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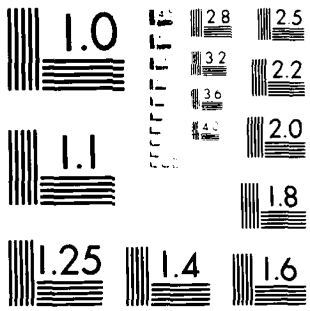

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DEPARTMENT OF THE AIR FORCE

AIR UNIVERSITY (ATC)

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

AIRCRAFT AVIONIC SYSTEM MAINTENANCE
CANNOT DUPLICATE AND RETEST-OK
ANALYTICAL SOURCE ANALYSIS

Gary L. Gemas, Captain, USAF

LSSR 49-83

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This study focuses on the aircraft avionic maintenance problems of cannot duplicate (CND) and retest-ok (RTOK) for three sampled F-16 wings. Analytical and survey methods are used to evaluate four hypotheses in an attempt to determine causes of CND and RTOK occurrences and evaluate if they point to usable solutions to these problems. Hypothesis one evaluates the statistical differences in CND and RTOK rates between the sampled wings. Hypothesis two compares RTOK rates between avionic intermediate maintenance (AIS) test stations. Hypothesis three compiles the frequency of CND occurrences for each aircraft to determine if some aircraft experience higher CND rates than others. Hypothesis four evaluates the number of days between CND or RTOK corrective actions and the next maintenance repair action. The RTOK rates evaluated in hypothesis one were significantly different and require further study. Test stations RTOK rates for hypothesis two were significantly different between test stations, and between wings, and requires further study. Results for hypothesis three indicate some aircraft, given to chance, will experience higher CND and/or RTOK rates than others. The results of hypothesis four imply that 50 percent of all aircraft malfunctions cleared as CND or RTOK require maintenance repairs.

LSSR 49-83

AIRCRAFT AVIONIC SYSTEM MAINTENANCE CANNOT DUPLICATE AND RETEST-OK ANALYTICAL SOURCE ANALYSIS

A Thesis

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

By

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Captain, USAF

September 1983

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CHAPTER 1

BACKGROUND

Introduction

The effect of high technology on modern weapons systems is monumental. For the United States Air Force (USAF) it has meant unparalleled advancements in aircraft systems capability over a relatively short time. "Fighter aircraft are dependent upon sophisticated fire control, weapons delivery, navigation, and display systems to provide pilots with the capacity to accomplish their missions [5:1-1]." With these advancements comes the problem of how to maintain these systems. Technology has outdistanced the technician's ability to cope with the problems and complexities of new systems. Given the complexity of the F-16 radar, for example, it is not surprising it could fail in a number of ways. Looking just at simple single report failures, the General Dynamics pocket reference (block 10 Avionics Fault Analysis Card) lists 157 ways in which the radar could fail (5:5-4,5-5). The technician can no longer rely on accomplishing the job via cognitive abilities, simple tools, checklists, and technical data. Realizing this dilemma, engineers have sought to simplify systems fault isolation by designing special test equipment to aid the technician.

Modern aircraft design incorporates built-in-test equipment (BITE) and automatic test equipment (ATE) to increase maintenance effectiveness and permit the use of lower skilled personnel (2:3). The F-16 avionic subsystems were required by the acquisition contracts to provide 95 percent failure detection and 95 percent fault isolation at the organizational maintenance level, with maintenance personnel troubleshooting the remaining failures (5:1-2). In many cases, the organizational level of maintenance cannot duplicate (CND) the problem or it removes equipment that subsequently retests-ok (RTOK) at the intermediate level of maintenance. Good units removed in error may be used again after being RTOKed, but while they are in the intermediate maintenance shop they are not available for re-issue. Temporary shortages result, affecting stock levels and often reducing aircraft availability (14:15). These maintenance errors reduce operational readiness and degrade the logistics support system. The Air Force must increase the effectiveness of maintenance organizations by reducing CND and RTOK occurrences. Effective maintenance organizations can reduce CND and RTOK rates and increase their unit's operational readiness.

The initial costs of acquisition of new high technology weapons systems are high. So, too, are the costs of the maintenance support required over their life to maintain operational readiness. Approximately one third of the total cost of new weapons and equipment is expended for electronics (12:38). Maintenance costs for the life cycle of a new system can only be estimated during acquisition but are measurable for systems in the field.

One cost of ineffective maintenance is lowered operational readiness (OR) rates. Aircraft not OR have lost their utility value for the time they are out for maintenance (6:15). The United States Navy, for example, is experiencing 52 to 58 percent operational readiness for F-14A aircraft (6:13); while the USAF is experiencing approximately 53 percent for daily sortie requests exceeding five aircraft (9:14). The cost to the Navy, based on aircraft acquisition cost, of F-14 aircraft not OR, using a 48 percent not OR rate and $21 million per aircraft, is approximately $1.5 billion (6:15). "Experts indicate that other weapons systems are experiencing the same or even lower operational readiness [6:13]." This is a drastic reduction in readiness compared to the 80 percent expected and achieved with weapons systems a few decades ago (6:14).

Maintenance Errors

A major contributor to the low operational readiness is the maintenance technician. "He is performing well below his natural potential [6:16]." The use of BITE and ATE fault isolation capability would make the flight line job routine if the system provided unambiguous indications of failure. BITE detects failure, signals the pilot or technician of a fault, and isolates the fault to a defective line replacement unit (LRU). Then, in the ideal situation, the technician removes the defective LRU, installs a serviceable one, and sends the defective LRU to the avionics intermediate shop (AIS) for repair (5:1-1). Such is not the case in reality. The indicators are often unreliable and malfunctions may occur in several systems at once or affect the performance of totally different systems (13:vi). The technician must deal with incomplete provisions for fault detection or excessive demand for reasoning on his part (2:37). Failure of the technician to understand the interrelationships of system components results in increased CND and RTOK and decreased maintenance effectiveness.

