AFIT/GLM/LSY/92S-20

COMPARISON OF FOUR-CURSOR BUTTONS VS JOYSTICK TO ACCESS COMPUTERIZED TECHNICAL INFORMATION FROM AN INTEGRATED MAINTENANCE INFORMATION SYSTEM

THESIS

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THESIS

Presented to the Faculty of the School of Systems and Logistics
of the Air Force Institute of Technology
Air University
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Requirements for the Degree of
Master of Science in Logistics Management

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Preface

In the last decade it has become apparent that paper-based technical orders (TO) are obsolete for a modern defense force in terms of efficiency and cost. In the near future, possibly 10 years, Air Force technicians will use automated TOs to access, display, and store information to operate and maintain Air Force equipment and resources. The Armstrong Laboratory at Wright-Patterson AFB, OH has been researching and experimenting with electronic medium devices for over 12 years and they have developed a ruggedized computer for use on the flight line. It was our distinct pleasure to assist the laboratory in this endeavor by testing two types of video access devices - a joystick and a four-button cluster cursor key.

For this experiment we tested a joystick device against a four-button cluster cursor key to determine which access method interfaced with a computer the fastest, and which device provided the most user satisfaction. The results of our research are presented in Chapter IV and in appendices H and I.

Completion of this thesis was one of the most rewarding experiences at AFIT because it allowed us to apply the knowledge and skill we gained throughout the academic year. With that in mind we take this opportunity to thank all our professors and advisors. Although the homework was over-bearing, the classroom lectures were boring, and the tests were unrealistic, the maturing process that "now" allows us

to think critically was worth it. Even we were surprised at what we truly understood and were able to apply when it came time to accomplish this thesis. Thank you!!!!

We especially thank our thesis advisors Art Munguia, and Barbara Masquelier. They provided us a wide latitude in which to perform our thesis research, but were always there to advise us and to set us back on course. We began this experiment with a pretty in-depth knowledge of technical orders, or so we thought, however, Art soon showed us the error of our thinking and skillfully expanded our knowledge of technical orders by a hundred-fold. Thanks Art for your knowledge, time and patience.

Barbara was instrumental in helping us to approach this experiment in a critical manner by forcing us to carefully plan every detail and just when we thought we had the perfect plan, she would offer us another insight. After many attempts we did succeed in developing a near flawless plan and everything progressed smoothly. Thank you Barbara for introducing us to the scientific aspect of the thesis and for answering all those Saturday telephone calls. And please thank everyone at the lab who assisted us in this experiment. Especially those we inconvenienced by stealing their computer.

We also offer our sincere thanks to our families and friends who endured these 15 months with us. We found that late night study sessions and last minute paper changes not only affected us but also affected the whole family.

Everyone in the house lost sleep when we were working in what was affectionately called "daddies dungeon". We look forward to sharing more of our lives with you and promise to leave the companionship of our computers for a night on the town. How about dinner?

Gerald Streff Robert Gundel

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Abstract

The purpose of this thesis was to evaluate the use of four-cursor buttons versus a joystick device to present technical order information on a portable maintenance aid computer for aircraft technicians in a maintenance environment. Studies to date have verified the superiority of computer-presented technical orders when compared to current paper-based systems; this research investigated the effectiveness of computer-based systems when technicians used a joystick or four-cursor buttons to display desired technical information. A comparison was made as to technician performance using a portable maintenance aid at the 4950th Test Wing, WPAFB OH. A total of thirty-two maintenance technicians performed two simulated tasks using a F-18 demonstration program. The technicians accessed and displayed technical information using the joystick device and the four cursor-keys. Results indicated no significant difference in the performance of maintenance technicians when using either access device in a controlled environment. The major conclusion was that either access device may be a viable answer for use in a flight line environment. The chief recommendation is that further studies be performed using a different joystick device and computer software that supports all eight joystick functions.

COMPARISON OF FOUR-CURSOR BUTTONS VS JOYSTICK TO ACCESS COMPUTERIZED TECHNICAL INFORMATION FROM AN INTEGRATED MAINTENANCE INFORMATION SYSTEM

I. Introduction

Accurate dissemination of information is an essential part of the United States Air Force whether it is in the form of combat orders, equipment operating instructions, safety procedures, or technical orders (TO). Every day, Air Force personnel use written communications to transfer information from one source to another. If information is inadequately communicated, the results can be life threatening - improperly conveyed safety procedures could result in death or equipment damage. It is extremely important for all information to be factual, timely, and concise if it is to serve the needs of the user or reader. For all Air Force personnel - aircraft pilots, x-ray machine operators, maintenance technicians, flight engineers, car mechanics, aerospace engineers - their TOs must be accurate and convey information effectively for them to perform their jobs correctly and safely.

Although the paper based TO system has adequately served the needs of the Air Force since 1940, it can no longer support the volume of information created by technological advances and sophisticated weapon system acquisitions. "TOs are too costly to update and maintain, too cumbersome to use, and too difficult to secure" (1:5). As outlined in Chapter Two of TO 00-5-1, the Air Force Technical Order System, there are five basic categories of TOs that provide technical information to operate, maintain, and modify Air Force equipment. TO use is mandatory for all Air Force personnel while operating or maintaining Air Force or Air Force contracted equipment (2:1).

The largest TO category is the Operations and Maintenance Technical Orders. These TOs describe installation, operation, maintenance and handling of Air Force equipment and material. This series is further broken down into seven separate manuals each having their own TO control number. See figure 1 on page 4 for a breakdown of the different categories of TOs (3:2-1).

The second major category is the Methods and Procedures Technical Order. These TOs establish policies and prescribe procedures for the care and use of Air Force equipment. Within this category there are six separate sub-sections including job guides, air crew flight manual publications, etc. Each sub-section has its own TO control number and areas of interest (3:2-2).

Abbreviated Technical Orders simplify equipment inspection routines by providing repair technicians with condensed forms of larger system TOs. Abbreviated TOs contain checklists, step-by-step equipment inspection routines, inspection charts, and lubrication charts. Within this series, there are three sub-sections that contain specific information controlled by separate TO numbers. These TOs are used extensively by maintenance personnel (3:2-2).

The fourth major category of TOs is the Time Compliance Technical Order (TCTO). This series controls equipment modifications by authorizing and standardizing the modification process. TCTOs provide detailed modification instructions to technicians so that all modified equipment meets established operating specifications. There are five sub-classes within this TO category. As seen in the other TO categories, these sub-classes are controlled by their own TO number (3:2-3).

The fifth type of TO is the Index Type Technical Order. These TOs provide Air Force managers, operators, and technicians with the means to track and identify the active TOs currently authorized for use on Air Force equipment. Index Type Technical Orders are broken down into four major categories. As previously noted in the other categories, each sub-category has its own TO number (3:2-2).

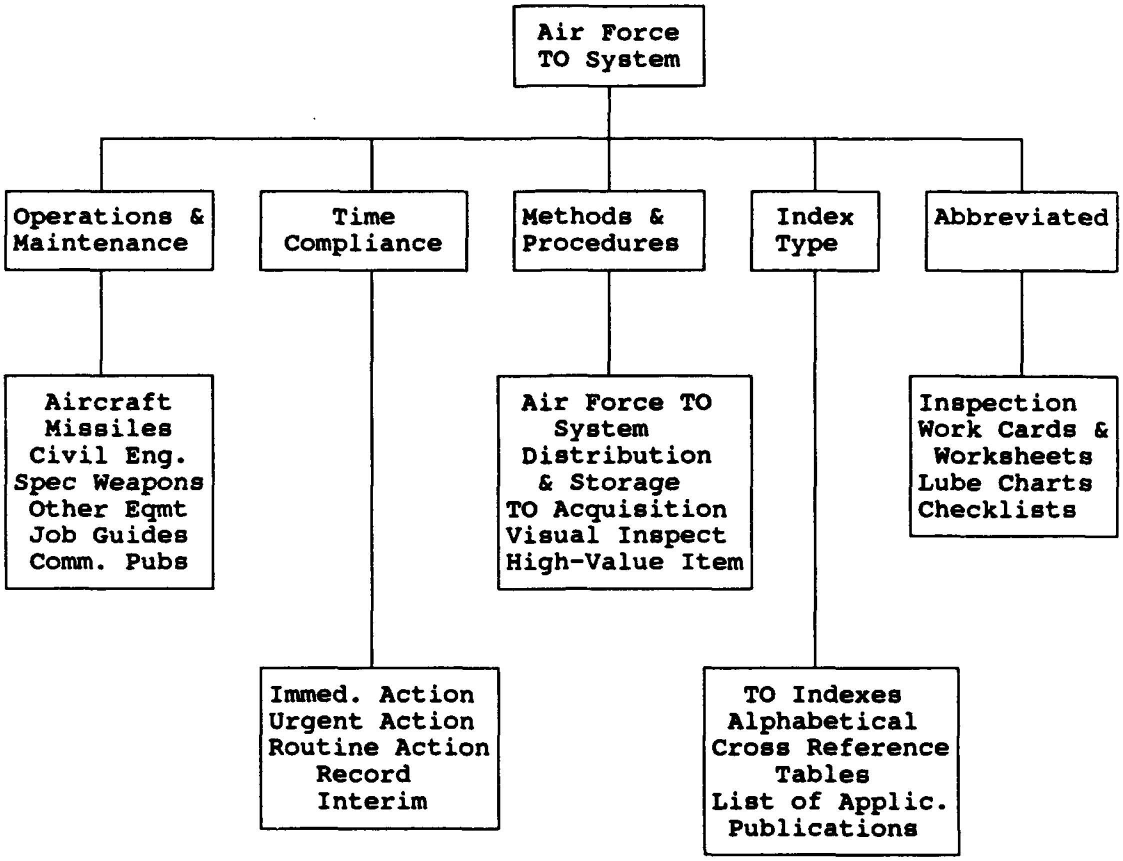


Figure 1. Technical Order Publications Breakout

It soon becomes apparent that a modern weapon system can easily generate millions of pages of written data that must be controlled, cataloged, updated, stored, and maintained. In addition, a change in one category of TO can easily cause numerous changes in other TO publications (3:1-1, 2-8). For a sophisticated, cost conscious Air Force, a paper based TO system has become too labor intensive and too costly to support. What the Air Force needs is a Technical Order system that utilizes state-of-the-art technology to store, update, and impart technical information in a manner and form easily used and understood by the technicians responsible for operating and maintaining these complicated weapon systems (4:2-1; 3-1). During the last thirty years, the Air Force has adopted several computerized data collection systems to reduce TO processing costs and improve information updating efficiency. In 1961, the Air Force upgraded its manual TO system to a punch card batch process system called the Logistics Management of Technical Orders System (GO-22) and converted engineering drawings to an aperture card (microfilm) system (4:3-2). This improvement was considered innovative for its time and significantly reduced TO processing time and storage problems. But this system soon became inundated with information through the acquisition of more complex weapon systems. This system was also time consuming and could not keep pace with the volume of material produced by these new weapon systems (5:6-10).

The next major conversion took place in March 1987 when the Air Force installed the Automated Technical Order System (ATOS). As originally conceived, ATOS would be implemented in three phases. Phase I would provide each Air Force Logistics Center with the capability to make page changes to TOs on a real time basis. Phases II would establish a TO management infrastructure that would manage all Air Force TOs and their methods of distribution. Phase III was designed to provide real-time access and distribution of TO information at base level. Phase I was implemented, but Phases II and III were not, due to budgetary constraints and technical difficulties. The present ATOS system can only make single page changes to TOs. It also serves as a storage and retrieval system and contains a system interface, a data tagging system file, and a data dictionary (6:10-2; 7:3-1,3-3; 8:1; 4:3-2).

During this same time frame, the Air Force also began digitally storing engineering information extracted from aperture cards (microfilm) under the Engineering Data Computer Assisted Retrieval System (EDCARS). Although both systems increased efficiency while decreasing labor and other overhead cost, they were sub-optimal and could not keep pace with huge amounts of information generated by new weapon system acquisitions (8:2).

Currently, the Department of the Air Force, in conjunction with its sister services and the Department of Defense (DOD), is concentrating on a system philosophy that would standardize the conversion and acquisition of all technical order information industry wide. Since 1987, the Air Force has initiated several TO management programs designed to create a modern TO management infrastructure.

The Computer-aided Acquisition and Logistic Support (CALS) initiative developed industry standards to convert the paper intensive TO system into a streamlined digitally based system. This system affected documentation, generation, and storage of technical information at all management levels of the Air Force and was designed to provide operational and maintenance personnel with technical information on a real time basis (9:3-9).

The second initiative, termed the Air Force Technical Order Management System (AFTOMS) was commissioned to streamline the existing Air Force TO system through creation of an infrastructure capable of managing, processing, storing, and distributing digitized technical information (4:4-2). In 1990, AFTOMS became a joint service program under the Joint Uniform Service Technical Information System (JUSTIS) initiative. JUSTIS will continue with the CALS concept and further develop a core program for complete modernization of the TO system (10:2-93, 2-100).

Although these new automated systems and management initiatives have revolutionized TO documentation and storage techniques, they do not easily interface with each other which makes coordination difficult. Furthermore, present-day technicians are still forced to use antiquated, time consuming, and hard-to-use paper instruction manuals to accomplish maintenance tasks because the Air Force does not have the capability to digitally store and transmit technical information to operational units and maintenance facilities. For example, two System Program Offices, the F-22 and B-2 SPOs, under the authority of their Program Manager have the capability to store and process the required technical information from respective defense contractors in digital form, but this information must be converted into paper TO form before dissemination throughout the Air Force.

Since 1964, the Air Force has also conducted several research projects in an effort to improve technical order content. The most significant of these projects was the Presentation of Information for Maintenance and Operations (PIMO) project conducted by Serendipity, Incorporated during 1964-1969 (5:8-10; 11:13-15). The PIMO project researched and developed proceduralized instruction manuals for all maintenance tasks except troubleshooting tasks. These instruction manuals provided technicians with short, easy-to-read instructions in the form of a small pocket sized manual. Between 1969 and 1972, the Armstrong Laboratory (AL) (formerly the Air Force Human Resources Laboratory), at Wright-Patterson Air Force Base, Ohio, in conjunction with the Air Force Logistics Command (AFLC) and civilian contractors, experimented, tested, and refined these new pocket sized instruction manuals for use on the flight line. Later, troubleshooting techniques were also introduced in paper based manual form. In 1972, the Air Force began procurement of these small instruction manuals, calling them job guides. Job guides were first implemented during 1976 in the Military Airlift Command (MAC) for the newly acquired C-141 Starlifter weapon system and were later developed for all remaining aircraft weapon systems. Now, job guides are used routinely by technicians throughout the Air Force (5:12-25; 12:1).

In the late 1970s and early 1980s, computer technology discoveries (micro-chips) reduced the costs of main frame computers and led to the production of desk-top computers. A short time after their development, the commercial sector began marketing and selling desk-top computers to commercial businesses and private individuals. Shortly thereafter, these technological advancements made their way into the defense environment and the Air Force began routinely using main frame and desk-top computers to conduct daily base-level and world-wide business. Recent computer-based systems have aided the Air Force to overcome the restrictions of their paper system reducing the complex departmental problems which once plagued them. The Air Force now has the means to collect, store and process huge amounts of information in a timely manner which has yielded better control and much needed standardization. However, problems soon developed became departmental and organizational computer systems could not effectively interface with one another. A few examples are: the Core Automated Maintenance System (CAMS) which stores technician training information; the Standard Base Supply System (SBSS) that processes supply requisitions; and the Comprehensive Engine Maintenance System (CEMS IV) that tracks and stores information on aerospace engines. The Air Force soon found that it could no longer quickly update, print, and distribute technical information in TO form to their operators and their technicians. Thus, although the information was readily available, operators and technicians had difficulty gaining access to it (12:5).

Armstrong Laboratory has been involved with testing and developing a base-level computer system, the Integrated Maintenance Information System (IMIS), which will act as the interface between these different computer systems. The IMIS system improves the capabilities of base-level aircraft maintenance organizations by providing technicians a single computerized information management system for intermediate and organizational maintenance (13:1). In fact, a recent survey of maintenance technicians conducted by the AL found that a computerized display of technical information was preferred over the paper TO system currently in use by seven of the twelve technicians tested (13:55-56). The IMIS is providing one answer to the access, integration, and information display problems plaguing the Air Force.

> It [the IMIS] will provide the technician direct access to several maintenance information systems and data bases including historical data collection and analysis, supply, technical orders, and automated training systems. (5:1)

The technician's primary interface with the IMIS is a compact, lightweight battery-powered portable computer that is rugged enough for flight line use (5:2). Although much work has been accomplished since 1977, when this idea was first conceived, there is still a tremendous amount of experimentation and research yet to be accomplished.

The next phase of the IMIS innovation process is to refine the information transferral process to its user by improving the design of its hardware, software and human/computer interface. The AL has been enhancing the IMIS computer device, its software, and user computer interfaces for almost 12 years. Their laboratory continually develops new prototype hardware to test the latest concepts and technologies. Prototypes are evaluated by users under field demonstrations and the results are documented in hardware and software specifications. Specifications are then transitioned to implementing commands. This study will support IMIS hardware and user interface definition by determining the best cursor control method(s) to be used to access information from a compact-ruggedized flight line computer. The information gained from this experiment will drive the hardware design of the IMIS prototype device and serve as the standard specification for System Program Offices (SPO) as they procure portable maintenance aids for their aircraft.

Management Problem

The management problem was, "Of the different indirect computer access methods available today, which method is best for the flight line environment."

Research Question

The methods available to access computerized information are bunched into two groups; those which provide direct control (a light pen or touch sensitive screen) on the screen surface and those which provide indirect control (cursor keys, joystick or mouse) away from the screen (6:238). The flight line is not conducive to the direct control methods currently available because these methods require spotless environments. During the literature review of indirect methods summarized in Chapter II, the mouse, trackball, and voice entry were eliminated, but two other access methods were chosen to be tested, a joystick and four-cursor keys. A joystick normally moves the cursor in any of eight directions in response to a corresponding movement by the computer user. Four-cursor keys, one each pointing up, down left and right, move the cursor one step in the direction of the key when it is depressed. The research question which emerged was "Which of two methods, the joystick or four-cursor keys, enables the user to access technical information from a ruggedized computer device the fastest and provides the most user satisfaction?"

Investigative and Measurement Questions

Based upon the intent of our research, the following areas were investigated:

1. Is there any difference between access times for either method?

2. Which access method provides the most satisfaction to the user/technician?

3. Is there a correlation between the fastest method and user satisfaction?

4. Does the overall access time vary between novice technicians and those who have at least 1 year of experience using computers?

Respondent comments were solicited using a questionnaire and a personal interview to determine each subject's satisfaction level with each access method tested. Some questions dealt with each respondent's level of experience and computer proficiency and compared them against access method completion times.

