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AN ANALYSIS OF TYPE IV PRECISION MEASUREMENT EQUIPMENT LABORATORY LOGISTICAL SUPPORT RELATIVE TO THE IMPLEMENTATION OF F-15/F-16 TWO-LEVEL MAINTENANCE

THESIS

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AFIT/GLM/LAR/94S-6

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THESIS

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Donald L. Clark

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Abstract

This study investigated the change in Type IV PMEL workload requirement resulting from the implementation of the two-level maintenance (2LM) concept. Seven Type IV PMELs were studied and the information was used to profile a "typical" Type IV PMEL. The researcher was able to predict the total inventory owned by the Type IV PMEL customers, the number of items supported by the Type IV PMEL, and the percent of the Type IV PMEL workload affected by 2LM. These values were determined by using inferential statistics and were expressed in terms of confidence intervals. The researcher also examined the first six months of production data recorded while operating in the 2LM concept. ANOVA and T-TESTs were used to test the hypothesis that the mean variety of equipment, mean maintenance hours expended, and mean AIS station utilization recorded were not significantly different from the mean values recorded for the same six-month period the previous year, while operating in the three-level maintenance (3LM) concept. The test results seem to indicate that implementing 2LM results in little or no difference in the Type IV PMEL workload. In addition, Type IV PMEL lab chiefs were interviewed to solicit their expert opinion with regard to the changes they see as a result of implementing 2LM. The consensus is that 2LM results in little or no change in the Type IV PMEL workload. This opinion is consistent with the statistical analysis performed in this study.

AN ANALYSIS OF TYPE IV PRECISION MEASUREMENT EQUIPMENT LABORATORY LOGISTICAL SUPPORT RELATIVE TO THE IMPLEMENTATION OF F-15/F-16 TWO-LEVEL MAINTENANCE

I. Introduction

General Issue

A significant portion of the total life cycle cost dollars is spent on operations and maintenance. The maintenance planning process should be accomplished as early as possible, because it establishes the baseline for other logistic support elements. Therefore, the greatest opportunity to save Air Force dollars rests with early maintenance planning. This Integrated Logistics Support (ILS) element establishes the maintenance concept, which includes the level of maintenance. In a memo dated June 11, 1992, the Secretary of the Air Force and the Chief of Staff directed adoption of two-level maintenance "for every new weapon system and encouraged this concept, to the extent practical, for existing systems" (Guide, 1993:1-1). This initiative, termed "two-level maintenance," is primarily aimed at reducing costs by consolidating base maintenance personnel and equipment (Draft, 1993:3). The two-level maintenance concept eliminates the intermediate level of maintenance and consolidates the intermediate tasks with those performed at the depot (Przemieniecki, 1993: 312).

We are living in a dynamic era. Consolidations and reorganizations, in which the face of logistics is changing day-by-day, are taking place throughout the Department of Defense. Two-level maintenance affects all Air Force flying organizations, as well as all the people in AFMC who work in maintenance, supply, transportation, and logistics (Ely, 1993:6).

Of specific interest is the Air Force Metrology and Calibration (AFMETCAL) program. The AFMETCAL program is comprised of measurement standards and test measurement and diagnostic equipment (TMDE), professional and technical metrologists, performing work centers (PWCs), a system of worldwide precision measurement equipment laboratories (PMELs), measurement equipment users, calibration data, and integrated planning. PMELs are authorized to possess Air Force base measurement standards and are responsible for maintenance, calibration, and certification of TMDE (AFR74-2, 1990:3). The different types of PMELs will be defined in the background section.

Members of the AFMETCAL community share a concern for the future role of the PMELs. This concern is: on a worldwide basis, what will be the impact of two-level maintenance on workload, manpower, and equipment requirements? To that end, this cross-sectional study was conducted.

Background

Most avionics systems in the current inventory employ a three-level maintenance concept: organizational, intermediate, and depot (O'Reilly, 1979:157). In his book, Logistics Engineering and Management, Benjamin S. Blanchard defines the systems maintenance concept and presents a detailed summary of the maintenance levels (Blanchard, 1992:115-117). Personnel engaged in organizational level maintenance perform on-aircraft troubleshooting of the system, remove and replace the defective unit, and transport the defective unit to the intermediate maintenance facility. Personnel performing intermediate-level maintenance tasks troubleshoot the defective unit, remove and replace the defective assembly, accomplish repair actions within their capability, and ship tasks beyond their capability to the depot. Finally, the depot level constitutes the highest type of maintenance and supports the accomplishment of tasks exceeding the capabilities available at the intermediate level to include complete overhauling, rebuilding, calibration, and the performance of highly complex maintenance actions (Blanchard, 1992:116).

The AFMETCAL program provides maintenance and calibration of TMDE to ensure the reliability and accuracy of systems, subsystems, and equipment (AFR74-2, 1990:2,3). PMELs are authorized to possess Air Force base measurement standards and are responsible for maintenance, calibration, and certification of TMDE (AFR74-2, 1990:3). The accuracy and uniformity of measurements are traceable to the National Institute of Standards and Technology (NIST) or other approved DoD sources through the vital base-level link provided by PMELs (AFR74-2, 1990:1). Measurement traceability of the AFMETCAL program is presented pictorially in Air Force Technical Order 00-20-14, page 1-3.

PMELs are strategically located throughout the world to provide TMDE support. The types of PMELs are:

1. Type I or Air Force Measurement Standards Laboratory; the highest level standards laboratory in the AFMETCAL Program. It maintains Air Force measurement standards certified by the NIST, the US Naval Observatory (USNO), or other nationally recognized standards (TO 00-20-14, 1992:1-4).

2. Type IIA; a base-level PMEL providing support to Air Logistics Centers (ALCs) and/or a geographical area. These laboratories are operated at each ALC by AFMC (TO 00-20-14, 1992:1-4).

3. Type IIB; a base-level PMEL which can support aircraft, missiles, ground systems, and/or other equipment on base or in the local area (TO 00-20-14, 1992:1-4).

4. Type IIC; a PMEL providing support to research, development, test, and evaluation programs as well as other operational and support functions (TO 00-20-14, 1992:1-4).

5. Type IID; a PMEL tailored to satisfy a special mission (TO 00-20-14, 1992:1-4).

6. Type III; a PMEL tailored to satisfy a specific mission and normally receiving calibration support from a Type II laboratory (TO 00-20-14, 1992:1-4).

7. Type IV; a capability established to support a specific weapon system. It uses a transportable measurement system in both fixed and deployed locations (TO 00-20-14, 1992:1-4).

TMDE includes all equipment used to maintain, measure, calibrate, test, inspect, diagnose, or otherwise examine materials, supplies, equipment, and systems to identify or isolate actual or potential malfunctions, or to determine if they meet specifications established in technical documents (AFR74-2, 1990:2). All organizations performing intermediate maintenance tasks utilize TMDE in the performance of these duties. Regardless of the logistics support requirements dictated by the maintenance concept employed, the test and support equipment calibration responsibility rests with the PMEL.

Type IV PMELs provide calibration support for aircraft weapon systems, specifically F-15 and F-16 avionics weapon systems. Two-level maintenance focuses on flightline and depot maintenance as the primary levels of support for aircraft avionics (Ely, 1993:6). Many Line Replaceable Units (LRUs), Shop Replaceable Units (SRUs), and Automated Test Stations (ATSs) formerly maintained at the intermediate level will now be sent to depot for repair. The mandated change in maintenance concept will produce a ripple effect impacting the Type IV PMEL's mission. For this reason, this study will focus on Type IV F-15 and Type IV F-16 PMELs.

Importance of Research

The two-level maintenance concept significantly alters the structure of aircraft maintenance organizations. In this era of declining defense budgets, it is critical that all users of Air Force resources exercise effective planning to facilitate efficient utilization of these resources in the accomplishment of the Air Force mission. This research will attempt to qualify and quantify the effect of the two-level maintenance concept on Type IV PMELs. The data generated by this study will enable the AFMETCAL program and Headquarters AFMC to more effectively project future PMEL logistical support requirements for avionics systems on F-15 and F-16 aircraft.

Specific Problem

No study has been performed to evaluate the possibility of the implementation of F-15 and F-16 two-level maintenance resulting in the closure of associated Type IV PMELs. For the purpose of this research, it is assumed that two-level maintenance completely eliminates the intermediate level of maintenance. This study focuses on aircraft avionic weapon system maintenance logistical support issues relative to Air Force Type IV PMELs. As of this writing, many details of this process have yet to be determined. Because of a lack of information, it is difficult for Headquarters AFMC and AGMC decision makers to efficiently and effectively plan future logistical requirements.

Research Objective

The objective of this research is to determine the impact of logistical support requirements for F-15 and F-16 Type IV PMELs resulting from the implementation of two-level maintenance. The following investigative questions determine the impact of the implementation of two-level maintenance on Air Force Type IV F-15 and F-16 PMELs.

Investigative Questions

1. What changes in the maintenance concept for Type IV PMELs have occurred?
2. How are the changes for Type IV PMELs indicated?