Past evaluation of maintenance effectiveness used time-related standards to measure maintenance performance against other organizations with like weapons systems. The 3-M Company developed a measure using three types of errors: Type I, Type II, and Type d (6:16).

"Type I error occurs when a good unit is removed erroneously [6:16]." This usually occurs when a technician cannot duplicate the problem and changes a unit for the sake of clearing a write-up.

"Type II error occurs when a bad or malfunctioning unit is not found, which often results in the wrong thing being repaired [6:16]." The technician clears the write-up with a CND record entry or a repair which results in a repeat write-up. Recent studies indicate that of all avionics equipment removed from aircraft, about 30 percent pass the retesting procedures at the intermediate level of maintenance (14:1-1).

"Type d error occurs when the maintenance activity produces damage or malfunctions in the system [6:16]." The technician damages a component, i.e. breaks a cannon plug, shorts a circuit board, or causes other damage in the process of troubleshooting. All three of these errors can be related to CND, RTOK, and the design of the system.

A related problem of flight crew interface adds to maintenance errors. "Debriefings by knowledgable senior maintenance technicians will eliminate unnecessary write-ups and provide maintenance with good descriptive failure write-ups [18:4.2.6]." "The accuracy of debriefing write-ups is directly proportional to the comprehension of the debriefers [14:18]." Although the selection of debriefing personnel from the units is made with some knowledge of their past technical performance, the overall selection process is random relative to their performance as debriefers. The experimenter assumes as a result of this randomness that this problem will have little or no effect on maintenance errors.

"Maintenance production is set up to facilitate management of resources and to promote effectiveness, deployability, and economy. It is divided into two categories, on-equipment and off-equipment [16:2]." On-equipment maintenance is performed by the organizational level of maintenance and off-equipment by the intermediate level of maintenance.

Maintenance performance at the organizational level is influenced by the nature of the aircraft, BITE and ATE design, and the interplay of its support elements (6:30). Maintenance effectiveness of accessing system status and correcting and preserving the system can be measured by Type I, II, and d error rate. System design should promote the reduction of errors and the time invested by maintenance to make a repair (6:30). System design factors that affect maintenance are: (1) assessment of system status; and (2) correction or preservation of system condition.

System status can be assessed with symptoms and cues. "Symptoms are system outputs that fall beyond allowable operating limits. Cues are bits of information concerning the relationships among the constituent parts of the system [6:35]." The technician uses cues to identify the failed components of the system.

Natural cues are the easiest to observe because they follow mechanical principles the technican can easily understand. Technicians identify the failure by simple examination for wear, misalignment, or broken parts (6:35). Beyond the simple natural cues are complex, or process, cues.

Process cues are used where the processes are not easily observed, as in electronic or hydraulic control systems. Process cues are instrumented readings, computer readouts, BITE and/or ATE results, or other indications of the final action of a system or its subsystems (6:35). Well designed process cues accurately depict the actual final results of the system's process as well as critical intermediate steps.

Military Standard, MIL-STD-1472C, "Human Engineering Design Criteria for Military Systems, Equipment, and Facilities", provides guidance for design maintainability through physical access, action accuracy, and action ease. The objective is to provide easy access on a hierarchical order to units requiring repair with critical high failure rate items the most accessible (15:5.9.4.5). Noncritical components will be given priority by frequency of maintenance actions (15:5.9.4.5). Additionally, common hand tools and simple handling equipment should be enough to perform most maintenance actions (15:5.9.4.6). Alignment pins and coding of parts aid assembling parts and insure use of correct parts (15:5.9.12.4-5). Physical access and action accuracy are brought together with action ease where the technician's skill level is related to the task he must perform (15:5.9.4.7). "The relative degree of action ease built into the hardware may influence both Type d error rate and maintenance time [6:39]," Logistics support for maintenance involves facilities, equipment, spares, manning, technical information, and maintenance management (6:40). Melaragno's (9:43) USAF F-15 study shows adequate logistics support exists for all but avionics systems and spares for avionics intermediate level shop (AIS) test equipment. Insufficient spare avionic LRUs has restricted the combat capability of the F-15 severely. Spare parts for the AIS test stations are also critical and in short supply (9:48). Lack of F-16 spares inventory was a major reason cited for cannibilization actions and had significant impact on how diagnosis is practiced (5:5-43).

Intermediate level maintenance diagnosis is accomplished on the AIS test station, a complex tester used to test avionic components for the F-16 aircraft. The tester compares the actual performance of the component, in the shop environment, against specific preset parameters that the system is designed to operate within. A hard copy printout is made by the test station identifying the fault or faults of the components. This printout is forwarded with the LRU when it is returned to depot for repairs beyond the base level capability.

Compounding the spares shortage is the effect of CND and RTOK. Maintenance organizations may become ineffective because of repair time, equipment, and supplies to test and repair components generated by CND and RTOK (6:26). The false demands cause artificially high supply stock levels by increasing the quantity required to cover repair cycle time (7). These repair cycle demands, along with other maintenance demands that create artificial requirements, are intensified by CND/RTOK occurrences and increase the costs of logistics support and degrade operational readiness. The reported CND and RTOK rates imply that significant logistics support is expended in troubleshooting, removing, retesting, and replacing serviceable avionics components thereby reducing aircraft availability and increasing total support costs (2:3). The real flexibility to increase operational readiness resides in identifying and reducing the errors of maintenance personnel in accessing system failures (6:56).