Scope and Limitations

Every attempt was made to make this experiment as realistic as possible, however certain limitations were encountered. The joystick device and software programming restricted the cursor movement to only four directions and would not allow diagonal screen movement of the cursor. Also, due to hard drive malfunctions, the PMA had to be reconfigured and connected to a UNISYS desk top computer using the keyboard terminal jack located at the rear of the computer. Consequently, only the keyboard function of the PMA was used in the test. This reconfiguration did not affect the validity of the experiment because the control devices were being tested, not the functionality of the PMA.

This experiment did not take place on the flight line. Instead, subject were observed operating the PMA keyboard and the UNISYS computer within the confines of a small office located in the maintenance complex of the 4950th Test Wing. These limitations will be discussed in further detail in Chapter III.

Chapter III, Methodology, describes the details of the experiment which was designed to determine the best indirect computer access method to use in a maintenance/flight line environment. The study observed technicians performing a maintenance task using one access method first followed by the other method. During the experiment, an observer recorded the amount of time to complete task phases and the completion time of the overall task. Overall task times were divided into phases so that, if necessary, a more in-depth analysis could be made by the researchers. Chapter IV describes experimental results and compares them against the experimental hypotheses. Chapter V lists our conclusions and recommendations for follow-on experiments.

Although previous research has examined access methods, their studies did not specifically evaluate performance of indirect access devices in relationship to user satisfaction and their practical use in a flight line environment. This is the first research experiment designed to test more than the correlation between access methods and cognitive learning ability and skill.

II. Literature Review

Background

Technical orders (TOs) have undergone considerable changes since they were introduced as single page "letters of instruction" in the Army Signal Corps in 1918 (14:1). According to Air Force Regulation 8-2, a TO constitutes a military order and is issued in the name of the Chief of Staff, USAF, by order of the Secretary of the Air Force. Virtually every system, subsystem, and item of equipment or support equipment must be operated and maintained according to the procedures contained in TOs (2:2). There are nearly 20 million pages of TOs maintained in the Air Force inventory (3:2-94). This does not include technical manuals maintained by civilian contractors. A typical TO averages between 100 and 150 pages and a simple electronic radio system can easily require over 15 separate TOs to operate, maintain, and repair its systems. On larger weapon systems, the B-1 for example, the number of TOs required can jump to nearly 4000 (10:1).

As modern weapon systems became more complex, technicians began criticizing the information contained in TOs. Usually technicians found TOs hard to use, and the information contained therein difficult to understand (1:5; 12:16-23). It soon became apparent that either the TO format would have to be improved or another information medium would have to be employed. This prompted research to study the possibilities.

In August 1962, a study completed by Losee, Allen, and Stroud of the AL determined that the Air Force TO system hampered (TOs were cumbersome to use and data was not always accurate) technician performance and would ultimately lead to degradation of weapon system integrity. The study found that the information contained in TOs was fragmented, inaccurate, hard to read, and lacked specific guidance (5:7). The results of this study laid the foundation for numerous follow-on research projects, one of which was completed in 1969 by Serendipity Incorporated.

The Serendipity project, called the Presentation of Information for Maintenance and Operations (PIMO) project, led to the development of proceduralized instruction manuals for all maintenance tasks except troubleshooting tasks. These proceduralized manuals provided technicians with condensed, easy-to-read instructions in the form of small pocket-sized manuals. Later refinements and standards developed by AL (Joyce, Laid, Mulligan, and Mallory in 1973) coupled with several field tests finally led to the implementation of these manuals between 1972 and 1976 as job guides (JG) (5:8-13). In 1975, Dr. Donald Thomas of the Armstrong Laboratory, conducted another opinion survey of Air Force maintenance personnel. These modern airman stated that, "Technical Orders are difficult to use, poorly organized, and written in terminology that is difficult to understand" (1:7).

Since the early 1960s, the Air Force has implemented several computerized data collection systems in an effort to improve TOs. In 1961, it activated a batch process system called the Logistics Management of Technical Orders System which converted engineering drawings to microfilm. Then in 1987, the Air Force installed the Automated Technical Order System (ATOS) which allowed them to make page updates to TOs on a real time basis while, at the same time, serving as a storage, retrieval, and interface system (3:2-97).

Later, the Air Force extended ATOS to digitize its TOs which decreased costs and improved update and delivery procedures. This change has progressed satisfactorily, but ATOS will fall short of its desired goal, "to eventually provide totally accurate and timely TOs for use by Air Force technicians" (14:10-26). The causes that led to the failure of ATOS were the extended length of time it took to update the information stored in the database (convert information from digital form to a paper instructional form) and the difficulty in deciding which procedure (paper or automated TOs) should be used to present and access the information. As weapon systems become more complex, the information necessary to operate, maintain, and repair them begins to expand geometrically. What the modern technician needs is a system which integrates information from many different computers into one retrieval system that is accurate, simple to use, easily accessible, and easy to update. Paper TOs no longer meet this demand and alternate information dissemination methods are required if technicians are to perform their jobs in a timely and responsible manner.

Development of the computer micro-chip and later refinements in micro-chip technology in the 1970s opened new avenues for collection and circulation of information. Computers were miniaturized and computer storage capacity was greatly expanded which led to the creation of mini- and micro-computers. Micro-computer technology opened a revolutionary means to gather and distribute technical information and, in 1977, under contract with Behavioral Technology Consultants of Silver Spring, Maryland, the Armstrong Laboratory began testing micro-computer technology as a means to automate the Air Force TO system (15:6). In 1979, Frazier of Behavioral Technology Consultants completed a study which produced the following conclusions:

(1) Multiple information levels should be provided to accommodate the varying experience levels of maintenance technicians.

(2) All information should be filed in one place to allow easy access and duplication.

(3) Menu options should be provided to allow a technician to access ancillary information involving test equipment operating procedures, etc.

(4) Information should be provided in a step-by-step format and used in conjunction with graphic illustrations.

(5) Graphic representations should be as simple as possible for ease-of-use and reduction of computer storage and retrieval times.

(6) Special keys should be used to reduce the requirement for extensive typing skills (15:6-7).

Following this study, AL began developing and testing micro-computer based, automated TO display devices under actual flight line conditions. Developmental studies were conducted on a contractual basis with private contractors, internally within the departments of the AL, and in partnership with agencies within other DOD departments.

In 1984, the AL determined that sufficient in-house experiments had been conducted and it was time to test a computer-based maintenance aiding system (CMAS) under field conditions. A test was scheduled at Offutt Air Force Base, Nebraska, in December 1984, to examine the practicality and user satisfaction of automated TOs. Strategic Air Command (SAC) technicians put the system through its paces. The results of this test were somewhat disheartening, as the performance of CMAS I failed to operate to technician's satisfaction. The system was too large and the computer response time too slow for routine use (15:7-8).

Returning to the drawing board, the Armstrong Laboratory started the development of CMAS II which made significant improvements to CMAS I based upon results obtained from the 1984 study. CMAS II was smaller in design, contained a greatly expanded memory, and provided technicians with a menu system, function keys, and cursor keys that were incorporated on a single keyboard. Another operational test was scheduled at Grissom Air Force Base, Indiana, and the results of this operational test were tremendously successful. Technicians found maintenance information to be easier to access and quicker to extract using the CMAS II as compared to researching the same information in a paper TO. Criticism of the CMAS II laid in its inability to display an entire schematic diagram. Technicians became frustrated when trying to determine the source of an equipment malfunction because the computer screen only displayed small segments of the total schematic diagram. When tracing signal paths, technicians were easily lost during the tracing process because they had to access several different computer screens to determine the total signal path. Once lost, the technician had to begin the signal tracing process over again. Except for this inconvenience, technicians accepted the CMAS II as a viable alternative to paper TOs (15:8-9).

In 1987, the Navy Personnel Research and Development Center at San Diego, California, performed tests using CMAS II to troubleshoot and fault identify a radio receiver-transmitter (16:2-4). The study concluded that,

> Computers can be used as an effective means to present technical information in an electronic format [and] more importantly, technicians appear willing to change to a different delivery method for obtaining maintenance information. (16:12)

Since 1987, the CMAS has been developed, refined, and expanded, and is now known as the Integrated Maintenance Information System (IMIS) program. This program has led to the development and testing of a technician's portable maintenance aid (PMA) that will not only improve a technician's access to weapon system information, but will interface with other computer-based systems currently used by the Air Force in its daily business routines. In 1991, the AL sponsored an experiment comparing the usefulness of a Head Mounted Monocular Device and the PMA to troubleshoot a malfunction in a radio transceiver. After evaluating 16 technicians using these devices, it was determined that no significant difference between the two devices existed, as both computer display devices worked equally well for technicians to accomplish maintenance routines (17:57). The Armstrong Laboratory has concentrated their research efforts on developing a IMIS PMA that would provide technicians with immediate and timely access to information necessary for job accomplishment. This research effort led to the development of a PMA sturdy enough for the flight line environment, versatile enough to display information in an easy-to-use format, and flexible enough to provide several information display levels to accommodate differing levels of technical experience (13:35-36). Now that a computer generated TO has proven to be technologically practical, the AL is also directing its research efforts toward evaluation of computer access method(s) and the design of human computer interfaces. At this point in time, direct access methods (touch screen, light pen) are not rugged enough to survive the chemical severity of the flight line (dirt, oil, cleaning solvents, etc.). Although indirect access methods are more rugged than direct access methods, some indirect access methods are impractical for use on a flight line. Therefore, the important question to be answered through this computer access research is, "Which of the indirect access methods can endure the flight line environment the best, while providing technicians with easy access to information?" Another important and possibly overriding factor to be studied is, "Which indirect access method is preferred by the technician?" The rest of this literature review explores the vast array of computer access methods currently available and attempts to determine their individual advantages and disadvantages. The review then narrows its focus to indirect access methods and their capacity to manipulate technical information in relation to their use on the flight line.

Integrated Maintenance Information System

Current data processing innovations have enabled the automation of many maintenance processes.

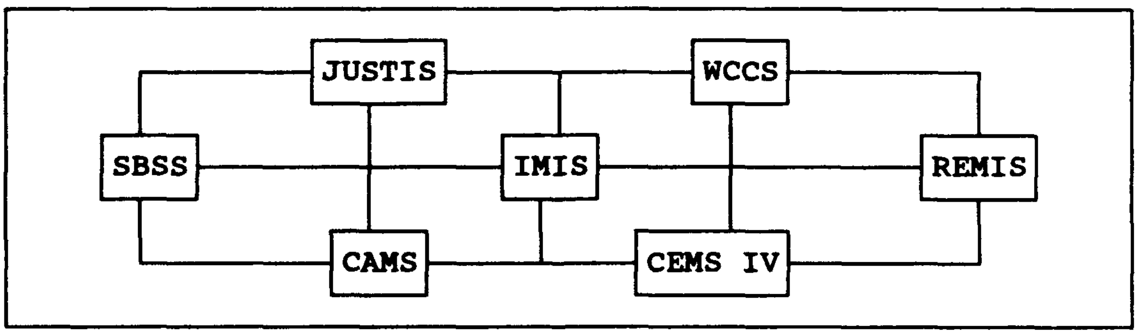
> These processes include interacting with maintenance databases, [retrieving] and using technical [information], and downloading and evaluating aircraft built-in-test to diagnose malfunctions in electronic and computer hardware. (13:1)

A number of computerized systems (CAMS, SBSS, CEMS IV) under development or already implemented by the Air Force will aid technicians to perform their tasks more efficiently in the future. These projects were designed, developed, and managed separately, leading to different hardware and human/computer interfaces for each system. Thus, automated tools designed to make a technician's job easier actually made it more complex because technicians had to use several computer systems. What technicians need is a single integrated computer system that improves the technical data retrieval process and easily integrates with other computer systems (13:1).

The AL has developed the Integrated Maintenance Information System (IMIS) to meet this need.

> The IMIS uses a portable computer to extract information from the aircraft and provides a single interface for information from CAMS, JUSTIS, SBSS, REMIS, WCCS, CEMS IV and any other information system required to support maintenance activities on the flight line and in the maintenance shop. (17:20)

Figure 2 displays these information systems and the current total interface scheme.



Source: Masquelier

Figure 2. Integrated Maintenance Information System

The IMIS contains five major elements:

- The technicians portable maintenance aid.

- A maintenance information work station.

- An aircraft interface panel link with computers.

- Integration software to present data consistently.

- Applications software to troubleshoot and identify the cause of malfunctions and perform maintenance (13:1-2).

The current portable maintenance aid (PMA) is

> A portable, ruggedized computer which operates using a battery pack or the aircraft's system power and acts as the single access unit for all the data needed to accomplish maintenance tasks. (13:1,4)

The technique(s) used to organize and display this information can determine the success of the system. Accordingly, AL personnel emphasized the importance of using the best data display and access techniques possible (13:3).

To test the utility of the IMIS, the AL performed a diagnostic demonstration on a F-16 fire control radar using twelve maintenance personnel from Homestead AFB, Florida for a two-week period (13:20). After a brief training period, each pair of subjects performed built-in-tests (BIT) to identify a problem, correct the problem, and then verify the repair using BIT again (13:22). After the demonstration, the outcome confirmed that the IMIS performed as expected. In fact, questionnaires employed by the AL revealed that most subjects rated the key operation, response time, screen size, character legibility, white space, and overall time and effort required to operate the PMA as very satisfactory or better (13:31). Also, seven of the twelve subjects stated that they would prefer the prototype (test) computer to paper TOs (13:55-56). During the course of this thesis research, the AL conducted more experiments with improved versions of the IMIS device which supported the F-18 demonstration computer preference choice. Result of those demonstrations were not published to be included in this literature search.

Since the Armstrong Laboratory has established the feasibility of the IMIS computer system, this study attempts to find the best pointing method(s) to access information from a flight line computer. The methods available to access computerized information can be clustered into two groups; those which provide direct control on the screen and those which allow indirect control away from the screen (6:238). Lightpens and touch screens can directly access information by touching the appropriate symbol or position on the computer screen with the lightpen or finger respectively. These methods cause the user's hand to obscure part of the screen and need the screen to remain oil and dirt free (6:240). Direct access methods would not work well for maintenance tasks because technicians need constant exposure to pertinent information and the flight line area is not clean. According to Schneiderman, several indirect pointing methods including a joystick, a mouse, and a trackball, could retrieve data from the IMIS. Four-cursor keys and voice entry could also be used (6:236-244).

Alternative Access Methods

Several authors have performed experiments with computers utilizing these devices to access different types of information and published their conclusions. Summaries of the research and their findings follow:

Table 1 summarizes these cursor control devices, their disadvantages and their recommended uses (18:154).

TABLE 1

CONTROL DEVICES

DEVICE	USES (CURSOR)	DISADVANTAGES	RECOMMENDED FOR	NOT RECOMMEND FOR
Joystick	Track/ select/ move	Mouse may be faster to select text	Tasks with intensive positioning	Frequent chgs to/from keyboard
Mouse	Point/ select/ draw/drag	**Needs desk space & has trailing cord**	Task needing little key-board use	Frequent mouse & key-board changes
Trackball	Track/ select/ move	Mouse may be faster to select text	Integrated graphics & keyboard	Frequent chgs to/from keyboard
4 Cursor Keys	Discrete cursor movement	Slow to move cursor long distance	Tasks needing short cursor movements	Extensive/ fine cursor movements
Voice Entry	Enter #s/ Start predefine actions	**Requires step-by-step confirmation of entries**	When hands or eyes are not free	**Noisy or stressful environments**

Source: Brown

Studies conducted by the University of York provide a detailed description of these access devices.

Joystick. The joystick is extremely popular to pick and position a cursor on a cathode ray tube (CRT) screen (19:109). Movement of the joystick causes a corresponding movement of the cursor in the same direction. Holding the joystick in one position continuously causes the cursor to move in that direction until the joystick is released. The joystick can be housed in the computer frame or attached to the computer by a control cable. When covered with a flexible rubber cover, the joystick is protected from penetration of dirt, moisture, and oil which would cause failure.

Mouse. This interface device is pushed along a clean, flat, and smooth surface near the computer. Movement of the mouse causes a corresponding cursor movement in the same direction and distance. This device is very popular for picking items on menus, positioning the cursor on objects displayed on a CRT, and for drawing lines on a CRT (20:109). The mouse is not suited for use on the flight line because it requires a clean, flat, oil-free surface to slide on.

Trackball. Movement of the cursor is accomplished by rotating a trackball within its socket to move the cursor on the CRT. The cursor can be moved in any direction using this device making it popular for picking and positioning (20:109). Functionally, the trackball is similar to the mouse, but highly prone to malfunction when exposed to dirt, moisture, and oil based contaminates. The trackball would not be well suited for use on the flight line for this reason.

Four-Cursor Keys. Cursor keys cause cursor movement in a left-right or up-down direction only, and are extensively used in word processing and templated documents. Novice users rely upon the cursor keys whereas experienced users usually employ other methods. Most cursor keys incorporate a single movement function and an auto-repeat function. In the single movement function, depressing the cursor key moves the cursor a single character or line, versus the auto-repeat function, where holding the cursor key down causes the cursor to move across multiple characters or lines (6:236-237).

Voice Entry. Commonly referred to as "the interface of the future", voice entry employs a speech recognition system that compares spoken words to voice patterns, or single words and phrases stored in memory. These reference patterns are entered into the machine a word or phrase at a time while the machine is in the training mode. Once the words/phrases have been entered into a computer's long-term memory, the computer listens to spoken words/phrases, and then compares these spoken words/phrases with those on file. When a match is recognized, a predetermined command is executed. Although highly effective under laboratory conditions, voice entry technology has not developed to the point of casual use. The automatic speech recognizer is easily confused by background noise, individual voice patterns/accents, and minute changes in people's voice over time resulting in non-performance or incorrect performance of commands. Also, a user's normal speech habits must be altered. The user must speak in a slow and deliberate manner, pausing after each word or phrase, to allow the speech recognizer time to listen, compare, and then respond. Although an usual speech pattern is not impossible to overcome, it becomes extremely frustrating to the user and results in counter productivity (20:37-41).

Table 2, summarizes three input techniques and lists the preferred access method(s) to perform the operation.

TABLE 2

PREFERRED INPUT DEVICES FOR DIFFERENT INPUT TECHNIQUES

Picking:	mouse, joystick/trackball, light pen/touch screen/soft keys, four-cursor keys.
Positioning:	mouse, joystick/trackball, light pen/touch screen, four-cursor keys.
Drawing:	mouse, light pen.

(Highest preferences are to the left and lowest to the right, with equal preferences separated '/')

Source: University of York

Access Method Selection

Even though most of these experiments suggest the mouse performs best, we eliminated it from our test for a flight line environment because it requires a flat surface close by to allow cursor movement, has a vulnerable connecting cord which could easily get tangled or ruined, and demands a clean environment. The trackball also needs a clean laboratory type environment to function reliably, so it should not be considered for flight line use either. In addition, the voice entry device should also be deleted because of the excessive noise prevalent during maintenance and the inadequate technology, causing it to be undependable. Therefore, the two access methods tested were the joystick and four-cursor keys.