3. How can the effects of the changes be measured?

4. What is the impact of these changes on the Type IV PMEL workload?

Measurement Questions

Measurement questions provide the information necessary to answer the investigative question (Emory and Cooper, 1991:79). The measurement questions were as follows:

1. What owning workcenters (OWCs) did you support prior to the implementation of two-level maintenance?

2. What was each OWC's total inventory?

3. How much of each OWC's total inventory is supported by the Type IV PMEL?

4. How many OWCs were eliminated or affected by the change in maintenance concept?

5. How many AIS strings/stations did you support prior to the implementation of two-level maintenance?

6. How many AIS strings/stations do you support now?

7. Has your unscheduled workload changed due to the change in maintenance concept?

8. What was/is your total inventory?

9. Are you being tasked to perform duties usually reserved for avionics personnel since experienced avionics technicians have been reduced in number or eliminated?

Scope and Limitations

The mission of Type IV PMELs is to support F-15 and F-16 avionics weapon systems. Due to the limitations of time, cost, and availability of the sampling population, nonprobability sampling was used in this research. The technique chosen to perform nonprobability sampling was the purposive judgement sampling technique. In this technique, the researcher handpicks the sample members based on an assumed level of experience (Emory and Cooper, 1991:275). This research examines seven Type IV PMELs in general and focuses on the Type IV PMELs at Langley and Shaw Air Force Bases. These two Type IVs were selected because they are the only Type IV PMELs where two-level maintenance has been implemented long enough for relevant data to exist.

Thesis Overview

Chapter I introduces this thesis research, provides background information concerning the selected topic, identifies the specific problem, establishes the research objective, and discusses the importance of this research.

Chapter II summarizes the literature review performed as part of this research project. The chapter presents a brief discussion of the history of aircraft maintenance, discusses the two-level and three-level maintenance concepts, and discusses some current initiatives relative to this study.

Chapter III discusses the methodology that was followed in completing this research project. Topics include the research methodology, sample selection process, data collection steps, and data analysis.

Chapter IV presents the results of the data analysis. The answers to the measurement questions provide information necessary to formulate the answers to the investigative questions. The discussion includes the formalized answers to the investigative questions.

Chapter V presents the conclusions derived from this research and offers suggestions for future research.

II. Literature Review

Introduction

The political, social, technical, and economic conditions in the world are rapidly changing. Events such as the breakup of the Soviet Union and the reunification of Germany have changed the focus of the perceived military threat. The United States has claimed victory in the Cold War. The Department of Defense (DoD) is reacting to the political and economic changes in predictable fashion.

Faced with a reduced budget, the Department of Defense is downsizing and restructuring under the Global Reach, Global Power doctrine. The United States Air Force, in turn, is forced to streamline and implement dramatic changes to existing processes. Air Force units are being asked to curtail management layers, speed decision making, reduce overhead, streamline operations, and devise improved business practices.

One example of the changes taking place occurred in 1992. The Air Force created a new command, the Air Force Materiel Command (AFMC), by merging the Air Force Systems Command (AFSC) with the Air Force Logistics Command (AFLC). This merger embraced the new philosophy of Integrated Weapon System Management (IWSM), the "cradle to grave" management of all Air Force Systems, as the guiding management concept for the new command (Przemieniecki, 1993:93-94).

Another concept currently being adapted into Air Force logistics policy is Lean Logistics. Lean Logistics is a focused project to integrate state-of-the-art business practices such as two-level maintenance into the broad area of Air Force logistics (Ziegler, 1994). Implementation of the two-level maintenance concept is the focal point of this research.

The remainder of this chapter presents a brief history of Air Force maintenance organizations. The concept of decentralized versus centralized maintenance, which may be equated to the three-level and two-level maintenance concepts, respectively, is introduced. The three-level and two-level maintenance concepts are further defined, and some relevant integrated logistics support issues are discussed. Finally, a brief discussion of some current issues of interest to the maintenance community is presented.

History

An examination of current defense journals revealed a myriad of articles related to the new world order, the public mandate to balance the federal budget, and the reduction in the defense budget. The history of logistics (and more specifically maintenance) is also well documented.

A general conclusion is that during times of peace or times of economic depression, the defense budget is usually reduced, and the military establishment must search for more efficient and effective means of conducting business. The aircraft maintenance community generally adopts a more centralized maintenance concept during these times. Centralization requires less equipment and manpower and accomplishes more efficient utilization of retained resources.

In contrast, during threatening times, times of war, or times of economic prosperity, the defense budget supports less austere measures. The aircraft maintenance community tends to adopt a more decentralized maintenance concept. This concept reduces the dependency on the resupply system by reducing the logistics tail size and by providing intermediate level repair capability at the flightline.

The first aircraft maintenance was performed by the owner or operator. It was not long before the complexity of aircraft technology began to increase. During World War I, the trend was toward maintenance specialization. During World War II, the complexity of aircraft continued to increase. The B-29 was one of the newest members of the inventory and was very complicated. In addition, jet technology was being developed. Following

World War II, with leaner budgets and constrained manpower, aircraft maintenance was predominantly centralized (Peppers, 1988:139-141). During the Korean War, a Rear Echelon Maintenance Combined Operation (REMCO) was established in Japan. The centralization of maintenance activities at the REMCO worked well but was not favored by the tactical commanders (Peppers, 1988:158-159). Although the centralized concept prevailed following World War II and the Korean conflict, Vietnam once again brought a shift toward decentralized maintenance (Przemieniecki, 1993: 303).

In the early 1970s, the drawdown from Southeast Asia led to a reduced defense budget, and aircraft maintenance organizations shifted toward a more centralized structure to cut military costs. Beginning in the late 1970s and continuing through the Reagan presidency, an ample military defense budget once again supported a decentralized aircraft maintenance concept. Finally, at the end of the Cold War, the emphasis is now on reducing the national debt and reducing the military defense budget. These factors are forcing the Air Force to streamline. The recent shift to two-level maintenance for engine and avionics repair is an attempt to save money by reducing manpower, equipment, and facility requirements.

Because an understanding of the three-level maintenance concept and the two-level maintenance concept is necessary to grasp the significance of changing from one concept to the other, definitions of these concepts are presented next.

Three-Level Maintenance Concept

Three-level maintenance is comprised of three distinct levels of maintenance: organizational, intermediate, and depot (AFR66-14, 1986:3). Organizational level maintenance is decentralized; it is accomplished on the aircraft and is conducted at the unit level for each base having assigned operational aircraft (AFR66-14, 1986:3). Intermediate maintenance tasks are decentralized when performed in the field but may be considered centralized when end items are repaired at fixed installations. Finally, depot maintenance tasks are centralized at locations to support specific geographical area needs or designated product lines (Blanchard, 1992:116).

Maintenance tasks assigned to each level are determined by several factors. Organizational tasks are normally limited to periodic checks of equipment performance, visual inspections, cleaning of equipment, some servicing, external adjustments, and the removal and replacement of some components (Blanchard, 1992:115). Intermediate maintenance tasks are generally more complex, require more specialized test equipment, specialized facilities, and higher skilled personnel than those at the organizational level (Blanchard, 1992:115). An example of intermediate maintenance is the fault isolation and in-shop repair of line replaceable units (LRUs) through the removal and replacement of shop replaceable units (SRUs) (O'Reilly, 1979:157). Depot maintenance includes complete overhaul, rebuild, and calibration of equipment as well as the performance of highly complex maintenance actions (Blanchard, 1992:116).

Two-level Maintenance Concept

The intermediate maintenance level is the focal point of the most recent two-level maintenance reorganization. The two-level maintenance concept currently being introduced into the Air Force has the potential to greatly affect mobility and associated planning efforts. Basically, under the two-level maintenance concept the intermediate, or shop-level, maintenance transfers from the operational wing to a depot (Cox, 1994). Two-level maintenance does not do away with one level of maintenance. Rather, it seeks only to redefine the levels and, if feasible, centralize some measure of intermediate-level functions at the AFMC depots (Smith, 1992:27).

Impacts

On the average, over 50 percent of life cycle cost dollars are spent on operations and maintenance (logistics support) (Blanchard, 1992:72). Changing to the two-level maintenance concept will impact integrated logistics support elements, such as manpower, support equipment, facilities, training, technical orders, spares, and transportation. Although two-level maintenance is being implemented to generate savings in these areas, it is difficult to predict the savings. As of this writing, many details of this process have not yet been determined. For example, the two-level maintenance concept will decrease manpower requirements, but the extent of the cuts required are not known at this time (Guide, 1993:1-1). A second example is the issue of the number of spares. An increase in the number of spares required would logically increase the PMEL workload; however, the two-level implementation guidance precludes the acquisition of additional spares (Guide, 1993:1-1).

Another issue is the detection of "false" failures. Such bench check serviceable (BCS) occurrences can represent a significant portion (between 20% and 30%) of the intermediate level avionics workload (Guide, 1993:7). Individual LRUs and SRUs that repeatedly enter the repair cycle at a higher rate than the total population of like items are identified as bad actors (Guide, 1993:8-1). For avionics, it is assumed that one test station of each type will be left at each operating base to reduce the BCS problem (Guide, 1993:10).