Problem Statement

The area of CND and RTOK has been identified by recent research as a significant contributor to the decline in OR rates (2:3). Reducing CND and RTOK will increase OR rates and decrease the life cycle costs of a system. This study focused on the aircraft maintenance problems of CND and RTOK. There is a definite need for an analytical method for determining causes of CND and RTOK occurrences and an evaluation of those causes leading to usable solutions.

Research Objectives

The objective of this research was to explore strategies for isolating reasons for CND and RTOK occurrences using the existing USAF maintenance data collection (MDC) system. Where differences between CND and RTOK rates exist among organizations with like weapons systems there are opportunities for isolating or inferring cause. The following hypotheses will be used to determine if statistical differences exist.

Research Hypotheses

1. Maintenance CND and RTOK occurrence statistics are not significantly different from wing to wing.

2. Test station RTOK occurrences are not significantly different from test station to test station among the bases sampled.

3. CND rates for avionic systems are not significantly different from aircraft to aircraft within a model design series (MDS).

4. The number of days between a CND or RTOK occurrence and the next maintenance action will be exponentially distributed with higher infant failures that reduce to chance failures over time.

CHAPTER 2

RESEARCH METHODOLOGY

Introduction

Many aspects of maintenance performance are used to quantify and analyze the maintenance process in an attempt to improve maintenance effectiveness and operational readiness. Two aspects, CND and RTOK, continue to plague the maintenance technician yet have historically received little formal study. However, significant research resources are now being devoted to identify the causes of high RTOK and CND rates (2:3). The research reported here explored strategies for isolating reasons for high CND/RTOK by evaluating the statistical differences hypothesized in Chapter One.

Target Population

The USAF active inventory aircraft are identified by mission design series (MDS). Some examples are, A-7, A-10, A-37, B-52, C-141, F-15, F-16, FB-111, RF-4, RF-111, and other attack, bomber, cargo, cargo tanker, fighter, helicopter, reconnaissance, and trainer aircraft. Nearly all USAF MDS incorporate radar, inertial navigation, doppler navigation, communication, or other avionic systems which use BITE or ATE to enhance maintenance effectiveness. The F-16 aircraft was chosen as the research sample because:

-- the F-16 has both BITE and ATE incorporated in its maintenance support package.

-- of the high degree of attention placed on accurate data gathering relative to maintenance effectiveness.

-- the Air Force Specialty Code (AFSC) support is representative of AFSCs used to support other aircraft with similar systems.

-- it has good climate/geographical representation:
Hill AFB: extremes of hot and cold, high/dry desert;
MacDill AFB: hot, humid, salt exposure, sea coast;
Nellis AFB: hot, dry desert.

Data Collection

The planning for and collection of useful data is recognized as a vital aspect in analyzing maintenance effectiveness. With the goal of improving the information and communications for the management of the F-16 program, the procurement of the F-16 centralized data system (CDS) became necessary (1:29-30). The CDS program focuses on the crucial automatic test equipments which have been the source of technical and managerial concern on earlier aircraft development programs (3:1-3). The CDS, along with the maintenance data collection system (MDC), was used to collect data into a master file containing; base, workcenter, job control number, aircraft identification number, work unit code, employee number, Air Force Specialty Code (AFSC), type maintenance, action taken, when discovered, how malfunction, system hours, and test station number. The master file was reduced as needed for analysis. These files form the sample populations for the analyses to answer the hypotheses stated in Chapter One.

The research was designed to compare the performance of avionics maintenance organizations in the three sample wings using data relative to on-equipment versus off-equipment maintenance, aircraft serial number, and the length of time a CND or RTOK repair action lasts before another maintenance action is required.

Data Analysis

The time period of 1 April 1981 to 31 March 1982 was used as a matter of convenience. It was assumed that the data, though historical, contains random occurrences of CND and RTOK. The Cyber computer, using the statistical package for social sciences (SPSS), was used to do a frequency analysis of the master file to determine which avionics system work unit codes (WUC) were greater than or equal to 10 percent of the total avionic system malfunctions. Those WUCs which fit this criteria went through a frequency analysis to determine if the combined CND and RTOK occurrences were greater than or equal to 10 percent of the malfunctions by using definitive malfunction codes (799 - no defect; 948 - operator error/no defect). These same malfunction codes were used to convert the files to a binomial coding of 799 or NOT (not 799). The files served as the sample populations for hypothesis number one. To accomodate hypothesis number two, all on-equipment and other "not bench tested" actions were removed from the files. The files were then ready for contingency table analysis.

To perform a contingency table analysis, it was assumed that independent random samples of size n_1, n_2, ... n_c is large (10:438-39). Since CND and RTOK efforts are separated by job control numbers, and repeat write-ups are treated as a new job, it is assumed all CND and RTOK occurrences are unique. The sampling method and assumptions lead to testing comparisons of several multinomial populations which is sometimes called a test of homogeneity (10:441).

The Chi-Square (χ^2) statistic was used to test for significant differences in CND and RTOK for hypotheses one and two. This compared the observed frequency of specific occurrences with the number of occurrences expected, assuming the distribution of CND and RTOK rates were equivalent. It further provided a measure for determining if chance variation could explain away the difference between the observed and expected frequencies.