These results correlate favorably with studies performed by the Armstrong Laboratory, which concluded that a joystick or four-cursor keys would function best under flight line conditions.

III. Methodology

Introduction

As indicated in Chapter 1, studies are still underway to determine if computer generated technical orders (TO) can replace paper TOs. Several studies have indicated that computer generated TOs are superior to paper TOs for ease of information access and user satisfaction. The purpose of this study is to investigate which of two computer access/user interaction devices provides the fastest access to information contained on a computerized maintenance database system, and which device provides its users with greater satisfaction. Two comparable "simulated" tasks were selected and programmed into a portable computer attached to a keyboard provided by the AL. A pilot study was conducted on both tasks to ensure they met all the experimental parameters and were similar enough both in their level of difficulty and the total time required to complete all the separate taskings to preclude any bias. The experiment took place in a controlled environment within the maintenance complex of the 4950th Test Wing at Wright-Patterson AFB OH.

Experimental Design

An independent, random sample of 32 technicians (16 experienced and 16 inexperienced) from various Air Force specialties employed within the 4950th Test Wing was selected to participate because of their availability. It was determined that maintenance technicians from the 4950th Test Wing would provide a good cross-sectional sample of the population of all Air Force technicians since this experiment investigates which access method results in the completion of two comparable tasks sooner. Each technician performed two "simulated" tasks which required access to maintenance data stored on the portable computer using either the joystick device or four-cursor keys. Data was collected and analyzed to test the investigative questions outlined in Chapter 1. Following the experiment, each respondent completed a questionnaire and was interviewed to determine their level of satisfaction with each device. Additional information and suggestions not readily apparent during the experiment were also solicited by the researchers. Appendix A contains the detailed experimental plan used to conduct the experiment and Appendixes B and C comprise detailed listings of the two simulated tasks. See Appendix D for the background survey and Appendix E for the observation form used to collect the access times and other information. Appendixes F and G display the questionnaire and interview questions.

Test Hardware

The Integrated Maintenance Information System (IMIS) portable maintenance aid (PMA), was originally intended to be used for this experiment. The IMIS PMA is an AL prototype ruggedized computer designed for flight line use.

It weighs about 8.75 pounds and measures 11" X 8.5" X 2.5". It houses four-cursor keys, a joystick, ten numeric keys, six function keys plus several other dedicated keys, and an 8"x 6" electroluminescent screen. However, due to a scheduling conflict with the Armstrong Laboratory, a UNISYS personal computer was used to run the tasks utilizing only the keys on an attached IMIS maintenance aid case (See Figure 3). Also, the layout of the PMA is shown in Figure 4 on page 34.

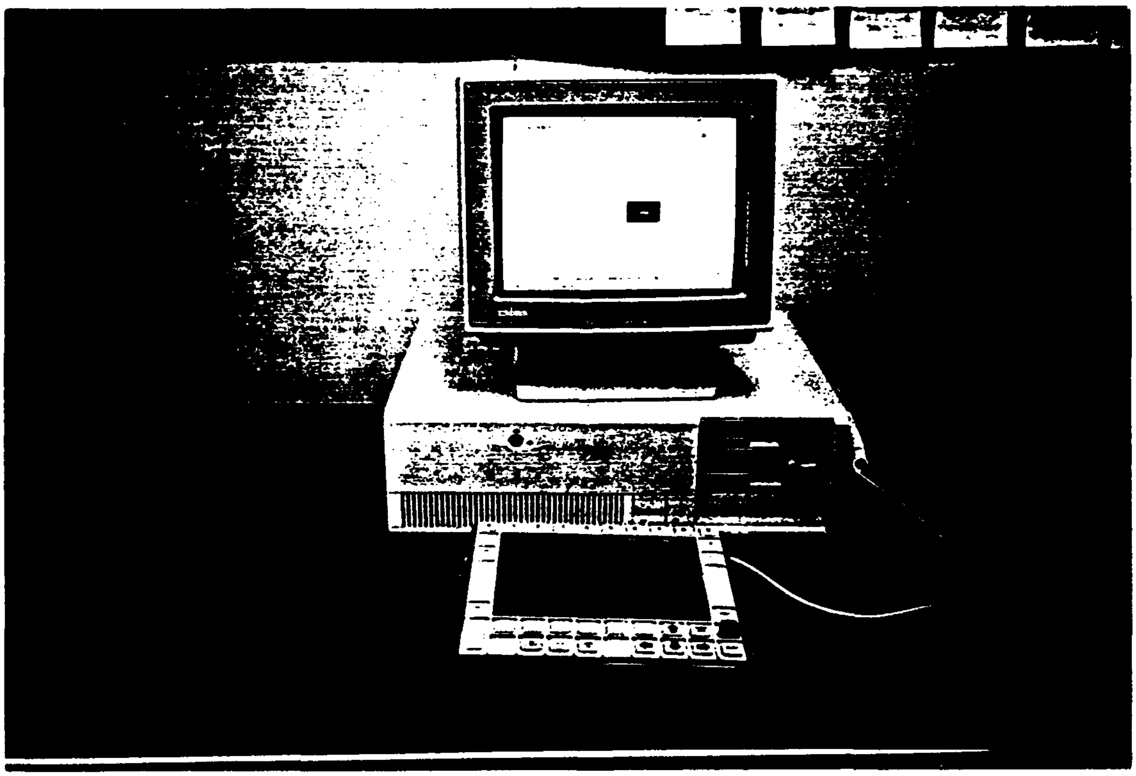


Figure 3. Combination UNISYS Computer/IMIS PMA Device

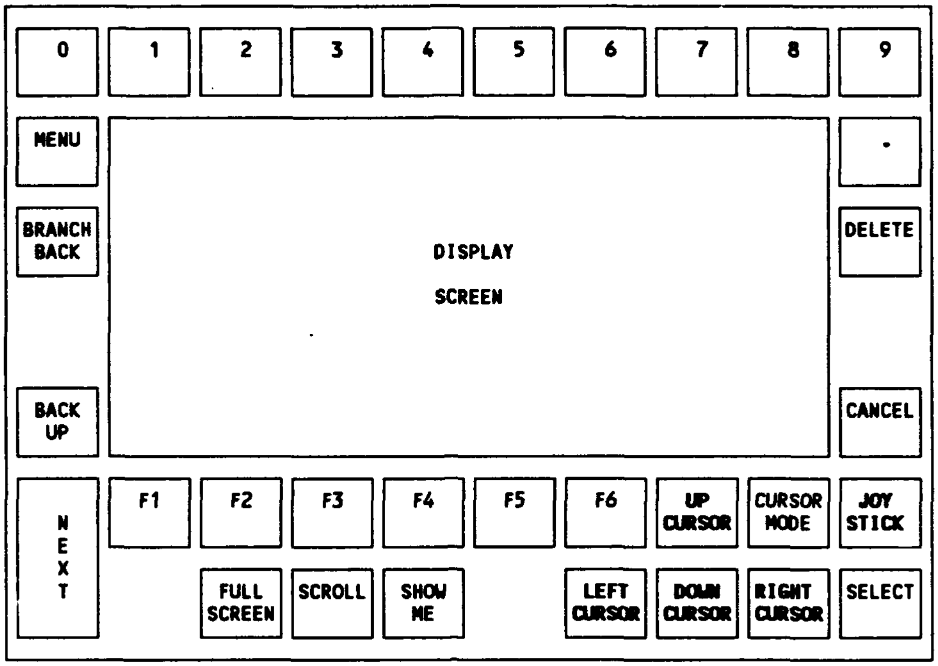


Figure 4. IMIS Portable Maintenance Aid (PMA) Layout

Table 3 lists some pertinent specifications for the UNISYS portable computer/IMIS keyboard combination.

TABLE 3

HARDWARE SPECIFICATIONS FOR THE UNISYS/IMIS COMPUTER

Computer Feature	Hardware
Random Access Memory	16 MBytes
Hard Disk Size	163 MBytes
CPU Processor	80386SX-20
Math Coprocessor	80387
Power Source	120 VAC

Experimental Tasks

Two tasks requiring access to information in several forms were developed for this experiment. A "simulated" Built-In-Test (BIT) routine for the F-18 Nose Wheel Steering (NWS) module served as task one while task two utilized an "artificially" developed Main F-18 BIT routine. These routines required the technicians to scroll about a computer screen to access and use different types of information to order parts, chose items from a menu, perform calculations using a screen displayed calculator and chose replacement parts from a parts list. Observations of technician and computer interaction provided an excellent means to determine the fastest method for accessing information stored in the IMIS. Each task used two continuity checks and the replacement of either a relay or a connector to present technical information. These "simulated" tasks underwent a pilot test using AFIT students and were refined prior to conducting this experiment.

Software

The UNISYS PC uses Microsoft MSDOS, version 5.0 as its operating system. The AL programmed the tasks using Version 1.1 of Smalltalk V and a program of their own creation, the F-18 Presentation System. Prior to this experiment, all necessary information, including some schematic diagrams, was loaded into the UNISYS computer. Smalltalk V is an off-the-shelf programming product and was chosen because of its response time, and its ability to easily maneuver about a computer screen (21). Smalltalk V has three features necessary to test the joystick and four-cursor keys, (1) the ability to design several different charts and diagrams, (2) two on-screen cursor select menus, and (3) the ability to scan through multiple screens of information relatively quickly. The next section provides details on the procedures required to operate the IMIS system and was extracted from the "Common User Interface Specification" for the F/A-18 Presentation System, Version 1.9, published by Logicon Eagle Technologies.

IMIS Primary Maintenance Aid Cursor Movement Procedures

Each user moved the cursor in one of two manners: by pushing the cursor-keys or by manipulating the thumb knob (joystick) device. When moving the cursor directly, a user employed a leap mode which worked like a tab key to induce the cursor to "leap", or jump, to the next selectable item (22:10). Thus, the cursor-keys and thumb operated knob provided alternate methods to perform the same action--move a cursor in one of four directions (up, down, left, right). The two control devices could be used interchangeably to produce the same cursor behavior. The AL added these two controls to the PMA specifically for this experiment to evaluate which device provided the most effective cursor control technique to access technical information (22:11). According to the F-18 Presentation Specification,

> The cursor-keys or thumb knob (joystick) may also be placed into a Scroll Mode, which temporarily disabled cursor movement and directed all cursor-key/thumb knob actions to the scrolling of a text, graphic or table pane. (22:10)

Cursor Movement Devices. There were four separate arrow keys which moved the cursor up, down, left or right when depressed. The thumb knob was a four position rocker-like force sensitive stick which didn't actually move, but responded to the force applied by the user. Each position had the same effect as the matching arrow key (22:12).

Selectable Items. Each selectable item on the screen had a "hot spot", or selectable region which highlighted (turned reverse video) whenever the cursor moved into that region (22:10). When a dialog box was active on the screen, the available selections would only be the entry fields and the push buttons displayed within the box (22:10).

Cursor Movement between Non-Adjacent Regions. The cursor did not appear on screen between any regions. It always "leaped" using a tabbing type method to move from one "selectable" region to another. A corner stitch of two tabbing schemes was used for each display: a horizontal and a vertical tab (22:14). The horizontal tabbing scheme assigned an order to all displayed selectable regions using the upper left corner of the screen as an anchor point. The regions would be assigned using a horizontal pixel procedure, moving down line by line until the bottom right corner of the display was reached. Also, the other (vertical) tab scheme assigned the same regions using a corresponding vertical pixel method until the identical corner was reached. The final result was a movement system which didn't move only horizontally or vertically, but a combination of both directions. Obviously, there were some deficiencies with the final "corner stitched" technique, but it ensured that a user could reach every available selectable region displayed on the screen, which was a problem perceived with many of the other available leaping modes (22:14-16). While the corner stitch system did ensure complete access to the screen, it remains to be seen whether this pattern will effect the experimental results by adversely influencing the joystick (thumb knob) response times.

Tasks

The F-18 Built-In-Test preventive maintenance routines used to test the access methods were selected because they required repetitive access to previously stored data and information to perform. Both tasks were matched in regards to complexity, the necessity to move across the computer screen several times, and the requirement to perform cursor movements within selected CRT displays (See Appendices B and C). Both tasks involved several types of cursor movements including searching for and selecting a string of text, using programmable function keys, moving about several block diagrams and multiplying two numbers using a screen displayed cursor based calculator. Each subject performed both tasks based on a random assignment to one of four groups. To help eliminate any learning curve bias, task one and the joystick were used first by only half of the technicians. To be precise, group one performed task one first using the joystick and task two with the four-cursor keys while group two accomplished task two first with the joystick followed by task one with the four-cursor keys. The other groups employed the same order of tasks, but used the four-cursor keys first (see Table 4).

TABLE 4

ACCESS METHOD AND GROUP ORDER USED FOR SIMULATED TASKS

GROUP NUM	FIRST TASK	FIRST METHOD	EXPERIENCE
GROUP 1	Task 1	Joystick	4-Low/4-High
GROUP 2	Task 2	Joystick	4-Low/4-High
GROUP 3	Task 1	Cursor-Key	4-Low/4-High
GROUP 4	Task 2	Cursor-Key	4-Low/4-High

Following the experiment, each technician filled out a questionnaire with 18 questions to determine what each subject thought about the cursor-keys and joystick and to allow them to recommend other access methods to explore in future research (See Appendix F). Then, each subject was interviewed to gain their observational insight and to determine their satisfaction level while using each access device. During the interview, respondents were given an opportunity to critique the access methods and the design of the experiment (See Appendix G).

Subjects

Thirty-two aircraft related maintenance technicians were randomly selected from the 4950th Test Wing at Wright-Patterson AFB, OH and divided in two separate groups based on their experience using computers. All selections were made on a random, independent basis. The technicians were categorized as experienced if they had over 1 year of experience using computers and as an apprentice if they had 1 year or less experience.

Data Collection

Total task and sub-task completion times were recorded by an observer as the technicians performed each routine. Each routine included three individual sub-tasks, which were timed and recorded to allow further analysis and comparison. Time measurement began when the technician started each sub-task and stopped when it was completed. Total task times were computed by summing the sub-task times and dividing by 60 to convert them to minutes. The same observer was used throughout this portion of the experiment to reduce bias.

Each respondent was interviewed by the second researcher to investigate information not readily apparent from the experiment and the questionnaire answers. To reduce bias, the questions listed in Appendix G were used to maintain consistency. Answers to the interview questions were used to help support the experimental results.

Scope and Limitations

The experiment was originally supposed to use the PMA only, however, a schedule conflict caused the researchers to employ a combination UNISYS personal computer (PC) and PMA keyboard. This change led to the requirement for the technicians to look at both the keyboard and the PC screen; the PMA would have precluded this extra necessity.

The research was conducted with the most recent PMA available which contained four cursor-keys and a thumb knob device, instead of a typical joystick. The uncharacteristic nature of the operation of this device may adversely affect the experimental results for the joystick.

The presentation system used by the Armstrong Laboratory utilized an unusual cross-stitch method which connected a horizontal and vertical scheme to move between different selectable regions on the screen. This system is also somewhat uncommon, especially to experienced computer users. Obviously, this liability could also be detrimental to the results obtained from the experiment.

Even though this experiment was conducted to determine the best access method to employ in an outdoor, flight line environment, a controlled area was used because of equipment and power requirements.

Experimental Hypotheses

The investigative questions outlined in Chapter One of this thesis served as the foundation for this research.

1. The joystick device will access technical information faster than the four-cursor keys.

2. Technicians using the joystick device will have greater satisfaction than those using the four-cursor keys.

3. Experienced technicians will require less access time than inexperienced technicians.

4. A single access method, the joystick, will work best for all types of tasks?

The prime concern of this research was to determine which access method was the fastest and had the greatest amount of user satisfaction.

Method of Analysis

An ANOVA (Analysis of Variance) and Linear Regression were used to evaluate the research results. An overall F-test with a 0.05 significance level was used to test for statistical significance.

IV. Experimental Results and Analysis

As mentioned in previous chapters, 32 maintenance technicians with varying levels of computer and maintenance experience participated in this experiment. Data in several forms were analyzed using Statistix, version 3.5, to determine the level of significance of the hypotheses. The methods used included the Analysis of Variance (ANOVA), Linear Regression (LR), graphs and histograms. ANOVA and LR results are summarized in this chapter while Appendixes H and I contain graphs and histograms. In addition to the time interval data presented below, other information provided by the subjects from interviews or questionnaires aided in analyzing two hypotheses.

The first evaluation was conducted on the raw test data which included computer processing time for display of information to the screen and user response time. Each task was divided into three phases. Table 5 lists the times for each phase in seconds and total task time in minutes. The table also shows technician computer experience in years and their military rank/civilian grade and specialty code. The data is arranged into four groups based upon which cursor control device and task were used first. The boxes with two extra vertical lines designate which access method was used first.

TABLE 5

CURSOR-KEY AND JOYSTICK TASK COMPLETION DATA

(INCLUDES COMPUTER RESPONSE TIMES)

NM BR	FIRST		CPTR EXP. (yr)	MIL RNK E-?	SPEC. CODE	JOYSTICK				CURSOR-KEYS			
	TSK	MTD				Phse1 (sec)	Phse2 (sec)	Phse3 (sec)	TOTL mins	TOTL mins	Phse1 (sec)	Phse2 (sec)	Phse3 (sec)
1	1	Joy	2.25	5	45770	223	299	157	11.3	12.1	210	300	215
2	"	"	4	2	45532	174	246	139	9.3	10.2	166	261	186
3	"	"	6	5	457X2	183	270	152	10.1	11.4	189	300	194
4	"	"	7	3	316X3	174	261	133	9.5	10.4	166	273	183
5	"	"	0	CIV	454X1	201	255	142	10.0	11.1	185	270	214
6	"	"	1	5	458X2	208	299	169	11.3	12.7	227	298	234
7	"	"	1	5	45471	192	267	133	9.9	11.5	211	275	205
8	"	"	1	6	45475	221	303	175	11.6	13.4	227	317	257
9	1	Key	1.08	5	45471	197	286	260	12.4	11.1	207	285	174
10	"	"	4	7	458X2	178	278	220	11.3	10.0	200	269	132
11	"	"	2	2	31633	171	262	185	10.3	9.9	185	258	149
12	"	"	1.17	CIV		216	313	259	13.1	12.1	251	296	177
13	"	"	0.83	CIV	45451	200	294	252	12.4	11.1	236	283	147
14	"	"	1	5	45871	226	292	227	12.4	10.8	214	287	149
15	"	"	1	5	45770	196	324	244	12.7	10.6	209	258	168
16	"	"	1	CIV		220	284	271	12.9	13.0	250	338	193
17	2	Joy	3	5	45471	248	321	256	13.8	11.3	229	288	162
18	"	"	9	4	45451	217	278	210	11.8	9.0	152	255	130
19	"	"	2.67	5	45873	201	298	225	12.1	10.5	215	263	153
20	"	"	2.5	5	45873	183	261	201	10.8	8.8	157	253	115
21	"	"	1	4	45451	203	269	221	11.6	8.6	155	237	123
22	"	"	1	5	45451	213	295	255	12.7	10.3	192	275	152
23	"	"	0.33	5	45451	255	320	251	13.8	11.8	226	306	175
24	"	"	0	5	45471	231	305	222	12.6	10.1	176	299	133
25	2	Key	1.75	3	31653	202	297	147	10.8	12.4	225	296	222
26	"	"	2	CIV		207	294	150	10.8	13.8	223	300	305
27	"	"	1.5	5	45770	222	319	200	12.4	14.4	268	342	264
28	"	"	4	3	31653	195	284	144	10.4	12.6	206	297	254
29	"	"	0.83	CIV	45470	219	333	174	12.1	15.4	270	318	331
30	"	"	0.75	5	31653	200	268	127	9.9	11.6	195	275	224
31	"	"	1	5	45770	239	335	200	12.9	14.3	272	302	283
32	"	"	0	4	45451	227	296	155	11.3	14.8	289	324	276

NOTES: Air Force Specialty Codes listed without shredouts
Extra vertical lines designate which access method was used first
Each group has four experienced (one year or more) and four inexperienced subjects

The following table shows how the joystick raw data task time compares against the raw data for the cursor-keys. Table 6 shows that the raw data completion times for the two complete tasks differed by 1.74 minutes or nearly 1 minute and 45 seconds. More importantly, the overall average time for the two access methods (underlined) were only 0.03 minutes (less than 2 seconds) apart.