The type of technology in use is a critical factor in terms of maintenance costs. With the advent of digital technology, the complexity of TMDE has increased. More support equipment, technical data, and skilled personnel are generally required to fault isolate and diagnose equipment malfunctions (O'Reilly, 1979:156). O'Reilly states that effective two-level maintenance necessitates the capability to fault isolate down to the SRU level on the aircraft. He states that this capability would eliminate the requirement for intermediate maintenance. Most present-day aircraft on-board systems and flight line systems can fault isolate the malfunction only to the LRU (O'Reilly, 1979:159-160). This troubleshooting limitation causes the selection of two-level candidates to be more difficult. The selection of candidates for two-level maintenance is a joint decision between the using MAJCOMs and the system program directors, with the coordination of the product group managers (Guide, 1993:3-1).

Current Initiatives

O'Reilly suggests that the two-level maintenance concept is the most expensive if the LRU must be returned to the depot (O'Reilly, 1979:160). Capability must be developed to fault isolate to a specific component in the aircraft and replace only that piece (O'Reilly, 1979:160). As mentioned earlier, this capability is feasible only if the ability exists to fault isolate down to the SRU level on the aircraft. However, it cannot be achieved using external test equipment but must be achieved via built in test (BIT). Digital technology has made BIT possible.

Most installed avionics equipment is exposed to the weather during maintenance. The PC card is incapable of withstanding the rough handling and exposure to the elements associated with organizational level maintenance (O'Reilly, 1979:160). To overcome this problem, Westinghouse has developed a PC board packaging concept which provides a rugged, easily removed and replaced module (O'Reilly, 1979:160). This "Line Replaceable Module" (LRM) eliminates the need to send LRUs to the depot. To effectively utilize aircraft space and to simplify wiring requirements, an equipment drawer is being designed. The single drawer would house all LRMs. When the drawer is extended, full access is provided to the LRMs. Design efforts include common components to reduce complexity, weight, and cost (O'Reilly, 1979:161). Maintenance requirements are also reduced by the increased reliability inherent in digital technology.

Lean Logistics is currently being adopted as part of Air Force logistics policy. Lean Logistics is a focused project to integrate state-of-the-art business practices such as: two-level maintenance, just-in-time (JIT), door-to-door, and pipeline visibility into the broad area of Air Force logistics. The goal of implementing this concept is to provide the customer with the best possible product, at the lowest possible cost, in the shortest possible amount of time. Specifically, under this concept, reparables pipeline times will be reduced, express transportation will be used, and right size inventory will be maintained. The reparables pipeline reduction will be accomplished by improving operations at depots and requiring more responsive service from contractors. Express transportation will require greater reliance on commercial carriers for door-to-door service. The resulting improvement in transportation service of increased flexibility and reduced travel time will also contribute to the reduction in the reparables pipeline. Improved depot operations, more responsive service from contractors, and reliance on express transportation permit a dramatic change in inventory management. The current inventory system bases stock levels on a "just-in-case" perspective, whereas Lean Logistics bases stock levels on a "guaranteed-on-time" perspective, thereby allowing inventory levels to be reduced to the "right size." Lean Logistics will ultimately result in a "smaller logistics infrastructure providing strong, less costly weapon system support to operational users, in peace and war" (Ziegler, 1994).

Conclusion

The chapter began with a review of the history of aircraft maintenance. The review was followed by a discussion of the three-level maintenance concept and the two-level maintenance concept, in turn. The chapter then discussed some of the integrated logistics support elements and highlighted the uncertainty associated with predicting their impact. Factors such as the system's fault isolation capability, BCS actions, bad actors, and the selection criteria used to identify two-level LRUs were discussed. In addition, the chapter presented a brief discussion of current initiatives designed to eliminate the necessity to remove and replace LRUs. Development of this capability could potentially result in tremendous monetary savings. Systems employing this technology will be designed and fielded for two-level maintenance support. Finally, the chapter presented a brief discussion of Lean Logistics. Chapter III presents the methodology used for analysis.

III. Methodology

Introduction/Overview

This research was conducted using the descriptive study method. In this type of study, the researcher is concerned with finding out who, what, where, when, or how much (Emory and Cooper, 1991:148). Figure 1 provides an overview of the research process. The topic selection was based on the researcher's personal interest and experience. The problem focus was formalized and investigative questions were applied to examine Type IV Precision Measurement Equipment Laboratory logistics support issues relative to the implementation of F-15/F-16 two-level maintenance. The research method was selected, and the population to be studied was identified (sample selection).

Investigative Questions

In order to answer the management question, the following investigative questions were formulated:

1. What changes in the maintenance concept for Type IV PMELs have occurred?
2. How are the changes for Type IV PMELs indicated?
3. How can the effects of the changes be measured?
4. What is the impact of these changes on the Type IV PMEL workload?

Research Methods

Because of the exploratory nature of this study, an empirical research methodology was employed. The case study research design was determined to be the most suitable research methodology. A case study is an empirical inquiry that investigates a

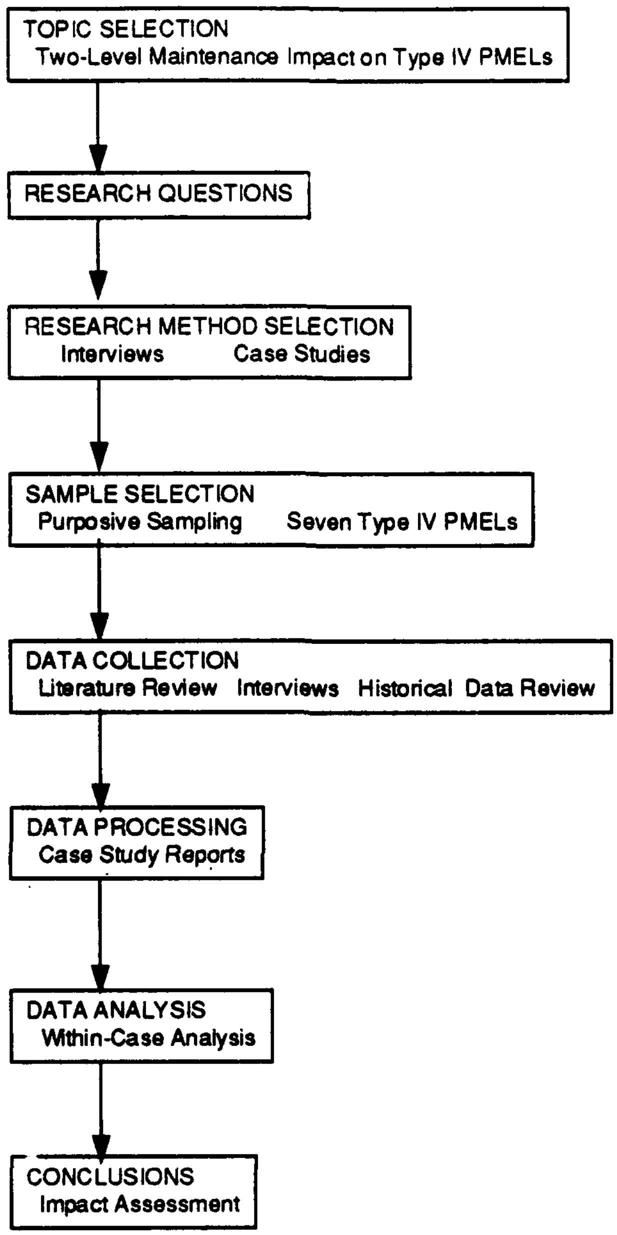

Figure 1. Steps in the Research Process

contemporary phenomenon within its real-life context when the boundaries between phenomenon and context are not clearly evident and which uses multiple sources of evidence (Yin, 1984:23). According to Yin, the case study is a research design particularly suited to situations where it is impossible to separate the phenomenon's variables from their context. Case studies may involve single or multiple settings and can be used for providing descriptions, testing theory, and generating theory (Eisenhardt, 1989:534-535). This research effort focused on a few selected Type IV PMELs deemed to be representative of the population as a whole. This research effort consisted of gathering information from seven Type IV PMELs for the purpose of generating a profile of a typical Type IV PMEL workload and assessing the effect of the implementation of the two-level maintenance concept.

Sample Selection

Sample size is a function of the variation in the population parameters under study and the estimating precision needed by the researcher (Emory and Cooper, 1991:248). The number of cases required for a good study is a product of many factors. Eisenhardt suggests that the number of cases studied should range between four and ten (Eisenhardt, 1989:545). Due to the limitations of time, cost, and availability of the sampling population, nonprobability sampling was used in this research. The technique chosen to perform nonprobability sampling was the purposive judgement sampling technique. In this technique, the researcher handpicks the sample members based on an assumed level of experience (Emory and Cooper, 1991:275). The actual sample selection was based on the individual Type IV PMEL chief's interest in and willingness to support this study. The selection process resulted in a cross-section of representative Type IV PMELs.

