to mechanics. Especially useful is the ability to grip the computer in multiple places to ease hand strain.

§ Larger screen sizes with bright screens are preferred. Eyestrain was noticeable during testing with the smaller screens. Color screens were not important for the type of manuals tested, and mechanics could not think of a situation where color would be required. At this time, color screens tend to fade out in sunlight more than black and white screens.

§ Although the Acrobat Reader™ was easy to learn and use, PDF file formats are not suited well to small screens on mobile computers. Mechanics were forced to zoom in to a document to read the words, rather than being able to read the document at the default screen size. Once a document was zoomed, it was difficult to navigate through the document because the page numbering system on the scroll bar did not reflect the page numbers at the bottom of each page. Also, PDF files are simply images of the paper manuals, so there is no word wrapping. On smaller screens, this is a serious problem because when the words are big enough to read, one cannot view the entire line at once and must resort to horizontal scrolling. Horizontal scrolling has been identified as a frustrating user action in a number of interface design texts. At the current time, the FAA has not approved any other digital format. However, it is expected that the ATA Spec 2100 will eventually become an aviation standard for SGML documents. This format allows word wrapping and word searching, as well as object handlers specific to many types of graphical data. Smaller screens should not be an issue when users are able to view words at a readable size without zooming out to see the words that are "off the screen." This research provides strong evidence for the use of data formats such as SGML that enable the use of various screen sizes.

The question of usefulness in the line maintenance job is particularly important when implementing broad changes in work design. Mechanics were generally positive about most aspects of the mobile computers, and viewed them as a significant improvement to the current method of looking up technical information. Mechanics envisioned themselves carrying the computers when necessary rather than wearing them in a holster or backpack. They believed that a workbench computer that could be undocked easily would the most effective method of use. Mechanics stated that the portable computers would be used most frequently in the following situations:

a) When values change frequently during repair (such as pressure limits during trim runs)

b) During lookups in the Illustrated Parts Catalog (IPC)

c) When accessing wiring diagrams (for zoom capability)

d) To send documents to other work stations (e.g. printing technical manual pages to a remote printer to discuss repairs with another mechanic or supervisor)

e) When there is limited or time-consuming access to paper or microfilm documents (such as the B-check pad)

f) During non-routine repairs and write-ups

g) When manuals could be accessed via modem while on road calls at remote repair stations

h) For use in accessing maintenance workcard and non-routine write-up systems.

Two of the mechanics emphasized that training for the system would need to be a high priority when it is actually implemented. Overall, the mechanics viewed the mobile pen computers as a useful and usable addition to their set of work tools, and looked forward to the implementation of a similar system in the future. Other mechanics not involved with testing who saw the units being used by their coworkers voiced similar positive attitudes toward the technology. The test of wireless technology in the line maintenance environment appears to have been successful. A broad implementation of a similar system would probably be accepted by many mechanics as long as concerns about legibility, training, handling, and data access are addressed.

APPENDIX A

Pen Computer Testing Script

Overview

The purpose of this test is to determine the effectiveness of using a wireless pen to look-up aircraft manuals in an airport environment. Information gathered from this study will be evaluated and applied to future development of the Document Management System.

The pen computer is similar to a normal computer, except that the pointing device is a pen rather than a mouse. Moving the pen across the screen will allow you to move the cursor. Tapping the pen on a button or a link on the screen will allow you to “select” that button.

The pen computer contains sample manual information for the B737-300 type aircraft. On the left side of the screen you will find buttons for the following manuals:

- AMM - Aircraft Maintenance Manual
- IPC - Illustrated Parts Catalog
- SRM - Structural Repair Manual
- MEL - Minimum Equipment List
- GMM - General Maintenance Manual
- Bulletin - M&E Bulletins

To open any manual, tap the button with the tip of the pen.

Practice

Tap/Select

Home

Toolbars

Scroll

Grab

Expand/Collapse

Hiding bookmarks

Full screen view

Zoom

Background

Aircraft 306 just arrived from EWR. The pilot called in stating that his VHF Com #1 is inop. He also mentioned three other log book entries that maintenance needs to look into.