TABLE 6

CURSOR-KEY AND JOYSTICK TASK COMPLETION DATA SUMMARY

(INCLUDES COMPUTER RESPONSE TIMES)

			JOYSTICK				CURSER KEYS			
GRP	FIRST MTHD	MEAN/ STANDRD DEVIATN	Phase1 (secs)	Phase2 (secs)	Phase3 (secs)	TOTAL (Min)	TOTAL (Min)	Phase1 (secs)	Phase2 (secs)	Phase3 (secs)
1	Joy	Mean	197	275	150	10.37	11.59	198	287	211
		Std Dev	18.3	20.8	15.0	0.849	1.006	23.2	18.2	23.5
2	Key	Mean	201	292	240	12.20	11.07	219	284	161
		Std Dev	18.3	18.2	26.2	0.886	0.977	22.5	24.1	18.8
3	Joy	Mean	219	293	230	12.37	10.04	188	272	143
		Std Dev	22.9	20.9	19.9	0.989	1.116	30.3	22.7	19.4
4	Key	Mean	214	303	162	11.32	13.67	244	307	270
		Std Dev	14.3	22.2	25.0	0.971	1.246	33.0	19.2	35.1
Total	N/A	Mean	208	291	196	11.56	11.59	212	287	196
		Std Dev	20.8	23.0	45.5	1.222	1.713	35.0	24.6	55.3

OTHER AVERAGE TOTAL TIME STATISTICS			
TASK NUMBER ONE	10.72 Mins	1st TASK FINISHED	11.87 Mins
TASK NUMBER TWO	12.46 Mins	2nd TASK FINISHED	11.29 Mins

As can be seen from the total average phase times listed in the summary table, the three phases are not equal. Both tasks were similar enough that the combination of phases one and two of both tasks entailed approximately the same movements. The same was true for phase three. A short list of the features of each task phase is listed below (See Appendixes B and C):

Phases One and Two:

1) Navigate a block diagram and select specified regions in the illustration.

2) Use pull-down menu to display calculator and choose specified numbers to calculate the product of two numbers.

3) Scroll through lists and highlight specific "hot spots" to answer system queries.

4) Move to a particular block in a diagram and enter a built-in-test code using the numeric keypads.

5) Relocate the cursor to a specified item in a list and choose it using the "Select" key.

6) Use a function key to access a list of the times that each task movement was performed and record the time for a specific movement task.

Phase Three:

7) Utilize the "Part Info" function key to produce a parts list and then find and select a part to be ordered.

8) Press a function key to display a cursor activated on-screen keyboard and then move the cursor to the required letters to define the quantity and packaging for the part.

9) Push the "next" key to scroll through the part ordering routine of the system.

The only elements which did not require intensive cursor movement were numbers six and nine.

Tables 7-10 display information comparing individual phase times for each access method, as well as total completion times for the tasks used in the experiment. To be precise, table 7 presents the data related to the "total times" to complete the tasks using the two access methods.

TABLE 7

ONE WAY ANOVA TEST FOR BOTH TASKS - Total all Phase Times

(INCLUDES COMPUTER RESPONSE TIMES)

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F	P
BETWEEN WITHIN TOTAL	1 62 63	0.01351 141.7 141.7	0.01351 2.286	0.01	0.9390
VARIABLE		MEAN	STD DEV	CHI SQ	P
JOYSTICK CURSOR-KEYS		11.56 11.59	1.241 1.741		
BARTLETT'S TEST FOR EQUAL VARIANCES				3.43	0.0639
COCHRAN'S Q LARGEST VAR / SMALLEST VAR COMPONENT OF VARIANCE FOR BETWEEN GROUPS				0.6631 1.968 -0.07101	

According to the "p-value" listed in table 7, there is a mere 6.1 percent chance that these access method times are different. The Bartlett's and Cochran's Q tests and the F-test value of 0.01 help support this claim.

The next three tables present the ANOVA information for each of the phases of both tasks used to test both cursor control devices.

TABLE 8

ONE WAY ANOVA TEST FOR BOTH TASKS - Phase One Only

(INCLUDES COMPUTER RESPONSE TIMES)

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F	P
BETWEEN WITHIN TOTAL	1 62 63	310.6 5.292E+04 5.323E+04	310.6 853.5	0.36	0.5485
VARIABLE		MEAN	STD DEV	CHI SQ	P
JOYSTICK CURSOR-KEYS		207.6 212.0	21.11 35.52		
BARTLETT'S TEST FOR EQUAL VARIANCES				7.91	0.0049
COCHRAN'S Q LARGEST VAR / SMALLEST VAR COMPONENT OF VARIANCE FOR BETWEEN GROUPS				0.7390 2.831 -16.96	

TABLE 9

ONE WAY ANOVA TEST FOR BOTH TASKS - Phase Two Only

(INCLUDES COMPUTER RESPONSE TIMES)

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F	P
BETWEEN WITHIN TOTAL	1 62 63	182.3 3.621E+04 3.639E+04	182.3 584.0	0.31	0.5784
VARIABLE		MEAN	STD DEV	CHI SQ	P
JOYSTICK CURSOR-KEYS		290.8 287.4	23.32 24.98		
BARTLETT'S TEST FOR EQUAL VARIANCES				0.14	0.7045
COCHRAN'S Q LARGEST VAR / SMALLEST VAR COMPONENT OF VARIANCE FOR BETWEEN GROUPS				0.5343 1.147 -12.56	

TABLE 10

ONE WAY ANOVA TEST FOR BOTH TASKS - Phase Three Only

(INCLUDES COMPUTER RESPONSE TIMES)

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F	P
BETWEEN WITHIN TOTAL	1 62 63	8.266 1.640E+05 1.640E+05	8.266 2646	0.00	0.9556
VARIABLE		MEAN	STD DEV	CHI SQ	P
JOYSTICK CURSOR-KEYS		195.5 196.2	46.20 56.19		
BARTLETT'S TEST FOR EQUAL VARIANCES				1.16	0.2809
COCHRAN'S Q LARGEST VAR / SMALLEST VAR COMPONENT OF VARIANCE FOR BETWEEN GROUPS				0.5967 1.479 -82.42	

Tables 7-10 show that the phase times are well linked to each other, validating the results presented in table 6, that the two access methods perform the same.

To obtain more meaningful information, the researchers performed both tasks to determine the amount of time it took for the computer to respond with a new screen after the previous one was completed. These computer times were added together within each phase and then subtracted from the previous totals so the aggregate time (listed in minutes) indicated only the human response times and no computer processing times. The next two tables exhibit the operator response time data for the phases, the whole task, and the statistics data. In fact, table 11 shows the same information as table 5, minus the computer response times.

TABLE 11

CURSOR-KEY AND JOYSTICK TASK COMPLETION DATA

(COMPUTER RESPONSE TIMES SUBTRACTED)

NM BR	FIRST TSK	FIRST MTD	CPTR CPTR EXP. (yr)	MIL MIL RNK E-?	SPEC. CODE	JOYSTICK Phse1 (sec)	JOYSTICK Phse2 (sec)	JOYSTICK Phse3 (sec)	JOYSTICK TOTL mins	CURSOR-KEYS TOTL mins	CURSOR-KEYS Phse1 (sec)	CURSOR-KEYS Phse2 (sec)	CURSOR-KEYS Phse3 (sec)
1	1	Joy	2.25	5	45770	178	180	138	8.27	7.10	146	117	163
2	"	"	4	2	45532	129	127	120	6.27	5.23	102	78	134
3	"	"	6	5	457X2	138	151	133	7.03	6.40	125	117	142
4	"	"	7	3	316X3	129	142	114	6.42	5.38	102	90	131
5	"	"	0	CIV	454X1	156	136	123	6.92	6.17	121	87	162
6	"	"	1	5	458X2	163	180	150	8.22	7.67	163	115	182
7	"	"	1	5	45471	147	148	114	6.82	6.53	147	92	153
8	"	"	1	6	45475	176	184	156	8.60	8.37	163	134	205
9	1	Key	1.08	5	45471	133	103	208	7.40	8.05	162	166	155
10	"	"	4	7	458X2	114	95	168	6.28	6.97	155	150	113
11	"	"	2	2	31633	107	79	133	5.32	6.82	140	139	130
12	"	"	1.17	CIV		152	130	207	8.15	9.02	206	177	158
13	"	"	0.83	CIV	45451	136	111	200	7.45	8.05	191	164	128
14	"	"	1	5	458X1	162	109	175	7.43	7.78	169	168	130
15	"	"	1	5	45770	132	141	192	7.75	7.53	194	139	149
16	"	"	1	CIV		156	101	219	7.93	9.97	205	219	174
17	2	Joy	3	5	45471	184	138	204	8.77	8.27	184	169	143
18	"	"	9	4	45451	153	95	158	6.77	5.90	107	136	111
19	"	"	2.67	5	45873	137	115	173	7.08	7.47	170	144	134
20	"	"	2.5	5	45873	119	78	149	5.77	5.70	112	134	96
21	"	"	1	4	45451	139	86	169	6.57	5.53	110	118	104
22	"	"	1	5	45451	149	112	203	7.73	7.27	147	156	133
23	"	"	0.33	5	45451	191	137	199	8.78	8.73	181	187	156
24	"	"	0	5	45471	167	122	170	7.65	7.08	131	180	114
25	2	Key	1.75	3	31653	157	178	128	7.72	7.40	161	113	170
26	"	"	2	CIV		162	175	131	7.80	8.82	159	117	253
27	"	"	1.5	5	45770	177	200	181	9.30	9.58	204	159	212
28	"	"	4	3	31653	150	165	123	7.30	7.63	142	114	202
29	"	"	0.83	CIV	45470	174	214	155	9.05	10.3	206	135	279
30	"	"	0.75	5	31653	155	149	108	6.87	6.58	131	92	172
31	"	"	1	5	45770	194	216	181	9.85	9.30	208	119	231
32	"	"	0	4	45451	182	177	136	8.25	9.83	225	141	224

NOTES: First task (tsk) and method (mtd) shown for all four groups
Extra vertical lines designate which access method was used first
Each group has four experienced (one year or more) and four inexperienced subjects

TABLE 12

CURSOR-KEY AND JOYSTICK TASK COMPLETION DATA SUMMARY

(COMPUTER RESPONSE TIMES SUBTRACTED)

GRP	FIRST MTHD	MEAN/ STANDRD DEVIATN	JOYSTICK				CURSER KEYS			
			Phase1 (secs)	Phase2 (secs)	Phase3 (secs)	TOTAL (Min)	TOTAL (Min)	Phase1 (secs)	Phase2 (secs)	Phase3 (secs)
1	Joy	Mean Std Dev	152 18.3	156 20.8	131 15.0	7.317 0.849	6.606 1.006	134 23.2	104 18.2	159 23.5
2	Key	Mean Std Dev	137 18.3	109 18.2	188 26.2	7.215 0.886	8.023 0.977	174 22.5	165 24.1	142 18.8
3	Joy	Mean Std Dev	155 22.9	110 20.9	178 19.9	7.390 0.989	6.994 1.116	143 30.3	153 22.7	124 19.4
4	Key	Mean Std Dev	169 14.3	184 22.2	143 25.2	8.267 0.975	8.685 1.246	180 33.0	124 19.2	218 35.1
To-tal	N/A	Mean Std Dev	153 21.9	140 38.0	160 32.2	7.547 1.017	7.577 1.367	157 33.9	136 32.1	161 43.3
OTHER AVERAGE TOTAL TIME STATISTICS										
1st TASK FINISHED			7.85 Mins				2nd TASK FINISHED		7.27 Mins	

Although the researchers subtracted the computer processing times from the raw data, the times for the joystick and cursor-keys remained comparable. After comparing each phase of both tasks, the widest separation noted was only 4 seconds. This disparity occurred twice in phases 1 and 2. It's interesting to note that the joystick was faster than the cursor-keys in phase one, but was slower in phase two. The researchers could not conclude the cause of this variance. Also, it's remarkable that the learning curve of 0.58 minutes or about 35 seconds (see underlined numbers) is only 7.7 percent of the total time. Although not a hypothesis, the researchers expected more variation in the access times due to a cognitive learning curve.

Since the overall average times for the two tasks were relatively close (roughly 10 seconds out of seven and one-half minutes), a one-on-one comparison of the times for each subject was conducted. Table 13 lists the task times for each technician, whichever method or order was utilized. Table 14, on page 53, displays the statistical information furnished for these pairs.

TABLE 13

TASK #1 VERSUS TASK #2 COMPARISON DATA - Total Times

(COMPUTER RESPONSE TIMES SUBTRACTED)

TASK ONE FIRST			TASK TWO FIRST		
SBJT NMBR	TASK #1	TASK #2	SBJT NMBR	TASK #1	TASK #2
1	8.27	7.10	17	8.27	8.77
2	6.27	5.23	18	5.90	6.77
3	7.03	6.40	19	7.47	7.08
4	6.42	5.38	20	5.70	5.77
5	6.92	6.17	21	5.53	6.57
6	8.22	7.67	22	7.27	7.73
7	6.82	6.53	23	8.73	8.78
8	8.60	8.37	24	7.08	7.65
9	8.05	7.40	25	7.72	7.40
10	6.97	6.28	26	7.80	8.82
11	6.82	5.32	27	9.30	9.58
12	9.02	8.15	28	7.30	7.63
13	8.05	7.45	29	9.05	10.33
14	7.78	7.43	30	6.87	6.58
15	7.53	7.75	31	9.85	9.30
16	9.97	7.93	32	8.25	9.83

NOTE: Subjects 1-16 completed Task #1 first and the others started with Task #2

TABLE 14

ONE WAY ANOVA TEST FOR TASK #1 VERSUS TASK #2

(COMPUTER RESPONSE TIMES SUBTRACTED)

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F	P
BETWEEN WITHIN TOTAL	1 62 63	0.5041 92.38 92.89	0.5041 1.490	0.34	0.5629
VARIABLE		MEAN	STD DEV	CHI SQ	P
TASK NUMBER 1 TASK NUMBER 2		7.651 7.473	1.128 1.307		
BARTLETT'S TEST FOR EQUAL VARIANCES				0.66	0.4177
COCHRAN'S Q LARGEST VAR / SMALLEST VAR COMPONENT OF VARIANCE FOR BETWEEN GROUPS				0.5730 1.342 -0.03081	

Statistically, the two tasks were comparable, as verified by the relatively large p-value (0.5629) and the closeness of the two standard deviations. One theory could stipulate that the order of the tasks must be the major cause of the disparity of the values even though the learning curve was considered negligible.

Hypothesis Number 1

This hypothesis speculates that the joystick device will access technical information faster than the four-cursor keys. Tables 15-18 present the access time data for the whole task and each phase for the technicians, allowing a true comparison of only the human response times.

TABLE 15

ONE WAY ANOVA TEST FOR BOTH TASKS - Total All Phase Times

(COMPUTER RESPONSE TIMES SUBTRACTED)

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F	P
BETWEEN WITHIN TOTAL	1 62 63	0.01381 92.87 92.89	0.01381 1.498	0.01	0.9238
VARIABLE		MEAN	STD DEV	CHI SQ	P
JOYSTICK CURSOR-KEYS		7.548 7.577	1.033 1.389		
BARTLETT'S TEST FOR EQUAL VARIANCES				2.64	0.1044
COCHRAN'S Q LARGEST VAR / SMALLEST VAR COMPONENT OF VARIANCE FOR BETWEEN GROUPS				0.6439 1.808 -0.04638	

TABLE 16

ONE WAY ANOVA TEST FOR BOTH TASKS - Phase One Only

(COMPUTER RESPONSE TIMES SUBTRACTED)

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F	P
BETWEEN WITHIN TOTAL	1 62 63	310.6 5.218E+04 5.249E+04	310.6 841.5	0.37	0.5457
VARIABLE		MEAN	STD DEV	CHI SQ	P
JOYSTICK CURSOR-KEYS		153.1 157.5	22.29 34.44		
BARTLETT'S TEST FOR EQUAL VARIANCES				5.60	0.0180
COCHRAN'S Q LARGEST VAR / SMALLEST VAR COMPONENT OF VARIANCE FOR BETWEEN GROUPS				0.7047 2.386 -16.59	

TABLE 17

ONE WAY ANOVA TEST FOR BOTH TASKS - Phase Two Only

(COMPUTER RESPONSE TIMES SUBTRACTED)

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F	P
BETWEEN	1	182.3	182.3	0.14	0.7070
WITHIN	62	7.922E+04	1278		
TOTAL	63	7.940E+04			
VARIABLE		MEAN	STD DEV	CHI SQ	P
JOYSTICK		139.8	38.59		
CURSOR-KEYS		136.4	32.65		
BARTLETT'S TEST FOR EQUAL VARIANCES				0.85	0.3565
COCHRAN'S Q				0.5829	
LARGEST VAR / SMALLEST VAR				1.397	
COMPONENT OF VARIANCE FOR BETWEEN GROUPS				-34.23	

TABLE 18

ONE WAY ANOVA TEST FOR BOTH TASKS - Phase Three Only

(COMPUTER RESPONSE TIMES SUBTRACTED)

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F	P
BETWEEN	1	9.766	9.766	0.01	0.9360
WITHIN	62	9.326E+04	1504		
TOTAL	63	9.327E+04			
VARIABLE		MEAN	STD DEV	CHI SQ	P
JOYSTICK		159.9	32.81		
CURSOR-KEYS		160.7	43.95		
BARTLETT'S TEST FOR EQUAL VARIANCES				2.57	0.1087
COCHRAN'S Q				0.6422	
LARGEST VAR / SMALLEST VAR				1.795	
COMPONENT OF VARIANCE FOR BETWEEN GROUPS				-46.70	

Although table 15 shows that the joystick finished the tasks first, the extremely small difference in the two completion times and the high p-value combine to validate that there is no statistical difference between the access tools. The phase charts establish that the joystick performed better (faster) during two of the three sections, numbers one and three. However, the p-values were very high indicating that the variation between the task times were insignificant. Therefore, the first hypothesis, that "the joystick will access information faster" was rejected at the 0.05 significance level.