This research focused on Type IV PMEL maintenance for two types of aircraft at seven different locations. The study included the F-15 Type IV PMELs located at Eglin AFB, Florida; Otis ANGB, Massachusetts; and Langley AFB, Virginia. In addition, the study included the F-16 Type IV PMELs located at Springfield, Ohio; Wright-Patterson AFB, Ohio; and Shaw AFB, South Carolina. Last, the study included the F15/16 Type IV PMEL located at Mountain Home AFB, Idaho.

Data Collection

Data collection was accomplished by using three methods: literature review, interviews, and examination of historical maintenance data. First, a literature review was conducted. Recent research studies, Department of Defense directives, Air Force regulations, professional journals, and other current writings were examined to provide background information for this research. The literature review provided a summary of the logistics policies, procedures, and plans covering the implementation of the two-level avionics weapon system maintenance concept.

On-site interviews, telephone interviews, and electronic mail interviews were used to supplement data from the literature review. First, an on-site interview was conducted at Headquarters AFMC. This interview provided information that helped to determine the scope of this study by revealing the current status of the conversion to two-level maintenance. Also, on-site interviews with personnel from the F-15 and F-16 SPOs provided valuable information with regard to the similarity of avionics weapon system support requirements for different series aircraft. In addition, the researcher learned the composition of the Avionics Intermediate Shop (AIS) string used to support each series aircraft and the modules contained in each AIS station. The final on-site interviews were conducted with the chief of the F-16 Type IV PMELs located at Wright-Patterson AFB, Ohio, and Springfield ANGB, Ohio. These on-site observations were employed to familiarize the researcher with Type IV PMEL and AIS shop operations.

Telephone and electronic mail interviews were conducted with the chief of the F-16 Type IV PMEL at Shaw AFB, South Carolina; with the chief of the F-15 Type IV PMELs located at Eglin AFB, Florida, Otis ANGB, Massachusetts, and Langley AFB, Virginia; and with the chief of the F15/16 Type IV PMEL located at Mountain Home AFB, Idaho. All personnel interviewed were asked a series of measurement questions. The measurement questions were as follows:

1. What owning work centers (OWCs) did you support prior to the implementation of two-level maintenance?

2. What was each OWC's total inventory?

3. How much of each OWC's total inventory is supported by the Type IV PMEL?

4. How many OWCs were eliminated or affected by the change in maintenance concept?

5. How many AIS strings/stations did you support prior to the implementation of two-level maintenance?

6. How many AIS stations/strings do you support now?

7. Has your unscheduled workload changed due to the change in maintenance concept?

8. What was/is your total inventory?

9. Are you being tasked to perform duties usually reserved for avionics personnel since experienced avionics technicians have been reduced in number or eliminated?

The third method examined maintenance production data in an attempt to detect a change in the workload requirement. The data necessary to support this thesis were broken down into two primary categories: current maintenance data collection information under the two-level maintenance concept and historical maintenance data collection information under the three-level maintenance concept. The required information is contained in the PMEL Automated Maintenance System (PAMS) history file. The maintenance production information was requested by model/part number and manhours per item for the first two quarters of FY94 from both Langley AFB and Shaw AFB. These two bases were the only two CONUS bases where two-level maintenance had been implemented at the time of this study. Although this is a small sample size, these quarters were the only two quarters of production completed under the two-level maintenance concept at the time this study was conducted. The same information was requested for the same two quarters of FY93. This information provided an historical basis for statistical comparison. The data from the same two quarters were used in an attempt to eliminate any differences due to seasonal variations. Sample data listings from Shaw AFB and Langley AFB are shown in Appendix A and Appendix B, respectively.

Data Analysis

Data were analyzed in relation to the four investigative questions. While there are many ways to analyze and present data, this researcher chose to create tables to present the information gained from the responses to the first four measurement questions. According to Miles and Huberman, narrative text alone is too weak and cumbersome for presenting information in a systematic manner. These researchers recommend the use of displays, like tables, for highlighting similarities and differences and allowing for a more refined data analysis (Miles and Huberman, 1984:21). Once the data analysis was completed, the responses relative to the management question were formulated.

What Changes Have Taken Place?

What changes in the maintenance concept for Type IV PMELs have occurred? This may seem like a rhetorical question given that the change in maintenance concept precipitated this study. However, for the first investigative question, the primary information needed to formulate an answer was contained in the literature review. Current DoD directives, recent AFIT theses, current journal articles, Air Force regulations, Air Force technical orders, and other sources were examined for relevant information. The researcher learned that two-level maintenance was being applied to two commodities relative to this study: avionics weapon systems and engines. Also, the literature review provided the current status of the two-level implementation process.

How Are the Changes Indicated?

How are the changes for Type IV PMELs indicated? This question served to guide the researcher in the formulation of the measurement questions that provided the "core" information needed in this study. A brainstorming session attended by the AFMC PMEL functional area manager, a technical advisor, and the researcher determined how the changes would be indicated. As a result, careful development of the measurement questions ensured proper response would provide valid and accurate data for usage in answering the research question.

Effects of the Change

How can the effects of the changes be measured? To answer this investigative question, responses provided to measurement questions #1, #2, #3, and #4 were examined. The information gained from the responses to these four questions was used to create a table for each survey location. The investigative question is answered in terms of number of work centers affected and percentage of workload affected. The answers to these questions are presented in narrative and tabular form, for each survey location, in Chapter IV. In addition, summary statistics are included in the presentation. The mean and standard deviation were calculated for the total inventory, the total workload supported by the Type IV PMEL, and the portion of the workload subject to two-level maintenance. Finally, the information was used to estimate the respective population parameters by using the t statistic. The T-Test was deemed appropriate because the population standard deviation is unknown and the Central Limit Theorem does not apply to small samples (McClave and Benson, 1991: 322-326). This test assumes the relative frequency distribution of the sampled population is approximately normal. The reliability of the estimate was expressed in terms of a confidence interval by using the small-sample estimation of a population mean.

Impacts of the Change

What is the impact of these changes on the Type IV PMEL workload? The data necessary to answer this question were derived from the maintenance production information collected by model/part number and man-hours per item from Shaw AFB and the AIS test station utilization data collected from Langley AFB. For the purpose of this study, the researcher determined to compare the model/part numbers serviced during the first two quarters under the two-level maintenance concept with the model/part numbers serviced during the same two quarters the previous year under the three-level maintenance concept.

The data from Shaw AFB were tested for significant differences in the variety of TMDE serviced by using the PROC ANOVA routine and the PROC TTEST routine in SAS. The PROC ANOVA routine was used to test the hypothesis that the variety of TMDE serviced during all four quarters is equal. The PROC TTEST routine was used to compare the six months of 2LM data with the six months of 3LM data. The hypothesis tested was as follows:

H_a: The two sampled populations do not have identical probability distributions.

In addition, the researcher deemed it necessary to examine the maintenance manhours expended. The purpose of this test was to determine if operation under the two-level maintenance concept resulted in the Type IV PMEL working a significantly different amount of man-hours. The PROC ANOVA routine was used to test the hypothesis that the man-hours expended during all four quarters are equal. The PROC TTEST routine was used to compare the six months of two-level maintenance data with the six months of three-level maintenance data. The hypothesis tested was as follows:

H_a: The two sampled populations do not have identical probability distributions.

The researcher then reexamined the information obtained from the F-16 Type IV PMEL located at WPAFB, Ohio. With the help and cooperation of assigned personnel, the researcher was able to calculate the maximum reduction in annual manhour requirement due to the implementation of the two-level maintenance concept. This organization was chosen due to location and availability of required data.

The data from Langley AFB were received in a different format. As a result, the data were tested in a different manner. The data contained information relative to the usage of individual AIS test stations. The researcher first used the PROC ANOVA routine in SAS to test the hypothesis that there was no difference in the utilization of the AIS test stations during any of the 12 months included in the study. Next, the PROC TTEST routine in SAS was used to test the hypothesis that the mean utilization of the AIS stations during the two-level maintenance period of observation equaled the mean utilization during the three-level maintenance period of observation.

Conclusion

This methodology approach provided useful data necessary to answer the investigative questions. Analysis of the answers to the investigative questions answered the research question and the management question. Data collection results and analysis of the collected data are reported in Chapter IV.

IV. Analysis

Introduction

This research focused on Type IV PMEL maintenance for two types of aircraft at seven different locations. The study included the F-15 Type IV PMELs located at Eglin AFB, Florida; Otis ANGB, Massachusetts; and Langley AFB, Virginia. In addition, the study included the F-16 Type IV PMELs located at Springfield, Ohio; Wright-Patterson AFB, Ohio; and Shaw AFB, South Carolina. Last, the study included the F-15/16 Type IV PMEL located at Mountain Home AFB, Idaho. This chapter describes the descriptive statistics, statistical tests, and the interview results and concludes with a summary of the analysis. The chapter begins by presenting the descriptive statistics that summarize the information contained in the sample. Numerical and graphical methods are employed to analyze and present the data. The next section presents the statistical tests performed on the maintenance production data provided by Langley AFB and Shaw AFB. The analysis is limited to these two bases because they were the first two CONUS bases to officially implement two-level maintenance (2LM) effective 1 October 1993. Due to the early stage in the 2LM conversion process, six months of production data, while operating in the 2LM concept, was not available for collection from these two bases until the following April. The interview results section presents the opinions of the Type IV Lab chiefs provided in response to measurement questions #5 through #9. The responses to each question are summarized in a table, and each table is followed by a discussion of the information. The chapter concludes by summarizing the data analysis.