You meet the aircraft at the gate. The flight crew has already left, so you review the open log book entries in the cockpit. You find these items:

- VHF Com #1 inop.
- Left Aft lav flush motor inop.
- #1 Engine FOD
- Right horizontal stabilizer leading edge bird strike

Planning has also requested that you change the Oxygen Cylinder during the holdover. After looking up deferrable items in the MEL, you decide to proceed with repairs.

Log Book Item 1: VHF Com #1 inop	***Hints***
Walk into the cockpit with the pen computer turned on. Using the computer to reference the appropriate manuals, troubleshoot the system with these steps:	
1. Tap the AMM button on the computer (with the tip of the pen).	*This will "**select**" and open the AMM.*
a. Select w**23 TOC** (Chapter 23 Table of Contents).	*Tap the tip of the pen once to the computer screen for selecting buttons and references.*
b. Locate the reference pages for VHF Com #1 Description and Operation.	*The reference location should be 23-21-00 pg. 1.*
c. Expand w**23 TOC** in the bookmark section and select **21-00 Pg. 1**.	*The bookmark section is the left-hand portion of the screen. You "**expand**" a chapter to see what the chapter contains by tapping on the small triangle* [w]. *You "**collapse**" a chapter the same way. When a chapter is expanded, the triangle will point downward* [s]**.**
d. Locate and read paragraph 5, Operation.	*You must "scroll" downward to see this paragraph. Tap the pen on the right side of the screen to move the document. This is the "scroll bar".*
e. Go to Figure 2, Wiring Diagram.	*You must scroll down again to see this figure.*

f. "Zoom" into the lower left corner of the drawing until you can read the words.	*Tap the button that looks like a plus sign inside a magnifying glass [ ]. Now use the pen and drag it over the section of the picture you want to see. That section will become magnified, or "**zoomed**".*
g. Restore the page to normal size by selecting the "Page Width" [2] button.	*The Page Width [2] button may be found at the top of the screen. Selecting this will always restore the document to normal size.*
h. Select **21-00 Pg. 101** in the bookmark section.	*The bookmark section is the left-hand portion of the screen.*
i. Go to paragraph 2, Troubleshooting Chart, and view the chart.	
j. Assume that the TRANSCEIVER ASSY-VHF COMM was found faulty, so you must replace the unit.	
2. Select the **Home** [ ] button in the upper part of the computer screen.	*This will always return you to the main reference page.*
3. Select the IPC button to lookup the part number:	*You have now opened the IPC.*
a. Select w**23 TOC**.	*Chapter 23 Table of Contents.*
b. Locate reference page for TRANSCEIVER ASSY-VHF COMM.	*You should see reference 23-21-21-02 Pgs. 0-4.*
c. Expand w**23 TOC** in the bookmark section and select **21-21-02 Pg. 0**.	*Expand by tapping the triangle [w] in the bookmark section. When a chapter is expanded, the triangle will point downward [s].*
d. Lookup the TRANSCEIVER ASSY-VHF COMM part number (effectivity 301379).	
e. Record part number here: _____	*Put the correct part number in the space provided.*
4. Assume that you have replaced the TRANSCEIVER ASSY-VHF COMM. The operational check you perform is OK.	**Congratulations!**
5. Select the **Home** [ ] button in the upper part of the computer screen to prepare for the next task.	*This will always return you to the main reference page.*

Log Book Item 2: Left Aft Lav won't flush	***Hints***
Walk to the aft of cabin to inspect the trouble. Enter the lavatory with the pen computer.	
1. Select the AMM button.	*This will open the AMM.*
a. Select w**38 TOC** in the bookmark section.	*The bookmark section is the left side of the screen containing chapter numbers.*
b. Locate the Toilet System Trouble Shooting procedures.	*You should see reference 38-32-00 pg. 101.*