First, the contingency and probability tables were developed for each hypothesis. Then the expected, or mean (χ^2), count in each cell was calculated assuming the null hypothesis of homogeneity of the samples. The observed and expected (estimated) counts in each cell were compared using the χ^2 statistics. Large values of X^2 indicate that the observed and expected counts do not agree and, therefore, the samples would not be homogeneous. Since the X^2 sampling distribution is approximately χ^2 distributed it can be used to determine how large X^2 must be before it is too large to be attributed to chance. The degree of freedom from χ^2 is (r-1)(c-1) where r is the number of rows and c is the number of columns of the contingency table (8:731-34).

The observed count in the cell is denoted by n_{ij}, with the i the row total being r_i, the j column total e_j and the sample size is n. The general form of the RXC contingency table is:

General r x c Contingency Table

		COLUMN 1	2	...	c	ROW TOTALS
	1	n_{11}	n_{12}	...	n_{1c}	r_1
ROW	2	n_{21}	n_{22}	...	n_{2c}	r_2
	⋮	⋮	⋮		⋮	⋮
	r	n_{r1}	n_{r2}	...	n_{rc}	r_r
COLUMN TOTALS		c_1	c_2		c_c	n

[8:734]

The general form of the table analysis is:

A Test of an Hypothesis About Multinomial Probabilities

H_o: $P_1 = P_{1,0}$, $P_2 = P_{2.0}$, ..., $P_k = P_{k.0}$,

where $p_{1.0}$, $P_{2.0}$, ..., $P_{k.0}$ represent the hypothesized values of the multinomial probabilities

H_a: At least one of the multinomial probabilities does not equal its hypothesized value

Test statistic: $$X^2 = \sum_{i=1}^{k} \frac{[n_i - E(n_i)]^2}{E(n_i)}$$

where $E(n_i) = np_{i,0}$, the expected number of outcomes of type i assuming H_0 is true. The total sample size is n.

Rejection region: $X^2 > \chi^2_{\alpha}$ where df - k - 1

Assumptions: The sample size n will be large enough so that, for every cell, the expected cell count, $E(n_1)$, will be equal to five or more. [8:734]

The specific contingency tables and their related hypotheses used in this study are located in Appendix B.

The analysis was accomplished using the statistical package for social sciences (SPSS) on the Cyber computer. The SPSS uses a program of cross tabulation and measures of association to accomplish the contingency table and Chi-Square statistical operations. Nornsis provides a practical guide to accomplishing the procedure (11:22-36).

After the SPSS analysis was completed, the results were verified by entering a known data set and following it through a complete analysis. This test, along with inspection and manual computation of some of the observed sample results, verified the procedure.

The analysis of hypothesis number three required developing a file with the number of NOT and CND occurrences for each aircraft. The SPSS frequency count of the number of aircraft by the number of failures should produce a distribution whose curve approximates a Poisson distribution.

The Chi-Square goodness of fit test rejects or cannot reject the fit of the frequency count to the Poisson distribution. If the frequency count is *not* Poisson distributed the null hypothesis must be rejected. Two assumptions were made when doing this analysis: (1) all the aircraft used the systems in question the same number of hours and, (2) the average failure rate (λ) was the same for all the aircraft.

Hypothesis number four required building a file from the master file that excluded cannibalization and time compliance technical order (TCTO) actions. The file was hand manipulated to extract the number of days from a CND or RTOK to the next repair action, adjusting for how malfunction codes P and Q which did not contribute to repair actions. The results of this manipulation were entered into a new file and graphed using the SPSS frequency analysis. The result should be a negative exponential curve or a curve that begins as a negative exponential and becomes uniform after a few days of data points. This assumes that a repaired system will mimic a new system, with a large number of early or infant failures and with failures decreasing to a relatively low and steady rate over time (18:20). The Chi-Square goodness of fit test rejects or cannot reject the fit of the curve to the hypothesized distributions.

Once verified, the variables were compared against the hypotheses stated in Chapter One. Where no significant statistical differences occur, it is not possible to draw any conclusions other than the populations are homogeneous for the particular hypothesis. Where the statistical differences are significant, inferences were explored in an effort to explain the differences and/or draw conclusions.

The statistical differences were evaluated by interviewing knowledgeable personnel assigned to the F-16 System Program Office (SPO) and the F-16 wings sampled. This effort attempted to isolate variables unknown to the researcher and explain all or a portion of the differences. Questions were formulated after the statistical findings were completed in order to insure that all the differences from the stated hypotheses were addressed. Informal, semi-structured, open ended interviews were conducted directly with F-16 SPO personnel assigned at Wright-Patterson AFB and by telephone with personnel of the three sample wings. Unexplained or inadequately explained differences were identified for further research beyond the scope of this study.

CHAPTER 3

FINDINGS

The method of data reduction described in Chapter Two was to reduce the original data base to usable files of sample populations for statistical analysis. The frequency analysis of avionic malfunctions identified three WUCs (74A00, 74AA0, and 74AB0) as being greater than or equal to 10 percent of the total avionic malfunctions listed in the data base with 25.9, 12.6 and 19.2 percent respectively. Of these three avionic WUCs, the percentage of CND and RTOK occurrences of the total write-ups for each WUC is 54 percent for 74A00, 6.2 percent for 74AA0, and 12 percent for 74AB0. Using only those CND/RTOK WUCs greater than or equal to 10 percent reduces the sample population to WUC 74A00, the fire control system; and WUC 74AB0, the radar low power radio frequency (LPRF) LRU. The hypotheses were then tested for these populations.