Descriptive Statistics

The requested information provided by each Type IV PMEL was collected and analyzed in an attempt to develop a profile of a typical Type IV PMEL. This section discusses the F-15 Type IV PMEL and the F-16 Type IV PMEL, contrasts engine shop and AIS shop impacts on Type IV PMELs, and attempts to profile a typical Type IV PMEL.

The number of owning workcenters (OWCs) supported by the F-15 Type IV PMELs in this study ranged from 28 to 37, with an average of 32 OWCs. The total inventory reported for each OWC ranged from 1005 units to 2322 units, with an average of 1783 units. The workload supported by the Type IV PMEL ranged from 1005 units to 2322 units, with an average of 1783 units. The number of units subject to 2LM ranged from 340 to 527, with an average of 462 units. This figure represents approximately 26 percent of the F-15 Type IV PMEL workload.

The number of OWCs supported by the F-16 Type IV PMELs in this study ranged from 9 to 21, with an average of 19 OWCs. The total inventory reported for each OWC ranged from 828 units to 1010 units, with an average of 941 units. The workload supported ranged from 301 units to 984 units, with an average of 615 units. The number of units subject to 2LM ranged from 67 to 89, with an average of 75 units. This figure represents approximately 12 percent of the F-16 Type IV PMEL workload.

The data reported by the F-16 Type IV PMELs in this study seems to indicate the overall impact is shared equally by the engine shop and the AIS shop workload. Although Shaw AFB did not break down the number reported by shop, the total seems to fall in line with the numbers reported by the other F-16 Type IV PMELs. The average workload subject to 2LM is approximately 40 units for each shop. However, this equality does not appear to be the case for the F-15 Type IV PMELs. The F-15 Type IV PMEL workload impacted by 2LM and belonging to the engine shop is approximately 50 units. The number reported by Otis ANGB appears higher than that reported by the other F-15 Type IV PMELs, because it includes torque wrenches while the others do not. The workload impacted by 2LM and belonging to the AIS shop is approximately 413 units. This large number of units subject to 2LM and belonging to the AIS shop would appear to account for the F-15 percentage of workload subject to 2LM amounting to double the F-16 percentage.

Based upon the results of this small sample, it would appear the average F-15 Type IV PMEL supports more customers (32 vs 19), supports a larger workload (1783 vs 615), and has a larger percentage of the workload impacted by 2LM (26 vs 12) than does the average F-16 Type IV PMEL. However, because of the small sample size employed in this study, this researcher chose to consider all Type IV PMELs together in an attempt to profile a typical Type IV PMEL. Responses to measurement questions #1 through #4 were compiled and used to create Tables 1 through 7. Column number one of each table lists the OWCs supported by the Type IV PMEL. Although the identification of OWCs is not standardized, the number of OWCs supported by the Type IV PMELs in this study ranged from 21 to 37. Column number two of each table lists the total number of items of Test Measurement and Diagnostic Equipment (TMDE) owned by each OWC. These figures represent the total inventory owned by the Type IV PMEL customers. The total inventory reported in this study ranged in number from 828 to 2322. Column number three lists the number of the items of TMDE listed in column number two for which the Type IV PMEL has calibration responsibility. This number represents the Type IV PMEL workload. The workload reported ranged in number from 301 to 2322. Finally, column four lists the number of the items of TMDE supported by the Type IV PMEL owned by OWCs converting to the 2LM concept. TMDE belonging to the engine shop is identified by an "E" appearing after the number. TMDE belonging to the AIS shop is identified by an "A" appearing after the number. The items in this column represent 21 percent of the Type IV PMEL workload. This figure represents the maximum possible decrease in Type IV PMEL workload should every item be removed from the Type IV PMEL inventory. The results of this effort follow.

TABLE 1
Mountain Home AFB F-15/16 Type IV PMEL

Owning Workcenter	Total Inventory	Type IV Supported	2LM
366 OSS ABDR	9	9	
389 FS LIFE SUP	9	9	
390 FS LIFE SUP	18	18	
391 FS LIFE SUP	11	11	
366 AGE SUP	54	54	
366 REP/REC	2	2	
366 ARMAMENT	50	50	
366 CMU SUP	42	42	
366 STRUCT REP	2	2	
366 SURVIVAL	2	2	
366 WEAPONS	6	6	
389 SUP SECT	191	191	
390 SUP SECT	145	145	
391 SUP SECT	115	115	
366 MAT SUP	42	42	
366 JETC	5	5	
366 FUEL SYS	42	42	
366 EGRESS	19	19	
366 PNEU	4	4	
366 ELEC/ENV	2	2	
366 F-16 IAIS	10	10	10 A
366F-15 AIS	198	198	198 A
366 EW PODS	38	38	
366 LANTIRN	54	54	
366 T4 PMEL	369	308	
Total	1439	1378	208

Note 1: This Type IV PMEL does not support the engine shop. This support is provided by the Type II PMEL.

Note 2: At the time of this survey, this Type IV PMEL was expanding support to include F-16 aircraft. F-16 support equipment is being added as it is received.

TABLE 2
Otis ANG F-15 Type IV PMEL

Owning Workcenter	Total Inventory	Type IV Supported	2LM
102 Cam Sq/Dock	60	60	
102Cam Sq/Mach	1	1	
102 Cam Sq/Surv	12	12	
102 Cam Sq/NDIS	1	1	
102 Cam Sq/Jene	77	77	77 E
102 Cam Sq/Rerr	18	18	
102 Cam Sq/Fuel	30	30	
102 Cam Sq/Elec	8	8	
102 Cam Sq/Pneu	11	11	
102 Cam Sq/Envr	5	5	
102 Cam Sq/Egrs	7	7	
102 Cam Sq/Ager	17	17	
102 Cam Sq/Avfl	32	32	
102 Cam Sq/Vdeo	8	8	
102 Cam Sq/Mag	7	7	
102 Cam Sq/Avts	107	107	107 A
102 Cam Sq/Mats	156	156	156 A
102 Cam Sq/Maap	249	249	
102 Cam Sq/Maw	32	32	
102 Cam Sq/Wpnr	16	16	
102 Cam Sq/Muns	28	28	
102 Cam Sq/Lspt	7	7	
102 Cam Sq/Mtrp	8	8	
101 TCS/Worc	23	23	
103 TFG/Conn	2	2	
212 EIS/Worc	6	6	
Det 1, 102FW	10	10	
274 CCSG	3	3	
106 CAMS	12	12	
102 FW/Elect	4	4	
102 FW/FD	1	1	
Lockheed	10	10	
243 EIS/Me	6	6	
BSI	13	13	
265 CCSG/Me	2	2	
213 EIS/NY	5	5	
267Com/Comm	11	11	
Total	1005	1005	340

TABLE 3
Eglin AFB F-15 Type IV PMEL

Owning Workcenter	Total Inventory	Type IV Supported	2LM
33 LSS LSTD	20	20	
33 OSS ABDR	2	2	
33 OSS OSTS	9	9	
3752 FTS FTD320	29	29	
58 FS DOL	12	12	
59 FS DOL	15	15	
60 FS DOL	15	15	
33 MS MAGS	34	34	34 E
33 MS	32	32	
33 MS MANS	13	13	
33 MS MAN1	26	26	
33 MS MANB	16	16	
33 MS MANC	29	29	
33 MS MARS	35	35	
33 MS MAFE	20	20	
58 FS MAU	212	212	
59 FS MAV	181	181	
60 FS MAU	222	222	
33 MS MAPE	41	41	
33 MS MAPT	21	21	
33 MS MAPQ	22	22	
33 MS MACF	65	65	
33 MS MACG	14	14	
33 MS MACP	20	20	
33 MS MACE	24	24	
33 MS MAVT	260	260	260 A
33 LG/LSWR	11	11	
33 MS MAVE	233	233	233 A
33 MS MAVS	16	16	
33 MS MAV4	673	673	
Total	2322	2322	527

TABLE 4

Langley AFB F-15 Type IV PMEL

Owning Workcenter	Total Inventory	Type IV Supported	2LM
27 FS DOLS	2	2	
27 FS MAU	118	118	
71 FS DOL	1	1	
71 FS MAU	140	140	
94 FS DOL	2	2	
94 FS MAU	128	128	
1 EMS EMRS	33	33	
1 CRS CRVA	228	228	228 A
1 EMS EMGS	17	17	
1 CRS CRPG	14	14	
1 CRS CRPT	14	14	14 E
1 CRS CRPS	20	20	20 E
1 CRS CRCG	4	4	
1 CRS CRCC	9	9	
1 EMS EMUA	10	10	
1 EMS EMUB	6	6	
1 EMS EMUC	5	5	
1 CRS CRVS	18	18	
FTD	20	20	
1 CRS CRCF	37	37	
1 LSS LSTD	18	18	
1 CRS CRVM	3	3	
1 CRS CRVE	256	256	256 A
1 OSS OSOI	9	9	
1 CRS CRCP	11	11	
1 EMS EMFE	7	7	
1 EMS EMMR	20	20	
1 CRS CRVF	872	872	
Total	2022	2022	518