c. Expand w**38 TOC** in the bookmark section and select **32-00 Pg. 101**.	*Expand by tapping the triangle* [w] *in the bookmark section. When a chapter is expanded, the triangle will point downward* [s].
d. Scroll downward to page 102 and begin reading "*Toilet does not flush. . .*"	*Use the scroll bar on the right hand side of the screen, or Page Down using the* [€] *button on the scroll bar.*
e. After reading the chart assume that the lav motor must be replaced.	
2. Select the **Home** [⌂] button on the tool bar of the Browser.	*This will always return you to the main reference page.*
3. Select the IPC button to lookup the replacement part number.	*This will open the IPC.*
a. Select w**38 TOC**.	*This will open the Table of Contents for Chapter 38.*
b. Locate the page reference for MOTOR ASSY-FILTER AND PUMP in the TOC.	*You should see 38-32-21-01 Pg. 0.*
c. Expand w**38 TOC** in the bookmark section and select **32-21-01 Pg. 0**.	*Expand by tapping the triangle* [w] *in the bookmark section. When a chapter is expanded, the triangle will point downward* [s].
d. Page down to Figure 1., Page 2.	*Use the scroll bar on the right hand side of the screen, or Page Down using the* [€] *button on the scroll bar.*
e. Lookup MOTOR ASSY-FILTER AND PUMP part number (effectivity 301379).	
f. Record the applicable Part No. _____.	
g. Assume that you attempted to order the part from stores, but the part number is not in stock. You must now review MEL requirements for a Lav Motor Inop placard.	
4. Select the **Home** [⌂] icon button to get MEL information.	
5. Select **MEL** button.	
a. Expand w**38 TOC** in the bookmark section and locate Lavatory Flush Motor Inop MEL Number.	*Expand by tapping the triangle* [w] *in the bookmark section. When a chapter is expanded, the triangle will point downward* [s].
b. Select the appropriate MEL Number in the bookmark section.	
c. Record MEL No. _____ Page No. _____.	
d. Review MEL requirements for Lav Motors Inop placards. Assume you have read the requirements and placed the placard properly.	*View this section briefly.*
e. Select the **Home** [⌂] button to prepare for the next task.	

Log Book Item 3: Foreign Object Damage (FOD) No. 1 Engine	***Hints***

Exit the aircraft and proceed to the front of the No. 1 engine.	
1. Select the AMM button.	
a. Select w**72 TOC** in the Bookmark section	
b. Page down to the reference for COMPRESSOR SECTION, BLADES - FAN ROTOR, Inspection/Check.	*You should see 72-31-02 Pg. 601.*
c. Expand w**72 TOC** in the Bookmark section and select **31-02 Pg. 601.**	*Expand by tapping the triangle* [w] *in the bookmark section. When a chapter is expanded, the triangle will point downward* [s].
d. Follow the inspection procedure in paragraph 2. D. 4). Page down to figure 601 to identify the damage.	*Use the scroll bar on the right hand side of the screen, or Page Down using the* [€] *button on the scroll bar.*
e. Assume you found a nicked area of approx. 0.025 depth on the leading edge, Area B.	
f. Follow the inspection task to paragraph 2. D. 4) (d) 1) to review the damage limits.	*Use the scroll bar on the right hand side of the screen, or Page Down using the* [€] *button on the scroll bar.*
g. Record the max allowable limit for leading edge Area B: _____	
2. Select the **Home** [🏠] icon button on the tool bar of the Browser to prepare for the next task.	

Log Book Item 4: Right Horizontal Stabilizer Leading Edge Bird Strike	***Hints***
On a ladder with access to the computer, assume you have just measured the depth and diameter of the dent at station 86.66. The depth was 0.045 inch and was 1.5 inches from adjacent hole material. Complete the following while remaining on the ladder:	
1. Select the SRM button.	*This will open the SRM.*
a. Select w**55 TOC** in the bookmark section.	
b. Locate Horizontal Stabilizer Skin Allowable Damage in the TOC.	
c. Expand w**55 TOC** in the Bookmark section and select **10-01 Pg. 101.**	*Expand by tapping the triangle* [w] *in the bookmark section. When a chapter is expanded, the triangle will point downward* [s].
d. Scroll Down to Page 103 and review illustration.	*Use the scroll bar on the right hand side of the screen, or Page Down using the* [€] *button on the scroll bar.*
e. Review Pages 104 and 105 to determine limits.	
f. Is damage allowable? (Circle One) YES NO	

g. What is that max allowable depth without repair? Depth _____	
2. Tap on the **Home** [🏠] icon button to prepare for the next task.	