Hypothesis Number 2

The second supposition maintains that "technicians using the joystick device will have greater satisfaction than those utilizing the four-cursor keys." The information provided by the questionnaire and personal interview was employed to evaluate this premise (See Appendixes H and I). Table 19, a summary of the data listed in Appendix H, shows that the cursor-keys were more popular with the technicians by an average 23 to 9 margin. In addition, 24 of the 32 subjects chose the cursor-keys as the device they would use in response to question 2 of the personal interview (See Appendix I), "which computer access method did you prefer?" The unconventional shape and operation of the joystick may be somewhat responsible for this lopsided count.

TABLE 19

SUMMARY OF QUESTIONNAIRE INFORMATION

RESEARCH QUESTIONS	AGREE	DISAGREE	UND.
FOUR-CURSOR KEYS were best to access/select information:			
in the calculator.	23	7	2
in all block diagrams.	23	6	3
in the parts lists.	23	5	4
in the menu.	22	8	2
caused fewer accessing/selection errors.	25	0	7
were preferred to access/select all tasks.	23	3	6
THUMBKNOB was best to access/select information:			
in the calculator.	8	9	15
in all block diagrams.	8	11	13
in the parts lists.	10	9	13
in the menu.	9	11	12
caused fewer accessing/selection errors.	9	6	17
was preferred to access/select all tasks.	7	8	17
Neither method worked best to access and select information for all tasks.	5	12	15
Accessing requested information was difficult due to the way the cursor moved across the screen.	14	6	12
I would recommend another access method	9	8	15
I would recommend using a light pen.	11	12	9
I would recommend using a mouse.	11	8	13
I would recommend a different access method.	6	6	20

Thus, the null hypothesis, "the technicians will prefer the joystick over the cursor-keys," is not proven since the cursor keys were selected by a majority of the personnel.

Hypothesis Number 3

This hypothesis states that "experienced technicians will require less time to access computer generated information than technicians with one year or less computer experience." The researchers sorted the task completion times based upon the computer experience level of each technician. Then a linear regression line testing the completion times for both tasks against each technician's computer experience level was created. Table 20 documents the results of this comparison for the combined times of the two tasks using both access methods. The p-value of 0.0084 reveals that there is a 99.2 percent chance that the level of computer experience is significant for this test case.

TABLE 20

LINEAR REGRESSION OF COMPUTER EXPERIENCE VS TOTAL TIME - Both Tasks

(COMPUTER RESPONSE TIMES SUBTRACTED)

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F	P
REGRESSION	1	27.825	27.825	7.95	0.0084
RESIDUAL	62	104.99	3.4997		
TOTAL	63	132.82			
VARIABLES	COEFFICIENT		STD ERROR	T	P
CONSTANT	8.3151		2.2366	3.72	0.0008
TOTAL	-0.04124		0.014626	-2.82	0.0084
R SQUARED		0.2095	MEAN SQUARE ERROR		3.500
ADJUSTED R SQUARED		0.1832	STANDARD DEVIATION		1.871

TABLE 21

LINEAR REGRESSION OF COMPUTER EXPERIENCE VS TIME FOR KEYBOARD

(COMPUTER RESPONSE TIMES SUBTRACTED)

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F	P
REGRESSION RESIDUAL TOTAL	1 30 31	19.662 113.15 132.82	19.662 3.7718	5.21	0.0297
VARIABLES	COEFFICIENT		STD ERROR	T	P
CONSTANT JOYSTICK	7.8972 -0.77103		2.5719 0.033771	3.07 -2.28	0.0045 0.0297
R SQUARED ADJUSTED R SQUARED	0.1480 0.1196		MEAN SQUARE ERROR STANDARD DEVIATION		3.772 1.942

TABLE 22

LINEAR REGRESSION OF COMPUTER EXPERIENCE VS TIME FOR CURSOR-KEYS

(COMPUTER RESPONSE TIMES SUBTRACTED)

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F	P
REGRESSION RESIDUAL TOTAL	1 30 31	29.458 103.36 132.82	29.458 3.4453	8.55	0.0065
VARIABLES	COEFFICIENT		STD ERROR	T	P
CONSTANT TOTAL	7.3958 -0.70187		1.8480 0.24003	4.00 -2.92	0.0004 0.0065
R SQUARED ADJUSTED R SQUARED	0.2218 0.1959		MEAN SQUARE ERROR STANDARD DEVIATION		3.445 1.856

After comparing the p-values (0.0297 vs 0.0065) listed in tables 21 and 22, it is obvious that the operation of the cursor keys was most affected by the level of computer experience. One potential reason for this difference is that most computer users must become familiar with the operation of cursor-keys to perform the majority of the functions on a personal computer. Even the high p-value for the cursor-keys transforms to a 97 percent chance that each subject's experience level is significant. Therefore, the third hypothesis, "a more experienced technician will complete each task faster," is not rejected at a 95 percent confidence level.

Hypothesis Number 4

The final hypothesis, "the joystick, will work best for all types of tasks," was tested using questions 2 and 3 of the personal interview (See Appendix I) when the researcher asked, "which access method did you prefer" and "did your choice work best in all tasks?" Of the 30 technicians who had a preference, six (only 20 percent) chose the joystick device. However, all six subjects who picked the joystick preferred it for every task. Of the 24 subjects who chose the cursor-keys, only one did not want to use it all the time. Since the 20 percent joystick selection rate is not statistically meaningful at a 0.05 significance level, this hypothesis is rejected. Nevertheless, Appendix I indicates that 29 of the 30 test subjects would have used their access choice for every task presented in this experiment. Thus, it is possible that a "typical" joystick device might be endorsed by a significant number of maintenance technicians during a future experiment, should one ever be performed.

V. Discussions, Conclusions, and Recommendations

Discussion of Quantitative Results

Data collected during this experiment indicated that there are no statistical differences in access times using either the joystick device or the four-cursor key configuration. As a result of these findings it was concluded that the joystick device does not access information faster and with greater user satisfaction than users of the four-button cursor keys. However, two factors surface as possible obstacles to the hypothesized outcome. The joystick device chosen by Armstrong Laboratory did not conform to a true joystick device as described in Chapter II. Also, the software program, Smalltalk V, did not allow the full range of movement (eight directions) normally associated with a joystick access device. Subsequent sections will discuss these impediments in greater detail.

Task Environment. This experiment took place in a small branch office of the Aerospace Ground Equipment hangar of the 4950th Test Wing and was not designed to simulate flight line conditions. Neither the computer unit nor the technicians were exposed to loud noise, aircraft exhaust fumes, dirt and grime, and the mobility synonymous with tecnnicians working in a flight line environment. Furthermore, technicians were required to accessed information from two maintenance tasks for an aircraft that they were not familiar, the F-18. Since no Air Force specialty was exempted from this experiment, the researchers felt that a unfamiliar task would ultimately test the access devices, not the prior maintenance experience of the technician. Technician movement was also limited. Subjects sat in a chair positioned directly in front of an office desk that supported the UNISYS PC computer with the Portable Maintenance Aid (PMA) keyboard attached. Technicians were then instructed by a researcher to access information from the maintenance routine (researchers desired to measure access time not reading ability and response time). Each task was broken down into phases and once a phase was completed, the researcher documented the response time. This experiment did not test the agility of the PMA or the ability of the technician to use each access device while maneuvering around equipment configurations in an aircraft.

F-18 Maintenance Task. All test subjects performed the same two maintenance F-18 test routines, the only difference being the access device used to perform the routine and the sequence in which the tasks were performed. The F-18 test routines had been used on numerous demonstration and test studies performed by Armstrong Laboratory and provided the researchers with a variety of accessible data. Individual routines were designed so that every technician would have to scroll across, or up and down a computer screen to access different types of information. During the course of each routine a technician accessed information necessary to order parts, chose items from a menu, documented information on supply forms, performed calculations using the calculator function, and chose replacement parts by scrolling a parts list. It was observed that novice technicians had a tendency to keep both hands on the PMA keyboard. The left hand was positioned to enable quick depression of the NEXT key and the FUNCTION keys that were located on the lower left side of the PMA. The right hand was positioned over the lower right portion of the PMA to operate the joystick (thumb knob) and the four-button cursor keys. The experienced technicians (those having more than one year's experience using computers) had a tendency to relax the hand which was not absolutely necessary to perform the task and move it into position as required. It was also noted that experienced technicians would use their left hand to perform some functions on the right hand side of the keyboard. Consequently, the experienced technicians appeared more confident using the computer than the unexperienced ones. Although this situation was noted, neither technique appeared to hamper the response time of a technician nor did it result in a large number of selection errors.

Hardware Configuration. As noted in Chapter III, the hardware configuration consisted of a PMA keyboard connected to the keyboard jack of a UNISYS PC computer. The PMA keyboard was constructed so that the cursor keys and the thumb knob were located on the lower right hand side. Consequently, both video access devices were operated with the subject's right hand and technicians were forced to alternate between their right index finger and their right thumb to make selections. Many technicians complained that the thumb knob was hard to depress and unresponsive while a few complained that it was too sensitive. It soon become obvious to the researchers that the majority of the technicians preferred the cursor keys over the thumb knob. As indicated in Chapter IV, statistically, there was no difference in access times between the cursor keys and the thumb knob. The researchers hypothesize that this situation occurred because the thumb knob tested did not function, nor was it configured like a true joystick device as described in Chapter II. The thumb knob was constructed to be pressure sensitive as well as directionally sensitive. Each technician was required to place downward pressure on the thumb knob to activate it while at the same time moving the thumb knob in an up/down, left/right direction. If both techniques were not properly employed, the curse would either not move or move in an undesired direction. This caused technicians some frustration. Also, although the thumb knob could be moved in a diagonal direction, the cursor would not respond in a like manner because of software programming limitations. Both researchers attribute some of the dissatisfaction of the thumb knob by the users and the lack of statistical difference of access times to the construction and operation of the thumb knob device and associated software.

Software Configuration. Smalltalk V, the application software program, that allowed display and maneuverability within the F-18 demonstration routine had limitations that restricted the operation of the thumb knob (joystick). First, the thumb knob restricted cursor movement to four, instead of eight, directions. Normally a joystick device with supporting hardware will accommodate cursor movement in eight directions, cursor up, cursor diagonally to the right, cursor right, cursor diagonally downward, cursor down, cursor diagonally to the left, cursor left, and cursor diagonally upward. The thumb knob used for this experiment could only move the cursor in an up/down, or left/right direction; diagonal movement was not possible.

Both access devices were limited by the software as to selection of objects on the screen. Smalltalk V would sequence every object in relationship to its numerical order (cursor would jump from item 1 then to item 2 and so forth) regardless of the cursor key selected or the direction chosen by the thumb knob. Consequently, technicians would depress either a cursor key or the thumb knob expecting it to move in one direction when it actually moved in another. Although this situation was overcome by the technician during the cognitive learning curve, it solicited negative comments from the majority of technicians performing this experiment.

The last software limitation involved the turbo action of the thumb knob. If the thumb knob was held in a depressed mode, the cursor would build up momentum that was difficult to react to. In some instances, technicians overshot their intended choices when the cursor failed to stop after the thumb knob was released. Some of the more experienced technicians adapted to this peculiar operating feature while the novice technicians became somewhat unnerved. The researchers believe that these limitations may have significantly affected the results of this experiment since both devices tested statistically insignificant.

<u>Discussion of Qualitative Results</u>

Both the questionnaire and the personal interview data suggests that the majority of technicians preferred the four-button cursor key access method over the thumb knob access method. And a few technicians felt that neither method would be suited for the flight line. A few technicians suggested alternate methods, touch sensitive screen, pen light, and the mouse, but voiced concern whether these access devices could survive the hazards of the flight line.

All but one technician felt that computerized technical orders were a definite improvement over paper-based technical orders. This lone technician felt that developmental cost of an automated technical order outweighed its usefulness. The remainder of technicians cited ease of use, rapid and immediate access to technical information, elimination of missing or soiled pages in a paper technical order, etc., as the main advantages of using automated technical orders.

Several technicians were concerned whether the PMA could withstand the oil and solvent contaminants used on the flight line. One hydraulics technician informed the researchers of a hydraulic fluid, Skydrol, that dissolves plastic and rubber components. This information was compiled and given to Armstrong Laboratory for further research.

Conclusions

The results of this experiment suggest that the four-cursor key access method is the method of preferred choice for maintenance technicians tested. Although all technicians performed equally well accessing information using either access method (statistically there was no difference in access times), qualitative data clearly identifies the cursor keys as the most preferred access device. As stated before, the researchers believe that the joystick device employed on the PMA resulted in this outcome as this device was difficult for technicians to operate.

The most encouraging outcome of this experiment was the overwhelming acceptance of automated technical orders. All technician felt that an automated TO system would be an improvement over the present paper-based system. Although technicians voiced concerned about the PMAs survival on the flight line and its reliability and repair cost, all the technicians felt that they would be able to complete their jobs faster using an automated technical order.

Recommendations for Follow-on Experiments

Accessing available technical information is an important part of any technician's job and paper-based technical orders have become too bulky and cumbersome to use on the flight line. Automated technical orders provide the next logical progression to alleviate this problem. However, automated technical orders can also become frustrating for technicians to use if they are unable to retrieve stored information using an access device that they prefer and are accustom to using. Cursor keys offer technicians a default alternative but there are better and faster methods available and new access methods are constantly being developed. The researchers believe that the joystick device is still a viable alternative. Furthermore we recommend that another test be performed comparing the cursor key configuration against the joystick device, but that another joystick device resembling those employed on computer games be used versus the thumb knob design used for this test. A joystick device that included a selection button on its top was suggested by several technicians during the interview segment of this experiment. Other recommended access devices were also received and a list was provided to Armstrong Laboratories.

Another recommended improvement would be software programming. A joystick device works best if a technician is given the ability to move in all directions not just four. Some consideration should be given in changing the present software programming package to one that fully employs the eight directional operating characteristics of a joystick device.

This study did not require technicians to move about a computer screen to select an electronic component or trace signal paths within a schematic diagram. The researchers believe that a test that incorporated this aspect of a technician's job would be extremely helpful in evaluating the usefulness of an access device. Tracing a signal path would force a technician to move in all directions and would be a truer test of user satisfaction and system agility.

The final suggestion involves evaluation of access devices as the technician actually performs a maintenance routine. The researchers believe that movement of a technician in the performance of a maintenance or job task will significantly affect which access method the technician will choose to use. Once further tests narrow down the access choices, that choice should be tested under flight line conditions to determine its suitability before being employed in the operational model of the PMA.

Appendix A

Experimental Plan

I. Description of Evaluation

Purpose.

The purpose of this research is to determine the quickest and most satisfying way to access maintenance information from a computerized data base, a joystick or four-cursor keys.

Hardware.

A combined UNISYS Personal Computer (PC) and Integrated Maintenance Information System (IMIS) Portable Maintenance Aid (PMA) prototype keyboard was used in all phases of the study to increase reliability.

Software.

The software used during this investigation includes MSDOS 5.0 and the Armstrong Laboratory developed authoring and presentation system called the F-18 Presentation System which allows maintenance information about the F-18 aircraft to be digitized. The F-18 Presentation System was composed on version 1.1 of Smalltalk V, a program which supports the formulation and display of graphical information.

Software System Limitations.

Smalltalk V utilizes a cross stitch cursor movement procedure which combines horizontal and vertical selection techniques to designate the next region to be chosen. While this process allows a user to select any displayed region, it is somewhat unconventional, which may affect how the test subjects respond to researcher instructions.

Subjects.

There will be a total of 32 maintenance technicians (16 experienced and 16 non-experienced) from several shops within the 4950th Test Wing located at Wright-Patterson Air Force Base OH participating in this experiment. These technicians will be divided into four categories to ensure each task and access method combination is used first by an equal number of subjects to minimize bias effects.

Tasks.

Each maintenance technician will complete two simulated maintenance tasks which will require them to find and access technical information from several different screens and configurations. The tasks will simulate the procedures to administer a F-18 Nose Wheel Steering Built-In-Test (BIT) and a Main BIT and should be comparable based on difficulty level and completion time. One task will be accomplished using one access method and the other method will be used for the second task. The order for task completion and which access method to employ will be randomly determined based upon which of the four groups each technician was assigned to (See Subjects paragraph above). Table 23 summarizes the method and task order assigned to each group.

TABLE 23

ACCESS METHOD AND GROUP ORDER USED FOR SIMULATED TASKS

GROUP NUM	FIRST TASK	FIRST METHOD	EXPERIENCE
GROUP 1	Task 1	Joystick	4-Low/4-High
GROUP 2	Task 2	Joystick	4-Low/4-High
GROUP 3	Task 1	Cursor-Key	4-Low/4-High
GROUP 4	Task 2	Cursor-Key	4-Low/4-High

Both tasks used during this experiment were validated during a pilot study using students from the Air Force Institute of Technology stationed at Wright-Patterson Air Force Base OH. None of the subjects had any Air Force maintenance experience, but they all had substantial experience with personal computer applications. No one used during the pilot study will be used during the actual experiment.

The task displays are representative of what a technician would need to actually perform maintenance on the built-in-test portions of a F-18 aircraft.

Data Collected.

Demographic data will be collected using the Background Survey (Appendix D). Some of the information provided by this form will be used to determine the experience level of each technician and to assign them to a group. Also, during the experiment, notes and observations, including the technique utilized by each experimenter to maneuver about the PMA screen and intermediate, error, and total times will be recorded. A questionnaire will be used to ascertain each user's evaluation of both access methods (Appendix F). Then a researcher will conduct an interview using Appendix G to obtain comments on both access methods, including any preferences. The following information will be collected during the performance of each task:

Total time to finish the complete task.
Time to complete phase one
Time to complete phase two
Time to complete phase three
Error times to subtract from each phase

Hypotheses.

The four research questions and their associated hypotheses are listed in Chapter I or Chapter III respectively.

Controls.

The following actions will be executed throughout the experiment to control experimental variation due to computer software programs.

1. The response times for both tasks will be compiled and subtracted to ensure the sub-task and total task times are representative of the actual task performance. The response times measured represent the times required to retrieve text screens, graphics screens, and any lists required to discharge the tasks. Statistical analysis will be performed both before and after the response times are subtracted to examine any differences.