TABLE 5
Springfield ANG F-16 Type IV PMEL

Owning Workcenter	Total Inventory	Type IV Supported	2LM
Org. Maint.	45	21	
Powered Sup Eq	29	15	
Dock & OMS Sup	19	11	
Release & Guns	51	29	
Weapons Load	46	46	
Munitions Maint.	42	27	
NDI	11	0	
Aircraft Structural	6	0	
Survival Equip.	19	14	
Jet Engine	80	37	37 E
Mission Systems	119	46	
Fuel Systems	20	7	
Egress	18	6	
Pneudraulics	22	6	
Electro/Environ	32	19	
AIS	72	32	32 A
PMEL	147	48	
ECM	21	11	
Repair & Rec	8	5	
CAMs Admin	1	1	
Metals Technology	20	0	
Total	828	301	69

TABLE 6
WPAFB F-16 Type IV PMEL

Owning Workcenter	Total Inventory	Type IV Supported	2LM
Life support	16	4	
Powered Age	30	16	
Phase Dock	17	10	
Weapons Release	32	32	
Weapons Load	37	37	
Munitions Storage	36	19	
NDI	31	1	
Sheet Metal	1	1	
Survival	31	3	
Crew Chiefs	61	55	
Transportation	20	2	
Flightline Avionics	78	59	
Engine Buildup	34	21	21 E
Test Cell	35	21	21 E
Fuels	53	43	
Egress	18	11	
Pneudraulics	24	16	
Elect/Envir	51	34	
AIS	68	47	47 A
PMEL	167	81	
QA	4	0	
Communications	16	0	
Disaster Prepare	85	0	
PODS	56	39	
REPR	9	9	
Total	1010	561	89

TABLE 7
Shaw AFB F-16 Type IV PMEL

Owning Workcenter	Total Inventory	Type IV Supported	2LM
T4 PMEL	60	60	
20 CRS	101	101	67*
20 EMS	198	198	
77 FIGHTER SQ	198	198	
78 FIGHTER SQ	163	163	
79 FIGHTER SQ	160	160	
20 OP SUP SQ	54	54	
20 OP GP	28	28	
20 LOG SUP SQ	22	22	
Total	984	984	67

* Shaw AFB did not report totals by individual shop.

The totals from each case were compiled and analyzed to obtain summary statistics for use in the study. This information is presented graphically in Table 8.

TABLE 8
Composite of Seven Type IV PMELs

Type IV	Total Inventory	Type IV Supported	2LM
Spfld	828	301	69
WPAFB	1010	561	89
Otis	1005	1005	340
Eglin	2322	2322	527
Mt Home	1439	1378	208
Shaw	984	984	67
Langley	2022	2022	518
Total	9610	8573	1818
Mean	1372.86	1224.71	259.7
Std Dev	583.34	737.47	204.09
N	7	7	7
Confi Int	432.14	546.31	151.19

The mean and standard deviation were calculated for the total inventory, the total workload supported by the Type IV PMEL, and the portion of the workload subject to 2LM. This information was then used for population estimation using the t statistic. The interval estimates were made using $\alpha = 0.05$ and (n-1) degrees of freedom. The reliability of the estimate was expressed in terms of a confidence interval by using the small-sample estimation of a population mean. The form of the small-sample confidence interval was as follows:

$$\bar{x} \pm t_{\alpha/2} s / \sqrt{n}$$

where

$\bar{x}$ = The sample mean

$t_{\alpha/2}$ = The t value with an area $\alpha/2$ to its right

$s / \sqrt{n}$ = The parameter s is the sample standard deviation and n is the sample size

The following intervals were formed using a t value of 2.447. This value was extracted from the table for $t_{0.025}$ with (n-1) degrees of freedom = 6 (McClave and Benson, 1991).

The first small-sample confidence interval was estimated for the total inventory. The mean value used was 1373 and the standard deviation used was 583. The interval estimate of the population total inventory ranged from 834 to 1912.

The next small-sample confidence interval was estimated for the total workload supported. The mean value used was 1225 and the standard deviation used was 737. The interval estimate of the population total workload supported ranged from 543 to 1906.

The final small-sample confidence interval was estimated for the total inventory affected by 2LM. The mean value used was 260 and the standard deviation used was 204. The interval estimate of the population total inventory affected by 2LM ranged from 71 to 449.

Statistical Tests

The maintenance production data from Shaw AFB contained information pertaining to the number and variety of model/part numbers actually processed as well as the actual maintenance man-hours expended. Results of statistical analysis support the null hypothesis that both the mean of the variety of model/part numbers and the mean of the maintenance hours expended are equal for both periods of observation (six months of three-level maintenance (3LM) vs six months of 2LM). The data provided by Langley AFB contained information pertaining to the actual usage of the AIS stations. Results of statistical analysis support the null hypothesis that the mean level of usage of the AIS stations was equal under both the 3LM concept and the 2LM concept for the period of observation.

Variety of Equipment. The data from Shaw AFB were tested for significant differences in the variety of TMDE serviced by using the PROC TTEST routine in SAS. The two quarters of maintenance production data collected after conversion to 2LM were compared to the maintenance production data collected for the same two quarters the previous year while operating in the 3LM concept. The test of hypthesis (ToH) that the variances are equal was not rejected due to the 0.8624 p-value, which was considerably larger than the 0.05 alpha used for this test. The ToH that the variety of TMDE serviced under 3LM and the variety of TMDE serviced under 2LM are equal was not rejected due to the 0.6864 p-value, which is considerably larger than the 0.05 alpha used for this test. The researcher then conducted additional tests on this data. The PROC ANOVA routine in SAS was used to test the hypothesis that the variety of TMDE serviced during all four quarters are equal. The ToH was not rejected due to the 0.9750 p-value, which was considerably larger than the 0.05 alpha used for the test. The implication is that there is no evidence that the probability distributions from which the samples were drawn are different. This would suggest that two-level maintenance has made no significant difference in the variety of TMDE serviced by the Shaw AFB F-16 Type IV PMEL.

Man-hours Expended. The data from Shaw AFB were tested for significant differences in the number of man-hours expended by using the PROC TTEST routine in SAS. The two quarters of maintenance production data collected after conversion to 2LM were compared to the maintenance production data for the same two quarters the previous year while operating in the 3LM concept. The ToH that the variances are equal was rejected due to the 0.0000 p-value, which was considerably smaller than the 0.05 alpha used for this test. The ToH that the man-hours expended under 3LM and the man-hours expended under 2LM are equal was not rejected due to the 0.3341 p-value, which is considerably larger than the 0.05 alpha used for this test. The researcher then conducted additional tests on this data. The PROC ANOVA routine in SAS was used to test the hypothesis that the man-hours expended during all four quarters are equal. The ToH was not rejected due to the 0.6144 p-value, which was considerably larger than the 0.05 alpha used for the test. The implication is that there is no evidence that the probability distributions from which the samples were drawn are different. This result would suggest that two-level maintenance has made no significant difference in the number of man-hours expended servicing TMDE by the Shaw AFB F-16 Type IV PMEL.

Actual Man-hours--Worst Case. The researcher determined that additional insight could be gained if the workload affected by 2LM could be translated into man-hours. The F-16 Type IV PMEL located at WPAFB, Ohio, was chosen for this test due to its location and the availability of required data. With the help and cooperation of assigned personnel, the researcher was able to calculate the maximum reduction in man-hour requirement due to the implementation of the 2LM concept. The calculated man-hour reduction was 418 hours. Based upon 2080 hours of work per year, this number equates to a reduction of approximately one-fifth of a man-year. The calculations are presented in Appendix C. The reader is reminded that this is a worst-case approximation.

AIS Use. The data from Langley AFB were tested for significant differences in the utilization of the AIS stations. The first test was performed by using the PROC ANOVA routine in SAS. The ToH was that there was no difference in utilization of the AIS stations for any of the 12 months included in the study. The hypothesis was not rejected due to the 0.7202 p-value, which was considerably larger than the 0.05 alpha used for this test. The researcher then conducted additional tests on this data. The utilization data were aggregated into classes by type maintenance concept: 3LM and 2LM. Next, a test was conducted using the PROC TTEST routine in SAS. The ToH for equal variance was not rejected due to the 0.1457 p-value, which was larger than the 0.05 alpha used for this test. The ToH that the mean utilization of the AIS stations while operating in a 3LM concept equals the mean utilization of AIS stations while operating in the 2LM concept was not rejected due to the 0.3806 p-value, which was larger than the 0.05 alpha used for this test. The results of both statistical tests support the conclusion that changing to the 2LM concept has not significantly changed the utilization rate of the AIS stations at the Langley AFB F-15 Type IV PMEL.