Planned Service Item 5: Oxygen Cylinder Servicing	***Hints***
Planning has informed you that the oxygen cylinder must be changed during the aircraft downtime. With the computer in hand, gain access to the forward cargo compartment.	
1. Select the GMM button to review procedures for servicing the oxygen cylinder:	
a. Expand w**LEP Chapter 09** in the Bookmark section and select **09-74-72 Oxygen Cylinder Servicing Procedures.**	*Expand by tapping the triangle* [w] *in the bookmark section. When a chapter is expanded, the triangle will point downward* [s].
b. Read paragraph 4, Replace Supply Cylinder.	*Located on pg. 4.*
c. Assuming you have now replaced the Supply Cylinder, Page Down to the Oxygen Temperature/Pressure Table.	*Located on pg. 6.*
d. Assume the Bottle temperature is 95 degrees. Locate the proper pressure for an 1850 PSI type bottle.	*You must read the table to get this value.*
e. Record the proper pressure here: _____ .	
f. Tap on the **Home** [🏠] icon.	*Congratulations. You have completed the simulation.*

Please return the computer and this script to the facilitator. You will be finished after completing a brief questionnaire.

APPENDIX B

Overview: Pen Computer Study

Thank you for participating in the study of wireless computer technology at Continental Airlines. Our objective with these tests is to evaluate:

1. The delivery of timely information to line mechanics over wireless networks

2. The usefulness of the pen computers

3. The durability of the pen computers

4. The ease-of-use of the pen computers.

There are no right/wrong answers to the tests. You will not be graded on your performance. We would simply like to get your honest feedback about using the computers. The more feedback we receive, the better judgements we can make concerning the equipment.

We hope that you will find this experience as trouble-free as possible. In order to facilitate your use of the computers, we have designed a set of practice exercises to get you familiar with the equipment and software.

Practice

Tap/Select

This is the method of choosing objects on the computer screen. Simply tap the tip of the pen on the desired object. When you tap a button, the button will perform a certain action. If you tap a text link (such as the name of a section of a manual) the computer will display that document.

Home

The **Home** [] button (or **Home** bookmark) will always return you to the top-most level of the manuals.

Toolbars

Rows of buttons are called Toolbars. The document viewer has a number of buttons which perform actions such as zooming in and out, fitting a page into the size of the screen, and changing the position of the document.

Scroll/Page Down

In order to move about in a document, it is necessary to use some tools. One tool is the scroll bar, which is always located on the right side of the screen. The plain button shaped object slides up and down the scroll bar when you drag it with the pen. To drag the button, simply touch the pen to the button and move it up or down. You can also move through a document by tapping on the buttons with small black triangles [€].

Grab

You will notice that sometimes the cursor turns into the shape of a hand. This allows you to grab things and drag them to new places. For example, when your cursor is over the document, it will become a small hand. Touch the pen to the screen and drag it downward. You will notice the page move as if you grabbed it with the hand.

Expand/Collapse

The bookmarks, or chapter/section titles, are outlined to the left of the screen. When you first view the bookmarks, only the major headings will show. Any chapter with sub-sections will have an open triangle next to it [w]. You "**expand**" a chapter to see what the chapter contains by tapping on the small triangle [w]. You "**collapse**" a chapter the same way. When a chapter is expanded, the triangle will point downward [s].

Hiding Bookmarks

You may hide the bookmarks section of the screen by selecting the ___ button. This will allow you to view a bigger portion of the document.

Zoom

Tap the button that looks like a plus sign inside a magnifying glass []. Now use the pen and drag it over the section of the picture you want to see. That section will become magnified, or "zoomed". You can zoom out by using the tool with the minus sign.