Hypothesis one; WUC 74A00, the fire control system, included only CND and not CND results because the malfunctions were internal to the fire control system and system removal for bench testing is not possible. The null hypothesis that the CND occurrences are not significantly different from wing to wing cannot be rejected. A raw Chi-Square (X^2) of 4.22712 is less than the χ^2 of 5.99147 needed to reject the null with a probability of rejecting the null if in fact the null is true (α), $\alpha = 0.05$. See Figure 1. 74AB0 has both CND and RTOK occurrences because the LPRF LRU can be tested as part of the system or bench tested on the AIS test station. In this case, the CND occurrences were not significantly different from wing to wing but RTOK occurrences were. The X^2 for CND is 0.79555 while X^2 for RTOK is 21.76180 and the χ^2 for both is 5.99147. See Figures 2 and 3.

Hypothesis two; applies to 74AB0, the LPRF LRU, since this hypothesis deals with only the AIS test stations. The results of the initial contingency table include all work identified to specific testers as well as work accomplished on the AIS test stations where the tester identification number was not included in the data. The results of the analysis, see Figure 4, reject the null hypothesis that RTOK occurrences are not significantly different. The X^2 of 69.23729 was much greater than the χ^2 statistic of 14.0671 for 7 degrees of freedom and $\alpha = 0.05$. Because the number of maintenance actions on AIS test stations that did not identify the tester was large, it was decided to repeat the test after removing the unnumbered tester actions from the file, see Figure 5. This resulted in a X^2 value of 26.15013, greater than the χ^2 of 12.5916 for 6 degrees of freedom and $\alpha = 0.05$. Again rejecting the null hypothesis and concluding that there is a significant difference from tester to tester.

Hypothesis three; using a failure rate (λ) of $\lambda = 1.783$, the resulting curve, see Figure 6, does not fit the Poisson distribution because of the large number of aircraft not experiencing CND and RTOK occurrences (120 observed compared to an expected 46.4), a full 43.5 percent of the aircraft. This is further confirmed by the Chi-Square goodness of fit test. Therefore, the null hypothesis that the CND and RTOK occurrences are nct significantly different, must be rejected unless more adequate information is available to make a judgment.

The findings for hypothesis four show 129 CND and RTOK actions on the LPRF LRU that were followed by repairs other than CND or RTOK in the period of study. The WUC 74A00 file was not analyzed because effects of the next maintenance action on the fire control system could not be clearly defined. The LPRF LRU cases comprise the files graphed in Figure 7 to show the number of days between CND or RTOK and the next corrective action, in one day increments. Forty-five percent of the CND and RTOK actions result in repeat write-ups on the same day they were signed off CND or RTOK (day zero) and if the first day following the original repair is grouped with day zero, 50.4 percent of the CND actions are accounted for. Figure 8 shows the entire file recoded in eight increments established using the probability of 0.125 for each frequency group. The Chi-Square value calculated from the data is 197.1395, compared to the Chi-Square test statistic of 12.592 for $\alpha = 0.05$ and 6 degrees of freedom. Therefore, the curve is not exponential nor does it begin as an exponential distribution.

CHAPTER 4

SURVEY QUESTIONS AND ANSWERS

The findings of Chapter Three open the following questions that are relative to analyzing the findings and drawing conclusions from them. These questions were used to conduct informal interfiews to gain insights into differences in the hypotheses and the findings.

Hypothesis One

Preface statement: none

Question 1: What is the mission of the Wing?

Responses:

Hill AFB: Two operations squadrons and two air crew training squadrons.

MacDill AFB: To provide training for maintenance and aircrew personnel.

Nellis AFB: Three operational squadrons.

Question 2: Are there significant differences in mission requirements, from the other sample wings, that could affect the radar low power radio frequency LRU?

Responses:

Hill AFB: Training squadrons require more use of LPRF LRU than OPS (operations) squadrons and generate more write-ups.

MacDill AFB: No, we fly the same U-rates as the other wings but we're not manned the same. We're manned less than the OPS squadrons but we do the same job.

Nellis AFB: No, the U-rate is the same as the other wings.

Question 3: Were the avionic line and shop units manned to authorized levels during the period of study, April 1981 to March 1982? Were the skill level authorizations met?

Responses:

Hill AFB: We experienced a change from 75 percent five and seven (skill) levels to 25 percent five and seven levels during that period. The quantity of manning met the authorized levels. Hill provided the maintenance cadre for all the F-16 units being formed.

MacDill AFB: Unknown

Nellis AFB: At the time the manning was constantly changing because of excessive three levels and cross-trainees.

Question 4: Were there any critical training problems related to F-16 fire control systems at the wing's organizational or intermediate levels of maintenance? If so, what were they?

Responses:

Hill AFB: Yes, there was an imbalance of grade skills to do maintenance and training.

MacDill AFB: No known training problems, but lack of corporate knowledge for the study period.

Nellis AFB: Yes, training was limited because of the limited number of five and seven levels.

Hypothesis Two

Preface statement: There are statistical differences in the results from AIS test stations where test stations experience different RTOK rates within the wing and between the sample wings.

Question 1: In what condition were the test stations in the period April 1981 to March 1982? Who maintained them? Who maintains them now?

Responses:

Hill AFB: Good condition. Maintained by wing with contractor assistance until January 1982. Maintained by wing since then.

MacDill AFB: Good condition. Maintained by wing.

Nellis AFB: Good condition. Maintained by wing with contractor assistance.