The alpha value used for all tests was 0.05. The results of the T-Tests performed are summarized in Table 9. The results of the ANOVA tests performed are summarized in Table 10.

TABLE 9
Summary of T-Tests

TEST	T	DF	P-VALUE	REJECT
VARIETY	-0.4039	710.0	0.6864	NO
MAN-HOURS	-0.9666	672.3	0.3341	NO
AIS USAGE	-0.8823	70.0	0.3806	NO

TABLE 10
Summary of ANOVA

TEST	F-VALUE	DF	P-VALUE	REJECT
VARIETY	0.07	3	0.9750	NO
MAN-HOURS	0.60	3	0.6144	NO
AIS USAGE	0.71	11	0.7202	NO

<u>Interview Results</u>

Interviews were conducted with the Type IV PMEL lab chiefs. These individuals retain the responsibility for day-to-day laboratory operations. Through the Type IV laboratory chiefs' responses, the researcher sought to generally understand the opinion of those in the field with regard to the impact of the change to the 2LM concept. Measurement questions #1 through #4 were discussed earlier in the Descriptive Statistics section. The following four tables present the answers to measurement questions #5 through #9.

Question #5 and #6: How will 2LM change the number of AIS strings/stations supported?

TABLE 11
AIS Strings/Stations

Base	No Change	Increase	Decrease
Mt Home	X		
Shaw		X	
Springfield	X		
Eglin			X
Otis	X		
WPAFB	X		
Langley			X

Conclusion: The responses to questions #5 and #6 serve to illustrate that at least one AIS string will remain in operation at each location studied. Shaw AFB dropped one string but added two Improved AISs. Langley AFB changed from 24 stations to 18 stations. The smaller Type IVs support one AIS string and will continue to do so. The general conclusion of this researcher is that the change in the number of AIS stations supported will be small and will not significantly impact the Type IV PMEL workload.

Question #7: Has your unscheduled workload changed due to the change in maintenance concept?

TABLE 12
Unscheduled Workload

Base	No Change	Increase	Decrease
Mt Home	X		
Shaw	X		
Springfield	X		
Eglin	X		
Otis	X		
WPAFB	X		
Langley		X	

Conclusion: The unscheduled workload will not change significantly due to 2LM. Shaw AFB did not report an increase in unscheduled workload, while Langley AFB reported a slight increase in unscheduled workload. It is interesting to note the observation of the Mountain Home Type IV lab chief, who reported that the support requirement has decreased slightly in terms of numbers of items supported but has not changed in terms of number of specific types of equipment supported. This observation is in complete agreement with the results of the statistical analysis performed regarding variety of equipment.

Question #8: What was/is your total inventory?

TABLE 13
Total Inventory

Base	No Response	Old Inventory	Current Inventory
Mt Home	X		
Shaw	X		
Springfield	X		
Eglin	X		
Otis	X		
WPAFB	X		
Langley		2079	2028

Conclusion: The lack of response to this question is probably due to the fact that most of the respondents have not converted to 2LM as of this study. Those who have converted have experienced a decrease of from 50 to 70 items. This reduction represents a two to three percent decrease. It is interesting to contrast this result with the information presented on page 30, which serves to illustrate that AIS and engine support, in total, comprise approximately 21 percent of the Type IV workload. This result supports the general conclusion that the Type IV PMEL workload will not change significantly due to the implementation of 2LM. This question will provide more meaningful information after 2LM has been fully implemented.

Question #9: Are you being tasked to perform duties usually reserved for avionics personnel since experienced avionics technicians have been reduced in number or eliminated?

TABLE 14
Extra Duties

Base	Yes	No
Mt Home	X	
Shaw		X
Springfield		X
Eglin	X	
Otis	X	
WPAFB		X
Langley	X	

Conclusion: Although this is a small sample of the population, the responses seem to indicate that PMEL technicians may in fact become, "the only game in town." This would be the case if electronic technicians from the AIS shops are eliminated. At least one Type IV reported that PMEL technicians know more about the AIS stations than the people running the stations. Also, several respondents indicate that PMEL technicians are being tasked to assist in station troubleshooting.

Summary

The researcher was able to profile a typical Type IV PMEL. Descriptive statistics were applied to predict total inventory, the total workload supported, and the workload affected by the implementation of the 2LM concept. The total inventory reported ranged from 828 to 2322, with a mean value of 1373 and standard deviation of 583. The total workload supported ranged from 301 to 2322, with a mean value of 1225 and standard deviation of 737. The workload impacted by 2LM ranged from 69 to 527, with a mean value of 243 and standard deviation of 202. Interval estimates of the population parameters were accomplished. The customer base of the typical Type IV PMEL represents a total inventory ranging from 834 to 1912 units. Of this number, the support provided by the Type IV PMEL ranges from 543 to 1906 units. The portion subject to 2LM ranges from 56 to 430 units. The relatively large spread in the estimated parameters may be attributed to the small sample size. The researcher is 95 percent confident that μ (mu) lies between the lower and upper confidence bounds of the confidence interval. This statement reflects the researcher's confidence in the estimation process rather than in the particular interval calculated from the sample (McClave and Benson, 1991: 314).

In addition, the researcher was able to execute statistical comparisons of pre-and post-2LM implementation maintenance production data and AIS station utilization data. The variety of TMDE serviced, man-hours expended, and AIS station utilization rates were found to be statistically equal under both maintenance concepts. However, the small sample size may limit the generalizability of the study.

Both the opinion of the Type IV lab chiefs interviewed and the results of the statistical tests performed suggest that the implementation of 2LM has little or no impact on the Type IV PMEL workload. In addition, in the opinion of the Type IV lab chiefs, the Type IV PMEL technicians will probably be called upon more frequently to perform troubleshooting and maintenance tasks formerly accomplished by AIS personnel.

V. Conclusions

Introduction

All organizations performing maintenance, regardless of the level, utilize test and support equipment in the performance of their duties. All test and support equipment must be properly maintained and calibrated to include accuracy certification traceable to Air Force or national reference standards. The Precision Measurement Equipment Laboratory (PMEL) is the base-level organization authorized to possess certified reference standards for the purpose of providing this calibration accuracy trail. Under the two-level maintenance (2LM) concept, maintenance tasks performed at the intermediate level are transferred to a centralized repair facility. Without a thorough understanding of the concept, one might assume this eliminates the intermediate level of maintenance. A Type IV PMEL is an intermediate level organization providing calibration support for F-15 and F-16 aircraft. Members of the Air Force Metrology and Calibration (AFMETCAL) community share a concern about how the implementation of 2LM will affect Type IV PMEL operations. The purpose of this study was to determine how the conversion to 2LM will impact the Type IV PMEL.

Conclusions

In the opinion of this researcher, **2LM impacts on Type IV PMELs are negligible**. At the present time, 2LM applies to avionics and engines. All equipment previously supported by the Type IV PMEL still requires support. Indeed, the majority of the Type IV PMEL workload is derived from flightline shops other than the avionics intermediate support (AIS) shop and engine shop. Under the 3LM concept, the Type IV PMEL provided some support to the engine shop, but the majority of the engine shop's TMDE was calibrated by a Type II PMEL or a depot. Thus, for engine TMDE, changing to 2LM does not significantly impact the Type IV PMEL.

In addition, not all line replaceable units (LRUs) supported by the AIS shop are affected by 2LM. LRUs with a high mean time between failure (MTBF) rate will continue to be supported by the 3LM concept. Also, the concern over LRUs that retest okay (RTOK), the length of the logistics tail, and the limited number of spares has prompted decision makers to leave one AIS string in place to test all LRUs at the intermediate level before transporting them to the depot. As a result, the Type IV PMELs experienced no reduction in the variety of avionics TMDE serviced, and little, if any, reduction in total workload supported.

Recommendations

The data investigated here indicte that the conversion to 2LM has not diminished the workload of the Type IV PMELs to any great extent. Logistical support planning should continue to include the Type IV PMELs. In the absence of AIS shop electronic technicians, PMEL technicians may be called on to perform maintenance troubleshooting and repair tasks formerly accomplished by AIS shop personnel. **Consequently, maintenance planners should consider expanding the role of PMEL technicians to include electronic troubleshooting and repair actions formerly performed by AIS personnel.**

Future Research

This study was limited by a lack of available data due to the 2LM conversion process being in its infancy. Therefore, a study should be conducted one year after the 2LM conversion process is completed. This study should include all types of PMELs on a worldwide basis. The Type IIA PMELs located at the depots should be studied to see if their workload has increased due to 2LM. In addition, the other Type II laboratories, as well as the Type III laboratories, should be studied for 2LM impacts. Lastly, the Type IV PMELs should be reexamined.

Summary

Although the sample size employed in this study was small, the researcher was able to profile the customer base supported by a typical Type IV PMEL and to demonstrate that a very small percentage of the customer base is affected by 2LM. In addition, statistical analysis of historical maintenance data supplied by the first Type IV PMELs to convert to 2LM revealed no change in the variety of TMDE serviced, no change in the mean number of man-hours expended servicing TMDE, and no change in the utilization of AIS stations.