2. All 32 subjects will be randomly selected and assigned to each experimental group within their experience category. The designated group will dictate the set of conditions they will undergo during the experiment.

3. All data collection will be performed in the same location at the 4950th Test Wing by one researcher. The other researcher will conduct the personal interviews and review the questionnaire in a separate private location at the Test Wing.

4. Both researchers will conduct their activities throughout the experiment to minimize any bias.

Performance Measurement.

The following guidelines will be used to control the data collection period and ensure that performance times represent the actual time required to complete the simulated tasks.

1. If a technician is experiencing difficulty in accessing the information because of program or training problems, the experimenter will aid the technician as required to assure the resulting times are representative of their real capability.

2. If a subject has not completed a task within 20 minutes, that task will be aborted. In accordance with the schedule, each technician will be allotted a total of 50 minutes to complete both tasks and move on to the questionnaire and interview section of the experiment.

II. Procedures to Conduct Experiment

Sequence of Events.

1. Completion of Background Survey (Appendix D).
2. Introduce experiment and demonstrate experimental device to group.
3. Random assignment of subjects to experimental groups.
4. Short "hands-on" training before executing tasks.
5. Perform both tasks using access methods dictated by the assigned group.
6. Fill out questionnaire.
7. Complete personal interview conducted by second researcher.

Introduction.

Each technician will receive a short description of the purpose and instructions for this experiment. The subjects will also be reminded that participation in this research is completely voluntary and that their names will not be used anywhere in the research report. Task performance and answers to the questionnaire or personal interview will not affect their job performance ratings in any way. See appendix G for the questions the experimenter will ask each subject.

Training.

Each technician will receive "hands-on" training with the PMA immediately prior to use to ensure familiarity with its operation. During this short training period, the researcher will be available to answer any questions that may arise. Once the technician is comfortable with the system to be used, the experiment will begin.

Debriefing.

After each subject executes both tasks, a questionnaire and personal interview will be administered. Before the end of each session, a researcher will remind the subjects not to talk to anyone else about the experiment until it's completed. Finally, technicians will be briefed on how their experimental data will be used.

Appendix B

Task 1 Listing

TEST OF NOSE WHEEL STEERING BUILT-IN-TEST

The following list was used by the researchers to lead the maintenance technicians through the task to test the operation of the two cursor control devices.

LOG-ON

Log onto the PMA; enter "3" for **"TECHNICIAN #1's NUMBER"**, then press <NEXT>

Press <NEXT> to choose **"SESSION 1"**

BEGIN PHASE ONE (Start Timing)

Press <NEXT> **once** to reach the **"Integrated Flight Control System"** screen

Highlight **"#7. Mission Computer"**, press <SELECT>, then highlight and <SELECT> **"#7. Elect System"**

Now press <CANCEL> button **twice** and choose **IFCS**, then press <NEXT> **twice**

At **"FCS NWS BIT Procedure"**, choose and <SELECT> **"Prelim with Hydro"**, then press <NEXT>

Choose **"No"** to 1553 Hookup, press <SELECT>, then press <NEXT>

Press <NEXT> **five** times to reach **"procedure #7"**

Press <MENU>, then <SELECT> **"7. Utilities"** followed by **"Calculator"** to display the Calculator

Highlight and <SELECT> numbers 3,9,&2, then <SELECT> "*", followed by 1,8,&3; check the answer: **71,736**

Press <CANCEL> button **three** times back to **"procedure #7"**

Press <NEXT> **six** times (past notes boxes) to reach **"procedure #8"**

Press <NEXT> **once** to reach **"procedure #9"**

END PHASE ONE/BEGIN PHASE TWO

Choose **INTEST/DEGD** for FSCA **only**, press <SELECT>, then press <NEXT>

Press <NEXT> **twice** to reach **Process BLIN results**, then press <NEXT>

Choose **"No"** to 1553 Hookup, press <SELECT>, press <NEXT>

Press <NEXT> **twice** to reach **"procedure #4"**

Press **LOG FILE** Soft Key <F4>; Scroll down the Log File and record time for **"Start Task: Read BLIN"**, then press <F1>

Press <NEXT> **three** times to reach **"BLIN CODE READING"** screen with Note Box, then press <NEXT> again

Highlight a **"CHANNEL 2"** box, enter **"4744"**, press <NEXT>

Press <NEXT> **twice** to reach the **"Block Diagram"** (WAIT)

Highlight and <SELECT> **"11. IFCS"**, then highlight and <SELECT> **"3. Nose Wheel Steering"**

Press **RANKED ACTIONS** Soft Key <F1>

Highlight and select option #4, **"NWS Selector...1903H"**, press <SELECT>, then press <NEXT> **twice**

Choose and <SELECT> all the **"Required Conditions"**, then press <NEXT> **three** times

Highlight and <SELECT> **"No"**, at 84P-G036 PIN prompt, then press <NEXT> **twice**

END PHASE TWO/BEGIN PHASE THREE

At **"Block Diagram"**, press **RANKED ACTIONS** Soft Key <F1>

Highlight and <SELECT> option #5, **"Repair Wiring...Relay"** then press <NEXT>

Press **PART INFO** Soft Key <F1> to produce parts list

Highlight a **"#7 Circuit Breaker/Relay Panel Assembly"**, press **PART INFO** Soft Key <F1>

At **"Relay Electromagnetic, 2PDT"** display, press <SELECT>, then press <NEXT>

Press <F3> **SOFT KEY** to use the Keyboard to enter a **Quantity** of "103", then <SELECT> **"SEND VALUE"**

Now choose **"Unit of Issue"** and press <F3> **SOFT KEY** to use the Keyboard to enter **"BOX"**, then <SELECT> **"SEND VALUE"**

Press **ORDER** key <F1> to **"Order"** this part

Press <NEXT> **five** times to reach the **"FCCA Input Conditions"** screen

Press <MENU>, then <SELECT> **"1. File"** followed by **"SET-UP"** to reset the computer

END PHASE THREE/LOG-OFF

Press <NEXT> to **"MAINTENANCE CLOSEOUT INFORMATION"**, then press <NEXT> again

At **"Inspector Code"**, enter "99", then press <NEXT>

Appendix C

Task 2 Listing

TEST OF MAIN BUILT-IN-TEST

The following list was used by the researchers to lead the maintenance technicians through the task to test the operation of the two cursor control devices.

LOG-ON

Log onto the PMA; enter "3" for **"TECHNICIAN #1's NUMBER"**, then press <NEXT>

Scroll and <SELECT> **"TRAINING SESSION 2"**, press <NEXT>

BEGIN PHASE ONE (Start Timing)

At **"Session Information"** press **FAULT VERIFY** Soft Key <F4>

At **"Fault Verification"** screen, press <NEXT> to choose **MAIN BIT**, then press <NEXT>

At **"FCS Main BIT Procedure"**, choose and <SELECT> **"PRELIM WITH HYDRO"**, press <NEXT>

Choose **"No"** to 1553 Hookup, press <SELECT>, then press <NEXT>

Press <NEXT> **four** times to reach **"procedure #6"**

Then choose **DEGD** for both **FSCA** and **FSCB** by pressing <SELECT>, then press <NEXT>

Choose and <SELECT> all the **"Required Conditions"**

Press <NEXT> **once** to **"BLIN Code Reading"**, then press <NEXT> again

Press <SELECT> to choose **"Electrical Power"**, then press <NEXT>

Choose **"No"** to 1553 Hookup, press <SELECT>, then press <NEXT>

END PHASE ONE/BEGIN PHASE TWO

Press <NEXT> **twice** to reach **"procedure #4"**

Press <MENU>, then highlight **"Utilities"** followed by **"Calculator"** to display the Calculator

Highlight and <SELECT> numbers 2,7,&1, then <SELECT> **"*"**, followed by 7,2,&9; check the answer: **197,559**

Press <CANCEL> button **three** times back to **"procedure #4"**

Press <NEXT> **four** times to reach **"BLIN Code Reading"** procedure check

Highlight **"CHANNEL 2"**, enter "4263", press <NEXT> **twice**

Highlight **"Electrical Power"**, press <SELECT>

Press <NEXT> **once** to reach the **"Block Diagram"** <u>WAIT!!</u>

Highlight **"#15. Aileron"**, press <SELECT>, then highlight and <SELECT> **"#18. Hyd Sys"**

Now press <CANCEL> **twice** and highlight **"Elect Sys"**, press **RANKED ACTIONS** Soft Key <F1>

Press <NEXT> to choose **"FCCA Continuity Check 1902B"**

Choose and <SELECT> all the **"Required Conditions"**, then press <NEXT> **twice**

Highlight and <SELECT> **"No"** at "Continuity" prompt, press <NEXT>

Choose and <SELECT> all the **"Required Conditions"**

Press <NEXT> **once** to reach the **"Block Diagram"** <u>WAIT!!</u>

END PHASE TWO/BEGIN PHASE THREE

At **"Block Diagram"**, press **RANKED ACTIONS** Soft Key <F1>

Highlight and <SELECT> option #2, **"Repair Wiring between...FCCA"**, then press <NEXT>

Press **PART INFO** Soft Key <F1> to produce a Parts List

Press <SCROLL> Key and cursor key to scroll **UP** the list to the top, then choose a **"Roll-Pitch-Yaw Computer (FCCB)** and press the **PART INFO** Soft Key <F1>

Press <SELECT> to choose a **"Computer, Roll-Pitch-Yaw"**, press <NEXT>

Press <F3> **SOFT KEY** to use Keyboard to enter a **Quantity** of **"201"**, then <SELECT> **"SEND VALUE"**

Now choose **"Unit of Issue"** and press <F3> **SOFT KEY** to use the Keyboard to enter **"CRATE"**, then <SELECT> **"SEND VALUE"**

Press **ORDER** Soft Key <F1> to **"Order"** this part

Press <NEXT> **five** times to reach the **"Repair Wiring"** screen

Press <MENU>, then <SELECT> **"1. File"** followed by **"SET-UP"** to reset the computer

END PHASE THREE/LOG-OFF

Press <NEXT> to **"MAINTENANCE CLOSEOUT INFORMATION"**, then press <NEXT> again

At **"Inspector Code"**, enter "99", then press <NEXT>

Appendix D

Background Survey

EXP? ____

Subject Identification Number ______ GROUP # ____

1. Check one: Military ___ Civilian ___

2. Total Active Military service _______ in Yrs and months.

3. Current pay grade: ______

4. Current job specialty or rating: ____________________

5. Prior Work Experience (crew chief, hydraulic technician, etc.):

	(1)	(2)	(3)
Career specialty:	________	________	________
Location:	________	________	________
Years experience:	________	________	________
Inclusive dates (m/y)	_/__:_/__	_/__:_/__	_/__:_/__

	(4)	(5)	(6)
Occupation specialty:	________	________	________
Location:	________	________	________
Years experience:	________	________	________
Inclusive dates (m/y)	_/__:_/__	_/__:_/__	_/__:_/__

6. Education/Formal training:

High grade completed (high school=12, college = 16): ___

Department of Defense Schools completed:

Courses:	________	________	________
Years experience:	________	________	________
Inclusive date	_/__:_/__	_/__:_/__	_/__:_/__

7. Computer/Electronic Experience:

Formalized Training: ___ Yes ___ No

Self-taught: ___ Yes ___ No

Computer Model/Type: __________ Exp (yr/mths) ________

Appendix E

Observation Form

Task Number: ________ Subject ID: ______________

Phase 1 Times Start: ______ Compl: ______ Error: _______

Phase 2 Times Start: ______ Compl: ______ Error: _______

Phase 3 Times Start: ______ Compl: ______ Error: _______

Phase 4 Times Start: ______ Compl: ______ Error: _______

Time Task terminated (if unsuccessfully completed): _______

Number of steps successfully completed: _______

Number of steps not completed: _______

The sequence number of step not completed: ___________

Reason for not completing: ____________________________

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

Problems/Notes:

Appendix F

Sample Questionnaire

ID #._______

User Evaluation Questionnaire

Please answer the following questions based on you participation in the computer interface evaluation. After reading the question place a mark in the appropriate box. The scales are as follows:

1. Strongly Agree
2. Agree
3. Undecided
4. Disagree
5. Strongly Disagree

I. Questions on the button cluster access method.

	1	2	3	4	5
1. Four-cursor keys were superior when accessing and selecting information in the calculator.					
2. Four-cursor keys were superior when accessing and selecting information in all block diagrams.					
3. Four-cursor keys were superior when accessing and selecting information in the parts lists					
4. Four-cursor keys were superior when accessing and selecting information in the menu.					
5. Fewer accessing and selection errors were made using the button cluster keys versus the thumb knob.					
6. Four-cursor keys are the preferred method for accessing and selecting all tasks performed during this evaluation.					

II. Questions on the thumb knob access method.

	1	2	3	4	5
7. The thumb knob is superior when accessing and selecting information in the calculator.					
8. The thumb knob is superior when accessing and selecting information in block diagrams.					
9. The thumb knob is superior when accessing and selecting information in parts lists.					
10. The thumb knob is superior when accessing and selecting information in the menu.					
11. Fewer accessing and section errors were made using the thumb knob versus the cursor key method.					
12. The thumb knob is the preferred method for accessing and selecting all tasks performed during this evaluation.					

III. Other Influencing Factors

	1	2	3	4	5
13. Neither the cursor keys nor the thumb knob access method worked best in accessing and selecting information for all tasks in this evaluation.					
14. Accessing requested information was difficult using either access method due to the manner in which the cursor moved across the screen.					
15. I would recommend another accessing method rather than the two methods provided in this evaluation.					
16. I would recommend using a light pen.					
17. I would recommend using a mouse.					
18. I would recommend using an accessing method not listed.					

Appendix G

Sample Interview Questions

1. Did you prefer one computer access method over the other one for all steps in both tasks?

2. Which computer access method did you prefer? Why?

3. Did your access choice work best in all task steps?

4. Which computer access method worked best on what tasks? Why?

5. Which maintenance tasks would you recommend using the joystick access method to complete?

6. Which maintenance tasks would you recommend using the cursor keys to complete?

7. Would another type of computer access method be more practical?

8. What advantages would your suggested computer access have over the two access methods tested?

9. Are automated technical orders practical on the flight line?

10. Were the steps in each task representative of tasks performed on the flight line?

11. Which tasks did not represent flight line tasks?

12. What recommendation could you offer that might improve the quality of this or similar experiments?

13. Do you think an automated technical order has any advantages over paper technical orders?

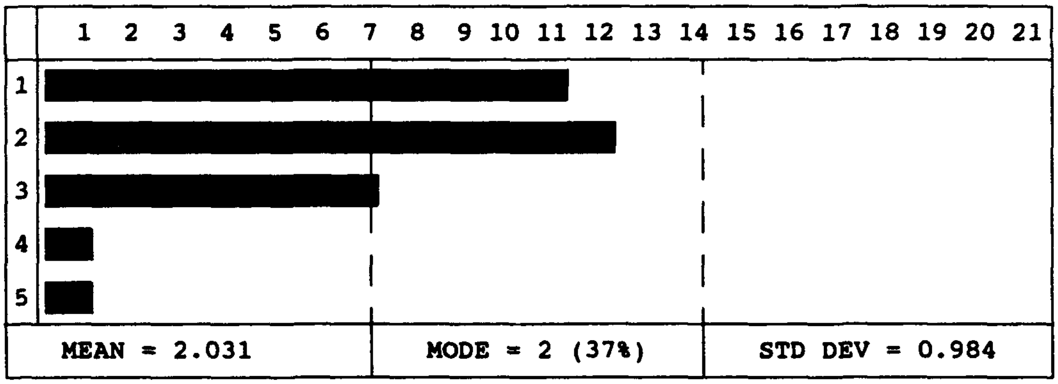
14. Do you have any other recommendations not discussed in any of the above questions?

Appendix H

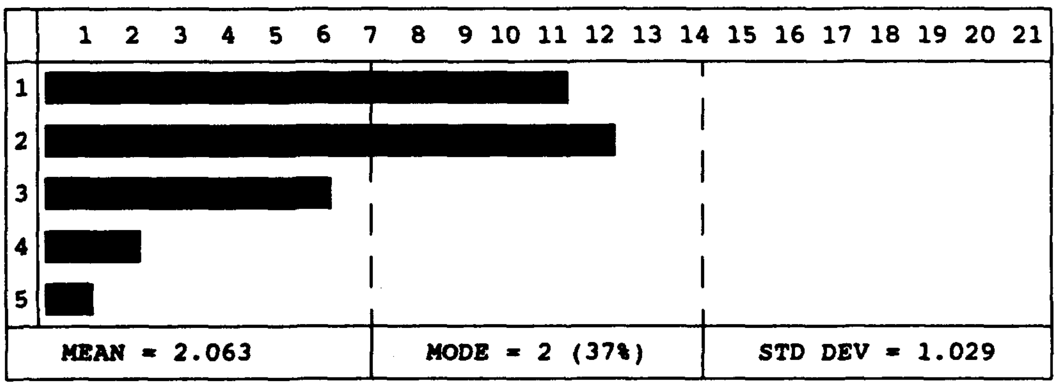
Questionnaire Results

The following histograms present the number of technicians who answered 1 (strongly agree) through 5 (strongly disagree) and the mean and standard deviation for each of the 18 questions on the questionnaire. Also, the mode is listed along with the percentage of technicians who chose the mode. When there is more than one mode, the percentage shown is for each separate value.

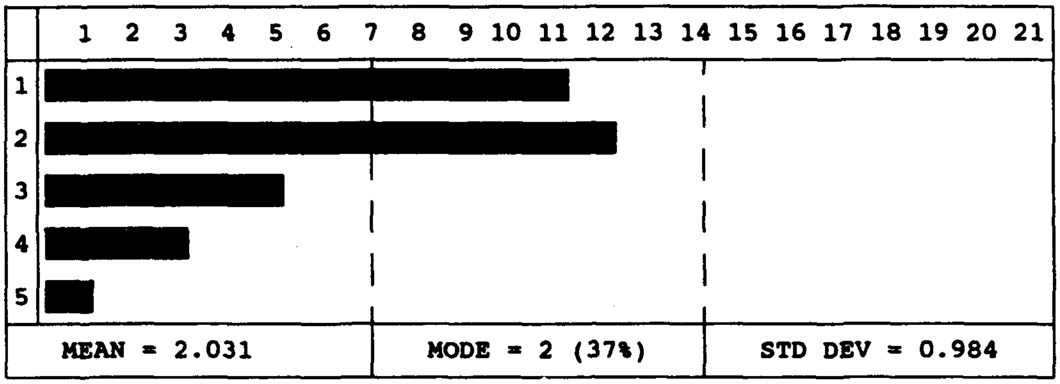
1. Four-cursor keys were superior when accessing and selecting information in the calculator.