Question 2: What are the test station numbers assigned your AIS now? Are they the same testers as were assigned during the study period? If not, why not?

Responses:

Hill AFB: I don't know the numbers off hand but they are the same testers originally assigned.

MacDill AFB: RF-15 and RF-16 were originally assigned and are still here.

Nellis AFB: RF-10 and RF-19 were here during that time. RF-33 came in last fall.

Question 3: Were any test stations given preferential use? If so, why?

Responses:

Hill AFB: No

MacDill AFB: To some degree yes. RF-15 had higher maintenance and parts problems. During a two-shift operation it was hard to get to boot-up in the morning, but the problem went away when it started on a three shift operation.

Nellis AFB: No.

Question 4: How frequently were calibrations required for AIS test stations? How frequently are calibrations required now? What directive requires the calibration and/or establishes the length of service between calibrations?

Responses: Components of the test stations require different frequencies of calibration. 1F-16A-37 gives specific directions on calibration. 30 days is the minimum and 180 days the maximum for the components.

Question 5: How much (subjective) adjustment, if any, is required to maintain the parameters during recalibration?

Responses:

Hill AFB: No significant problems, phase two provisioning for test equipment has not been done.

MacDill AFB: There does not seem to be a problem to calibrate or maintain the parameters.

Nellis AFB: Some minor problems, but they seem to hold the parameters well.

Hypothesis Three

Preface statement: none

Question 1: Do you have specific aircraft whose fire control systems generate more LPRF LRU RTOKs than others in the wing? If so, explain.

Responses:

Hill AFB: Yes, because of the age of block five and ten aircraft.

MacDill AFB: No. Good coordination between organizational and intermediate maintenance helps keep this from happening.

Nellis AFB: No, although it has been looked into.

Question 2: If yes answer to question one above, do maintenance personnel expend additional man hours of organizational or intermediate maintenance on these aircraft fire control systems? If yes, doing what?

Responses:

Hill AFB: Yes, because as the failure rate increases the cannibalization rate increases. Less than 50 percent of CANs (cannibalizations) are reported. There are no spares so if we deploy no spares for WRS. This CAN rate increases the frustration level and may affect retention of personnel.

Question 3: Is there a formal or informal limit on the number of times a LPRF LRU and RTOK before it is returned to depot for further analysis and maintenance? If so, what is the limit? How are RTOKs recorded and accounted for this purpose?

Responses:

Hill AFB: No, there is no bad actor program.

MacDill AFB: No.

Nellis AFB: No. Keep serial numbers of LRUs and track them through the CDS system.

Hypothesis Four

Preface statement: none

Question 1: Were CND and RTOK corrective actions given any special management attention during the study period? If so, what were they?

Responses:

Hill AFB: There is management of individual components through deficiency analysis.

MacDill AFB: Requires a seven level to sign off forms on all CND and ROTKs.

Nellis AFB: Yes, we require verification of who is signing it off, their skill level, and, in some cases, double testing and seven level sign off.

Question 2: Were there any formal or informal policies related to CND and RTOK corrective actions during the study period? If so, what were they? Are there any such policies now? If so, what are they?

Responses:

Hill AFB: There is a MOI (maintenance operating instruction) that requires that the second CND be signed off by a seven level, the same as repeat or recurring hard failures. This policy has been expanded along with the look to expanding repair capability.

MacDill AFB: AFR 66-5 requires a formal policy for CND and RTOKs. A seven level has to sign off on CND and RTOKs and a written record action is sent through quality assuance for review, then to analysis.

Nellis AFB: We have a local MOI for CND and repeat write-ups.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Introduction

This research explored different strategies for isolating reasons for CND and RTOK occurrences by analyzing data that currently is available through the MDC system. Four hypotheses were subjected to statistical testing to determine if there are statistical differences between CND and RTOK rates using historical data from the F-16 CDS system.

Conclusion

The portion of hypothesis one dealing with CND occurrences in the fire control system (74A00) and the LPRF LRU (74AB0) resulted in no significant differences. Therefore, it is not possible to draw any conclusions other than the populations are homogeneous. There were statistical differences in the occurrences of RTOK in the LPRF LRU between the sample wings. When these differences are compared against the responses to the survey questions, you would expect Nellis AFB to have the lowest CND rate because there is less use of the fire control systems, where it is used, the pilots would have more experience with it. Hill AFB would be expected to be the median and MacDill AFB the highest. In fact, Nellis AFB experienced the highest CND rate, followed by Hill AFB and MacDill AFB. This may prove a fruitful area for further study. However, it should be recognized that contingency table analysis with the Chi-Square versus X^2 differences, although statistically significant for this data, may not prove valuable as a procedure for smaller populations.

The RTOK occurrences were broken out by tester identification numbers for hypothesis two. The difference between not RTOK (NOT) and RTOK is significant although the explanation provided by MacDill personnel would negate differences between their own testers. Their testers performed significantly different from the other two sample wings, however. This may be attributed to the age of the aircraft and test equipment, as indicated by the block numbers of the aircraft, or any number of other possibilities. These differences in RTOK and not RTOK offer possible avenues for further research.

The rejection of the null hypothesis for hypothesis three was not unexpected by the researcher but was contrary to the expectations of all personnel surveyed. The data supports a statistical difference in the CND/RTOK rates for specific aircraft by serial number. In reality, aircraft do perform sporadically with periods of higher instances of failure and unexplained malfunctions. The tail of the curve supports that, over time, a few aircraft will exhibit higher CND rates than the rest of the fleet. Predicting which aircraft, out of the fleet, will experience the high CND/RTOK rates is not possible as they can only be attributed to chance.