Given that limited resources are the driving force behind current downsizing and restructuring efforts, it is important for decision makers to make the right decisions. The current maintenance concept in support of F-15 and F-16 aircraft is neither pure 2LM nor pure 3LM but a combination of both. The Type IV PMEL will continue to play a vital role in support of these aircraft. Future aircraft acquisition design efforts should incorporate the 2LM concept in the maintenance plan in order to realize the dollar savings offered by the 2LM concept.

Appendix A: Shaw AFB Sample Maintenance Data

Part Number	Noun	Date	Units
2070	TORQUE WRENCH	93316	1
1001SM0	TORQUE WRENCH	93301	1
1001SM0	TORQUE WRENCH	93300	1
1001SM0	TORQUE WRENCH	93351	1
1009KG	PRESS GAGE	93351	1
100UU	PRESS GAGE	93327	1
100Z	PRESS GAGE	93351	1
100ZZ	PRESS GAGE	93305	1
100ZZ	PRESS GAGE	93301	1
1064	ACFT TIRE GAGE KIT	93280	1
1064	ACFT TIRE GAGE KIT	93280	1
1064	ACFT TIRE GAGE KIT	93306	1
1064	ACFT TIRE GAGE KIT	93305	1
1064	ACFT TIRE GAGE KIT	93308	1
1064	ACFT TIRE GAGE KIT	93309	1
1064	ACFT TIRE GAGE KIT	93334	1
1064	ACFT TIRE GAGE KIT	93350	1
1064	ACFT TIRE GAGE KIT	93350	1
1065	INFLATOR KIT ASSY	93308	1
1065	INFLATOR KIT ASSY	93321	1
1065	INFLATOR KIT ASSY	93335	1

Note: This table demonstrates the format in which Shaw AFB reported their maintenance data.

Appendix B: Langley AFB Sample Maintenance Data

WUC	Part No.	Date	Units	Start	Stop	T/M	A/T	W/D
FBA10	2129608-6	10/2/92	1	7:00	12:30	B	J	F
FBA10	2129608-5	10/20/92	0	23:50	24:00	J	J	T
FBA10	2129608-5	10/20/92	0	8:00	16:00	J	J	T
FBA10	2129608-5	10/21/92	1	18:00	20:30	J	C	T
FBA10	2129608-5	10/21/92	0	7:00	11:00	B	J	F
FBA10	2129608-5	10/26/92	0	12:00	16:00	J	F	T
FBA10	2129608-5	10/26/92	0	7:00	15:30	B	J	F
FBA10	2129608-5	10/29/92	1	16:00	21:10	J	C	T
FBA10	2129608-5	11/3/92	0	7:00	15:00	J	K	T
FBA10	2129608-5	11/4/92	0	7:00	15:00	B	K	F
FBA10	2129608-5	11/5/92	1	7:00	14:00	J	K	T
FBA10	2129608-5	11/10/92	0	7:00	15:30	B	K	F
FBA10	2129608-5	11/16/92	1	16:00	18:00	B	C	F
FBA10	2129608-6	11/17/92	0	16:00	24:00	J	K	T
FBA10	2129608-6	11/19/92	0	:01	4:00	J	K	T
FBA10	2129608-6	11/24/92	0	8:00	15:00	J	J	T
FBA10	2129608-6	11/25/92	0	7:00	15:00	J	K	T
FBA10	2129608-6	12/2/92	1	7:00	9:30	J	K	T
FBA10	2129608-6	12/3/92	0	16:00	24:00	J	K	T
FBA10	2129608-6	12/4/92	0	16:00	24:00	J	K	T
FBA10	2129608-6	12/7/92	1	16:00	17:00	J	K	T
FBA10	2129608-6	12/11/92	1	16:00	24:00	B	K	V
FBA40	2129608-4	10/5/92	0	16:00	17:00	J	A	T

Legend:

WUC: Work Unit Code
T/M: Type Maintenance
A/T: Action Taken
W/D: When Discovered

Note: This table demonstrates the format in which Langley AFB reported their maintenance data.

Appendix C: Man-Hour Calculation

Item	Cals/Yr	Hrs/Cal	Hrs/Yr	Item	Cals/Yr	Hrs/Cal	Hrs/Yr
1	1.000	2.000	2.000	41	0.667	8.000	5.336
2	1.000	2.000	2.000	42	2.000	12.000	24.000
3	1.000	2.000	2.000	43	2.000	12.000	24.000
4	1.000	2.000	2.000	44	0.667	1.000	0.667
5	1.000	2.000	2.000	45	1.200	0.750	0.900
6	1.000	2.000	2.000	46	4.000	24.000	96.000
7	1.000	2.000	2.000	47	0.667	4.000	2.668
8	1.000	3.000	3.000	48	0.667	4.000	2.668
9	1.000	1.500	1.500	49	2.000	4.000	8.000
10	1.000	1.500	1.500	50	0.667	8.000	5.336
11	2.000	4.000	8.000	51	0.667	0.750	0.500
12	1.000	8.000	8.000	52	0.667	0.750	0.500
13	1.000	8.000	8.000	53	2.000	0.750	1.500
14	2.000	16.000	32.000	54	0.667	0.750	0.500
15	2.000	4.000	8.000	55	3.000	4.000	12.000
16	2.000	1.500	3.000	56	4.000	1.000	4.000
17	2.000	2.000	4.000	57	2.000	3.000	6.000
18	2.000	1.000	2.000	58	2.000	0.750	1.500
19	2.000	2.500	5.000	59	2.000	2.000	4.000
20	1.000	2.500	2.500	60	0.800	3.000	2.400
21	1.000	1.000	1.000	61	0.667	3.000	2.000
22	1.000	3.000	3.000	62	1.000	3.000	3.000
23	1.000	1.000	1.000	63	1.000	3.000	3.000
24	1.250	1.500	1.880	64	1.000	0.750	0.750
25	1.000	2.500	3.130	65	1.000	0.750	0.750
26	1.250	2.500	3.130	66	1.000	0.750	0.750
27	3.000	2.000	6.000	67	4.000	0.750	3.000
28	4.000	2.200	8.800	68	1.000	0.750	0.750
29	1.000	16.000	16.000	69	4.000	0.750	3.000
30	2.000	1.000	2.000	70	0.667	0.750	0.500
31	0.750	1.500	1.130	71	0.667	0.750	0.500
32	0.750	1.500	1.130	72	0.667	0.750	0.500
33	2.000	2.500	5.000	73	4.000	0.750	3.000
34	2.167	3.000	6.501	74	0.667	0.750	0.500
35	4.000	0.750	3.000	75	4.000	0.750	3.000
36	4.000	0.750	3.000	76	4.000	0.750	3.000
37	1.000	0.750	0.750	77	4.000	0.750	3.000
38	4.000	0.750	3.000	78	4.000	0.750	3.000
39	0.667	5.000	3.335	79	4.000	0.750	3.000
40	0.800	3.000	2.400	80	4.000	0.750	3.000
Subtotal			175.686				242.475
Total	418.161						

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Vita

Mr. Donald L. Clark was born on 6 August 1942 in Urbana, Ohio. He graduated from Urbana High School in Urbana, Ohio in 1960. After graduating from high school, he attended various colleges part-time from 1963 to 1981. In June of 1981, he graduated with honors from Clark State Community College, Springfield, Ohio, with an A.S. in Electrical Engineering. Mr. Clark graduated Magna Cum Laude from Park College, Wright-Patterson AFB Branch, Ohio, in August of 1991 with a Bachelor of Science in Management Science. He began his civil service career in 1968 after completing eight years of active duty in the United States Air Force. During the past 26 years, his assignments have included duties as an: electronic measurement equipment calibrator with the 2750th Air Base Wing WPAFB, Ohio; electronic measurement equipment mechanic, electronic measurement equipment mechanic inspector, and Section Supervisor, Production Control/Scheduling, 4950th Test Wing WPAFB, Ohio. Currently, Mr. Clark is assigned as the Electronic Measurement Equipment Mechanic General Foreman for the Precision Measurement Equipment Laboratory, 645th LOG WPAFB, Ohio.

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13. ABSTRACT *(Maximum 200 words)*

This study investigated the change in Type IV PMEL workload requirement resulting from the implementation of the two-level maintenance (2LM) concept. Seven Type IV PMELs were studied and the information was used to profile a "typical" Type IV PMEL. The researcher was able to predict the total inventory owned by the Type IV PMEL's customers, the number of items supported by the Type IV PMEL, and the percent of the Type IV PMEL workload affected by 2LM. All these values were determined by using inferential statistics and were expressed in terms of confidence intervals. The researcher also examined the first six months of production data recorded while operating in the 2LM concept. ANOVA and t tests were used to test the hypothesis that the mean variety of equipment, mean maintenance hours expended, and mean AIS station utilization recorded were not significantly different from the mean values recorded for the same six month period the previous year, while operating in the three-level maintenance (3LM) concept. The test results seem to indicate that implementing 2LM results in little or no difference in the Type IV PMEL workload.

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