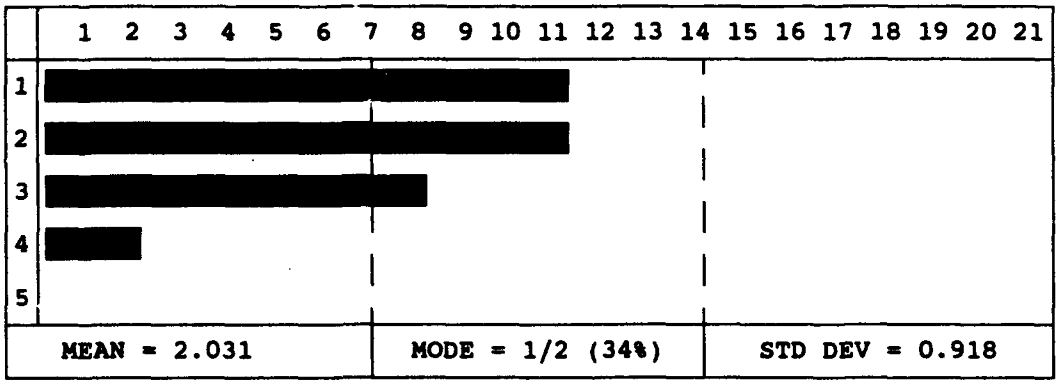
2. Four-cursor keys were superior when accessing and selecting information in all block diagrams.



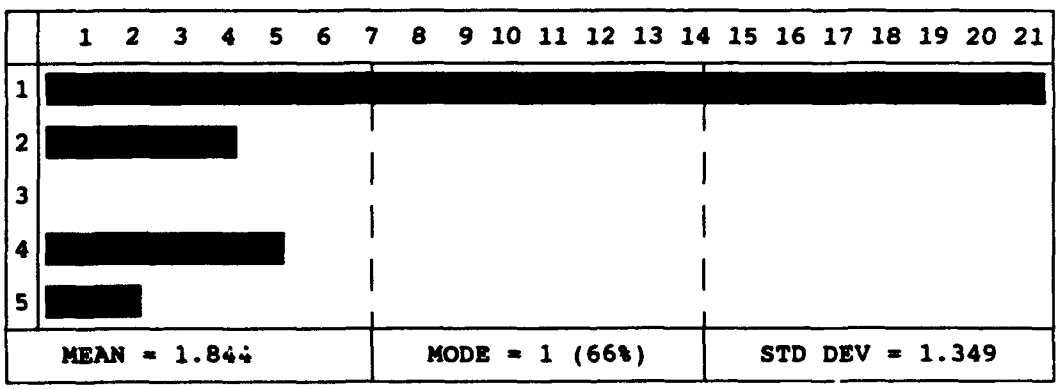
3. Four-cursor keys were superior when accessing and selecting information in the parts lists.



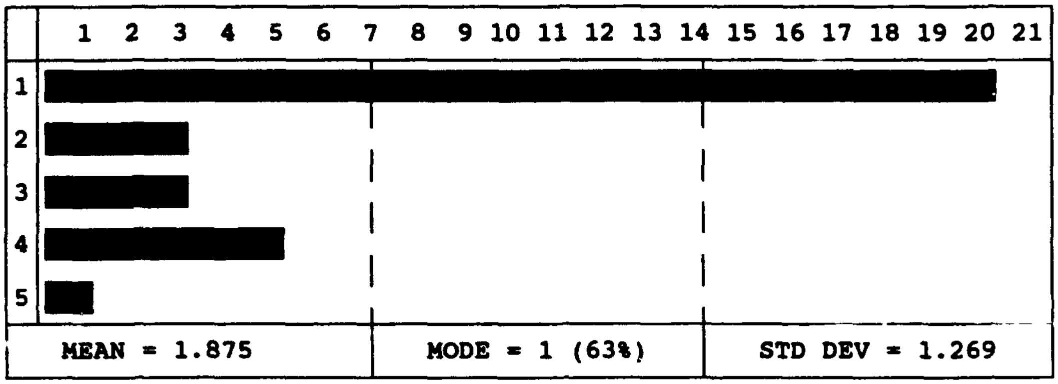
4. Four-cursor keys were superior when accessing and selecting information in the menu.



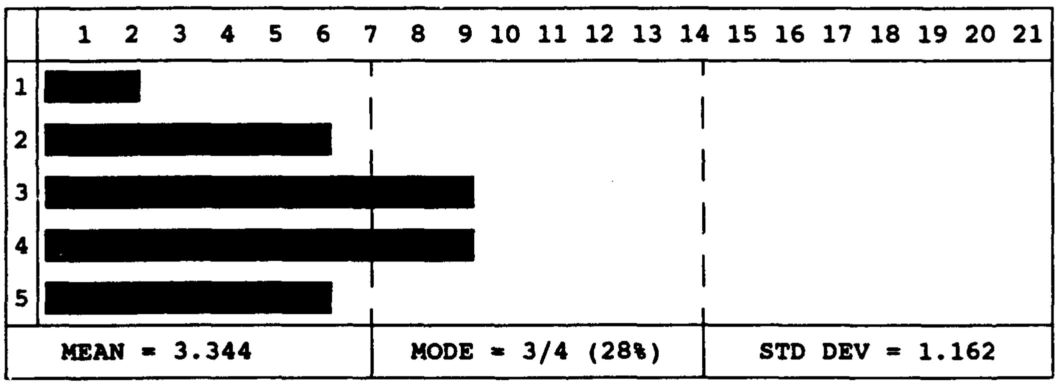
5. Fewer accessing and selection errors were made using the cursor keys versus the thumb knob.



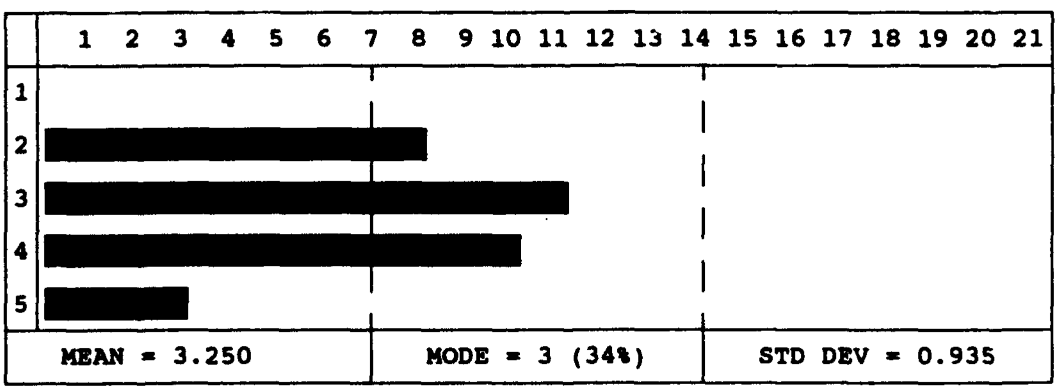
6. Four-cursor keys is the preferred method for accessing and selecting all tasks performed during this evaluation.



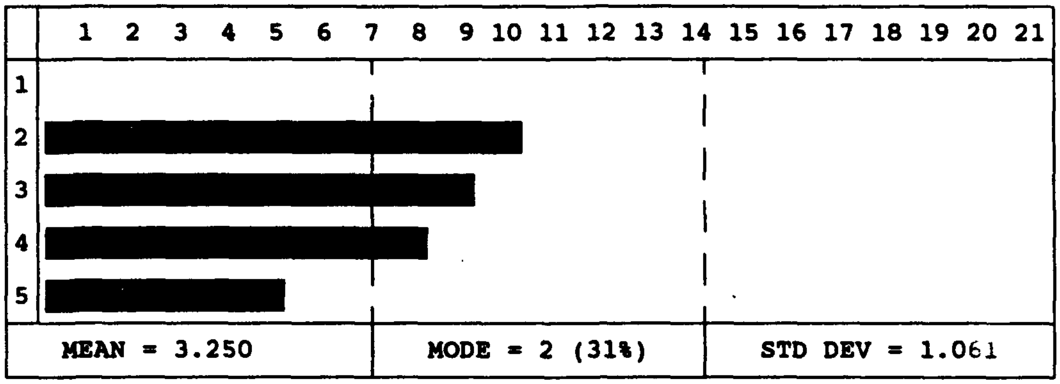
7. The thumb knob is superior when accessing and selecting information in the calculator.



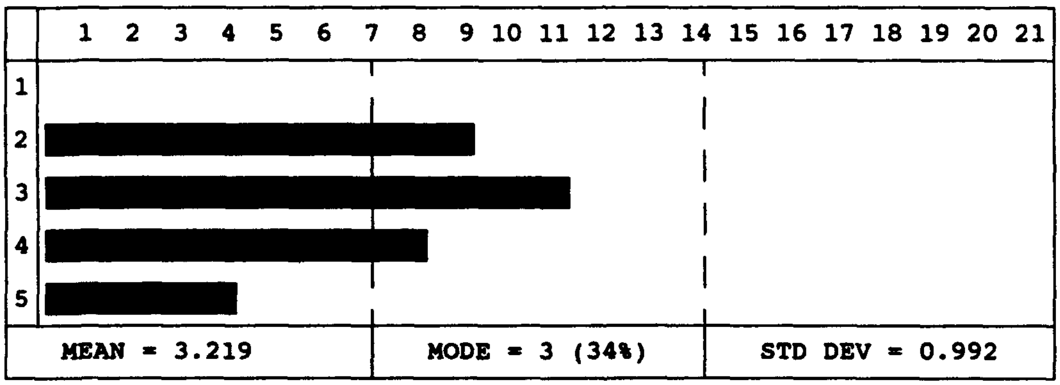
8. The thumb knob is superior when accessing and selecting information in all block diagrams.



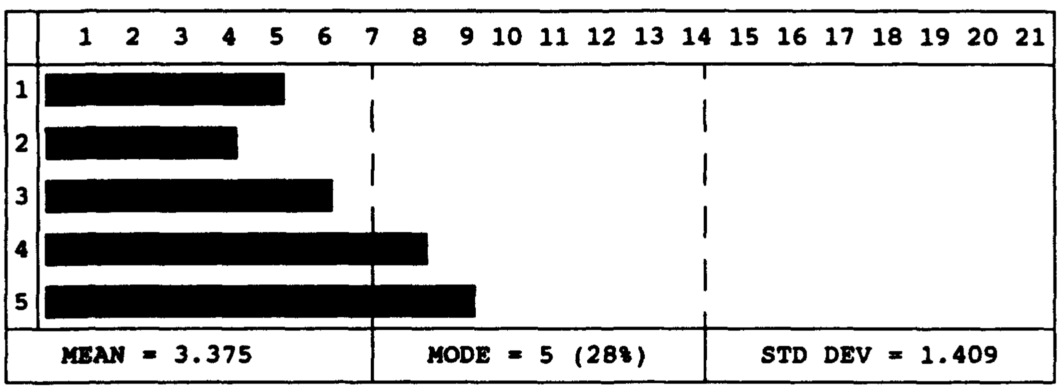
9. The thumb knob is superior when accessing and selecting information in the parts lists.



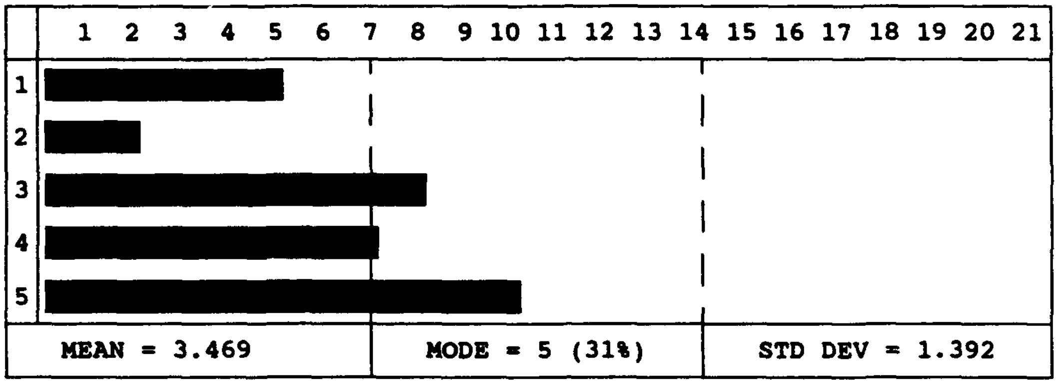
10. The thumb knob is superior when accessing and selecting information in the menu.



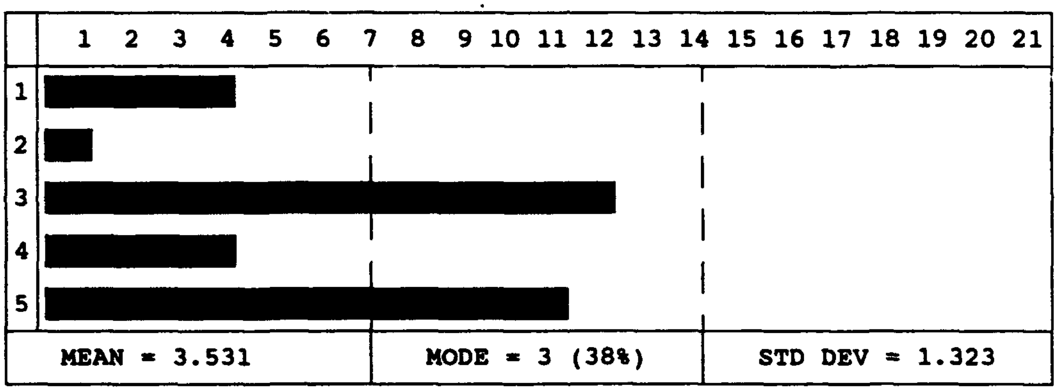
11. Fewer accessing and section errors were made using the thumb knob versus the cursor keys.



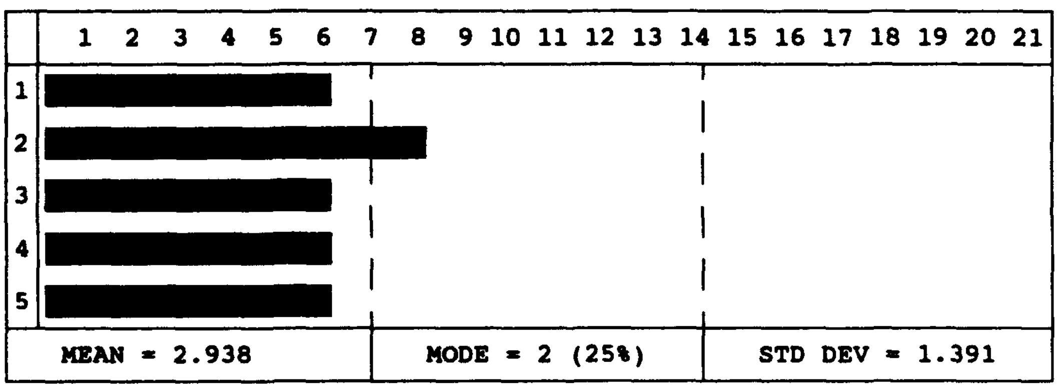
12. The thumb knob is the preferred method for accessing and selecting all tasks performed during this evaluation.



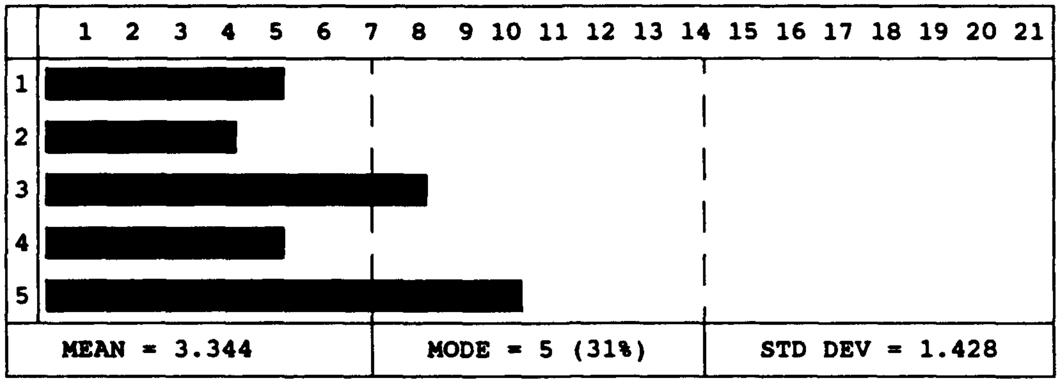
13. Neither the cursor keys nor the thumb knob access method worked best in accessing and selecting information for all tasks in this evaluation.



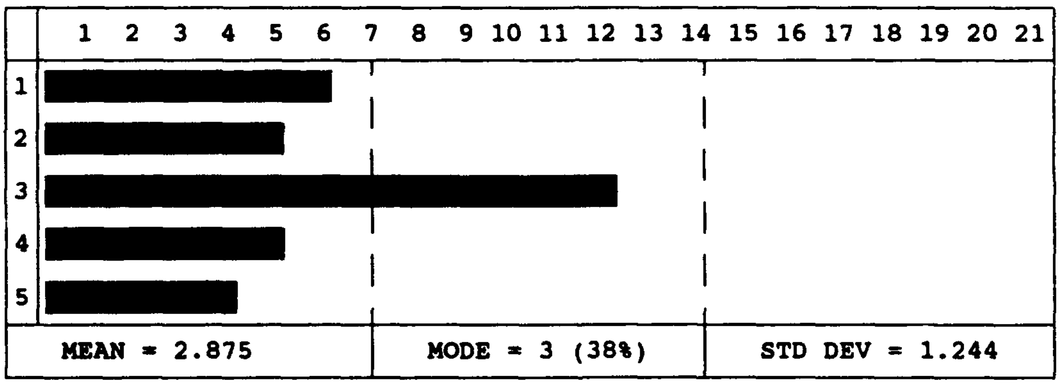
14. Accessing requested information was difficult using either access method due to the manner in which the cursor moved across the screen.



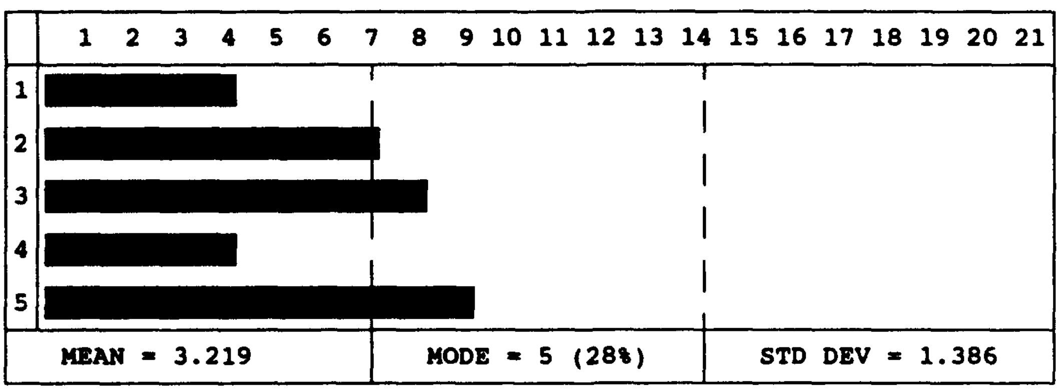
15. I would recommend another accessing method rather than the two methods provided in this evaluation.