Hypothesis four offers little opportunity for modeling because it fits no known distributions nor could it be fitted to a curve that would be useful in analyzing other data bases. What can be observed is the high incidences, greater than 50 percent, of CND/RTOK corrective actions that prove to be ineffective. This indicates that the organizations are justified in expending additional man hours and management attention on CND and RTOK corrective actions. Further, it indicates that even with the best technicians involved, there is only a 50 percent chance of being right when using CND/RTOK corrective actions. From this, it can be concluded that BITE and ATE are not fulfilling their intended purpose, either as a result of design shortcomings or failure to provide for adequate interpretation of test outputs for maintenance personnel.

About the Data Base

The data base in the CDS system uses the same collection design as the MDC system. There were numerous cases where incorrect data was evident, i.e. two or three removal actions for a LPRF LRU on the same aircraft over a two month period but with no interim installation actions. Some aircraft had more than one LPRF LRU installed without an interim removal action. Other aircraft had LPRF LRUs RTOK without being removed from the aircraft or subsequently installed in the aircraft. It was not possible to insure the accuracy of all the data in the files analyzed but it was assumed that there were no affects on the outcome of the analyses.

Other considerations were the lack of subcategories for WUCs, how malfunction codes, and action taken codes in order to better account for actual maintenance actions and the effect they may have on the interrelationships between components of the system. Additionally, because of the spares shortages, LRUs are commonly swapped from aircraft to aircraft by maintenance personnel attempting to do fault diagnosis. This disrupts the system and in many cases goes unreported or is inappropriately reported do to lack of subcategories.

Recommendations

The following recommendations should be initiated to further the Air Force's capability to identify and reduce sources of CND and RTOK occurrences.

1. Further analysis of the statistical differences between test stations.

2. Improve BITE and ATE interface with maintenance personnel to reduce false or misinterpreted test indications.

3. Add additional WUCs to system branches and components to reduce the number of system write-ups cleared by using general system WUCs.

4. Add new work unit codes and how malfunction codes to account for system intrusions by maintenance personnel that are not otherwise accounted for.

5. Implement bar coding components with WUC, serial number, part number, and nomenclature in an effort to reduce paperwork for maintenance personnel and increase record accuracy.

APPENDIX A

GLOSSARY

α	Probability of rejecting H_o if in fact H_o is true (Type I error)
AFSC	Air Force Speciality Code
AIS	Avionics Intermeditate Shop
ATE	Automatic Test Equipment
BITE	Built-In Test Equipment
c	Number of columns in a contingency table
CDS	Computerized Logistics Decision Support Package
CND	Cannot Duplicate
JCN	Job Control Number
λ	Mean of a Poisson Distribution
LRU	Line Replaceable Unit
LPRF	Low Power Radio Frequency
MDC	Maintenance Data Collection
MDS	Mission Design Series
n	Sample Size
OR	Operational Readiness
r	Number of rows in a contingency table
RTOK	Retest-OK
SPO	System Program Office
SPSS	Statistical Package for Social Sciences
USAF	United States Air Force
WUC	Work Unit Code
X^2	Mean Square
x^2	Chi-Square Statistic

APPENDIX B
TABLE OF RESULTS

Hypothesis #1 74A00 CND

Base by How Malfunction

BASE	HMAL	NOT	1799	ROW TOTAL
	COUNT / ROW PCT / COL PCT / TOT PCT			
KRSM (Hill)	COUNT	159	530	689
	ROW PCT	23.1	76.9	38.0
	COL PCT	34.2	39.3	
	TOT PCT	8.8	29.2	
NVZR (MacDill)	COUNT	99	250	349
	ROW PCT	28.4	71.6	19.3
	COL PCT	21.3	18.6	
	TOT PCT	5.5	13.8	
RKMF (Nellis)	COUNT	207	567	774
	ROW PCT	26.7	73.3	42.7
	COL PCT	44.5	42.1	
	TOT PCT	11.4	31.1	
COLUMN TOTAL		465	1347	1812
		25.7	74.3	100.0

RAW CHI SQ = 4.22712 WITH 2 D.F., SIG. = .1208

Fig. 1 74A00 CND Contingency Table

Hypothesis #1 74ABO CND

Base by How Malfunction

Controling for Tester

BASE	HMAL: NOT	1799	ROW TOTAL
(COUNT / ROW PCT / COL PCT / TOT PCT)			
KRSM (Hill)	193 54.7 47.5 25.4	160 45.3 45.2 21.1	353 46.4
NVZR (MacDill)	100 50.8 24.6 13.2	97 49.2 27.4 12.8	197 25.9
RKMF (Nellis)	113 53.8 27.8 14.9	97 46.2 27.4 12.8	210 27.6
COLUMN TOTAL	406 53.4	354 46.6	706 100.0

RAW CHI SQ = .79555 WITH 2 D.F., SIG. = .6718

Fig. 2 74ABO CND Contingency Table

Hypothesis #1 74ABO RTOK

Base by How Malfunction
Controlling for Tester

BASE	COUNT / ROW PCT / COL PCT / TOT PCT	HMAL: NOT	HMAL: 1799	ROW TOTAL
KRSM (Hill)	COUNT	198	58	256
	ROW PCT	77.3	22.7	43.9
	COL PCT	44.5	42.0	
	TOT PCT	34.0	9.9	
NVZR (MacDill)	COUNT	128	18	146
	ROW PCT	87.7	12.3	25.0
	COL PCT	28.8	13.0	
	TOT PCT	22.0	3.1	
RKMF (Nellis)	COUNT	119	62	181
	ROW PCT	65.7	34.3	31.0
	COL PCT	26.7	44.9	
	TOT PCT	20.4	10.6	
COLUMN TOTAL		445	138	583
		76.3	23.7	100.0