Normal View

You can always return to the normal view of the document. The Page Width [2]button may be found near the top of the screen, third button to the right. Selecting this will always restore the document to normal size.

Multiple Tapping

Sometimes the computer is slow to respond because it needs time to perform an action. You will see an hourglass icon next to the cursor when this happens. This means to wait for the computer to finish what you have asked it to do. Tapping the pen more than once when it is performing an action can cause the computer to malfunction or "freeze up." Be patient and you will get the hang of it.

APPENDIX C

Mechanic's Feedback

Thank you for participating in the study of new maintenance technology. Feedback about your experiences will help determine future tools that might be used by you and your fellow mechanics. Please rate your agreement to the following questions using the rating scale below:

1 = Strongly Disagree	2 = Disagree	3 = Undecided	4 = Agree	5 = Strongly Agree
Time	**1. Having all necessary references on the pen computer would save me time.**			**1 2 3 4 5**
	2. The pen computer would take more time to use than the microfilm machine.			**1 2 3 4 5**
	3. With more practice, I would probably save time using the pen computer.			**1 2 3 4 5**
Usefulness	**4. Using technical documents on the portable computer would help me in my work duties.**			**1 2 3 4 5**
	5. The pen computer with digital documents would *not* assist me in completing my work.			**1 2 3 4 5**
	6. With some improvement, the pen computer would be a useful tool.			1 2 3 4 5
	7. The pen computer would *not* be of much use to me.			1 2 3 4 5
Pen Computer vs. Microfilm	8. I would rather use the pen computer than print out the documents at the microfilm machine.			1 2 3 4 5
	9. I prefer using paper documents printed from microfilm.			1 2 3 4 5

	10. Having reference information on the portable computer is better than using the microfilm machine.	1 2 3 4 5
	11. I would prefer to use the pen computer to my current method of getting technical information.	1 2 3 4 5
	12. Viewing documents on the pen computer is easier than viewing on the microfilm reader.	1 2 3 4 5

Legibility	1. The words were clear enough for my work tasks.	1 2 3 4 5
	2. The graphics/diagrams were clear enough for my work tasks.	1 2 3 4 5
	3. I found it easy to read words.	1 2 3 4 5
	4. I found it easy to read graphics.	1 2 3 4 5
	5. The screen size was large enough.	1 2 3 4 5
	6. I did not have much trouble with screen glare.	1 2 3 4 5

1 = Strongly Disagree	**2 = Disagree**	**3 = Undecided**	**4 = Agree**	**5 = Strongly Agree**

Navigation	**1. Locating documents on the computer is fairly easy.**	**1 2 3 4 5**
	2. Zooming in and out of the document was *not* difficult.	**1 2 3 4 5**
	3. I found it difficult to position documents so I could use them.	1 2 3 4 5
	4. I thought it was easy to navigate through the documents.	1 2 3 4 5
Input	5. The pen was easy to use.	1 2 3 4 5
	6. Pointing and clicking was easy to get used to.	1 2 3 4 5
	7. Using the on-screen keyboard was fairly difficult.	1 2 3 4 5
	8. Logging into the system using the pen was simple.	1 2 3 4 5
Response Time	1. The pen computer was too slow to be of use.	1 2 3 4 5
	2. Loading documents took only a short time.	1 2 3 4 5
	3. I spent too much time waiting for the computer to load documents.	1 2 3 4 5
	4. The response time of the pen computer was good.	1 2 3 4 5

Handling	5. Wearing the computer would not hinder my ability to do my work.	1 2 3 4 5
	6. I don't like carrying around the pen computer.	1 2 3 4 5
	7. The pen computer is too bulky for general use.	1 2 3 4 5
	8. The carrying straps are well designed.	1 2 3 4 5
	9. The carrying case is well designed.	1 2 3 4 5
Durability	10. I think the pen computer would be durable enough for use on the job.	1 2 3 4 5
	11. I would bring the pen computer with me for rough jobs.	1 2 3 4 5
	12. I could wear/carry the pen computer into most work areas without fear of damage.	1 2 3 4 5