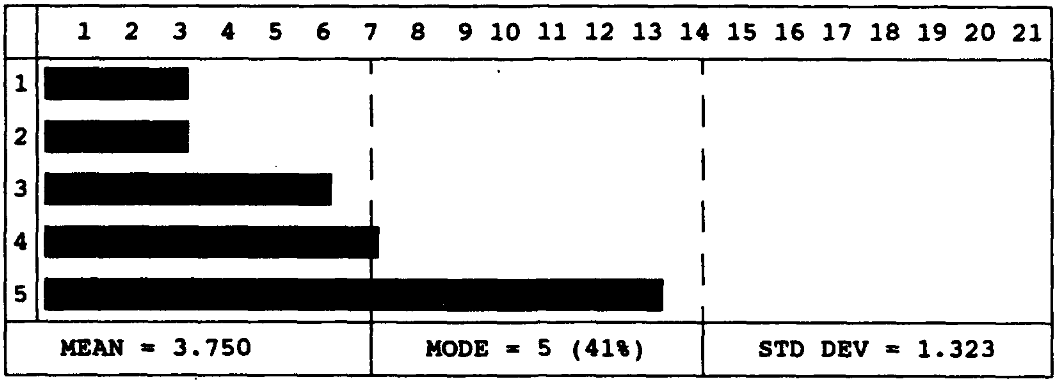
16. I would recommend using a light pen.



17. I would recommend using a mouse.



18. I would recommend using an accessing method not listed.

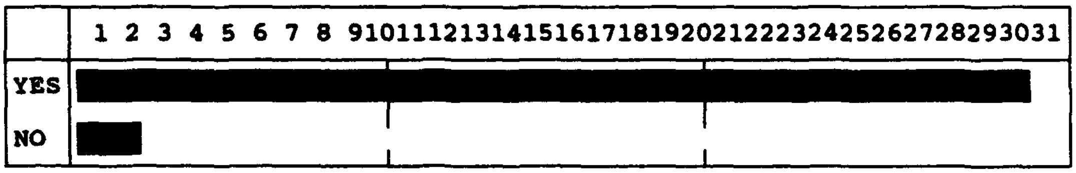


Appendix I

Personal Interview Results

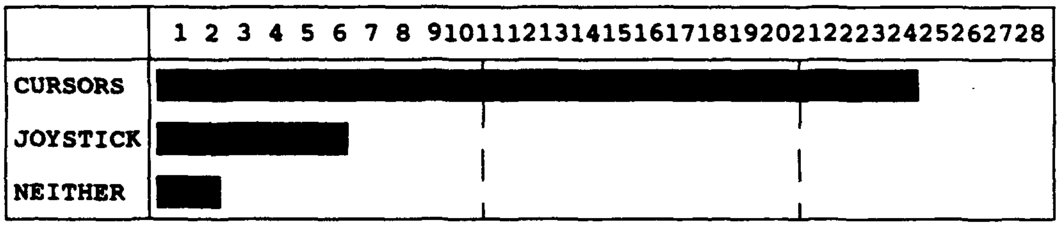
1. Did you prefer one computer access method over the other one for all steps in both tasks?

Only two technicians did not have a preference.



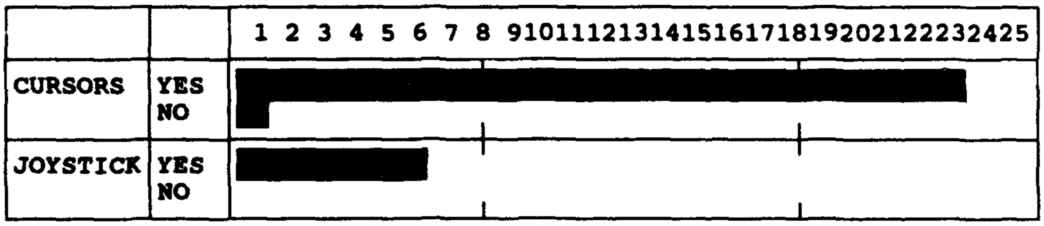
2. Which computer access method did you prefer? Why?

Of the 30 who did have a preference, 24 chose the cursor keys.



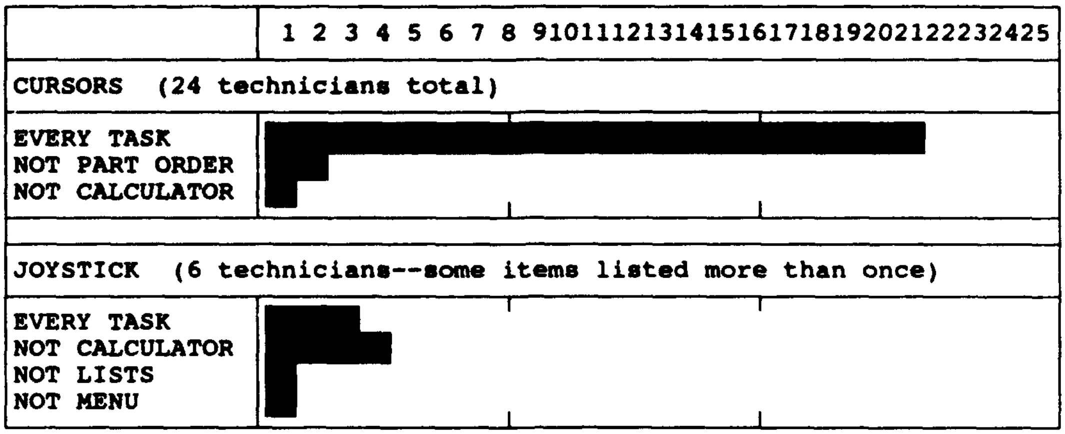
3. Did your access choice work best in all task steps?

The cursors performed all tasks well for 23 of 24 respondents. All 6 technicians who liked the joystick preferred it for every task.



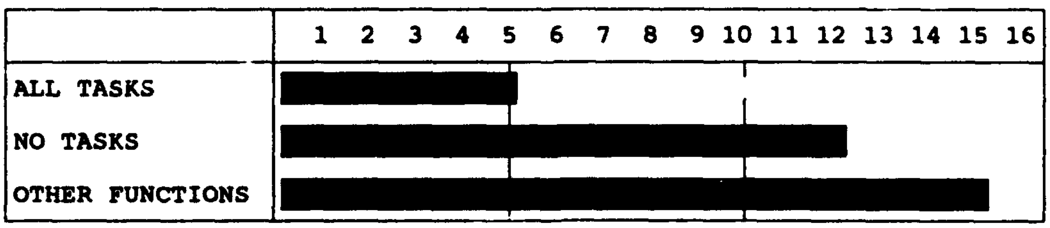
4. Which computer access method worked best on what tasks? Why?

For the cursors: 21 technicians liked them for every task, while 2 would not use them to order parts and one wouldn't employ them to calculate totals. For the joystick: 3 of the 6 preferred it for every task, but 4 subjects disliked it for the calculator and the joystick wasn't chosen for lists or menus by one technician.



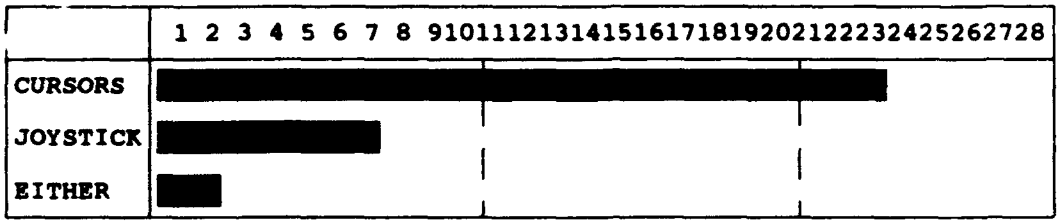
5. Which maintenance tasks would you recommend using the joystick access method to complete?

5 test subjects liked the joystick for all tasks, but 12 didn't choose it at all. The other 15 technicians some functions including the calculator, scrolling, part orders, and menus.



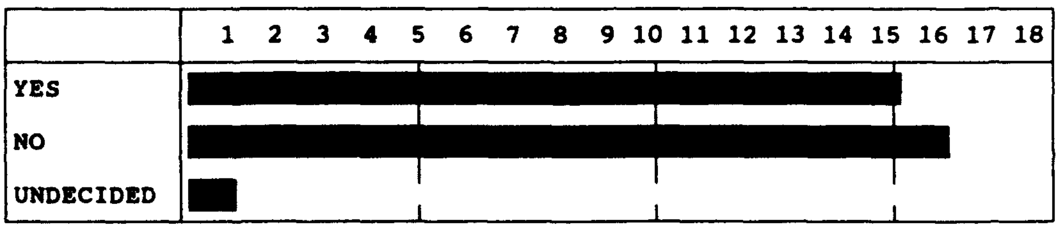
6. Which computer access method would work best on the flight line?

23 of the 30 subjects with a preference chose the cursor keys as best for a flight line. The other two were undecided.



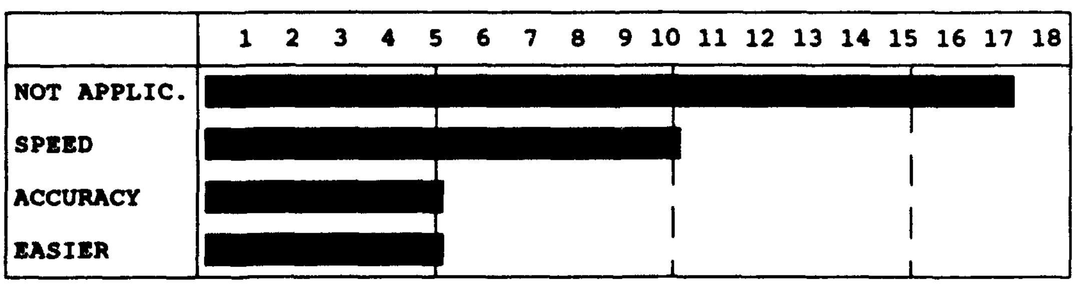
7. Would another type of computer access method be more practical? Why?

15 test subjects did think a different access method would be more useful, while 16 were satisfied with the two methods tested. One technician was undecided.



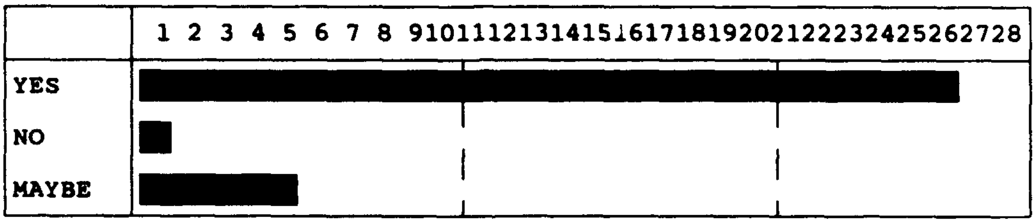
8. What advantages would your suggested computer access method have over the two access methods tested?

10 technicians suggested a light pen, 2 a mouse and one desired a different keyboard. 2 others wanted an improved joystick. The improvements described by the subjects are listed below.



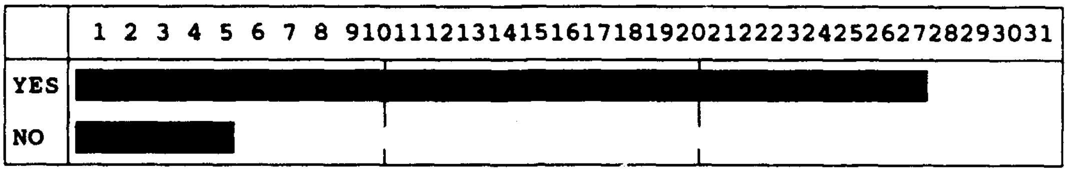
9. Are automated technical orders practical on the flight line?

26 subjects thought computerized TOs are practical, but one didn't agree. The other five were undecided.



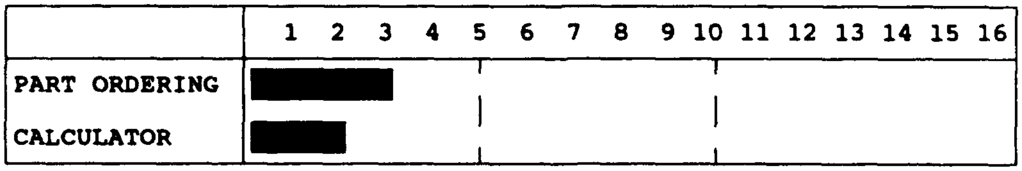
10. Were the steps in each task representative of tasks performed on the flight line?

27 technicians thought that all tasks were representative of flight line tasks, but 5 did not.



11. Which tasks did not represent flight line tasks?

Of the 5 technicians, 3 of them selected part ordering and two picked the calculator.

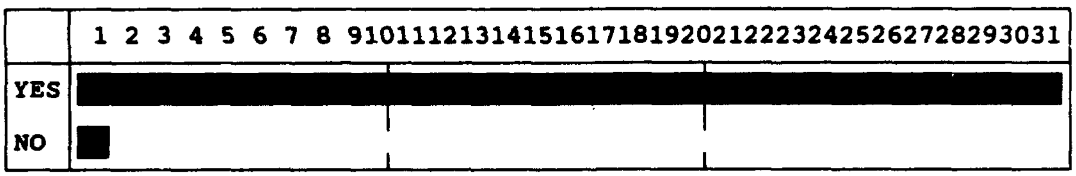


12. What recommendations could you offer that might improve the quality of this or similar experiments?

- Move the joystick to the (left) side of the PMA.
- Presentation should allow diagonal movement.
- Use an "ALPHA," not a "QWERTY" keyboard.
- Install a normal (or taller) joystick.
- Add a select button as part of joystick.
- Use tasks which match technicians career field.
- Use CD-ROM and/or removable "hard/floppy disks" to update and store information.
- Consider hazardous materials (hydrazine, skydrol, etc) and ruggedness before approving the PMA.
- Incorporate separate experience levels in presentation system.
- Speed-up response times.
- Provide random access to information.
- Change the "NEXT" button to "ENTER".

13. Do you think an automated technical order has any advantages over paper technical orders? Why?

31 technicians thought automated TOs would improve flight line operations.



REASONS LISTED IN ORDER BASED ON NUMBER OF RESPONSES

- Automated system easier to use and operate.
- Easier to research and find information with automatic system.
- New system weighs less, is less bulky and faster.
- Information is more consolidated in IMIS system.
- Less storage space will be required for disks as opposed to paper Technical Orders.
- Less chances of paper pages blowing away.
- Better survivability because paper tears/deteriorates.
- New system will help eliminate mistakes.
- New system should cost less to develop.
- New system will ensure information is current.

14. Do you have any other recommendations not discussed in any of the above questions?

None mentioned.

Appendix J

Air Force Specialty Breakout of Technicians Tested

31633 - Apprentice Instrumentation Specialists

31653 - Instrumentation Specialists

45451 - Avionics Guidance and Control Systems Specialists

45471 - Avionics Guidance and Control Systems Technician

45472 - Air crew Egress Systems Technician

45475 - Strategic Electrical and Environmental Systems Technician

45532 - Apprentice Communication and Navigation Systems Specialist

45752 - Airlift Aircraft Maintenance Specialists

45770 - Strategic Aircraft Maintenance Technician

45852 - Aircraft Structural Maintenance Specialists

45871 - Nondestructive Inspection Technician

45873 - Fabrication and Parachute Supervisor

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Vita

Captain Robert H. Gundel was born on May 6, 1960 in Jacksonville, Florida. He graduated from Largo High School in Largo, Florida and attended the Georgia Institute of Technology, graduating with a Bachelor of Civil Engineering in December 1983. In March, 1985, he was commissioned from Officer Training School and then served as an Acquisition Logistics Officer at Wright-Patterson AFB, Ohio. He was assigned to several simulator programs which would help train pilots to fly aircraft including the C-5, C-141, KC-135 and the C-17. Next, he moved on to Columbus AFB, Mississippi during February, 1988 where he performed as the Installation Mobility Officer. Also, he managed the base War Reserve Material and the Resource Management Plans programs. In August, 1990, he was transferred to Kwang-Ju AB, Korea where he became chief of the Logistics Plans Branch, responsible to coordinate the base draw down to 14 personnel. On April 1, 1991, he was installed as the base detachment commander as part of the Korean Collocated Operating Base program for one month until he entered the School of Systems and Logistics, Air Force Institute of Technology in May 1991.

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Vita

Captain Gerald E. Streff was born on October 25, 1950 in Orleans, Nebraska. He graduated from Orleans High School and attended Oklahoma City University, graduating with a Bachelor of Science in Technical Management Degree during December, 1984. In April, 1985, he was commissioned from Officer Training School and then attended Aircraft Maintenance Officer's school at Chanute AFB, Illinois. For his first assignment, he served as an Aircraft Maintenance Officer at McChord AFB, Washington. During his three year tour, he served as a Branch Supervisor of the C-141 Flight Line and as the chief of the Fabrication Branch. In June, 1988, Captain Streff was reassigned to Hickam AFB, Hawaii and began his tour as a Flight Line Supervisor. In July, 1989, he assumed the task of Field Maintenance Supervisor where he was responsible for on-equipment and off-equipment maintenance of C-141, C-5, KC-10 and C-130 aircraft. In May of 1990, Captain Streff took over the duties of Aircraft Maintenance Unit Supervisor under MAC's "New Maintenance Concept" plan and remained in this position until he entered the School of Systems and Logistics, Air Force Institute of Technology in May 1991. He is married to the former Sandra Rodenbaugh and they have five children.

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13. ABSTRACT (*Maximum 200 words*)

The purpose of this thesis was to evaluate the use of four-cursor buttons versus a joystick device to present technical order information on a portable maintenance aid computer for aircraft technicians in a maintenance environment. Studies to date have verified the superiority of computer-presented technical orders when compared to current paper-based systems; this research investigated the effectiveness of these computer-based systems when technicians used a joystick or four-cursor button to display desired technical information. A comparison was made as to technician performance using a portable maintenance aid at the 4950th Test Wing, WPAFB OH. A total of thirty-two maintenance technicians accessed and displayed technical information using a joystick device and the four-cursor keys. Results indicated no statistically significant difference in the performance of maintenance technicians when using either access device in a controlled environment. The major conclusion was that either access device may be a viable answer for use in the flight line environment. The chief recommendation is that further studies be performed using a different joystick device and computer software that supports the eight joystick functions.

14. SUBJECT TERMS
Portable Maintenance Aid (PMA), Integrated Maintenance Information System (IMIS), joystick device, four-button cursor keys, automated technical data, maintenance personnel.

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