RAW CHI SQ = 21.76180 WITH 2 D.F., SIG. = .0000

Fig. 3 74ABO RTOK Contingency Table

Hypothesis #2 74ABO

Test station by Hal Malfunction

COUNT ROW PCT COL PCT TOT PCT TESTER	NOT	799	
	387 91.1 46.5 38.4	38 8.9 21.7 3.8	425 42.2
08 (Hill)	81 76.4 9.7 8.0	25 23.6 14.3 2.5	106 10.5
10 (Nellis)	44 69.8 5.3 4.4	19 30.2 10.9 1.9	63 6.3
13 (Hill)	85 82.5 10.2 8.4	18 17.5 10.3 1.8	103 10.2
15 (MacDill)	70 82.4 8.4 7.0	15 17.6 8.6 1.5	85 8.4
16 (MacDill)	58 93.5 7.0 5.8	4 6.5 2.3 .4	62 6.2
18 (Hill)	32 68.1 3.8 3.2	15 31.9 8.6 1.5	47 4.7
19 (Nellis)	75 64.7 9.0 7.4	41 35.3 23.4 4.1	116 11.5
COLUMN TOTAL	832 82.6	175 17.4	1007 100.0

RAW CHI SQ = 69.23729 WITH 7 D.F., SIG. = .0000

Fig. 4 All Tests

Hypothesis #2 74ABO

Tester by How Malfunction

TESTER (COUNT / ROW PCT / COL PCT / TOT PCT)	NOT	799	Row Total
08 (Hill)	81 76.4 18.2 13.9	25 23.6 18.2 4.3	106 18.2
10 (Nellis)	44 69.8 9.9 7.6	19 30.2 13.9 3.3	63 10.8
13 (Hill)	85 82.5 19.1 14.6	18 17.5 13.1 3.1	103 17.7
15 (MacDill)	70 82.4 15.7 12.0	15 17.6 10.9 2.6	85 14.6
16 (MacDill)	58 93.5 13.0 10.0	4 6.5 2.9 .7	62 10.7
18 (Hill)	32 68.1 7.2 5.5	15 31.9 10.9 2.6	47 8.1
19 (Nellis)	75 64.7 16.9 12.9	41 35.3 29.9 7.0	116 19.9
COLUMN TOTAL	445 76.5	137 23.5	582 100.0

RAW CHI SQ = 26.15013 WITH 6 D.F., SIG. = .0002

Fig. 5 Identified Testers Only

Hypothesis #3

```
              CODE
                  I
              0   ******************************      (120)
                  I
                  I
              1.  *********                           ( 32)
Number            I
  of              I
Failures      2.  ***********                         ( 39)
                  I
                  I
              3.  *********                           ( 33)
                  I
                  I
              4.  *****                               ( 16)
                  I
                  I
              5.  ******                              ( 18)
                  I
                  I
              6.  ***                                 (  8)
                  I
                  I
              7.  **                                  (  4)
                  I
                  I
              8.  **                                  (  3)
                  I
                  I
              9.  **                                  (  2)
                  I
                  I
             11.  *                                   (  1)
                  I
                  I
                  I.........I.........I.........I.........I
                  0        40        80       120       160
                  FREQUENCY
                                      Number of Aircraft
           MEAN  1.783      STD DEV  2.151
```

Fig. 6 Failures per Aircraft

```
                             Hypothesis #4
                CODE
                    I
                0   *****************************         (58)
                    I
                    I
                1.  *****                                 ( 7)
                    I
                    I
Number of       2.  **                                    ( 2)
Days Between        I
CND/RTOK and        I
next Main-      3.  **                                    ( 1)
tenance             I
Action              I
                4.  **                                    ( 1)
                    I
                    I
                5.  ***                                   ( 3)
                    I
                    I
                6.  **                                    ( 1)
                    I
                    I
                7.  **                                    ( 2)
                    I
                    I
                9.  **                                    ( 2)
                    I
                    I
               11.  **                                    ( 2)
                    I
                    I
               12.  **                                    ( 2)
                    I
                    I
               13.  **                                    ( 1)
                    I
                    I
               14.  **                                    ( 1)
                    I
                    I
               15.  **                                    ( 1)
                    I
                    I
               16.  **                                    ( 2)
                    I
                    I
                    I.........I.........I.........I.........I
                    0        20        40        60        80
                    FREQUENCY
                                                Number of Aircraft
```

Fig. 7 Frequency of Days (16)

Hypothesis #4

```
                   CODE
                      I
                   1. ***********************************     (67)
                      I
                      I
                   2. ****                                    ( 5)
Number of             I
Days Be-              I
tween              3. ****                                    ( 5)
CND/RTOK              I
and next              I
Maintenance        4. ****                                    ( 6)
Action                I
                      I
                   5. *****                                   ( 8)
                      I
                      I
                   6. ****                                    ( 6)
                      I
                      I
                   7. ******                                  (10)
                      I
                      I
                   8. ************                            (22)
                      I
                      I
                      I.........I.........I.........I.........I
                      o        20        40        60        80
                      FREQUENCY
                                           Number of Aircraft

                      Mean     3.395       STD DEV      2.871
```

Fig. 8 Frequency of All Days Recoded

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